Buffering Climate Change with Nature

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ABSTRACT: It is increasingly evident that climate sustainability depends not only on societal actions and responses, but also on ecosystem functioning and responses. The capacity of global ecosystems to provide services such as sequestering carbon and regulating hydrology is being strongly reduced both by climate change itself and by unprecedented rates of ecosystem degradation. These services rely on functional aspects of ecosystems that are causally linked—the same ecosystem components that efficiently sequester and store carbon also regulate hydrology by sequestering and storing water. This means that climate change adaptation and mitigation must involve not only preparing for a future with temperature and precipitation anomalies, but also actively minimizing climate hazards and risks by conserving and managing ecosystems and their fundamental supporting and regulating ecosystem services. We summarize general climate–nature feedback processes relating to carbon and water cycling on a broad global scale before focusing on Norway to exemplify the crucial role of ecosystem regulatory services for both carbon sequestration and hydrological processes and the common neglect of this ecosystem–climate link in policy and landscape management. We argue that a key instrument for both climate change mitigation and adaptation policy is to take advantage of the climate buffering and regulative abilities of a well-functioning natural ecosystem. This will enable shared benefits to nature, climate, and human well-being. To meet the global climate and nature crises, we must capitalize on the importance of nature for buffering climate change effects, combat short-term perspectives and the discounting of future costs, and maintain or even strengthen whole-ecosystem functioning at the landscape level.

SIGNIFICANCE STATEMENT: Natural ecosystems such as forests, wetlands, and heaths are key for the cycling and storage of water and carbon. Preserving these systems is essential for climate mitigation and adaptation and will also secure biodiversity and associated ecosystem services. Systematic failure to recognize the links between nature and human well-being underlies the current trend of accelerating loss of nature and thereby nature's ability to buffer climate changes and their impacts. Society needs a new perspective on spatial planning that values nature as a sink and store of carbon and a regulator of hydrological processes, as well as for its biodiversity. We need policies that fully encompass the role of nature in preventing climate-induced disasters, along with many other benefits for human well-being.

KEYWORDS: Feedback; Flood events; Carbon cycle; Climate change; Ecosystem effects

1. Introduction

We are currently facing two major and interlinked global change trends; one of rapidly rising CO_2 levels and associated global temperature rise, and one of a rapid loss and degradation of nature and biodiversity (Brondizio et al. 2019; Ruckelshaus et al. 2020; IPCC 2022). In brief, since the industrial revolution, CO_2 concentration in the atmosphere has risen from around 280 ppm to approaching 420 ppm today, with predictions for 2100 ranging from 425 to 800 ppm CO_2, corresponding to temperature increases of 1.5°–4.5°C (https://www.co2.earth/2100-projections). While the higher end of these estimates is becoming increasingly unlikely (Hausfather and Peters 2020), a warming in the range of 2.2°–2.7°C by 2100 may be expected (IPCC 2022). The prospects for humanity, even by the most optimistic among these scenarios, are dramatic, as evidenced by the harmful and costly effects already apparent from the current CO_2 levels and associated warming of only around 1.1°C (IPCC 2022; Kramer and Ware 2020; Munich RE 2021). We already face increased incidence and severity of heat waves, fires, droughts, and floods: extreme climate events that may induce domino impacts on a suite of factors that are critical for ecosystem and societal sustainability (IPCC 2022; Reichstein et al. 2021).

While the climate crisis is increasingly on the policy agenda, a parallel and equally pressing global crisis is still largely going under the radar—the striking loss and degradation of wilderness and natural ecosystems such as forests and wetlands, resulting in dramatic and accelerating declines in the biodiversity as well as in the bulk biomass of wild plants and animals (Bar-On et al. 2018; Brondizio et al. 2019). In fact, many of the currently proposed policies aimed at "saving the climate" may directly conflict with saving nature, often because these two issues are treated as separate challenges (Bastin et al. 2019; Pörtner et al. 2021). The decline in wildlife populations since the onset of agriculture some 10 000 years ago is

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estimated at 83% for terrestrial mammals, and 80%, 50%, and 15% for marine mammals, plants, and fish, respectively, and the estimated biomass ratio of terrestrial mammals is 36% humans, 60% domestic animals, and 4% wild mammals (Bar-On et al. 2018). More broadly, the abundance of naturally occurring species (across all organismal groups) has declined by 23%, natural ecosystems have declined by 47%, and, as a consequence, one million species are now under threat of extinction (Brondizio et al. 2019). Extinction risk is disproportionally affecting large plants and animals, and those with a slower pace of life (Carmona et al. 2021). This is especially worrying because these "megabiota" play key roles in ecosystem functioning and resilience (Enquist et al. 2020). We now know that all realistic pathways to limit climate change depend heavily on maintaining or strengthening the "land sinks," that is, the ability of terrestrial ecosystems to capture and store carbon (C) from the atmosphere (Pachauri et al. 2014; IPCC 2018). Key ecosystems in this respect are forests and wetlands; systems that also are essential for the terrestrial–atmospheric–aquatic water balance, both by absorbing excess water and by storing it during dry periods.

