Climate Science

Zero Carbon Analytics

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The IPCC report on land use and climate change

Key points:

- The wellbeing of the Earth's land is key to the future of the planet. This brief draws from the latest scientific research to describe key land challenges and their relation to climate change.
- Human activity affects 75% of the Earth's land surface, causing widespread land degradation. Agriculture and timber/logging are key drivers of degradation, desertification and carbon emissions. A combination of climate change and human activity will increase pressure in the future.
- Land use change already causes a quarter of man-made emissions, and climate change will have wide reaching impacts on land. At the moment, the land is a net carbon 'sink', but it's possible climate change could damage land to the point where it becomes a net source of carbon emissions.
- Sustainably managing land will be a key way to cut emissions and reduce the impacts of climate change. There are many options for 'land based mitigation' that cut emissions from land. We will need to pursue options that bring strong co-benefits, and strong synergies with each other.
- Managing land well will be a key solution to climate change. Drawing on local and indigenous knowledge and gender-proofing mitigation and adaptation in this space will be vital for making good choices about how to proceed in this space.

Introduction

The land surface of the Earth provides critical resources to human society, helps regulate the climate and has the potential to play an important role in limiting climate change. Many governments have already made pledges about how they will use land to address climate change, and land-related initiatives make up 20% of current planned total emission reductions by 2030 under the Paris Climate Agreement.

But human demands[1] are driving unprecedented depletion of natural land resources. Degradation of land contributes to climate change, and could undermine the potential land has to help solve the climate crisis.

The SRCCL[2] is the latest special report produced by the Intergovernmental Panel on Climate Change (IPCC), the UN body responsible for assessing the latest climate change

[1] Land use can be understood as the set of activities carried out by humans on land, for example, changing land cover via deforestation, afforestation, or agricultural production. https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter06_FINAL.pdf
[2] The full title of the report is the "Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse gas fluxes in Terrestrial Ecosystems".

science. Released in August 2019[3], it explores what climate change will mean for the future of land and human society, and explains how we can address climate change by using the Earth's land more carefully.

The relationship between land and climate change is complicated. It's hard to predict the future of land, and the people that rely on it. Generalisations are hard because the land system and the science that studies it is complex. Nevertheless, the SRCCL is the most comprehensive analysis of land and climate the IPCC has produced to date. It relies on the most recent scientific papers. The analysis of land and climate it contains will be a key input to the next IPCC Assessment Report (AR6), due to be published between 2021-22.

Land and climate change

Sinks and sources of emissions

Land, land use and land management are an important part of the climate system. The Earth's soils, forests and other plants - its land system - emit greenhouse gases (GHGs), but also absorb them. Carbon cycles between the atmosphere and the land, and is stored in soil and biomass. When land is damaged or degraded - when soil becomes thinner, forests are cut down or replaced with plantations - the degraded land system releases the carbon it has stored, driving climate change through increased GHG emissions.

Land produces a lot of greenhouse gas emissions, accounting for about 23% (12 +/- 3 Gt carbon dioxide equivalent a year) of total net human emissions between 2007 and 2016. For carbon dioxide specifically, land produced the equivalent of 13% of total human carbon dioxide emissions over that period, mostly due to human activity, particularly deforestation[4].

Land use change also emits methane (44% from human activities), and nitrous oxide (82% from human activities), both of which are powerful greenhouse gases[5]. Agriculture is a major source for both. Agriculture emissions nearly doubled between 1961 and 2016, and make up just over half[6] total greenhouse gas emissions in the land sector. Livestock (66%) and rice production (24%) are the major sources of methane, while about two-thirds of nitrous oxide emissions are associated with fertiliser use and manure management.[7] Livestock emissions are split between Asia (37%), North America (26%), Latin America and the Caribbean (16%), Africa (14%) and Europe (8%)[8].

