Forestry and Land Scotland
Coilltearachd agus Fearann Alba

Appendix XVI

Climate change adaptation considerations

Introduction

Global warming is an increasing issue that has implications for governments, businesses and citizens around the world. Climate scientists predict the West Highlands to experience a warmer wetter climate. However, this will mean prolonged dry spells in summer with the increased rainfall being in the form of weather events, particularly in winter months. At this point in time it is unclear by how much temperatures will increase in our area over the next few decades as it will be determined by the speed of mitigation action and type of actions implemented by all countries.

The climate scientists have produced a range of temperature and rainfall changes we may experience on a regular basis which is based on UK Climate Projections:

- RCP 2.6 which represents limiting the increase of global mean temperature to 2℃ above pre-industrial levels.
- RCP 8.5 which represents the global mean temperature reaching 4℃ above pre-industrial levels.

Low, median and high models for annual, winter and summer temperature and precipitation have been created for each of the above projections showing the range of potential change that we can experience in different parts of the UK.

The Clunes and Loch Arkaig Land Management Plan (LMP) has considered how these changes can impact forest and land management and what mitigation and adaptation can be implemented to improve resilience to the wide range of changes that can be expected over the next few decades.

The following sections demonstrate these considerations in relation to the UK Forestry Standard (UKFS) Climate Change section, the additional UKFS Practice Guide and the FLS Climate Change Adaptation Checklist for use by Forest Planners. Also refer to the Loch Arkaig and Clunes Climate Change Adaptation Concept maps.

UK Forestry Standard 2017: climate change

The UK Forestry Standard section 6.2: Forests and Climate Change sets out factors that are important for forests and climate change. The following tables set out these factors and their importance for climate change in terms of climate mitigation and climate adaptation measures as well as the actions proposed in the Clunes and Loch Arkaig Land Management Plan (LMP).

Mitigation

Mitigation factor	Importance for climate change
Carbon in forest products	**UKFS:** “In addition to storing carbon, forest products can substitute for more energy-intensive materials and can be used as a source of renewable heat and electricity.” **Actions in the LMP:** Continue to grow the second rotation conifer crops to maximise sawlog production, where possible, for long term carbon storage end use. Those crops which will not attain sawlog production could be harvested for biomass and wood fibre markets to substitute more energy-intensive materials or used as a source of renewable heat and electricity. This can include some of the accessible native birch crops that lie within 200m of forest roads which may benefit from respacing/tending/thinnings. Consideration can be given to localised Oak production close to the forest road network at low elevations away from ASNW sites. This can take the form of Oak nest management which can also serve as visitor zone amenity management especially around the Great Glen Way in Clunes Forest. Could possibly be considered around parts of the Allt Mhuic Butterfly Reserve to attain wood pasture standards.
Carbon in soil	**UKFS:** “Soils often contain the major proportion of carbon in the forest ecosystem. It takes decades or centuries to accumulate but can be rapidly lost through disturbance.” **Actions in the LMP:** The restoration of 613ha of PAWS designations enabled, in the long term, through harvesting will provide soil stability in future forests. This will eventually build up the soil flora, fauna and carbon levels to achieve stable mature soils which are unlikely to undergo further mechanised disturbance. The establishment of diverse native woodlands on these sites with varied rooting structures (plate, heart and tap root habits), will improve the resilience of soil carbon through increased soil stability on these steep slopes, in particular Clunes Forest and Loch Arkaig Forest at the Dark Mile.

Mitigation factor	Importance for climate change
	Around 9ha of hagged banket bog habitat in upper Gleann Chia-aig will be restored under the Peatland Code. There are sizeable areas of hagged bog habitat on Clunes hill. These will be smoothed to halt carbon release provided machines can safely access the sites and funding is available.
Carbon in forest ecosystems	**UKFS:** "Forestry can contribute to climate change mitigation by protecting and increasing forest carbon stocks." **Actions in the LMP:** Loch Arkaig Forest lies within the Scottish Raniforest zone, however, Clunes Forest has ancient woodland areas that are rich in Scottish rainforest features, such as bryophytes and lichens. These features in combination with deadwood, veteran trees and trees in senescence provide a carbon rich ecosystem. The PAWS restoration which will continue into the future will expand this ecosystem over most of the LMP forested areas by creating conditions that will allow the ancient woodland features to spread outside their current extent. The FLS Deadwood Strategy aims to concentrate deadwood habitat in places where the cycle is ongoing, such as in ancient woodland, semi-natural woodland, other native woodland and riparian woodland habitats.
Operational carbon footprint	**UKFS:** "Reducing fossil fuel usage in management activities can enhance the role of forestry in climate change mitigation." **Actions in the LMP:** FLS has already started to replace old diesel vehicles with new electric vehicles. Forest machinery will rely on fossil fuels until suitable alternatives can be found. The use of species mixtures removes the need for fertiliser to improve soil fertility. Much of the forested land is inaccessible for forest machinery, but where ground preparation does occur it will be the minimum necessary to establish the trees.

Adaptation

Adaptation factor	Importance for climate change
Forest planning	**UKFS:** "Forest design, structure and composition need to be resilient to the effects of a changing climate and extreme weather events." **Actions in the LMP:** The design of the forest will evolve from a conifer production forest to one dominated by native woodland. This will take many years to complete. Where possible, natural regeneration of native species will be encouraged. Supplementary planting provides the opportunity to introduce desirable native species to increase forest species and structural diversity. Riparian woodland will be created to provide soil stability during weather events but also to provide the ideal dappled shade habitat to optimise water quality and temperature. The gradual removal of larch species, in line with the FLS Larch Strategy will continue and will lower the risk of spread of Phytophthora ramorum disease to new areas. The removal of mature lodgepole and Corsican pines will provide increased resilience for the Dark Mile Caledonian pinewoods by lowering the threat of Dothistroma needle blight. Native ash will be left in the hope of identifying trees which are resistant to Ash Dieback *(**Hymenoscyphus fraxineus***). Some management of ash trees will occur where there is a threat to safety or infrastructure. In this case, the minimum amount of remedial work will take place. Replacing spruces with Scots pine and native broadleaf species on non-PAWS sites will increase forest resilience on podzolic soils with encroaching heather vegetation. The climate of prolonged drier summers will also suit the pines.