Land-use change is the major driver of the "nature crisis," and these changes are also of staggering magnitude; more than 75% of terrestrial areas have now been significantly transformed by human activities, including a disproportionally high fraction of Earth's most fertile areas suited for agriculture, which now covers 12% of the land surface (excluding ice-covered areas) with another 25% being used for pasture, according to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES; Montanarella et al. 2018; Brondizio et al. 2019). These reports further estimate that 83% of the global wetlands have been drained or otherwise lost since preindustrial time, whereas the area of global rain forests has been reduced by 50%. A consequence of these massive human landscape transformations is that human forcings now dominate the fluxes of energy, nutrients, and matter through the biosphere to the extent that 42% of the annual terrestrial photosynthetic productivity is sequestered by humans and our crops and stocks (Krausmann et al. 2013). These bidirectional climate–ecosystem function linkages argue strongly for explicitly incorporating and accounting for ecosystem components in climate mitigation and adaptation (Rockström et al. 2021).

This current massive human appropriation of space and biomass severely limits the energy and resources left for supporting biodiversity and all the other ecosystem functions, benefits, and services upon which we depend, including key climate-related services such as carbon and water sequestration and storage in our landscapes. Also, the overall ecological structure of managed ecosystems—such as replacement of native with alien tree species and mixed stands with monocultures, along with a host of forest management strategies narrowly aimed at increasing tree stem growth rate—will be decisive for the climate change vulnerability of forests and other natural ecosystems and their potential to deliver ecosystem services crucial for climate change mitigation and adaptation (Huuskonen et al. 2021; Levia et al. 2020; Osuri et al. 2020). Loss of natural and diverse landscape elements and ecosystem structures thus imply "double trouble"; as stored CO_2 is lost and the buffering capacity of water extremes is reduced, both the positive feedbacks to climate warming per se and the climate change vulnerabilities of ecosystems increase. It follows from this line of argument that protecting and restoring natural ecosystems will also have double benefits—functioning, resilient ecosystems will benefit both climate mitigation and societal adaptation.

To secure a sustainable future, we thus need a transformation in the way the global society interacts with nature and ecosystems. This is clearly stated in the recent IPBES and IPCC reports, and a growing literature arguing that to meet these dual crises, we must change the way that we as a global society interact with, and relate to, nature and climate (Díaz et al. 2019; Ellis 2015; Folke et al. 2021; Mace 2014). The urgency of this call for action is strengthened by the fact that climate change and ecosystem degradation are now also recognized as the major threat to human health globally (Romanello et al. 2021). Despite increasing scientific awareness of these issues, they have not really been manifested by meaningful political action, and most of the negative trends continue and are now "back on track," after a temporary slowdown caused by coronavirus disease 2019 (COVID-19; Ripple et al. 2021).

A missing link in driving the necessary societal transformation forward is a lack of understanding, and appreciation, of the interdependencies and feedbacks between societal and ecological systems. Only when these relationships are understood, and acknowledged, at local as well as global scales, can we develop and implement effective governance systems and institutions. One of the major tools toward this end is better conceptualization and communication of nature's benefits to people and ecosystem services at large (Díaz et al. 2018; Pascual et al. 2017), including expanding the quantification and economic valuation to effectively assess the magnitude and replacement costs of the free benefits and services we receive from nature (such as pollination, carbon sequestration, water purification, soils, and flood and drought regulation), and thus also the long-term economic and societal costs of ecosystem degradation.

The striking variation in current climate scenarios for the planet less than 80 years ahead, ranging from a hothouse to a climatically stable Earth (IPCC 2022), results from two major levels of uncertainty; uncertainties in how society (including politics, economy, technology, patterns of consumption and social norms) will respond, and uncertainties in how ecosystems (including biodiversity, ecosystem functioning, and resilience) will respond.

The COVID-19 pandemic has strengthened our awareness of the urgency in dealing with these interlinked challenges, but also the ability of the global community to respond in concert. The European Commission in their mission report A Climate Resilient Europe (Hedegaard et al. 2020) explicitly states what is at stake: "The COVID-19 pandemic has taught a lesson about how closely environmental, societal and human health are connected. What we have lived through and still will is a mild foretaste of the shocks that climate change may and will cause in the future." Europe must prepare for stormy weather, literally. The Mission report emphasizes the opportunities offered by natural ecosystems in this context, and, in doing so, leverages efforts to meet commitments under the Biodiversity Strategy 2030. These opportunities include restoring natural habitats as a key nature-based climate change solution, increasing high-diversity landscape features of agricultural areas to at least 10%, and using afforestation and reforestation actively to adapt our forests to climate change. The mission report points to the quadruple benefits of these measures: they offer climate change mitigation and adaptation solutions while also increasing natural and societal resilience.

In this paper, we will exemplify how and why protecting intact ecosystems and restoring degraded ecosystems can be efficient and cost-effective precautionary climate change adaptions while allowing win/win scenarios for a range of ecosystem services, including human well-being. We will focus on ecosystem carbon and water storage, and our point of departure will be general before we zoom in on Norwegian examples. Norway is an interesting case study in this context for several reasons; climate change is happening at a rapid pace in the north adding urgency to climate change adaptation and mitigation, Norway is a wealthy country both in terms of financial and natural capital and a number of actions are hence relevant and should be possible, and finally also because these issues are high on the national policy agenda due to numerous current conflicts between nature conservation and nature (over)exploitation.

