The Royal Society – Written evidence (NSD0050)

Summary

- Land and marine ecosystems play a fundamental role in the world's climate and efforts to stabilise it. Protecting, restoring and managing the world's land and marine systems sustainably can contribute to achieving net zero greenhouse gas (GHG) emissions by 2050 as well as adapting to the impacts of climate change. Land-based mitigation could provide up to 20 – 30% of the net emissions reductions needed by 2050 to keep the global average temperature rise to 1.5 – 2°C, but will only be effective if combined with rapid and deep reductions in fossil fuel emissions. Nature-based solutions should play a vital role in the strategy for combating climate change while delivering multiple co-benefits for society.

Introduction and Overview

- The Royal Society welcomes the opportunity to submit evidence to the Committee's inquiry into nature-based solutions for climate change to assist in achieving the UK's target of net zero greenhouse gas emissions by 2050. The Society is the National Academy of Science for the UK and the Commonwealth. It is a self-governing Fellowship of many of the world's most distinguished scientists working across a broad range of disciplines in academia and industry. The Society draws on the expertise of its Fellows and Foreign Members to provide independent and authoritative scientific advice to UK, European and international decision makers.

- This submission draws on a number of existing pieces of work, works-in-progress and the specific expertise of fellows. This includes our recent report on 'Climate Change and Land: the science of working with nature towards Net Zero'[1], our report on 'Why efforts to address climate change through nature-based solutions must support both biodiversity and people'[2] and our workshop on how UK research can contribute to the UN Decade of Ocean Science[3], as well as our upcoming report on 'Multifunctional Landscapes' and briefing entitled 'Climate Change and Biodiversity: interlinkages and policy options'.

The relationship between Nature-based Solutions and emissions reductions

Ambitious climate change mitigation action that combines rapid phasing out of fossil fuel use with rapid scaling-up of robust, sustainable nature-based solutions will significantly reduce the severity of impacts on societies and ecosystems. However, researchers stress that nature-based solutions for climate change mitigation and adaption need to be used as a complement to, and not a substitute for, rapid reductions in fossil fuel consumption and emissions.

The land, with the ocean, has effectively soaked up more than half of the greenhouse gases humans have put into the atmosphere since the Industrial

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[1] https://royalsociety.org/-/media/policy/projects/climate-change-science-solutions/climate-science-solutions-land.pdf
[2] https://royalsociety.org/topics-policy/projects/biodiversity/nature-based-solutions/
[3] https://royalsociety.org/topics-policy/publications/2021/ocean-decade-workshop/

Revolution[4]. However, the land's capacity to absorb carbon is already being weakened by the impacts of climate change[5], and there is no guarantee that land and ocean will continue to absorb CO_2 as it has done historically if atmospheric levels continue to rise[6]. Climate change may itself reduce land and ocean sink capacities if greenhouse gas emissions are not reduced rapidly.

Emissions also arise through self-reinforcing effects as a result of the impacts of climate change: for example, as land is degraded through forest fires which emit carbon or as permafrost melts and carbon dioxide and methane are emitted[7]. The IPCC concluded that the net impact of climate change on carbon cycle processes will be 'to exacerbate the increase of CO_2 in the atmosphere'[8].

Carbon offsetting programmes cannot therefore be seen as a 'get-out-of-jail-free' card for emitters, tradable for any volume of fossil fuel emissions. Nature-based mitigation options are not a substitute for immediate and aggressive emission reduction across all sectors. However, if fossil fuel emissions are cut, terrestrial and marine nature-based solutions can still play an important part for climate change mitigation and adaptation[9].

Nature-based solutions as part of multifunctional landscapes

There is a role for land and marine areas in addressing climate change through a variety of interventions. Activities that reduce or avoid emissions include conserving forests, grasslands, coastal wetlands, seagrass meadows or peatlands – thus preventing emissions from their conversion or degradation – and sustainable agricultural methods which build soil carbon and release fewer greenhouse gas emissions.

'Nature-based solutions' are intended to protect, sustainably manage, and restore ecosystems that address environmental societal challenges while providing human wellbeing and biodiversity benefits.

These challenges range wider than mitigation and adaptation to climate change – nature-based solutions may also be employed to reduce risk from environmental hazards such as flood, fire or drought, and often will address

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[4] The Royal Society. 2021. Briefing 7 | The Carbon Cycle: better understanding carbon-climate feedbacks and reducing future risks. Available at: https://royalsociety.org/topics-policy/projects/climate-change-science-solutions/

[5] . IPCC. 2014 Future climate changes, risks and impacts. In: Climate Change 2014: synthesis report. Contribution of working groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change. Pachauri, Meyer LA et al. (eds). Geneva, Switzerland: IPCC. See https://ar5-syr.ipcc.ch/topic_futurechanges.php

[6] The Royal Society. 2021. Briefing 7 | The Carbon Cycle: better understanding carbon-climate feedbacks and reducing future risks. Available at: https://royalsociety.org/topics-policy/projects/climate-change-science-solutions/

[7] . National Academy of Sciences, The Royal Society. 2019 Climate change and ecosystems. See https://royalsociety.org/-/media/about-us/ international/climate-change-and-ecosystems-2019.pdf

[8] IPCC. 2013 Summary for policymakers. In: Climate Change 2013: the physical science basis. Contribution of working group I to the fifth assessment report of the Intergovernmental Panel on Climate Change. Stocker TF et al. (eds). Cambridge, United Kingdom: Cambridge University Press. See https://www.ipcc.ch/site/assets/uploads/2018/02/ WG1AR5_SPM_FINAL.pdf

[9] Anderson CM et al. 2019 Natural climate solutions are not enough. Science 363, 933–934. (doi:10.1126/science.aaw2741)

multiple challenges at once as well as providing a range of other benefits[10]. For example, afforestation and reforestation alone can potentially contribute to 13 of the 17 UN SDGs if undertaken sustainably[11]. Nature-based solutions can, when delivered strategically and in consultation with local communities, give rise to multiple ecosystem services at once while supporting healthy lives and stimulating economic development[12]. Artificial solutions (such as carbon-capture and storage or built flood defences), though appropriate in certain circumstances, tend to address only the problem for which they were built.