Adaptation factor	Importance for climate change
	Some of the old conifer coupes in Clunes remain vulnerable to windthrow due to the lack of adequate windfirm edges. However, many of these areas lie in low DAMS score areas. The current areas of windblow are awkward to reach and are affected by the Coire Glas exploratory works impeding haulage access. The adoption of “forest development types” management will ensure the woodland is diverse in terms of species and structure from planting to maturity. It also increases soil health, fertility and stability. The difficulty with regards to Clunes Forest and south east Loch Arkaig Forest is how to manage the developing forests through thinning or CCF interventions on such steep slopes. The civils infrastructure will be assessed for future resilience to cope in summer and winter storm events
Adaptive management	**UKFS:** “Approaches to management that are flexible, reactive and anticipatory will help forests and woodlands adapt to the changing climate.” **Actions in the LMP:** This LMP is dominated by native woodland restoration. Areas of ASNW are spread throughout the forested areas and include: upland birch woodland, upland oak woodland, upland mixed ash woodland, hazel woodland and pinewood. The areas around these precious remnants will be managed in such a way that the ancient woodlands can naturally move to more suitable niches or develop into another priority woodland habitat as the climate changes over a long period of time. This requires working with all the neighbours in the Arkaig landscape scale native restoration. The establishment of riparian woodland will provide natural windfirm boundaries for crops. Deer management is important to facilitate the expansion of native woodland and montane scrub into the non-bog habitats of the Clunes open hill by means of natural regeneration. The management of INNS and non-native regeneration is crucial to the success of native woodland restoration. The felling of spruce crops will be reviewed to optimise sawlog production whilst minimising the non-native seeding impact on adjacent native habitats. Rotation length may be reduced if the growing season is increased.
Tree and shrub species selection	**UKFS:** “Introducing diversity in tree species and origins will ensure some thrive should others decline.” **Actions in the LMP:** The use of Forest Research ESC using the 2080 worst case scenario climate model will determine suitable species for a given site and woodland management objectives. The right tree in the right place is key to health and resilience. Native species will be sourced from specified local seed zones. Supplementary planting can introduce native species which may act as an ecological replacement for ash.
Ecological connectivity	**UKFS:** “Woodland and trees can be used to develop ecological connectivity between habitats to enhance the ability of woodland ecological communities to adapt to climate change.” **Actions in the LMP:**

Adaptation factor	Importance for climate change
	Ancient woodland will be connected by PAWS restoration, non-PAWS native woodland and the creation of riparian woodland post harvesting operations. The Dark Mile pinewood provides the pivotal potential link between the Arkaig pinewoods and the Glengarry pinewoods. This link will be enhanced by the removal of the poorly performing spruce crops in north Chia-aig and the restocking of native woodland which will contain some scattered native pines. Native woodland creation just uphill of these areas will improve this link to the native woodland creation areas of north Clunes and Fhudair Lochan area of Glengarry Forest. It will also help to bridge the gap to the montane scrub remnants as it includes some willow scrub species and the potential for juniper. The pinewood connectivity can also take place along the upper forested slopes of Clunes to link the Dark Mile pinewoods with native woodland at Craig Liath. The Clunes and Glengarry Mountain Woodland project may be able to ecologically connect the pinewoods via Clunes hill.
Environmental protection	**UKFS:** “Woodland and trees that are appropriately located can help to alleviate the impacts of climate change on society and the environment.” **Actions in the LMP:** Manage visitor behaviour to eliminate campfires and the burning of deadwood habitat including the cutting of trees, especially ecologically important native species to facilitate the campfires. Manage visitor behaviour to eradicate the human waste and other antisocial behaviour in the forest and land, especially where it negatively impacts the local community. Manage visitor behaviour to respect the Clunes private water supply and prevent it being used for daily ablutions. The PAWS restoration areas around Achnasaul, Chia-aig and south Clunes will also act as slope stability woodland to improve resilience for the public road network, utility infrastructure and housing that lie downhill. The PAWS restoration will eventually improve the private water supply catchment for Clunes hamlet. Sustained management of deer, INNS and non-native regeneration will be key to environmental protection. Early interventions will maximise economic sustainability.

UK Forestry Standard Practice Guide: adapting forest and woodland management to the changing climate

The purpose of this practice guide is to provide information for forest managers to better understand and assess the risks associated with climate change. This enables planning for the future to adapt forest and land management.

The following table uses the risks and opportunities table provided in the practice guide and applied climate change implications with mitigation measures for the Clunes and Loch Arkaig LMP in both the short and long term.