2. Ecosystem carbon and water storage in a variable and changing climate

a. Carbon storage and climate change

In the context of anthropogenic climate change, arguably the largest of all ecosystem services (Millennium Ecosystem Assessment 2005) is the role of ecosystems in sequestering and storing carbon and stabilizing hydrological cycling. The relevant carbon in this context is that circulating through the biosphere and atmosphere in the short (or rapid) cycle, and the critical question is how the stocks and fluxes within this cycle react to impacts from climate change and other human drivers, notably land-use change, leading to ecosystem degradation and loss (Chapin et al. 2006). The soils and vegetation on Earth contain a total of around 2300 Gt C, with 600 Gt in vegetation and 1700 Gt in soil and other dead organic matter (Archer 2010; Kayler et al. 2017). At present, the atmosphere contains 800 Gt C, and the "short cycle" of total annual fluxes to and from terrestrial ecosystems composes nearly 20% of the atmosphere's total C content (~123 Gt C; IPCC 2022). A critically important lesson to draw from these numbers is how large the fluxes between terrestrial ecosystems and the atmosphere are, both relative to the total atmospheric C stock and also to the fossil fuel emissions (33.4 Gt in 2019; International Energy Agency 2020). It follows that the atmosphere's C content is highly sensitive, at very short time scales, to any changes in the ecosystems' net C balance. Herein lie great opportunities but also considerable risks.

b. Water storage, climate, and nature degradation

Global, regional, and local hydrological cycles relate heavily to natural ecosystem components, notably forests, wetlands, and lakes. Climate change and warming of land and oceans cause a redistribution of precipitation both temporally and spatially, and regional hydrological cycles may be broken and flip systems like the Amazon from forest to a savannah-like alternative stable state (Lovejoy and Nobre 2018). Loss of natural ecosystems will generally reduce the landscape water storage capacity, and land-use change from multispecies to monoculture forestry will in most cases have a similar effect (Held and Soden 2006). Furthermore, local interventions in these ecosystem components may promote, for example, landslides (Lehmann et al. 2019). Given the already observed and predicted increase in hydrological anomalies such as massive rainfalls, flooding and drought, catchment elements such as forests, wetlands and bogs are essential for dampening run-off oscillations (Holden 2005). This "sponge effect" implies that these landscape elements not only prevent damage by flooding, but also promote a steady supply of water in dry periods.

c. Integrating climate mitigation and land-use policy

While climate change science and policy acknowledge the facts of the carbon stocks and fluxes in the earth system, and indeed point to ecosystems as critical parts of climate change adaptation and mitigation strategies, through afforestation or land-use (AFOLU) and/or biocarbon capture and storage (BCCS) (IPCC 2018, 2022), we are still far from having any consensus on practical and scalable solutions. Indeed, many suggested policy options are based on simplistic "one size fits all" solutions such as the idea that general and uncritical planting of trees everywhere will increase carbon uptake and thereby mitigate climate change (e.g., Bastin et al. 2019). Here, we illustrate how current approaches to mitigate climate change via strengthening the terrestrial land sink are hampered by a lack of appreciation of the complexity of ecosystems and the context dependencies in their functioning, and, in particular, of the variation in the magnitude, temporal dynamics, and the resilience of ecosystem carbon storage. These aspects are increasingly important to safeguard ecosystem carbon storage from new threats from the changing climate.

There is a general agreement that over the next 30 years we need to obtain net global uptake of CO_2, and a first priority should be safeguarding the major existing pools of organic C that already exist against oxidative conversion to CO_2. While the importance of this is recognized in the climate models, there still is a continuing loss of these pools from our landscapes, with consequences both for climate and biodiversity. And while increased carbon sequestration is high on the policy agenda (e.g., AFOLU and BCCS), protection of extant ecosystem carbon pools, especially nonbiomass pools, is less well articulated. While local communities and nations have many "good reasons" for degrading nature, this "tragedy of the carbon commons" is driven by the cumulative and long-term impacts of national (or local) actions. So how do these interlinked issues and challenges play out at a national scale? Under the general framework of the Paris Convention, climate change policies are developed and implemented at the regional to national level, and we here explore how the general issues relating to terrestrial ecosystems and their role in

