commentary

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Key Messages from European Science Academies for UNFCCC COP26 and CBD COP15

The urgency of the climate and biodiversity crises requires closer coordination between UNFCCC and CBD

Summary

This commentary has two purposes. Firstly, to identify key messages that have emerged from the last 10 years of work by Europe's science academies covering the environment, energy and biosciences. We believe that many of the analyses of the links between science and policy will be relevant to issues of concern to Contracting Parties to both conventions, and the concise summaries provided in section 2 can give readers a fast-track access to the many hundreds of pages of analyses available. These analyses straddle climate change, the role of biomass energy, greenhouse gas emissions from different oil feedstocks, policies towards mitigation in transport, buildings and infrastructure, and the interactions between climate change and human health. Systemic issues such as the barriers to the transformative changes required to tackle climate and biodiversity crises are also addressed.

Secondly, we have reviewed recent science relating to two critical issues which underlie the scope and urgency of actions within both conventions. We attach a discussion of the wide range of interactions between climate change and biodiversity, and the case for closer coordination and collaboration between the two conventions. We also provide reviews of the current state of the climate and consider whether climate change has already become 'dangerous' in the context of the UNFCCC's undertaking to avoid 'dangerous climate change'.

Regarding the first issue, climate change, if left unchecked, is likely to overtake land use change as the primary cause of biodiversity loss. In the other direction, ecosystems and their biodiversity buffer society from climate change by providing the resources that enable societies to adapt to climate change, and by absorbing greenhouse gases through carbon sequestration and storage. Addressing both

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crises can be achieved through use of nature-based solutions to remove carbon dioxide and build resilience to climate change, while also enhancing biodiversity and human well-being. In contrast, separate treatment of both carries risks of actions in one domain having negative impacts on the other. This commentary concludes that both crises are critically urgent and require the most to be made as soon as possible of potential synergies and co-benefits.

The joint workshop between IPCC and IPBES in December 2020 should lead to a sustained dialogue aimed at ensuring that all policy actions are beneficial to both climate and biodiversity. The recent launch of the UN Decade of Ecosystem Restoration will depend on action within both conventions and can provide a common objective for both UNFCCC and CBD to develop further coordinated and joint actions.

On the second issue, ‘tipping points’ are often seen as a gateway to ‘dangerous’ climate change. In this commentary we find that humanity has already entered irreversible changes in ice sheet melt and is in danger of passing points of no return in critical biomes such as the Amazon, and increasing emissions of naturally captured carbon dioxide (CO_2) and, potentially, methane from their ancient land and ocean stores. However, while the term ‘tipping point’ has some value in emphasizing the non-linearity of complex systems such as the Earth and its climate, it also risks projecting a misleading vision of well-identified points up to which climate change can be seen as ‘safe’. Moreover, by focusing on single points, it is possible to overlook the interconnectivity that increases risks, and the seriousness of underlying linear trends. Human societies and the crops and livestock on which they have depended have limited adaptability, and current trends show that the temperature and humidity changes that may occur over the next 50 years will expand greatly areas of land where it is difficult or even impossible to survive. Such catastrophically disrupting trends will be experienced as gradual incremental changes rather than passing any arbitrary tipping point. Such trends and recent extremes in temperature and precipitation raise concerns whether the commitment in Article 1.1 of the UNFCCC to “prevent dangerous anthropogenic interference with the climate system” can be achieved.

In conclusion, when governments meet to discuss these critical issues, the choices they make will determine the extent to which we can halt biodiversity decline and avoid dangerous climate change, and safeguard human civilisation as we know it. With the meeting schedules so close together, with their closely related policy agendas, and set against the backdrop of the COVID-19 pandemic, negotiators have the opportunity to take coordinated, bold and transformative action to deliver a new, more integrated and coherent framework for addressing biodiversity loss and climate change together.

1 Introduction

Parties to the Convention on Biological Diversity (CBD) plan to meet in October 2021 in China at COP15 to agree on a new post-2020 framework for addressing biodiversity loss. In November, Parties to the United Nations Framework Convention on Climate Change (UNFCCC) expect to meet in the UK at COP26 to review progress towards meeting the Paris Agreement climate targets. Both have been delayed by the pandemic from the COVID-19 virus, itself part of an increasing trend in the number of zoonoses that are spilling over from animals to humans (Smith *et al.*, 2014). The latter trend has been linked to the reduction in the barriers between humans and host animals, such as intrusion into natural ecosystems in pristine landscapes, the wildlife trade and increased livestock production (S7, 2021), interlinking human health with trends that are also driving biodiversity loss and climate change. Such interconnections have led to the concept of planetary health (Lancet Commissions, 2015) where human health and well-being are linked to the state of the planet. Such holistic assessments point to human health and even survival of our civilisations (Bradshaw *et al.*, 2021) under threat from changes to the environment that include biodiversity loss, climatic change, ocean acidification, land degradation, water scarcity, over-exploitation of fisheries and resource depletion.

The meetings of the UNFCCC and the CBD will take decisions on two of the most pressing global challenges facing humankind (Club of Rome, 2020; IAP, 2021; S7, 2021). The two conventions treat climate change and biodiversity separately but their interconnectedness is becoming increasingly apparent. Examples include the following.

- Replacing tropical forests with agriculture reduces biodiversity at the same time as releasing stored carbon, reducing carbon uptake in the land and increasing emissions of other greenhouse gases (GHGs).
- Increasing temperatures and associated changes to precipitation reduce agricultural productivity as well as moving species outside their habitable range, in some cases driving them to extinction.
- Warming and acidifying oceans alongside weakened circulation reduce the oceans’ capacity

to absorb and remove CO_2 from the atmosphere, while shifting or degrading ecosystems.

- Conserving, managing and restoring ecosystems can mitigate climate change and enable adaptation to its impacts while also enhancing biodiversity.

When governments meet to discuss these dual issues, the choices they make will determine the extent to which we can halt biodiversity decline and avoid dangerous climate change, and safeguard human civilisation as we know it. Set against the backdrop of the COVID-19 pandemic, negotiators have the opportunity to take coordinated, bold and transformative action to deliver a new, more integrated and coherent framework for addressing biodiversity loss and climate change together.