The nature-based solutions concept is also grounded in the knowledge that biodiversity loss and climate change share many of the same drivers and hence share some of the same solutions. In particular, land use change is both the biggest driver of biodiversity decline (accounting for approximately 30% of the decline in global terrestrial habitat integrity[1]) and the second biggest source of GHG emissions (accounting for 23%)[13]. Protecting or enhancing carbon stores through the restoration of natural ecosystems can therefore, in theory, both reduce warming and slow biodiversity decline.

<u>Detailed responses to the Committee's Questions</u>

1. What is the potential scale of the contribution that nature-based solutions can make to decarbonisation in the UK?

Which ecosystems are most relevant to the UK for nature-based solutions, and which have the largest potential to sequester carbon or reduce emissions?

- Peatlands
- Woodland and forests
- Agricultural land
- Coastal zones
- Urban areas

How much of the UK's 'hard-to-mitigate' emissions can be offset by nature-based solutions? How much of the UK's land and exclusive economic zone (EEZ) coastal areas would need to be managed to achieve this, and what level of investment would be required?

Peatlands encompass a diverse set of lowland and upland landscapes. They store an estimated 40% of the UK's soil carbon, mainly in upland peat soil which holds nearly 300 Mt of carbon. However, peatlands in a near-natural state have a moderate carbon sequestration effect, but only 23% of the UK's peatlands fall into this category. Peatlands which are used for cropland, grazing, forestry or

[10] The Royal Society. 2021. Briefing 8 | Weathering the storm: how science can contribute to improving global climate resilience through adaptation. Available at: https://royalsociety.org/topics-policy/projects/climate-change-science-solutions/
[11] Strassburg et al. 2020 Global priority areas for ecosystem restoration. Nature.
[12] Yachi S and Loreau M. 1999 Biodiversity and ecosystem productivity in a fluctuating environment: the insurance hypothesis. Proc. Natl. Acad. Sci. USA 96, 1463 – 1468. (https://doi.org/10.1073/pnas.96.4.1463)
[13] IPCC. 2019 Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems Shukla PR et al (eds).

direct extraction for horticultural use or fuel contribute to the UK's carbon emissions (see table). While it is important to restore peatlands or modify their management to reduce land use emissions and increase long-term carbon storage capacity, they should not be relied on as a major source of negative emissions. According to the CCC, restoring 50% of upland peat and 25% of lowland peat would reduce annual peatland emissions by 5 $MtCO_2e$ per year by 2050[14]

Habitat type	Land area (ha) [year of data collection]					Proportion of UK peatlands	Contribution to UK total Emissions (Mt CO_2 equivalent)
	England [2013]	Wales[1990]	Scotland[1990]	N Ireland [2007]	UK Total		
*Near-natural	134,885	26,222	490,497	41,281	692,885	23%	-1.8
Semi-natural	214,528	38,638	958,087	45,423	1,256,676	42%	3.4
Arable cropland	182,701	102	8,181	3,141	194,125	7%	7.6
Grassland	75,576	15,570	110,435	33,180	234,761	8%	6.3
Woodland	65,492	9,520	332,746	31,534	439,292	15%	4.6
Extracted	9,019	0	47,804	88,064	144,887	5%	1.2
Total	**682,201**	**90,052**	**1,947,750**	**242,623**	**2,962,626**		**21.3**

Source: https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1904111135_UK_peatland_GHG_emissions.pdf

Woodland and forests

A primary objective of woodland creation is to increase the UK's carbon stock – the total carbon stock of all species of tree within English forests as at 31 March 2020, is estimated to be 125 Mt of carbon (459 Mt CO_2e)[15]. Broadleaf trees, have an estimated carbon stock of 95.5 Mt (350 Mt CO_2e). Conifer trees, have an estimated carbon stock of 30 Mt (109 Mt CO_2e). Mixed woodland may be more effective at increasing carbon uptake and biodiversity.[16][17] Soil carbon stocks in forestry soils are variable depending on the soil type and varies throughout the soil profile. Despite being of importance to climate change mitigation, soil carbon pools are not measured routinely, and so are an uncertain component of forest carbon cycles[18].

The rate of carbon sequestration over time varies depending on species planted (see below figure) and management strategy. For instance, native broadleaf woodlands with no intervention sequester less carbon than non-native conifers for the first 20 years after planting, but offer over double the carbon

14 https://www.theccc.org.uk/publication/land-use-reducing-emissions-and-preparing-for-climate-change/