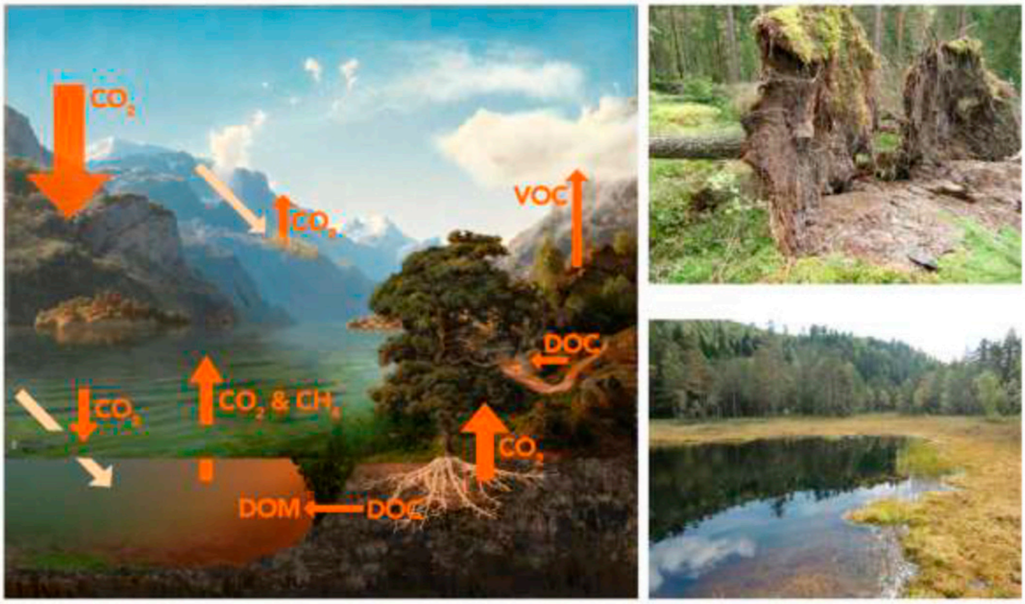

FIG. 1. (left) Major pools and fluxes of carbon compounds in a boreal catchment and (right) illustration of different soil development, carbon, and water storage with topography. There is a major drawdown of atmospheric CO_2 via photosynthesis and geological binding that is sequestering C in the biosphere and lithosphere. There are also feedbacks to the atmosphere, and these are likely to increase with human interventions. DOC = dissolved organic carbon, DOM = dissolved organic matter, and VOC = volatile organic carbon. The right panels illustrate how the carbon and water storage properties differ with topography in two adjacent landscape elements, where the boggy depression holds huge stores of carbon and water and represents a landscape element that should be preserved (photographs: D. O. Hessen).

carbon dynamics are discussed and taken into account in a national climate policy setting in Norway.

3. Nature and climate mitigation in Norwegian policy

a. The boreal north

The boreal and Arctic biomes are critically important in the terrestrial ecosystem carbon balance and hydrological cycle, while at the same time being affected by high rates of climate change (IPCC 2019). Boreal forests are major global reservoirs of terrestrial carbon, storing around 1000 Gt C, of which more than 80% is found below ground, in roots, soil and soil organisms, and peat (Bradshaw and Warkentin 2015). The boreal zone also contains large tracts of the most carbon-rich ecosystems globally—intact peatlands (Leifeld and Menichetti 2018). Altogether, as a result of this high density of carbon-rich ecosystems, especially rich in soil carbon, boreal regions harbor the world's largest terrestrial ecosystem carbon stocks (Crowther et al. 2019). The same peatlands hold major stores of water, again pointing to these as effective buffers of climate change.

A boreal catchment is a complex flow of carbon in different organic and inorganic forms with fluxes between compartments and a continuous uptake and release of CO_2 (Fig. 1), and climate change affects the carbon sequestration and hydrology in boreal ecosystems in several ways. While warming in combination with CO_2 fertilization may increase carbon sequestration in temperature-limited forest regions, the net ecosystem effect is not clear as warming may also increase soil and plant respiration and increase the probability of extreme events such as drought, windthrow, and fire (Friend et al. 2014). Warmer and occasionally drier soils in the boreal domain may lead to more mineralization of the soil organic carbon (Doetterl et al. 2015). While fire may not compromise carbon stocks or fluxes in naturally fire-prone biomes, climatic warming-driven increases in fire frequency and severity in boreal systems may reduce net storage and weaken the carbon sink properties (Pérez-Izquierdo et al. 2021; Rogers et al. 2015). Habitat loss, degradation, and conversion, operating via changes in fire regimes, soil and peat drainage, forestry, and afforestation practices, are now driving substantial changes in the processes controlling boreal and Arctic ecosystem carbon and water fluxes, and hence terrestrial carbon stocks and landscape hydrology. These processes and linkages may be exacerbated by climate change, to the extent that human impacts significantly degrade and compromise the net ecosystem carbon sinks and the associated climate feedbacks in the boreal regions. Our ability to safeguard and manage these critical ecosystem services for the future is currently compromised by a lack of understanding, or acknowledgment of the existing knowledge, about climate, ecosystem functioning, and carbon resilience. As we will elaborate below, Norway may serve as an example of the tragedy of the carbon commons caused by a fragmented (local) management of nature combined with a misleading perception that there is endless nature in the "country of wilderness," leading to fragmented nature.

b. The Norway case

Since the Brundtland report in 1987, Norway has aspired to a role as an international frontrunner in climate change and nature conservation policy. Norway has regarded itself as ideal to take on this role due to high levels of natural, financial, and human capital, the latter expressed as high and equally distributed levels of education, wealth, and public health, along with high trust in authorities and strong social institutions. A high level of social security and social robustness may, however, have caused a sense of inertia toward risks, captured in the surprising and paradoxical outcomes of a recent poll (Smith 2019) where Norway ranks third among the least climate concerned nations in the world, just behind Saudi Arabia and the United States. This lack of concern in the general population may explain why there has so far been little real political action to reduce and prepare for climate risks.

Climate threats are recognized, however. As a mountainous country in a relatively high-precipitation climate, indirect and direct effects of floods impact life, wealth, and health of Norwegians. Recent extreme flooding events have blocked roads for extended periods, affected houses, telecommunication, food supply, electricity, and access to hospitals and other medical aids. At least 27% of the public roads in Norway are vulnerable to avalanches and rockslides (Frauenfelder et al. 2013). Future scenarios list further increases in flooding as a severe threat (Hanssen-Bauer et al. 2017), notably along the coast where the topography is most rugged, rainfall highest, and infrastructure most vulnerable.

Given the latitudinal and elevational extent of Norway, the long coastline, and harsh climate, it comes as no surprise that anxiety and perception of vulnerability to an increasing number of extreme events is affecting the health of people of coastal and rural areas (Jacobsen et al. 2016; O'Brien et al. 2004). While people living in exposed areas are, to some extent, prepared for heavy rain and flooding, this places a heavy toll on everyday life, and a climate-induced escalation of the conditions is alarming (Jacobsen et al. 2016). Interestingly, this also affects the urban population. A recent study among the citizens of Bergen argued that over the past 15 years, Bergen's identity has been shifting from a "weather city" to a "climate city" (Bremer et al. 2020).

