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Sustainable land management: managing land better for environmental benefits

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OVERVIEW

England is at a historical crossroad for the governance of land and the natural environment. Actions for addressing and adapting to climate change, achieving food security and tackling the biodiversity crisis are all embedded in and depend on how land is managed.

Existing Government policy and targets have so far failed to address many of these complexities of land, farming and the natural environment.[1] Since the Government Office for Science Foresight report "Land Use in the UK in the 21st Century" was published in 2001, many environmental indicators, such as those for biodiversity and water quality, are still in decline.[2] In 2018, the 25 Year Environment Plan (25 YEP) set out the Government's ambitions for the natural environment under separate policy areas.[3]

Yet the Environmental Audit Committee have stated the 25 YEP does not provide sufficient direction to leave the environment in a better state, and that existing Government policy and targets are inadequate to remedy historic and current rates of biodiversity loss - which characterises the UK as the most nature depleted nation in the G7.[1] Over the past decade, the UK has failed to meet a raft of international targets to prevent further declines in the state of nature.

Existing policies and targets are not joined up across government to address biodiversity loss. The challenges arising from interactions between discrete policy siloes have been discussed through integrated decision making frameworks like natural capital accounting,[4] payments for ecosystem services[5] and Nature Based Solutions.[6] There are also examples of more specific 'on the ground' opportunities, such as integrating policies that both support bee populations and improve food production. For example, policies that encourage planting flowering strips in combination with lower pesticide use (through integrated pest management) can provide both crop yield benefits for agriculture and provide the environmental benefit of enhanced bee biodiversity, which supports other ecosystem processes. There is also the example of tree planting, which if done in the right locations, can mitigate flooding (POSTNote 636) and sequester carbon dioxide (POSTNote 623), but if in the wrong place, will undermine these efforts. These and other examples illustrate the need to integrate policy across the discrete environmental sectors.

As part of its efforts to tackle these challenges, the Government is designing frameworks to replace the former subsidy arrangements under the EU's Common Agricultural Policy, with the Environment Bill setting out a new regulatory framework for environmental targets and objectives.

Defra has identified what sustainable use of available land area looks like and the full suite of natural environment considerations and outcomes that are desired, while highlighting the major challenges to be addressed,[7] and is developing new schemes to shape land management practices.[8]

As part of the Agricultural Transition Plan, Defra are proposing the Sustainable Farming Incentive, the Local Nature Recovery and Landscape Recovery Schemes to act as the main mechanisms for tackling the environmental challenges of climate change, ecosystem and biodiversity recovery and sustainable farm businesses.[8] However, there are significant levels of uncertainty within the farming community and the proposals have faced substantial criticism by a wide range of conservation, farming and political organisations.[9–11]

Sustainable Land Management (SLM) could be a way of addressing the criticisms the Government's schemes face. SLM is a broad framework to help decision making around how we manage our land for greatest societal benefit. It emphasises local buy-in, stakeholder and community engagement as part of a larger coherent national scale spatial plan showing what to do and where.

It is a cross scale approach recommending that actions are supported by adequate knowledge transfer, data, monitoring, funding and democratic participation. SLM could also be a key tool for Government to integrate frameworks to address multiple land use pressures (POSTNote 627).

It is important to acknowledge the scale of the evidence base for SLM; which is limited to only a small number of targeted environmental outcomes in developed countries. Most examples of SLM as land policy are often found in developing countries where food security have been central concerns within processes of environmental and social change.

The Welsh Government has recently adopted SLM in its land management strategy. The ambition is a transition towards landscapes that are multifunctional. This means that they: produce healthy food; protect wildlife; provide clean water; help to address climate change; provide protection from hazards; and they reflect cultural heritage values.[12] This approach will require drawing on the full range of approaches that SLM offers to support land managers with adequate data, know-how, appropriate policy frameworks, financial support and other enabling conditions.

This POSTBrief describes how SLM frameworks can bridge the gaps between institutions, deliver cross-sector communication between partners and sets out 10 key principles common to these frameworks. It demonstrates the relevance of these principles in five key areas across food and farming, nature recovery, water management, climate change, culture and heritage (see Principles in Practice).

