Executive Summary

Chapter 2, building on prior assessments[1], provides a global assessment of the observed impacts and projected risks of climate change to terrestrial and freshwater ecosystems, including their component species and the services they provide to people. Where possible, differences among regions, taxonomic groups and ecosystem types are presented. Adaptation options to reduce risks to ecosystems and people are assessed.

Observed Impacts

Multiple lines of evidence, combined with the strong and consistent trends observed on every continent, make it *very likely*[2] that many observed changes in the ranges, phenology, physiology and morphology of terrestrial and freshwater species can be attributed to regional and global climate changes, particularly increases in the frequency and severity of extreme events (*very high confidence*[3]) {2.3.1; 2.3.3.5; 2.4.2; 2.4.5; Table 2.2; Table 2.3; Table SM2.1; Cross-Chapter Box EXTREMES in this chapter}. The most severe impacts are occurring in the most vulnerable species and ecosystems, characterised by inherent physiological, ecological or behavioural traits that limit their abilities to adapt, as well as those most exposed to climatic hazards (*high confidence*) {2.4.2.2; 2.4.2.6; 2.4.2.8; 2.4.5; 2.6.1; Cross-Chapter Box EXTREMES in this chapter}.

New studies since the IPCC 5th Assessment Report (AR5) and the Special Report on Global Warming of 1.5°C (SR1.5) (with data for >12,000 species globally) show changes consistent with climate change. Where attribution was assessed (>4,000 species globally), approximately half of the species had shifted their ranges to higher latitudes or elevations and two-thirds of spring phenological events had advanced, driven by regional climate changes (*very high confidence*). Shifts in species ranges are altering community make-up, with exotic species exhibiting a greater ability to adapt to climate change than natives, especially in more northern latitudes, potentially leading to new invasive species *(medium confidence)* {2.4.2.3.3; 2.4.2.7}. New analyses demonstrate that prior reports underestimated impacts due to the complexity of biological responses to climate change (*high confidence*). {2.4.2.1; 2.4.2.3; 2.4.2.4; 2.4.2.5; 2.4.5; Table 2.2; Table SM2.1; Table 2.3}

Responses of freshwater species are strongly related to changes in the physical environment (*high confidence*){2.3.3; 2.4.2.3.2}. Global coverage of quantitative observations in freshwater ecosystems has increased since AR5. Water temperature has increased in rivers (up to 1°C per decade) and lakes (up to 0.45°C per decade) {2.3.3.1; Figure 2.2}. The extent of ice cover has declined by 25% and duration by >2 weeks {2.3.3.4; Figure 2.4}. Changes in flow have led to reduced connectivity in rivers (*high confidence*) {2.3.3.2; Figure 2.3}. Indirect changes include alterations in river morphology, substrate composition, oxygen concentrations and thermal regime in lakes (*very high confidence*) {2.3.3.2; 2.3.3.3}. Dissolved oxygen concentrations have typically declined and primary productivity has increased with warming. Warming and browning (increase in organic matter) have occurred in boreal freshwaters, with both positive and negative repercussions on water temperature profiles (lower vs. upper water) (*high confidence*) and primary productivity (*medium confidence*) as well as reduced water quality (*high confidence*) {2.4.4.1; Figure 2.5}.

Climate change has increased wildlife diseases (*high confidence*). Experimental studies provide *high confidence* in the attribution of observed increased disease severity, outbreak frequency and the emergence of novel vectors and their diseases into new areas to recent trends in climate and extreme events. Many vector-borne diseases and those caused by ticks, helminth worms and the chytrid fungus (*Batrachochytrium dendrobatidis*, Bd) have shifted polewards and upwards and are emerging in new regions (*high confidence*). In the high Arctic and at high elevations in Nepal, there is *high confidence* that climate change has driven the expansion of vector-borne diseases (VBDs) that infect humans. {2.4.2.7, 7.2.2.1, 9.8.2.4, 10.4.7.1, 12.3.1.4, 13.7.1.2, 14.4.6.4; Cross-Chapter Box ILLNESS in this chapter}

Forest insect pests have expanded northward, and the severity and extent of outbreaks have increased in northern North America and northern Eurasia due to warmer winters reducing insect mortality and longer growing seasons favouring more generations per year (*high confidence*) {2.4.2.1; 2.4.4.3.3}.