A 2019 Norwegian Directorate for Civil Protection report ranking climate as the 3rd most serious threat to national security, after pandemic and lack of access to critical medicines. The Norwegian Environmental Agency Climate and Health report states: "The Norwegian population in general have good health status, and as such is geared to cope with the impacts of climate change. Still increased precipitation, heatwaves and droughts will have health implications" (Hessen 2021). The report puts floods and avalanches as the top risk, followed by heatwaves, new diseases, impaired access to food and beverages, detrimental impacts on allergy and air quality, release of toxic compounds, increased demands for biocides and, last, mental health consequences.

c. Trees—Obscuring our view of the full ecosystem carbon?

In 2020 Norwegian authorities released "Klimakur" (Miljødirektoratet et al. 2020), a plan for remediation of climate change impacts and fulfilling our obligations under the Paris Convention. The "cure" consists of three main tools: (i) a business and industry segment, (ii) a transport and food production segment, and (iii) a spatial planning and forestry segment. The latter is primarily focused on massive forest planting, more efficient forestry practices, and especially fertilization of forests to increase the uptake of CO_2 by trees and plantations. In contrast, the plan puts strikingly little emphasis on existing terrestrial carbon stocks, thus ignoring opportunities to develop policies and instruments to (i) cut back losses of ecosystem carbon storage through stricter regulation habitat loss and degradation, (ii) safeguard the vast belowground components of boreal and Arctic carbon stores, and (iii) restore lost sinks and stores of carbon. The major role of intact ecosystems in mitigating (partially) climate-induced societal risks such as fires and flooding is also not discussed. Interestingly, the "cure" thus ignores not only major trends in the international policy landscape, but also current national guidelines for climate, energy, and climate adaptations, which explicitly include the principle of ecosystem-based climate adaptation (https://lovdata.no/dokument/SF/forskrift/2018-09-28-1469). This striking discord between higher-level policy documents and the resulting action plans prompts the question of how and why core components of these higher-level aspects of the policies are "lost in translation" when developing specific plans and instruments.

Around the time of Klimakur, the Norwegian Institute of Nature Research released a report commissioned by the World Wildlife Fund-Norway (WWF) that summarized the knowledge base on carbon storage and uptake in Norwegian terrestrial ecosystems (Bartlett et al. 2020). This report documents vast carbon stores in Norwegian terrestrial ecosystems, and whereas the largest cumulative stores of carbon in Norway are found in our forests (32%) these cover 38% of the total land area, indicating that forests actually deliver below-average in terms of carbon storage. The reason for this perhaps surprising finding is that wetlands and permafrost, covering only 9% and 3% of the total landmass, respectively, store 31% of the nation's terrestrial ecosystem carbon (>2.2 Gt C). These water- and temperature-limited ecosystems are thus incredibly carbon dense, with 53 and 48 kg C m^{-2} for wetlands and permafrost, respectively. The next densest storage of carbon can be found in freshwater lake sediments, with 45 kg C m^{-2}, amounting to 13% of the national carbon stores. Another perhaps surprising finding is that forests and the heaths of low-midalpine zones sequester comparable amounts of carbon on an annual basis (0.0055 and 0.0053 Gt C yr^{-1}, respectively). Overall, the Norwegian terrestrial land sink is almost 3 times as carbon intensive as the global average (0.18% of the terrestrial ecosystem storage on 0.07% of the terrestrial land area). This high carbon-to-area ratio is likely due to the large extent of carbon-rich peatlands (alpine and lowland) along with boreal forests and wet heaths. A shared feature of these habitats is that a vast

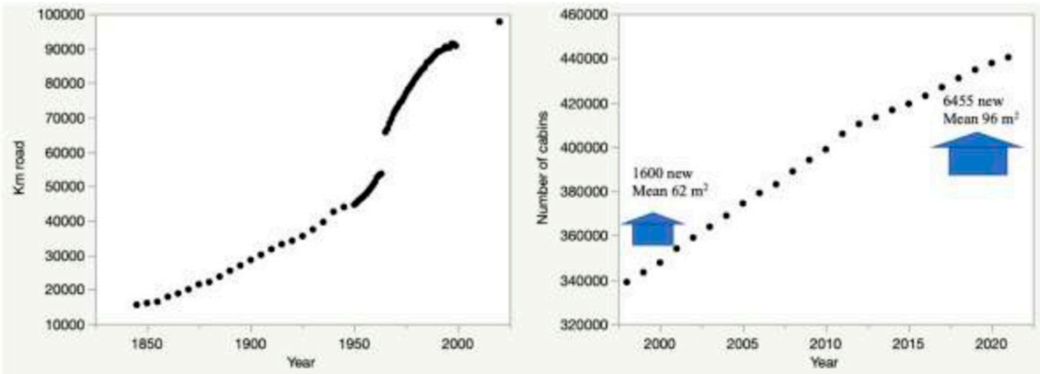

FIG. 2. Time trends for major landscape transitions that strongly affect landscape elements storing carbon and water: (left) road construction and (right) cabins. For the latter, new cabins per year and their average size are indicated at the start and end of the time series. Source: Statistics Norway (https://www.ssb.no/en).

majority of the stored carbon (<90%) is found belowground, in roots, soil organisms, and soil. The same ecosystem components also have a disproportional importance in regulating hydrology, preventing flooding during heavy rainfall and securing water supply in dry periods.

