Chapter 14
Nature-Based Carbon Sinks: Carbon Conservation and Protection Zones

Kriti Nagrath, Kate Dooley, and Sven Teske

Abstract Basic information on ecosystem-based approaches to climate mitigation is provided, and their inclusion in international climate and nature conservation treaties is discussed. Key concepts around net-zero emissions and carbon removal are examined, as are the roles they play in the One Earth Climate Model, which develops a 1.5 °C-compatible scenario by combining ecosystem restoration with deep decarbonization pathways. The carbon removal potentials of the five ecosystem restoration pathways—forests and agricultural lands, forest restoration, reforestation, reduced harvest, agroforestry, and silvopasture—are provided. Land-use management options, including the creation of 'carbon conservation zones' (CCZ), are discussed.

Keywords Ecosystem-based approaches · Ecosystem restoration pathways · Forest restoration · Reforestation · Reduced harvest · Agroforestry · Silvopasture · 'Carbon conservation zones' (CCZ)

14.1 Ecosystem Approaches to Climate Action

This section looks at the variety of ecosystem approaches available for implementation as climate solutions. It also follows the global developments of ecosystem and nature outcomes from the recent climate summit, the 26th Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC).

K. Nagrath · S. Teske (✉)
University of Technology Sydney – Institute for Sustainable Futures (UTS-ISF), Sydney, NSW, Australia
e-mail: sven.teske@uts.edu.au

K. Dooley
University of Melbourne, Melbourne, VIC, Australia

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14.1.1 Understanding Ecosystem Approaches

Climate change and climate action can no longer be discussed without reference to their environmental impacts, in particular the crises of biodiversity loss and ecosystem decline. Ecosystem approaches to climate management that restore degraded ecosystems and focus on nature will play important roles in climate solutions, for both mitigation and adaptation. These approaches aim to maintain and increase the resilience of people and the ecosystems upon which they rely and to reduce their vulnerability (Lo, 2016). Healthy, well-managed ecosystems have climate change mitigation potential, through the sequestration and storage of carbon in healthy forests, wetlands, and coastal ecosystems (IPBES, 2019).

Approaches to protecting and restoring nature can take a variety of forms. These include initiatives such as the sustainable management, conservation, and restoration of ecosystems. The ecosystem approach is a strategy for the integrated management of land, water, and living resources, which promotes their conservation and sustainable use in an equitable way, as defined by the Convention on Biological Diversity (CBD). The convention also defines 'ecosystem-based adaptation' (EbA) as the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change.

Ecosystem services are the benefits people obtain from ecosystems, which have been classified by the Millennium Ecosystem Assessment as supporting services, such as seed dispersal and soil formation; regulating services, such as carbon sequestration, climate regulation, water regulation and filtration, and pest control; provisioning services, such as the supply of food, fibre, timber and water; and cultural services, such as recreational experiences, education, and spiritual enrichment.

The International Union for Conservation of Nature (IUCN) defines nature-based solutions (NbS) as 'actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits'. These solutions include ecosystem restoration strategies, such as ecological restoration, ecological engineering, and forest landscape restoration; issue-specific ecosystem-related strategies, such as ecosystem-based adaptation or mitigation and disaster risk reduction; infrastructure-related strategies; ecosystem-based management strategies; and area-based ecosystem protection strategies.

'Landscape restoration' refers to the improvement of degraded land on a large scale, to rebuild ecological integrity and enhances people's lives. It involves restoring degraded forests and agricultural lands by reducing the intensity of use or improving productivity with mixed-use approaches, such as agroforestry and climate-smart agriculture (Winterbottom, 2014).

'Ecological engineering' is defined as the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both. It includes ecosystem rehabilitation (actions that repair the structures and functions of indigenous ecosystem), nature engineering, and habitat reconstruction and reclamation (stabilization, amelioration, increases in utilitarian or economic value). However, indigenous ecosystems are rarely used as models (Mitsch, 2012).