To bring context to these principles, the report takes a broad review of the challenges in implementation in these areas that have emerged from the evidence base. An annex also provides an overview of the history of agricultural land use in England, identifying key factors that shaped these landscapes.

Key Points in this POSTbrief include:

- Land management is a complex challenge that requires integrated approaches across science, technology and economics, while being strongly shaped by cultural and social values and local traditions.
- Around 75% of land in England is farmed,[13] which makes farming and farm-land managers central to the Governments' environmental ambitions. Farming policy is itself undergoing generational changes in connection to Brexit and the Agricultural Act 2020. Conditions facing farm businesses will also change substantially over the coming years.
- Better land management can be incentivised through both private finance and public payments. But the "what", "where" and "how" will be determined by the willingness of land managers. The challenge is in delivering a full range of public goods from land and balancing these so that one does not unduly affect others. For example, through generating unacceptable trade-offs between food provision and nature conservation. The National Food Strategy recommends that Government produce a Rural Land Use Map and Strategy to support spatial decision making for sustainable land use.
- Despite Government's ambitions for land and the range of policy priorities in connection to this, the proposed frameworks such as the Agriculture Act 2020, the Environment Bill 2019-21 and the Planning Bill 2021, do not address or consider the trade-offs that inevitably arise from land management choices.[14]
- SLM is a broad, holistic framework that seeks to align institutions, funding, knowledge and practice at all scales of governance and management. It could be an effective framework for managing the multiple pressures on English landscapes while facilitating the delivery of public goods. It emphasises local buy-in using demonstration sites and knowledge exchange, while building on existing decision support tools like natural capital accounting.
- Food and farming face substantial challenges. SLM provides a way of considering both farmers' agency and consumer behaviour. The catchment approach for water is an existing example of collaboration between stakeholders, such as farmers, water companies and conservation bodies. Biodiversity and Net Zero policies are accountable to international treaties but delivery relies on management at landscape scale and depends on landowners working together. Culture and heritage are key to the value of landscapes and how they have been managed.
- SLM can benefit farming through agri-environmental practices that tie improving yields to environmental outcomes. Improved science and knowledge transfer that links agricultural practice to biodiversity and

ecosystem service outcomes at different spatial scales with economic incentives is only part of the solution. Institutional and cultural factors need to be considered to account for the way land managers see their role in delivering public goods. Current approaches currently lack sufficient knowledge of social science to understand land-owner motivation, cultural norms and historic information on the environment. Land manager trust in the Government is low, and principles of SLM show ways of improving this.

- To deliver the Governments' natural environment goals, land managers need to work with different actors and scales across the water, conservation and climate sectors in the private, government and third sector. There are challenges of scale, planning, skills and funding, since SLM plays out at landscape rather than field scale. Government funding and policy will need to address these challenges.
- SLM takes a root and branch approach to the underlying factors that shape landscapes and the public goods provided. It connects high level governance to the grassroots challenges of fostering working relationships within local community partnerships. Tensions between local parties and between the local and national governance are foregrounded to support more cooperative approaches navigating multiple sources of funding and regulation.
- Optimising this complex arrangement is best achieved through polycentric governance where multiple authorities at different levels of governance (national, regional and community) coordinate coherently. Poly-centric governance for SLM needs to be supported by adequate funding, aligned policy frameworks and improved knowledge transfer. The difference would be supporting managers with knowledge on the ground for "how to" do SLM rather than merely showing "what" the problems are. The Dasgupta review recommended poly-centric governance to deliver land use and management policy change. This allows local concerns and values to engage and negotiate with national environmental and biodiversity objectives.[15]

BACKGROUND

Sustainable Land Management

Sustainable Land Management (SLM) is an internationally-recognised concept, defined by the United Nations (UN) as: "The use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term potential of these resources and the maintenance of their environmental benefits."[16]

SLM encompasses a wide variety of management and governance structures, interventions and functional scales of approach. SLM includes, but is not limited to, actions taken at the field scale that provide cumulative benefits and emergent properties that reshape sustainable landscapes. This would include restoring ecological processes and interactions, for example improving soil health and benefiting food production, but also water quality and natural flood prevention.[17,18] Hence, a strict "one size fits all" definition of SLM would obscure one of its core intentions – adaptability.