Main likely future changes in UK climate in 2100*	**Impact of changes***	**Risk/opportunity***	**Influencing site factors***	**LMP short term implication and mitigation measures**	**LMP long term implication and mitigation measures**
Carbon dioxide increase	Atmospheric CO_2 concentration will continue to increase, depending on global measures to reduce emissions. By 2050 CO_2 concentration could be between 440 and 540ppm (parts per million), compared with the pre-industrial 280ppm.	Increased tree growth. Increased growth of other vegetation.	Increases may be constrained by changes in rainfall, soil, water availability, nutrition, pests and disease and other limiting factors. Warmer temperatures may be more beneficial in cooler wetter upland areas than in drier warmer lowland areas.	**Implication:** Blanket bog habitat occupies 15.5% of the LMP area. Around 59% of the blanket bog contains areas of very hagged peat which is emitting carbon. These hagged areas lie in Coire Bhan and the slopes of Meall Breac and Ruighe na Beinne with a small area in upper Gleann Chia-aig. The need to replace carbon emission heavy construction materials with stored carbon materials. **Mitigation:** Reduce carbon emissions: • Restore the hagged peat in upper Gleann Chia-aig and restore the hagged bogs in Coire Bhan, Meall Breac and Ruighe na Beinne where access permits. • Continue with commercial conifer sawlog production for existing stands. • Supplementary planting to introduce desirable species	**Implication:** Management interventions need to minimise carbon emissions and maximise opportunities to sequester and store carbon. **Mitigation:** The non-native commercial conifer crops may require earlier fell dates if rates of growth increase. Current trends show that sawmills favour smaller diameter sawlogs. Native habitats and biodiversity: • Maximise carbon sequestration and storage through effective deer management. This will enable native natural regeneration to extend well into the open habitats of Clunes hill without the need for roading, ground preparation, planting and maintenance of trees other than the removal of NNR and INNS. It will also help to protect the blanket bogs from poaching.

Main likely future changes in UK climate in 2100*	Impact of changes*	Risk/opportunity*	Influencing site factors*	LMP short term implication and mitigation measures	LMP long term implication and mitigation measures
				may need to occur earlier than normal to avoid weed competition and reduce the need for chemical treatment. • Control INNS at an early stage of its development, especially Gaultheria shalon. • Roadside drains and verge management should take place at regular intervals to avoid the need for major road upgrades.	• The establishment of extensive native woodland habitat will enable carbon storage in stable soils, deadwood, and lower plant communities as well as in the native trees. • Create opportunities for native broadleaf fuelwood and sawlog production within easy reach of forest roads and on accessible slopes of non-PAWS and ASNW locations. Increased growth rates will strengthen oak sawlogs and potentially increase the rate of return on fuelwood. There is, however, uncertainty regarding the future use of wood for fuel due to particulates in the air. • The permanent native woodland cover will reduce carbon losses associated with clearfelling and routine establishment operations. • Effective deer management will also improve the condition of blanket bog, tall herb communities, and rare montane habitats including montane scrub. • Zero tolerance of INNS will avoid costly and difficult management of native

Main likely future changes in UK climate in 2100*	Impact of changes*	Risk/opportunity*	Influencing site factors*	LMP short term implication and mitigation measures	LMP long term implication and mitigation measures
					habitats. It is essential to work with our neighbours to achieve effective outcomes at a landscape scale.
Temperature increase	All UK regions are expected to warm – more in summer than in winter. The growing season will become longer. Warmer temperatures imply reductions in humidity, particularly in summer, and could cause drought. Changes in phenology. (seasonal changes in plants and animals)	New species options. Nursery production planning. Pests and disease	Risks increased by: • Monoculture or low levels of species, genetic or structural diversity. • Sites with poor biosecurity. • Sites where trees are stressed by other pressures such as wind or drought. • Undermanaged/unmanaged sites. • New tree species with higher vulnerability than existing species.	**Implication:** The north west Highlands experienced drought conditions in May and early June 2023. This LMP area was close to drought conditions with prolonged periods of relatively hot weather which is unusual. This included a forwarder overheating on a south facing site in Loch Arkaig Forest which resulted in the destruction of the machine which went on fire. The fire destroyed some products at roadside as well as burning an area of birch crop. Clunes Forest and the adjacent Cam Bealach section of Glengarry Forest contain ASNW with healthy young and mature wych elm. Since 2019 Dutch elm disease has devasted elms in the Highlands north of Drumnadrochit. **Mitigation:** Maximise the opportunities to establish native woodland through natural regeneration. This lessens the risk of drying of soil and roots through ground disturbance associated with the planting of trees.	**Implication:** Predicted climate change suggests that this LMP area will be subjected to prolonged dry and hotter conditions on a more regular basis than currently experienced. The ancient woodland remnants in this LMP host fine examples of Scottish rainforest features which are reliant on high humidity levels. Stressed trees as more vulnerable to pests and disease. **Mitigation:** The conversion from conifer clearfell management to permanent native woodland management will lessen the stress and negative impacts of high temperatures on the shoots and roots of young trees. Future stand structure will be diversified through localised interventions such as group felling or natural processes and as such minimises the exposure of seedlings and saplings to hotter temperatures and desiccation.

Main likely future changes in UK climate in 2100*	Impact of changes*	Risk/opportunity*	Influencing site factors*	LMP short term implication and mitigation measures	LMP long term implication and mitigation measures
				FLS are working with the Royal Botanic Gardens Edinburgh to try and secure the future of wych elm in the Highlands. The Cam Bealach site in Glengarry lies immediately next to the Clunes Cam Bealach ASNW. The adjacent Glengarry site will be one of the places that will host a high elevation trial for wych elm, the aim of which is to grow healthy wych elm that is located above the elm bark beetle (*Scolytus scolytus*), flight zone. If successful there are some suitable locations for wych elm around the lower margins of the mountain woodland project area above Loch Lochy. Native restocking will aim to maximise species diversity which will lessen the impact of pests and disease, but also lower transmission of disease by avoiding large viral loads that could develop in monocultures. The felling of conifer crops on south facing slopes using forwarder extraction will be completed by the end of this LMP period.	Native woodlands need to be managed to establish/restore woodland ground flora. This will act as a mulch to retain as much soil moisture as possible. This will be achieved through deer management and low level interventions. Creating a permanent cover woodland will help to control/ moderate temperatures and humidity inside the woodland. Restoring riparian woodland around all watercourses will help to stabilise humidity levels especially around the “Allts” which host oceanic ravine habitat. Permanent dappled shade will also help to reduce evapotranspiration of native trees, will help to sustain the bryophyte communities and the lobaria type lichens which shrivel and discolour as humidity decreases. With long term management of a sustainable density of deer, natural regeneration should extend along much of the watercourses in the mountain woodland project area and thus reducing exposure to direct sun along all or most of these watercourses.

