The Impacts of Climate Change on the Landscapes of Cumbria and the Lake District: Evidence and Research Analysis, March 2020

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Part 1 Introductory Context

1.1 Friends of the Lake District and CPRE, The Countryside Charity, commissioned this baseline evidence and research analysis to review the latest predictions on the impacts of climate change on the landscapes of Cumbria and the Lake District. The findings will be used to:

- Bring together relevant climate change research, literature and evidence relating to Cumbria's landscapes;
- Summarise the likely impacts on the main attributes of the landscape, and identify gaps in knowledge where further research might be necessary;
- Provide a baseline for a detailed analysis of how climate change will impact upon the landscape character types and attributes of Cumbria and the Lake District; and
- Help inform future adaptation and mitigation management prescriptions to make the landscape more resilient.

1.2 Most of the evidence on climate change is not Cumbria-scale specific, and more up to date and refined evidence is continually being published. In terms of predictions for climate change we are using:

- The Committee on Climate Change – Climate Change Risk Assessment Evidence Report 2017 (Committee on Climate Change 2017);
- The Met Office State of the UK Climate Report (Kendon, et al. 2019)
- The 2019 UK Climate Projections Update (UK Met Office Hadley Centre 2019), to inform our overall findings and analysis.

1.3 Some key headline findings from the 2019 Climate Projections Update are shown in Appendix 1. Key predicted changes relevant to Cumbria's landscape include:

- Greater temperature extremes;
- Hotter, drier summers and wetter, warmer winters;
- More intense and frequent rainstorm events e.g. Storm Desmond in December 2015 (Otto, et al. 2018)
- Significantly decreased snowfall;
- Sea level rises magnified by storm events/flooded rivers; and
- Summer soil moisture decreases.

1.4 The significance of the effects will depend upon the actual emission levels in future. For example, under UKCIP 2080 high carbon emission scenarios, vegetation composition is likely to change dramatically and in unpredictable ways (Holdgate 2019), (Committee on Climate Change 2017), (Committee on Climate Change 2017).

1.5 For a summary of the bigger picture around the urgency of tackling greenhouse gas emissions at a global level we suggest reading the United Nation's Environment Programme's Tenth Annual

Emission Gap Report 2019 (UN Environment Programme 2019). The Climate Change Risk Assessment Report 2017 (Committee on Climate Change 2017) identifies the six top priorities for the UK where more action is needed, including on Natural Capital

> *Climate change presents a substantial risk to the UK's native wildlife and to the vital goods and services provided by natural capital, including food, timber and fibre, clean water, carbon storage, and the cultural benefits derived from landscapes."* (page 5, Synthesis Report).

1.6 Climate change predictions model complex systems. Working down from the global scale to the regional-local level inevitably involves significant uncertainties as to the actual consequences on the landscape (Pearce 2015). Some changes are immediate and dramatic, such as the impacts of flooding or fires on wildlife habitats and soils. Many changes will evolve gradually over a longer time frame, comprising subtle changes to landscape characteristic features such as trees, hedges, vegetation mosaics and geomorphological processes. Climate change risks are also exacerbated because they occur in combination with existing pressures, particularly for biodiversity, soils and water.

1.7 Direct, primary impacts on landscape character are the main focus in this research. The impacts are recorded against seven Landscape Attributes that encompass the core elements from the Landscape Character Assessments, and in the case of the Lake District National Park, the World Heritage Site's Outstanding Universal Values. Cleary, however, understanding the dynamics of landscape character and natural processes requires an integrated approach. Hopefully, significant connectivities are drawn out and obvious, but the reader should bear in mind any separation of these different attributes risks simplifying real-life local landscape changes.

1.8 Secondary impacts depend on many external factors such as political/public resource decisions or changes in society's behaviour. Given our landscape focus the research does highlight secondary impacts where they relate to Defra's "Making the Country Resilient to a Changing Climate" (Department for Environment, Food and Rural Affairs 2018), The 25 Year Environment Plan (Department of Environment, Food and Rural Affairs 2018) and the recent Committee on Climate Change Report "Land use: Policies for a Net Zero UK" (Committee on Climate Change 2020) priorities that tie in with the adaptation strategy. For example, we will see an increase in tree planting, more extensive natural 'slow the flow' flood and coastal realignment/natural retreat land management practices.

1.9 This research has not sought to cover wider potential consequences on the economy, people's health & well-being, food security or transport, energy & communications infrastructure. In terms of biodiversity we do not look at changes in individual species, but cover the broader changes to wildlife habitats, and with the marine environment, we look at on-shore flooding connected to sea level rises, but not oceanic acidification or temperature changes.

1.10 Recent work by Natural Resources Wales analysing the effects on climate change 2019-2050 on landscapes (Natural Resources Wales 2017), showed significant effects would be related to the potential spread of pests, pathogens and diseases, in particular for tree cover and vegetation, with hotter drier summers adding to stresses. Wetter winters and more intense storms causing soil waterlogging, increased run-off and higher potential for flooding, affecting lowland and coastal edge areas in particular. Their report states that landscape character provides an important communication tool to raise awareness and understanding of the risks and opportunities of climate change, because people relate to landscapes as places where they live, work and enjoy.

1.11 This capture of evidence and literature review forms Phase 1 of the research Friends of the Lake District is aiming to carry out. It does not factor in future public policy or investment responses to help address climate change impacts (for example, the new ELMS prescription payments Post-Brexit, or the EA's Flood Defence infrastructure programme). Phase 2 (bullets 3 and 4, Para.1.1 above), will take these into account in the local context of Cumbria and the Lake District, and inform the work of the Lake District National Park Partnership Landscape Character Sub-Group.

1.12 Friends of the Lake District will use the findings in this report to inform their on-going policy and property management work, and deliver at least one Leaders Landscape Training Course to help increase wider awareness on climate change and the landscape. The report also feeds into the national Landscape Character Enhancement research currently being carried out by Land Use Consultants on behalf of CPRE, The Countryside Charity.

1.13 The Report comprises the following parts:

- Climate change – landscape attribute impacts & research gaps;
- Discussion of overview messages, key findings and conclusion;
- A research summary document
- Short summaries of the most relevant documents that were reviewed for this study containing a synopsis of relevant research key points and a link to the full reports and journal articles.
- An Appendix listing further background data

Part 2 Overview, Key Findings and Conclusions

Climate Change and Cumbria's Landscapes - Overview messages

2.1 Landscape character is multi-faceted, combining natural and ecological processes with human influences, physical and perceptual. Climate change impacts - air/water temperature/precipitation changes, extreme weather events, flooding, sea-level rise and vegetation/habitat loss/migration – are cross cutting drivers affecting all aspects of this landscape character.

2.2 This research has shown that time-depth knowledge is critical background context for understanding the changes to landscape character as influenced by climate change[1]. Those born today see a landscape very different to that experienced 20, 50 or 100 years ago. To many people the changes stemming from climate change aren't immediate, tangible or visible in the course of day-to-day life. Yet they are evolving bit by bit, are cumulative, and will likely result in disastrous long-term consequences if proactive decisions and changes are not implemented.

2.3 Critically looking at landscape character, climate change is not the only, and in many cases, not the dominant factor influencing changes. Past and current land use policies/fiscal incentives, agricultural production/forestry management, water supply, energy & utilities infrastructure, societal values & recreation choices, etc. all play critical roles. The impacts of climate change, however, often adds further pressure onto landscape processes/attributes which are already under stress, a 'multiplier' effect. For example, soil erosion in Cumbrian upper river catchments is contributing to siltation of spawning beds for Salmon and Brown Trout. Grazing/stocking pressures and lack of woodland cover make soils vulnerable, and increased droughting/water logging, storm events and wildfires, further increases erosion.

2.4 Research on the waterbodies of the Lake District/Cumbria is some of the world's most extensive thanks to the work of the Lake District-based Freshwater Biological Association and latterly the Centre for Ecology and Hydrology (CEH)[2]. This shows how complex and dynamic modelling/monitoring change is, unique to individual lakes and river systems and their own geography/micro-climate circumstances. This also reinforces the risks of both isolating and trying to predict cause and effect from the impacts of climate change alone.

2.5 When deciding future land use changes to strengthen landscape resilience or help absorb more atmospheric carbon, other benefits must be factored in, such as wildlife habitat expansion/recovery/connectivity, soil health, water quality improvements, cultural heritage protection and clean air for people. The good news is that if carefully planned, land use changes can be a win-win for taking action to address climate change *and* enhance landscape integrity/wildlife habitats.

2.6 It is also important to have qualitative, not just quantitative, data behind landscape character evidence, bringing together scientific and aesthetic knowledge to better understand the dynamics of landscape change and inform judgements on appropriate future changes. People's engagement with landscape is multi-sensorial, making an emotional connection, for example, hearing bird song or smelling the scent from a carpet of wild bluebells (Lumber, Richardson and Sheffield 2017). Simply

[1] (Muchan 2020) (Chiverrell, et al. 2019) (Orr, et al. 2018) (G. Watts, R. W. Battarbee, et al. 2015) (Ferranti, Whyatt and Timmis 2009) (George, Hurley and Hewitt 2007) (Chiverrell, Harvey and Foster 2007) (Chiverell 2006).

[2] (Muchan 2020)

throwing facts and data at people will not led to behavioural change unless they feel a connection to the issue in their daily lives.

Key Findings

2.7 Over 1,000 research papers, theses, articles and media reports were examined and those with most relevance analysed and included in the Research Summary at the end of this report (Section 5). Outside of the direct landscape impacts of flooding, erosion and storm damage to the land and vegetation/trees, most climate change impacts on the area are subtle, gradual changes requiring long-term field monitoring. In Cumbria the two standout examples of this are lake/river quality monitoring by CEH and upland montane and peatbog habitats monitoring from the North Pennines Moor House field station. The 'time-lag' effect for writing/publishing research should be noted in reading this report as a snap-shot caveat. For example, ash dieback disease will have a significant effect on extensive areas of woodland across the Morecambe Bay Limestone landscape character type and yet there is little evidence on the contribution of climate change at present.

2.8 For many Cumbrian landscape character attributes the direct impacts of climate change are negligible in the short-term (next 10 years). However, under the high emissions scenarios to 2080, landscape impacts look set to significantly increase during this time period[3]. There are some critically damaging harmful impacts driven especially by climate change on some significant core Landscape Character Areas/attributes affecting many landscapes across Cumbria (refer to impacts table section for greater details). They are:

2.9 Coastal landscape/habitat loss of and damage to Cumbria's internationally/nationally significant resource of coastal landscape, heritage, biodiversity and recreational access assets. Whilst the Coastal Strategy[4] provides opportunities to create new/replacement habitats around managed realignment, much detailed research is required to provide these positive solutions. Furthermore pressure for more hard engineering to protect properties, heritage assets and transport infrastructure will create potentially negative landscape impacts around the coastline and add to the 'squeeze' damage to sensitive habitats.

2.10 Soils and peatland loss through erosion directly scars the landscape via for example gullying and landslips, but also causes significant wider ecosystem service damage, including reduced carbon storage, poorer water quality and freshwater habitat/species decline. The complexity of the make-up of our soils is poorly understood and yet it is a critical, non-renewable resource underpinning many of the attributes of landscape character.

2.11 Montane and Arctic Alpine habitats are especially vulnerable to further damage/losses stemming from climate change impacts. Cumbria contains 84% of this priority habitat in England, representing a huge proportion of this international/nationally important designated landscape across the County's uplands. Many rare wildlife species will also be adversely affected, including the bilberry bumblebee and mountain Ringlet butterfly. The loss of winter snow cover in these cooler upland environments is linked and will negatively impact upon opportunities for winter recreational pursuits and affect people's sense of wildness of the mountains.

2.12 Upland Atlantic Oak dominated woodland – This is an internationally important habitat, representing our 'temperate rainforest'. Although not directly threatened by climate change, its quality and extent could be damaged. Associated bryophyte, moss and lichen communities will be affected by

[3] (Holdgate 2019), (Carr 2020), (Committee on Climate Change 2017)
[4] (Cumbria County Council 2019)

weather changes, other tree species will increasingly compete for space (eg, beech), earlier budding could impact on several native ground-storey plant communities such as native bluebells, increased winter survival of pest species (eg. grey squirrel) and barriers to allow migration to higher altitudes could undermine future resilience.

2.13 On the positive side, the management adaptation responses for climate change mitigation/landscape resilience provide significant landscape enhancement opportunities. For example, increased native tree planting on bracken covered slopes can connect existing pockets of woodland, help stabilise soils, increase carbon absorption, reduce the speed of water run-off, enhance wildlife habitat value, strengthen landscape character throughout all the seasons and provide high amenity woodland walking/cycling experiences. Equally, increasing water storage capacity of the land to help ameliorate climate change impacts including down-stream flooding, will provide many of these benefits and more natural-looking water bodies reinforce the Lake District's sense of place.