Sustainable land use and land management are often used interchangeably in the literature but with differentiation in context. For example, land use could involve decision making over spatial arrangements of forestry vs agricultural land, whereas land management refers to management practices within specific land uses. The two are often related closely to one another. SLM has been defined within academic circles as way of delivering multifunctionality through "a knowledge-based procedure that helps to integrate land, water, biodiversity, and environmental management to meet rising economic, environmental and social demands while sustaining ecosystem services and livelihoods".[19] The term refers to activities from farm to landscape-scale but is predicated on site level actions and particular stakeholder groups.[20] SLM is also known as "integrated land management" (POSTnote 627), potentially becoming an umbrella term for various landscape management frameworks incorporating sustainable multi-functional land use, conservation farming or sustainable agriculture.

The Welsh Government's 2019 'Sustainable Farming and our land' consultation describes its overarching approach to future support as being based on an objective of achieving a system of SLM. The consultation defines SLM in line with the above UN definition.[12] Importantly, although the Welsh Government highlights sustainable food production as the major policy focus, it also emphasises wide-ranging contributions of farmers, in terms of economic, environmental and social factors.

The Welsh Government's proposed Sustainable Farming Scheme aims to 'reward famers for delivering SLM outcomes', with landowners expected to co-operate across relevant scales to deliver these outcomes. [21] Key features of this reward are outlined as: a meaningful and stable income stream, outcome-based payments, rewarding new and existing practices and maintaining flexibility for all types of farm. The "Sustainable Farming Payment" proposed by the Welsh Government also aimed to support SLM outcomes which are not rewarded by the market, such as social and heritage resources (public health, including farmer mental health, education, culture, access), as well as supporting inter-generational equality.

Natural Resources Wales are also developing seven area statements setting out the key challenges and opportunities for the sustainable management of natural resources in those areas (POSTnote 627), with that for Northwest Wales based around supporting sustainable land management.[22] A broader definition of SLM is needed, encompassing all aspects of land use, including culture and heritage values, cross-sectoral approaches and all aspects of sustainability (see Defining the 'sustainable' in land management), to meet the challenges of 21st century environmental management.

Sustainable Land Management is a knowledge-based approach that aims to manage trade-offs between outcomes and between actors. Evidence shows that its success will depend on a series of wider principles of sustainable development that address land use capacity, knowledge, expertise and collaboration between actors.[23,24] Since land management cross cuts multiple sectors, scales and policy domains, there are risks that SLM can be undermined by misaligned policies, financial actions like payments and subsidies, or other food system dynamics.[19] The disassociation between scales of cause and effect means SLM needs to rely on processes that operate at multiple spatial levels (i.e. polycentric governance), are people-centric, designed for wide buy-in, build knowledge and awareness and deliver strategies and partnership approaches that are spatially specific and organisationally decentralised. Social governance, collective decision-making processes, knowledge based capacity and ethical considerations shape innovative cultures of natural resource management. Practices of SLM are informed by science, but shaped by land managers values and aspirations, which evidence shows are broader than economic self-interest limited to payment incentives.[25,26]

The motivations and interests of local land users is one of the central SLM challenges associated with aligning with landscape scale transformations, restoration and ecological networks. Existing decision making systems may be spatially optimised at the field scale (for example: within various farming decision support systems[27]), but do not necessarily align with land managers own desires, or with the expectations of land managers in the surrounding area. SLM is a systemic challenge, where "one size fits all" solutions frequently fail. Landscapes are complex social and ecological mosaics that are shaped by forces arising from different origins and stakeholders,[28] with the ecological, historical, economic and cultural processes local to the area reflected in the landscape (Box 1).

Box 1. What is a "landscape"?

