A Response from the British Ecological Society to the Welsh “Brexit and our Land” consultation

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This consultation response is the product of input from a range of academic based in Wales, with the questions answered reflecting this expertise. Many of the contributors would be willing to provide further insight upon request. For further information on contributors and further contributions, please contact:

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From Chapter 4: Land Management Programme We propose a new Land Management Programme consisting of an Economic Resilience scheme and a Public Goods scheme. Do you agree these schemes are the best way to deliver against the principles? If NO, what alternatives would be best?

Key Points and Recommendations:

- **The British Ecological Society (BES) welcomes the Welsh Government's proposals for a public goods approach.**
- **Provisioning services should be covered by the Economic Resilience Scheme (ERS).**
- **The ERS and PGS should be part of a sustainability framework that explicitly incorporates objectives set out in the Environment (Wales) Act 2016 and the Well-being of Future Generations (Wales) Act 2015.**
- **PGS should be available to non-productive land owners, with the potential to cover multiple landowners at large spatial scales that truly capture ecosystem function.**
- **Alongside the PGS and ERS, all landowners should have to adhere to properly enforced minimum environmental standards.**

1.1 Biodiversity loss and land degradation in Wales

Wales has, relative to the rest of the UK, passed progressive legislation to drive action to combat species declines and improve natural resource management, such as the Environmental (Wales) Act 2016 and the Well-being of Future Generations (Wales) Act 2015. While some species have recently improved in population status[1], including red kites and otters, the overall trend for Welsh wildlife is one of ongoing net decline[2] and Wales was found to be in the lowest fifth of the 218 countries analysed in the Biodiversity Intactness Index (BII)[3].

Biodiversity decline has primarily been driven by a suite of pressures that are primarily (but not exclusively) linked to agricultural activities, including the loss, degradation and isolation of habitats; over-exploitation and unsustainable use of natural resources; and excessive nutrient input and other forms of pollution[3,4]. However, the pace of change experienced by ecological communities due to climate change is expected to overtake land use as the leading cause of biodiversity loss in the near future[5].

A new approach to rural land-management is therefore crucial to the long-term sustainability of not just the environment, but also the economy, with the safeguarding of regulating ecosystem services such as soil formation and nutrient cycling being vital to the industries that depend on them, such as

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1 RSPB. (2016). State of Nature: Wales Report
2 RSPB. (2016). State of Nature: Wales Report
3 RSPB. (2016). State of Nature: Wales Report.
3 RSPB. (2016). State of Nature: Wales Report.
4 RSPB. (2016). State of Nature: Wales Report.
5 http://rspb.royalsocietypublishing.org/content/285/1881/20180792

agriculture[6,7]. Addressing the challenges posed by climate change, biodiversity decline, poor soil quality, adverse air quality and poor water quality must therefore be central to any future land management policy.

1.2 Public money for public goods is a welcome change

The BES welcomes the Welsh Government's proposal to reform land management in Wales. In particular, we welcome Principle 4, which recommends that future support encompasses the provision of additional public goods from land (please see our answer to Question 10 for our definition of publics goods). We recognise that post-Brexit, the Economic Resilience Scheme (ERS) will play an important role in protecting the economic stability and sustainability of many Welsh land managers.

We are pleased to see the acknowledgement of the environmental problems associated with the Common Agriculture Policy (CAP)Research has strongly linked Pillar 1 payments to increased agricultural intensification and associated environmental degradation[8]. Pillar II payments, which were intended as income for conservation, have received insufficient funding to reverse environmental degradation and biodiversity loss in Wales[9]. This is evidenced by the decline in environmental public goods in Wales, such as biodiversity and air and water quality, that has occurred concomitant with the current system of production-focused CAP payments[10].

As such, we welcome a new programme of subsidies that incentivise the protection and restoration of environmental public goods[11,12] that may not otherwise be delivered by the market, or through subsidies primarily designed to support production of goods for the market. The proposals to incentivise the protection and restoration of regulating ecosystem services are particularly welcome. (we discuss the public goods delivered by ecosystem services further in Question 10).

1.3 Using PGS and ERS to deliver the potential of Welsh legislation

The new Land Management Programme should be used to implement the environmental ambitions in the Wellbeing of Future Generations (Wales) Act 2015 (WBFGA) and the Environment (Wales) Act 2016 (EWA). However, the objectives for the PGS that are set out in the consultation do not explicitly mention the WBFGA or the EWA, potentially weakening the delivery of the objectives. The Land Management Programme is a chance to target and prioritise public money to implement and meet

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[6] Kremen, C., and Miles, A. (2012). Ecosystem Services in Biologically Diversified versus Conventional Farming Systems: Benefits, Externalities, and Trade-Offs. *Ecology & Society*, 17(4).

[7] Bommarco, R., et al. (2013). Ecological intensification: harnessing ecosystem services for food security. *Trends in Ecology and Evolution*, 28(4): pp.230-238.

[8] Pe'er, et al. (2014). EU agricultural reform fails on biodiversity. *Science,* 344(6188).

[9] Donald et al (2006), Further evidence of continent-wide impacts of agricultural intensification on European Farmland Birds, 1990-2000, Agriculture, ecosystems and environment.

[10] RSPB. (2016). State of Nature: Wales Report

[11] A public good is something which is a benefit to humans and provided by the environment, such as nutrient cycling, pollination, soil formation and climate regulation. All provisioning and regulating ecosystem services are public goods. We discuss the definition of public goods further in our answer to Question 10.

[12] Cooper, T., *et al.* (2009). Provision of ublic goods through agriculture in the European Union. Institute for European Environmental Policy.

environmental objectives. As such, the objectives must explicitly deliver on the requirements already set out in legislation, such as the Sustainable Management of Natural Resources (SMNR) requirements in the EWA.

1.4 Information is missing on how public goods will be measured and assessed

It is unclear how the delivery of public outcomes will be measured and assessed. Monitoring and evaluation enable policy refinement and improvement based on robust evidence of the efficacy of previous interventions[13,14]. We acknowledge that measuring these outcomes is scientifically complex, and we strongly urge the Welsh Government to consult widely on appropriate indicators for doing so.

Question 8 of 20

From Chapter 6: Public Goods We have set out our proposed parameters for the Public Goods scheme. Are they appropriate? Would you change anything? If YES, what?