Recommended Monitoring:

2.14 Landscape character change, combining climate change impacts and other drivers, is not currently being monitored within Cumbria[5], including within the Lake District National Park World Heritage Site[6]. It is recommended that monitoring within the LDNP specifically for the landscape change indicator within the State of the Park Report, should cover the following:

- Park-wide core attributes of Outstanding Universal Values (OUV)/Special Qualities, to include: field boundaries/walls, native & ancient woodland cover on valley-sides, gills and within bracken beds; and
- Four to six ADCs (Areas of Distinctive Character) that include core OUV elements of mountains/common land, lake(s) & river(s), valley in-bye, ancient woodland & parkland, vernacular farmsteads/settlement[7].(i) Monitoring these attributes' should cover both scenic qualities, perceptual qualities (eg. Tranquillity/Dark Skies) and ecological networks [8] (land cover, habitat connectivity, health and diversity) *together* in an integrated way.
- For the visual/scenic monitoring using fixed-point photography, consider using Thomas West's viewing stations[9] (established in 1778) around the five major lakes. The fixed-point monitoring to include views from within and out of the four ADCs.
- Park-wide core attributes of OUV/Special qualities

2.15 The Park-wide attributes are those which the Lake District National Park climate change risk assessment report is not covering under other strands and ones which are core to the landscape character of the English Lake District World Heritage Site Outstanding Universal Value and National Park's Special Qualities. The patterns of field wall enclosure are common in many upland areas, but in the glacial context of U-shaped, steep enclosed valleys of the Lake District National Park their dominance to overall character is very significant. The focus on woodland cover, gill topography and bracken beds is linked to the next stages. Whichever forward landscape change policy you apply -

[5] (Wain 2011)
[6] (Lake District National Park Partnership 2018)
[7] We recommend the ADCs to cover different Landscape Character Types, and would include – Borrowdale (Area 22), Brothers Water and Hartsop (Area 32), Low Furness Fells (Area 47) and Whitbarrow and the Winster Valley (Area 59).
[8] Focus on priority habitats, see the Cumbria Biodiversity Evidence Base, Cumbria Biological Data Centre, 2014.*(46)*
[9] (Lake District National Park Authority 2020)

natural flood management, re-wilding, biodiversity enhancement, habitat connectivity, sustainable soil management/water quality - increases in tree cover will be a central theme. Bracken beds are a good indicator where natural tree cover should be on deep soils, don't follow artificial straight lines on the ground and do not involve the loss of valued grazing.

Choice of Areas of Distinctive Character

2.16 The ADCs chosen aim to cover the 'spokes of the wheel' glaciated valleys from high fells flowing out. This complex radiating geology and landforms are unique to the Lake District National Park WHS with all the cultural heritage influences integrated into the topography and landscape character, with an interplay of Mountain-Lake-Valley. Importantly, the visual monitoring must include views out from the ADCs, as well as key internal perspectives.

2.17 Outside the LDNP landscape, monitoring change should prioritise landscape areas affected by the key harmful impacts identified in the findings above. These would include the uplands of the North Pennines[10] and the *Yorkshire* Dales and some of the most vulnerable coastal areas and river corridors/flood plains, especially estuaries of Morecambe Bay and the Solway Coast (covering both coastal AONB areas[11]). For the latter, this should be linked in with developing action plans for the Cumbria Coastal Strategy and River Catchment Management Plans.

2.18 People's views on landscape change in light of climate change impacts should also be ascertained, including visitors (day and staying) given the importance of the tourism economy to the county and its dependency/brand tied to the quality of the landscape.

Conclusions

2.19 There is a lack of research integrating landscape change monitoring with climate change, both at the national[12] and Cumbria level. What is being carried out has a narrow focused upon specific ecological, heritage or ecosystem service assets. This is a missed opportunity given what Natural Resources Wales states in the 2019 report[13], that "connecting people with understanding landscape change through their sense of place is a powerful communication tool in the climate change agenda".

2.20 Two good research examples highlighted are, firstly, the Thirlmere Resilience catchment-scale monitoring capturing data on erosion, soils/peat and vegetation health and land cover, precipitation/weather events[14]. The core of this is the hydrological cycle related to water quality standards. It builds upon the good on-going legacy work of CEH on lake/river water bodies, but importantly pulls together multiple sources of data combining visual, geomorphological, ecological, water, weather/climatic information. In addition, the watersheds linked to catchment boundaries relate well to valleys, people's sense of place and the ADCs in the Lake District National Park.

2.21 Secondly, the current PhD research by Lancaster University and Eden Rivers Trust[15] examining at a catchment-scale, how linear landscape field boundaries (hedges/walls) influence water run-off and

[10] (Durham County Council 2008)
[11] (Arnside & Silverdale AONB Partnership; Land Use Consultants 2015), (Irving 2010)
[12] Within the UK Climate Change Risk Assessment 2017 under Natural Capital a priority action needed, *includes 'NE14 Risks and Opportunities for changes in landscape character*' as a cross cutting theme, with an action to: Monitor impacts and ensure climate change is accounted for in future landscape character assessments. (page 58, Synthesis Report).*(28)*
[13] (Berry, et al. 2019)
[14] (Lake District National Park Partnership 2018)
[15] (Wallace 2020)

soil protection. A good example of combining visual/heritage landscape surface features with hydrological processes and the underlying soil resource.

2.22 The next stage of this climate change work in Cumbria can take these examples further using GIS to combine spatial data covering multiple landscape attributes at the core to understanding the effects of climate change. The landscape areas recommended above as priorities for monitoring are informed by the research findings and the national/international value of much of Cumbria's landscape. Gaps in knowledge in relation to core landscape attributes are identified in the impacts table and research should be undertaken to feed into future stages.

Part 3: Summaries of impacts of climate change on Cumbria's landscapes

Type of Impact	Landscape Attribute[16]
	Surface Water (Inland and Coastal)
Direct Impacts[17]	Annual flooding of lower lying estuaries and river basins from rising sea levels[18]
	Changes in UK lake and river water quality are primarily driven by changes and intensification of land-use and point sources[19]
	High intensity rainfall events as witnessed in the last five years are increasing soil erosion and surface run-off (as well as contaminated wash out from old mines); all leading to higher sedimentation and pollution inputs into rivers and lakes affecting species[20].
Secondary Impacts	Pressures to construct New Shore Control Structures (and opportunities to remove non-viable existing structures) via Shoreline Management Plans and Cumbria Coastal Strategy 2019 significantly affecting landscape character.[21]
	Increased peak flows and flooding leading to migration river flood plains/re-naturalisation, de-canalising river channels[22] and fencing off buffer strips adjacent to rivers and tributaries[23].

[16] Timescales:
Now – 2030 short term;
2030 – 2050 medium term;
2050 – 2080 long-term

[17] Most of the research connected to landscape attribute changes is not directly correlated to the greenhouse gas emissions scenario timeframes: Where they do so this is highlighted, but most impacts have started, are gradual and continue as the century progresses. Time-depth human experience and paleaoecological (radiocarbon, pollen and soil particulates) evidence provides essential context and understanding to individual weather events and longer-term climate variability (eg. 1,500 years of data for Brotherswater deposits)*(36).*

[18] (Carrington 2020), (Kulp and Strauss 2019) (Climate Central 2019) (Otto, et al. 2018), (Committee on Climate Change 2017) (Centre for Ecology and Hydrology 2015)
[19] (Lake District National Park Partnership 2018) (Moorhouse, et al. 2018) (G. Watts, R. Battarbee, et al. 2012) (Hatfield, et al. 2008), (Chiverrell, Harvey and Foster 2007), (Chiverell 2006)
[20] (Carr 2020), (Lake District National Park 2014)
[21] (Cumbria County Council 2019)
[22] (Lake District National Park 2014)
[23] (Department for Environment, Food and Rural Affairs 2018)

	Increased algal blooms from nutrient enrichment are exacerbated by rising temperatures affecting both water quality and aquatic species[24] see also[25] on temperatures rises.
Summary of Impacts	Significant and extensive increases in annual flooding events by 2050, including Leven, Lyth & Winster valleys, Walney Island & Barrow, Duddon, Eskmeals/Ravenglass, Derwent and extensive areas around the Solway Plain[26]. (See Map - Figure 2 in Appendix).
	Coastal flooding is likely to get worse, due to the combined effects of higher sea level rises than previously thought and more extreme rainfall[27].
	Sea level rise means deeper waters and bigger waves reaching saltmarsh, dunes, shingle and maritime cliffs, eroding the seaward edge. This coastal 'squeeze' of natural habitats between sea and land causes the loss of these coastal habitats and the range of benefits they provide, such as a natural defence against the sea as well as the capture and storage of carbon[28].
Research gaps identified	The Cumbria Coastal Strategy 2019 recommends further investigations within most of the 25 priority units around the coastline, including impacts on landscape character. What are the priorities, timescales, climate change impact scenarios and landscape enhancement opportunities?
	Groundwater levels, quality or temperatures, as this contributes particularly to summer flows.
Resources	
	Flood Risk Zone Maps: Coastal: https://ckan.publishing.service.gov.uk/dataset/flood-map-for-planning-rivers-and-sea-areas-benefiting-from-defences Inland: https://flood-map-for-planning.service.gov.uk/ Surface Water: https://www.gov.uk/government/publications/flood-risk-maps-for-surface-water-how-to-use-the-map
	Regular monitoring is carried out on the two basins of Windermere, England's largest natural lake (15km2 with a maximum depth of 64m), Bassenthwaite Lake (5.3km2), Derwent Water (5.2km2), Esthwaite Water (1.0km2), Grasmere (0.62km2) and Blelham Tarn (0.1km2). Research on some of these lakes was initiated by the Freshwater Biological Association but CEH has maintained this work for the last quarter century. In addition, quinquennial, seasonal surveys of 20 Cumbrian lakes, the "Lakes Tour", are undertaken in conjunction with

[24] (Moorhouse, et al. 2018)
[25] (Muchan 2020)
[26] (Kulp and Strauss 2019), (UK Met Office Hadley Centre 2019)
[27] (Williams, Impacts of climate change on UK coasts and seas are highlighted 2020)
[28] (Williams, Impacts of climate change on UK coasts and seas are highlighted 2020), (Richards, et al. 2008)

	stakeholders. Data from Windermere and Esthwaite Water contribute to the Environmental Change Network. https://www.ceh.ac.uk/our-science/monitoring-site/lake-observatories
	Detailed weather station results show winter rainfall under SW conditions has increased from 1960 to 2007, with the magnitude of increase in upland areas particularly leeward-upland zones, are experiencing the greatest increase in rainfall under SW conditions[29].
	Lakes at high altitude and latitude are typically Oligotrophic (nutrient-poor) ecosystems where external factors outweigh the relative importance of in-lake processes, making them ideal sentinels of climate change, Lowland lakes affected from nutrient enrichment more from sewerage, slurry and fertilizer run-off[30].
Landscape Attribute	**Vegetation, Trees/Woodlands & Wildlife Habitats (See Cumbria Priority Habitats[31])**
Direct Impacts	Loss of Montane Heath due to temperature rise[32].
	Loss of Blanket Bog by 2080[33]
	Coastal Salt Marsh areas lost[34]
	Water stress may result in tree loss/damage and affect establishment of new planting. Adverse weather increases likelihood of wind-blow and storm damage. Phenology changes expected (e.g. date of bud burst). Extremes of wetting and drying may lead to greater uprooting of trees[35].
	Upland Oak/and Mixed Ash Woodland: Range restricted to wetter regions and replaced by communities more typical of lowland broadleaved and mixed woodland, eg. beech encroachment where climate is warmer and wetter. Rowan and birch increase in dominance in areas affected by wind-blow. Decline in extent and quality of bryophytes (mosses) and lichens[36].
	Frequency of extreme events - high winds & soil droughting/waterlogging increasing frequency of wind throw, leading to the loss of mature and veteran trees and an increased break up of large, unstable crowns in veteran trees, particularly those that have fallen out of the pollard cycle[37].

[29] (Ferranti, Whyatt and Timmis 2009)
[30] (H. L. Moorhouse 2016)
[31] (Department for Environment, Food and Rural Affairs 2019), (Eweda and Frost 2014)
[32] (G. Watts, R. W. Battarbee, et al. 2015), (Harrison, Berry and Dawson 2001)
[33] (Arnside & Silverdale AONB Partnership; Land Use Consultants 2015), (Ovens 2014),
[34] (Carrington 2020), (Kulp and Strauss 2019) (Climate Central 2019) (Otto, et al. 2018), (Committee on Climate Change 2017) (Centre for Ecology and Hydrology 2015)
[35] (Rotherham 2015), (Lake District National Park 2014)
[36] (Natural England; RSPB 2014), (Forestry Commission 2010)
[37] (Natural England; RSPB *ibid*)

	Upland Hay meadows species composition changes with earlier growth of competitive species adapted to higher temperatures pushing out typical meadow species (eg. geranium spp)[38].
	Cumbria contains 59% of England's limestone pavement and a critical landscape, geological and wildlife habitat component in several areas. Research indicates climate change impacts are not a significant effect on their quality or extent[39], compared to land use management and broader tree disease, such as Ash Dieback.
Indirect impacts	Increased tree planting to meet national targets and contribute to Natural Flood Measures 'slow the flow' land management (NB. Consider potential negative impacts of increased trees in certain areas affected by summer drought, low-flow periods caused by the trees drawing water out of the soil affecting low river flows)[40].
	Expansion of wetland habitats on river flood plains and upper catchments from land management 'slow the flow' works. NB. Natural Flood Management measures are more effective in smaller catchments[41].
	Alien Species – role of climate change small compared to human-assisted introductions driven by socio-economic factors[42].
Summary of Impacts	Significant designated landscapes affected by coastal erosion/flooding damaging distinctive features such as coastal cliffs, limestone hills, intertidal habitats such as sandflats, sand dunes, mudflats and saltmarshes, beaches and existing coastal defences.
	Significant direct loss of mudflats saline lagoons, coastal sand dunes, coastal floodplain grazing marsh and salt marshes in two internationally important habitats, Morecambe Bay and The Solway from increased annual flooding events[43]. Coastal grazing marsh is the habitat most vulnerable to sea-level rise[44] . Current England-wide plan to realign 10% of the coastline by 2030 (15% by 2060) creating opportunities for new habitat gains[45].
	There is a high concentration of priority SAC and SSSI priority habitats in Lake District and North Pennine Uplands (e.g. arctic, montane and blanket bog communities).