In this commentary, the European Academies' Science Advisory Council (EASAC), the European regional academy network within the global InterAcademy Partnership, draws on its previous work, independent of commercial or political bias, from across its energy, environment and biosciences programmes, to identify conclusions relevant to both Conferences of the Parties. These short 'key messages' are given in section 2, and readers are invited to refer to the reports cited to follow up on the reasoning or policy options related to each of the key messages.

We also provide in Annexes 1 and 2 updates on science that is relevant to the agendas of both conventions: linkages between biodiversity and climate change are covered in Annex 1; the current situation in regard to dangerous climate change and tipping points is given in Annex 2. The scientific evidence in these annexes that supports calls for closer coordination between the two conventions is summarised in section 3. This commentary has been prepared by the environment programme and reviewed by EASAC's three steering panels. It includes papers published until the end of July 2021, and thus does not include the IPCC Sixth Assessment report on the physical science basis released in August 2021.

2 Key messages from recent EASAC analyses that are relevant to the UNFCCC, the CBD, or both

(a) Messages relevant to the energy transition

Message 1. Large-scale use of **forest biomass as a replacement for coal** risks exacerbating climate change in the short-term owing to an initial increase in CO_2 emissions. The simplified rationale that this initial increase will be reabsorbed by forest regrowth fails to recognise the timescales involved, and that increases in atmospheric levels of CO_2 may therefore persist for decades or even centuries. At the same time, the growth in demand for forest biomass by wood pellet plants drives pressures for clear-cut harvesting and for expansion of plantation forestry that may conflict with biodiversity[1]. The use of forest biomass instead of coal for power generation is made economically viable by a combination of subsidies and reporting rules that allow emissions at the point of combustion to be excluded from facility and national accounts (since forest biomass should be accounted for at the point of harvest). The UNFCCC has recognised these risks but further work is required to ensure that the use of forest biomass meets climate and biodiversity objectives (EASAC, 2017a; 2018a; 2019a; Norton *et al.*, 2019).

Message 2. Similar risks exist for **bioenergy with carbon capture and storage** for which substantial uncertainties remain about the environmental impact and the net CO_2 removal that is achievable in practice. When carbon emissions are properly accounted for and the time required for growing biomass feedstock is included, net carbon removals may be significantly lower than anticipated and delayed for decades (EASAC, 2018b; 2019a). Such time-dependent factors have yet to be fully included in assessments of the role of bioenergy with carbon capture and storage in climate models which, as a result, have come to be relied upon too much in IPCC scenarios that meet Paris Agreement targets (Warszawski *et al*., 2021).

Message 3. There are large differences in the **carbon footprints of oil feedstocks** depending on the source and energy required for processing, with advanced extraction techniques (oil sands and shale) tending to have high carbon footprints along the supply chain. Improving the transparency of reporting of the carbon intensity of such feedstocks would enable operators to reduce emissions while oil remains a substantial component of fossil fuels supply, by avoiding high-emission sources (EASAC, 2016).

Message 4. Hydrogen is an energy carrier that is well suited for applications that are difficult to electrify (e.g. steel production, ships and trucks), but it is currently produced from fossil fuels, which offer offers no climate benefit. In contrast, 'renewable' hydrogen can be produced by electrolysis of water using renewable electricity, and 'low-carbon' hydrogen can be produced using low-carbon electricity or by steam reforming of natural gas together with carbon capture and storage. International trade in renewable hydrogen could open

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[1] While EASAC's work has focused on the climate impacts of biomass for energy, global meta-analyses of how bioenergy crops affect site-level biodiversity (see, for example, Núñez-Regueiro *et al.*, 2021) show that species diversity and abundance are generally lower in crops considered for bioenergy relative to the natural ecosystems they may replace.

up opportunities for its production in very sunny or windy locations at competitive costs (EASAC, 2020a).

Message 5. Electricity storage using batteries is expanding rapidly to balance the grid over short periods, for electric vehicles and for self-consumption in household photovoltaic systems. Maximising the benefits requires system-level integration of all available resources, including electric vehicles to support grid balancing, and to provide reserves, capacity and generation adequacy as well as congestion management. Research continues on large-scale electricity storage for longer periods, but further work is needed to bring down the costs (EASAC, 2017b).

Message 6. Buildings account for over a quarter of Europe's GHG emissions; approximately half from on-site space and water heating, and half from district heating systems and electricity. Decarbonisation strategies include designing new buildings with zero emissions, reducing energy demand in existing buildings through energy efficiency renovations, and replacing on-site use of fossil fuels (natural gas) by heat pumps to use decarbonised electricity efficiently. In addition, energy efficiency renovations can reduce energy poverty and offer health and well-being benefits to building occupants, including improved air quality, increased access to daylight, less draughts and less overheating. Designers of new buildings and renovations must also minimise embodied GHG emissions in the materials and components used (EASAC, 2021a).

(b) Clean transport

Message 7. Stronger 'avoid, shift and improve' policies are needed to reduce demand for transport, building on recent experience that has shown how travelling can be replaced by video conferencing and home working. Walking and cycling can be increased with only modest infrastructure costs and bring valuable health benefits. Passenger and freight transport need to be shifted to transport modes with lower emissions (including electric vehicles, trains, buses and ships). Performance can be improved through vehicle design, more efficient powertrains and sustainable energy carriers (including low-carbon electricity, ammonia, hydrogen or synthetic fuels). Electrification needs to be accompanied by a substantial reduction in the carbon intensity of the electricity supply if climate benefits are to be achieved (EASAC, 2019b).

(c) Nature-based solutions and CO_2 removal

Message 8. Stopping and reversing habitat loss and environmental degradation has long been recognised as the most cost-effective means of slowing biodiversity decline and GHG emissions (e.g. Stern, 2006; IPBES, 2018). On land, the preservation and restoration of wetlands, grasslands and forest systems are the most effective nature-based solutions for avoiding GHG emissions and removing CO_2 from the atmosphere (e.g. Epple *et al*., 2016; Griscom *et al.*, 2017; IPBES, 2018). Despite this, wetlands remain in long-term decline (Ramsar, 2018), grasslands are imperilled (Ceballos *et al.*, 2010) and deforestation continues apace with the loss in 2020 exceeding 42,000 km^2 of tree cover in key tropical regions, the third worst year for forest destruction since the start of monitoring in 2002 (WRI, 2021). Drivers continue to be dominated by agriculture, with cattle, followed by oil palm and soya, being the main reasons for land conversions (WRI, 2021).