The complex factors that underlie what makes a landscape have been discussed within the UK Government's 25 Year Environment Plan (25YEP).3 Like SLM, the definitions of a landscape are not uniform. Boundaries might follow ecological or, physical features or jurisdictional factors, or identify units that function conceptually as distinct 'cultural landscapes'.[29–32]

In 2019, the Defra Science Advisory Council assessed the current and historical context of the term "landscape". [33] The definition used to describe a static feature with inherent characteristics but has now shifted to embrace an appreciation for the dynamic natural and human processes that define those features. The United Nations World Heritage Committee in 1992, influenced the European Landscape Convention's definition of landscape as 'an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors'. [34]

Natural England and its predecessor agency with special responsibility for landscape protection in England, the Countryside Commission, have long shaped their work on landscapes to improve understandings over what gives England's varied landscapes character. "The Countryside Character Programme" was designed in the 1990s 'to be a framework for helping to incorporate the rich heritage of landscape diversity into present day decisions, not as a process that seeks to prevent activities.'[35] Natural England has defined landscapes by their underlying geology, soils, topography, land cover, hydrology, historic, social and cultural development, and climatic factors (Figure 1). Landscape character may be defined as a distinct and recognisable pattern of these elements that make one landscape different from another. [5] The Landscape Character Assessment (LCA) is a process of identifying the unique combination of elements that make landscapes distinctive to inform management decisions which depend on active engagement from communities of place and communities of interest. [36]

Landscape scale policies have been commonplace in forestry, biodiversity, and watershed management for some time.[37,38] Evidence shows SLM can best manage this efficacy of scale if it is designed for collective decision-making processes that permit users and policy makers to ask who SLM is for, for what purpose, by which means and with what impact?[39] Such questions can

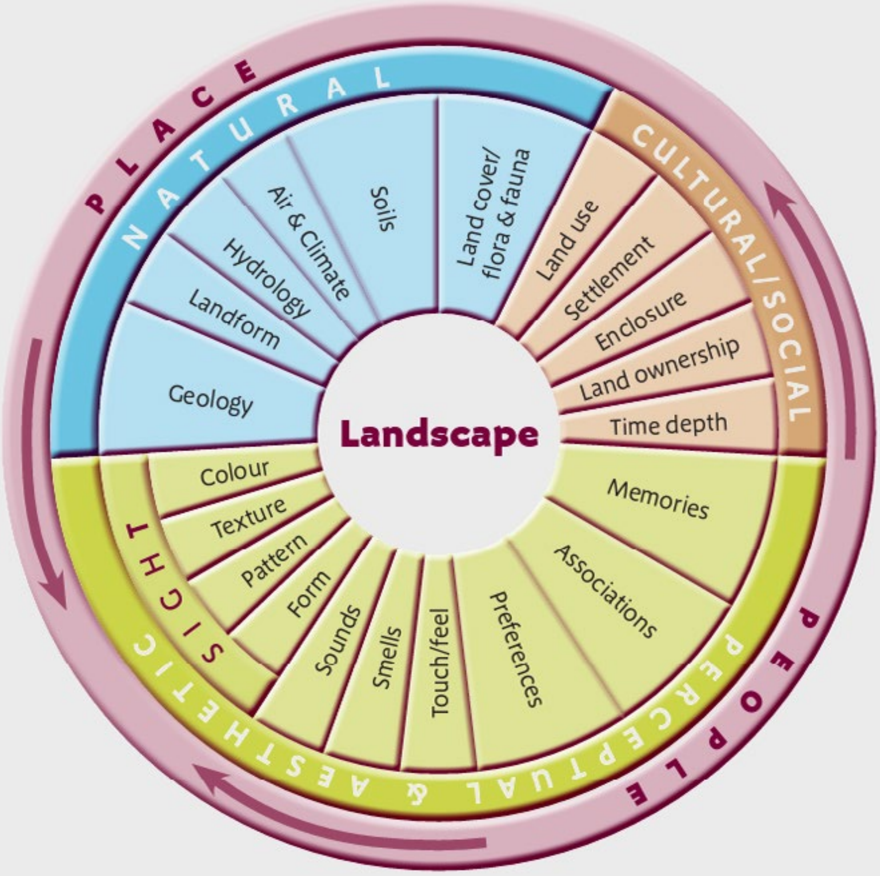

Figure 1.