Key Points and Recommendations:

- **The BES welcomes a shift in focus towards ecosystem services such as regulating nd supporting services, rather than just provisioning services.**
- **The Welsh Government should identify key biodiversity elements that confer resilience in desirable ecosystem services, and the conservation of these species should be integral to schemes.**
- **An outcomes-based approach would be more effective than an action-based approach.**
- **Collaboration between landowners is necessary to develop coherent ecological netowrks and reverse habitat fragmentation, yet there is little clarity on how schemes could be adopted by multiple landowners.**
- **We agree that spatial targeting is an effective way to help identify existing and potential ecosystem services.**

8.1 The relationship between biodiversity and public goods

In order to safeguard key ecosystem services and the environmental outcomes associated with these services, it is important to understand the link between biodiversity and ecosystem service delivery and resilience

There are likely to be certain biodiversity thresholds below which service delivery starts to fail. Pressures on biodiversity that lead to significant impairments in a population, for instance, following reduced genetic diversity, the removal of keystone species or altered trophic levels, may result in the

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[13] Batáry et al (2015). The role of agri-environment schemes in conservation and environmental management. *Conservation Biology,* 29(4): pp. 1006-1016.
[14] Mark et al (2017). Improving the link between payments and the provision of ecosystem services in agri-environment schemes. *Ecosystem Services*, 9: pp. 44-53.

irrecoverable deterioration of a dependent ecosystem service, even after the pressure on biodiversity has been removed[15].

Folke (2004)[16] defined resilience as 'the capacity of a system to absorb disturbance and reorganise while undergoing change so as to retain essentially the same function, structure, identity and feedbacks'. Drawing on Chapin et al., (2000)[17], Peterson et al., (1998)[18], and Durance et al., (2016)[19]; 'key biodiversity and emerging ecosystem properties that confer service resilience are likely to include population genetic variability, phenotypic plasticity, functional group diversity, species' traits/response modes, and food web stability because these provide the capacity for rapid biological or functional recovery in the face of perturbations'.

Historical investigation, such as the response of freshwater to increases and decreases in acidification, can aid understanding[20]. Predicting species responses to future stressors such as climate change will require the use of long-term species level data and matching environmental data and the use of allometric-based models[21] of food web structures and dynamics[22]. Once decision-makers have identified key ecosystem services, they must also, using the above techniques, identify the key species or populations of species that maintain the integrity and resilience of the service, and put in place conservation plans to protect them against current and future threats.

8.2 Parameter 1: Scope of the scheme

We welcome the PGS as it is clearly dedicated to addressing urgent environmental issues and supporting public goods. To move towards more sustainable agriculture with fewer synthetic inputs regulating and provisioning ecosystem services must be abundant and robust. Public goods are beneficial to both farming and a healthy environment, as they provide services such as nutrient cycling and pest regulation, and consequently reduce the instances of inorganic chemical interventions[23].

8.3 The benefits of using an outcomes-based approach for the delivery of public goods

[15] Truchy et al (2015). Linking biodiversity, ecosystem functioning and services, and ecological resilience: towards an integrative framework for improved management. *Adv. Ecol. Res*. 53, 55–96.
[16] Folke, C (2004). Traditional knowledge in social-ecological systems. *Ecol. Soc.* 9 (3), 7.
[17] Chapin et al (2000). Consequences of changing biodiversity. Nature 405 (6783), 234–242.
[18] Peterson et al (1998). Ecological resilience, biodiversity, and scale. Ecosystems 1 (1), 6–18.
[19] Durance et al. Chapter 3: The challenges of linking biodiversity to ecosystem services: Lessons from a large-scale freshwater study. Ecosystem services: From Biodiversity to Society, Part 2. Ed, Guy Woodward, David Bohan (2016).
[20] Durance et al. Chapter 3: The challenges of linking biodiversity to ecosystem services: Lessons from a large-scale freshwater study. Ecosystem services: From Biodiversity to Society, Part 2. Ed, Guy Woodward, David Bohan (2016).
[21] See Cohen et al (2003). Ecological community description using the food web, species abundance, and body size. Proc. Natl. Acad. Sci. U. S. A. 100, 1781–1786. Cohen et al (2009). Food webs are more than the sum of their tritrophic parts. Proc. Natl. Acad. Sci. U. S. A. 106, 22335; Petchey et al (2008). Size, foraging, and food web structure. Proc. Natl. Acad. Sci. U. S. A. 105, 4191; Williams and Martinez (2000). Simple rules yield complex food webs. Nature 404, 180; Woodward et al (2010a)
[22] Durance et al. Chapter 3: The challenges of linking biodiversity to ecosystem services: Lessons from a large-scale freshwater study. Ecosystem services: From Biodiversity to Society, Part 2. Ed, Guy Woodward, David Bohan (2016).
[23] Fiedler et al. (2008). Maximizing ecosystem services from conservation biological control: The role of habitat management. *Biological control,* 45(1): pp.254-275.

Outcome-based schemes present a number of potential advantages over the current approach of paying farmers for specific options. Outcome-based approaches are preferable where biodiversity is more sensitive to conservation action and when it is difficult for a central agency to determine an appropriate level of conservation action. This is partially because outcome-based payments allow individual managers to optimise their level of action[24]. The relative cost of monitoring action (compliance with an agreement to manage in a certain way) versus outcomes (e.g. the presence of certain species or habitats) should also be considered. One of the advantages of outcome-based payments is that the monitoring provides information on the outcomes of interest, such as national or international targets (potentially allowing adaptive management), rather than simply providing information on compliance with agri-environment options[25]. Furthermore, an outcome-based approach can incentivise land-managers with local knowledge to join the scheme and apply their knowledge to improving the target biodiversity and associated ecosystem services[26].

8.4 Parameter 2: Open to all

The BES welcomes the inclusion of both existing and potential public goods outcomes within the PGS scheme. This approach will broaden scheme take-up, resulting in more environmental outcomes because of wider participation. It will also incentivise the creation of new habitats, leading to more public good outcomes[27].

Intensive farming has caused habitat loss and fragmentation, reducing the provision of ecosystem services and environmental outcomes[28]. Habitat restoration and creation must therefore be a priority in order to restore ecological connectivity and ecosystem functions.