Nature-based solutions can deliver climate change mitigation and adaptation objectives as well as biodiversity conservation across many ecosystems, but forests have a key role to play. Ceasing deforestation, improving forest management to enhance carbon sequestration and storage as well as other ecosystem services, restoration of natural forest systems and reforestation remain critically important priorities for meeting biodiversity and climate objectives, while reducing the demand for meat in the diet reduces one of the main drivers of land conversion and agriculture's contribution to GHG emissions (see also Annexes 1 and 2) (EASAC, 2017a; IAP, 2019).

Message 9. Soils host more than 25% of the Earth's species biodiversity, are the largest carbon stocks in terrestrial systems, and are important in carbon storage and regulating GHG emissions. The complex interactions between soil-dwelling organisms ultimately control the short- and long-term fluxes of carbon in and out of soils. One-third of soils globally are currently assessed to be moderately to highly degraded, with a reduced ability to maintain and store carbon. Halting the loss of carbon-rich soil ecosystems such as peatlands and wetlands, and/or improving soil carbon, soil health and soil fertility, contribute both to biodiversity and to climate change objectives (EASAC, 2018c). However, the potential of the current 4perMille initiative may be less than anticipated owing to a reduction in the capacity of the soil to capture carbon as atmospheric CO_2 levels increase (Terrer *et al.*, 2021).

Message 10. Carbon dioxide removal technologies to extract CO_2 from the atmosphere (including bioenergy with carbon capture and storage mentioned in message 2) offer no credible solutions above the few millions of tonnes per year scale: this represents one-thousandth of the levels that feature in some Intergovernmental Panel on Climate Change (IPCC) models complying with Paris Agreement goals. **Carbon capture and storage** remains a potentially effective technology to be applied to emissions from energy-intensive industries and power stations but progress has been too slow to meet expectations of large-scale removals by 2030 (EASAC, 2018b; 2019a).

(d) Human health

Message 11. Climate change is already impacting human health, and decarbonising the economy reduces air pollution and provides other health co-benefits. Phasing out fossil fuels and the inappropriate use of biomass will reduce the current high levels of premature deaths from ambient air pollution estimated at millions globally (EASAC, 2019c). European and global public health needs require a combination of solutions involving mitigation measures to reduce GHG emissions and adaptation measures to adapt to the unavoidable. In addition, decarbonisation targets are required for the health-care sector itself with local and near-term benefits to health, for example through greener hospitals, improved patient diets and new models of care (EASAC and FEAM, 2021). Health professionals active in the community can advise on how climate change risks health and how to adopt sustainable, healthy lifestyles.

(e) Transformative change

Message 12. The **urgency of transformative change**. The 'Great Acceleration' into the Anthropocene epoch (Steffen *et al.*, 2015a) has allowed humanity to grow rapidly in numbers, and in material and energy consumption since the 1950s, but at the expense of approaching or exceeding planetary boundaries (Steffen *et al.*, 2015b) beyond which the planet cannot support current human civilisations. Unlike previous environmental problems (e.g. ozone, acid rain) that were capable of being reversed, current trends may have already passed tipping points that are irreversible. For example, glaciers and ice sheets will not reform even if warming ceases; sea level will continue to rise; species extinctions remain irreversible (see Annex 2). Arctic warming and permafrost melting may also have significant implications for human health, for example in terms of (re-)emerging pathogens (IAP, 2020). Disruption to ocean circulation is not yet unavoidable but worrying trends can be detected (EASAC, 2021c). Failure to embrace the need for transformative change and continuing with business as usual will inevitably take us closer to dangerous climate change, and biodiversity losses on a scale not experienced since the last great extinction event (the Cretaceous–Palaeocene event) 66 million years ago (IPBES, 2019).

Message 13. Solutions to tackling climate change and reversing biodiversity loss are to be found through **transformational change** across technological, political, cultural, economic and social domains, at local, regional and global scales (EASAC, 2020b, S7, 2021). The UNFCCC COP26 and CBD COP15 provide potential springboards for the changes required to set the trajectory for ensuring a more equal, biodiverse, climate-safe and prosperous future for humanity. The scale of the challenge is, however, enormous: the annual rate of decline in emissions needs to quadruple to keep global warming below 2 °C by 2100, and to increase 30-fold to stay below 1.5 °C (Liu and Raftery, 2021). Already around 1 million species face extinction, and, even if climate change is kept to within 2 °C, estimates suggest 5% of all species will be at risk (IPCC, 2019a). Such challenges emphasise the need for fundamental and transformative change in the way economies are managed and incentivised. Transformative change involves large shifts in attitudes and behaviour, and encounters strong resistance from vested interests including those related to fossil fuels and unsustainable land use. Public awareness is a precondition for political action to tackle long-term issues such as climate change and biodiversity loss, and the knowledge gained from the social and behavioural sciences is particularly relevant. Such measures can be prioritised in COVID-19 recovery measures to accelerate the transformation away from the fossil-fuel-based economy (EASAC, 2020b; 2020c).

Message 14. Simple economic solutions for addressing both climate change and biodiversity loss are well known but poorly applied; for example, governments continue to subsidise fossil fuels and other environmentally harmful practices such as overfishing, and to invest in damaging activities that undermine, rather than protect, natural capital (EASAC, 2020b). Five times as much is spent by governments globally on activities that harm biodiversity, such as fossil fuels, mining and agriculture, as to protect it (OECD, 2020)[2]. New environmentally and socially sustainable economic models are required, together with replacing gross domestic product with measures that include socio-ecological, human health and well-being factors. Well-being indicators should guide economic instruments such as subsidies, payments, taxation, pricing and discounting for internalising environmental costs, in order to steer production and consumption behaviour to a sustainable form (EASAC, 2020b). In the case of climate change, for example, a social cost for carbon is still not applied comprehensively and at levels sufficient to reduce emissions to rates compatible with Paris Agreement targets (EASAC, 2020b). Moreover, recent estimates that include the costs of temperature-related mortality increase the social cost of carbon drastically to between US$69 and US$545 (mean of US$258) per tonne of CO_2 (Dressler, 2021).