Local population extinctions caused by climate change have been widespread among plants and animals, detected in 47% of 976 species examined and associated with increases in the hottest yearly temperatures (*very high confidence*) {2.4.2.2}. Climate-driven population extinctions have been higher in tropical (55%) than in temperate (39%) regions, higher in freshwater (74%) than in marine (51%) or terrestrial (46%) habitats, and higher in animals (50%) than in plants (39%). Extreme heat waves have led to local fish dying out in lakes and mass mortality events in birds, bats, mammals and fish {2.3.3.5, 2.4.2.7.2, Cross-Chapter Box EXTREMES in this chapter}. Intensification of droughts contributes to the disappearance of small or ephemeral ponds that often harbour rare and endemic species. {2.4.2.2; Cross-Chapter Box EXTREMES in this chapter}

Global extinctions or near-extinctions have been linked to regional climate change in three documented cases {2.4.2.2}. The

1 Previous IPCC assessments include the AR5 (IPCC, 2013; IPCC, 2014b; IPCC, 2014c), the SR1.5 (IPCC, 2014a), the Special Report on Ocean and Cryosphere in a Changing Climate (SROCC) (IPCC, 2019b) and the IPCC Sixth Assessment Report Working Group I (IPCC, 2021a).

2 In this report, the following terms have been used to indicate the assessed likelihood of an outcome or a result: virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, about as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10% and exceptionally unlikely 0–1%. Additional terms (extremely likely 95–100%, more likely than not >50–100% and extremely unlikely 0–5%) may also be used when appropriate. Assessed likelihood is typeset in italics, e.g., *very likely*). This report also uses the term '*likely range*' to indicate that the assessed likelihood of an outcome lies within the 17–83% probability range.

3 In this report, the following summary terms are used to describe the available evidence: limited, medium or robust; and for the degree of agreement: low, medium or high. A level of confidence is expressed using five qualifiers: very low, low, medium, high and very high, and is typeset in italics, e.g., *medium confidence*. For a given evidence and agreement statement, different confidence levels can be assigned, but increasing levels of evidence and degrees of agreement are correlated with increasing confidence.

cloud forest-restricted golden toad (*Incilius periglenes*) was extinct by 1990 in a nature preserve in Costa Rica following successive extreme droughts (*medium confidence*). The white sub-species of the lemuroid ringtail possum (*Hemibelideus lemuroides*) in Queensland, Australia, disappeared after heat waves in 2005 (*high confidence*): intensive censuses found only 2 individuals in 2009. The Bramble Cay melomys (BC melomys, *Melomys rubicola*) was not seen after 2009 and was declared extinct in 2016, with sea-level rise (SLR) and increased storm surge associated with climate change being the most probable drivers (*high confidence*). Additionally, the interaction of climate change and chytrid fungus (Bd) has driven many of the observed global declines in amphibian populations and the extinction of many species (*high confidence*) {2.4.2.7.1}.

A growing number of studies have documented genetic evolution within populations in response to recent climate change (*very high confidence*). To date, genetic changes remain within the limits of known variation for species (*high confidence*). **Controlled selection experiments and field observations indicate that evolution would not prevent a species becoming extinct if its climate space disappears globally (*high confidence*).** Climate hazards outside of those to which species have adapted are occurring on all continents (*high confidence*). More frequent and intense extreme events, superimposed on longer-term climate trends, have pushed sensitive species and ecosystems towards tipping points that are beyond the ecological and evolutionary capacity to adapt, causing abrupt and possibly irreversible changes (*medium confidence*). {2.3.1; 2.3.3; 2.4.2.6; 2.4.2.8; 2.6.1; Cross-Chapter Boxes ILLNESS and EXTREMES in this chapter}