Therefore, there is a diversity of approaches that can be adopted to protect and restore the natural world.

14.1.2 Ecosystem and Nature Outcomes at COP26

The 2021 Glasgow Climate Pact recognizes the critical role of protecting, conserving, and restoring nature, while ensuring social and environmental safeguards, through the following text:

> Emphasizes the importance of protecting, conserving and restoring nature and ecosystems to achieve the Paris Agreement temperature goal, including through forests and other terrestrial and marine ecosystems acting as sinks and reservoirs of greenhouse gases and by protecting biodiversity, while ensuring social and environmental safeguards. (*Decision-/CP.26 Glasgow Climate Pact*, 2021).

Food, land, and nature were popular topics at COP26 and featured in a series of pledges, speeches, initiatives, and coalitions (Chandrasekhar & Viglione, 2021). These included deforestation pledges, new climate pledges, the methane pledge, and other agricultural innovation and policy announcements. The key pledges included:

- 141 countries containing >90% of global forests signed the Glasgow Leaders' Declaration on Forests and Land Use and committed to working collectively to halt and reverse forest loss and land degradation by 2030. Their efforts will include agricultural policies and programmes to incentivize sustainable agriculture, promote food security, and benefit the environment (2021). This declaration has mobilized over US$22 billion of public and private finance (gov.uk, 2021).
- 28 governments, representing 75% of global trade in key commodities that can threaten forests, signed a new Forest, Agriculture and Commodity Trade (FACT) Statement, which will reduce pressures on forests and deliver sustainable trade (gov.uk, 2021).
- The Global Methane Pledge was signed by 110 countries, responsible for nearly half the global methane emissions, with the aim of reducing their methane emissions by 30% from 2020 levels by 2030, using emissions mitigation strategies.
- The Agriculture Innovation Mission for Climate saw US$4 billion in new public-sector investment pledged for agricultural innovation, including climate-resilient crops and regenerative solutions to improve soil health.
- Canada announced CDN$1 billion in international support for nature-based solutions, a fifth of its climate finance budget.

Although these declarations are signs that we are moving in the right direction, there are concerns regarding the uncertainty around key definitions and the transition from promise to action, which must be resolved soon.

A World Wild Fund for Nature (WWF) study found that 92% of countries' new climate action plans now include measures to tackle nature loss. One hundred and five of the 114 enhanced Nationally Determined Contributions (NDCs) submitted by 12 October included nature in their climate mitigation or adaptation plans. Of the 96 NDCs that cited using nature for climate mitigation, 69 quantified these as numerical targets, mostly in the forest sector (Bakhtary et al., 2021).

14.1.3 Concepts of Consequence

This section discusses key concepts around net-zero emissions and carbon removal that we must understand to model the pathways in Chap. 11.

'Net zero' refers to the balance between the amount of greenhouse gases (GHGs) produced by humans and the amount removed from the atmosphere. This means that for any remaining emissions produced, an equivalent amount must also be removed through processes such as planting new forests, which reduce the GHGs accumulating in the atmosphere, to reach net-zero emissions.

As discussed in previous chapters, it is imperative for the various industry sectors to reduce their energy emissions (which primarily arise from fossil fuels) to zero. Given the temporal differences between the fossil and terrestrial carbon cycles, any essential residual emissions arising from non-energy sources and processes must be removed via geological storage, to go beyond net-zero emissions and eventually achieve net-negative emissions to reduce atmospheric GHG concentrations.

Carbon dioxide (CO_2) removal (CDR) is the process of removing CO_2 from the atmosphere and locking it away in a carbon 'sink' for a long period of time. A carbon sink is a natural or human-made reservoir that accumulates and stores carbon and thus lowers the concentration of CO_2 in the atmosphere. Forests and oceans are natural carbon sinks and absorb more CO_2 from the atmosphere than they emit. CDR requires that we enhance the ability of these natural sinks to remove and store carbon, or store this carbon geologically.