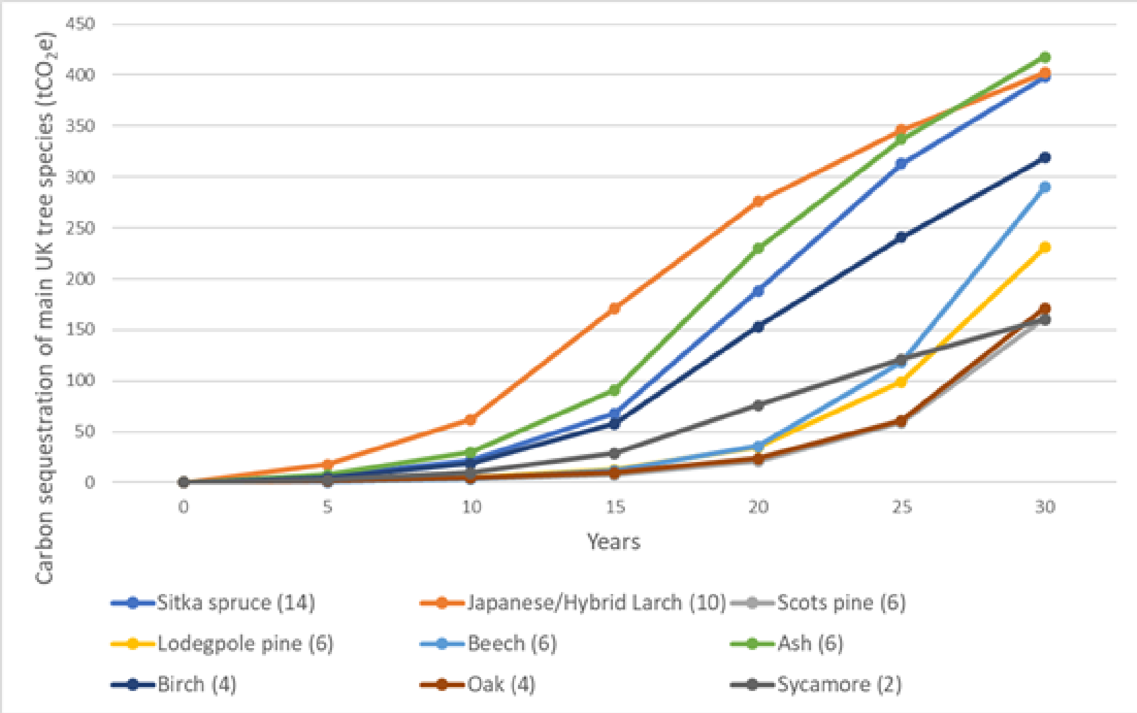
15 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/925426/9_Greenhouse_gas_removal_2020_accessible.pdf

16 https://www.scopus.com/record/display.uri?eid=2-s2.0-85082833000&doi=10.1016%2fj.foreco.2020.118127&origin=inward&txGid=d9c253f04316d582498e6effbeca4ce9

17 Carbon Storage and Sequestration by Habitat 2021 - NERR094 (naturalengland.org.uk)

18 https://doi.org/10.1111/sum.12025

sequestration per hectare 60 years after planting, due to different growth rates in the species.



Carbon sequestration rates for nine of the predominant tree species generated using the CARBINE carbon accounting tool. Yield classes (given in brackets) were taken from median YC for each species based on National Forestry Accounting Plan 2021-2025.

Approximately 41% of woodlands are unmanaged, which can have negative consequences for biodiversity. The CCC recommends that unmanaged broadleaf forest will be brought back into production, with 80% actively managed by 2030. Management strategies, such as thinning (as opposed to clear felling)[19],[20], can improve forest growth. Managing a diversity of trees (not just for species, but for stand age as well) can also help to support more resilient woodlands.[21],[22]

Agricultural land

There are many "agroecological" techniques which may reduce emissions or facilitate negative emissions from farming that can have a neutral or positive impact on yield. These include habitat integration on areas of low productivity, intercropping, rotational farming or reduced tillage.[23]

Organic farming depends on natural alternatives to mineral and chemical fertilisers, herbicides or pesticides. It can reduce emissions and build soil carbon.

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[19] https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/forestry-statistics-2020/4-carbon/

[20] Land use: Policies for a Net Zero UK - Climate Change Committee (theccc.org.uk)

[21] https://doi.org/10.1093/forestry/cpt012

[22] https://doi.org/10.1093/forestry/cpp023

[23] Lopez Barrera E, Hertel T. 2021 Global food waste across the income spectrum: implications for food prices, production and resource use. Food Policy 98, 101874. (doi:10.1016/j.foodpol.2020.101874)

Use of organic methods on agricultural land (particularly grades I-III) which result in reduced yields could risk displacing food production overseas to countries with otherwise higher biodiversity and lower environmental standards. Models suggest that, if England and Wales switched completely to organic farming, the greater reliance on imports would lead to an increase in total greenhouse gas emissions associated with food supply (known as "carbon leakage").[24]

In addition, it will be necessary to reduce food waste, promote sustainable diets, adopt novel technologies (such as those supported by the Innovate UK Transforming Food programme[25]) as well as understand why and where yield gaps are occurring[26]. The resulting land that could be freed up via this combined approach has the potential to provide space for nature-based solutions without risking carbon leakage. A mix of sustainably high-yield farming, low-intensity farming and land managed primarily for nature (the "three-compartment model") is likely to be optimum for meeting climate and nature goals whilst maintaining a sustainable food supply, though land within each compartment should still be managed for multiple, locally appropriate benefits.[27][28]

Coastal ecosystems & marine protected areas

Coastal ecosystems sequester substantial amounts of carbon (known as blue carbon) as well as protecting and supporting coastal communities; their protection and enhancement can therefore deliver multiple benefits. Blue carbon systems offer an emerging opportunity to support the UK Government in tackling the dual issues of climate change and biodiversity loss, as well as delivering social co-benefits. Blue carbon ecosystems include reefs, seagrass ecosystems, mudflats, mangroves, and maerl beds, all of which are found in the UK or UK Overseas Territories. More research is needed into the carbon sequestration rate and stock capacity of UK blue carbon ecosystems and the role of nature-based solutions within them.