Since AR5, biome shifts and structural changes within ecosystems have been detected at an increasing number of locations, consistent with climate change and increasing atmospheric CO_2 (*high confidence*). New studies are documenting the changes that were projected in prior IPCC reports have now been observed, including upward shifts in the forest/alpine tundra ecotone, northward shifts in the deciduous/boreal forest ecotones, increased woody vegetation in the sub-Arctic tundra and shifts in the thermal habitat in lakes *(high confidence)*. A combination of changes in grazing, browsing, fire, climate and atmospheric CO_2 is leading to observed woody encroachment into grasslands and savannah, consistent with projections from process-based models driven by precipitation, atmospheric CO_2 and wildfires (*high confidence*) {2.4.3; Table 2.3; Table SM2.1; Box 2.1; Figure Box 2.1.1; Table Box 2.1.1}. There is *high agreement* between the projected changes in earlier reports and the recent trends observed for areas of increased tree death in temperate and boreal forests and woody encroachment in savannas, grasslands and tundra {2.5.4; Box 2.1; Figure Box 2.1.1; Table Box 2.1.1}. Observed changes impact the structure, functioning and resilience of ecosystems as well as ecosystem services, such as climate regulation (*high confidence*) {2.3; 2.4.2; 2.4.3; 2.4.4, 2.5.4, Figure 2.11, Table 2.5, Box 2.1; Figure Box 2.1.1; Table Box 2.1.1}.

Regional increases in the area burned by wildfire (up to double natural levels), tree mortality of up to 20%, and biome shifts of up to 20 km latitudinally and 300 m up-slope have been attributed to anthropogenic climate change in tropical, temperate and boreal ecosystems around the world (*high confidence*), damaging key aspects of ecological integrity. This degrades the survival of vegetation, habitat for biodiversity, water supplies, carbon sequestration, and other key aspects of the integrity of ecosystems and their ability to provide services for people (*high confidence*). {2.4.3.1; 2.4.4.2; 2.4.4.3; 2.4.4.4; Table 2.3; Table SM2.1}

Fire seasons have lengthened on one-quarter of vegetated areas since 1979 as a result of increasing temperature, aridity and drought (*medium confidence*). **Field evidence shows that anthropogenic climate change increased area burned by wildfire above natural levels in western North America in the period 1984–2017: a doubling above natural for the western USA and 11 times higher than natural in one extreme year in British Columbia (*high confidence*).** In the Amazon, the Arctic, Australia and parts of Africa and Asia, burned area has increased, consistent with, although not formally attributed to, anthropogenic climate change. Wildfires generate up to one-third of ecosystem carbon emissions globally, a feedback that exacerbates climate change (*high confidence*). Deforestation, draining of peatlands, agricultural expansion or abandonment, fire suppression, and inter-decadal cycles such as the El Niño-Southern Oscillation (ENSO), can exert a stronger influence than climate change on increasing or decreasing wildfire in some regions {2.4.4.2; Table 2.3; Table SM2.1; FAQ 2.3}. Increase in wildfire from the levels to which ecosystems are adapted degrades vegetation, habitat for biodiversity, water supplies and other key aspects of the integrity of ecosystems and their ability to provide services for people (*high confidence*). {2.4.3.1, 2.4.4.2, 2.4.4.3, 2.4.4.4; Table 2.3; Table SM2.1}

Drought-induced tree mortality attributed to anthropogenic climate change has caused up to 20% loss of trees in the period 1945–2007 in three regions in Africa and North America *(high confidence)*. It has also potentially contributed to over 100 other cases of drought-induced tree mortality across Africa, Asia, Australia, Europe, and North and South America (*high confidence*). Field observations have documented post-mortality vegetation shifts (*high confidence*). Timber cutting, agricultural expansion, air pollution and other non-climate factors also contribute to tree death. Increases in forest insect pests driven by climate change have contributed to tree mortality and shifts in carbon dynamics in many temperate and boreal forest areas (*very high confidence*). The direction of changes in carbon balance and wildfires following insect outbreaks depends on the local forest insect communities (*medium confidence*). {2.4.4.3; Table 2.3; Table SM2.1}