Land also absorbs greenhouse gases, acting as a 'carbon sink'. So although the land sector produces emissions, overall it is a net sink of emissions, taking more carbon out of the atmosphere than it puts in. Between 2007 and 2016 these sinks removed 29% of total human carbon dioxide emissions from the atmosphere[9].There is no guarantee the land will continue to be a net carbon sink as climate change alters how natural systems work. More carbon dioxide in the atmosphere may boost plant growth leading to more uptake of carbon from the atmosphere[10] but climate change will also degrade land's capacity to store

[3] The approval plenary runs from the 2nd - 6th August - see https://www.ipcc.ch/site/assets/uploads/2019/06/Info_Note_Participants_final.pdf
[4] Global models estimate net CO2 emissions of 5.2 ± 2.6 GtCO2 yr-1 (likely range) from land use and land-use change during 2007-16. These net emissions are mostly due to deforestation, partly offset by afforestation/reforestation, and emissions and removals by other land use activities (very high confidence) from (Table SPM.1; SPM, A.3.1)
[5] Table SPM 1
[6] Estimate is in comparison of the 24% emissions from AFOLU sector. Calculated by IPCC through a combination of models.
[7] https://www.nature.com/articles/nclimate3158
[8] SRCCL, Chapter 2, 2.4.2.2, p. 39, line 47-53
[9] Represents a net sink of around 11.2 GtCO2 yr-1, see Table SPM 1
[10] This is a process known as CO_2 fertilisation, which stimulates plant growth and could lead to increases in vegetation, but this "greening" trend is contested in the literature/empirical evidence. https://onlinelibrary.wiley.com/doi/10.1111/j.1365-3040.1995.tb00630.x; https://www.pnas.org/content/113/36/10019

carbon, providing an opposing effect. Whether land will act as a net sink or a source in the future remains uncertain.

Climate change's effect on land

Broadly, land use change often causes climate change, and climate change causes land change. Climate change affects land by changing weather patterns, including extreme events, which can lead to damage like vegetation loss, fire damage, or permafrost and coastal degradation[11]. For example:

- Changes in rainfall patterns and more intense rainfall increase the risk of land degradation through landslides, extreme erosion events or flash floods.
- In North America, thunderstorms could cause major landslides and flash flooding with severe economic losses (over US$20 billion annually).
- Extreme events, such as heat and drought, increase the frequency and intensity of wildfires in forests.[12] In the Brazilian Amazon, during the drought of 2015, fire increased by 36% even with declining deforestation rates.

Attributing land degradation to climate change by making direct links between the two[13] can be hard, as impacts depend on local contexts and how land is managed. The effects are also often complex. For example, deforestation in the tropics will likely cause the climate to warm, but in temperate and boreal regions it will likely have a cooling effect. Climate change might even improve the state of the land in some parts of the world. Processes known as feedbacks – which amplify or dampen climate change and land degradation – further complicate the picture.

Despite the uncertainties, it is clear that climate change creates new and unprecedented risks for the land system and will likely lead to worse outcomes overall. Action is needed to protect land from climate change.

Land degradation

As well as being threatened by climate change, land is also under severe pressure from land use change. The resulting land degradation takes many forms[14], but overall reduces the land's biological productivity, its ecological integrity and its role in providing services to humans and the planet[15]. Estimates of how much of the Earth's land is degraded vary – it could be between 7 and 40% of the land surface. When land becomes degraded, it is more likely to produce greenhouse gas emissions, and less likely to act as a carbon sink.

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[11] https://www.nature.com/articles/17789; https://www.nature.com/articles/nature01286; https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2007GL032838; https://www.sciencedirect.com/science/article/pii/S0022169413004800/; https://journals.ametsoc.org/doi/10.1175/JCLI-D-14-00324.1; https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016GL069896; https://www.ncbi.nlm.nih.gov/pubmed/28360268

[12] https://www.pnas.org/content/113/42/11770;https://www.nature.com/articles/srep26886; http://dx.doi.org/10.1038/s41558-017-0014-8

[13] When degradation of land has been associated with climate change.

