House of Lords Science and Technology Committee's Nature-based solutions for climate change Inquiry

Submission by the Society for Applied Microbiology

Introduction

The Society for Applied Microbiology (SfAM) welcomes the opportunity to respond to the House of Lords Science and Technology Committees' Nature-based solutions for climate change inquiry.

Questions:

The Committee is seeking evidence on the following questions (**there is no requirement to answer all questions in your submission**):

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?**

While our response may be biased as it is based on a microbiological perspective, the terrestrial and aquatic ecosystems are the ecosystems that are most relevant and with the largest potential to reduce emissions.

Terrestrial carbon sequestration, in which atmospheric carbon dioxide is taken up by plants during photosynthesis and stored in biomass and soils, can play a significant role in reducing carbon in the atmosphere. This process also has the bonus benefit of reversing soil fertility loss due to agricultural practices including animal and crop farming.[1]

Around 80% or 2500 gigatons of terrestrial ecosystem's approximate 3170 gigatons of carbon is stored in soil.[2] This is approximately three times the stock of carbon in plants (around 500 gigatons) and twice that of carbon stock in the atmosphere (around 800 gigatons).[3] The highest estimate of maximum potential soil carbon sequestration (CSC) around 7 gigatonnes of carbon per year.[4] However, factors such as reversibility, maintaining practices, and time for sink saturation take on average 20 years.[5]

Only the aquatic ecosystem can store more carbon than soil with the ocean storing about 38,400 gigatons.[6] The two main methods for carbon sequestration in the ocean is via direct

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[1]Introduction to Terrestrial Carbon Sequestration. 29 March 2017. https://link.springer.com/chapter/10.1007/978-3-319-53845-7_9.
[2] Soil Carbon Storage. 2012. https://www.nature.com/scitable/knowledge/library/soil-carbon-storage-84223790/.
[3] How to measure, report and verify soil carbon change to realize the potential of soil carbon sequestration for atmospheric greenhouse gas removal. 30 August 2019. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.14815
[4] Negative emissions—Part 2: Costs, potentials and side effects. 22 May 2018. https://iopscience.iop.org/article/10.1088/1748-9326/aabf9f">unlikely
[5] Negative emissions—Part 2: Costs, potentials and side effects. 22 May 2018. https://iopscience.iop.org/article/10.1088/1748-9326/aabf9f">unlikely
[6] Soil Carbon Storage. 2012. https://www.nature.com/scitable/knowledge/library/soil-carbon-storage-84223790/

injection into deep saline aquifers (oil and gas fields) and ocean fertilization with microalgal nutrients.[7] However, environmental concerns around the long-term environmental impact on the ocean chemistry, low pH, and marine organisms (e.g. stunting coral growth) poses substantial challenges.[8]

- 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?

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

Some nature-based solutions may be slightly less effective than other techniques, such as chemical and engineering. This is likely to be due to the time required to offset or the scale of offsetting. However, some chemical and engineering techniques may result in more environmental pollutants so all these factors need to be taken into account.

It is important to note that only after conducting a Life Cycle Assessment (LCA) can the true environmental impact of an offsetting technique be determined. If an LCA is not properly taken into account, then the techniques used may not actually offset carbon emissions but only shift the problem to another area of production, resulting in the same carbon footprint or environmental pollution. An LCA considers various areas of environmental impact across the entire life cycle of a technique.[9] The International Organisation for Standardisation (ISO) has produced specific guidelines for conducting LCAs in its 14000 series of environmental management standards.[10] The life cycle assessment of a technique is robust with an analysis of each stage including raw material extraction, transports, production processes, end of life treatment/ recycling, and final disposal.[11]

Several soil interventions for improving plants health and regenerating soil in order to capture more carbon are currently being investigated. Using autotrophic organisms (organisms that produce biomass from resources like carbon dioxide and minerals) like microalgae to transform carbon into lipids, gene editing of photosynthetic bacteria, and increasing plant resilience through microbial supplementation and bacterial treatments are all strategies for improving plant and soil health, which then enables soil and plants to store more carbon.[12] Researchers have found that the microbial communities, known as microbiomes, in soil largely determine the amount of carbon that is captured in soil or