Main likely future changes in UK climate in 2100*	Impact of changes*	Risk/opportunity*	Influencing site factors*	LMP short term implication and mitigation measures	LMP long term implication and mitigation measures
					Riparian woodland will help in reducing the risk of high water temperatures and improve the survival of fish.
Rainfall change	Reduced rainfall: There may be lower summer rainfall. In conjunction with warmer average temperatures this will increase the risk of droughts, both duration and frequency. Lower summer rainfall implies increased solar radiation.	Wildfire	Risks are higher for: • Young stands of pine, spruce, fir, cypress or eucalyptus. • Newly established plantings where there is substantial ground vegetation. • Little silvicultural diversification. • High recreational use, particularly during hot, dry periods. • Undermanaged or unmanaged sites. • Limited or no fire risk-reduction measures. • High fire risk in adjacent areas e.g. moorland. • Outbreaks of pests/disease that increase available fuel . • Located in drier locations.	**Implication:** As per temperature increase section – the hot and prolonged dry period in May and June 2023 created tinder conditions and saw a forwarder combust due to overheating burning wood products at roadside and an area of young birch woodland in Loch Arkaig. Recent years have seen an increase in visitor numbers to the LMP area. This is in combination with a trend to light campfires even in very dry hot weather. This occurs close to the Clunes community, at the Trailblazer campsite and in the vicinity of car parks and trails. Tree roots are being burnt, stems and foliage also being scorched. The campfires are not being contained in one area as people are choosing to find new locations. During this dry period all the small watercourses dried up completely and the larger “Allts” were mere trickles. Water temperatures were high, mosses and lichens were dried up. The local private water supply was becoming vulnerable.	**Implication:** Continuing trend to have campfires in forested areas can have a negative impact on the deadwood habitat which is greatest in riparian and ancient semi-natural woodland. Persistent and extended periods of low rainfall could negatively impact the humidity levels required to sustain the European important Scottish rainforest habitat. Persistent low rainfall can impact the sustainability of the local private water supply from the forest. Increasingly difficult establishment of native pines especially on podzolic soils that are naturally dry. The stress to trees caused by drought will leave them more vulnerable to attack from pests and disease. Conversely there may be a reduction in occurrence of fungal attacks if humidity levels drop.
		Drought	Risks are higher for: • Young and newly planted trees. • Light/shallow soils that hold less water than deep soils. • Tree species and species combinations with poor drought tolerance. • High ground vegetation competition. • Lack of mixed planting, as some species can “lift” water from deeper soils.		

Main likely future changes in UK climate in 2100*	Impact of changes*	Risk/opportunity*	Influencing site factors*	LMP short term implication and mitigation measures	LMP long term implication and mitigation measures
				The prolonged dry period in May and the first half of June 2023 raised an issue of dust clouds from haulage- along forest roads. An even bigger issue was the dust clouds caused by visitors accessing the Clunes car park. This negatively impacted the local community and in particular those working in the Arkaig- Community tree nursery at the entrance to Clunes Forest. The issue of dust relating to forestry civils is being realised as a health and safety issue. **Mitigation:** Erect signage at campfire hotspots to explain the environmental dangers of campfires at locations such as the forest car parks, hill access routes, Clunes hamlet and Kilfinnan entrances, the GGW noticeboards and the Trailblazer campsite. Establish all currently felled areas with native woodland. Bolster the riparian woodland stocking density to 2500 trees/ha with 20% open space. This is particularly important on the south facing slopes of Loch Arkaig and Clunes. This will help to establish dappled shade conditions more quickly and help to add resilience to water quality, quantity and oceanic ravine humidity management. This also applies to	**Mitigation:** Work with Scottish Government and NatureScot to strengthen the wording of the SOAC to remove ambiguity regarding the use of campfires in wooded areas and vulnerable/ sensitive open habitat. Visitor Services teams should educate the public via signage and face-to-face communication about the prohibition of campfires in the LMP area. Remove the fire pit at the Trailblazer campsite. The conversion from non-native conifer production to native woodland will improve wildfire resilience through the establishment of a lush woodland ground flora. This may require localised interventions to vary stand structure to manage light levels for ground flora development and to manage fuel loads in the highest risk areas. The conversion to native woodland habitat will improve the resilience of the local private water supply by removing thirsty non-native species from the catchment – including removing sitka spruce from the natural reserve. Bolstering and expanding the riparian woodland will help to reduce the rate of water loss through the creation of dappled