[14] Land degradation has many definitions across the scientific literature. In this report, the IPCC uses a broad definition derived from the IPCC AR 5 definition of desertification: “A negative trend in land condition, caused by direct or indirect human-induced processes including anthropogenic climate change, expressed as long-term reduction or loss of at least one of the following: biological productivity, ecological integrity or value to humans. [Note: This definition applies to forest and non-forest land. Changes in land condition resulting solely from natural processes (such as volcanic eruptions) are not considered to be land degradation. Reduction of biological productivity or ecological integrity or value to humans can constitute degradation, but any one of these changes need not necessarily be considered degradation.]” SRCCL, Glossary, p.33

[15] https://arizona.pure.elsevier.com/en/publications/land-in-balance-the-scientific-conceptual-framework-for-land-degr; https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-AnnexII_FINAL.pdf; https://www.unccd.int/sites/default/files/relevant-links/2017-01/UNCCD_Convention_ENG_0.pdf

Degradation has many causes, from direct ones like changes to soil characteristics, deforestation or changes in plants' composition, to changes in climate or environmental conditions, like changes in rainfall patterns, to changes in land use and management, like changing farming systems or urbanisation and infrastructure expansion[16]. Overall, humans are the main cause of degradation, affecting 75% of the Earth's land surface, with grazing, forest harvesting and forest plantations the main damaging activities.

Agriculture is a major cause of degradation. Agricultural land covers a large amount[17] of the Earth's land surface, and the amount of cropland is increasing, with most of the expansion driven by demand for livestock products. Irrigated areas have also expanded by about 50% over the last fifty years, contributing to freshwater withdrawals[18] and local climate variability in many regions, and cropland expansion is also driving soil erosion, particularly in Sub-Saharan Africa, South America and Southeast Asia. An increase in mechanized agricultural systems is a major driver of deforestation in the Amazon,[19] and also creates severe pressure on soils. Agriculture is also becoming more intense. The use of nitrogen fertilisers increased nine times over the same period[20], driving further land degradation.

Deforestation is another important cause of degradation. Global forest area has declined by 3% since 1990 and continues to decline, although there are large uncertainties in this measurement.[21] Between 60 and 85% of the total global forested area is used by humans at different levels of intensity. Only the tropics and northern boreal zones have large remaining areas of unused forest. Between 73 and 89% of other, non-forested natural ecosystems (natural grasslands, savannas, etc.) are used by humans.[22] Around the world, pastures are replacing natural grasslands, and croplands are replacing forests[23].

Humans are having a huge effect on the planet, but it is hard to say how the overall balance of forest, savanna and grassland area is changing. For example, some research suggests forest area has actually increased globally. Taken together, human activity has had a huge and transformative effect on the Earth's land surface and driven degradation of the land. Choices we make about future land management will be increasingly important as we address climate change; sustainable land management will be essential[24].
Desertification: degradation of drylands

When land degradation takes place in 'drylands'[25] it is termed desertification[26], a reduction in the land's health, its productivity and its usefulness[27]. Drylands cover nearly half the world's land surface, are some of the most sensitive areas to climate change and human