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[7] Chapter Thirteen - Contemporary Issues in Environmental Assessment. 2012. https://www.sciencedirect.com/science/article/pii/B9780123884442000130.
[8] Chapter 6 - Eliminating CO2 Emissions from Coal-Fired Power Plants. 2010. https://www.sciencedirect.com/science/article/pii/B9781856176552000067.
[9] A Guideline for Life Cycle Assessment of Carbon Capture and Utilization. 14 February 2020. https://www.frontiersin.org/articles/10.3389/fenrg.2020.00015/full
[10] ISO 14000 Family Environmental Management. https://www.iso.org/iso-14001-environmental-management.html
[11] A Guideline for Life Cycle Assessment of Carbon Capture and Utilization. 14 February 2020. https://www.frontiersin.org/articles/10.3389/fenrg.2020.00015/full
[12] Unearthing the Soil Microbiome, Climate Change, Carbon Storage Nexus. 13 May 2021. https://asm.org/Articles/2021/May/Unearthing-the-Soil-Microbiome,-Climate-Change,-Ca

released back into the atmosphere.[13] Manipulating soil microbiomes to better sequester carbon is a promising nature-based solution with additional benefits including bioremediation applications (e.g. converting environmental pollutants into less harmful products). However, all of these soil-based solutions are threatened by the negative effects of climate change and poor land management such as precipitation patterns and soil degradation.[14]

Microbial fuel cell (MFC) technology, which uses bacteria's metabolism power to generate electricity, offers a sustainable source of energy and carbon sequestration.[15] MFCs also have the added benefits of bioremediation including consuming toxic compounds and removing heavy metals from wastewater.[16] As MFC technology is a recent development, scaling up MFC technology for large scale production is a challenge. In addition, MFC technologies require further research for improving their suitability in field conditions and developing low-cost long term stable electrode materials and membranes for fabrication.[17]

Biocementation, which is an ecological process based on microbial application used to engineer biobased cements, provide a low-cost and sustainable alternative to environmentally costly conventional cement.[18] While the initial cost of installing biocementation processes is costly, the bacterial enzyme used in the process can be reused so it is a cheaper solution in the long run.[19]

Aviation biofuel, whereby waste carbon monoxide is captured and upgraded with microalgae and converted into ethanol for jet fuel, is a sustainable alternative to traditional fossil based jet fuels. Since the aviation industry is one of the largest greenhouse gas emitters, airlines switching to biofuel could have a significant impact on carbon emissions. However, the high costs of biofuels requires international policies that support and incentivise its wide roll out.[20]

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[13] The Traits of Microbes Matter in Microbial Carbon Cycling and Storage. 19 August 2020. https://www.energy.gov/science/ber/articles/traits-microbes-matter-microbial-carbon-cycling-and-storage

[14] The soil microbiome — from metagenomics to metaphenomics. June 2018. https://www.sciencedirect.com/science/article/pii/S1369527417302205

[15] Microbial fuel cells, a renewable energy technology for bio-electricity generation: A mini-review. April 2021. https://www.sciencedirect.com/science/article/pii/S1388248121000874

[16] Application of bioelectrochemical systems for carbon dioxide sequestration and concomitant valuable recovery: A review. December 2019. https://doi.org/10.1016/j.mset.2019.08.003

[17] Application of bioelectrochemical systems for carbon dioxide sequestration and concomitant valuable recovery: A review. December 2019. https://doi.org/10.1016/j.mset.2019.08.003

[18] State-of-the-art review of biocementation by microbially induced calcite precipitation (MICP) for soil stabilization. August 2016. https://www.researchgate.net/publication/306896391_State-of-the-art_review_of_biocementation_by_microbially_induced_calcite_precipitation_MICP_for_soil_stabilization

[19] State-of-the-art review of biocementation by microbially induced calcite precipitation (MICP) for soil stabilization. August 2016. https://www.researchgate.net/publication/306896391_State-of-the-art_review_of_biocementation_by_microbially_induced_calcite_precipitation_MICP_for_soil_stabilization

[20] Biofuels for aviation: Technology brief. February 2017. https://www.irena.org/publications/2017/Feb/Biofuels-for-aviation-Technology-brief.

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?