The contribution of blue carbon solutions to climate mitigation depends on the health of coastal ecosystems. Marine ecosystems face an array of human and environmental pressures, including from land-use, pollution, and over exploitation, and in future will experience growing pressure from sea-level rise, as well as ocean warming, acidification and deoxygenation. Further research into the pressures blue carbon systems face, including how multi-stressors interact with one another and how they might change in severity with climate change, is needed to better understand the usefulness of blue carbon nature-based solutions.[29]

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[24] https://www.nature.com/articles/s41467-019-12622-7

[25] https://www.ukri.org/our-work/our-main-funds/industrial-strategy-challenge-fund/clean-growth/transforming-food-production-challenge/

[26] R. Sylvester-Bradley, S. Clarke, D. Kindred, S. Roques, P. Berry and S. Welham (2019) Variation across scales indicates that best progress in crop yields should come from farmer-centric research pp 917-924 Conference Proceedings: Precision Agriculture '19, Ed. J.V. Stafford. 1030 pp., Wageningen Academic Publishers, The Netherlands.

[27] Finch, T, Day, BH, Massimino, D, et al. Evaluating spatially explicit sharing-sparing scenarios for multiple environmental outcomes. *J Appl Ecol*. 2021; 58: 655– 666. https://doi.org/10.1111/1365-2664.13785

[28] https://www.nationalfoodstrategy.org/

[29] The Royal Society. 2021. UN Decade of Ocean Science workshop - full report. Available at:

Successful deployment of marine nature-based solutions primarily requires enhancing, restoring or protecting existing coastal ecosystems. As on land, introducing new species or creating new ecosystems where they do not already occur can have trade-offs if not implemented carefully. For instance, encouraging seagrass growth where it does not already grow naturally can sequester carbon, but will greatly disrupt existing ecosystems and may harm community lifestyles[30]. Similarly, disrupting ecosystems to create new habitats may disturb marine sediments and release carbon. Bespoke, localised strategies are needed, based on existing ecosystems and community practices, to deliver optimal benefits[31].

Expansion of the UKs Marine Protected Areas network, as well as new investment in their management and enforcement of protection rules will improve their efficacy, therefore helping to ensure marine carbon sequestration capacity and carbon stocks are maintained[32].

How do the costs and benefits (including co-benefits), of implementing nature-based solutions compare to other techniques for offsetting 'hard-to-decarbonise' sectors?

Carefully implemented nature-based solutions are an effective way of delivering multiple benefits for climate mitigation and adaptation, while supporting the livelihoods of UK communities and protecting biodiversity. They can be a highly effective carbon sequestration strategy, though they must be implemented carefully to deliver optimal benefits. Planting trees to sequester carbon is a viable and robust offsetting strategy available today, but may not deliver wide-ranging co-benefits if not implemented using NbS principles. In contrast, non-NbS approaches, such as carbon capture and storage technologies used in tandem with Bioenergy (BECCS) are in their infancy with no certainty around the scalability required to meet CCC's 6th Carbon Budget[33]. Moreover, the land use component required to support this (estimated at between 0.7-0.8 Mha across the UK by 2050[34]) would be an opportunity cost for further nature-based solutions. Other key greenhouse gas removal technologies such as enhanced weathering, biochar in agricultural soils, and direct air carbon capture and storage are not yet proven viable technologies and require substantial testing to ensure their environmental safety is acceptable for widespread use[35].

2. What major scientific uncertainties persist in understanding the effects of nature-based solutions and affect their inclusion in carbon accounting, and how can these uncertainties be addressed?

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https://royalsociety.org/topics-policy/publications/2021/ocean-decade-workshop/

[30] The Royal Society. 2021. UN Decade of Ocean Science workshop - full report. Available at: https://royalsociety.org/topics-policy/publications/2021/ocean-decade-workshop/

[31] The Royal Society and Royal Society of Edinburgh. 2021. Workshop: From coast to countryside: interlinkages between biodiversity and climate change.

[32] The Royal Society. 2021. Briefing: Climate change and biodiversity – interlinkages and policy options.

[33] https://www.theccc.org.uk/publication/sixth-carbon-budget/

[34] https://www.theccc.org.uk/wp-content/uploads/2020/12/UK-CEH-Updated-quantification-of-the-impact-of-future-land-use-scenarios-to-2050-and-beyond.pdf

[35] https://royalsociety.org/-/media/policy/projects/greenhouse-gas-removal/royal-society-greenhouse-gas-removal-report-2018.pdf

How reliable are the estimates of the quantity of greenhouse gas emissions reduction or sequestration by nature-based solutions, as well as the duration and reliability of storage?
Better monitoring and verification systems are needed with clear standards to show that land-based options are delivering genuine emissions reductions. Further research can help identify good practice and performance metrics. A major concern with implementing these options is 'leakage', say if land is restored in one area, land clearing may then take place in another. Better monitoring standards can address this, along with the general aims of NbS as a holistic approach to ecosystems services.

Understanding how biodiversity will respond to climate change at the local or regional scale in the face of multiple, interacting stressors may also improve our estimates of the efficacy of nature-based solutions. Stressor interactions are complex and may lead to ecosystem changes which are more substantial than expected. Study of the susceptibility of species to climate change, the prevalence of climate extremes, and how biodiversity change impacts ecosystem functioning and human wellbeing will also further our understanding of the durability and reliability of nature-based solutions in the face of environmental change[36].