Natural England's definition of landscapes formed from underlying geology, soils, topography, land cover, hydrology, historic, social and cultural development, and climatic factors. [36]

help manage trade-offs between local and regional landscapes interactions and interests.[39,40] SLM requires a systems framework that prioritises working at multiple levels of governance in order to engage with local knowledge in order to effect change at sufficient scale (for example, to respond to efforts directed towards climate change mitigation). Effective processes for engaging stakeholders make SLM more durable, in contrast to narrow and predetermined outcomes flowing linearly from centralised systems.[41]

This report presents the key principles that comprise an SLM approach (see The Principles of Sustainable Land Management) first in an abstract context. Then, this report follows up with an examination of the evidence base for its implementation within five key areas of practice, which SLM approaches have been attempted or could potentially impact (Ch 3-7: Principles in Practice). The following sections set out some of the key concepts and approaches that inform and overlap with SLM, including sustainability, the ecosystem approach and natural capital, ecosystem services and natures contribution to people, multifunctional landscapes, landscape resilience and ecosystem integrity.

Defining the 'sustainable' in land management

A coherent policy agenda may be limited without a clear definition of what "sustainable" implies for land management.[42] Sustainability is usually described as encompassing three dimensions of human-natural systems—social, environmental, and economic dimensions.[43]

The term sustainable emerges from general concepts and can mean different things in different contexts (POSTnote 408). This section outlines key definitions of sustainable in terms of land management and land use, across environmental, social and economic dimensions and their interactions. In the context of land management policy, sustainability conveys approaches connected to human values and needs including economic dimensions as well as physical definitions of landscape resilience and ecosystem integrity.[44]

Sustainable Development

There is no universally accepted definition of "sustainable" within land use policy.[45] The term was coined after the Bruntland report by the World Commission on Environment and Development of the United Nations in 1987, which defined 'sustainable development' as, "Development which meets the needs of the present, without compromising the ability of future generations to meet their own needs."[46] The UN 2030 Agenda currently states that sustainable use of land is directly and indirectly related to several of its Sustainable Development Goals (SDGs):[47]

- **SDG 3.** Good Health and Well-being – Ensure healthy lives and promote well-being for all at all ages; indirectly by producing healthy food from landscapes.
- **SDG 6.** Clean Water and Sanitation – Ensure availability and sustainable management of water and sanitation for all
- **SDG 11.** Sustainable Cities and Communities – Make cities and human settlements inclusive, safe, resilient and sustainable
- **SDG 12.** Responsible Consumption and Production – Ensure sustainable consumption and production patterns; indirectly through reducing environmental impact of production.
- **SDG 13.** Climate Action – Take urgent action to combat climate change, for example Nature Based Solutions (see Principles in Practice: Biodiversity, Ecosystems and the Nature Recovery Network)
- **SDG 15.** Life on Land – Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

England's New Legislative Framework

The UK's departure from the European Union has often been spoken about as a unique opportunity to shape domestic agricultural and environmental policies in new ways and in line with ongoing pressures and demands arising from land.[48] The new legislative framework for the UK and England will set the terms for how land management can be addressed is set out below; sustainable land management (SLM) approaches could deliver the objectives of this framework.

The range of environmental goals for land use within the 25 YEP, the Environment Land Management scheme (ELMs) and the Environment Bill are trying to foster the creation of what is often called multifunctional landscapes (see Defining 'sustainability' in the context of land management) which provide multiple benefits for a range of human needs as well as nature.[49]

The Agriculture Act

The Agriculture Act 2019-21 provided the legislative framework for replacing agricultural support schemes when the UK left the EU and Common Agricultural Policy (CAP). It received Royal Assent on 11th November 2020 and is now the Agriculture Act 2020. The Agriculture Act provides a range of powers to implement new approaches to farm payments and land management. In England, farmers will be paid to produce 'public goods' such as environmental or animal welfare improvements and this will replace the area-based Direct Payments under the CAP.