Main likely future changes in UK climate in 2100*	Impact of changes*	Risk/opportunity*	Influencing site factors*	LMP short term implication and mitigation measures	LMP long term implication and mitigation measures
				the areas which will be felled during the plan period. As per the increased temperature section above - The felling of conifer crops on south facing slopes using forwarder extraction will be completed by the end of this LMP period. The Civils team should consider the viability of a road surface type that eliminates or minimises the impact of dust between the B8005 and Clunes Forest car park. “FCTN020: Reducing greenhouse gas emissions from forest civil engineering” recommends the use of “harder aggregates that also have a high attrition values as long as these are well bound and profiled in a well-shaped surface”. For legacy restocking and upcoming restocking in the LMP period the Forest Research ESC 2080 worst case climate scenario has been used to determine native species that are suited to current climate and also suited to the worst case climate prediction in 50 to 60 years’ time.	shade conditions adding resilience to water habitat and private water supply quantity and quality. Increasing native woodland stand structure diversity using an understory of native shrubs and hazel will add resilience to humidity management and minimise water loss. Forest Research ESC 2080 worst case climate scenario used to determine native species that are suited to current climate and also suited to the worst case climate prediction in 50 to 60 years’ time for the remaining future restocking, with the exception of the areas occupied by the Coire Glas development zone. Ensuring that all native woodland areas use diverse site native species with the three types of rooting habit to enable those with tap roots to obtain water from greater depths during times of drought. Forest development type approach should ensure this is delivered. The requirement for mechanised felling diminishes as the commercial conifer crop is totally harvested. Roadside verge management should minimise the threat of fire

Main likely future changes in UK climate in 2100*	Impact of changes*	Risk/opportunity*	Influencing site factors*	LMP short term implication and mitigation measures	LMP long term implication and mitigation measures
	Increased rainfall: Summer rainstorms may be heavier when they do occur. Together with the trend towards higher winter rainfall, this suggests that wetter soils and flooding are more likely.	Flooding and waterlogging	Risks are higher for sites with: • Poorly drained heavy soils. • Limited or poorly maintained road networks. • Flooding during the growing season is more damaging to trees. • Lowland and floodplain forests and woodlands. • Species sensitive to root damage during waterlogging.	**Implication:** Wetter winters and increased summer storm events which can lead to landslips. The greatest threat is the area along the C1153 and B8005 from Achnasaul at the east end of Loch Arkaig to Clunes Forest School near Loch Lochy. Steep slopes, outcrops and strewn boulders lie uphill of a concentration of infrastructure: public and forest roads, houses and utilities. There are three coupes within this zone that will be felled in the next 10 years. SEPA flood maps do show areas where there is a 10% chance of flooding around Allt Bhan to the west and south of Clunes hamlet. **Mitigation:** Native slope stability woodland restoration especially important in Achnasaul, the Dark Mile and Clunes south facing slopes. These native woodlands will be established to include site native but diverse species that ensures a mosaic of the three different	from gorse along the route of the Great Glen Way. Routine forest roads maintenance will enable fire tender access to most forested areas. **Implication:** Wetter winters and increased summer storm events which can lead to landslips. The vast majority of forested areas in Clunes Forest lie on steep slopes. The forested soils are mainly podzolising brown earths and podzols. There are localised areas of peatier soils in the upper slopes in Loch Arkaig Forest. **Mitigation:** Completion of the native slope stability woodland between Achnasaul and the Clunes Forest School. Use Forest Research ESC 2080 worst case climate scenario and Forest Development Types approach to determine species suitability and management type for all areas including where soils are increasing in podzolisation. Native slope stability woodland should be extended to all steep areas of Clunes Forest to improve the resilience of the forest road

Main likely future changes in UK climate in 2100*	Impact of changes*	Risk/opportunity*	Influencing site factors*	LMP short term implication and mitigation measures	LMP long term implication and mitigation measures
				rooting habits that maximises root anchorage and soil binding. The Civils team will need to assess all roading infrastructure and drainage to ensure resilience to increased storm events. Providing access is possible and funding is available, the restoration of the hagged blanket bog areas in the Allt Bhan catchment of Coire Bhan, Meall Breac and Ruighe na Beinne will help to hold more water in the upland areas. It should also help to slow the rate of flow off these habitats into the Allt Bhan during storm events.	infrastructure and the route of the Great Glen Way. This includes the riparian areas of the LMP streams. Civils should identify areas where drainage culverts empty into the steep forested areas. Here localised areas of wet woodland species can be established to be managed as water holding areas. Managing deer to sustainable levels will help to protect all water holding habitats to mitigate downstream flooding.
Reduced frost and snow days	The number and severity of air frosts are expected to decline: however, their timing in relation to plant and animal cycles may change. Significant reduction in the number of snow days, mean snowfall rates and the frequency of heavy snowfall events are projected.	Frost damage Pests and disease	• Frost - prone sites and/or tree species vulnerable to frost damage. • Species with short term dormancy or dormancy changing as a result of climate change. • Lowland and floodplain forest and woodlands. • Species sensitive to root damage during waterlogging.	**Implication:** In recent years the winters have been relatively mild and springs have been erratic. **Mitigation:** All establishment during the LMP period will be native. Where possible natural regeneration will be encouraged with supplementary planting of desirable natives species using local seed source provenance will help to minimise the impact of late spring and early autumn frosts. Ash is vulnerable to late spring frost damage, however, due to an embargo on planting ash as a result of Chalara infection this species will	**Implication:** The montane heath habitats of Clunes hill extend over 344ha of ground occupying 11.5% of the LMP area. Within the montane heath are rare snowbed communities which are adversely susceptible to a warming climate. These include: U7 – Narus stricta – Carex bigelowii grass heath. U10 – Carex bigelowii – Racomitrium lanuginosum moss heath. Grows in Arctic conditions where herbivores are rare. U11 – Polytrichum sexangulare – Kiaeria starkei snowbed. It is found in areas of the most prolonged snow lie and is rare in GB.