Terrestrial ecosystems currently remove more carbon from the atmosphere, 2.5–4.3 Gt yr-1, than they emit (+1.6 ± 0.7 Gt y-1), and so are currently a net sink of -1.9 ± 1.1 Gt y-1. Intact tropical rainforests, Arctic permafrost, peatlands and other healthy high-carbon ecosystems provide a vital global ecosystem service of preventing the release of stored carbon (*high confidence*). Terrestrial ecosystems contain stocks of ~3500 GtC in vegetation, permafrost, and soils, three to five times the amount of carbon in unextracted fossil fuels (*high confidence*) and >4 times the carbon currently in the atmosphere (*high confidence*). Tropical forests and Arctic permafrost contain the highest ecosystem carbon stocks in aboveground vegetation and in soil, respectively, in the world (*high* *confidence*). Deforestation, draining, burning or drying of peatlands, and thawing of Arctic permafrost, due to climate change, has already shifted some areas of these ecosystems from carbon sinks to carbon sources (*high confidence*). {2.4.3.6; 2.4.3.8; 2.4.3.9; 2.4.4.4}

Evidence indicates that climate change is affecting many species, ecosystems and ecological processes that provide ecosystem services connected to human health, livelihoods, and well-being (*medium confidence*). These services include climate regulation, water and food provisioning, pollination of crops, tourism and recreation. It is difficult to establish full end-to-end attribution from climatic changes to changes in a given ecosystem service and to identify the location and timing of impacts. The lack of attribution studies may delay specific adaptation planning, but there is evidence that protection and restoration of ecosystems builds resilience of service provision. {2.2; 2.3; 2.4.2.7; 2.4.4; 2.4.5; 2.5.3; 2.5.4; 2.6.3; 2.6.4; 2.6.5; 2.6.6; 2.6.7; Cross-Chapter Boxes NATURAL, ILLNESS and EXTREMES in this chapter; Cross-Chapter Box COVID in Chapter 7; Cross-Chapter Box MOVING PLATE in Chapter 5; Box 5.3; section 5.4.3.4}

Projected Risks

Climate change increases risks to fundamental aspects of terrestrial and freshwater ecosystems, with the potential for species' extinctions to reach 60% at 5°C global mean surface air temperature (GSAT) warming (*high confidence*), biome shifts (changes in the major vegetation form of an ecosystem) on 15% (at 2°C warming) to 35% (at 4°C warming) of global land (*medium confidence*), and increases in the area burned by wildfire of 35% (at 2°C warming) to 40% (at 4°C warming) of global land (*medium confidence*). {2.5.1; 2.5.2; 2.5.3; 2.5.4; Figure 2.6; Figure 2.7; Figure 2.8; Figure 2.9; Figure 2.11; Table 2.5; Table SM2.2; TableSM2.5; Cross-Chapter Box DEEP in Chapter 17; Cross-Chapter Paper 1}

Extinction of species is an irreversible impact of climate change, with increasing risk as global temperatures rise *(very high confidence)*. The median values for percentage of species at *very high risk* of extinction (categorized as "critically endangered" by IUCN Red List categories)(IUCN, 2001) are 9% at 1.5°C rise in GSAT, 10% at 2°C, 12% at 3.0°C, 13% at 4°C and 15% at 5°C *(high confidence)*, with the *likely* range of estimates having a maximum of 14% at 1.5°C and rising to a maximum of 48% at 5°C (Figure 2.7). Among the groups containing the largest numbers of species at a *very high risk* of extinction for mid-levels of warming (3.2°C) are: invertebrates (15%, and specifically pollinators at 12%), amphibians (11% overall, but salamanders are at 24%) and flowering plants (10%). All groups fare substantially better at lower warming of 2°C, with extinction projections reducing to <3% for all groups, except salamanders that reduced to 7% (*medium confidence*) (Figure 2.8a). Even the lowest estimates of species' extinctions (median of 9% at 1.5°C rise GSAT') are 1000 times the natural background rates. Projected species' extinctions at future global warming levels are consistent with projections from AR4, but assessed for many more species with much greater geographic coverage and a broader range of climate models. {2.5.1.3; Figure 2.6; Figure 2.7; Figure 2.8; Cross-Chapter Box DEEP in Chapter 17; Cross-Chapter Paper 1}