Which bodies should be involved in establishing an agreed evidence base to inform best-practice techniques for restoring peatlands?

To what extent do we understand the capacity of the oceans and coastal ecosystems to sequester greenhouse gases through nature-based solutions?
Coastal and marine ecosystems have a high capacity to sequester and store carbon. However, there is uncertainty in the rate and carbon storage capacity of different coastal and marine ecosystems in different areas, especially in light of climate-related stressors. Further developing approaches towards quantification of blue carbon storage, as well as understanding their present and future benefits and vulnerabilities, is needed to improve our understanding of the capacity of oceans and coastal ecosystems to sequester and store carbon.

There remains great uncertainty over how the efficacy and capacity of coastal carbon sinks will change in the future, following human and environmental pressure. There will be multiple stressors acting synchronously on coastal ecosystems; understanding how each stressor will change, interact, and impact coastal ecosystems is needed. To help address this, there is a need for improved monitoring and data gathering of coastal ecosystems to better understand the complex and interrelated stressors faced by these systems at varying scales.

Questions we need to address to help improve our understanding include[37]:

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[36] The Royal Society. 2021. Climate change and biodiversity: insights from the Royal Society Global Environmental Research Committee.
[37] The Royal Society. 2021. How UK research can contribute to the UN Decade of Ocean Science. Available at: https://royalsociety.org/topics-policy/publications/2021/ocean-decade-workshop/

- What are the non-climate anthropogenic stressors on marine environments (such as sediment influx and pollution) and how might they change in the future?
- What are the environmental stressors on marine environments (such as ocean warming and acidification)
- What are the cumulative impact of pressures?
- How does land-use change effects blue carbon systems?
- What is the impact of expansion of ocean-based activities, including offshore energy and mining?
- What indicators can be established and used to measure ecosystem health and vulnerability?
- Which regions are undergoing the most change and at what rate?
- Where can coastal ecosystems be most easily and rapidly restored?

3. What frameworks already exist for the regulation and financing of nature-based solutions?

What can be learned from the implementation of the Woodland and Peatland Codes for the regulation and financing of nature-based solutions?

Are there good examples of nature-based solutions already being undertaken in the UK or elsewhere, and what can we learn from them?