[38] (Natural England; RSPB *ibid*)
[39] (Viles 2003)
[40] (Department for Environment, Food and Rural Affairs 2018)
[41] (Kay, et al. 2019)
[42] (Hulme 2016)
[43] (Natural England; RSPB 2014), (Richards, et al. 2008), (Harrison, Berry and Dawson 2001), (Shackley, et al. 1998)
[44] (Richards, et al *ibid)*
[45] (Williams, Impacts of climate change on UK coasts and seas are highlighted 2020), (Committee on Climate Change 2020)

	There is likely to be a significant loss of Montane Heath habitat from Lake District and North Pennines 2030-50[46]. Evidence of significant climate change stress vulnerability to peat and blanket bogs[47]. Potentially 59% of blanket bog would suffer greater desiccation and more peat erosion due to warmer temperatures[48]. Cumbria has 42,000 hectares of peatland with only half actively growing and absorbing carbon dioxide[49].
	Increased Nitrogen deposition especially affects upland montane and arctic alpine species[50].
	Upland Oak Woodland dieback from soil moisture stress, range could expand to higher altitudes with rising temperatures[51]. Mosses (bryophytes) within this woodland are particularly at risk of being unable to respond to changing climatic conditions, which could have implications for the key ecosystem services they provide (i.e. water purification, carbon storage, flood alleviation) and global consequences as the UK hosts internationally important populations of these taxa[52].
	Damage to trees and woodlands, especially in parkland and wood pastures in Cumbria, is likely to increase from pests and pathogens and from wind storms, droughts and wildfires. Pest and pathogen damage is likely to increase because of more suitable conditions for their spread, including more environmental stresses that will make trees more susceptible, and because of new introductions of both pests and pathogens[53].
	Climate change is predicted to advance the day of budburst, extending the growing season, and increasing biomass production.
	Hotter, drier summers and reduced precipitation, particularly in southern England in summer is predicted to cause drought stress in most forests and increase the risk of fires.
	Wetter winters are likely to increase waterlogging of soils resulting in fine root die back and therefore impairing drought resistance and tree survival in summer. Given that future storm events will likely increase in severity, tree damage and loss may also increase.

[46] (Natural England; RSPB *ibid*) , (Harrison, Berry and Dawson 2001)
[47] (Ovens 2014)
[48] (Committee on Climate Change 2017), (House, et al. 2010)
[49] (JNCC 2011)
[50] (Armitage, et al. 2011)
[51] (Forestry Commission 2010), (Harrison, Berry and Dawson 2001)
[52] (Committee on Climate Change 2017)
[53] (Committee on Climate Change *ibid*)

	Milder and wetter winter weather may not reduce future pest populations as effectively as winter weather has in the past, therefore resulting in greater mortality of trees[54]
	Upland Hay Meadow species composition changes (eg. reductions in wood cranesbill, and increases in great burnett)[55]. Potential worsening of pollinator abundance/ability link[56]
Research gaps	Morecambe Bay and The Solway - estuary-wide studies looking at future gains and losses in marsh and flats to improve our understanding of how the estuary is changing and identify sites where we might be able to consider future managed realignment (see Cumbria Coastal Strategy, Engagement Summary, November 2019, pp:123)[57]. NB. They represent two of the top five most important estuaries in the country for scarce internationally valuable habitats.
Resources	Moor House is a flagship Environmental Change Network (ECN) monitoring site. The long-term data is a valuable resource for detecting change and assessing against experimental work, providing baseline continuous monitoring of a wide range of variables. https://www.ceh.ac.uk/our-science/monitoring-site/moor-house-enabling-long-term-uplands-research see also (House, et al. 2010)
Landscape Attribute	**Landform, Geology & Soils**
Direct Impacts	Increased frequency of extreme flood events[58] leading to landslips, gully erosion and increased soil erosion[59]
	Increases in water turbidity due to peat/soil erosion in upper catchments (see UU in (Wallace 2020)).
Indirect impacts	Increased use of Natural Flood Management (NFM) measures
	Managed retreat causing losses of coastal sand dunes[60].
Summary of impacts	Increased soil erosion from loss of protective winter snow cover making surface more vulnerable to intense winter rain storms. Summer drying of peat leaving surface exposed to crusting, and vulnerable to intense rain events or wind blow triggering carbon emissions[61].
	Soil will become more susceptible to water erosion and potentially wind erosion. Due to higher temperatures and reduced soil moisture, soil is also likely to experience decreases in organic matter, with adverse consequences for soil biodiversity and carbon storage[62].
	Highly coloured water (Dissolved Organic Carbon content), increasing from UU monitoring in Haweswater and Thirlmere Reservoir Catchments. The trend in raw water colour at the Watchgate Water Treatment Works from 1990 to 2012 has been a steady rising in colour

[54] (Rotherham 2015)
[55] (Harrison, Berry and Dawson *ibid*)
[56] (Hennessy, et al. 2020)
[57] (Cumbria County Council 2019)
[58] (Chiverrell, et al. 2019)
[59] (Carr 2020), (Lake District National Park 2014), (Chiverrell, Harvey and Foster 2007), (Chiverell 2006)
[60] (Department for Environment, Food and Rural Affairs 2018), (Otto, et al. 2018)
[61] (Carr *ibid*) (Lake District National Park *ibid)*, (Countryside Recreation Network 2008)
[62] (Carr ibid), (Lake District National Park ibid),

	levels at the inlet. There has also been increased seasonal variability and higher peak levels with high colour events tending to occur during autumn[63]. The Thirlmere Resilience Programme continuing monitoring with vegetation change (Reporting 2021).
	In terms of erosion intensity, changing the sediment supply to the regions lakes and encouraging gully incision or debris flow activity on the hillslopes, climate is only part of the story with the largest increases in geomorphic activity strongly affected by human-mediated land use changes[64]. The key reason for the lack of peat forming vegetation is the predominance of high levels of sheep grazing. This suppresses the peat forming vegetation, such as sphagnum mosses and promotes less biodiverse non-peat forming habitats such as acid grassland dominated by species such as the mat grass *Nardus stricta*. This combined with the erosion of peat by livestock, weather and visitor pressure in combination with other climate change impacts is resulting in deteriorating raw water quality in the Lake District[65].
Research gaps	There is a lack of robust data available to quantify the impact that interventions such as hedges, walls and others have on the soil around them and the movement of water across land[66].(1)
	Gaps in soil sampling so we are unable to quantify soil loss in the county, especially in the steeper, upper catchments and the impacts of downstream deposition.(see 37)
Resources	Soilscapes Map: http://www.landis.org.uk/soilscapes/index.cfm and Peatlands data.*(54)*
Landscape Attribute	**Agricultural, Cultural & Historic Features**
Direct Impacts	Increased flooding of farmland[67]
	Drier summers resulting in peat shrinkage, damaging paleo-environmental and archaeological deposits. Potential loss of vegetation leading to erosion and damage to archaeological deposits. Increased risk of wildfires potentially affecting archaeological and listed features in susceptible areas.
	Flood damage to historic mines and increased water erosion of archaeological features, disruption to buried sediments and damage to earthworks.

[63] (Lake District National Park Partnership 2018)
[64] (Chiverell 2006)
[65] (Lake District National Park Partnership 2018)
[66] (Wallace 2020)
[67] (Lake District National Park Partnership 2018)

	Sea-level rise and short-term storm surges damaging historic buildings/bridges (eg. Pooley Bridge) and archaeological features[68].
	Greater extremes of wetting and drying may affect foundations in walls and traditional stone farm buildings, with a risk of needing additional maintenance[69].
Indirect impacts	Longer growing season potentially more intensive management and earlier grassland cutting.
	Area of viable grazing land could be reduced due to insufficient water supply, particularly areas already susceptible to drought (eg. Limestone bedrock).
	Increased use of Natural Flood Management (NFM) measures altering farmed landscape features eg. hedgerows/walls in flood plains, or new storage/irrigation reservoirs. Increased use of Natural Flood Management (NFM) measures and managed retreat/realignment causing losses of archaeological remains[70].
Impacts summary	If the Atlantic Meridional Overturning Circulation was to occur the Gulf Stream effect would be reduced potentially reversing current warmer/wetter trends and reducing arable farming in North Cumbria, Carlisle area and Eden Valley due to significant reduced rainfall (See Figure 3 in Appendix, and [71].
	Impacts of climate change have already been observed at a range of coastal heritage sites due to increased erosion, flooding, weathering or decay[72]. The 2019 Cumbria Coastal Strategy[73] identifies 50 Scheduled Ancient Monuments, 100 Listed Buildings, 20 Conservation Areas, 1 Historic Park & Garden, Hadrian's Wall and Lake District WHSs, and Humphrey Head and St Bees Head national important geological sites. These historic and cultural heritage features face serious implications because they are a non-renewable resource.
Research Gaps	Absence of analysis from repeated flooding events on farmed landscape pastures, field boundaries and parkland trees from river and coastal low lying areas (eg. Solway Plain).
Landscape Attribute	**Settlements**
Direct impacts	Long-term sea level rise, coastal erosion and storm surges disrupting coastal communities[74].

[68] (Williams, Impacts of climate change on UK coasts and seas are highlighted 2020),
[69] (Lake District National Park 2014), (English Heritage 2013)
[70] (English Heritage 2013)
[71] (Ritchie, et al. 2020)
[72] (Williams, Impacts of climate change on UK coasts and seas are highlighted 2020)
[73] (Cumbria County Council 2019)
[74] (Department for Environment, Food and Rural Affairs 2018)

	Effects of storm events on moisture ingress becoming more frequent and severe in western and coastal locations in the UK affecting the building stock[75]. Farms, villages and towns dominated by vernacular buildings directly damaged from flooding, rain penetration, droughting affecting foundations, etc[76].
Indirect impacts	Drive to make settlements & infrastructure more resilient will alter the layout/design and location of buildings and structures in all settlements, especially in flood risk zones[77].
Impacts summary	Clearly the greatest impact is upon towns and villages affected directly by flooding on low lying coastline and in river flood plains both from flooding itself and also from flood defence infrastructure (eg. Appleby, Kendal, Carlisle).
Research gaps	No Cumbria specific research identified and most national work focuses on the effects on cities/urban areas and infrastructure networks where greater numbers of people are affected (e.g. Committee on Climate Change: The Future of UK Cities[78]). There is a need to identify impacts in particularly on vernacular buildings, especially farmsteads and field barns in connection with the Lake District WHS pastoral landscapes
	Flood Relief Infrastructure Schemes (eg. Carlisle, Keswick and forthcoming in Kendal) indicate the need for improved cultural heritage assessments to inform the decision-making process for future profiling such climate change mitigation measures.
Landscape Attribute	**Outdoor Recreation – Visitor Access & Leisure**
Direct impacts	Loss of coastal rights of way and recreation infrastructure due to sea level rise/storm events, especially new England Coast Path.
	Damage to public access and Public Rights of Way (PROW) infrastructure by extreme weather events, particularly floods/erosion, damage to public perception of area, safety of staff and public[79].
	Increase in frequency and severity of wildfires and associated access restrictions, affecting walking & other activities and amenity value of fells and woodlands[80].
	Increased low and high river and lake levels, poor water quality incidents damaging water recreation opportunities[81].

[75] (Orr, et al. 2018)
[76] (Low Carbon Lake District 2014)
[77] (HM Government 2011)
[78] (Holmes 2018)
[79] (Keith Buchan Associates 2016), (Lake District National Park Authority 2016), (Lake District National Park 2014), (Countryside Recreation Network 2008)
[80] (Lake District National Park *ibid*)
[81] (BBC News 2010)

	Lower river flows and lake and tarn levels will result in concentration of pollutants and higher water temperatures/depleted oxygen levels in summer contributing to declines in fishing species such as Arctic Charr, Trout and Salmon[82].
	New bird species adding interest for wildlife watching (e.g. Little Egret, Avocet), but loss of others such as upland birds like Dotterel, Golden Plover & Ring Ouzel[83].
	Tourism and recreation may benefit from hotter, perhaps drier summers, especially if 'traditional' holiday destinations on the Mediterranean become uncomfortably hot[84]. NB. Research shows visitor behaviour is complex and more to do with socio-economic, educational profiles and strength of visitor destination brand[85], not helped by simplistic media coverage[86].
Indirect impacts	Water quality declining as a result of higher water temperatures[87], lower river flows and increased algal blooms[88] affecting wild swimming and core perceptions of the Lakes as a high quality environment.
	Less opportunities for winter- snow activities – skiing, ice climbing/winter mountaineering[89].
	Increased erosion scars affecting aesthetic appeal of mountains/open access/common land[90].
	Increased Mosquitos from re-naturalized flood plains and coastal managed retreat creating more wetlands, causing increased levels of nuisance and disease vectors[91].
	Visitor numbers reduced when major PROW network repairs taking place after flooding events[92].
Summary of impacts	Cumbria's landscape represents a huge outdoor resource/visitor attraction, for example, 2,140 square km of Open Access Land, 7,500km of Footpaths, Bridleways and Byways (3,105km in LDNP) and highest concentration of inland waterways and length of rivers in England[93]. Greatest impact on visitor/recreational activities relate to major storm damage/erosion. For example, significant damage to 18% and 4% of PROW network in LDNP and Cumbria from Storm Desmond,

[82] (Carr 2020), (Lake District National Park *ibid*)
[83] (Natural England; RSPB 2014)
[84] (Lake District National Park 2014),
[85] (Taylor, Dessai and Bruin 2014), (McEvoy, et al. 2008)
[86] (Ma and Kirilenko 2019)
[87] (Muchan 2020)
[88] (G. Watts, R. Battarbee, et al. 2012)
[89] (A. L. Kay 2016)
[90] (Durham County Council 2008)
[91] (Medlock and Vaux 2015)
[92] (Keith Buchan Associates 2016), (Lake District National Park Authority 2016), (Countryside Recreation Network 2008)
[93] (Lake District National Park 2014), (Natural England 2009)

	respectively temporarily reduced visitor numbers, plus repair costs of nearly £6m[94].This could magnify with a 40-59% increase in likelihood of storm Desmond events due to climate change[95].
Research gaps	Improve knowledge base of the effects of climate change on different types of tourism activities and coastal recreation, stakeholders and geographies at the local level. Very little is known about the extent to which visitor behaviours are – or have to be – modified at the coast or elsewhere; how tourism and recreational activities are diverted, displaced or lost (i.e. destination) level[96]. For example, Blue green algae and other pollution incidents impact on visitor use of waterbodies (e.g. cancellation of recent lake swimming events[97]).
Resources	Example of mountaineers' perceptions of loss of winter snow via media[98].