Public goods were defined by Defra as: "goods or services that no one can be stopped from using and where one person's use does not affect another's. For the environment, this includes such goods as an attractive landscape or a public park. If left to the market alone, the benefits to society provided by these goods would be underprovided or not provided at all, due to a lack of profit incentive."[50]

Economists have defined public goods as: "a benefit, such as clean air, with two characteristics: 1) its consumption does not exclude others from its availability and 2) its consumption does not reduce the amount available to others. The lack of incentive to pay for public goods can lead to their under supply and over-exploitation, which means intervention is required to maintain their provision" (POSTNote 557).

The Agriculture Act includes wider measures, including for improving fairness in the agricultural supply chain and on the operation of agricultural markets. The Act has five parts which includes enabling powers for support measures also widely known as public money for public goods, which will be delivered through the Environmental Land Management Scheme (ELM).[50]

Environmental Land Management Scheme

The "public goods" eligible for financial assistance are informed by the environmental ambitions that the Government set out in the 25 Year Environment Plan in 2018[3] and will be supported by the Environment Bill (see below), which has not yet received royal assent. ELM is being designed to pay farmers and land managers for managing land or water in a way that protects or improves the environment and cultural and natural heritage; enables public access to the aforementioned "public goods"; helps to mitigate and adapt to climate change; prevents, reduces and protects from environmental hazards; and protects and improves livestock welfare.

Public goods include clean water, healthy soils, climate mitigation and wildlife habitats and specific outcomes likely be numbered in the hundreds.[50] The Agriculture Act itself does not contain details on the specific schemes that might be set up under these powers, however it does include measures over how future schemes can be administered, including regulations and conditions for payments.

Defra has set out an Agricultural Transition Plan outlining the changes that will take place over the next seven years until Direct Payments are completely phased out by 2028. The reforms for farm support in the Agriculture Act are also envisaged to link to England's Peat Strategy, [51] support the "30 by 30 target" (to protect 30% of England's land for biodiversity by 2030) and England's Tree Strategy.[52]

Defra has outlined that the Environmental Land Management scheme will be built around three "components" that had previously been called Tiers in the earlier 2020 policy update and consultation document.[53] The three components of ELM set out in the Agricultural Transition Plan are:[54]

- **The Sustainable Farming** Incentive which is open to all farmers and will support a foundational sustainable approach to food production, including through environmental management and animal husbandry.
- **Local Nature Recovery Strategy**, which will focus on activities designed to create, manage and restore the natural environment for wildlife and natural flood management, as well as manage for geodiversity and heritage assets.
- **Landscape Recovery Strategy**, which is envisaged to incentivize and support large scale, collaborative landscape changes for purposes like rewilding, the establishment of a Nature Recovery Network and meeting commitments under the Climate Change Act for making the UK net zero by 2050.

Defra has been running tests and trials in order to involve land managers in the "co-design" of ELM, ahead of starting a national pilot launch for ELM from late 2021 until 2024.[55] It has set out an Agricultural Transition Plan outlining the changes that will take place over the next seven years until

Direct Payments are completely phased out by 2028.[54] The reforms for farm support in the Agriculture Act are also envisaged to link to England's Peat Strategy, support the "30 by 30 target" (to protect 30% of England's land for biodiversity by 2030) and England's Tree Strategy.

The National Food Strategy recommends that Defra guarantee agricultural payments until at least 2029 to help farmers transition to sustainable land use.[56] Defra envisages that ELM will be the main support measure available for farmers. Details are expected to be worked out during the pilot scheme, but flexibility and adaptability are a core principle. There is, however, no clear pathway from headline policy to landscapes designed for different measures of sustainability (see Defining 'sustainable' in the context of land management).

The Environment Bill 2019-21

Much of the UK's environmental law and policy derived from the EU, so the purpose of the Environment Bill 2019-21 is to amend this existing environmental legislation and introduce new measures in a range of environmental policy areas within the UK.