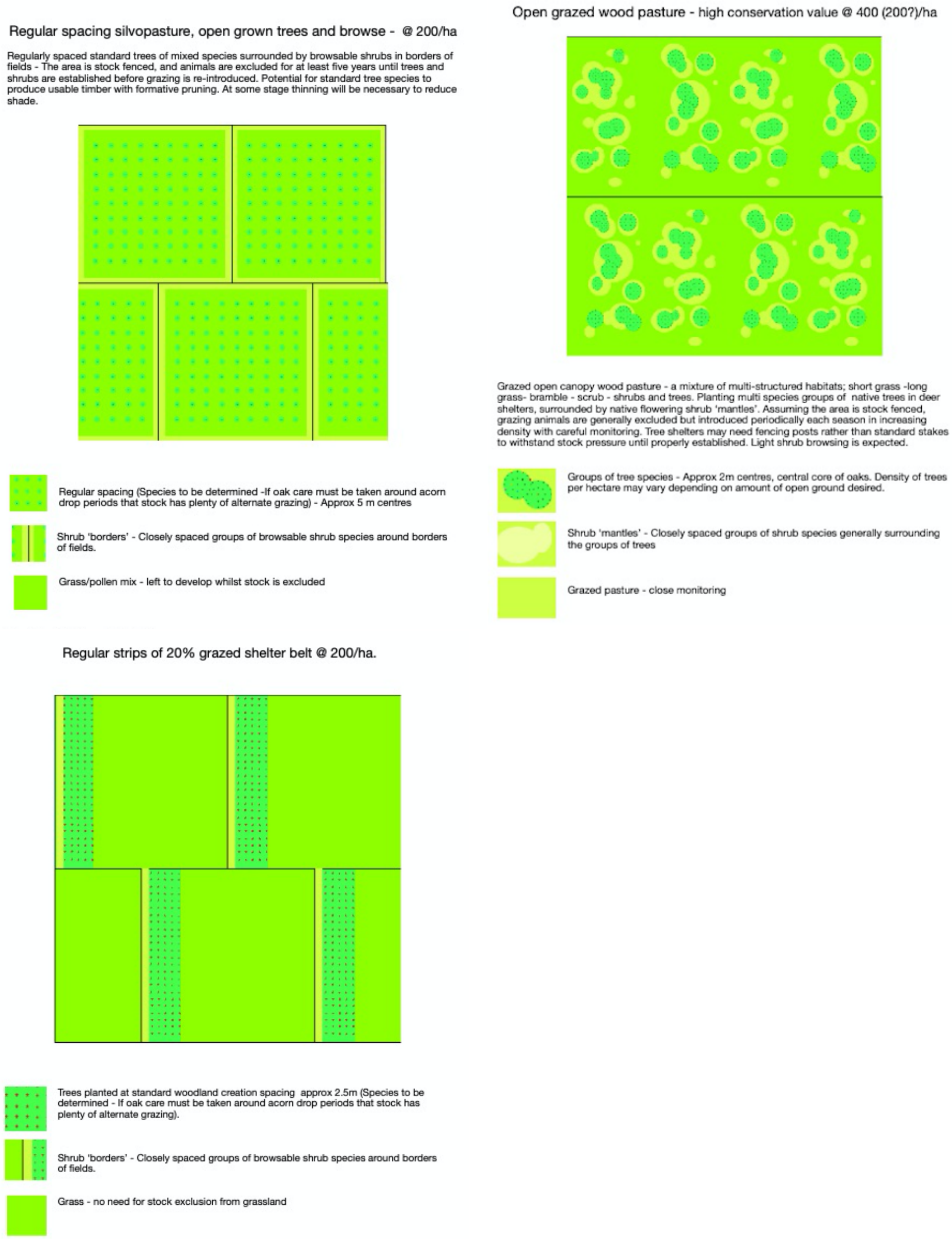
<u>Example 1</u>

Silvopasture Field Lab, Devon

Rothamsted Research North Wyke in collaboration with The Farming and Wildlife Advisory Group, Woodland Trust and Organic Research Centre have begun a £100,000, 12-year trial of silvopastoral farming – blending forestry with livestock – with eight farmers across Devon. The trial will examine overall productivity in tandem with delivery of ecosystems services, such as biodiversity, water and air quality, soil health and carbon sequestration. Silvopasture can offer shade and shelter for livestock and pasture, granting a protective effect through changing seasons. The mix of broadleaf trees being planted for the trial include Oak, Willow and Hazel which offer nutritional and medicinal benefits to the livestock. The trees will be actively managed for timber, providing ongoing financial return for the farm businesses.

The trial will examine three different designs of silvopasture (see fig). The fields in the trial vary from 0.7 – 4.5 ha, with a total of 43 ha across the trial. A key objective will be to evaluate the impact of silvopasture on the soil health of the farms. More than 1,500 soil samples have been taken to assess the initial state of the soils including their organic carbon content. Further objectives include the evaluation of animal behaviours such as how they use the silvopasture areas, impacts on health and productivity, biodiversity monitoring to look at population trends of birds, bats, moths and invertebrates, and practical considerations around the establishment and management of silvopasture across the three different designs. The trial will also monitor the dynamics of pasture production as the trees develop and how this changes under different management and thinning regimes.

Fig 1:



Example 2

The Dell Estate mixed objective woodland, Forest Carbon collaboration, Inverness-shire

Forest Carbon was set up in 2006, to facilitate woodland development for the carbon market. They have created 6,500 hectares of forestry with more than 10 m trees planted, equating to 2.1 mtCO_2e transacted across 220 projects. One such project is a 300 ha mixed woodland on the Dell Estate spread across a range of altitudes in Fort Augustus on the southern bank of Loch Ness in Inverness-shire.

Beginning in 2011, the Green Insurance Company and Allstar Business Solutions partnered with Forest Carbon to create a multifunctional forest with three components. The lower ground has been designated for timber production with Lodgepole Pine and Sitka Spruce due to the greater ease of access for maintenance and felling and better-quality soil. On the mid-altitude slopes there is new native Caledonian Pinewood stock. The rockier uplands are being forested with native broadleaf woodland through natural succession of birch, alder, juniper, aspen, ash, oak and rowan. The woodlands help to support habitat connectivity providing habitats for several protected species including red squirrels, pine martens, crested tits and crossbills. Across the entire site, the anticipated CO_2 capture will be more than 80,000 tonnes over 70 years.

Example 3

Garron Plateau Bog Restoration, Antrim

The Garron Plateau in Antrim is the largest blanket bog in Northern Ireland. During the 1960s, gullies were dug into the peat to lower the water table allowing for the grazing of livestock. The drying of the plateau led to changes in its vegetation from mainly sphagnum mosses to coarse grasses, which themselves were then reduced through grazing and trampling by livestock. The peatland was then vulnerable to even further erosion through weathering by wind and rain.

This resulted in the peatlands becoming inhospitable to many of its native species, an increased level of dissolved organic carbon output into the local water catchment and causing net carbon emissions of the estimated 6 Mt of carbon stored across the plateau.

In 2013, the RSPB NI Futurescapes programme formed a partnership with the Northern Ireland Environment Agency and Northern Ireland Water, in which 2000 ha were designated for rewetting by refilling the trenches, restoring native vegetation and reducing livestock density.

The result has been a return of rare species like the plant marsh saxifrage or birds such as hen harriers, curlews and cuckoos. There have also been public health and commercial benefits. Raw water quality coming off the bog having improved, with colour, turbidity and total organic carbon being reduced and attenuated since the restoration began – requiring less processing before serving the 14,000 households in the surrounding Dungonnell catchment. With time this restoration will also allow the plateau to return to being a valuable carbon sink that contributes to climate change mitigation.

How should a hybrid public-private financing model be regulated? How should any carbon offsetting markets be regulated to ensure that they prioritise and support well-designed and effective nature-based solutions?

Finance is essential to engendering new climate change mitigation projects. Carbon markets can facilitate private sector investment in natural climate solutions.

Businesses in the UK voluntary carbon market purchase carbon for a variety of reasons. They may do so to report carbon credits against their emissions from UK-based operations, fulfil internal Corporate Responsibility targets, or for public relations exercises.

Carbon standards are crucial to ensuring the integrity of carbon markets. In the UK, the Woodland Carbon Code, the peatland code, and the ICROA Code of Best Practice are available. Carbon standards are essential to certify that projects are well managed and effective, and are crucial for investor confidence.

Natural climate solution projects can sell their carbon in two ways. Firstly, carbon credits can be sold as *Ex-ante* credits through Pending Issuance Units, which acts as a promise to deliver a predetermined amount of carbon sequestration in the future. Pending Issuance Units can be converted to verified carbon units throughout the project's lifetime. Secondly, *Ex-post* credits, which represent verified carbon sequestration, can be sold.