Species are the fundamental unit of ecosystems, and the increasing risk of local losses of species increases the risks of reduced ecosystem integrity, functioning and resilience with increasing warming (*high confidence*). As species become rare, their role in the functioning of the ecosystem diminishes (*high confidence*). Loss of species locally reduces the ability of an ecosystem to provide services and lowers its resilience to climate change (*high confidence*). At 1.58°C GSAT warming, >10% of species are projected to become endangered (median estimate, with "endangered" equating to a *high risk* of extinction, sensu IUCN), and at 2.07°C this rises to >20% of species, representing a *high* and *very high* risk of biodiversity loss, respectively (*medium confidence*) {2.5.4; Figure 2.8b, Figure 2.11; Table 2.5; Table SM2.5}. Biodiversity loss is projected for more regions with increasing warming, and will be worst in northern South America, southern Africa, most of Australia and at northern high latitudes (*medium confidence*) {2.5.1.3; Figure 2.6}.

Climate change increases risks of biome shifts on up to 35% of global land at ≥4°C GSAT warming, that emission reductions could limit to <15% for <2°C warming (*medium confidence*). Under high-warming scenarios, models indicate shifts of extensive parts of the Amazon rainforest to drier and lower-biomass vegetation (*medium confidence*), poleward shifts of boreal forest into treeless tundra across the Arctic, and upslope shifts of montane forests into alpine grassland (*high confidence*). Area at high risk of biome shifts from changes in climate and land use combined can double or triple compared to climate change alone (*medium confidence*). Novel ecosystems, with no historical analogue, are expected to become increasingly common in the future (*medium confidence*). {2.3, 2.4.2.3.3, 2.5.2; 2.5.4, Figure 2.11; Table 2.5; Table SM2.4; Table SM2.5}

The risk of wildfire increases along with an increase in global temperatures (*high confidence*). With 4°C GSAT warming by 2100, wildfire frequency is projected to have a net increase of ~30% (*medium confidence*). Increased wildfire, combined with soil erosion due to deforestation, could degrade water supplies (*medium confidence*). For ecosystems with an historically low frequency of fires, a projected 4°C global temperature rise increases the risk of fires, with potential increases in tree mortality and the conversion of extensive parts of the Amazon rainforest to drier and lower-biomass vegetation (*medium confidence*). {2.5.3.2; 2.5.3.3}

Continued climate change substantially increases the risk of carbon stored in the biosphere being released into the atmosphere due to increases in processes such as wildfire, tree mortality, insect pest outbreaks, peatland drying and permafrost thaw (*high confidence*). These phenomena exacerbate self-reinforcing feedbacks between emissions from high-carbon ecosystems (that currently store ~3000–4000 GtC) and increasing global temperatures. Complex interactions of climate change, land use change (LUC), carbon dioxide fluxes and vegetation changes, combined with insect outbreaks and other disturbances, will regulate the future carbon balance of the biosphere. These processes are incompletely represented in current earth system models (ESMs). The exact timing and magnitude of climate–biosphere feedbacks and potential tipping points of carbon loss are characterised by large uncertainty, but studies of feedbacks indicate that increased ecosystem carbon losses can cause large temperature increases in the future (*medium confidence*). (section 5.4, Figure 5.29 and Table 5.4 in (Canadell et al., 2021)), {2.5.2.7; 2.5.2.8; 2.5.2.9; 2.5.3.2; 2.5.3.3; 2.5.3.4; 2.5.3.5; Figure 2.10; Figure 2.11; Table 2.4; Table 2.5; Table SM2.2 Table SM2.5}