[16] SRCCL, Chapter 1, 1.2.2.3, p. 11, lines 11-14
[17] "Globally, cropland area changed by +15% and the area of permanent pastures by +8% since the early 1960s (FAOSTAT 2018), with strong regional differences" - SRCCL, Chapter 1, 1.2.2.3, p. 10, lines 17-18
[18] "Water withdrawals are defined as freshwater taken from ground or surface water sources, either permanently or temporarily, and conveyed to a place of use". https://data.oecd.org/water/water-withdrawals.htm
[19] https://www.ncbi.nlm.nih.gov/pubmed/16973742; https://www.sciencedirect.com/science/article/abs/pii/S0959378001000073; https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.13068
[20] SRCCL, Chapter 1, 1.2.2.3, p. 11, line 7
[21] SRCCL, Chapter 1, 1.2.2.3, p. 11, lines 25-26
[22] SRCCL, Chapter 1, 1.2.2.2, p. 9, lines 9-16
[23] SRCCL, Chapter 1, 1.2.2.3, p. 11, lines 15-16
[24] https://www.unccd.int/sites/default/files/documents/2019-06/LDN_CF_report_web-english.pdf; https://pubs.acs.org/doi/abs/10.1021/es302545b; https://pdfs.semanticscholar.org/1dcd/dcb78cb7010fedb248f8c1f402ed5a0a731c.pdf
[25] Drylands areas constitute of arid, semi-arid, and dry sub-humid areas.
[26] https://www.jstor.org/stable/25595197?seq=1#page_scan_tab_contents; https://www.millenniumassessment.org/documents/document.291.aspx.pdf; https://www.tandfonline.com/doi/abs/10.2989/AJRF.2009.26.3.2.947
[27] This definition was developed by the IPCC to explain the specific type of land degradation - desertification - that happens in a particular part of the world - the drylands. As such, it is defined in the report as "Land degradation in arid, semi-arid, and dry sub-humid areas resulting from many factors, including climatic variations and human activities (UNCCD, 1994)". SRCCL, Glossary, p.16
https://treaties.un.org/Pages/ShowMTDSGDetails.aspx?src=UNTSONLINE&tabid=2&mtdsg_no=XXVII-10&chapter=27&lang=en

activity, and host a large and growing portion of the world's population – nearly forty per cent – so desertification is a critical challenge.

Desertification reduces soil fertility and its capacity to sequester carbon, as warmer and drier soils release more soil carbon to the atmosphere. It can also decrease crop and livestock productivity, and contribute to food insecurity, poverty, migration and even conflict[28]. Countries in Africa and Asia, the Mediterranean region and Latin America and the Caribbean are particularly at risk. There are many causes. Across Africa desertification is mainly caused by drought, but in northern China it is mainly a result of human activity. Expanding croplands and unsustainable land management practices are the most important cause.

Climate change can drive desertification, but it depends on local context and interactions with other human activities[29]. For example, natural climate cycles were responsible for two-thirds of the expansion of the Sahara Desert between 1920 and 2003, while in China both human and climate factors have played a role in desertification. It isn't always possible to demonstrate a clear climate link - different studies reach opposite conclusions on whether climate change has actually played a role in desertification in the Sahel region, for example. As a result, attribution of climate change to desertification is still challenging, in part because desertification is caused by multiple natural and human factors that vary between places and over time[30].

Land, climate and the food system

The way we produce and consume food contributes to many environmental and socio-economic problems, including climate change and land degradation. Since 1961, food supply per person has increased more than 30%. Over the same time period, use of nitrogen fertilisers has grown about eight times, and the water resources used for irrigation have more than doubled[31].

This increase in food supply has not stopped many people globally suffering from hunger and diet-related diseases. An estimated 821 million people are undernourished worldwide – particularly in low-income countries, including parts of sub-Saharan Africa, South-Eastern Asia, Western Asia, and Latin America. At the same time, in many parts of the world an increase in the availability of food and diets higher in animal-based products have increased adult obesity rates. Globally 1.9 billion adults are overweight.

Food system[32] emissions account for an estimated 25 to 30% of total human emissions[33], with agriculture producing the largest portion of 10 to 12% from crop and livestock activities. Other emissions are produced along the food supply chain: 8 to 10% from land use and land use change including deforestation and peatland degradation, and 5 to 10%

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[28] https://www.sciencedirect.com/science/article/pii/S1877343513000109?via%3Dihub; https://www.nature.com/articles/nclimate2837, https://www.nature.com/articles/nclimate3275; https://www.researchgate.net/publication/287507867_Effect_of_climate_change_on_the_vulnerability_of_a_socio-ecological_system_in_an_arid_areaa; https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.12581; https://www.ecologyandsociety.org/vol23/iss1/art34/; https://www.sciencedirect.com/science/article/pii/S014098831400098X; https://www.nature.com/articles/nclimate3253