There are both natural and technological strategies to remove carbon from the atmosphere and store it in a sink. Natural strategies include reforestation and the ecosystem restoration approaches discussed above, where carbon is removed from the atmosphere by photosynthesis and stored in vegetation and soil. Although natural solutions, such as restorative agriculture and reforestation, can help remove carbon, they must be thoroughly monitored and balanced against competing demands on land use. Technological strategies, such as direct air capture and enhanced mineralization, that capture carbon underground or under the ocean or in products such as concrete, are also being explored but are yet to be commercialized on a large scale.

The OECM model focuses on natural strategies for carbon removal. The different land management pathways for achieving this are discussed in the next section.

14.2 Ecosystem Restoration Pathways

The OECM model presents a 1.5 °C-compatible scenario combined with ecosystem-based approaches. The ecosystem restoration pathways outlined in this section have been published as Littleton et al. (2021) and have been built on previous work by Meinshausen and Dooley (2019) .

14.2.1 Pathways

The five pathways involve forests and agricultural lands: forest restoration, reforestation, reduced harvest, agroforestry, and silvopasture. The first three pathways focus on the forestry sector, and the latter two are most relevant for the agriculture and food sector. In all three forest pathways, the intervention is natural regeneration with no active planting of trees (Littleton et al., 2021).

Forest restoration sets aside natural (secondary) forest areas that are partly deforested or degraded for conservation purposes. This pathway is applied to all biomes. Reforestation includes the reforestation of mixed native species maintained for conservation purposes. It is limited to biomes that would naturally support forests, after the identification of previously forested land in close proximity within 70–105 km for tropical forests and within 11–18 km of temperate forests. Reforestation in boreal biomes is excluded because the albedo effect accompanies changes from deforested to forested land types, specifically at high latitudes, which can potentially increase warming. The reforestation pathway is the only land-management intervention in this scenario that requires a change in land use. Reduced harvest describes a reduction in harvest intensity by 25% in commercial forests in boreal and temperate biomes. In tropical and subtropical biomes, commercial timber extraction is halted completely, given the lack of evidence that any form of reduced-impact logging leads to increased carbon stocks. These management interventions only apply to natural managed forests and not to plantations. Areas of shifting cultivation are excluded from consideration for reduced harvesting, to avoid impacting communities dependent on subsistence agriculture (Littleton et al., 2021).

The pathways involving the regeneration of agricultural areas—agroforestry and silvopasture—allow for existing land uses to continue. Temperate, subtropical, and tropical cropland and grazing areas with mean annual precipitation ranging from 400 to 1000 mm per year were targeted for these two pathways. Agroforestry can be implemented in many different ways, but here it is assumed to be the integration of additional trees into agricultural landscapes, which will result in significant sequestration across large areas of temperate and tropical croplands. Silvopasture, defined here as a reduction in grazing intensity on managed pastures, results in almost twice the level of carbon sequestration over a similar land area.

14.2.2 Methodology

Spatial distribution for the five pathways was identified using WRI's global map of forest condition and the ESA-CCI land cover maps for the forest and agriculture pathways, respectively. The areas identified for ecosystem restoration were simulated in a community land surface model, the Joint UK Land Environment Simulator (JULES) to get the carbon sequestration potential. JULES also incorporates the dynamic global vegetation model TRIFFID to simulate vegetation and carbon cycle processes. JULES simulations were run using meteorological forcing output from HadGEM2-ES, covering the period 1880–2014 (historical) and 2015–2100 (SSP1–2.6) on a 3-hour timestep at the N96e grid size.

For temperature projections, MAGICC, a reduced-complexity probabilistic climate emulator, was used, which reflects updated climate science knowledge. The scenarios are consistent with limiting warming to 1.5 °C by the end of the century, although at best, with a roughly 50–50 chance of staying below this limit.