- **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?**

Peatlands act as substantial global soil carbon stores and play a fundamental role in mediating greenhouses gases within the atmosphere.[21,22] However, the carbon stored within peatlands is frequently destabilised by peatland degradation, propelled by both anthropogenic drainage and climate change.[23,24] As peatland degradation contributes to increased carbon dioxide emissions and loss of biodiversity, there have been considerable efforts to restore damaged peatlands.[25] Typically, restoration is achieved through rehydrating peatlands, yet there is great uncertainty over the effectiveness of rewetting alone in fully restoring peatlands.[26] A crucial element in peatland restoration, involves the return of microbial communities which are essential to ecosystem functioning.[27] Despite the growing evidence suggesting rewetting has a positive impact in restoring near natural microbial communities, further research will be required to address the current research methodologies and limitations.[28] In addition, peatland microbiomes should be considered together with predictive functional profiling during peatland recovery.[29]

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

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[21] Northern peatlands: Role in the carbon cycle and probable responses to climate warming. May 1991. Northern Peatlands: Role in the Carbon Cycle and Probable Responses to Climatic Warming (umn.edu)
[22] Northern peatland carbon stocks and dynamics: a review. October 2012. bg-9-4071-2012.pdf (copernicus.org)
[23] Agricultural peatland restoration: effects of land-use change on greenhouse gas (CO_2 and CH_4) fluxes in the Sacramento-San Joaquin Delta. February 2015. doi: 10.1111/gcb.12745
[24] Drought-induced carbon loss in peatlands. November 2011. https://doi.org/10.1038/ngeo1323
[25] Towards ecosystem-based restoration of peatland biodiversity. January 2017. doi:10.19189/MaP.2013.OMB.150
[26] Long-term effects of drainage and initial effects of hydrological restoration on rich fen vegetation. November 2007. https://www.jstor.org/stable/25488436
[27] Belowground biodiversity and ecosystem functioning. November 2014. https://doi.org/10.1038/nature13855
[28] The Response of Microbial Communities to Peatland Drainage and Rewetting. October 2020. The Response of Microbial Communities to Peatland Drainage and Rewetting. A Review (nih.gov)
[29] Recovery of fen peatland microbiomes and predicted functional profiles after rewetting. April 2020. Recovery of fen peatland microbiomes and predicted functional profiles after rewetting | The ISME Journal (nature.com)

- **To what extent do we understand the capacity of the oceans and coastal ecosystems to sequester greenhouse gases through nature-based solutions?**

Phytoplankton are an important group of the aquatic ecosystem, owing to their role in both oxygen production and carbon sequestration.[30] Due to the important contribution of phytoplankton in the global carbon cycle, there is growing interest in the study of phytoplankton diversity within the aquatic ecosystem. Phytoplankton diversity is not only seen across geographical regions such as the North Atlantic, there is also growing evidence for seasonality in phytoplankton communities with transitions in plankton composition between winter and spring.[31] Further to this, harsh meteorological conditions in winter create oceanic structures known as Submesoscale Coherent Vortices (SCV), which can have significant influence on the distribution of nutrients within the phytoplankton community and its ability to produce and store carbon.[32] Fundamentally, more research is needed to understand how we can harness the ability of phytoplankton to sequester carbon dioxide.

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?**

Peatland rewetting and paludiculture are a good example of a nature-based solution that all UN member states in 2019 agreed to increasingly develop and implement more. The Global Peatlands Initiative, formed in 2016 by 13 member countries and now 44 international organisations, was also established to dedicate resources to peatland protection and rewetting. Peatlands provide the largest natural terrestrial carbon store with 42% of all soil carbon storage, which is twice that of forests.[33] They also protect biodiversity and help prevent flooding and droughts. Paludiculture is the farming of crops on wet soils, mostly peatlands, and contributes to rewetting peatlands.[34]

Despite these benefits, peatlands are still being drained for ephemeral use and rewetting has been slow. Draining peatlands enables oxygen to enter the soil and microbial decomposition of the peat. This releases significant amounts of carbon dioxide and nitrogen into the atmosphere as well as a reduction in water and land quality and increased risk of

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[30] World's biggest oxygen producers living in swirling ocean waters. September 2017. World's Biggest Oxygen Producers Living in Swirling Ocean Waters - Eos