Main likely future changes in UK climate in 2100*	Impact of changes*	Risk/opportunity*	Influencing site factors*	LMP short term implication and mitigation measures	LMP long term implication and mitigation measures
				be left to nature in the hope that some will develop natural resilience. These trees will become the future seed trees. The locally native species are used to prolonged periods of wet ground conditions. Introduce wet woodland species such as common alder and willows to areas that will naturally hold water. Their root systems are specially adapted to cope with wet ground conditions.	U12 – Salix herbacea – Racomitrium heterostichum snow bed. Considered a rare vegetation type with considerable nature conservation value. Native trees are tolerant of winter cold however, early bud burst in combination with late spring frost can cause damage to new shoots especially on ash trees. Shorter periods of cold weather will increase the survival of some pests and disease. Deer and green spruce aphid are just some of the pests and disease that can negatively impact of the forest habitats. Increased warming may shorten the lifecycle of hylobius resulting in shorter fallow period management. **Mitigation:** There are no mitigation measures which can be applied in the long term management of this land to protect the above montane heath snowbed communities. Limit damage to any single species dominated native woodland by establishing a crop that is diverse in species and timing of leaf development. This will require supplementary planting to introduce desirable trees and

Main likely future changes in UK climate in 2100*	Impact of changes*	Risk/opportunity*	Influencing site factors*	LMP short term implication and mitigation measures	LMP long term implication and mitigation measures
					shrubs to limit damage from late spring and early autumn frosts. A concerted effort to manage a deer population to the lower end of the 2-7 deer/km2 target is required to sustain healthy forested and open habitats. The impact of hylobius and green spruce aphid attack diminishes as the forest is converted to native woodland. However, scots pine will still be vulnerable to hylobius attack and as such will require management as per Forest Research Hylobius Management Support System. Encouraging the natural regeneration of scots pine may increase its resilience to hylobius attack.
Increased storm frequency and wind speeds	Changes to atmospheric circulation may lead to a shift in storm tracks. Some increase in winter storms and average wind speed is expected.	Windthrow	• High elevation and exposed sites. • Tree species vulnerable to wind. • Gleyed shallow soils. • Recent harvesting nearby. • Recent stand thinning. • Undermanaged or over-mature stands. • Increased volume of damaged timber.	**Implication:** To date the Clunes and Loch Arkaig LMP forests lies mostly in areas of low DAMS scores (sheltered). In recent years winter storms have come from the east. Storm Arwen blew down much of the central Clunes LTR which was important for red squirrel habitat. This area was costly to harvest – windblown large trees felled motor manually, skyline winch extraction and banksman management along the route of the Great Glen Way.	**Implication:** Increase in storm event intensity and frequency is likely. Storm damaged trees and those in the vicinity of the damage are stressed leaving them vulnerable to attack from pest and disease. **Mitigation:** Much of the Clunes and Loch Arkaig LMP forested areas are in PAWS areas. As these areas are restored to native woodland, non-PAWS areas and riparian areas should also be turned to native

Main likely future changes in UK climate in 2100*	Impact of changes*	Risk/opportunity*	Influencing site factors*	LMP short term implication and mitigation measures	LMP long term implication and mitigation measures
				The Allt Dearg LTR was also badly impacted by this event. This coupe was an important coupe for landscaping (viewed from the A82) and for amenity (GGW & Trailblazer campsite). This was compounded by a lack of windfirm coupe edges in an old crop. It is expected that this type of event with wind from a non-prevailing direction will occur more often. Currently the sawmills are favouring good form but smaller diameter sawlogs. Clunes and Loch Arkaig have produced good quality but large sawlogs from older crops. **Mitigation:** Over the 10 year period of the LMP felled areas will be established as native woodland. The native woodland habitats will be variable according to local site conditions. Native regeneration will be encouraged and is expected to be dominated by birches. These naturally regenerating trees are likely to develop stronger root anchorage than planted trees. Supplementary planting will introduce desirable and diverse site specific native trees species with differing rooting habit from the birches to further strengthen resilience to windthrow through greater anchorage.	woodland habitats to create permanent woodland cover. The soils can be quite variable due to leaching increasing with slope and variability of bedrock, topography and aspect. This leaching/podzolisation process will continue. Native woodland species will reflect these variabilities to create diversity of species, rooting habit and stand structure as per the desirable outcomes of the “forest development types” woodland management. This should promote increased resilience to windthrow. Some windblow is part of a normal woodland process and is necessary to create gaps for regeneration opportunities and so perpetuate native woodland cover in the landscape. Continuing with the steady rate of conversion to native woodland in Clunes and Loch Arkaig Forest will mean that, from an early age, the trees will develop resilience to the changes in wind frequency, intensity and direction by early stage flexing and subsequent wood strength development. Further resilience will come from encouraging as much natural regeneration as possible. The roots of these trees develop according

Main likely future changes in UK climate in 2100*	Impact of changes*	Risk/opportunity*	Influencing site factors*	LMP short term implication and mitigation measures	LMP long term implication and mitigation measures
				The planting of site native shrubs (e.g. hazel, holly), and small trees (e.g. rowan), near public roads, utilities and homes will provide windthrow resilience to local infrastructure between the Clunes and Achnasaul communities. Taller native (non-ancient) broadleaf species can be managed by coppicing to minimise windthrow risk to infrastructure. Include some felling of slightly younger crops before they approach terminal height. Forest gales suggests felling around 37 years for coupe 61054 in Clunes. This takes account of weather, wind risk and soils. Other sitka spruce coupes are mostly timed for felling around 40 years of age.	to local ground conditions and tend to be more windfirm than planted trees. The continual management of the deer population to a healthy sustainable density will promote the natural regeneration of native species and scrub into the mountain woodland and montane scrub area which is currently open hill in Clunes. Here the trees should grow according to local conditions and as such will decrease in height and form as elevation and exposure increases with the aim of creating a sub-alpine Krummholz habitat. The FLS West Region Incident Plan includes contingency planning for wildfire, windblow, flooding and extreme weather.