A no-removal baseline scenario is modelled under a shared socioeconomic sustainability future (SSP1) and represents CO_2 emissions from forestry and land use (including land-use changes) in the absence of the ecosystem restoration measures considered here. To minimize the risk of double-counting sequestration, all carbon sequestration reported in this baseline scenario are set to zero from 2050 onwards.

14.2.3 Results

The results of Littleton et al. (2021) showed the median gross cumulative potential of additional CO_2 removal with the five ecosystem restoration pathways to be 93 Gt of carbon (C) until 2100, as shown in Table 14.1. The peak annual sequestration rate for all ecosystem restoration pathways (forest restoration, reforestation, reduced harvest, agroforestry, and silvopasture) is 3.1 GtC per year in 2041, as forests reach maturity. Then on, the flux declines, with an average annual sequestration rate of 1.1 GtC per year from 2050 to 2100. This removal will be offset by ongoing net land-use emissions but still has a significant contribution to temperature reduction. Combined with a 100% renewable energy scenario by 2050 in the OECM, this additional carbon uptake reduced 2100 temperature by a further 0.12 °C when compared to a no-removal scenario (Littleton et al., 2021).

The most successful restoration pathway identified in terms of carbon sequestration is *reduced harvest* in the tropics, with carbon gains of 80–100 tC per hectare by 2100 in Southeast Asia and the Amazon basin. Reduced harvest means that less timber is harvested. The pathway assumes that harvest intensity in temperate and

Table 14.1 Summary statistics for the cumulative uptake of CO_2 in all pathways

Pathway	Cumulative uptake ($GtCO_2$ in 2020–2100) (global average)	Land area (million ha) (land-use change in bold)
Forest restoration	21	541
Reforestation	29	**344**
Reduced harvest	33	1047
Agroforestry	5.2	849
Silvopasture	1.6	478
All pathways	93	3259
(of which land-use change)		344

boreal biomes is decreased, and commercial harvesting is completely stopped in tropical forests. Reduction in harvest can be achieved through either reduced harvest intensity in natural forests or doubling the length of rotation of managed forests. This will have a significant impact on timber supply and on the economics of forestry industries. Strategies to continue to meet the timber demand include shifting away from wood products, increasing efficiency, and recycling of wood-based products, to avoid the expansion of plantation forests.

The next highest gains are seen in reforestation in China, Latin America, and Southeast Asia in the decade leading up to 2050. Reforestation target areas are adjacent to existing intact forests and are consistent with targets in national policies and international commitments like the Bonn Challenge. The analysis acknowledges that natural succession to native vegetation is more cost-effective and has a greater success rate than planting new forests. As the carbon sequestration potential of full regrowth of deforested land to forested land is higher than in recovering carbon stocks in degraded forests, this is the only pathway that requires a land-use change of 344 Mha converted from deforested areas to reforested land. All other pathways maintain the existing land uses.

As seen in Table 14.2, the largest concentrations of carbon storage occur where humid tropical and warm temperate forests are allowed to regenerate. Higher rates of sequestration will be seen in Asia, Latin America, and Africa, where tropical biomes have higher net primary productivity than elsewhere, but also because greater land areas are forested in the tropics.

The pathways were designed to ensure that they do not negatively impact agriculture production; it does not completely eliminate the competition for land. Agroforestry should enhance agricultural productivity and has wide geographic applicability. Silvopasture could enhance it or could require reduced stocking rates. Silvopasture results in lower uptake, due to higher initial soil carbon content in temperate pasture lands compared to croplands. Both pathways result in rapid but temporary increase in carbon stocks (Littleton et al., 2021).