There are several conditions for success of woodland carbon sequestration projects. Collaboration is highly important in creating and managing successful and productive natural climate solutions. Use of domestic carbon codes provides authority, integrity and rigour to the projects, inspires investor confidence, and provides scope for evolution of carbon standards. Liquidity up-front is essential for initiating projects. Trusted intermediaries between landowners and investors are also needed to ensure productive project development and management. Furthermore, willingness to learn helps participants understand the available opportunities and limitations.

The imperative placed on organisations to meet net zero targets has caused demand to far exceed supply in the UK, with investors seeking unrealisable quantities of sequestered carbon over unfeasibly short time scales. This challenge is compounded by increases in carbon prices, which incentivises farmers to delay carbon sequestration initiatives in expectation of further price rises.

Regulation may benefit from being grounded in principles of effective NbS-building, including finding a way to measure value and co-benefits outside of traditional financial value, and including local communities in the design and management of NbS strategies[38].

[38] https://www.naturebasedsolutionsinitiative.org/nbs-case-studies/, NB much of this section is taken close to

How can we ensure that the carbon accountancy is science-based, robust, and consistent across nature-based solutions?
New markets are arising, including biodiversity, soil carbon and blue carbon markets. The organisation Forest Carbon is working to develop codes of best practice for soil and blue carbon markets.

New technologies, including blockchain and remote sensing for verification, will play a role in further catalysing carbon markets in the UK.

As carbon markets continue to expand, a keen focus on additionality must be maintained. Additionality is the principle that sequestered carbon for sale would not have been possible without investment. This tenet therefore underpins carbon markets and the UK's move towards a net zero society.

4. Who are the key stakeholders for the implementation of nature-based solutions in the UK? How can stakeholders' expertise and concerns inform the incentives and requirements for implementing nature-based solutions?

How can farmers (including tenant farmers) and land managers be supported in their deployment of nature-based solutions by policy and legislative frameworks?

Are there examples of projects which have engaged with stakeholders and local communities to implement nature-based solutions successfully, and what can we learn from them?
UK NbS stakeholders include farmers, agricultural businesses, landlords, wildlife trusts, national parks, communities working with or situated near peatland, UK coastal managers, communities in proximity to NbS strategies (both in urban and rural areas), and coastal communities.

Several principles emerge from NbS case studies[39]. Firstly, engagement with local communities at the planning to the implementation and management stages is essential. Local communities will have specific views and values which will not be evident without thorough engagement. For an NbS to be successful, it must not conflict with local values. Education programmes and fora for discourse can help build relationships with local communities, understand their views, and make clear the benefits NbS can bring.

5. How should implementation of nature-based solutions be integrated with other government policies for landscapes and seascapes, for example, agricultural, forestry, and land-use planning policies?

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verbatim from discussion at our Creating Connections event: from coast to countryside – interlinkages between biodiversity and climate change.

[39] https://www.naturebasedsolutionsinitiative.org/nbs-case-studies/

How could nature-based solutions implementation contribute to the UK's goals surrounding biodiversity, the preservation of nature, and adaptation to climate change?

In its forthcoming *Multifunctional landscapes* report, the Royal Society will make policy recommendations to facilitate a strategic approach to land use planning which integrates objectives for climate, nature, food and development. In brief and subject to change, these recommendations are:

1. **National objectives for land use should be expressed in National Land Use Frameworks** which guide how and where objectives could be met. England, Scotland, Wales and Northern Ireland should establish frameworks that reflect their unique contexts, but in the case of UK-wide objectives (such as net zero), the division of responsibility for meeting them should be agreed collectively. International obligations, national government priorities and public deliberation should inform national objectives, which should take into account the need to maintain and build natural capital stocks.
    a. **National Land Use Frameworks should reconcile land use objectives** for food and fibre production, development, climate change mitigation and adaptation, nature recovery and societal health and wellbeing – **this will require integration of planning for development with other aspects of land use**.
    b. The design of National Land Use Frameworks should take into account socioeconomic consequences such as effects on rural communities, food prices, employment and trade. This will require **development of advanced interdisciplinary analytical capabilities and policy join-up beyond the agriculture and the environment sectors.**
    c. **The "three-compartment model"** (in which areas are identified as broadly suited to high-yield farming, low-yield farming or semi-natural land), advocated by the recently published National Food Strategy, is useful to identify areas that are best suited to deliver different national objectives, but it is vital that **multifunctionality and sustainability are embedded within each compartment**.
    d. National Land Use Frameworks should not narrowly dictate how land will be used but should provide the scaffold within which to **develop "Place-based" Land Use Frameworks, informed by locally appropriate data and with input from local stakeholders.** Place-based land use frameworks should cover the whole country. **Vertical coordination will be needed between national and subnational levels** to ensure that, collectively, place-based frameworks align with national objectives.
    e. **A statutory, independent body should be tasked with monitoring and reporting on progress towards land use objectives,** so that progress is maintained in the face of the numerous short-term challenges any administration will face. We do not make specific recommendations about its constitution, nor whether it requires a new body or an extension of the remit of an existing body.

2. **Comprehensive, long-term monitoring programmes and the ability to integrate data** across the full range of values and services derived from land, from granular to highly aggregated scales, are needed to enable decision-makers and other groups to track progress towards national and

subnational objectives and adjust policy as needed. Government can foster greater data and analytic interoperability by setting rules and standards, while existing and future science innovation provide exciting new ways of obtaining and analysing data.

3. **Public priorities for landscapes should be explicitly sought** to inform the development of national and place-based land use frameworks. This should entail participatory dialogue with representative samples of those affected by and who stand to benefit from landscape decisions, particularly people who lack a voice in debates at present. Consensus will not always be obtained and decisions should be taken as part of the political process, but active engagement will engender greater trust and buy in.