Landscape attribute	**Perceptual & Aesthetic Character**
Direct impacts	Visual impact of lower summer water levels of lakes and tarns; reservoir drawdown; and increased Algal blooms[99].
Indirect impacts	Significant negative publicity and reports of damages caused by flooding /erosion/PROW infrastructure damage post major storms[100].
Summary of impacts	Although there has been research on general perceptions of environmental change, to date there has been little research on how people have perceived climate change in the landscape[101].
	When it comes to perceptions of climate change impacts, the available evidence suggests that those in the UK more readily associate climate change with different weather events (e.g. flooding and heavy rainfall) than countries with warmer climates[102].
Research gaps	No specific research identified in relation to climate change impacts. It would be helpful to carry out some surveys of perceptions with residents and visitors focusing on fell erosion/storm damage, flooded valley bottoms and drawdown scars on waterbodies.

[94] (Keith Buchan Associates 2016)
[95] (Otto, et al. 2018)
[96] (Williams, Impacts of climate change on UK coasts and seas are highlighted 2020)
[97] (BBC News 2010)
[98] (McKenzie 2020)
[99] (Lake District National Park 2014)
[100] (Keith Buchan Associates 2016), (Lake District National Park Authority 2016)
[101] (Committee on Climate Change 2017) Chapter 3
[102] (Taylor, Dessai and Bruin 2014)

Part 4

Summary of research papers of particular relevance to this research

	Research Paper/Evidence:	Data Source/ citation	Data Available
1	**PhD study into flood mitigation and water quality, Lancaster University/Eden Rivers Trust. Current, ongoing.**	(Wallace 2020)	
Five key interventions are being measured in this study. The first four aim to quantify the value of the intervention in the amount of overland flow generated during floods as well as factors that may be causing it. The research includes stone-walls. There isn't any research on the effect of stone walls on overland flow, so this study will look at difference in soil moisture above/below stone walls on steep slopes and does this effect persist at varying distances from the wall. There is a lack of robust data available to quantify the impact that interventions such as hedges, walls and others have on the soil around them and the movement of water across land. https://edenriverstrust.org.uk/projects/research-and-monitoring/phd-studentship/		Lancaster University & Eden Rivers Trust	?
2	**This winter in Europe was hottest on record by far, say scientists - Climate crisis likely to have supercharged temperatures around world, data suggests. March 2020:**	(Carrington 2020)	
The EU's Copernicus Climate Change Service (C3S) data dates back to 1855. It said the average temperature for December, January and February was 1.4C above the previous winter record, which was set in 2015-16. New regional climate records are usually passed by only a fraction of a degree. Europe's winter was 3.4C hotter than the average from 1981-2010. In the UK, serious flooding is likely to have been made worse by higher temperatures, as in 2015. In the UK, the Met Office said in January that a series of high temperature records were broken in 2019 as a consequence of the climate crisis. This included the hottest temperature ever recorded in the country: 38.7C on 25 July in Cambridge. https://www.theguardian.com/environment/2020/mar/05/truly-extreme-winter-2019-20-in-europe-by-far-hottest-on-record		The Guardian (Damian Carrington, Environment Editor)	No
3	**Why is there less snow on Scotland's mountains this year? BBC Scotland article. February 2020**	(McKenzie 2020)	
Perceptions of Scottish Mountain users and Mountain Weather information Service. Whilst the weather patterns this winter are part of natural variability over the north Atlantic, these 'westerly winters' have been generally more common in		BBC Scotland News (Steven McKenzie)	N

the past couple of decades as global temperatures have risen. Ben Dolphin, president of Ramblers Scotland and a winter walking enthusiast, said it wasn't unusual for conditions to vary from year to year on the hills. But he added: "I don't know any Scottish winter enthusiast who'd feel at ease with what's happened for the last two years, or who would think those winters fit into the 'normal' pattern of mild and cold winters. "It's not just the lack of snow, it's the high night-time temperatures, and the longevity and persistence of mild weather patterns." https://www.bbc.co.uk/news/uk-scotland-highlands-islands-51279607			
4	**Bees may struggle in winds caused by global warming, study finds, The Guardian. February 2020**	(Hennessy, et al. 2020)	
The study by University of Sussex researchers raises fears that bees and other flying pollinators may struggle in the higher and more frequent winds caused by global heating. With no wind, the bees on average took nectar from 5.45 flowers during their 90-second time trial. When wind speeds were increased, this fell to an average of 3.73 flowers. Over the course of a day, a bee's capacity to supply its colony with food would be significantly curtailed. With wind speeds predicted to increase in the years ahead, understanding how we can help pollinators in a changing climate is becoming ever more pressing. Dave Goulson, professor of biology at the University of Sussex, said: "Insect pollinators already face many pressures in the modern world, such as loss of habitat and exposure to pesticides, and a great many are in decline. Coping with increasingly blustery weather under climate change may be the final straw for some." https://www.msn.com/en-gb/news/offbeat/bees-may-struggle-in-winds-caused-by-global-warming-study-finds/ar-BB1072Qr?		University of Sussex (Georgia Hennessy)	No
5	**Climate Friendly Farming: The Facts about British Meat, February 2020**	(NFU (National Farmers Union) 2020)	
Livestock farming and grassland pastures are a significant land use in Cumbria. Sets out data comparing global agricultural livestock farming in comparison with the UK, and argues the carbon benefits of grass-based pastures. https://www.nfuonline.com/nfu-online/sectors/livestock/climate-friendly-farming-the-facts-about-british-meat/		NFUOnline	No
6	**Warming trend revealed in eight decades of Cumbrian lake temperature records, January 2020**	(Muchan 2020)	
In the UK we benefit from the availability of multiple sources of long-term environmental data such as rainfall and river flows. In addition, UKCEH has been monitoring the biological, chemical and physical properties of four Cumbrian Lakes since 1945.		Centre for Ecology and Hydrology (CEH) (K Muchan)	No

Initiated by the Freshwater Biological Association (FBA), and continued by UKCEH and its predecessors from 1989, this scheme has cumulatively delivered more than 400 years of lake data, making it the world's largest long-term lake monitoring programme. This long-term collection of high quality data can be used to assess trends and variability, enabling us to study the impact of climate change within these fragile systems. Data are analysed and presented for four lake basins – Esthwaite Water, Blelham Tarn and Windermere (North basin and South basin). Across all four lakes, despite their different locations and sizes, there is a clear long-term change from temperatures predominantly lower than the baseline pre-2000, to predominantly higher than the baseline post-2000. This pattern in water temperatures reflects **recent analysis published by the Met Office** showing that in the decade of 2010-2019 eight new high temperature records were set across a variety of seasons. Similarly to the air temperature records, in all four lakes, at least four of the five warmest years have occurred since 2000. In both basins of Windermere, all five have occurred since 2000 and two of those are since 2014. **https://www.ceh.ac.uk/news-and-media/blogs/lakes-hot-water-warming-trend-revealed-eight-decades-cumbrian-lake-temperature**			
7	**Impacts of Climate Change on UK Coasts and Seas are Highlighted, January 2020**	(Williams, Impacts of climate change on UK coasts and seas are highlighted 2020)	
The Marine Climate Change Impacts Partnership (MCCIP) has produced its latest 'Report Card 2020', a comprehensive, updated review on the range and scale of physical, ecological and societal impacts of climate change on UK coasts and seas. Its findings are based on a wealth of research collated by scientists from several organisations including the UK Centre for Ecology & Hydrology (UKCEH). • Coastal flooding is likely to get worse, due to the combined effects of higher sea level rises than previously thought and more extreme rainfall. • Impacts of climate change have already been observed at a range of coastal heritage sites due to increased erosion, flooding, weathering or decay. • Fixed landward coastal defences are becoming unsustainable and creating 'coastal squeeze', highlighting the need to work with natural processes to recreate more-natural shorelines where possible. https://www.ceh.ac.uk/news-and-media/news/impacts-climate-change-uk-coasts-and-seas-highlighted		The Marine Climate Change Impacts Partnership (MCCIP), (Simon Williams, CEH)	
8	**Major shift in UK land use needed to deliver Net Zero emissions, January 2020**	(Committee on Climate Change 2020)	

In 2017, land use – including agriculture, forestry and peatland – accounted for 12% of total UK greenhouse gas emissions. The Committee's in-depth analysis shows that emissions from UK land use can be reduced by 64% to around 21 $MtCO_2e$ by 2050. There are five objectives for new policy: • Increase tree planting – increasing UK forestry cover from 13% to at least 17% by 2050 by planting around 30,000 hectares (90 – 120 million trees) of broadleaf and conifer woodland each year. • Encourage low-carbon farming practices – such as 'controlled-release' fertilisers, improving livestock health and slurry acidification. • Restore peatlands – restoring at least 50% of upland peat and 25% of lowland peat. • Encourage bioenergy crops – expanding UK energy crops to around 23,000 hectares each year. • Reduce food waste and consumption of the most carbon-intensive foods – reduce the 13.6 million tonnes of food waste produced annually by 20% and the consumption of beef, lamb and dairy by at least 20% per person, well within current healthy eating guidelines. **https://www.theccc.org.uk/2020/01/23/major-shift-in-uk-land-use-needed-to-deliver-net-zero-emissions/**		Committee on Climate Change	No
9	**Shifts in national land use and food production in Great Britain after a climate tipping point, Nature Food, January 2020**	(Ritchie, et al. 2020)	
Using GB data a methodology to analyse the impacts of a climate tipping point causing Atlantic Meridional Overturning Circulation (affecting the Gulf Stream warming effect), on land use and economic outcomes for agriculture. Showing that economic and land-use impacts of such a tipping point are likely to include widespread cessation of arable farming 2030-2050. [Evidence of this in MCCIP Report Card 2020, above]. https://www.nature.com/articles/s43016-019-0011-3		Exeter University (Paul D. L. Ritchie et al)	Yes
10	**Climate Adapt - The European Climate Adaptation Platform (Climate-ADAPT) is a partnership between the European Commission and the European Environment Agency (EEA). Climate-ADAPT is maintained by the EEA with the support of the European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation (ETC/CCA). November 2019**	(European Environment Agency 2019)	
Aims to support Europe in adapting to climate change by helping users to access and share data and information on: expected climate change in Europe; current and future vulnerability of regions and sectors; EU, national and transnational adaptation strategies and actions; adaptation case studies and potential adaptation options; and tools that support adaptation planning. https://www.eea.europa.eu/themes/climate-change-adaptation/climate-adapt		EC/EEA	?

11	**Cumbria Coastal Strategy – Engagement Summary, November 2019**	(Cumbria County Council 2019)	
A coastal strategy is a plan that sets out how we will manage the risks related to coastal flooding and erosion along our coastline over the next century. It builds upon the policies set in the North West Shoreline Management Plan, which was adopted in 2010. Divides the coastline into 25 policy areas identifying priority units where: there are key assets at possible risk from coastal flooding or erosion, the current Shoreline Management Plan policy has been questioned, or there are opportunities to improve the environment and bring benefits to an area. https://www.cumbria.gov.uk/elibrary/Content/Internet/6640/17802/4378316245.pdf		Cumbria County Council	Yes
12	**United Nations Environment Programme – Emissions Gap Report 2019**	(UN Environment Programme 2019)	
This is the tenth edition of the United Nations Environment Programme (UNEP) Emissions Gap Report. It provides the latest assessment of scientific studies on current and estimated future greenhouse gas (GHG) emissions and compares these with the emission levels permissible for the world to progress on a least-cost pathway to achieve the goals of the Paris Agreement. The summary findings are bleak. Countries collectively failed to stop the growth in global GHG emissions, meaning that deeper and faster cuts are now required. Reflecting on the report's overall conclusions, it is evident that incremental changes will not be enough and there is a need for rapid and transformational action. The Intergovernmental Panel on Climate Change (IPCC) issued two special reports in 2019: the "*Climate Change and Land*" report on climate change, desertification, land degradation, sustainable land management, food security and greenhouse gas fluxes in terrestrial ecosystems, and the "*Ocean and Cryosphere in a Changing Climate*" report. Both reports voice strong concerns about observed and predicted changes resulting from climate change and provide an even stronger scientific foundation that supports the importance of the temperature goals of the Paris Agreement and the need to ensure emissions are on track to achieve these goals. https://wedocs.unep.org/bitstream/handle/20.500.11822/30798/EGR19ESEN.pdf?sequence=13		United Nations	No
13	**Flooded Future: Global Vulnerability to sea level rise worse than previously understood, - Land Projected to be Below Annual Flood Level in 2050. October 2019**	(Kulp and Strauss 2019)	
Global warming and sea level rise models overlaid with new elevation data (LiDAR). Flooding derived from tide and storm data, excludes precipitation and river run-off, but does not take account of sea defences.		ClimateCentral.org (Scott A. Kulp)	On-line interactive map to local level

https://www.climatecentral.org/news/report-flooded-future-global-vulnerability-to-sea-level-rise-worse-than-previously-understood			
14	**UK Climate Projections: Headline Findings, September 2019**	(UK Met Office Hadley Centre 2019)	
Global and regional climate change models resolute at a 60-300km and 10-50km scale respectively. This headlines findings document uses the UKCP18 data but analyses at a new 2.2km scale representing a step forward in our ability to simulate small scale behaviour seen in the real atmosphere, especially the influence of mountains, coastlines and urban areas. We can continue to expect increases to extreme coastal water levels driven mainly by increases in mean sea level rise, although we cannot rule out additional changes in storm surges. https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp-headline-findings-v2.pdf		Met Office, Hadley Centre	Yes
15	**State of the UK Climate 2018, July 2019**	(Kendon, et al. 2019)	
This report presents summary statistics for year 2018 and the most recent decade (2009–2018) against 1961–1990 and 1981–2010 averages. All the top 10 warmest years for the UK in the series from 1884 have occurred since 2002. The most recent decade (2009–2018) has been on average 0.3°C warmer than the 1981–2010 average and 0.9°C warmer than 1961–1990. The most recent decade (2009–2018) has had 5% fewer days of air frost and 9% fewer days of ground frost compared to the 1981–2010 average, and both 15% fewer compared to 1961–1990. Six of the 10 wettest years for the UK in a series from 1862 have occurred since 1998. The most recent decade (2009–2018) has been on average 1% wetter than 1981–2010 and 5% wetter than 1961–1990 for the UK overall. Summer 2018 was among the most warm, dry and sunny summers experienced by the UK for over 100 years. There are no compelling trends in storminess as determined by maximum gust speeds from the UK wind network over the last five decades. https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/joc.6213		Royal Meteorological Society, Journal of Climatology (M. Kendon et al)	Yes
16	**What Does Climate Change Really Mean for Cumbria? June 2019**	(Holdgate 2019)	
Sir Martin Holdgate CB, Emeritus President of Friends of the Lake District, former Chief Scientist for the Department for the Environment, and international conservationist, presents the future for the Cumbrian landscape as a consequence of potential climate change impacts (direct and indirect). https://www.friendsofthelakedistrict.org.uk/news/what-does-climate-change-really-mean-for-cumbria		Sir Martin Holdgate	No
17	**Using lake sediment archives to improve understanding of flood magnitude and frequency: Recent extreme flooding in northwest UK May 2019**	(Chiverrell, et al. 2019)	