8.5 Parameter 3: Opportunities for Action

8.5.1 The importance of a landscape scale approach in a Public Goods Scheme

The future Land Management Programme should enable partnerships between landowners, where collaboration is needed to deliver schemes at the appropriate spatial scale to deliver ecosystem services[29,30]. Developing coherent ecological networks for species to reverse the impacts of habitat fragmentation requires landscape scale coordination and cooperation between adjoining farmland,

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[24] Gibbons et al. (2011) Should payments for biodiversity conservation be based on action or results? *Journal of Applied Ecology*, 48(5).
[25] Gibbons et al. (2011) Should payments for biodiversity conservation be based on action or results? Journal of Applied Ecology, 48(5).
[26] Gibbons et al. (2011) Should payments for biodiversity conservation be based on action or results? *Journal of Applied Ecology*, 48(5).
[27] European Commission. (2017). Agri-environment schemes: Impacts on the agricultural environment. Science for the environment policy. Issue 57. Available at: http://ec.europa.eu/environment/integration/research/newsalert/pdf/AES_impacts_on_agricultural_environment_57si_en.pdf
[28] Debinski and Holt. (2000). A survey and overview of habitat fragmentation experiments. *Conservation Biology,* 14(2): pp.342–355.
[29] Anthony et al. (2012) Contribution of the Welsh AgriEnvironment Schemes to the Maintenance and Improvement of Soil and Water Quality, and to the Mitigation of Climate Change. Agri-Environment Monitoring and Technical Services Contract Lot 3: Soil, Water and Climate Change (Ecosystems). Welsh Government, Cardiff, UK.
[30] Westerink et al (2017). Collaborative governance arrangements to deliver spatially coordinated agri-environmental management. Land Use Policy, 69: 176-192.

resulting in greater linkages between farming units and other land parcels such as protected areas[31]. Prioritising perennial habitats such as forests, hedgerows, river corridors and perennial grasslands can form part of long-term environmental management, as well as creating more complex landscapes to allow for greater biodiversity[32].

Landscape structure, which can be defined as: "*the pattern of a landscape, which is determined by its type of use, but also by its structure, i.e. the size, shape, arrangement and distribution of individual landscape elements*"[33] includes the type and expanse of habitat and therefore the type, abundance and populations of different species. Heterogeneity of landscapes provide a range of different habitats which allow for greater biodiversity. Intensively farmed landscapes are often dominated by monocultures and therefore have lower levels of biodiversity because of the limited type and availability of habitats. Landscapes with greater structural complexity can improve ecosystem functions for farms by increasing pest suppression and supporting pollinators[35]. Moreover, research[34] into spatial coordination of environmental management from five EU member states found that groups of farmers who formed an organisation were more effective in delivering agri-environment objectives[35]. A farm-level only focus to PGS would be a missed opportunity for delivering public goods, yet it is unclear how collaborations and possible landscape-scale cooperation will be facilitated within PGS.

8.6 Parameter 4: Evidence-based public goods

The BES is pleased to see the consultation acknowledge the need to for evidence to show the connection between land management activities and public goods outcomes in the PGS. We recommend that monitoring and evaluation be used to enable policy selection, refinement and improvement, based on robust evidence of the efficacy of previous interventions[36,37]. To achieve this, PGS will need a well-funded, large-scale, high-quality, scientifically robust monitoring system to underpin continual evaluation.

Given the current lack of standardised methodologies for collecting or reporting data[38], the Welsh Government should try to standardise reporting requirements wherever possible, in order to aid systematic future systematic reviews. Evaluating the impact of new schemes should involve robust indicators, for which there should be further consultation. Data sharing amongst government agencies

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31 Kark et al (2015). Cross-boundary collaboration: key to the conservation puzzle. *Current Opinion in Environmental Sustainability*, 12: pp.12-24.
32 Concepcion et al (2008). Effects of landscape complexity on the ecological effectiveness of agri-environment schemes. *Landscape Ecology*, 23: pp.135–148.
33 Walz (2011). Landscape Structure, Landscape Metrics and Biodiversity. Living Reviews in Landscape Research, 5(3
35 Drieu and Rusch (2017). Conserving species-rich predator assemblages strengthens natural pest control in a climate warming context, *Agricultural and Forest Entomology*, 19(1): pp.52-59.
34 Westerink et al (2017). Collaborative governance arrangements to deliver spatially coordinated agri-environmental management. Land Use Policy, 69: pp.176-192.
35 South Downs National Park Authority. (2018). Selborne farm cluster. [Online]. Available at: https://www.southdowns.gov.uk/national-park-authority/our-work/farm-clusters/selborne-farm-cluster/
36 Batáry et al (2015). The role of agri-environment schemes in conservation and environmental management. *Conservation Biology,* 29(4): pp. 1006-1016.
37 Reed et al (2017). Improving the link between payments and the provision of ecosystem services in agri-environment schemes. *Ecosystem Services*, 9: pp. 44-53.
38 Further information about iCASP can be found at https://icasp.org.uk/

will be required as well as knowledge exchange among the devolved administrations to ensure the data is available to support the indicators, and monitoring outcomes are shared.

A summary of a research review and its findings into the possible evidence gaps in the efficacy of previous agri-environment schemes can be found in Appendix 1.

8.7 Parameter 5: Additionality

We welcome the commitment to the delivery of outcomes that go beyond the level required for regulatory compliance. The level required for regulatory compliance in the agricultural sector should be at a high enough standard to prevent environmental degradation, regardless of participation in the PGS. This would ensure that those who do not wish to participate in either of the schemes, do not let their land management fall below a set of environmental standards which maintain and promote habitat restoration.

Given that the WBFGA explicitly calls for the maintenance of water, soil, air, woodlands, vegetation and biodiversity, a high standard of regulatory compliance for land management activities to meet these objectives is a logical extension of the criteria set out in existing statute.

8.8 Parameter 6: Advisory support for land managers

A new land management programme will require extensive advisory services. We are pleased to see this acknowledged in the consultation and hope to see the necessary levels of public funding committed to this need. We discuss our recommendations for advisory services during the post-Brexit transition period and beyond in further detail in Question 14.

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From Chapter 6: Public Goods Are there any other public goods which you think should be supported? If YES, why?

Key Points and Recommendations:

- **PGS and ERS should deliver resilient habitats and ecosystems by improving ecological connectivity and enabling species and habitats to adapt to climate change.**
- **It is important to restore peatlands for carbon sequestration.**
- **We recommend that the Welsh Government develop a soil strategy that sets out a vision for soil conservation.**
- **PGS and ERS should support, maintain and extend existing Catchment Management Partnerships, in order to deliver improved water quality.**
- **Landscape features, including woodlands and ponds, can reduce the risk of flooding, and save money that would otherwise be spent of reparations. These features should be incentivised through PGS and ERS.**

- **PGS should incentivise reductions in greenhouse gas emissions associated with farming and compliance with the UNECE Gothenburg Protocol targets on air pollution.**
- **Heritage and recreation payments should facilitate the enjoyment of biodiversity, where appropriate.**

The BES welcomes the public goods listed in the consultation. For the addition of other public goods, we recommend that they adhere to the following definition:

> *A public good should be defined as non-excludable and non-rivalrous. In the context of the environment, this means that no one should be prevented from accessing it and one person or one nation's access does not prevent access to another nation or person. For example, no person or nation is excluded from accessing air, and clean air for one person or nation does not come at the expense of other people or nations, so it is non-rivalrous. A public good is something which is a benefit to humans and provided by the environment, such as nutrient cycling, pollination, soil formation and climate regulation. All provisioning[39] and regulating[40] ecosystem services are public goods[41].*

All public goods fundamentally impact life on earth and all interact with and impact each other. Below we highlight valuable services from public goods.