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[2] The Organisation for Economic Co-operation and Development (OECD) recently estimated that total global biodiversity finance is around US$78 billion to 91 billion per year compared with the US$500 billion per year spent on activities that are harmful to biodiversity including fossil fuels, agriculture, fishing and mining. RAN (2021) show the extent to which investments by major banks are still supporting new fossil fuel infrastructure and use which will 'lock-in' economies to fossil fuel dependence; and that fossil fuel financing (lending and underwriting) from the world's 60 largest commercial and investment banks was higher in 2020 than it was in 2016.

Message 15. Agriculture provides an opportunity to transform food systems to meet nutritional, environmental, climate and development objectives (EASAC, 2017c). Developing sustainable and resilient food systems under a changing climate and in the face of increasing competition for land use requires the sustainable intensification of agriculture: agriculture that takes account of pressures on other critical natural resources, particularly water, soil and energy, and the continuing need to avoid further loss in ecosystem biodiversity, including pollinators (EASAC, 2015). Climate-resilient agriculture requires an evidence-based, flexible and proportionate regulatory system to encourage innovation; for example, when using genomics to inform new plant breeding techniques. Food systems need to adapt to climate change, reduce their own contribution to GHG emissions, reduce waste, increase sustainable consumption patterns and integrate climate and biodiversity considerations into dietary choices (EASAC, 2020b; EASAC, 2021b).

Message 16. Extreme weather and adaptation The increasing trends to extreme weather events (particularly extreme heatwaves and floods) were analysed in EASAC (2013) and EASAC (2018d), which stressed the importance of adapting to an inevitable increase in extremes at the same time as implementing urgent mitigation strategies. EASAC (2021c) updated estimates for sea level rise in the European area to advocate planning to adapt to a 1 metre rise by 2100. Further extremes encountered throughout the world during 2021 reinforce the message that urgent action is required on both mitigation and adaptation. The occurrence of extremes outside the range of climate models underpins calls in S7 (2021) to improve climate and other numerical models to better predict local effects and the mechanisms of changes currently underway.

3 The case for further integration of biodiversity and climate action

As described in Annex 1, the science academies of the G7 nations (S7, 2021) and the InterAcademy Partnership (IAP, 2021), the biodiversity crisis intersects with the climate crisis. Climate change, if left unchecked, is likely to overtake land-use change as the primary cause of biodiversity loss. Contributions to addressing both crises can be achieved through locally appropriate use of nature-based solutions to mitigate and build resilience to climate change, while also enhancing biodiversity and human well-being.

These linkages have been recognised by both conventions, but Maljean-Dubois and Wemaëre (2017) observed that it is the CBD that has regularly highlighted them and recommended action. For instance, the CBD recognises that '*Climate change and biodiversity loss are inseparable threats to humankind and must be addressed together*' and conducted a detailed review of the linkages in 2003 (CBD, 2003). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (SBSTTA, 2019) also noted that '*some measures intended to mitigate climate change could have significant negative impacts on biodiversity and even on greenhouse gas emissions*' (such as the Reducing Emissions from Deforestation and Forest Degradation (REDD) and Clean Development Mechanism (CDM) mechanisms). Annex 1 to this commentary includes examples where policies can have negative consequences for both climate change and biodiversity: a lose–lose scenario. It has thus long been recognised that avoiding such actions requires consideration in parallel by both conventions and their scientific groups.

Mechanisms for integration between the CBD and UNFCCC (and the UN Convention to Combat Desertification) have existed since 2001 through a Joint Liaison Group which has made recommendations to improve collaboration between national focal points, convention bodies and secretariats, cooperation on climate and biodiversity issues, and collaboration on cross-cutting issues such as technology transfer, capacity building, research and reporting. Interactions between climate change and biodiversity have also been considered by the scientific and technical bodies of the two conventions.

Most recently, a joint IPCC/IPBES workshop was held in December 2020 (Pörtner *et al.*, 2021) that drew 41 general conclusions related to the interaction between climate and biodiversity, current trends, the role and implementation of nature-based solutions and their part in the sustainable development of human society. The group noted that '*… functional separation creates a risk of incompletely identifying, understanding and dealing with the connections between the two. In the worst case it may lead to taking actions that inadvertently prevent the solution of one or the other, or both issues. It is the nature of complex systems that they have unexpected outcomes and thresholds, but also that the individual parts cannot be managed in isolation from one another*'. In particular, the group cautioned that '*measures narrowly focused on climate mitigation and adaptation can have direct and indirect negative impacts on nature and nature's contributions to people*'.

The workshop concluded that mutual reinforcing of climate change and biodiversity loss would mean that satisfactorily resolving either issue requires consideration of the other, in contrast with previous policies largely tackling the problems of climate change and biodiversity loss independently. In the future, policies that simultaneously address synergies between mitigating biodiversity loss and climate change, while also considering their societal impacts, offer the opportunity to maximise co-benefits.

Proposals already exist for further strengthening collaborative work (IBPES, 2021a) through joint assessments, co-sponsored workshops or joint technical papers. Joint workshops could identify key areas where both conventions share common technical challenges: for instance, ecosystem restoration is a central feature of both conventions; while avoiding applications of bioenergy that have negative impacts on both climate and biodiversity is a common objective. In addition, the many common drivers of both biodiversity loss and climate change (Annex 1) require the same transformational changes (including indicators that include socio-ecological, human health and well-being factors, internalising environmental and social externalities in prices and taxes, as well as halting subsidies and investment in fossil fuels and shifting revenues and investments to low-carbon energy deployment (EASAC, 2020b)).

The IPBES Plenary (IPBES, 2021b) decided that IPBES would continue to explore with the IPCC future joint activities and invite member states to submit suggestions for thematic or methodological issues that would benefit from collaboration. For more progress to be achieved than in the past, the CBD post-2020 framework and next round of biodiversity targets need to be defined with climate impacts and potential for climate mitigation and adaptation in mind (Arneth *et al.*, 2020). Similarly, the UNFCCC Paris Agreement negotiations need to reflect and support the delivery of national commitments to the CBD and SDGs. In this context, the national science academies of the G7 nations (S7, 2021) advocated that countries should be encouraged through the respective conventions to coordinate and integrate the currently separate National Climate Plans and National Biodiversity Strategies.