Contributions of Adaptation Measures to Solutions

The resilience of biodiversity and ecosystem services to climate change can be increased by human adaptation actions including ecosystem protection and restoration (*high confidence*). Ecological theory and observations show that a wide range of actions can reduce risks to species and ecosystem integrity. This includes minimising additional stresses or disturbances; reducing fragmentation; increasing natural habitat extent, connectivity and heterogeneity; maintaining taxonomic, phylogenetic, and functional diversity and redundancy; and protecting small-scale refugia where micro-climate conditions can allow species to persist (*high confidence*). Adaptation also includes actions to aid the recovery of ecosystems following extreme events. Understanding the characteristics of vulnerable species can assist in early warning systems to minimise negative impacts and inform management intervention. {2.3; Figure 2.1; 2.5.3.1, 2.6.2, Table 2.6, 2.6.5, 2.6.7, 2.6.8}

There is new evidence that species can persist in refugia where conditions are locally cooler, when populations of the same species may be declining elsewhere (*high confidence*) {2.6.2}. Protecting refugia, for example, where soils remain wet during drought or fire risk is reduced, and in some cases creating cooler micro-climates, are promising adaptation measures {2.6.3; 2.6.5; Cross-Chapter Paper 1; CCP5.2.1}. There is also new evidence that species can persist locally because of plasticity including changes in phenology or behavioural changes that move an individual into cooler micro-climates, and genetic adaptation may allow species to persist for longer than might be expected from local climatic changes (*high confidence*) {2.4.2.6; 2.4.2.8, 2.6.1}. There is no evidence to indicate that these mechanisms will prevent global extinctions of rare, very localised species already near their climatic limits or species inhabiting climate/habitat zones that are disappearing (*high confidence*). {2.4.2.8, 2.5.1, 2.5.3.1, 2.5.4, 2.6.1, 2.6.2, 2.6.5}

Since AR5, many adaptation plans and strategies have been developed to protect ecosystems and biodiversity, but there is limited evidence of the extent to which adaptation is taking place and virtually no evaluation of the effectiveness of adaptation measures in the scientific literature (*medium confidence*). This is an important evidence gap that needs to be addressed, to ensure a baseline is available against which to judge effectiveness and develop and refine adaptation in future. Many proposed adaptation measures have not been implemented (*low confidence*). {2.6.2; 2.6.3; 2.6.4; 2.6.5; 2.6.6; 2.6.8; 2.7}

Ecosystem restoration and resilience building cannot prevent all impacts of climate change, and adaptation planning needs to manage inevitable changes to species distributions, ecosystem structure and processes (*very high confidence*). Actions to manage inevitable change include the local modification of micro-climate or hydrology, adjustment of site management plans and facilitating the dispersal of vulnerable species to new locations by increasing habitat connectivity and by active translocation of species. Adaptation can reduce risks but cannot prevent all damaging impacts so is not a substitute for reductions in greenhouse gas (GHG) emissions (*high confidence*). {2.2; 2.3; 2.3.1; 2.3.2; 2.4.5; 2.5.1.3; 2.5.1.4; 2.5.2; 2.5.3.1; 2.5.3.5; 2.5.4; 2.6.1; 2.6.2; 2.6.3; 2.6.4; 2.6.5; 2.6.6; 2.6.8; Cross-Chapter Box NATURAL in this chapter}

Ecosystem-based adaptation (EbA) can deliver climate change adaptation for people, with multiple additional benefits including those for biodiversity (*high confidence*). An increasing body of evidence demonstrates that climatic risks to people including floods, drought, fire and overheating, can be lowered by a range of EbA techniques in urban and rural areas (*medium confidence*). EbA forms part of a wider range of nature-based solutions (NbS); some have mitigation co-benefits, including the protection and restoration of forests and other high-carbon ecosystems as well as agro-ecological farming (AF) practices. However, EbA and other NbS are still not widely implemented. {2.2; 2.5.3.1; 2.6.2; 2.6.3; 2.6.4; 2.6.5; 2.6.6, 2.6.7; Table 2.7; Cross-Chapter Box NATURAL in this chapter; Cross-Chapter Paper 1}