10.1 Soil quality

Conserving healthy soils is vital to any land management strategy. Healthy soils are both a living system of intrinsic value and a key natural capital asset[42], delivering a range of ecosystem services beyond food production, including storing and filtering water; storing carbon and regulating greenhouse gas emissions; and hosting an estimated quarter of the world's biodiversity[43].

While soil biodiversity may receive less attention than aboveground diversity, soil holds the highest percentage of life on earth[44]. The diversity in soil is what allows the soil web to perform many important ecosystem functions from recycling nutrients, management of pest and diseases, erosion prevention, and the breaking down of organic matter. Healthy soils sustain biological productivity,

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39 Supporting services such as soil formation, photosynthesis, nutrient cycling, primary production, water cycling, provisioning of habitat.

40 Regulating services such as water purification, air quality maintenance, flood alleviation, pollination, climate regulation, waste management, regulation of human disease, and biological control of agricultural pests and diseases.

41 Uitto, J.I. (2016) Evaluating the environment as a global public good. *Evaluation*, 22(1): pp. 108–115.
Carvalheiro, L.G., Kunin, W.E., Keil, P., Aguirre-Gutiérrez, J., Ellis, W.N., Fox, R., Groom, Q., Hennekens, S., Van Landuyt, W., Maes, D., Van de Meutter, F., Michez, D., Rasmont, P., Ode, B., Potts, S.G., Reemer, M., Roberts, S.P.M., Schaminée, J., Wallis DeVries, M.F., Biesmeijer, J.C. (2013) Species richness declines and biotic homogenisation have slowed down for NWEuropean pollinators and plants. *Ecology Letters*, 16: 870-878.

42 Natural Capital Committee (2013), *The State of Natural Capital: Towards a framework for measurement and valuation*

43 Wachira, et al. (2014). Conservation and Sustainable Management of soil biodiversity for agricultural productivity. *Sustainable Living with Environmental Risks*, pp.27-34.

44 Wachira, et al. (2014). Conservation and Sustainable Management of soil biodiversity for agricultural productivity. *Sustainable Living with Environmental Risks*, pp.27-34.

including food production[45]. Conservation of species important to soil health is necessary to enable the soil deliver provisioning public goods as well as regulating and supporting services.

As the major terrestrial reservoir of carbon globally (containing approximately 1500 billion tonnes)[46], soils have a considerable influence on the global carbon cycle and atmospheric CO_2 levels. Degradation of carbon-rich soils releases significant quantities of CO_2 into the atmosphere. UK soils contain approximately 10 billion tonnes of carbon and peat soils play a particularly important role in soil carbon storage, holding around 40% of UK soil carbon[47,48]. It is particularly important to restore peatlands to lock up carbon that is currently being released because of degradation; especially as many lowland peatlands have been drained for agriculture and this has resulted in millions of tonnes of carbon being emitted to the atmosphere[49].

Given the importance of soil health, we recommend that the Welsh Government develop a soil strategy that sets out a vision for soil conservation, for instance, addressing soil erosion by wind and rain, soil compaction, species conservation and organic matter decline. The PGS and ERS should then incentivise the delivery of this strategy.

10.2 Water quality

The BES is pleased the consultation suggests creating opportunities for land managers to improve water quality. Water pollution negatively impacts the environment in a number of ways. For example, eutrophication, often caused by agricultural run-off, causes oxygen depletion in water bodies. This suffocates aquatic species, leading to 'dead zones' with a loss of general diversity but algae blooms, some of which produce neurotoxins harmful to aquatic mammals[50]. As Ormerod et al (2016)[51] explains, low oxygen levels in the UK's rivers makes numerous species more susceptible to climate change impacts. Common mayfly species, for example, are less able to tolerate temperature changes in rivers with high levels of pollution and low levels of oxygen.

10.3 Natural flood defences

Natural flood management can support biodiversity and habitat creation. Through the creation of habitats such as wetlands, flood storage capacity is expanded while a biologically diverse habitat is

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45 Wachira, et al. (2014). Conservation and Sustainable Management of soil biodiversity for agricultural productivity. *Sustainable Living with Environmental Risks*, pp.27-34.

46 Scharlemann, J.P.W., Tanner, E.J.V., Hiederer, R., Kapos, V. (2014). *Global soil carbon: understanding and managing the largest terrestrial carbon pool*, Carbon Management, 5(1), pp81-91.

47 UK National Ecosystem Assessment (2011) *The UK National Ecosystem Assessment: Synthesis of the Key Findings*. UNEP-WCMC, Cambridge.

48 Defra publication (2009) Safeguarding our Soils: A Strategy for England. Available at: <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69261/pb13297soil-strategy-090910.pdf>

49 Natural England. (2010) England's peatlands: Carbon storage and greenhouse gases. NE257. Available at: <publications.naturalengland.org.uk/file/6741421035356160>

50 Carpenter (2005). Eutrophication of aquatic ecosystems: Bistability and soil phosphorus. *PNAS*, 102(29).

51 Ormerod et al (2016). Field and laboratory studies reveal interacting effects of stream oxygenation and warming on aquatic ectotherms. *Global change biology*, 22: pp. 1769-1778.

extended [52]. Natural flood management through wetlands, for example, helps improve the connectivity between habitats, and facilitates better species movement. The ability of species to have bigger, more connected habitat for dispersal is particularly important to species' climate change adaptation (as described in more detail in the climate change adaptation section below).

'Soft engineering' options to reduce downstream flood risk include riparian woodlands, floodplain woodlands, storage ponds, restoring peat moorlands, re-meandering rivers, targeted woodland planting and improving floodplain connectivity. Management measures need to be implemented over a large scale (and require cooperation across multiple land/farm holdings) to ensure a significant effect on reducing flood risk [53, 54, 55]. PGS and ERS should incentivise the provision of natural flood management that both reduces flood risk and provides other ecosystem services such as increased biodiversity and carbon sequestration.