Other common policies identified by the Club of Rome (2020) to provide solutions for biodiversity loss, climate stability and human health include the following:

- declaring critical ecosystems as Global Commons;
- setting a global moratorium on deforestation;
- a moratorium on the exploration and exploitation of Arctic oil and gas reserves, and establishing a Cryosphere Preservation Plan;
- a New Ocean Treaty (under the United Nations Convention on the Law of the Sea (UNCLOS)) for the protection and sustainable use of biodiversity in areas beyond national jurisdiction;
- a halt on the conversion of wetlands, grasslands and savannas for the production of agricultural commodities;
- public and private finance flows for restoration of critical ecosystems.

At the same time, the recent launch of the UN Decade of Ecosystem Restoration to reverse the current trends in degradation of terrestrial and marine environments includes massive targets for ecosystem protection and rewilding of areas equivalent to the size of China (UNEP and FAO, 2021). Such measures would depend on coordinated action within both conventions to gain sufficient international support, and could provide a common objective for both the UNFCCC and CBD to develop further coordinated and joint actions.

A second argument for closer collaboration emerges from Annex 2, since both crises are critically urgent and thus require the most to be made as soon as possible of potential synergies and co-benefits. Annex 2 examines the concept of tipping points and to what extent we are already encountering 'dangerous climate change'. While the term 'tipping point' has some value in emphasising the nonlinearity of complex systems such as the Earth and its climate, it also risks projecting a misleading vision of well-identified points up to which climate change can be seen as 'safe'. The reality is that there are already several irreversible trends taking place which are associated with dangerous climate change. Sea-level rise is the best characterised trend, but tipping points for the Amazon, ocean circulation, the stability of the permafrost and deep ocean GHG stores are others. However, as pointed out in Annex 2, by focusing on such single issues, it is possible to overlook the interconnectivity that increases risks, and the seriousness of underlying linear trends.

As pointed out in Annex 2, the areas of the world where it is simply impossible to work or even live outside because of the combination of heat and humidity is increasing, and areas that become incapable of being tolerated by humans will have to be abandoned. Before the extreme outcome of survivability, there is a continuum of adverse effects on health, productivity and quality of life which is predicted to affect 3 billion people within 50 years, if warming continues at current rates.

In addition, recent events involving combinations of atmospheric phenomena have led to extreme heat or precipitation well outside the range of extremes expected in previous climate models. The rapid increase in Arctic temperatures caused by 'Arctic amplification' has already been linked with a weakening and meandering jet stream, but the local and regional interactions that led to the extreme heat in July in western Canada and northwestern USA and floods in Germany are only just becoming successfully reproduced in climate models. For instance, Fischer *et al.* (2021) show the increased probability of record-shattering extreme heat in a rapidly-warming climate, and high-resolution regional models applied by Kahraman *et al.* (2021) found that storms across Europe may move slower, becoming quasi-stationary with continued warming, lengthening periods of extreme rainfall and increasing flood risk. Policy-makers thus need to remember that uncertainties in scientific modelling and prediction can go both ways: the outcome can be worse than the worst case as well as better. Such observations add to the urgency of focusing future policy on transformative change where all conventions would need to work together.

The COVID-19 pandemic has provided a stark reminder of how connected the well-being of humanity is to the health of the planet. We face two separate but interdependent crises of accelerating climate change and biodiversity loss. But, as countries start to implement their economic and social recovery packages, unprecedented opportunities exist to place biodiversity and climate objectives at their centre. EASAC encourages the parties to the meetings of the CBD and UNFCCC this year to lead by example in demonstrating that the political will exists to undertake the transformative and deep structural changes necessary.

Annex 1 Climate change and biodiversity: two-way interactions

As highlighted recently in Pörtner *et al*. (2021), climate change and biodiversity interdependencies are multiple and complex. Moreover 'biodiversity' has to be seen within the context of ecosystem structure and function[3] and the 'ecosystem services' they provide such as food, water and carbon sequestration, which have been estimated as worth more than global gross domestic product to humanity (Constanza *et al*., 1997; Dasgupta, 2021). This annex summarises some of these interactions.

Ecosystems all over the world and across all biomes are being affected by climate change. Impacts vary because ecosystem sensitivity and vulnerability are dependent on complex interactions among organisms, their environment and other stressors (Turner *et al*., 2019). Changes in species distributions and assemblages, altered population dynamics and different seasonal cycles have been observed (IPBES, 2019), indicating impacts are occurring from genes to ecosystems (Arneth *et al*., 2020). So far, climate change is not the primary driver of biodiversity and ecosystem loss; however, large reductions in, and local extinctions of, populations are widespread, indicating many species cannot cope locally with the rapid pace of climate change (IPBES, 2019). Projections suggest that global warming of 2 °C could lead to 18% of insects, 16% of plants and 8% of vertebrates losing half of their climatically determined geographic range (IPCC, 2018). Coral reefs, already under stress from pollution, over-exploitation, ocean acidification and invasive species are projected to decline by 99% if the global average temperature increase reaches 2 °C above pre-industrial levels (IPCC, 2018). Overall, the fraction of species at risk of extinction due to an increase in the average global temperature of 2 °C is projected to be 5% (IPBES, 2019).

Ecosystems and their biodiversity buffer society from climate change by providing the resources that enable societies to adapt to climate change, and by absorbing GHGs through carbon sequestration and storage: in 2020, an estimated 32% and 24% of anthropogenic CO_2 emissions were absorbed by land and the oceans respectively (Friedlingstein *et al*., 2020). They also influence other biophysical processes including albedo, hydrology, and surface-roughness and evapotranspiration, which affect climate patterns locally, regionally and globally, including the fire regime (Diaz *et al*., 2009). It is the biota in soils that ultimately control the flows of carbon in and out of soils (Bach *et al*., 2020). In coastal systems, seagrass meadows, tidal marshes and mangrove forests contribute significantly to carbon sequestration (Macreadie *et al*., 2019) as well as land protection. In the oceans, biodiversity influences the biological processes responsible for moving carbon from the surface and sequestering it into deep waters and sediments (Solan *et al*., 2020).