The WWF report contrasts the Klimakur approach in that it quantifies the carbon capture capacity and above- and belowground carbon stores of existing ecosystems, not just the added capture and aboveground accumulation that could be achieved from land-use change (notably, forest planting and intensified forestry practices). In doing so, it illustrates (i) the relatively minor differences between terrestrial ecosystems in carbon capture capacity (net annual uptake rate per unit area), which contrasts with (ii) the vast variation between them in total ecosystem carbon density or storage capacity (total above- and belowground carbon stock per unit area). These findings make sense in light of recent developments in our understanding of how photosynthetic capacity is primarily limited by light and biophysical constraints (moisture availability, waterlogging, temperature as a rate-limiting factor), and less by soil fertility, reflecting local adaptations in plant resource use and nutrient allocation (Smith et al. 2019). In contrast, the huge variation in ecosystem carbon density, the vast majority of which is found belowground, points to a huge variation between ecosystems in their carbon storage and retention capacity, linked to variation in decomposition rates (Clemmensen et al. 2013; Crowther et al. 2019). This variation is highly relevant for ecosystem management options to increase terrestrial carbon storage capacity, as it suggests that, especially in boreal regions, we should be putting more effort into designing and implementing policies and management options to safeguard and strengthen total ecosystem carbon storage capacity, rather than in policies to increase carbon capture. In other words, we should focus less on how we can increase instant rates of carbon gain through increasing photosynthetic rates and aboveground biomass, and more on how we can decrease carbon loss from the ecosystem at large through decreasing decomposition rates, erosion, and aquatic carbon loss through runoff. This will again necessitate a focus on how to build and safeguard total ecosystem carbon stocks and more generally ecosystem resilience.

d. Nature—The blind spot in spatial planning

In spatial planning, conserving nature is typically seen as a special interest competing with the needs of society, and the priority value of nature is largely assessed in terms of biodiversity alone [e.g., protecting red-listed species, habitats (cf. Henriksen and Hilmo 2015; Lindgaard and Henriksen 2011)] disregarding the majority of the ecosystem services that nature provides. However, these ecosystem services can be imminent, large, and difficult and/or costly to replace. For example, forests in areas of high avalanche and landslide risk may offer direct physical shelter via the trees and anchoring via roots that reduce both the risk and impact of landslides and avalanches. In addition, the role of vegetation and in particular trees in regulating climate and hydrology, especially the extremes, may be even more important. More intense flooding and erosion is a well-known result of local deforestation (Holden 2005). Several dramatic landslides in southern and central Norway have occurred on old deposits of marine clay (quick clay) in areas where natural vegetation has been removed and degraded, and while exact risk assessments and causality are hard to establish in each individual case, Norway possesses many such unstable areas, and there have been a number of massive and deadly landslides. Over the millennia, these marine clay deposits become naturally less stable by removal of salt through groundwater and runoff, which may be exacerbated by loss of natural ecosystems, and preserving natural forests and waterways is no doubt a cheap precautionary measure. Again, this would also serve the purpose of preserving nature and aid ecosystem carbon storage.

Three major societal drivers of nature loss and distortion of stored carbon and water in Norwegian nature are road constructions, buildings, and infrastructure (Fig. 2). All of these drivers have increased strongly in recent years, with current public plans indicating significant increases in the future (Rørholt and Steinnes 2020). These developments are now increasingly debated, especially locally, where public opposition is centered on the nature costs in terms of loss of biodiversity and ecosystem services such as carbon and water, agriculture, recreational areas, and cultural values. The conflicts often revolve around how the loss of nature and ecosystem services are not sufficiently considered or costed in the concession planning and societal cost–benefit analyses, and around the agency of those reaping the benefits versus those paying the costs (e.g., national or global commercial interests vs local stakeholders). Three examples illustrate these conflict lines:

1) First, the recently released Norwegian national plan for transport (Samferdselsdepartementet 2021) projects a 25% increase in personal transport and a 29% increase in transport of goods by 2050. Most of this planned increase is road traffic, yet the plan does not mention conflicts with climate or nature nor discuss how this locks in a narrow range of options for reaching our Paris Accord obligations. Planning is largely based on societal cost–benefit analyses, but with both the costs of lost nature and the benefits of intact nature unaccounted for. This creates a paradox where increased road travel, longer commutes, and increased transport becomes a societal benefit, according to model specifications, despite the higher time allocation, economic costs, energy use, pollution, and risks to individuals and nature this increase in transport necessarily entails.
2) Second, extensive and accelerating construction of private holiday homes or cabins is responsible for 25% of the nature lost to built areas in Norway between 2008 and 2019 (accounting for around 125 km^2) (Rørholt and Steinnes 2020). The public debate around cabin developments revolves around their location in vulnerable coastal and alpine natural areas, and the increasing per cabin spatial and resource footprints due to increasing average cabin sizes and increasing infrastructure demands for roads, parking lots, developed paths, water and electricity that puts a toll on the affected landscape and ecosystems (Xue et al. 2020).
3) A third area of current conflict between nature loss and societal development has been the development of the wind power industry. Norway's vast hydroelectric power development dating back more than a century primed the country for embracing new "green energy" solutions. Norway also has considerable wind resources. Starting around 2000, the wind power capacity has accelerated and is now at an annual production of around 8.2 TW h, with a projected increase to 15.6 TW h (i.e., 10% of the national energy demand) when current licenses are realized (Olje- og Energidepartementet 2020). In parallel with the increasing development of this industry, public opposition has increased, and again, locals, in collaboration with nature conservation societies, are protesting what they see as massive, globalized industrial developments in their local natural backyard. These protests are fueled by a distrust in the licensing process, which is deputized to a sector authority and governed by sector law rather than being anchored in generalized spatial planning (Inderberg et al. 2019). Again, the full costs and benefits in terms of loss of nature and ecosystem services are not formally quantified in the societal cost–benefit analyses underlying the licenses. Instead, nature is considered as a secondary point or even as a detriment to green development, where the benefits of clean power are weighed against the legal protection of rare and threatened nature. The benefits of intact, natural ecosystems and their services are not quantified, considered, or costed. The wind power concessions are largely located along the western coastline of Norway, in natural or near-natural areas, exacerbating the conflict to a level where the concession process is now under reassessment by the government, and where the sector authority is expecting a full stop in new concessions between 2022 and 2030 (Norges Vassdrags og Energidirektorat 2020).