10.4 Improved air quality

Agriculture accounted for 88% of total ammonia emissions in the UK in 2016, with an increase of 3.2% mainly due to the manure management of larger dairy herds. Ammonia released because of agricultural practices (e.g. through livestock waste such as slurry and manure) also contributes to atmospheric pollution and can cause soil acidification and eutrophication of terrestrial and freshwater ecosystems[56]. While much of the available research on the impacts on biodiversity focuses on the impacts of nitrogen more generally, some studies have begun to show ammonia's impact. For instance, bog and peatland habitats and lichens and mosses are particularly sensitive to ammonia pollution[57]. Ammonia pollution can negatively impact plant species as it is toxic to most leaves, which in turn impacts the diversity and composition of available food sources for many wildlife species[58]. PGS should therefore incentivise the reduction of ammonia pollution from agriculture.

10.5 Resilient habitats and ecosystems

Alongside its intrinsic value and social benefits, biodiversity is also a leading determinant of ecosystem function[59], If Wales is to maintain a stable supply of ecosystem goods and services, especially under rapidly changing conditions, maintaining and improving levels of biodiversity is essential[60]. Despite this, Europe has experienced a major decline in biodiversity associated with agro-ecosystems (even

[52] Maltby et al. (2013). The challenges and implications of linking wetland science to policy in agricultural landscapes – experience from the UK National Ecosystem Assessment. *Ecological Engineering,* 55.
[53] Parliamentary Office of Science and Technology (2011). POSTnote 396: *Natural Flood Management*.
[54] Dixon et al (2016) The effects of river restoration on catchment scale flood risk and flood hydrology. *Earth Surface Processes and Landforms* (41): pp. 997–1008.
[55] Burgess-Gamble et al (2018). Working with Natural Processes – Evidence Directory. Environment Agency Project number: SC150005
[56] Good et al (2011). Fertilizing Nature: A Tragedy of Excess in the Commons. *PLoS Biol,* 9(8).
[57] Royal Society. The impact of ammonia emissions from agriculture on biodiversity: An evidence synthesis.
[58] Royal Society. The impact of ammonia emissions from agriculture on biodiversity: An evidence synthesis.
[59] Tilman, D., *et al*. (2014). Biodiversity and Ecosystem Functioning. *Annual review of ecology, evolution and systematics,* 14: pp.471-493.
[60] Hooper, D. U., *et al*. (2005). Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological Monographs*, 88(3).

with implementation by Member States of the Birds and Habitats Directives and AES)[61,62] and new measures such as 'greening' are not yet helping the EU achieve its 2020 Biodiversity Targets. In fact, the European Court of Auditors in their report on Greening states[63]:

Agriculture, in particular, intensive farming, exerts a negative impact on the environment and climate. Greening - a direct payment rewarding farmers for farming practices beneficial for soil quality, carbon sequestration and biodiversity – was introduced in 2015, as a means to enhance the environmental and climate performance of the EU's Common Agricultural Policy. We found that greening, as currently implemented, is unlikely to meet this objective, mainly due the low level of requirements, which largely reflect normal farming practices. We estimate that greening has led to a change in farming practice on only around 5 % of all EU farmland.

Identifying the important elements of biodiversity for ecosystem function is an essential element of conservation planning[64,65]. As detailed in our answer to Question 13, decision-makers need to choose among protection, management or restoration, between species and/ or habitats[66], or between populations of species at different sites depending on their importance to wider ecosystem function[67,68]. The PGS should prioritise important species for ecosystem function and habitat connectivity and resilience (see Question 8 for the relationship between biodiversity and public goods, and Question 8 parameter 3). Such an approach would help to increase biodiversity more generally, in line with the Aichi targets and the Welsh Nature Recovery Network programme[69].

10.6 Climate Change Adaptation

We are pleased to see the Welsh Government include climate change adaptation in the PGS. Climate change (see Appendix 2 for agricultural emissions) is predicted to become the leading cause of biodiversity loss globally[70], with impacts across Wales including coastal zones, freshwater habitats, uplands and woodlands. Studies have shown that up to 82% of core ecological services could also be disrupted[71]. Climate change has already begun to negatively impact different species, as range reduction and fragmentation have accelerated extinction. For instance, the lesser horseshoe bat has seen a steep population decline in recent decades and climatic changes are expected to push them from south-west Wales to north wales, where they may not have access to the necessary roosting

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61 European Environment Agency. (2015). Report: EU 2010 biodiversity baseline — adapted to the MAES typology.
62 European Environment Agency. (2013). Report: The European Grassland Butterfly Indicator: 1990–2011 Technical report
63 European Court of Auditors. (2017). Special Report: Greening: a more complex income support scheme, not yet environmentally effective (pursuant to Article 287(4), second subparagraph, TFEU) No21/2017.
64 C.R. Margules & R.L. Pressey (2000), Systematic conservation planning, Nature
65 Kerrie A. Wilson et al (2011), Optimal restoration: accounting for space, time and uncertainty, Journal of Applied Ecology
66 Noss et al (2009) Prioritizing ecosystems, species, and sites for restoration. Quantitative methods and computational tools.
67 Westphal et al (2003), The use of stochastic dynamic programming in optimal landscape reconstruction for metapopulations, Ecological Applications.
68 Evans et al (2013), The robustness of a network of ecological networks to habitat loss, Ecology Letters.
69 Hayhow, D.B., *et al*. (2016). *State of nature 2016.* The State of Nature Partnership. (CEH Project no. C04535).
70 IPCC (2014) Summary for Policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change <https://www.ipcc.ch/pdf/assessment-report/ar5/wg2/ar5_wgII_spm_en.pdf>
71 Scheffers, BR *et al.* (2016) The broad footprint of climate change from genes to biomes to people, Science, 354(6313).

sites and habitats[72]. Other species which could see population reductions and even extinction in Wales due to climate change include the Song Thrush and Heath Fritillary and Arctic-alpine species such as the Snowdon Lily and Purple Saxifrage. An estimated 47% of land mammals and 27% of birds have already been negatively impacted by climate change[73]. Prioritising climate change adaptation in the PGS will help the Welsh Government to address these potential habitat shifts and prevent further biodiversity losses[74].

10.7 Enhanced beauty, heritage and engagement with the natural environment

The BES would welcome incentives to improve access to nature, where this would not result in recreational disturbance of vulnerable species such as ground nesting birds[75,76,77]. The outdoors inspires people, gives them a sense of place, and a better understanding of heritage and culture[78]. Pedagogy of place allows people to understand complex environmental issues and see how nature is relevant to them. It can also provide clarity on what public funds are used for and why protections are in place for many areas[79].