Biodiversity and climate change may have synergistically negative interactions. For instance, the devastating impacts on biodiversity of the 2019 Australian fires (1 billion to 3 billion animals and 21% of Australian temperate broadleaf and mixed forests destroyed) have been attributed in part to climate change (van Olderborgh *et al*., 2021), but the decline in many of Australia's native marsupial species that would have previously lowered leaf litter accumulation and thus fire potential may have contributed (Hayward *et al*., 2016). As a result of the fires an estimated 650 million to 1.2 billion tonnes of CO_2 were released into the atmosphere, far exceeding Australia's annual contribution to global GHG emissions (Hughes *et al*., 2020).

Both biodiversity losses and climate change share the same underlying drivers: population growth, economic growth, and associated unsustainable production and consumption of natural resources. Since 1950, the global population has tripled (Roser *et al*., 2019), the world's urban population has risen almost sixfold (WEF, 2019) and income per head increased by 4.4 times (Roser *et al*., 2019). This combination of factors has led to a pronounced increase in the use of biomass, fossil fuels, ores, minerals and water, from less than 10 billion tonnes in 1950 to over 70 billion tonnes in 2010 (UNEP, 2015).

Land-use change and degradation account for almost a quarter of emissions (mostly from deforestation), a 15% decline in species richness, and the loss of natural systems such as forests, savannas, natural grasslands and wetlands (IPCC, 2019a). Growing demand for food and energy has had the greatest impact on land use, but atmospheric nutrient deposition and climate change are exacerbating these impacts (Segan *et al*., 2016; IPBES, 2019). Wealthier populations have led to dietary shifts from staple crops to meat and dairy products that require more land, so that food production now occupies 50% of the Earth's habitable land with demand projected to double by 2050 on current trends

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[3] Species richness and functional diversity are key attributes associated with increased resistance, stability and resilience in ecosystem functions such as primary productivity and carbon sequestration.

(IPBES, 2019). Incentives for renewable energy have led to a rapid expansion in bioenergy which has accounted for 36% of agricultural land-use change since 1994, at a rate of 4.4 million hectares per year between 2000 and 2011 (Alexander *et al*., 2015). Particularly in the use of forest biomass in energy production, it is possible to find many cases where the combination of the type of forest biomass harvested and its use causes harm to biodiversity while also failing to deliver climate benefits (Camia *et al.*, 2021), while other practices may help mitigate climate change but at the expense of biodiversity. Other examples of 'lose–lose' trends are found in the loss of forests for agricultural expansion with the increase in carbon emissions and loss of biodiversity, while warming and increasing acidification of the oceans reduces biodiversity and the capacity of this natural sink for CO_2.

In terms of mitigation, policy interventions aimed at reducing land degradation, and protecting, restoring and maintaining important areas for biodiversity and carbon, would contribute both to global biodiversity and to climate change targets. Natural systems such as peatlands, seagrass beds, mangroves, coral reefs and tropical forests have an important role in climate mitigation and adaptation (e.g. Griscom *et al.*, 2017; 2020). Protecting, restoring or maintaining carbon-dense areas that coincide with areas of high ecological intactness, as well as the last refuges for unique biological communities, are starting points for priority setting (Soto-Navarro *et al.*, 2020). However, biodiversity and climate benefits are not always aligned. For instance, care is needed to ensure that the quest for carbon (e.g. carbon off-setting or carbon farming) is not at the expense of biodiversity (Morán-Ordóñez *et al.*, 2017; Seddon *et al.*, 2021).

Considering the time-frame over which benefits will accrue is also important as diversity is essential for long-term stability and resilience, but may not be important in the delivery of short-term carbon benefits. 'Nature-based solutions' (Seddon *et al.*, 2019) aimed at maximising the co-benefits for biodiversity and climate have been proposed that take advantage of the role that ecosystems can play in climate mitigation as well as enhancing the buffering ability of ecosystems against the impacts of climate change (Global Commission on Adaptation, 2019; Lavorel *et al.*, 2020). Mori *et al.* (2021) show how biodiversity, climate change mitigation and productivity of forests are linked, with areas having greater tree diversity tending to be more productive, providing a greater carbon sink. Over the next 50 years, they calculate that climate change at current rates (business as usual) would cause a 9–39% reduction in terrestrial primary productivity across different biomes, whereas swift GHG mitigation could help maintain tree diversity and protect these natural carbon sinks. The authors point out that maximising such 'triple wins' for climate, biodiversity and society requires conservation of tree biodiversity in reforestation programmes—a clear link to forest-related initiatives within the UNFCCC.

Ecosystem restoration is one of the most effective means of delivering nature-based solutions for food insecurity, climate change mitigation and adaptation, and biodiversity loss. In recognition of this, 2021–2030 has been declared the UN Decade of Ecosystem Restoration. A major role is seen for 'rewilding' in addressing both biodiversity and climate crises. UNEP (2021) has called on governments to deliver on a commitment to restore at least 1 billion hectares of land by 2030 and make a similar pledge for the oceans. This would need to be associated with a quadrupling of annual investments in nature if the climate, biodiversity and land degradation crises are to be tackled by the middle of the century, which is equivalent to overcoming a financing gap of US$4.1 trillion (UNEP, 2021).

Targeting the underlying pressures on the environment will have mutual benefits for biodiversity and climate. Addressing the unsustainable production and consumption of food and energy across supply chains is one policy action. Reducing food waste (including food losses) could lower GHG emissions by 8–10%. A global dietary shift towards more flexible diets and plant-based foods would reduce pressure on soil, forestry and fisheries resources, and could reduce GHG emissions by 25–60% by 2050 (Mbow *et al.*, 2019; FAO *et al*., 2020). Hayek *et al.* (2021) assess the potential for carbon sequestration resulting from the restoration of ecosystems in areas released by lower agricultural demand on land to produce plant-based diets by 2050 to be 332–547 gigatonnes of CO_2, improving the probability of limiting warming to 1.5 °C to 66%. Reducing energy demand and a wholesale shift to low-carbon renewables will also be key.