These examples illustrate how spatial planning in Norway still fails to account, quantitatively or qualitatively, for the value of nature in providing key ecosystem services, including those critical for climate change mitigation and adaptation. As a consequence, our decision-making processes fail to account for the societal value of these ecosystem services in cost–benefit analyses, leading to decisions that result in rapid loss in quality and extent of the very same ecosystems that deliver these increasingly important services.

e. Protected but in peril—The continued decline of Norwegian nature

For Norway, 2020 marks a year when the necessity of changing course in order to come to grips with our massive and increasing sustainability and environmental impacts should at least start to sink in: According to a report produced by a collaboration between all the major environmental organizations in Norway in 2020, Norway reached none of the Aichi targets (though there had been some progress toward some of them) (Naturvernforbundet et al. 2020), and Norway is also leading in a "race to the bottom" in terms of welfare achieved relative to ecological footprint (Hickel 2020). These new statistics do not come as a surprise, over the past 100 years, national spatial statistics have documented a steady decline in the fraction of the Norwegian land area that by definition is "wilderness" (>5 km to nearest larger human impact in terms of roads, houses, dams etc.): in 2018 this amounted to no more than 1.5% of the area, with 44% of the land area being more than 1 km away from the nearest larger human impact. The rates of areal loss show no signal of decreasing: the latter area declined by 620 km^2 in the 5 years from 2013 to 2018 (Statistics Norway; https://www.ssb.no/en).

Of more direct relevance to the climate and nature crisis, the Norwegian nature index estimates the state and trends of the biodiversity and thus the ecological integrity of seven main ecosystems in Norway—the ocean, coast, freshwater, wetland, forest, mountain, and open lowland ecosystems—relative to a reference condition defined as a theoretically intact nature with negligible human impact and given climatic conditions in the 1961–90 normal period (Jakobsson and Pedersen 2020). The nature index is based on 260 indicators, which are combined and normalized to a 0–1 scale for each ecosystem, where 1 refers to a theoretically intact nature state. In 2020, the lowest index value is found for forests (0.41), followed by open lowland (0.44) and mountain ecosystems (0.56), whereas wetland and freshwater ecosystems fared slightly better at 0.68 and 0.74, respectively. The nature index increased slightly from 2000 to 2020 for forests and freshwater ecosystems, whereas it has decreased slightly for mountains and decreased sharply for open lowland ecosystems. An expert judgement-based analysis shows that impact from land use and infrastructure are the main drivers behind low values and negative trends. These patterns and trends are reflected in the national red-lists for species and habitats, where high numbers of red-listed species are found in forests, seminatural habitats, and wetlands, and where habitat degradation and loss were identified as the main drivers of loss of both species and nature types (Henriksen and Hilmo 2015; Lindgaard and Henriksen 2011). The loss of bogs is especially relevant for carbon and hydrology, and it is estimated that the area of bogs has declined by 30% over the past 5–6 decades, causing massive losses of carbon, hydrological buffering, and biodiversity (Sabima; https://www.sabima.no/trua-natur/myr/).

In general, all of these assessments paint a clear picture of biodiversity and ecosystems that are severely degraded and continue to be lost, also in a country like Norway, with perceived national pride in its large areas of wilderness. Concerningly, the downward trends were not halted by the implementation of the Norwegian Act on Biodiversity ("Naturmangfoldloven"; Ministry of Climate and Environment 2009) nor by repeated political statements, white papers (Klima- og Miljødepartementet 2015), and reports stating that biodiversity and nature conservation should be a national priority.

f. Perverse incentives, tragedy of the commons, tyranny of the moment, and shifting baselines

This analysis illustrates how the global decline of nature takes place also in a country that praises itself for its environmental awareness and fondness of nature. Our analysis further illustrates how the loss is driven by an engrained systemic ignorance in our decision-making processes of the values these losses represent both for nature itself, for human well-being, for climate robustness. This is perhaps ironic, as a sparse population over vast areas in rugged landscapes with a harsh climate leaves Norway susceptible to climate-induced disasters, such as avalanches and landslides, yet can be explained by wealth, prosperity, and perhaps also a fossil-based economy that renders Norway with a sense of inertia as well as ignorance of such risks. The perception of Norway as a country of endless wilderness may also weaken the perceived urgency. Another point worth noting is that many of the most vulnerable areas in terms of carbon storage, biodiversity, and flooding control are near populated areas, and thus simultaneously most at threat form land-use change and most important in delivering these ecosystem services. Add to this mix sectorialized laws and licensing processes and weak systems for accounting for biodiversity and ecosystem services, as illustrated above, and a government that places a strong focus on decentralized decision-making. The end result is a "perfect storm" within our societal decision-making for a fast and steady piece-by-piece loss and degradation of nature.