The basis of the Bill was shaped by a series of public consultations and the goals of the 25 Year Environment Plan (25 YEP), which outlined the Government's approach to the environment. The 25 YEP is also considered to be the first in a series of Environmental Improvement Plans, published every four years, against which that a new independent Office for Environmental Protection (OEP) will measure progress against. The OEP is envisaged to provide scrutiny, advice and enforcement functions for the Government. However, some groups believe there should be further separation between the Office and government, and that its functions should be strengthened.[57,58]

Key elements of the Environment Bill include using a natural capital approach (POSTNote 542), introducing a mandatory 'biodiversity net gain' (POSTBrief 34) in planning decisions, commitments to reduce flood and hazard risks, an aim to increase woodland cover; as well as mitigating and adapting to climate change. The Bill contains a series of clauses shaped by 25 YEP, which

set out 10 goals that the Government aims to achieve over the next 25 years. These include:

- Clean Air
- Clean and plentiful water
- Thriving plants and wildlife
- A reduced risk from environmental hazards such as drought and flooding
- Using resources from nature more sustainably and efficiently
- Enhanced beauty, heritage and engagement with the natural environment
- Mitigating and adapting to climate change
- Minimising waste
- Managing exposure to chemicals
- Enhancing biosecurity.

The Environment Bill requires that environmental targets with objectives need to be delivered by a given date. These targets will be consulted on in 2022.[59] The Commons Library provides briefings with further details on the Agriculture Act, the Environment Bill and the 25YEP with further details.

The Ecosystem Approach and Natural Capital

The Government's policy frameworks for the natural environment (25YEP,the Agriculture Act 2020 Bill and ELMS) are closely linked to the UN's ecosystem approach which is a 'strategy for the integrated management of land, water and living resources that promotes sustainable conservation and use'.[48]

The ecosystem approach was first adopted by the UN in 1995 to shape sustainable management in support and protection for the natural environment's full range of ecosystem services, rather than simply the protection of species diversity, although the two are connected (see Principles in Practice: Biodiversity, Ecosystems and the Nature Recovery Network). The ecosystem approach provides a way of thinking about the value of nature, justifying its importance in planning and decision making at all levels. The approach was the tool to achieve the balance of the three key objectives of the Convention namely Biodiversity Conservation, Sustainability and Equitable use of natural resources.[60] It connects understanding of ecosystem function to land users by including people within the decision making process. The principles of the ecosystems approach are similar to the SLM (see The Principles of Sustainable Land Management). Ecosystem services are described as the "benefits provided by ecosystems which contribute to making human life both possible and worth living" and depend on the quality and the condition of natural, cultural/social and human capital of an ecosystem (POSTNote 542).

The Natural Capital Committee has defined natural capital as "the elements of nature that directly or indirectly produce value to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions". [61] According to the Committee, it includes the living aspects of nature (such as fish stocks or plants) as well as the non-living aspects (such as minerals and energy resources). A core strength of the natural capital concept in defining sustainability is its suggestion to include the environment in economic decision making and political processes alongside production, healthcare, education and other key determinants of wellbeing, although current evidence suggests this complexity may have led to failure.[62,63]

The idea of a "wholescape" was developed out of the Natural Capital and Ecosystems Approach concepts. Wholescape thinking aims to identify the key elements that cross boundaries within water and coastal management, by including ecosystems that border these water resources. These might include both direct management of the ecosystem, such as planting trees to slow the flow of water. To effect meaningful chance, the Natural Capital Initiative say wholescape thinking must lead to simplification, not increased complexity, with the aim of making natural capital management clearer to all parties.[64]

The 'mainstreaming' of the natural environment into decision making is a key contribution of the 'natural capital approach' and considered to be an essential prerequisite for sustainable development. However, evidence shows that most natural capital exercises end up being poor equivalents of monetary values, in order to be set against monetary values in the economy. Monetary valuation is often a misleading way to represent societal value.[65]