Table 14.2 Gross regional carbon sequestration rates in ten world regions as categorized for the RCP database (Littleton et al., 2021)

World region	Carbon uptake in 2050 ($GtCO_2$)	Cumulative uptake by 2100 ($GtCO_2$)
Africa	0.35	5.8
China+	0.57	18.8
India +	0.13	4.0
Latin America	0.71	18.7
Middle East	0.00	0.0
Northern America	0.55	12.1
Pacific OECD	0.13	2.8
Reforming economies	0.67	12.7
Rest of Asia	0.57	14.3
Western Europe	0.24	3.9
World total	3.9	93.0

Importantly, all ecosystem restoration pathways presented here reach the full extent in terms of area by 2040 and then held constant over the rest of the study period. This is coupled with the assumption that net deforestation will be halted by 2030. Without firm action to stop deforestation, gains made through the proposed ecosystem pathways will be offset by forest loss.

It is also important to realize that these ecosystem pathways do not and should not be used to offset fossil fuel emissions. Carbon uptake from land-based mitigation is slow and offers long-term temperature reduction. However, this approach needs to be implemented in conjunction with net-zero targets for other sectors not as a substitute. While removing more carbon from the atmosphere than is emitted into it would begin to reverse some aspects of climate change, some changes would still continue in their current direction for decades to millennia. The reversal of global surface warming lags the decrease in the atmospheric CO_2 concentration by a few years (IPCC, 2021).

14.3 Managing Land Use

This section discusses the impact of the ecosystem restoration pathways on existing land use and the land-use changes required for agriculture to meet the future food demand.

14.3.1 Mapping Land Use for Agriculture

One of the biggest challenges in managing land use is the agricultural expansion required to feed 9 billion people in 2050. Based on the 2012 Food and Agriculture Organization (FAO) projections, the overall demand for agricultural products is expected to grow at 1.1% per year from 2005/2007 to 2050, which will result in a 60% increase globally by 2050 to meet the increased demand. Meeting this demand will require additional land for agriculture, but there is no consensus in the literature on how much more land will be required. The FAO projections indicate that about 70 million ha of additional land will be required for agricultural use in 2050 (Alexandratos & Bruinsma 2012). Several studies have discussed doubling production to meet the 2050 demand, particularly given the shift towards protein-rich diets and the consequent need for land to grow animal feed (Ray et al. 2013). Scenarios that do not link production with health and nutrition involve the expansion of agricultural lands into forests (Maggio et al. 2018). However, Hunter et al. (2017) disagree with the call to double agriculture production, largely because of recent production gains and because it is claimed that an increase of approximately 25%–70% above the current production levels should be sufficient to meet the 2050 demand. Conijn et al. (2018) noted that the planetary boundary for agricultural land was already exceeded in 2010, and a 2050 scenario without efficiency gains to meet the increased demand for food would require an increase of >3.5 Gha in agricultural land (grassland and cropland areas would increase by 78% and 67%, respectively). The FAO's latest alternative pathways to 2050 estimate that arable land must increase by 86 million ha from 2012 in the sustainability scenario and by 165 million hectares in the business-as-usual scenario.

Therefore, projections of the increased land required for agriculture range from 70 million ha to 3.5 billion ha. The FAO (2018) has identified a global reserve of at least 400 million ha of suitable and unprotected land that could be brought under rain-fed cultivation. However, when losses to urbanization and degradation are considered, less than half of this reserve will be available. Data from the FAO–International Institute for Applied Systems Analysis (IIASA) Global Agro-ecological Zones (GAEZ v4) suggest that around 360 million ha of additional and unprotected areas and areas that are highly suitable for rain-fed crop production will be available by 2050. The majority of this land is situated in low- and medium-income countries.

All these scenarios involve increasing agricultural land at the expense of forests, and the resulting deforestation will have drastic consequences for the emission intensity of the sector. However, if a small expansion is coupled with the other strategies discussed in Chap. 6, there may be enough land to feed the 9 billion people estimated to exist in 2050 (FAO Forecast).

14.3.2 Mapping Land Use for Forestry

Unlike agricultural land, forested land has been declining over time, and in 2020, 4 billion ha were recorded as under forest. An estimated 420 million ha of forest was lost through deforestation between 1990 and 2020, although the rate slowed over that period and the net reduction in the global forest area was about 178 million ha (FAO 2020a). Agriculture has driven an estimated 80% of the deforestation worldwide (FAO 2017). The global expansion of agricultural land has stabilized over the last 20 years at around 4.9 billion ha (FAO 2017).