[29] https://wad.jrc.ec.europa.eu/sites/default/files/atlas_pdf/1_WAD_Introduction.pdf

[30] https://www.sciencedirect.com/science/article/abs/pii/S0034425716302280; https://www.ncbi.nlm.nih.gov/pubmed/26525278; https://onlinelibrary.wiley.com/doi/abs/10.1002/eco.1849;http://adsabs.harvard.edu/abs/2016AGUFM.A33G0330M;https://journals.ametsoc.org/doi/full/10.1175/2010JCLI3794.1;https://www.sciencedirect.com/science/article/abs/pii/S0140196316301641?via%3Dihub; https://journals.ametsoc.org/doi/10.1175/JCLI-D-17-0187.1

[31] SRCCL, Chapter 5, Executive summary, p. 5, line 4-6

[32] The High Level Panel of Experts on Food Security and Nutrition defines food system as a system that "gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the output of these activities, including socio-economic and environmental outcomes."

[33] Percentage contribution to total human greenhouse gas emissions, averaged over 2007-2016. SRCCL, Chapter 5, p.61.

from supply chain activities[34]. High levels of food waste along the supply-chain and at consumer level also contribute.

Climate change already has huge impacts on the food system; future effects are likely to be very significant, but will vary widely across regions. For example, warming in India over the period 1981–2009 reduced crop yields by 5.2%, but in Australia reduction of crop yields have so far been countered by improvements in management and technology. Industrial livestock production will suffer, mostly from indirect climate change impacts, leading to rises in production costs and destruction of infrastructure. Farming systems will also suffer risks from variable grain availability and cost, and animals struggling to adapt to new climates[35].

Climate change will also have a negative effect on a host of issues which set the context for our food system, including poverty and vulnerability, cultural practices and gender issues. It can reduce incomes and impact farmers' ability to endure price rises. It can affect food safety and human health in a range of ways, like lowering the nutrient content of food, or affecting contaminating organisms. It can threaten food security by increasing instability of supply due to increased frequency and severity of extreme events. It may cause widespread crop failure contributing to spikes in food prices, migration and conflict.

How will climate change affect land in the future?

Scientists use climate models and different scenarios for temperature rise and socio-economic development to try and map out the future of land and climate[36]. But even so, predicting the future of land and climate change is complicated. Temperatures, land processes and human society will evolve differently across regions and biomes, with different implications for land use/cover. Mitigation policies can also impact land use as well as land-based mitigation impacts other land-related challenges. All this makes it harder to create universal predictions for the future. Instead, scientists describe many possible futures, or scenarios.

What is true in most future scenarios?

Most scenarios agree that land will play a key role in the future of our climate. The choices we make about how to manage land could act as a control knob for as much as 0.5°C of temperature rise in low-emissions scenarios. With the world looking to limit temperature rise to 1.5°C, this is hugely significant.

Land degradation alone is projected to reduce global food production[37]. Warming is likely to reduce crop yields, productivity and livestock production, with impacts varying across regions. Each 0.5 degree Celsius of temperature rise[38] will likely increase the risk of lower crop yields, but the effect will depend on how temperatures fall across the year and align

[34] SRCCL, Chapter 5, Executive summary, p. 6, line 16-20
[35] SRCCL, Chapter 5, Section 5.2.2.2, p. 29, line 8-10
[36] For more information see Cross-Chapter box 9 in Chapter 6 of the SRCCL report. It includes explanations of the socioeconomic scenarios used by scientists as well as the policies that can be implemented in each future world, focused on land-related challenges.
[37] https://onlinelibrary.wiley.com/doi/full/10.1111/1467-8489.12072; https://onlinelibrary.wiley.com/doi/full/10.1002/fes3.99; https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0066428
[38] The reference period for the modeling study is the "'current decade' from 2006–2015 forced by observations including observed CO2 concentrations that have increased from 380.9 parts per million (ppm) to 402.9 ppm over this decade. Mean warming over this period corresponds to about 0.9°C above the 1860–1880 period in the Berkeley Earth GMT dataset. The Future 1.5°C experiment is based on the RCP2.6 experiment and takes constant forcing for greenhouse gases and aerosols and sea-surface temperatures from the 2091–2100 decade. CO_2 concentrations in this experiment are constant at 423.4 ppm. The Future 2°C experiment uses scaled atmospheric and sea-surface temperature forcing from RCP2.6 and RCP4.5 with CO_2 concentrations set to 486.6 ppm".