[31] Small phytoplankton dominate western North Atlantic biomass. July 2020. Small phytoplankton dominate western North Atlantic biomass (nih.gov)

[32] A submesoscale coherent vortex in the Ligurian Sea: From dynamical barriers to biological implications. May 2017. A submesoscale coherent vortex in the Ligurian Sea: From dynamical barriers to biological implications - Bosse - 2017 - Journal of Geophysical Research: Oceans - Wiley Online Library

[33] IUCN Peatlands and climate change. https://www.iucn.org/resources/issues-briefs/peatlands-and-climate-change

[34] Paludiculture as a sustainable land use alternative for tropical peatlands: A review. 20 January 2021. https://www.sciencedirect.com/science/article/abs/pii/S0048969720356400

flooding.[35] It is therefore vital that countries continue to commit to peatland rewetting. However, lack of knowledge as well as substantial costs in changing operations and adapted machinery for landowners and farmers have resulted in a slow rollout of peatland rewetting and paludiculture. Governments will need to incentivise SMEs with better land management policies, which are consistent with sustainability policies, to invest in the changes in operational management from grassland to wetland.

- **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?**

While SfAM's expertise lies outside of financial regulation, members are aware of a few financial initiatives that are devising standards for better transparency surrounding sustainability. Since there is currently no set standard for companies to disclose ESG endeavours, organisations are developing comprehensive corporate reporting frameworks, including the International Integrated Reporting Council (IIRC), Sustainability Accounting Standards Board (SASB), GRI, Task Force on Climate-related Financial Disclosures (TCFD), CDP and Climate Disclosure Standards Board (CDSB), to ensure that environmental, social and governance metrics are represented in financial statements.[36]

- How can we ensure that the carbon accountancy is science-based, robust, and consistent across nature-based solutions?

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?**

The implementation of nature-based solutions often involves numerous actions over broad landscapes and seascapes, intersecting jurisdictional boundaries. Therefore, there is a need for a more comprehensive stakeholder list to reflect this, not just farmers, land managers and local communities but conservation groups, NGOs, policymakers, scientists and financiers (private/public initiatives etc). Nature-based solutions offer huge potential, but to be successful they must be implemented within a systems-thinking framework to account for the diverse ecosystems and varying perspectives from a range of stakeholders.[37] Consequently, the governance of nature-based solutions requires cooperation from

[35] The Power of Nature-Based Solutions: How Peatlands Can Help Us to Achieve Key EU Sustainability Objectives. 9 October 2020. https://onlinelibrary.wiley.com/doi/10.1002/adsu.202000146

[36] How can we finance climate adaptation? Nature-based solutions to the Americas' climate change risks. 30 April 2021. https://www.environmental-finance.com/content/market-insight/how-can-we-finance-climate-adaptation-nature-based-solutions-to-the-americas-climate-change-risks.html

[37] Understanding the value and limits of nature-based solutions to climate change and other global challenges. January 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges | Philosophical Transactions of the Royal Society B: Biological Sciences (royalsocietypublishing.org)

stakeholders, because when addressing different climatic impacts, the priorities, values and needs of stakeholders may diverge or even conflict.[38]

- 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?

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?

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

Nature-based solutions are gaining traction within government policies within the UK and internationally, owing to their potential to address the climate change while protecting or enhancing biodiversity.[37] In order to help deliver the UK's Nationally Determined Contributions (NDC), nature-based solutions should be prioritised and integrated in UK adaptation policy for climate change adaptation.[39]

- 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?

About the Society for Applied Microbiology

The Society for Applied Microbiology (SfAM) is the oldest microbiology society in the UK, representing a global scientific community that is passionate about the application of microbiology for the benefit of the public. Our members work to address issues spanning the environment, human and animal health, agriculture, and industry.

www.sfam.org.uk **September 2021**

[38] A conceptual model to improve links between science, policy and practice in coastal management. May 2019. https://doi.org/10.1016/j.marpol.2019.02.029
[39] The Role of Nature-based Solutions for Climate Change Adaptation in UK Policy. December 2020. GuidanceUKAdaptationCommuncationV2_Sections.pages (rspb.org.uk)