"We present the first quantitative reconstruction of palaeofloods using lake sediments for the UK and show that for a large catchment in NW England the cluster of devastating floods from 1990 to present is without precedent in this 558-year palaeo-record. Our approach augments conventional flood magnitude and frequency (FMF) analyses with continuous lake sedimentary data to provide a longer-term perspective on flood magnitude recurrence probabilities. The 2009 flood, the largest in >558 years, had a recurrence interval larger (1:2,200 year) than revealed by conventional flood estimation using shorter duration gauged single station records (1:1,700 year). Flood-rich periods are non-stationary in their correlation with climate indices, but the 1990-2018 cluster is associated with warmer Northern Hemisphere Temperatures and positive Atlantic Multi-decadal Oscillation." https://onlinelibrary.wiley.com/doi/full/10.1002/esp.4650			No
18	**UK Biodiversity Indicators 2019, Indicator B4 – Spring Index. May 2019**	(Department for Environment, Food and Rural Affairs 2019)	
Highlights a biological response to climate change and the impact of temperature change on the timing of biological events such as flowering or migration in the spring. The UK Spring Index is calculated from the annual mean observation date of the following four biological events: first flowering of hawthorn (*Crataegus monogyna*), first flowering of horse chestnut (*Aesculus hippocastanum*), first recorded flight of an orange-tip butterfly (Anthocharis cardamines), and first sighting of a swallow (*Hirundo rustica*). The average date of these events is now (1999-2018) about 6 to 7 days in advance of the average for the period 1891 to 1947. https://hub.jncc.gov.uk/assets/0578b770-954e-49ba-b1a5-89fdacad1365		DEFRA/Joint Nature Conservation Committee (JNCC)	No
19	**Climate Change and Tourism in English-Language Newspaper Publications. April 2019**	(Ma and Kirilenko 2019)	
Tourism is one of the sectors of the economy that is most dependent on climate, creating multiple vulnerabilities and new opportunities arising with changing climate. Among the substantial body of scientific literature investigating climate change and tourism, research has mainly focused on the potential impacts of climate change on tourism, yet the response of the tourism industry to climate change is relatively lack of scrutiny. Mass media is assumed to be the bridge between the scientific community and public regarding climate change and tourism topics, and effective communication and information sharing is essential for the public to fully understand and wisely		Journal of Travel Research (S Ma, AP Kirilenho)	No

respond to these issues. Yet we are reminded that there is a long way to go for mass media to reach such goals. The reportedly emerging growth of tourism and potential market opportunities in climate change contexts are criticized in academia as short-sighted and likely to cause more damage to the destinations in the long term, and are not confirmed to be beneficial to destinations. https://www.researchgate.net/publication/332231396_Climate_Change_and_Tourism_in_English-Language_Newspaper_Publications/link/5d77ab6c4585151ee4ab5505/download			
20	**An assessment of the potential for natural flood management to offset climate change impacts, April 2019.**	(Kay, et al. 2019)	
Natural Flood Management (NFM) aims to work with natural processes to reduce flood risk, and can potentially contribute to integrated flood risk management (alongside engineering solutions) by providing landscape-based resilience to climate change impacts. Here, two approaches are used to assess the extent to which NFM could offset the impacts of climate change on floods in Great Britain. The results show that NFM measures are much less likely to be able to offset the impacts of climate change for later time-slices and for higher emissions scenarios, but also that the chance of offsetting the impacts of climate change in any individual catchment will depend on its type (how sensitive it is to climatic changes) and its location (due to spatial variation in climatic changes). https://iopscience.iop.org/article/10.1088/1748-9326/aafdbe		Journal of Environmental Research Letters (Kay et al, 2019)	No
21	**LANDMAP, Landscape and a Changing Climate, Report 314, Natural Resources Wales. March 2019**	(Berry, et al. 2019)	
A project to start to identify and communicate the direct and indirect impacts of projected climate changes for Wales in 2050 on landscape character and qualities, and what that might look like in the landscape we recognise today. Identifying the impacts of climate change on broad landscape types using the LANDMAP Visual & Sensory spatial dataset, supported by key statistics and using a series of written narratives of potential change for each landscape type. NB. Caveat - The analysis highlights the uncertainties associated with undertaking future predictions, in particular in trying to understand the potential outcomes from synergistic effects of multiple changes on ecological and hydrological systems over large areas covered by the LMP14 landscape types. Predicted impacts are based on judgement and are broad brush in scope. Impacts in any one location will be affected by local conditions and underlying geological, soil and landform characteristics.		Countryside and Community Research Institute (CCRI), University of Gloucestershire (Berry et al, 2019)	Yes

https://cdn.naturalresources.wales/media/688626/eng-landmap-landscape-and-a-changing-climate.pdf?mode=pad&rnd=131989289330000000 See Datasets included: https://data.gov.uk/dataset/58d3a7b4-4985-4954-a56b-1b8e1189cb43/landmap-visual-and-sensory			
22	**Climate change: Lake District facing 'dramatic' soil erosion, BBC Look North, January 2019**	(Carr 2020)	
The Lake District is suffering from soil erosion at a 'dramatic rate' and could look very different in 50 years' time. Dr Simon Carr, programme leader for geography at the University of Cumbria, said extreme weather caused by climate change is stripping the fells and the rate of loss is really quite dramatic, amounting to about 3cm (1.2") per year. Within a few decades we're going to see the areas of bare rock we see on the mountains stretching further and further down slope. He also pointed to a rise in organic carbon being found in water as a result of peat being washed into rivers, and increased sedimentation being found in lake basins. https://www.bbc.co.uk/news/uk-england-cumbria-51183134		University of Cumbria (simon.carr@cumbria.ac.uk)	?
23	**Water Quality Safeguarding Zone briefing note for Lake District National Park Partnership *State of the Park Report* from United Utilities. 2018**	(Lake District National Park Partnership 2018)	
Measures water turbidity (DOC colouration) over 20 year period for Haweswater and Thirlmere Reservoir Catchments. For the Thirlmere Resilience programme we will be monitoring both raw water quality, at a sub-catchment level, and also vegetation change. We will have up to 6 monitoring stations in the main sub-catchments at Thirlmere. These will be recording DOC (Dissolved Organic Carbon) and Turbidity every 15 mins as well as recording water depth/flow rate. We will also be pulling in rainfall data from the catchment so that this can be included in the production of some modelling to show how the catchment is performing and responding to weather events. For the vegetation monitoring we have a reasonable baseline for Thirlmere, we conducted vegetation surveys in 2012/13 and then followed these up in 2018. We plan to repeat these again in 2023. https://www.lakedistrict.gov.uk/__data/assets/pdf_file/0009/1661598/SOTP-Report-2018-V6-FINAL-02.05.19.docx.pdf		United Utilities (John Gorst)	Yes
24	**Climate change impacts and adaptation. November 2018**	(Environment Agency 2018)	

Based on existing syntheses and the latest climate science this report outlines what has happened and what is expected to happen to the UK climate and describes some of the impacts of these changes for England. It outlines the main adaptation actions that are being taken or are planned to prepare for the impacts of climate change. It does not replace the Environment Agency's formal reporting under the Climate Change Act on progress and future plans to adapt to a changing climate. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/758983/Climate_change_impacts_and_adaptation.pdf		Environment Agency	?
25	**Wind-driven rain and future risk to built heritage in the United Kingdom: Novel metrics for characterising rain spells. November 2018**	(Orr, et al. 2018)	
Wind-driven rain (WDR) is a prominent environmental risk to built heritage, as it contributes to the damage of porous building materials and building element failure. Although the average number of spells is predicted to remain constant, they will be shorter with longer of periods of time between them and more intense with wind-driven rain occurring for a greater proportion of hours within them. It is likely that in this scenario building element failure – such as moisture ingress through cracks and gutter over-spill – will occur more frequently. There will be higher rates of moisture cycling and enhanced deep-seated wetting. These increases will be more severe for western and coastal locations that already experienced higher WDR exposure during the twentieth century. The projected impact on building exposure are higher frequency and severity of building element failure, near-surface cycling, and deep-seated wetting. https://www.sciencedirect.com/science/article/pii/S0048969718319478?via%3Dihub		Journal of Science of the Total Environment (S A Orr et al)	No
26	**Regional versus local drivers of water quality in the Windermere catchment, Lake District, United Kingdom: The dominant influence of wastewater pollution over the past 200 years. September 2018**	(Moorhouse, et al. 2018)	
Freshwater ecosystems are threatened by multiple anthropogenic stressors acting over different spatial and temporal scales, resulting in toxic algal blooms, reduced water quality and hypoxia. We used sedimentary algal pigments as an index of changes in primary producer assemblages over the last ~200 years in a northern temperate watershed consisting of 11 upland and lowland lakes within the Lake District, United Kingdom, to test our hypotheses about landscape drivers. Findings show that nutrient inputs from point sources overwhelm climatic controls of algae and nuisance cyanobacteria, but highlights that large-scale stressors do not always initiate coherent regional lake response. Furthermore, a lake's position		Global Change Biology (H L Moorhouse et al)	No

in its landscape, its connectivity and proximity to point nutrients are important determinants of changes in production and composition of phototrophic assemblages. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.14299			
27	**The National Adaptation Programme and the Third Strategy for Climate Adaptation Programme – Making the Country Resilient to a changing climate. July 2018**	(Department for Environment, Food and Rural Affairs 2018)	
The National Adaptation Programme explains the range of climate risks which affect our natural environment, our critical infrastructure services, our communities and buildings, local government and businesses. The importance of adapting to these climate challenges and transitioning to a low carbon economy is set out, drawing on a large body of ongoing work across government. We are seeing changes to ecosystems due to temperature, sea level rise or extreme events, of which the latter are predicted to increase in frequency and severity. We are also seeing shifts in the distribution and abundance of some terrestrial, freshwater and marine species due to higher temperatures. There is evidence that some species are already moving northwards and to higher altitudes, tracking where suitable climates are now found. Where species are unable to move in response to climate change there is a risk they will continue to decline. Such risks from climate change are heightened because the natural environment is already under pressure. Pollution, habitat loss and fragmentation, diseases and invasive non-native species, the continuing drainage of wetlands and the unsustainable use of soil, water and marine resources all reduce the natural resilience of species and ecosystems and their ability to adjust and adapt. **Risks to natural capital including terrestrial, coastal, marine and freshwater ecosystems, soils and biodiversity.** The National Action Plan lays out actions that will be taken to: • Introduce a new Environmental Land Management scheme which will deliver environmental outcomes; • Develop and start to implement a Nature Recovery Network, linking habitat restoration and creation to improved access, flood protection and water quality; • Incentivise good soil management practices that enhance soil's ability to deliver environmental benefits through future environmental land management schemes; • Introduce a sustainable fisheries policy as we leave the Common Fisheries Policy and prepare marine plans that include policies for climate adaptation; • Build ecological resilience on land, in our rivers and lakes and at sea; and • Protect soils and natural carbon stores.		Department for the Environment, Farming and Rural Affairs (DEFRA)	No

	https://www.gov.uk/government/publications/climate-change-second-national-adaptation-programme-2018-to-2023		
28	**Lake District National Park Landscape Character Assessment and Guidelines. Revised May 2018 (Unpublished)**	(Lake District National Park Partnership 2018)	
In 2017 the Lake District National Park Partnership agreed to carry out a review of the Landscape Character Assessment to ensure it referred to the full extent of the National Park (following its extension in 2016) and reflected key studies that have been published since 2008. These include the World Heritage Site, Cumbria Biodiversity Evidence Base and Cumbria Cumulative Impacts of Vertical Structures. It has been updated to reflect the current forces for change affecting the Park and Lake District National Park Management Plan ambitions.		LDNPA et al	Yes
29	**Climate change increases the probability of heavy rains in Northern England/Southern Scotland like those of storm Desmond—a real-time event attribution revisited. January 2018**	(Otto, et al. 2018)	
On 4–6 December 2015, storm Desmond caused very heavy rainfall in Northern England and Southern Scotland which led to widespread flooding. A week after the event we provided an initial assessment of the influence of anthropogenic climate change on the likelihood of one-day precipitation events averaged over an area encompassing Northern England and Southern Scotland using data and methods available immediately after the event occurred. The analysis was based on three independent methods of extreme event attribution: historical observed trends, coupled climate model simulations and a large ensemble of regional model simulations. All three methods agreed that the effect of climate change was positive, making precipitation events like this about 40% more likely, with a provisional 2.5%–97.5% confidence interval of 5%–80%. Here we revisit the assessment using more station data, an additional monthly event definition, a second global climate model and regional model simulations of winter 2015/16. The overall result of the analysis is similar to the real-time analysis with a best estimate of a 59% increase in event frequency, but a larger confidence interval that does include no change. https://iopscience.iop.org/article/10.1088/1748-9326/aa9663		Journal of Environmental Research letters (F E L Otto et al)	No
30	**Committee on Climate Change – The Climate Change Risk Assessment Evidence, Chapter 3: Natural Environment and Natural Assets. January 2017**	(Committee on Climate Change 2017)	
This report draws together the available evidence relating to the risks and opportunities from the impacts of climate change in the UK. The aim of the report is to assess the urgency of further action or research in the next five years, to help the UK and devolved governments and others prioritise their resources. The six immediate priority areas are related to risks of flooding and coastal change, the impact of high temperatures in the built environment, risks to natural capital, risks		Committee on Climate Change	?