Question 13 of 20

From Chapter 6: Public Goods Some actions can deliver multiple public goods in the same location. For example, peat bog restoration can have benefits for carbon sequestration and flood risk reduction. However, some locations could be suitable for multiple public goods from different activities. For example, one location may be suitable to either plant trees for carbon sequestration, or to revert to wetland for biodiversity. How could locations for single, multiple or competing benefits be prioritised?

Key Points and Recommendations:

- **The BES recommends using knowledge of ecological networks to guide management options on specific sites.**
- **Choosing an appropriate conservation action for an ecological network will depend on the features of the site and the local area.**

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[72] Climate change and Biodiversity in Snowdonia. [Online]. Available at: http://www.eryri.llyw.cymru/__data/assets/pdf_file/0006/314682/ClimateChange-and-Biodiversity_e.pdf
[73] Pacifici et al. (2017). Species' traits influenced their response to recent climate change, *Nature Climate Change*, 7.
[74] IPCC (2014) Summary for Policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.
[75] Mallard et al., (2007). Linking recreational disturbance to population size in a ground-nesting passerine. *Journal of Applied Ecology*, 44:1.
[76] Botsch et al (2017). Experimental evidence of human recreational disturbance effects on bird-territory establishment. *Proceedings of the Royal Society B: Biological Sciences*, 284(1858).
[77] Marzano and Dandy. (2012). Recreational use of forests and disturbance of wildlife. Forestry Commission.
[78] Natural England. (2009). Experiencing Landscapes: capturing the cultural services and experiential qualities of landscape. Natural England Commissioned Report NECR024.
[79] Kaplan (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, 15(3): pp. 169–182.

- **We recommend giving land owners a menu of environmental benefits to choose from, with the options differing between areas.**

13.1 Designing resilient ecological networks

In the absence of unlimited funds, priority setting is an essential element of conservation planning[80,81,87]. Decision-makers need to choose among protection, management or restoration, between species and/ or habitats[82], or between populations of species at different sites depending on their importance to wider ecosystem function[83,84]. Understanding of complex species interactions networks has grown considerably[85,86]. Advances in technology, such a 'barcoding' and the application of genetic algorithms[87] allow for increasingly sophisticated understanding of species networks, while Isaac et al (2018)[88] highlight the importance of increasing ecological connectivity in order to make ecosystems more resilient, and some of the new techniques for doing so.

New developments in ecological theory – such as metapopulation and network theory – and advances in computational methods make it possible to model how species will respond to multiple future scenarios and over large spatial scales. With the right data, it is possible to model the future resilience of existing and proposed ecological networks. Given the costs associated with creating and managing ecological networks, decision-makers should harness these powerful tools in order to optimise decision-making and subsequent outcomes[89]. Analyses should use proxy measures to articulate resilience: area of high-quality habitat; median patch size; total area of suitable habitat for multiple species; and network conductance[90]. Using existing process-based models combined with highresolution remote sensing imagery would help identify locations where there are opportunities to provide key public benefits in the most cost-effective way[91,92]. In order to understand the impacts of policy-decisions, interventions should be measured against non-intervention 'control' sites, for

[80] C.R. Margules & R.L. Pressey (2000), Systematic conservation planning, Nature
[81] Kerrie A. Wilson et al (2011), Optimal restoration: accounting for space, time and uncertainty, Journal of Applied Ecology
[87] Kukkula & Moilanen (2013)
[82] Noss et al (2009) Prioritizing ecosystems, species, and sites for restoration. Quantitative methods and computational tools.
[83] Westphal et al (2003), The use of stochastic dynamic programming in optimal landscape reconstruction for metapopulations, Ecological Applications.
[84] Evans et al (2013), The robustness of a network of ecological networks to habitat loss, Ecology Letters.
[85] Evans et al (2013), The robustness of a network of ecological networks to habitat loss, Ecology Letters.
[86] For reviews, see Fontaine et al (2011) The ecological and evolutionary implications of merging different types of networks. Ecol. Lett; and Kefi et al (2012) (2012). More than a meal… integrating non-feeding interactions into food webs. Ecol. Lett
[87] Evans et al (2013), The robustness of a network of ecological networks to habitat loss, Ecology Letters.
[88] Isaac et al (2018), Defining and delivering resilient ecological networks: nature conservation in England, Journal of Applied Ecology.
[89] Isaac et al (2018), Defining and delivering resilient ecological networks: nature conservation in England, Journal of Applied Ecology.
[90] Isaac et al (2018), Defining and delivering resilient ecological networks: nature conservation in England, Journal of Applied Ecology.
[91] Emmett B.E. and the GMEP team (2017) Glastir Monitoring & Evaluation Programme. Final Report to Welsh Government - Executive Summary (Contract reference: C147/2010/11). NERC/Centre for Ecology & Hydrology (CEH Projects: NEC04780/NEC05371/NEC05782)
[92] Reed et al (2014). Improving the link between payments and the provision of ecosystem services in agri-environment schemes in UK peatlands. *Ecosystem Services* 9: pp. 44-53.

instance, to see whether intervention sites are experiencing lower extinction rates, higher colonization rates, or smaller colonization rates than control sites[93].

In order to continually improve upon decision-making, decisions should form part of an adaptive management cycle[94], linking science, planning and implementation. Adapted from Isaac *et al* (2018)[95], under this model:

- Features of the existing ecological network would be evaluated regularly;
- Plausible conservation actions focussed on sites or species would be identified and evaluated for their potential to improve network resilience;
- Chosen actions are directed at sites or species;
- Their effectiveness are monitored.

When choosing conservation actions, consideration should also be given to the conservation status of species and how any action will contribute to the achievement of the Aichi Targets[96].

Targeting options to areas where they are most appropriate and needed can improve the impact of the scheme (as long as it is recognised that prioritising one option over another may result in trade-offs; therefore proposed option decisions should be carefully assessed to ensure that an optimal set of outcomes can still delivered - e.g. increasing upland woodland planting to reduce flood risk in a catchment may impact on local upland breeding wader populations). Assessing the benefits (and those that are foregone because of trade-offs) will enable payments to be linked directly to actions and will make the economic case to both the farmers and public.