To realise potential benefits and avoid harm, it is essential that EbA is deployed in the right places and with the right approaches for that area, with inclusive governance (*high confidence*). Interdisciplinary scientific information and practical expertise, including Indigenous and local knowledge (IKLK), are essential to effectiveness (*high confidence*). There is a large risk of maladaptation where this does not happen (*high confidence*). {1.4.2; 2.2; 2.6; Table 2.7; Box 2.2; Figure Box 2.2.1; Cross-Chapter Box NATURAL in this chapter; Cross-Chapter Paper 1; 5.14.2}

EbA and other NbS are themselves vulnerable to climate change impacts *(high confidence).* They need to take account of climate change if they are to remain effective and they will be increasingly under threat at higher warming levels. NbS cannot be regarded as an alternative to, or a reason to delay, deep cuts in GHG emissions. *(high confidence)* {2.6.3, 2.6.5; 2.6.7; Cross-Chapter Box NATURAL in this chapter}

Climate Resilient Development

Protection and restoration of natural and semi-natural ecosystems are key adaptation measures in view of the clear evidence that damage and degradation of ecosystems exacerbates the impacts of climate change on biodiversity and people (*high confidence*). Ecosystem services that are under threat from a combination of climate change and other anthropogenic pressures include climate change mitigation, flood risk management, food provisioning and water supply (*high confidence*). Adaptation strategies that treat climate, biodiversity and human society as coupled systems will be most effective. {2.3; Figure 2.1; 2.5.4; 2.6.2; 2.6.3; 2.6.7; Cross-Chapter Boxes NATURAL and ILLNESS in this chapter}

A range of analyses have concluded that ~30–50% of Earth's surface needs to be effectively conserved to maintain biodiversity

and ecosystem services (*high confidence*). Climate change places additional stress on ecosystem integrity and functioning, adding urgency to taking action. Low-intensity sustainable management, including that performed by Indigenous Peoples, is an integral part of some protected areas, and can support effective adaptation and maintain ecosystem health. Food and fibre production in other areas will need to be efficient, sustainable and adapted to climate change to meet the needs of the human population. (*high confidence*) {Figure 2.1; 2.5.4; 2.6.2; 2.6.3; 2.6.7}

Natural ecosystems can provide the storage and sequestration of carbon at the same time as providing multiple other ecosystem services, including EbA (*high confidence*), but there are risks of maladaptation and environmental damage from some approaches to land-based mitigation (*high confidence*). Plantation, single-species forests in areas which would not naturally support forest, including savanna, natural grasslands and temperate peatlands, and replacing native tropical forests on peat soils, have destroyed local biodiversity and created a range of problems regarding water supply, food supply, fire risk and GHG emissions. Large-scale deployment of bioenergy, including bioenergy with carbon capture and storage (BECCS) through dedicated herbaceous or woody bioenergy crops and non-native production forests, can damage ecosystems directly or through increasing competition for land, with substantial risks to biodiversity. {2.6.3, 2.6.5, 2.6.6, 2.6.7; Box 2.2; Cross-Chapter Box NATURAL in this chapter; CCP7.3.2; Cross-Working Group Box BIOECONOMY in Chapter 5}

Terrestrial and aquatic ecosystems and species are often less degraded on land managed by Indigenous Peoples and local communities than on other land (*medium confidence*). Involving indigenous and local institutions is a key element for developing successful adaptation strategies. IKLK includes a wide variety of resource-use practices and ecosystem stewardship strategies that conserve and enhance both wild and domestic biodiversity. {2.6.5; 2.6.7; Cross-Chapter Box NATURAL in this chapter; Chapter 15; Box 18.6; CCP2.4.1; CCP2.4.3; Box CCP7.1}

Increases in the frequency and severity of extreme events, that WGI has attributed to human greenhouse gas emissions, are compressing the timeline available for natural systems to adapt and also impeding our ability to identify, develop and implement solutions (*medium confidence*). There is now an urgent need to build resilience and assist recovery following extreme events. This, combined with long-term changes in baseline conditions, means that implementing adaptation and mitigation measures cannot be delayed if these are to be fully effective. {2.3; Cross-Chapter Box EXTREMES in this chapter}