of future water shortages, impacts on the global food system, and risks arising from new and emerging pests and diseases. https://www.theccc.org.uk/wp-content/uploads/2016/07/UK-CCRA-2017-Synthesis-Report-Committee-on-Climate-Change.pdf https://www.theccc.org.uk/wp-content/uploads/2016/07/UK-CCRA-2017-Chapter-3-Natural-environment-and-natural-assets.pdf			
31	**Repairing flood damage to the Cumbria Right of Way network - Value for Money Appraisal, Keith Buchan Associates. 2016**	(Keith Buchan Associates 2017)	
There has been significant disruption to the Right of Way network throughout Cumbria and in the Lake District National Park (LDNP) in particular; with just over 18% in the LDNP remaining out of service and the equivalent for Cumbria outside the LDNP is 4%. The research assesses how much the disrupted network will reduce, or prevent growth in, the levels of walking locally and in a national context (and how far this will switch to non-walking activities/and switching to walking elsewhere. Health benefits from by restoring levels of walking are estimated at £12.44m and economic benefits from restoring visitor numbers at £45.18m (discounted over 20 years). Although not as serious as the 2015 damage, there was significant flooding in Cumbria at the end of 2009. Visitor numbers were down in 2010 (although national numbers were also down) and also down in both 2011 and 2012-3, when repairs were being undertaken. In these years LDNP visitors fell by about 7% while national tourism was growing. Once repairs were complete, strong growth resumed and then overtook national levels in 2015. The estimate of damage in this report assumes a fall of 3.4% and is thus below that actually recorded for a lower level of damage.		LDNPA (Mark Eccles)	No
32	**LDNPA Storm Desmond Cumbria and Lake District PROW Damage Assessment and Repairs Funding European Agricultural Development Fund Application. 2016**	(Lake District National Park Authority 2016)	
In the LDNP 562km of PROW damaged (18% of the network, 307 paths), 249 bridges and other furniture (stiles, kissing gates, etc) needing repairs/replacing, at a total cost of nearly £6m. A further funding bid called Routes to Resilience in February 2019 identified 174 additional repairs to restore the network to the standard prior to Storm Desmond (62 bridges, 76 paths at a cost of nearly £2m).		LDNPA (Mark Eccles)	Yes
33	**Issues of water and flooding for trees, woods and forests, March 2016.**	(Rotherham 2015)	
Flooding affects this firstly by direct, short-term or immediate impact on trees of inundation e.g. oxygen starvation of roots and possible death or die-back, physical damage due to flood-swept debris, possible tree failure. Secondly, there is indirect, short-term or immediate impact on tree of inundation e.g. rotational slippage of trees on slopes, damage by mud-slides or landslides. These effects may lead to additional hazards through tree fall on highway cuttings etc. The impacts may vary depending on whether ambient conditions are hot or cold, such as high rainfall or snowfall causing increased risk of tree failure. Furthermore, the impacts		Arboricultural Journal (I D Rotherham)	No

of extreme weather events may not be apparent for several years after the incident, with weakened and diseased trees, and later failure or death. In the climate change literature it has been suggested that the following may occur: • Southern beech woods – will lose out as climate warms – squeezed out and unable to move quickly enough in the landscape. • Presently localised yew woods will spread. • Upland oak woods may suffer. • Native pine forests in Scotland may be under pressure. • There will be more fires on heaths, bogs, commons, and in forests and woods. • Landscape fragmentation will probably continue unabated because of economics and population growth and this will place further pressure on resources. • Stresses through drought and flood, through urbanisation and globalisation, plus climate change, will trigger more pests and diseases affecting trees. • Species moved by human agency to areas where they are not native (such as sycamore and beech in parts of northern Britain), may quickly find themselves adapting to new and favourably environmental conditions. https://doi-org.ezproxy.lancs.ac.uk/10.1080/03071375.2015.1137432			
34	**Regional synthesis of algal community change in the lakes and tarns of the Windermere catchment, Lake District, UK, since the 19th century. July 2016**	(H. L. Moorhouse 2016)	
The rural Windermere catchment UK comprises 11 upland and lowland lakes which feed into Windermere. Palaeolimnological algal records, alongside long-term climate and catchment land use monitoring data from all basins in the catchment were used to quantify the relative importance of regional and local-scale drivers of algal community change. Regression tree analyses suggest that nutrient enrichment has an overarching effect, with temperature playing a secondary role. This work demonstrates that lakes within a few kilometres of one another respond uniquely to environmental change depending on physical characteristics and landscape position. Management measures should focus on reducing nutrients from wastewater effluent and develop local stewardship programmes to increase environmental awareness in the region. https://ethos.bl.uk/ProcessOrderDetailsDirect.do?documentId=1&thesisTitle=Regional+synthesis+of+algal+community+change+in+the+lakes+and+tarns+of+the+Windermere+catchment%2C+Lake+District%2C+UK%2C+since+the+19th+century&eprintId=689799		University of Nottingham (H Moorhouse)	
35	**A review of snow in Britain: The historical picture and future projections. June 2016**	(A. L. Kay 2016)	
Climate change is likely to have a significant effect on snow globally, with most effect where current winter temperatures are close to 0°C, including parts of upland Britain. There is evidence of decreasing trends in observations of snowfall and lying snow in Britain, and climate projections suggest a continuation of this		Journal of Progress in Physical Geography: Earth and	

trend. Although river flows in Britain are generally dominated by rainfall rather than snowmelt, some upland catchments have a significant snowmelt contribution. There is evidence of changes in observed and projected river flows in some catchments in Britain, linked to changes in snow, but it can be difficult to distinguish the effects of snow changes from those of other concurrent changes (climatic and non-climatic). https://journals.sagepub.com/doi/10.1177/0309133316650617		Environment (A L Kay)	
36	**Climate change and biological invasions: evidence, expectations, and response options. May 2016**	(Hulme 2016)	
A changing climate may directly or indirectly influence biological invasions by altering the likelihood of introduction or establishment, as well as modifying the geographic range, environmental impacts, economic costs or management of alien species. A comprehensive assessment of empirical and theoretical evidence identified how each of these processes is likely to be shaped by climate change for alien plants, animals and pathogens in terrestrial, freshwater and marine environments of Great Britain. https://onlinelibrary-wiley-com.plsa2r.idm.oclc.org/doi/full/10.1111/brv.12282		Journal of Biological Reviews (P E Hulme)	No
37	**A climate change report card for water - Working technical paper: Climate change and water in the UK – past changes and future prospects, Defra & LWEC (Living With Environmental Change) Partnership. First Published 2012-13**	(G. Watts, R. Battarbee, et al. 2012)	
This paper addresses one of the possible barriers to climate change adaptation in the UK: reliable, clear information about the current and possible future impact of climate change on the water cycle. The natural variability of the UK climate makes change hard to detect; only historical increases in air temperature can be attributed to climate change, but over the last fifty years more winter rainfall has been falling in intense events. Future changes in rainfall and evapotranspiration could lead to changed flow regimes and impacts on water quality, aquatic ecosystems and the water available for use by people. Summer flows may decrease on average, but floods may become larger and more frequent. Water quality may decline as a result of higher water temperatures, lower river flows and increased algal blooms. Water demand may increase in response to higher summer temperatures, placing additional pressure on water resources. Section 4 considers the implications for adaptation, identify research gaps and draw conclusions. https://nerc.ukri.org/research/partnerships/ride/lwec/report-cards/water-source14/ Update in: Water in a changing climate: past changes and future prospects for the UK, 2016: https://nerc.ukri.org/research/partnerships/ride/lwec/report-cards/water-source15/		Environment Agency (G Watts et al)	No

38	**Briefing 15/01 – North West floods, hydrological update – issued by the Centre for Ecology & Hydrology. December 2015**	(Centre for Ecology and Hydrology 2015)	
Storm Desmond has been a record breaker, with the rain gauge at Honister Pass in the Lake District recording 341.4 mm in the 24 hours up to 1800 GMT on 5 December 2015. The recently released FEH13 rainfall frequency model estimates that this observation has a return period of about 1300 years at this particular location, corresponding to a probability of 0.08% in any one year. In a warming world, we expect an intensification of rainfall as, put simply; a warmer atmosphere can hold more moisture. There is little compelling evidence for any upward trend in long records of flood magnitude or frequency in the UK. However, the north and the west of the UK has seen an increase in high river flows since the early 1960s that has been associated with changes in atmospheric circulation patterns, in particular, the North Atlantic Oscillation which in its positive state, as is it now, results in milder, wetter winters in the north-west. The flooding has also occurred against the backdrop of a strong El Niño, which in early winter is generally thought to increase the likelihood of a positive NAO, but the link is complicated by lots of other factors. https://www.ceh.ac.uk/news-and-media/blogs/north-west-floods-hydrological-update		CEH	?
39	**Simulating the influences of groundwater on regional geomorphology using a distributed, dynamic, landscape evolution modelling platform. December 2015**	(Barkwith, et al. 2015)	
A dynamic landscape evolution modelling platform (CLiDE) is presented that allows a variety of Earth system interactions to be explored under differing environmental forcing factors. The impact of differing groundwater regimes on sediment discharge is examined for a simple, idealised catchment, Sediment discharge is found to be a function of the evolving catchment morphology. Application of CLiDE to the upper Eden Valley catchment, UK, suggests the addition of base flow-return from groundwater into the fluvial system modifies the total catchment sediment discharge and the spatio-temporal distribution of sediment fluxes during storm events. The occurrence of a storm following a period of appreciable antecedent rainfall is found to increase simulated sediment fluxes. https://www.sciencedirect.com/science/article/pii/S1364815215300463?via%3Dihub		Journal of Environmental Modelling and Software	Y
40	**Arnside and Silverdale AONB Landscape Seascape Character Assessment. November 2015**	(Arnside & Silverdale AONB Partnership; Land Use Consultants 2015)	
The assessment describes the key elements and qualities that make up the distinctive landscape and seascape character of the AONB and classifies its distinctive character types and areas. The assessment also identifies the inherent sensitivity of the AONB's landscape and seascape character and its capacity for change. Current and anticipated forces for change are identified		Arnside and Silverdale AONB (Lucy Barron)	Yes

and recommendations set out for future management and protection of the nationally important AONB landscape and the adjoining areas that form the setting to it. https://www.arnsidesilverdaleaonb.org.uk/what-we-do/planning/landscape-seascape-character-assessment/			
41	**Prediction of blanket peat erosion across Great Britain under environmental change. October 2015**	(Li, Holden and Irvine 2016)	
A recently developed fluvial erosion model for blanket peatlands, PESERA-PEAT, was applied at ten sites across Great Britain to predict the response of blanket peat erosion to environmental change. Modelling results suggested that as climate changes, the response of blanket peat erosion will be spatially very variable across Great Britain. Both relative changes and absolute values of sediment yield were predicted to be higher in southern and eastern areas than in western and northern parts of Great Britain. The model suggested that summer desiccation may become more important for blanket peat erosion under future climate change, and that temperature was more dominant than precipitation in controlling long-term blanket peat erosion change. https://link-springer-com.plsa2r.idm.oclc.org/article/10.1007%2Fs10584-015-1532-x		Journal of Climate Change (P Li, J Holden, B Irvine)	?
42	**Analysis: Regional Attitudes to climate change across the UK. May 2015**	(Pearce 2015)	
Respondents in the South-West were the least sceptical of all the government regions with 82% of people disagreeing with the statement that humans don't cause climate change. This could be partly a result of the region experiencing severe flooding, says Barasi. A recent study suggests the 2013/2014 floods in the UK pushed up public acceptance of human-caused climate change, particularly among those personally affected. https://www.carbonbrief.org/analysis-regional-attitudes-to-climate-change-across-the-uk		Public Opinion - Carbon Brief Rosamund Pearce	No
43	**Impacts of the creation, expansion and management of English wetlands on mosquito presence and abundance – developing strategies for future disease mitigation. March 2015**	(Medlock and Vaux 2015)	
The incidence of mosquito-borne diseases is increasing in Europe. Owing to the impacts of climate change there is an urgent need for environmental adaptation, such as the creation of new wetlands to mitigate coastal and inland flooding. In		Journal of Parasites and Vectors (JM	No