(* from table 1 UK Forestry Standard Practice Guide: Adapting forest and woodland management to the changing climate)

FLS climate change adaptation checklist

Topic	Question to explore relevance in this LMP area	How to	Does this topic apply to this LMP	Comment by Planner
LMP and broader aims	Do the LMP aims and objectives deliver Scottish Government policy and meet the needs to the stakeholders and community in addressing climate and biodiversity crisis?	Consultation and checking against SFS and SCCAP	Y	Scottish Forestry Strategy (SFS): Applies to Strategic drivers: • Resilience • Reversing biodiversity loss Applies to delivery and action: • Ensuring forests and woodlands are sustainably managed (UKWAS certification) • Increasing the adaptability and resilience of forests and woodlands. • Enhancing the environmental benefits provided by forests and woodlands. Scotland's Climate Change Adaptation Programme (SCCAP): • The LMP is relevant to Outcome 5: "Our natural environment is valued, enjoyed, protected and expanded and has increased resilience to climate change".
Synergistic/ combined effect	Is there a high likelihood that multiple stresses combined will impact the future forest e.g. P&D/temperatures/wind/waterlogging/ drought?	Think through the interactions	Y	**Wind** damage creates stress to the surrounding- crop making it vulnerable to attack from pests and disease. Recent **drought** during spring/early summer has shown a vulnerability to risk of wildfire, loss of very young trees through soil water loss and excessive evapotranspiration. Continued annual drought events may threatened the humidity levels required to sustain the features of the Scottish rainforest. It has highlighted the issue of dust raised by traffic along forest roads. Successive **warmer winters** increase the survival of pests such as green spruce aphid and Hylobius.
Tree species selection*	Given the site opportunities and the management objectives are there opportunities to diversify? Is there an opportunity to introduce species from southern regions (mainly on the better ground)? If you have chosen monoculture crops what is the justification?	ESC 2020 and ESC 2080 associated guidance	Y	The LMP is dominated by PAWS restoration. Monocultures are avoided at all times to create diversity in species, stand and ensure the right tree is planted in the right place in the diverse mosaic of soils. The future species are determined using the worst case climate scenario for 2080 in ESC.

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Provenance	Will the provenance chosen be suitable now and in the future climate?	Speak to FM foresters and ESC 2080	Y	Native habitat species will use the appropriate native provenance which is resilient to current and predicted future climate.
Structure*	Has a permanent network of woodland and open ground been included to provide biodiversity corridors and improve climate resilience (E.G. riparian woodland)?	Work with Environment team	Y	LMP proposes the creation and extension of riparian buffers to link woodland habitat form low elevation ASNW to montane scrub and to link with future PAWS restoration. It also helps to improve links with the CPI areas of Arkaig with those of Glengarry via the Gleann Chia-aig Fhudair pass and via Clunes Forest along the Great Glen.
Structure*	Are there any opportunities to build resilience by changing from clearfelling to CCF?	Forest development types	Y	Yes, but it will be in very localised conifer areas where machine access is possible. The future forest is dominated by restoring permanent native woodland habitat.
Thinnings*	Has the thinning area been maximized and an assessment of thinning risk been undertaken?	Working with Delivery team	Y	Yes, as above. In very localised areas where machine access is possible. Much of the Arkaig mid-rotation crops are impacted by the ground preparation and felled stumps of the previous crop on moderate slopes.
Longer growing season*	Does a longer growing season present any opportunities?	Forest Research UKFS Practice Guide: Adapting forest and woodland management to the changing climate	Y	It will increase the potential for productive broadleaves such as oak timber and birch, alder and aspen fuelwood. Increase conifer growth will likely mean shorter rotations as current markets do not favour large sawlogs.
Natural regeneration	Are there any opportunities to use natural regeneration?	Working with Delivery team	Y	Adjacent native species and retentions on felled sites provide some seeding opportunities for PAWS/native restocking.
Drought*	Will extreme drought conditions cause mortality, productivity loss or drought crack in chosen spp? E.g. in parts of the East.	Forest Research UKFS Practice Guide: Adapting forest and woodland management to the changing climate	Y	The drought in 2023 has highlighted a risk, although it is too early to know the long term pattern to gauge whether this is a big risk for this LMP. The creation of permanent native woodland habitat will help to create shade and cooling under canopy to protect ground water, ground flora and lower plant communities.
Pests and disease*	Are chosen species at risk of known specific pests and disease?	SF and FLS guidance	Y	Native pines are vulnerable to Dothistroma needle blight. The LMP will propose to remove mature LP and CP to lower the risk to the native pines. Hymenoscyphus fraxineus is currently affecting the native ash. Leave as many ash as possible in the hope of identifying resilient trees as future seed sources.
Soils and Cultivation	Do the LMP proposals comply with national Ground Preparation guidance on impact reduction?	Discuss with FM and Stewardship forester	Y	The minimal ground preparation will be undertaken to secure establishment. Ground preparation is unlikely on PAWS restoration sites to protect ancient woodland features and unlikely on steep ground.
Mammals/ Deer*	Can chosen species be protected from deer etc?	See Wildlife dashboard	Y	Most species are vulnerable to deer. FLS will aim to reduce deer numbers to sustainable levels in partnership with our neighbours.