4. **Regulation and financial and social incentives should be designed to achieve the objectives of a National Land Use Framework** and should be monitored and adjusted over time to maintain progress.
    a. **Compliance with environmental regulations should be improved,** requiring strengthening and investment in the authorities concerned. Consistent with a just transition, there should be an ambition to achieve higher standards of environmental stewardship than exist at present.
    b. **Financial and social incentives should be tailored to secure multiple outcomes from landscapes** in accordance with national and place-based objectives. Clarity is needed on what constitutes "public good" eligible for public funds and the total amount of public investment should be informed by natural capital accounting. Eligibility for public good payments should apply both to land that does and does not currently receive support through Single Farm Payments.

5. **Land managers should be given the advice, skills and training** needed to capitalise on new opportunities for multifunctional land management.
    a. **Advice and facilitation ("extension services") should be accessible for all forms of land management** and should align with land managers' needs as well as national objectives. A mixed public-private funding model would be appropriate, reflecting the multiple public and private goods provided by multifunctional landscapes.
    b. **Looming skills gaps in land management and adjacent sectors (eg data management) should be filled**. This will require retraining for some people but also provides an opportunity to create new green jobs.

Well-designed nature-based solutions can deliver multiple benefits including to biodiversity, ecosystem resilience, and human well-being. Nature-based solutions which contribute towards adaptation, biodiversity, and ecosystem functioning (as well as climate mitigation), including protecting and restoring ecosystems such as peatlands and seagrass meadows and reforesting woodlands[40].

[40] The Royal Society. 2021. Briefing: Climate change and biodiversity – interlinkages and policy options.

In the forthcoming briefing, *Climate change and biodiversity: interlinkages and policy options,* The Royal Society will outline five principles which can guide policy makers when designing strategies to mitigate climate change and benefit biodiversity:

- **Transformation**: addressing climate change requires transformation, including internalising environmental and social externalities, redirecting fossil fuel subsidies and investment towards sustainable policies, and redefining value (for instance, replacing measures like GDP, which only accounts for produced capital, with "inclusive wealth" which captures the value of natural and social capital too).
- **Collaboration**: the Government cannot act alone. Multiple stakeholders are needed, including local communities.
- **Integration**: using holistic approaches to understand climate relationships with biodiversity and society, as well as over scale (e.g. transboundary impact of national policies).
- **Additionality**: NbS should not delay or reduce ambition to reduce emissions. They must be used as additional actions rather than a replacement for emissions reductions.
- **Best practice**: NbS success depends on best practice. In many cases, best practice will involve a highly-localised approach to NbS design, creation and management, as well as appropriate and robust frameworks to avoid unintended consequences[41].

Which ongoing governmental plans, policies, and strategies are relevant to nature-based solutions, and can they be better coordinated? For example, are the Nature for Climate Fund and associated targets for peatland and forestry restoration designed so as to support nature-based solutions?

Should incentives for nature-based solutions be included in future agri-environment schemes, and if so, how?

6. How should nature-based solutions be planned and monitored at the national level?

What measuring, reporting, and verification requirements should be put in place to determine the degree of success of nature-based solutions? Which techniques and technologies are best suited to accomplishing robust monitoring?

Datasets relating to natural capital with relevance to nature-based solutions have historically been (and in some cases are still actively) collected by key organisations including Ordnance Survey, British Geological Survey, HM Land Registry (England and Wales), government agencies (for example Natural England, Scottish Environmental Protection Agency, Natural Resource Wales, The Agricultural and Horticultural Development Board), non-profit groups (for example National Biodiversity Network, Local Environmental Record Centres) and academic institutions (for example Cranfield University soils dataset, Rothamsted Research electronic archive, ADAS).

[41] The Royal Society. 2021. Briefing: Climate change and biodiversity – interlinkages and policy options.

Many of these datasets have the potential to be made "FAIR" (findable, accessible, interoperable, reusable)[42], and could help facilitate the government's ENCA (Enabling Natural Capital Approach) but at present the infrastructure, funding and resource to do so has prevented this in most cases. A major barrier is that many datasets are not open access for reasons of privacy and ownership. So far, the UK has failed to resolve these primarily legal and regulatory issues in a way that is fair and acceptable to the owners of the data and stakeholders who may be able to use them. As a result, data are not accessible to the market to design and innovate integrated data services.

A market-led system is likely to result in a more responsive, iterative system of monitoring that is better suited to the constantly changing ecosystems they seek to measure. However, there is a need for public investment in enabling infrastructure such as earth observation technologies and data transmission networks and role for the state in brokering agreements with third parties where data gaps are identified and setting baseline data definitions, standards and hierarchies – making it easier to collect consistent data across different areas and at different times, and to use it in multiple ways.

The National Capital Ecosystem Assessment (NCEA)[43] which has completed its initial 18-month pilot and is in the review phase for the next 3 years of funding for £60M p.a. in the upcoming spending review seeks to create an open-access, environmental dataset described above. Building on The NCEA will aim to set a baseline for measuring the multiple aspects from ecosystems then build on these with monitoring taking place every 5 years via a combination of official field testing, citizen science and automated remote sensing. The dataset this will provide an invaluable means of monitoring ecosystems services which would otherwise be treated as externalities for environmental interventions of all kinds, especially nature-based solutions.

8 September 2021

[42] https://www.go-fair.org/fair-principles/

[43] https://www.edie.net/news/11/Defra-unveils-natural-capital--assessment--funding-as-post-Brexit-green-recovery-shapes-up/