some cases, these initiatives can be coupled with environmental change strategies to protect a range of endangered flora and fauna species. This paper reviews field studies conducted in England to assess the impact of newly created wetlands on mosquito colonisation in a) coastal, b) urban and c) arable reversion habitats. It also considers the impact of wetland management on mosquito populations and explores the implications of various water and vegetation management options on the range of British mosquito species. In terms of invasive alien species that have known economic or biodiversity impacts, the taxa that are likely to be the most responsive are plant pathogens and insect pests of agricultural crops. https://pubmed.ncbi.nlm.nih.gov/25889666/		Medlock, AGC Vaux)	
44	**Climate change and water in the UK – past changes and future prospects. February 2015**	(G. Watts, R. W. Battarbee, et al. 2015)	
Climate change is expected to modify rainfall, temperature and catchment hydrological responses. This paper reviews the impact of anthropogenic climate change on water in the UK and looks at projections of future change. The natural variability of the UK climate makes change hard to detect; only historical increases in air temperature can be attributed to anthropogenic climate forcing, but over the last 50 years more winter rainfall has been falling in intense events. Future changes in rainfall and evapotranspiration could lead to changed flow regimes and impacts on water quality, aquatic ecosystems and water availability. Summer flows may decrease on average, but floods may become larger and more frequent. River and lake water quality may decline as a result of higher water temperatures, lower river flows and increased algal blooms in summer, and because of higher flows in the winter. In communicating this important work, researchers should pay particular attention to explaining confidence and uncertainty clearly. Much of the relevant research is either global or highly localized: decision-makers would benefit from more studies that address water and climate change at a spatial and temporal scale appropriate for the decisions they make. https://journals.sagepub.com/doi/full/10.1177/0309133314542957		Journal of Progress in Physical Geography: Earth and Environment (G Watts, RW Battarbee, JP Bloomfield)	No
45	**The implications of climate change for the water environment in England. February 2015**	(Arnell, et al. 2015)	
The future impact of climate change on the water environment and its management is uncertain. Impacts are dependent on changes in the duration of dry spells and frequency of 'flushing' events, which are highly uncertain and not included in current climate scenarios. There is a good qualitative understanding of ways in which systems may change, but interactions between components of the water environment are poorly		Journal of Progress in Physical Geography: Earth and Environment (NW Arnell, SJ	No

understood. The impacts of climate change depend on other pressures on the water environment in a catchment, and also on the management interventions that are undertaken to achieve water management objectives. The paper develops a series of consistent conceptual models describing the implications of climate change for pressures on the water environment, based around the source-pathway-receptor concept. They provide a framework for a systematic assessment across catchments and pressures of the implications of climate change for the water environment and its management. https://journals.sagepub.com/doi/full/10.1177/0309133314560369		Halliday, , RW Battarbee)	
46	**Adapting to Climate Change in the Lake District National Park: Update and forward strategy. November 2014**	(Lake District National Park 2014)	
Examines the potential impacts of climate change, the associated risks/opportunities and current/planning/potential mitigation/adaptations actions, covering: Access, Recreation and Tourism, Biodiversity, Community, Culture and Economy, Farming and Land Management, Historic Environment, Landscape and the Business Community. Provides an update on evidence and progress since January 2012; Details the links to our strategy for climate change mitigation through carbon reduction; and Explains how we will organise our work on climate change adaptation for the year ahead. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/503254/climate-adrep-lake-district-national-park.pdf		LDNPA (Dean Mason)	
47	**Public perception of climate risk and adaptation in the UK: A review of the literature. 2014**	(Taylor, Dessai and Bruin 2014)	
This article reviews the relevant public perception literature around climate change risk and adaptation for the UK, which includes a broad range of fields including psychology, risk management, human geography and social policy. Non-experts' perceptions of climate change and associated risks often conflate with other environmental problems (e.g. ozone depletion). Non-experts' mental models of climate change has also been found to impact on their climate change risk perception. Many perceive the impacts of climate change as affecting distant geographical areas, occurring further into the future, and harming other social groups rather than themselves (Locke and Latham, 1990). This "psychological distance" from climate change has been associated with lower concern about climate change and greater uncertainty about its existence amongst UK residents. When making judgments and choices from experience, people can overestimate the likelihood of hazards that have recently been experienced.		Journal of Climate Risk Management	No

Studies conducted in the UK and elsewhere have shown that perceived and experienced changes in local weather are associated with stronger climate change beliefs. Emotions have long been recognised as playing a key role in public risk perception. While alarmist imagery may succeed in inducing climate change concern, it may also reduce perceptions about being able to do "something about climate change" and increase psychological distancing, denial and apathy. Research focussing on barriers to climate change mitigation amongst members of the UK public found that participants often expressed powerlessness (e.g. the sentiment that individual actions made little difference) and lower responsibility for carbon emissions than other actors (e.g. the government, larger countries such as the US); a finding that is posited to result from motivated reasoning to justify a lack of motivation to act, or avoid anxiety. It has been argued that factors such as culture, identity, attachment to place, values and regional risk attitudes will determine both the perceived need to adapt and the acceptability of particular adaptive measures. However, we found no UK studies examining the role of place attachment in support for climate change adaptation. When it comes to perceptions of climate change impacts, the available evidence suggests that those in the UK more readily associate climate change with different events (e.g. flooding and rainfall) than countries with warmer climates. https://www.sciencedirect.com/science/article/pii/S2212096314000291			
48	**Priority Habitats in Cumbria. August 2014**	(Eweda and Frost 2014)	
Cumbria has the most diverse range of habitats of any English county and is the only county with all 24 different habitats represented**.** Cumbria is particularly significant in the context of England for the priority habitat Mountain Heath and Willow scrub, holding 84% of the total area of the habitat (Table 2). The county is also very important for Limestone Pavement (59%); Lowland Raised Bog (45%); Upland Flushes (44%); Upland Hay Meadows (25%); Upland Calcareous Grassland (23%); Saltmarsh (22%); and Blanket Bog (22%). http://www.cbdc.org.uk/uploads/downloads/Priority_Habitats_Cumbria_CBDC_August_2014.pdf		Cumbria Biodiversity Data Centre (E Eweda & T Frost	Yes
49	**Climate Change Adaptation Manual – Evidence to Support Nature Conservation in a changing climate, June 2014:**	(Natural England; RSPB 2014)	
Some habitats are particularly vulnerable to climate change, including Coastal Saltmarsh, Montane, Saline Lagoons, Standing Water, Lowland Fen, Rivers and Streams (highest risk). The risks are clearest for montane habitats (to increased temperature), wetlands (to changes in water availability) and coastal habitats (to sea-level rise). The evidence base on climate change and the natural environment has strengthened significantly in recent years and provides a sufficient basis for adaptation actions to start. There remain considerable uncertainties however,		Natural England and RSPB (Andy Neale)	No

and, while these must be acknowledged in adaptation actions, they may also be reduced by research and practical experience. http://publications.naturalengland.org.uk/publication/5629923804839936			
50	**The vulnerability of broad vegetation community types to climate and land use change within Northumberland National Park, Doctoral thesis, February 2014:**	(Ovens 2014)	
The model provides a novel approach for providing spatially-explicit assessments of the vulnerability of vegetation communities to changes in both climate and land use at the landscape scale. The results clearly indicate that, within NNP at least, climate rather than land use, is likely to play a much more significant role in influencing the vulnerability of vegetation communities at the landscape scale as early as 2050. Although this represents a positive change for the majority of the Priority Broad Vegetation Communities, others, that are particularly significant within NNP in terms of national and European conservation policy, are generally unaffected, i.e. Heath, but for Blanket Bog and Raised Bog effects are likely to be highly negative due to climate change. http://nrl.northumbria.ac.uk/23584/1/ovens.christopher_phd.pdf		Northumbria University (C S Ovens)	No
51	**Climate change: the future of UK cities, January 2014**	(Holmes 2018)	
The most urgent risks to UK cities are from flooding, heat, and extreme weather impacts on infrastructure. In some areas of the UK there is also a risk of water demand exceeding supply by 2030. Sewer networks lack sufficient capacity to cope with the heavier rainfall that climate change is expected to bring, and new building developments are adding to this risk by increasing the flow of water into the sewerage system. This is more likely to occur in cities due to the urban heat island effect. Around 2,000 heat-related deaths occur each year in the UK and this is projected to increase to 7,000 by 2050 as average temperatures rise with climate change. We all rely heavily on digital and information communications technology whether for personal or business use, or for the operation of services. Surprisingly, there is no national plan from industry or government to address climate change risks in the digital or ICT sectors. https://www.theccc.org.uk/2018/01/04/uk-cities-climate-change/		Committee on Climate Change	No
52	**Assessment of Heritage at Risk from Environmental Threat – A Key Message Report. November 2013**	(English Heritage 2013)	
Vulnerability assessment looking at climate change impacts including coastal processes, inland water inundation, extremes of wetting and drying, fire and pests and diseases. Conclusion that these represented the greatest threat facing the historic environment in the short to medium term. NB. Next iteration of this report will model the density and number of assets on the National Heritage List in Flood Risk Zone(s).		English Heritage	?

53	**The local impact of global climate change: reporting on landscape transformation and threatened identity in the English regional newspaper press. September 2011**	(Brown, et al. 2011)	
This paper contributes to extant understandings of media representations of climate change by examining the role of the English regional newspaper press in the transformation and dissemination of climate change discourse. The broader significance of such stories is considered in relation to long-standing debates concerning the importance of landscape to notions of national and regional identity. There is clear evidence from the stories that we have analysed that the already happening or predicted impact of global climate change is presented as a threat to English (though often presented as British) identity. By framing climate change as a "threat" to traditional symbols of "Britishness" or "English identity," and also significantly as a contributor to a more positive dynamic identity, the newspaper press play a very important, and hitherto largely neglected, role in shaping public engagements with climate change. They highlight the complex interplay between loss and nostalgia, and a more optimistic, future-orientated vision of identity that is also associated with global change. Just as broadsheet newspapers have been recognised for their important "agenda-setting" function, the (re)presentation and cultural politics of climate change discourse in the UK's local and regional press should be acknowledged and its impact more widely debated. **https://journals.sagepub.com/doi/10.1177/0963662510361416**		Public Understanding of Science (T Brown et al)	No
54	**Nitrogen deposition enhances moss growth, but leads to an overall decline in habitat condition of mountain moss-sedge heath. July 2011**	(Armitage, et al. 2011)	
In the UK, ongoing loss of the internationally important arctic/alpine moss-sedge community, *Racomitrium* heath, has been linked to elevated N deposition, high grazing pressures and their combination; however, the relative importance of these drivers remains unclear. Our results clearly show that regional variation in the condition of *R. lanuginosum* across Europe is primarily associated with the impacts of N deposition, with climate (air temperature) and grazing pressure playing secondary roles. https://abdn.pure.elsevier.com/en/publications/nitrogen-deposition-enhances-moss-growth-but-leads-to-an-overall-		Journal of Global Change Biology (H F Armitage et al)	No
55	**Climate Resilient Infrastructure: Preparing for a Changing Climate. May 2011**	(HM Government 2011)	
The document highlights important themes such as: the risk climate change presents to infrastructure interdependencies; adaptation investment; and		HM Government	No

potential economic opportunities. The document is linked to wider Government work on infrastructure, in particular the Government's National Infrastructure Plan. In addition, the UK Government's first Adaptation Programme in 2012 will report on progress made and what further actions might be required to increase the climate resilience of infrastructure. Integrate adaptation into infrastructure investment decisions, in particular assets with a 20 year+ lifetime. • Look at innovative financial approaches to incentivise adaptation in long-life assets. • To work with infrastructure owners to increase climate resilience to reduce exposure risk. https://www.publicinformationonline.com/download/22449			
56	**Towards an assessment of the state of the UK Peatlands, JNCC Report No.445. April 2011**	(JNCC 2011)	
This report is the first time that such a range of peatland information has been brought together and it is hoped that an understanding of the differences in the data available will help address how the information is used. The information coverage and intensity of data recorded on peatlands significantly varies across the UK. Site specific studies and one-off surveys have indicated changes in the extent and quality of peatlands. By contrast, the changes in the wider extent and quality of peatlands have mainly been inferred from limited studies rather than extensive survey or statistically valid sampling. In part driven by the climate change mitigation agenda, extensive work is being undertaken at the UK level to overcome classification differences and monitor soils to improve our estimate of the soil carbon stock. This will help secure sustainable management which delivers large-scale biodiversity and other ecosystem services in a manner which also delivers better resilience to climate change. https://hub.jncc.gov.uk/assets/f944af76-ec1b-4c7f-9f62-e47f68cb1050		JNCC	Yes
57	**Cumbria Landscape Guidance and Toolkit, Part One Landscape Character Guidance, March 2011:**	(Wain 2011)	
Part One includes Cumbria's Landscape Character Assessment and links with other national, regional, and protected landscape assessments. Part Two includes a toolkit to help understand the role of landscape character assessment and how and when to use it. https://www.cumbria.gov.uk/eLibrary/Content/Internet/538/755/2789/406869467.pdf		Cumbria County Council	Yes
59	**Solway Coast AONB Landscape and Seascape Assessment, Solway Coast AONB, November 2010:**	(Irving 2010)	

Potential major changes in the physical size and appearance of the area, as the area of exposed coastal habitats (flats, sands, saltmarsh) may be reduced as a consequence of sea level rise. The general approach to sea level rise as advocated in the Shoreline Management Plan will be to manage realignment of the coast. https://www.solwaycoastaonb.org.uk/documents/LSCA-AONB.pdf		Solway Coast AONB (Brian Irving)	Yes
60	**Climate change: impacts and adaptation in England's woodlands, FCRN201, September 2010:**	(Forestry Commission 2010)	
Covers impacts and recommended adaptation measures for woodland types and individual trees, with regionalised analysis. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/695127/Climate-change-impacts-adaptation-English-woodlands.pdf		Forest Research (duncan.ray@ForestResearch.gov.uk) 0300 067 5977	Yes
61	**The future climate of North West England, EcoCities, 2010:**	(Cavan, Carter and & Kazmierczak 2010)	
Summarises climate projections information for the North West region in tables, graphs, maps and descriptions. It provides information for a range of climate variables, time periods, emissions scenarios and probability levels. https://www.research.manchester.ac.uk/portal/files/50400419/FULL_TEXT.PDF		University of Manchester	?
62	**Development and application of topographic descriptors for conditional analysis of rainfall, July 2009:**	(Ferranti, Whyatt and Timmis 2009)	
A high-resolution database of meteorological observations was constructed for Cumbria. Synoptic and local site characteristics allow the rainfall associated with specific conditions to be defined and analysed over different time periods and in different geographic settings. Preliminary results show winter rainfall under SW conditions has increased from 1960 to 2007, with the magnitude of increase varying between geographic settings. Upland regions, particularly leeward-upland zones, are experiencing the greatest increase in rainfall under SW conditions. Ongoing research is repeating this methodology to investigate how the frequency distribution of rainfall amount may be changing for different synoptic situations and geographic settings. This, combined with the conditional analysis of other meteorological parameters such as wind speed, wind direction and temperature, will provide a detailed synopsis of Cumbrian rainfall patterns and processes under a changing climate.		Royal Meteorological Society - Atmospheric Science Letters Ferranti et al 2009	Yes