Annex 2 Tipping points, their current status and 'dangerous' climate change

As mentioned in the introduction, the 'Great Acceleration' into the Anthropocene (Steffen *et al.*, 2015a) has delivered development to an expanding human population at the expense of unsustainable exploitation of nature's resources and the erosion of nature's life-support systems, to the point that some of the planet's environmental boundaries have been, or are about to be, exceeded (Steffen *et al.*, 2015b). This annex considers the evidence for several such boundaries and the degree to which tipping points towards irreversible and dangerous changes are being approached or even exceeded.

A fundamental commitment of the UNFCCC is to avoid '*dangerous anthropogenic interference with the climate system*', commonly referred to as **dangerous climate change**. As part of this, it is also recognised by the IPCC that Earth systems change in a nonlinear manner, referring to '*abrupt or irreversible changes and tipping points*' (e.g. IPCC, 2019b). Recent work also suggests that the Earth's climate does not have stable equilibrium points at any temperature, and shifts from one state may lead to step jumps to very different states, one of which can be characterised as a hothouse Earth incompatible with continued human civilisation and the ecosystems on which we depend (Steffen *et al.*, 2018).

Dangerous climate change lacks a formal scientific definition but the UNFCCC indicates that key factors would be (Article 1.1) '*changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare*'. Article 2 also mentions the need '*to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner*'. The IPCC (2013) states that tipping points involve '*a large-scale change in the climate system … that causes substantial disruptions in human and natural systems*'. They may occur because that part of the climate system exhibits a threshold beyond which even a small perturbation triggers a large change, and where positive feedback mechanisms amplify the initial change. Once triggered, the processes may be irreversible and even returning atmospheric concentrations of GHGs to previous levels does not return the system to its previous state. For instance, returning GHG levels to pre-industrial levels would slow or stop additional loss from melting ice sheets, but not revert them to their previous state; biome shifts in the Amazon rainforest or in boreal forests would not be reversible for many generations.

The IPCC (2018) has identified tipping points as including loss of the West Antarctic and Greenland ice sheets, slowdown of the Atlantic Meridional Overturning Circulation, disruption of the El Niño–Southern Oscillation and the role of the Southern Ocean in the global carbon cycle. Other syntheses have included Amazon rainforest dieback, West African and Indian monsoon shifts, release of methane from permafrost and ocean methane hydrates, coral reef die-off and shifts in the boreal forests. Lenton *et al.* (2019) provide an overview of current trends, concluding that global tipping points pose an existential threat to civilisation, while Ripple *et al.* (2021) point to 16 out of 31 tracked planetary vital signs (including GHG concentrations, ocean heat content and ice mass) as setting new records that indicate that key tipping points are being approached or exceeded as the Earth heats up.

Trends in some tipping points

Melting of both the **Greenland and Antarctic ice sheets** will be the main driver of sea-level rise in the future, since they contain water masses equivalent to a 7-m (Greenland) and 58-m (Antarctica) sea-level rise respectively. The IPCC (2018) concluded that even the low emissions pathways consistent with a 1.5–2 °C warmer world would still represent a moderate risk of triggering irreversible loss of the Greenland ice sheet. More recent measurements of ice loss from 1992 to 2018 (IMBIE, 2020) found that cumulative ice losses from Greenland have been close to the rates predicted by the IPCC for their high-end climate warming scenario, while Hofer *et al.* (2020) point out that the more recent climate models (the sixth phase of the Coupled Model Intercomparison Project, CMIP6) suggest faster rates of melting than in the previous (CMIP5) models. The more recent models suggest losses after 1,000 years of 8–25% (representative concentration pathway (RCP)2.6), 26–57% (RCP4.5), or 72–100% (RCP8.5) of the present-day mass, contributing 0.59–1.88 m, 1.86–4.17 m or 5.23–7.28 m respectively to global mean sea level. Recent work on the current warming in the **Arctic** suggests that the ice is thinning at twice the rate previously thought (Mallett *et al.*, 2021), while Boers and Rypdal (2021) infer that the western Greenland ice sheet has been losing stability and may reach a tipping point beyond which its current configuration would become unstable.

In **Antarctica**, the threshold for survival of Antarctic ice shelves is estimated by Pattyn *et al.* (2018) to be from 1.5 to 2 °C annual average air temperature above present (which, owing to the faster rate of warming near the poles, is likely to be reached within the next decade or so). Slater *et al.* (2020) point out that the current rate of melt is at the high end (RCP8.5) of projections of climate model sea-level rise in the Fifth IPCC assessment. In the past 3 years, the flow of the

Pine Island Glacier (which, together with the Thwaites Glacier impede the flow to the ocean of the West Antarctic Ice Sheet) has increased by 12%, a trend that if continued could destabilise the glacier far sooner than would be expected by surface- or ocean-melting processes (Joughin *et al.*, 2021). Taken together, and including the rise due to thermal expansion in the oceans, the time it will take to reach a sea-level rise of 10 m varies from 10,000 years if warming is limited to 1.5 °C, to less than 1,000 years if warming proceeds above 2 °C.

In its pristine state, the **Amazon biome** is a self-supporting system since intact forest generates around half of its own rainfall through evapotranspiration and convection that create clouds and more rainfall. It has long been recognised (e.g. Salati *et al.*, 1979) that reducing the amount of rainfall or forest can shift the climate into a drier state that cannot support a rainforest, and that the ecosystem will gradually shift to a savanna-like mixture of grassland and woodland. Current trends to forest degradation and reduction in area arising from deforestation are leading to reductions in rainfall and increased drought. This is exacerbated by the reduced rate of transpiration due to the pores in plant leaves opening less as atmospheric CO_2 concentrations increase[4].

Uncertainty remains over effects on future rainfall in the Amazon basin and how the vegetation responds. Currently, losses in the forest area of the Amazon are approaching the 20–25% level that Lovejoy and Nobre (2019) consider will lead to a shift to non-forest ecosystems in eastern, southern and central Amazonia within 50 years (Cooper *et al.*, 2020). Some debate remains over the speed of future shifts and Chai *et al.* (2021) argue that historical records of temperature and rainfall suggest collapse or dieback is not likely this century. However, the Amazon biome has already switched from being a carbon sink to a source of carbon (Gatti *et al.*, 2021). This is attributed to an intensification of the dry season due to climate change combining with deforestation to promote ecosystem stress and an increase in fire occurrence. Within the Amazon, the eastern section, which is around 30% deforested, emits 10 times more carbon then in the west (around 11% deforested). Regardless of the speed of future transitions to a savanna, various adaptation measures have also been proposed that bring benefits irrespective of the rate of future dieback (Lapola *et al.*, 2018).