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Wind	The forest will be subject to more frequent extreme storms including wind and rainfall? Can stability be improved with better design? Are there opportunities to make any clearfelling coupes independent of one another and avoid elevated exposed edges.	Forest Research "Forest Gales" and local knowledge.	Y	The current conifer crop is resilient to prevailing winds, however, in recent years winds from the east have caused some windblow. Future forests will be more diverse both in species and rooting habitat.
Flooding*	Is the LMP area upstream of a SEPA Objective target area for river flooding? Are any of our fellings likely to impact the ground below and/or neighbours, due to increased run-off.	FLS flooding guidance and Flooding maps	N	The LMP is not affected by a SEPA objective target.
Flooding*	Is the LMP area upstream of any locally sensitive areas prone to flooding e.g. farm/house/bridge. Are any of our fellings likely to impact the ground below and/or neighbours, due to increased run-off?	From local knowledge or from scoping consultation	Y	Felling uphill of Clunes village may increase run-off in the short term post felling.
Water Quality*	River Basin Management Planning: Can/should FLS take any specific action to improve the water quality of river/burn segments affected by the LMP area. Is the LMP area upstream of/does it include particularly sensitive species or habitats which require proposals to increase resilience?	FLS guidance on SEPA RBMP	Y	The hydro development affecting Allt Chia-aig has lowered the waterbody catchment from high to moderate. The LMP proposals will not alter this. However, improved riparian management, restoration of blanket bog and widespread PAWS restoration will improve water quality resilience over the longer term.
Water quality and quantity*	Public Water Supply - Scottish Water. Do we need to take any specific action to protect water quality or quantity?	FLS guidance	N	No public water catchments associated with this LMP.
Water quality and quantity*	Private Water Supplies - Do we need to take any specific action to protect water quality or quantity, particularly in light of potential future water scarcity?	FLS Guidance	Y	Improvements to the PWS catchment involving the removal of mature conifers, including the removal of sitka spruce in the natural reserve and replacing with PAWS restoration will improve this catchment. Riparian woodland habitat will be created within 20m of the stream below the upper forest road and within 50m of the abstraction point. Removal of non-native broadleaves will also improve riparian habitat.
Effect on neighbours	Will our activity affect neighbours in light of more extreme weather events?	Consider implications outside FLS boundaries	Y	A storm event coinciding with felling uphill of the Clunes community may impact neighbours. To should be noted that ASNW separates the fell site from homes and infrastructure.
Shade*	Are there any issues relating to future shade benefits of trees? E.g. shade near recreation areas	Consultation feedback	Y	The formal car parks are already resilient with shade. Travelers along the Great Glen Way are somewhat exposed to direct sunlight. Felling in the new LMP will further open areas to direct sun. This will improve through time as the current and upcoming felled areas establish as native woodland offering dappled shade.
Land slip*	Is there a risk of landslide onto property/transport links?	FW Slope instability layer	Y	The section of slope uphill of the Dark Mile from Achnasaul to Clunes Forest School has potential slope instability in the form of boulders and crags/outcrops

Topic	Question to explore relevance in this LMP area	How to	Does this topic apply to this LMP	Comment by Planner
				on steep ground. This can impact on public roads C1153 and B8005 as well as properties and powerlines close to the forest road at Clunes entrance.
Habitat connectivity*	Are there opportunities to build resilience in strengthening open and forested habitats? Where are the opportunities to improve resilience?	Discuss with Environment team	Y	PAWS restoration and riparian woodland creation will help to link low lying ASNW with montane habitat. Resilience will greatly improve through management of deer to sustainable levels to promote long term natural regeneration to establish mountain woodland and montane scrub habitat.
Species connectivity*	Are there specific species which require supported through specific actions?	Discuss with Environment team	Y	Not really, although red squirrels need an improved habitat for long term resilience. Native woodland linkages within and out with the LMP area will improve the habitat. Also consideration will be given to retaining Norway spruce and Douglas fir for as long as possible. Also, the expansion of Scottish rainforest habitat through PAWS restoration and the wider Arkaig landscape scale restoration will help with the spread of associated lower plant communities.
Species connectivity*	Is there a specific threat from Invasive non-native species INNS?	Discuss with Environment team and see SEPA	Y	Rhododendron and Gaultheria shalon are the biggest threats to native habitats both within the LMP area and out with it. Buddleia is also spreading in south Clunes and Loch Arkaig Forest. Management of this will need to be considered.
Peatland*	Has the national guidance on restocking been applied, restoring all tranche 1 peatlands and considering all tranche 2 peatlands for restoration?	Speak to national peatland team	Y	No forest to bog restoration identified. Hagged blanket bog has been identified in upper Gleann Chia-aig for restoration. High elevation hagged blanket bog will be restored pending machine access and funding.
Fire	Has the national guidance on forest design for wildfire resilience been applied?	Forest Research guidance	Y	Followed the best practice. Greater use of native broadleaf species will improve wildfire resilience over time. Maintenance of existing roads and verges will improve access in the event of wildfire. FIRE RISK: The dry hot spell in 2023 saw the destruction of a forwarder on a fell site. It went on fire after the day's operations unable to cooldown from being permanently exposed to direct sun on the south facing slopes of Arkaig. Also worrying is the increasing trend for visitors to light campfires in wooded areas even in very hot weather.
Roads/bridges/ culverts	Have full assessments of high scenario rainfall been included in water crossing design and have all roads been designed or modified to reduce wash out and landslide risk and reduce their impact on the water environment?	Civil Engineering	Y	The FLS Civils team has yet to assess infrastructure against a high scenario rainfall. However, local staff do carry out resilience measures when the opportunity arises.

Topic	Question to explore relevance in this LMP area	How to	Does this topic apply to this LMP	Comment by Planner
Sea level rise	Will our activity be affected by say 90cm sea level rise? See Dynamic Coast data	Dynamic Coast	N	N/A

* As well as delivering on adaptation, some actions can also deliver on carbon capture and the biodiversity crisis - at site level there is often synergy or co-benefits in our actions right across the climate change emergency and the biodiversity crisis, this is good and should be encouraged.