with growing seasons. One degree of warming (relative to a 1981–2010 baseline)[39] will likely reduce average wheat, rice and soybean yield globally[40], but some regions will see an increase; past three degrees[41] of warming all crop yields will be impacted, unless adaptation measures are deployed. Lower yields could lead to instability in global grain trade and international grain prices, affecting those who are most vulnerable to food price spikes. Rising carbon dioxide levels in the atmosphere will also affect food production - more carbon dioxide could increase yield productivity, for example, but reduce the nutrient content of crops[42].

Drylands are expected to expand as a result of climate change. A temperature rise of 4°C - our current policy trajectory - would increase the area of drylands globally by 23% to cover 56% of the total land surface, with most of this expansion in developing countries. Most scenarios show climate change will likely increase the vulnerability of drylands to desertification. Climate change is also expected to decrease carbon sequestration from land, particularly in forests.

Risks from desertification are projected to increase. Depending on assumptions made about the future, the number of people in drylands impacted by threats to water, energy or land could reach over a billion, in worst-case scenarios with more than two degrees of temperature rise. In better managed futures with lower temperature rise the number could be much lower.[43]

What affects which future we get?

What actually happens in the future will depend on how much temperatures rise, how much carbon dioxide is in the atmosphere, on the choices we make about how aggressively to mitigate climate change, where climate impacts occur, how we use land, and different scenarios of socio-economic development[44]. The exact effects of temperature rise on land degradation, desertification and food security will also vary depending on context and location.

Without any efforts to limit climate change, global mean temperatures are expected to rise between 2°C and 7.8°C by 2100[45], with warming over land 1.2 to 1.4 times higher than global mean temperature rise. Even the lower end of this spectrum will be hugely damaging and disruptive; the upper end is likely to be disastrous for humans, the biosphere and land.

Future outcomes are highly dependent on what future socio-economic, development and political pathways human society chooses. For any level of temperature rise, vulnerability and exposure of people and land to climate damage will be higher in futures where there is higher population growth and lower incomes[46] or higher consumption[47]. Such futures will

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[39] In comparison with 1981–2010 baseline. "The temperature impact was calculated as the yield change during the warming period relative to the yield during the baseline period normalized to +1 °C impact, assuming the impact showed a linear temperature response".

[40] A limitation of this study is the linear assumption between yield responses and temperature increase as yield response for each degree Celsius warming differs by growing season temperature level. Different CO_2 concentration in the atmosphere can also affect yields.

[41] "Some of the studies have associated temporal baselines, with center points typically between 1970 and 2005", https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap7_FINAL.pdf, p.498

[42] https://ideas.repec.org/a/spr/climat/v124y2014i4p763-775.html; https://pubag.nal.usda.gov/catalog/237405; https://onlinelibrary.wiley.com/doi/10.1111/jac.12057; https://www.nature.com/articles/nature13179; https://advances.sciencemag.org/content/4/5/eaaq1012.abstract

[43] See SRCCL, sections 2.3, 3.2.1, 3.3.2, 3.6.1, 3.6.2, 7.3.2.

[44] These mitigation options can have positive or negative impacts on land and people.