Aside from the colossal loss of biodiversity, loss of the rainforest's ecosystem services has been valued at US$0.9–3.6 trillion over a 30-year period, while loss of its carbon sink would mean that deeper cuts in emissions elsewhere would be needed to stop the rise in atmospheric CO_2 (Lapola *et al.*, 2018).

Turning to **permafrost**, the amount of carbon accumulated in the frozen ground from the dead plants and animals that have accumulated over thousands of years is around twice as much as in the Earth's atmosphere. Thawing allows biodegradation of the organic carbon in the soil which releases CO_2 and methane, while the heat generated by the bacteria can amplify this process locally. The IPCC (2019a) note that record high temperatures at approximately 10–20 m depth in permafrost have been '*documented at many long-term monitoring sites in the northern hemisphere circumpolar permafrost region*'. In some places, these temperatures are 2–3 °C higher than 30 years ago and may already be releasing an estimated 300 million to 600 million tonnes of net carbon per year (https://arctic.noaa.gov/).

The IPCC (2019a) estimate that by 2100 the near-surface permafrost area will decrease by 2–66% for RCP2.6 and 30–99% for RCP8.5; this will release tens to hundreds of gigatonnes of carbon as CO_2 and methane to the atmosphere, accelerating climate change. Such permafrost thaw would be irreversible on timescales relevant to human societies and to natural ecosystems. The same warming trends that are melting permafrost also threaten to release methane from methane hydrates found in large quantities under the seafloor on continental shelves, although the rate of release remains uncertain.

The **boreal zone,** along with the tundra, is warming rapidly and continued temperature rise is associated with dieback and increased vulnerability to disease and fires (Lenton, 2012; Seidl *et al.*, 2017). Siberian fires are an indication of this trend underway.

Overall situation

The evidence above is that humanity has already entered irreversible changes in ice sheet melt and is in danger of passing points of no return in critical biomes such as the Amazon, as well as starting emissions of naturally captured CO_2 and, potentially, methane. In addition to this concerning conclusion, Lenton *et al.* (2019) point to the interactions between climate features that add to the already large risks. For instance, Rocha *et al.* (2018) found that exceeding tipping points in one system can increase the risk of crossing them in others, and that such links were found for 45% of possible interactions. Wunderling *et al.* (2021) found that even at the Paris Agreement level of 2 °C warming, interactions tend to destabilise a network of tipping elements, with the polar ice sheets on Greenland and West Antarctica the

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[4] Smaller pores lose less water, so less water returns to the atmosphere through transpiration.

initiators of tipping cascades including a shift in the Amazon biome. Uncertainty also remains over exactly what temperature may lead to irreversible changes in each of the possible tipping points, and whether short-term overshoots would still allow the transition to a vastly different state to be avoided if temperatures could be swiftly reversed (Ritchie *et al.*, 2021).

Overall, from a policy perspective there is a danger in seeing the debate over tipping points as implying that these points are single indicators that can be monitored, and their status assessed for action to be taken in time to avoid the most dangerous effects. The interactions above make risk assessment very difficult and impractical to use in a policy framework. In addition, as pointed out by Heinze *et al.* (2021), the combination of stressors (for the ocean the combination of warming, declines in oxygen levels and increasing acidification) may lead to a 'quiet crossing of tipping points' that may be as significant (and irreversible) as single catastrophic events. For instance, Agostini *et al.* (2021) found that while warming alone led to 'tropicalization' whereby tropical corals, fishes and other species gradually replace temperate ecosystems such as macroalgal forests, this trend was disrupted by acidification of seawaters. Instead, the combination of warming and increased acidity led to simplified marine habitats swamped by green algae that severely reduced the provision of goods and services

Considering tipping points and the trends towards dangerous climate change thus merely reinforce the urgency of achieving the sharp reduction in emissions required to meet the commitments in the Paris Agreement to limit global warming to well below 2 °C, preferably to 1.5 °C, compared with pre-industrial levels.

The debate about tipping points also needs to be seen in the context of limits to the adaptability of human societies. As pointed out by Xu *et al.* (2019), human populations have resided for millennia in the same climate characterised by a mean annual temperature of around 11–15 °C, a climate niche shared by the crops and livestock on which we have depended. Current trends show that the areas within this temperature niche will shift substantially over the next 50 years, and one-third of the global population is projected to experience a mean annual temperature of over 29 °C currently found in only 0.8% of the Earth's land surface (mostly in the Sahara). Such catastrophically disrupting trends will be experienced as gradual incremental changes rather than passing any arbitrary tipping point; nevertheless, they will be irreversible and devastating in their impact.

Related studies by Raymond *et al.* (2020) point to the combined effects of heat and humidity on the human body and that a wet-bulb temperature (a means of measuring the combined effects) of 35 °C marks the body's upper physiological limit, while much lower values have serious health and productivity impacts. Some areas have already reported such extremes, and weather station data show that their frequency has more than doubled since 1979. Increasing areas of the planet where it becomes physically impossible to live, let alone function in a society, can be predicted as average global surface temperatures rise. Further calculations by Suarez-Gutierrez *et al.* (2020) show that, at above 3 °C of mean post-industrial warming, maximum monthly wet-bulb temperatures above 26 °C are expected to occur over large areas in all continents; while projections surpass the 28 °C danger threshold for vulnerable individuals on average for an entire month over parts of east China, the Arabian Peninsula, Pakistan and northern India. Although, as mentioned above, there is no scientific definition of 'dangerous' in the UNFCCC, these trends raise concerns about whether its commitment to avoid 'dangerous anthropogenic interference with the climate system' can be achieved.

Finally, from the perspective of palaeology, atmospheric CO_2 is already at levels last seen around 4 million years ago in the Pliocene epoch. It is rapidly heading towards levels last seen some 50 million years ago in the Eocene epoch, when temperatures were up to 14 °C higher than they were in pre-industrial times. Such changes clearly are existential threats to civilisation and not assessable through cost–benefit analysis (EASAC 2020b).

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