13.2 Spatial targeting and land use modelling can help determine the most effective management options

Cost-benefit exercises[97] can then be undertaken to establish the most effective management options whilst not compromising land profitability. Successful spatial targeting (see Appendix 3) can increase the population of priority species through habitat creation (although it should be recognised that prioritising one species over another may result in trade-offs for other species depending on the habitat created- see our answers to Questions 8 and 10). For example, case studies have shown that spatial targeting has successfully increased the population size of micro moths (Lepidoptera) through the creation of grassland habitat on arable field margins[98] and increased the nest density of wild

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[93] Isaac et al (2018), Defining and delivering resilient ecological networks: nature conservation in England, Journal of Applied Ecology.
[94] Westgate et al (2013) Adaptive management of biological systems, Biological Conservation.
[95] Isaac et al (2018), Defining and delivering resilient ecological networks: nature conservation in England, Journal of Applied Ecology
[96] Hagen et al (2016), Restoration priorities and strategies, TemaNord.
[97] Collins et al (2016). Tackling agricultural diffuse pollution: What might uptake of farmer-preferred measures deliver for emissions to water and air? *Science of the Total Environment*, 547: pp.269-281.
[98] Alison et al (2016). Spatial targeting of habitat creation has the potential to improve agri-environment scheme outcomes for macro-moths. *Journal of Applied Ecology,* 53 (6): pp. 1814 – 1822.

bumblebees thanks to an increase in suitable forage[99]. The evidence base for effective spatial targeting should be significantly expanded to improve the quality of land management policy and delivery. This evidence could come from land use modelling, using random sampling within land classes to validate model outputs.

13.3 National Character Landscape Area Maps could be a basis for land prioritisation

We recognise that there is no ideal administrative unit for managing landscapes, but National Character Landscape Area (NCLA) maps provide a basis for prioritising land-management options in each area. They are the best existing structure to use due to the bio-physical determination of their boundaries rather than purely administrative. The achievement of effective multi-functional landscape management is incredibly valuable and will deliver substantial societal gains, but the administrative route to achieving needs further work. To manage NCLAs effectively, a new administrative body may be needed to coordinate individual NCLAs, ensuring regional and national multifunctional landscape priorities are appropriately understood and articulated. This new body could also act as the primary channel for communication between those bodies responsible for the wider socio-economic functions offered by landscapes such as health, housing, etc.

13.4 Choice experiments could be used to deliver the Public Goods Scheme

An alternative option for prioritising public goods outcome is choice experiments, which was done for the Biodiversity Action Plan, to get members of the public to rank public goods in priority order for their region. There is no evidence that such preferences change significantly from year to year, but there is evidence that they differ regionally across the UK, enabling farmers to choose from options that are regionally targeted to public preferences but that do not constantly change in response to changing public opinion.

Land managers could be given a menu of environmental benefits to choose from, in addition to restoring and creating ecological networks, with the menu differing between areas, depending on which benefits can most cost-effectively be provided in any given location, and public preferences[100,101]. For example, existing process-based models combined with high-resolution remote sensing imagery can identify locations where there are opportunities to provide key benefits in the most cost-effective way[102,103]. In this way, spending is prioritized (by increasing scheme points available) to the locations that can most easily provide the benefits that society wants, and land managers in those locations are paid for the work they do on a stable, long-term basis[104]. Therefore,

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[99] Wood et al (2015). Targeted agri-environment schemes significantly improve the population size of common farmland bumblebee species. Molecular Ecology, 24 (8): pp.1668 – 1680.

[100] Christie and Rayment (2012). An economic assessment of the ecosystem service benefits derived from the SSSI biodiversity conservation policy in England and Wales. *Ecosystem Services*, 1(1): 70–84.

[101] Christie et al (2011). Economic valuation of the Benefits of Ecosystem Services delivered by the UK Biodiversity Action Plan. Defra, London.

[102] Emmett and the GMEP team. (2017). Glastir Monitoring & Evaluation Programme. Final Report to Welsh Government - Executive Summary (Contract reference: C147/2010/11). NERC/Centre for Ecology & Hydrology (CEH Projects: NEC04780/NEC05371/NEC05782).

[103] Reed et al (2014). Improving the link between payments and the provision of ecosystem services in agri-environment schemes in UK peatlands. *Ecosystem Services,* 9: 44-53.

[104] Reed et al (2017) A Place-Based Approach to Payments for Ecosystem Services. *Global Environmental Change*, 43: 92-106.

place-based schemes have the potential to integrate payments for multiple services and habitats to provide payments at higher levels over longer periods than are currently available for similar work under the EU funding[105]. However, it is important to note that there would be both winners and losers if those managing certain areas are paid more or less; based on the different levels of benefits they are able to provide society.

An alternative option, which could be combined with the previous option, is to supplement public funding for the provision of environmental benefits from peatlands, for example, with private funding via Payments for Ecosystem Services schemes, such as the Woodland Carbon Code and the Peatland Code. Place-based schemes have the potential to integrate payments for multiple services and habitats to provide payments at higher levels over longer periods than are currently available for similar work under the EU funding[106].

Question 14 of 20

From Chapter 6: Public Goods Given that support for the delivery of public goods will be a new approach in Wales, there will be a requirement for a significant amount of training and advice for the sector. How best could this training and advice be delivered? Which areas of the sector need the most attention?

Key Points and Recommendations:

- **A comprehensive advisory service is needed.**
- **Training schemes should be monitored and reviewed regularly, with integration of comprehensive, long-term monitoring at a national scale (which will feed back into evaluation of the effectiveness of interventions.**

The effectiveness of previous and current agri-environment schemes is highly variable, and often depends on the level of engagement, experience and skills of the farmer[107]. Good quality advice and training are therefore essential, with biodiversity outcomes improving when farmers and landowners received training[108, 109]. Supporting and encouraging peer-to-peer support among farmers also

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105 Reed et al (2017) A Place-Based Approach to Payments for Ecosystem Services. *Global Environmental Change*, 43: 92-106.
106 Reed et al (2017) A Place-Based Approach to Payments for Ecosystem Services. *Global Environmental Change* 43: 92-106
107 McCracken et al (2015) Social and ecological drivers of success in agri-environment schemes: the roles of farmers and environmental context. *Journal of Applied Ecology,* 52: pp. 696-705.
108 Guillem and Barnes (2013). Farmer perceptions of bird conservation and farming management at a catchment level. *Land Use Policy,* 31: pp.565– 575.
109 Dicks et al (2017) Farmland Conservation Pages 245-284 in: W.J. Sutherland, L.V. Dicks, N. Ockendon & R.K. Smith (eds) What Works in Conservation 2017. Open Book Publishers, Cambridge, UK.

significantly improves environmental outcomes, with farmers feeling more confident and being more likely to engage in environmental management in their wider area[110,111,112,113].