[45] Relative to the 1850-1900 reference period

[46] At similar temperatures, risks are higher in SSP3 than in SPP2 and SSP1. https://www.sciencedirect.com/science/article/pii/S0959378016300681

[47] SSP 3.

likely be more affected by land degradation, desertification, and food insecurity,[48] compared to more equitable scenarios. By contrast, futures with lower demand for agricultural commodities, and/or higher levels of agricultural productivity and globalized trade[49] will likely lead to better outcomes - the lowest emissions from land, lower food prices over time, and lower levels of forest loss[50].

Impacts on food will vary, with studies showing that by the end of the century, worlds characterised by nationalism and rising inequality[51] could see some 400 or 600 million people respectively suffering from malnourishment. More optimistically, food insecurity could decline substantially in futures with higher incomes[52]. Most future socio-economic worlds see higher water stress.

How can land help solve the climate crisis?

The land sector can be part of the solution to climate change. Indeed, all future pathways that limit temperature rise to 1.5 or well-below two degrees Celcius will require land-based mitigation and land-use change[53].

If done sensitively, there are mitigation options in the land space that can limit climate change and provide co-benefits for land. But land-based mitigation could also create adverse side effects for land and people by changing the land use system. To be effective, land-based mitigation will need to be regionally and context- dependent[54], as countries suffer impacts differently and have different socio-economic characteristics.

Using land to help address climate change will be complex, and also increasingly likely to run into tradeoffs. For example, to limit temperature rise to 1.5 or two degrees[55] negative emissions technologies[56] may need to be deployed over very large areas of land, which could contribute to desertification and land degradation[57]. Some 1.5°C scenarios are achieved with limited or no NETs deployment, but are associated with large scale behavioural changes (including eating less meat and reducing food waste), agricultural intensification, and mitigation in other sectors. The longer we delay action, the more we will be into the realm of exceptionally hard choices, and delay will increase the need for adaptation, and potentially make land-based solutions less viable[58].

Reducing emissions from the land use space and preparing for the effects of climate change will require a sophisticated policy approach that recognises and incorporates local and indigenous knowledge. Indigenous peoples and local communities have extensive knowledge of the land and the characteristics of their specific region and this expertise can guide policy in these complex spaces. For example, indigenous knowledge can better predict future climate change and contribute insight where data is lacking, or facilitate

[48] https://www.sciencedirect.com/science/article/pii/S0959378016300681; https://www.pnas.org/content/111/9/3292/tab-article-info; https://www.sciencedirect.com/science/article/pii/S0959378016303399
[49] SSP 1. https://www.sciencedirect.com/science/article/pii/S0959378016300681; https://www.sciencedirect.com/science/article/pii/S0959378016303399
[50] SSP 1. https://www.sciencedirect.com/science/article/pii/S0959378016300681; https://www.sciencedirect.com/science/article/pii/S0959378016303399
[51] SSP3 and SPP4, respectively.
[52] SSP 1- Higher income (e.g., SSP1, SSP5), higher yields (e.g., SSP1, SSP5), and less meat intensive diets (e.g., SSP1) tend to result in reduced food insecurity SRCCL, CH.6, p.19.
[53] Pathways assessed on the SRCCL.
[54] SRCCL, Chapter 1, Section 1.4, p.29, line 4-10.
[55] https://www.nature.com/articles/nclimate3096; https://www.sciencedirect.com/science/article/pii/S1876610217319410;https://www.nature.com/articles/nclimate2870
[56] https://www.sciencedirect.com/science/article/pii/S0959378016303399; https://www.sciencedirect.com/science/article/pii/S0959378016300681; https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SR15_Chapter2_Low_Res.pdf
[57] https://www.sciencedirect.com/science/article/pii/S0959378016303399; https://iopscience.iop.org/article/10.1088/1748-9326/aabf9f
[58] SRCCL, Chapter 6, Executive Summary , p.5

climate adaptation. Mainstreaming gender in policy is also essential. Addressing gender issues ensures adaptation measures can benefit those who most need them, and can also unlock mitigation options by - for example - empowering women to participate in decision-making in agriculture.