This is happening despite a biodiversity law that explicitly safeguards both biodiversity at all levels and ecosystem services ("Naturmangfoldloven"; Ministry of Climate and Environment 2009), suggesting that the implementation, rather than the legal framework, is the critical factor. Losses of nature—and the related lost capacity to buffer climate change—thus reflects a systemic ignorance of these key ecosystem services in political and management practice. In particular, current regulatory regimes and laws are not constructed with the full range of interests and benefits that nature can provide in mind, and hence nature's interests keep being reduced to one among many competing interest, where our understanding of what it entails to "conserve nature" is limited to avoiding extinction of species and habitats (Hanssen et al. 2015; Stokstad et al. 2020). In addition, perverse incentives, such as subsidizing construction of roads for accessing and logging of valuable forests, dredging of bogs, and other impacts are main drivers that run counter to the protection of nature. The net result in a "tragedy of the commons" where nature's interests and values are systematically underaccounted for in decision-making, and where numerous decisions are made individually and without considering their additive (or multiplicative) impacts.

However, as illustrated in the examples above, public awareness is now growing of the potential role of especially forest and wetlands in fighting climate change, and more generally in supporting human well-being. This shift in the public opinion may potentially be a game changer, as a lack of public awareness of the wide-ranging consequences, for example related to land degradation, is identified as a major societal barrier to action against the destruction of nature (Montanarella et al. 2018). To translate this general public awareness into societal action requires the values of nature and ecosystem services to be realized within the national policy agenda, which to date has been focused on conserving isolated "representative" examples of characteristic and threatened species and habitats, rather than on enabling society to capitalize on the services delivered by the nature in our "everyday landscapes."

g. Discounting the future

The widespread decline of nature and the political neglect of nature's potential as a buffer against climate change and climate disasters, even in a country like Norway, may seem paradoxical, but is related to our ability to compare different values, weigh interests of different stakeholder, and conceptualize the values of current versus future costs and benefits. First, as exemplified above, costs of lost ecosystem services such as carbon or water storage are treated as economic externalities, and thus not implemented in cost–benefit analysis. There is also a difference in power between stakeholders, where specific private entrepreneurs may profit from the destruction of nature, whereas the costs are borne by the general public. Further, humans have a surprisingly short time horizon, and "future" is commonly seen over a time horizon of no more than 15–20 years, whereas democratic systems and decisions typically operate over a time horizon of 4 years (Krznaric 2020; Tonn and Conrad 2007). Activities such as road construction, building cabins, and local industry that provide work and tax income today are typically valued over the long-term values of nature services because economic value is more tangible and also because the future value of nature is discounted (Carpenter et al. 2009; Jacobs 2016). Finally, there is often a temporal decoupling or the *tragedy of the contemporary*, where the short-term benefits override the long-term costs or the consequences for future generations, since even one or two generations ahead may seem like a distant future, and climate change projections typically end at 2100. Since gradual and slow changes are hard to conceive, we psychologically adapt to these gradual, but harmful, changes by *shifting baselines* (Klein and Thurstan 2016). These psychological drivers may be difficult to tackle, but insights in couplings between nature and climate, and the risks involved, should be the point of departure to tackle the challenges.

h. The Norwegian paradox on the global arena

In the national paradoxes between a scientific understanding and public awareness of the role of nature for buffering climate disasters and the policy inaction, nature's values in its own rights, and the need for precautionary management often fall victim to "thinking fast" populism at the expanse of "thinking slow" evidence-based policy development (Kahneman 2011). This can be illustrated by the "Klimakur" versus national guidance documents example, and while the situation is clearly not unique to Norway, it is especially paradoxical here given the level of wealth, education, and environmental self-esteem as a sustainable nation. Even more paradoxes arise when Norway as a global actor is considered. As an active nation on the international environmental arena since the Brundtland Commissions in 1978, and as a major donor for funds aimed for the preservation of the Amazon and the Guinean tropical forests, Norway prides itself as a "nation of good." Norway is currently the world's most active advocate of corporate social responsibility in all international arenas. However, Norwegian national interests are also involved in the mining industry in the Amazon, have until recently had their Norwegian Government Pension Fund Global, by far the world's largest sovereign wealth fund, invested in coal companies, and are very reluctant to slow down oil and gas exploration, even in vulnerable Arctic areas. Thus, Norway is also guilty of selfishly feathering its own nest at the expense of other nations, the planet, and, therefore, ultimately its own welfare over the long term (Wilson and Hessen 2014). Again, the critical issue is the ability to see nature and climate in context and to apply decisions to the benefit of "the others" in space and time.

4. Summary and conclusions

We urgently need a completely new take on area planning based on a realization of the value of nature not only for biodiversity, but also as a sink and storage of carbon, for regulating hydrological processes, and its role for preventing climate-induced disasters, along with a multitude of other goods for diversity and human well-being. We also need to judge and treat ecosystems not only by their diversity or endangered species but to encompass their "bulk values," not least their ability to buffer climate change. As a minimum, long-term planning must be implemented, where the discount rate of the future should approach zero, and the long-term benefits and broad value of nature for future generations and nature per se is fully recognized. At the national level, there is a need to implement a strategy for biodiversity and ecosystem services following up the findings and recommendations from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, the new international commitments under the Biodiversity Convention (CBD), and the national implementation of these principles. Such a strategy should acknowledge that ecosystems have value for their biodiversity per se, as critical components of a functioning biosphere, and in underpinning human lives and livelihoods.

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