These results will be significant for other mid-latitude upland areas dominated by a maritime climate both within the United Kingdom and globally. https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/asl.228			
63	**Responding to the Impacts of climate change on the Natural Environment: The Cumbria High Fells, Natural England, Report NE115R. First Published 2009**	(Natural England 2009)	
A detailed pilot assessment of the potential impacts of climate change covering temperature rise, rainfall changes, increased storminess and tourism & recreation in the landscape. It outlines: • The significant biodiversity, landscape, recreational and historic environment assets; • Assesses the potential risks climate change poses to these assets; and • Suggests practical actions that would make them more resilient to the impacts of climate change. **http://publications.naturalengland.org.uk/publication/55001?category=10003**		Natural England	Yes?
64	**Changes to Climate and Visitor Behaviour: Implications for Vulnerable Landscapes in the North West Region of England. January 2009**	(McEvoy, et al. 2008)	
Many high quality landscapes can be found in the North West region of England, including those of international significance such as the Lake District National Park. Focusing on two landscape types considered to be the most vulnerable to a changing climate, the coastal zone and the uplands, this paper presents 'downscaled' climate change scenarios, and provides an assessment of how a combination of climate and non-climate factors are likely to impact these vulnerable landscapes in the future. Recent research findings have highlighted that the relationship between the impact of climate change and visitor behaviour (demand side of the visitor economy) is complex. In fact, econometric analysis conducted for the CCVE research project found that visitors in the region are fairly resilient to weather, with socio-economic variables considered much more influential in determining behaviour. In the case of the Lake District, stakeholders were most concerned about footpath erosion, particularly in light of the predicted increase in rainfall intensity (which is a critical factor influencing erosion rates). The risk of erosion will be heightened by human influence, as the process is accelerated when trampling and rainfall alternate. Stakeholders consider this a serious problem as modern clothing and equipment make it more likely that walkers are now out on vulnerable upland areas in all weathers.		Journal of Sustainable Tourism (D McEvoy et al)	No

Decision-making relating to tourism has been found to be much more based on climate information (destination and period selection), whereas recreation/leisure is much more weather-dependent and reliant on short term forecasts. https://www-tandfonline-com.ezproxy.lancs.ac.uk/doi/abs/10.1080/17451590609618117?src=recsys			
65	**Regional assessment of climate change impacts on coastal and fluvial ecosystems and the scope for adaptation. July 2008**	(Richards, et al. 2008)	
Presents the methodologies and results of biodiversity meta-models used within the Regional Impact Simulator for two regions of the UK: East Anglia and North West England. Potential impacts and adaptations to future climate and socio-economic scenarios are analysed for three habitat types in floodplains (saltmarsh, coastal grazing marsh and fluvial grazing marsh) and selected species. An important finding is that management choices, which can be linked to socio-economic futures have a greater potential impact on habitat viability than climate change. The choices society makes will therefore be key to protection and conservation of biodiversity. There is intense competition between saltmarsh and coastal grazing marsh for space in the intertidal zone, where coastal squeeze is causing a decline of saltmarsh, and coastal grazing marsh is restricted to protected land within the coastal floodplain which is also suitable for saltmarsh re-creation. The analyses also show that coastal grazing marsh is the most vulnerable habitat to sea-level rise, although there is a scope for substituting losses with fluvial grazing marsh. https://link-springer-com.plsa2r.idm.oclc.org/content/pdf/10.1007/s10584-008-9451-8.pdf		Journal of Climate Change (JA Richards, M Mokrech, RJ Nicholls, PM Berry)	No
66	**Sediment dynamics in an upland temperate catchment: changing sediment sources, rates and deposition. June 2008**	(Hatfield, et al. 2008)	
Examines sediment dynamics in an upland, temperate lake system, Lake Bassenthwaite, in the context of changing climate and land use, using magnetic and physical core properties. Three successive, major pulses of erosion and increased sediment flux appear linked to specific activities within the catchment, specifically: mining activities and associated deforestation in the mid-late nineteenth century; agricultural intensification in the mid-twentieth century and, within the last decade, the additional possible impact of climate change. These results are important for all upland areas as modifications in climate become progressively superimposed upon the effects of previous and/or ongoing anthropogenic catchment disturbance. https://www.researchgate.net/publication/226714565_Sediment_dynamics_in_an_upland_temperate_catchment_Changing_sediment_sources_rates_and_deposition		Journal of Paleolimnology (RG Hatfield, BA Maher, JM Pates, PA Barker)	No

67	**County Durham Landscape Character Assessment: The North Pennines. April 2008**	(Durham County Council 2008)	
The County Durham Landscape Character Assessment is a detailed assessment of the character of the county. It works within the framework of Countryside Character Areas and Natural Areas, identifying variations in landscape character at a sub-regional and local level. The assessment is based on a detailed Geographical Information System (GIS) database of landscape elements which was used to identify landscape types and character areas at a number of levels from regional landscapes, like the North Pennines or the West Durham Coalfield, to local landscapes like historic parklands and wooded denes. http://www.durhamlandscape.info/media/13394/County-Durham-Landscape-Character-Assessment-The-North-Pennines/pdf/CDLACNorthPennines.pdf		Durham County Council	Yes
68	**Preparing for Climate Change in the Outdoor Recreation Sector, January 2008:**	(Countryside Recreation Network 2008)	
Seminar looking at climate change predictions and management responses. Relevant Case Study looking at upland path erosion in the Lake District. https://www.outdoorrecreation.org.uk/wp-content/uploads/2017/02/2008-Seminar-Preparing-for-Climate-Change.pdf		Countryside Recreation Network	No
69	**The impact of climate change on the physical characteristics of the larger lakes in the English Lake District. July 2007**	(George, Hurley and Hewitt 2007)	
The larger lakes of the English Lake District have been the subject of intensive scientific study for more than 60 years. We combine the results of long-term measurements and the projections from a Regional Climate Model (RCM) to assess the potential impact of climate change on the surface temperature and residence times of the lakes. An analysis of the meteorological data acquired between 1940 and 2000 shows that there have been progressive increases in the winter air temperature and in the rainfall which are correlated with the long-term change in the North Atlantic Oscillation. A simple model of the year-to-year variations in surface temperatures showed that the highest winter temperatures were recorded in the deeper lakes and the highest summer temperatures in the lakes with the shallowest thermoclines. When this model was used to predict the surface temperatures of the lakes in the 2050s, the greatest winter increase (+1.08°C) was observed in the shallowest lake and the greatest summer increase (+2.18°C) in the lake with the shallowest thermocline. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2427.2007.01773.x		Journal of Freshwater Biology (G. George, M. Hurley, D. Hewitt)	No

70	**Hillslope gullying in the Solway Firth — Morecambe Bay region, Great Britain: Responses to human impact and/or climatic deterioration? February 2007, Vol.84:**	(Chiverrell, Harvey and Foster 2007)	
Little or no hillslope geomorphic activity has been identified occurring during the early Holocene, but there is abundant evidence for late Holocene hillslope erosion (gullying) and associated alluvial fan and valley floor deposition. Interpretation of the regional radiocarbon chronology available from organic matter buried beneath alluvial fan units suggests much of this geomorphic activity can be attributed to four phases of more extensive gullying identified after 2500–2200, 1300–1000, 1000–800 and 500 cal. The increased susceptibility to erosion of gullies is a response to increased anthropogenic pressure on upland hillslopes during the late Holocene, and the role of this pressure appears crucial in priming hillslopes before subsequent major storm events. In particular, the cycles of expansion and contraction in both population and agriculture appear to have affected the susceptibility of the upland landscape to erosion, and the hillslope gullying record in the region, therefore, contributes to understanding of the timing and spatial pattern of human exploitation of the upland landscape. https://www.sciencedirect.com/science/article/abs/pii/S0169555X06002352?via%3Dihub		Journal of Geomorphology (RC Chiverrell, AM Harvey, GC Foster)	No
71	**Past and Future Perspectives upon landscape instability in Cumbria, the North West, January 2006, Vol.6:**	(Chiverell 2006)	
Reviews evidence for the late Holocene landscape instability in the uplands of Cumbria, and its causes. The evidence from sediment records in lakes, hillslopes and river systems. Gully development and associated tributary junction alluvial fan progradation are direct evidence for instability and erosion on upland hillslopes. The past shows that the largest increases in erosion and sediment movement occur in the wakes of major intensifications in land pressure that primarily affect previously wooded or protected hillslopes, circumstances that land management strategists should mitigate against. In terms of erosion intensity, changing the sediment supply to the regions lakes and encouraging gully incision or debris flow activity on the hillslopes, climate is only part of the story with the largest increases in geomorphic activity strongly affected by human-mediated land use changes. This paper reviews the evidence for late Holocene. https://www.researchgate.net/publication/225789316_Past_and_future_perspectives_upon_landscape_instability_in_Cumbria_northwest_England		Journal of Environmental Change (Richard C. Chiverrell)	?
72	**Conceptual modelling of the impacts of climate change on karst geomorphology in the UK and Ireland. 2003**	(Viles 2003)	

Climate change is likely to influence three key aspects of karst geomorphology, i.e. hydrology, dissolution rates and the operation of other geomorphological processes such as mass movements. An assessment is made of the sensitive aspects of the geomorphology and detailed climate predictions given for the 2020s and 2050s (using the UKCIP 1998 scenarios downscaled to the bioclimatic classes identified by the MONARCH project). The impacts of future climate change on British and Irish karst areas need to be considered alongside the already extensive human impacts in these areas, but are unlikely to cause major geomorphic change, although impacts on sensitive landforms and allied biota may have negative effects on conservation. https://www.sciencedirect.com/science/article/abs/pii/S1617138104700357		Journal for Nature Conservation (Viles, Oxford)	?
73	**Climate change and Natural Forces – the consequences for Landscape Character (Topic Paper 9). April 2002**	(Countryside Agency 2002)	
This Topic Paper outlines the evidence which has been gathered to demonstrate how climate is changing and is likely to change, identifying those variables particularly relevant to the study of landscape. It identifies some of the key impacts on landscape which could possibly occur, suggests how the issue might be incorporated into Landscape Character Assessment and offers suggestions as to how climate change impacts might be responded to in terms of mitigation and adaptation. It includes examples of how climate change impacts have been integrated into LCAs, but none are within Cumbria. The background data is out of date, using the UKCIP 2002, 50km scale figures. http://publications.naturalengland.org.uk/publication/6538550904356864		Countryside Agency	No
74	**Climate Change and Nature Conservation in Britain and Ireland - Modelling natural resource responses to climate change (The Monarch Project). First Published 2001**	(Harrison, Berry and Dawson 2001)	
Multi-data GIS based mapping of impacts within Britain and Ireland on the potential responses of species, habitats and geomorphological features to climate change. Including detailed analysis of 12 habitats of concern, including Blanket Bog, Coastal Salt Marsh, Raised Bog, Montane Heath Upland Hay Meadow, Upland Oak Woodland. MONARCH has provided a useful template that can be built upon in order to help direct the management strategies of the conservation bodies to improve understanding of climate change impacts. https://www.eci.ox.ac.uk/research/ecosystems/downloads/Monarch1_tech.pdf		The UK Climate Impacts Programme (UKCIP) – Monarch	Yes
75	**Changing by Degrees - The Impacts of Climate Change in the North West of England, December 1998:**	(Shackley, et al. 1998)	

The methodology employed combines expert judgement, stakeholder assessment, qualitative and quantitative scenario construction and assessment methods, and literature review. We investigated the impacts upon five 'landscape domains' (coastal zone, rural lowlands, rural uplands, urban fringe and urban core) and upon key economic sectors in the region through assessment of scientific findings and through interviews with stakeholders. The landscape domains are a geographically-based framework for bringing together the physical, biological and socio-economic character of the land. https://www.ukcip.org.uk/wp-content/PDFs/NW_tech.pdf	'Climate Change in the North West' Group (A partnership of regional bodies (some no longer exist)	Yes

Appendix: Background Climate Change Data resources.

Greenhouse Gas Emissions:

https://ec.europa.eu/knowledge4policy/foresight/topic/climate-change-environmental-degradation/greenhouse-gas-emissions_en

Rising Temperatures:

https://ec.europa.eu/knowledge4policy/foresight/topic/climate-change-environmental-degradation/rising-temperatures_en

Ice-Melt and Permafrost – Sea Level Rise:

https://ec.europa.eu/knowledge4policy/foresight/topic/climate-change-environmental-degradation/melting-ice-cover-permafrost_en

See also free on-line Climate Research Journal: https://www.int-res.com/journals/cr/cr-home/

Climate-ADAPT . https://climate-adapt.eea.europa.eu/

National Hydrological Monitoring Programme (CEH & BGS), e.g. The Future Flows and Groundwater Levels Project (104 River flow stations and 37 groundwater boreholes across UK): https://www.ceh.ac.uk/our-science/projects/future-flows-and-groundwater-levels

Useful Research Journals:

Archaeology; Climate Change; Climatology; Earth Systems and Environment; Earth Surface and Landforms, Ecohydrology; Ecological Engineering; Environmental Modelling and Software; Environmental Research letter; Flood Risk Management; Geomorphology; Global Change Biology; Global Planetary Change; Landscape Ecology; Landscape Research; Progress in Physical Geography: Earth and Environment; Sustainable Tourism.

Accessed via:

- Cumbria Libraries 'Access to Research' system; and
- Lancaster University's 'OneResearch' online database.

See also: The British Library – EthOS e-theses online service with over 500,000 UK PhD theses: https://ethos.bl.uk/SearchResults.do

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