The rate of net forest loss has been decreasing substantially as deforestation declines in some countries, whereas an increase in forest area has been seen in other countries, with both afforestation and the natural expansion of forests. However, there has been a reduction in the rate of forest expansion in the last decade (FAO 2020a).

Regional inequalities are not reflected in this global overview. In tropical and subtropical regions, annual forest losses still amounted to 7 million ha in 2000–2010, whereas the agricultural area expanded by 6 million ha per year in the same period (FAO 2018). The largest reductions were observed in Brazil (down 53.2 million ha) and Indonesia (down 27.5 million ha). However, small increases were seen in Europe and the United States. The largest increase was in China, where the forest area was 51.2 million ha larger in 2015 than in 1990 (EUROSTAT 2020).

14.3.3 Implications for Decarbonization

As seen in previous chapters, the *services* and *industry* sectors can decarbonize their energy emissions (i.e. *Scope 1* and *Scope 2* emissions) by incorporating energy efficiency and transitioning to a 100% renewable energy source. The electrification of industry process heat, although harder to achieve, is another key step in the decarbonization pathway, and there is increasing innovation and technological development to support this. The largest challenge in reaching net-zero emissions remains the management of non-energy process emissions. The OECM model estimates 2.2 GtC will be released in unavoidable emissions annually in 2050 from the nine industrial sectors modelled in this study.

Ecosystem approaches can potentially remove CO_2 from the atmosphere at the gigatonne scale, with potentially significant co-benefits, as discussed above (Meinshausen & Dooley, 2019). To achieve 93 GtC sequestration until 2100, land use must shift towards forest on over 350 million ha of land (Littleton et al., 2021).

The annual peak uptake calculated by Littleton et al. (2021) for all five ecosystem pathways is 3.1 Gt/year in 2041 and 1.1 Gt C per year from 2050 to 2100. While in the short term this appears to provide an opportunity to offset non-energy-related industrial process emissions (e.g. from cement and steel production) that are difficult to avoid with currently available technologies by using ecosystem approaches, in the long term these emissions must be reduced to zero or removed and stored geologically to prevent further warming.

Decarbonization pathways are being developed at the global level. At this level, there is little conflict between the competing uses of cropland, pastureland, and forests for carbon removal. Adopting ecosystem approaches, such as agroforestry or silvopasture, where trees are integrated into cropland or grazing lands, will help to increase the carbon stock while meeting the increasing demand for forestry and agricultural products. It should be noted that a lot of deforestation and the capacity and demand for increased agricultural and livestock products will occur in tropical and subtropical regions, often in developing countries. At the local level, there must be a nuanced approach to addressing the balance between environmental, economic, and well-being outcomes.

14.4 Creating Carbon Conservation Zones (CCZ)

The role of nature and ecosystem services as climate solutions is gaining increasing attention. As well as their climate mitigation and carbon sequestration potential, ecosystem approaches have co-benefits that contribute to sustainable development goals in terms of livelihoods, productivity, biodiversity conservation, health, and ecosystem services. However, it is important to note that even with ambitious land-use restoration, carbon removal can still only compensate for a small part of current emissions. The vast majority of emissive activities must cease if we are to achieve an approximately 1.5 °C target, and all the available removal strategies are required to achieve net-negative emission pathways and reduce the atmospheric concentrations of CO_2.