Question 17 of 20

From Chapter 8: Transition, delivery and legislation What is the most appropriate way to phase out the Basic Payment Scheme to start implementation of the new schemes?

Key points and recommendations:

- **The Welsh Government should ensure that there is no gap in payments for environmental stewardship.**

We welcome new funding programmes which are focused on the environment, but it is important to avoid a gap between the end of current payment schemes and the start of the new PGS, as it uncertain how protected plant and animal communities would respond to the withdrawal of active management[114] as a result of a hiatus in funding. Furthermore, it is also unknown how farmers would adjust their land management practices if they were between payments, while uncertainty may also inhibit landowners from taking up new schemes. In order to avoid jeopardising the objectives in the Environment (Wales) Act 2016, the Welsh Government should avoid a gap in funding for sustainable land management.

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[110] Welsh Government. (2018). New service to support farmers and foresters to apply for the RC-RDP Sustainable Management Scheme. [Online]. Available here: https://gov.wales/topics/environmentcountryside/farmingandcountryside/cap/wales-ruralnetwork/news/59591494/?lang=en

[111] Rose Regeneration. Putting the Spotlight on Farming Communities: The role of Farmer Networks in challenging areas. Farmers Network Project report 2013. Commissioned by the Royal Agricultural Society of England (RASE).

[112] Lastra-Bravo et al (2015). What drives farmers' participation in EU agri-environmental schemes? Results from a qualitative meta-analysis. *Environment Science & Policy*, 54: pp. 1–9.

[113] Hejnowicz et al (2016). A survey exploring private farm advisor perspectives of agri-environment schemes: The case of England's Environmental Stewardship programme. *Land Use Policy*, 55: 240-256.

[114] Reed et al (2013). Anticipating and managing future trade-offs and complementarities between ecosystem services. *Ecology & Society,* 18(1): p5.

BRITISH ECOLOGICAL SOCIETY

Appendix 1- Evidence-base for agri-environment schemes

The evidence-base for a number of agri-environment scheme options has been assessed in recent research[115,116]. The research looked at whether the scheme delivers on 'public money for public goods'. The scheme options which were analysed were: fencing waterways from livestock, soil loosening, tree planting on floodplains, conversion of grass to woodland, conversion of arable to woodland, buffer strips, agroforestry, tillage practices, organic amendments to arable land, hedges, cover crops, over-winter stubble, and leys. The public goods which were considered were: water quality (including N and P concentrations, suspended sediment, *E. coli*), flood risk alleviation (based on changes in channel discharge, soil bulk density, aggregate stability, porosity, infiltration rate and hydraulic conductivity), climate change mitigation (carbon stocks) and soil health (based on papers using earthworm numbers as an indicator). In addition, the impact on yields was analysed to identify potential trade-offs.

The following table lists scheme options for which there was robust evidence for specific public goods, based on certain well-studied indicators:

Scheme option	**Public good** (indicator used in brackets)
Watercourse fencing to exclude livestock	Water quality (led to a reduction in P and *E. Coli*)
Buffer strips in arable systems	Soil health (soil organic carbon, bulk density, aggregate stability)
Converting arable land to woodland	Climate change mitigation (soil carbon stock increases)
Grass-clover leys in arable rotation	Climate change mitigation (soil carbon)
Minimal tillage	Soil health (bulk density and hydraulic conductivity)
Hedges in arable land	Climate change mitigation (soil carbon)
Organic amendments	Climate (soil carbon) and soil health (aggregate stability, earthworms) BUT could lead to reductions in water quality
Converting arable land to woodland	Climate (soil carbon)

For other scheme options and public goods, evidence was mixed or weak and it was not possible to assess the magnitude or rate of change, requiring more research. For example, overall cover crops maintain soil health in the short term (less than 10 years) and may improve soil health in the long term (greater than 10 years), but these effects were highly variable between different sites. Another example is how organic amendments increase soil organic carbon stock, aggregate stability and earthworm population. However, some organic amendments could lead to the build-up of potential

[115] The research was conducted by the Resilient Dairy Landscapes project (funded by the Global Food Security Programme, Resilience of the UK Food System in a Global Context) and Yorkshire Integrated Catchment Solutions Programme (iCASP, funded by the Natural Environment Research Council). Two teams of researchers completed reviews of 13 scheme options and considered peer-reviewed evidence.

[116] Chapman et al (2018). Draft summary: Agricultural Land Management for Public Goods Delivery: iCASP Evidence Review on Soil Health.

pollutants within the soil which could end up in water courses and affect yield, such as phosphorus and pharmaceuticals.

Appendix 2- Emissions from agricultural pollution

Globally, agriculture contributes approximately 5.0–5.8 Gt CO_2e yr^{-1}or c 11% of total anthropogenic GHG emissions, (not including land-use change)[117]. Agricultural emissions are also significant at national levels, contributing an average of 35% of emissions in developing countries and 12% in developed countries according to countries' GHG emissions inventory reports to the UNFCCC. In the UK, emissions from agriculture are in the region of 44.1 − 52.1 $MtCO_2e$[124]. and in 2015 were reported as causing 9% of the UK's greenhouse gas (GHG) emissions (composed of nitrous oxide (around 55%), which is produced by the use of synthetic and organic fertilisers; methane (around 36%), which is created through the digestion processes in livestock animals and the production and use of manure and slurry; carbon dioxide (around 9%) from energy used for fuel and heating)[118].

Appendix 3 – Spatial targeting

At a catchment scale, research has been conducted in Wales which shows spatial targeting can successfully be used to determine the influence of agri-environment schemes on water quality[119]. The research compared catchments that were part of a scheme against catchments which were not. A spatially explicit modelling framework was applied to each catchment to measure disuse pollutant emissions and determine scheme effectiveness[120]. This kind of modelling could be used to determine the existing and potential public good outcomes for the PGS.

[117] Smith et al. (2014) Agriculture, forestry and other land use (AFOLU). In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (eds Edenhofer O, Pichs-Madruga R, Sokona Yet al.), pp.811–922. Cambridge University Press, Cambridge. [124] Richards et al (2015). Agriculture's contributions to national emissions. CCAFS Info Note. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

[118] Gov UK report: 2010 to 2015 government policy: greenhouse gas emissions.

[119] Jones et al (2017). Do agri-environment schemes result in improved water quality? *Journal of Applied Ecology*, 54: 537546.

[120] Jones et al (2017). Do agri-environment schemes result in improved water quality? *Journal of Applied Ecology*, 54: 537546.