Feasible approaches to CDR using land-based mitigation options cannot be implemented in a vacuum but must address broader social and environmental objectives. Carbon conservation zones, which implement different ecosystem approaches, must address these broader objectives:

- Respecting indigenous rights and knowledge of land

Indigenous peoples and their connection to land play an important role in protecting and conserving nature and advancing climate solutions. This connection and their stewardship in protecting nature is particularly important in forested areas around the world. Several studies have found that the best forest protection is provided by people with collective legal titles to their land, i.e. by indigenous people (Fa et al., 2020; FAO and FILAC, 2021), and have recognized the contributions of indigenous knowledge to ecosystem-based climate solutions. For the first time, COP26 formally acknowledged the roles and contributions of indigenous people's culture and knowledge in climate action and nominated indigenous peoples to engage directly with governments as knowledge holders and experts (2021a; UN Climate Change News, 2021).

Assisted natural regeneration strategies based on indigenous knowledge are promising ways to restore degraded lands (Schmidt et al., 2021). Formal recognition of indigenous people's rights over their forested lands can slow deforestation (Ricketts et al. 2010; Ceddia et al. 2015). These efforts must be supported by policies and actions that recognize collective territorial rights, provide compensation for environmental services, and allow community forest management, the revitalization of ancestral knowledge, and the strengthening of grassroots organizations and mechanisms for territorial governance (FAO and FILAC, 2021).

- Understanding financial implications

A study investigating the benefits of investing in ecosystem restoration found that tropical forests offered one of the highest value for restoration investment (after coastal and inland wetlands) (De Groot et al., 2013). Case studies across the world have also established that natural regeneration is significantly cheaper than tree planting, while simultaneously providing much higher carbon sequestration, but need to be incentivized by long-term funding mechanisms (Di Sacco et al., 2021). Much of the restoration opportunity identified in this study lies in tropical forested developing countries, and financing incentives and support will be critical to ongoing success.

Reducing **E**missions from **D**eforestation and Forest **D**egradation (REDD) is an effort to provide incentives through payment for results, allowing developing countries to reduce emissions from forested lands. REDD+ goes beyond addressing deforestation and forest degradation and fosters conservation, the sustainable management of forests, and the enhancement of forest carbon stocks. Initiatives like the Reforestation Accelerator are working with impact investment funds and innovative incubation ideas to provide seed funding to unlock ecosystem-based solutions (The

Nature Conservancy, 2022). Such mechanisms can address the lack of financial support that is a major barrier to implementing ecosystem approaches.

- Protecting and conserving biodiversity

Reversing land degradation and limiting climate change depend upon retaining forests with high ecological integrity. A wide diversity of values and services tends to be found at higher levels in the more-intact forests of a given type. Biomass carbon stocks are a good example (Keith et al. 2009; Mackey et al. 2020), and forests and other ecosystems with no history of significant disturbance collectively absorb around 30% of anthropogenic carbon emissions annually (Friedlingstein et al. 2020).

Ambitious policies that prioritize the retention of forest integrity, especially in the most-intact areas, are now urgently required, in parallel with the current efforts to halt deforestation and restore the integrity of forests globally (Grantham et al., 2020). Higher levels of biodiversity generally support greater levels of ecosystem service production (e.g. carbon sequestration) than lower biodiversity levels, and ecosystem properties, such as resilience, are important considerations when managing human-modified ecosystems (Ferreira et al., 2012). It is necessary to build on the synergies between climate action and activities directed towards conserving biodiversity.

- Influencing supply chains and investment portfolios

Over the last decade, there has been a swell of industry-led commitments to zero-deforestation supply chains, but they are not yet implemented and many companies are yet to act (NYDF Assessment Partners 2020). The Carbon Disclosure Project's (CDP) Investor Report flagged that industry targets for net-zero deforestation are unlikely to be met unless commodity producers in the supply chain manage of their deforestation risk. This highlights the issue that certification is not enough and that companies require initiatives, such as education and financing, to promote sustainable agriculture and demonstrate strong policy commitments to end deforestation (Sin et al., 2020).

Forests and forest products are important parts of a number of supply chains for food, consumer goods, transport, etc., and companies and investors can play an important role in protecting and conserving nature through corporate commitments and by influencing their downstream supply chains.

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