Ecosystem services and Natures Contribution to People

The Ecosystem Services (ES) concept evolved alongside the development of land system science.[66] ES has been formally codified by Common International Classification of Ecosystem Services (CICES).[67] ES outputs are highly variable in nature, including (but not exclusively) from terrestrial environments: cultivated crops and animals, soil stabilisation, climate regulation, pollination and seed dispersal; from aquatic environments: water supply and quality, flood protection and aquaculture. Cultural services, practices related to: experiential (e.g. wildlife watching) & physical use (e.g. walking); scientific/educational (subject matter of research, education, in-situ and ex-situ); aesthetic (e.g. art, poetry, writing); spiritual and/or emblematic (e.g. emblematic or sacred plants and animals) are also included in this concept.[68]

The ES framework of the Millennium Ecosystem Assessment [69] has been adapted and amended for multiple land systems frameworks, theories and applications.[70–72] ES have often been limited to the more easily quantified services, generally by focusing on services that tend to have a relatively narrow focus on provisioning services (mainly food production)[73] and impacts on carbon sequestration and others.[71] There remains little agreement over the nature of "supporting services" within ecosystem services. [74,75] There has been relatively less emphasis in policy on regulating services and especially the less readily defined cultural services,[76] though notably this is beginning to change with their increased emphasis within both the Welsh Government's Sustainable Farming and Our Land[12] and Natural England's Natural Capital Atlas.[68] This has led to criticism of ES frameworks for crowding out other values and perspectives on human–nature relationships that do not fit squarely within a natural capital stock/economic benefit flow framing, such as in valuation of ecosystems of Costa Rica.[77,78] UN negotiations are currently moving towards creating a statistical standard for valuation (SEEA) of ecosystem assessment. [78]

The ES framework has informed international land use and management concepts and policies such as Payment for Ecosystem Services (PES)[79] and REDD+.[80] Critiques of ES related policies highlight that they do not adequately integrate the diverse and often competing value systems of relevant stakeholders, or address important social trade-offs. [81–83] Such policy instruments as PES and REDD+ may have limited capacity to transform the institutions governing land systems toward being more so as to make them sustainable, efficient and just in the longer term, in line with SDGs. [83]

Partly as a response to these concerns, the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) proposed the Nature's Contribution to People (NCP) framework. The aim of NCP is to achieve broader inclusion of the knowledge of humanities and, social science recognition of the values of longstanding knowledge and practices among indigenous peoples and local communities. It also offers more explicit recognition of the role of knowledge systems and cultural contexts in determining different ways in which human–nature relations take shape around the world.[61] NCP includes both positive and negative contributions from nature to people's quality of life as 'Material', 'non-Material' and 'Regulating', and contributions may be classified into several categories. For example, food may make a material contribution as well as a non-material one to society, based on intangible aspects such as rights, identity, spirituality, etc.

There are ongoing debates as to whether there is a need for NCP beyond ES, particularly in the context of determining the value of cultural ecosystems (see Principles in Practice: Cultural and Heritage Landscapes). Some claim that ES already captures all elements of NCP,[84] and that a too many terms may confuse policy makers.[85] In ES frameworks, ecosystems are connected with human wellbeing, usually positively, via 'flows' of discrete types of ES that are considered amenable, through measurement. Monetisation, exchange within market systems, and through bargaining and integration in existing policy tools such as taxes, payments, subsidies and other economic incentive schemes (e.g. PES). Whereas some ecosystem services like CES are not monitizable and so are less amenable to existing policy tools based around.

In NCP frameworks, the values connecting nature with human quality of life are modulated by their observers' respective cultural perspectives, such as the inter-relatedness of all forms of life. [86] NCP is intrinsically connected with quality of life, from 'harmony with nature' to other cultural norms and beliefs. The difficulty in understanding this concept is that, unlike ES, the NCP framework does not lend itself easily to quantification. Both perspectives may also overlap. In NCP, nature and quality of life themselves are also not easily distinguished. [87]

Multifunctional landscapes

A multifunctional landscape approach is the ability of given parcels of land or landscapes to deliver multiple benefits simultaneously to add to its value and versatility.[88] For example, by enhancing synergies between different types of land use such as food production and wildlife protection (see Box 2). As such the approach contrasts with concepts of land management at the farm level (i.e. common agricultural policy) that was associated with the application of fossil-fuel-based technologies to agriculture to maximise food productivity in the 20th century (see Annex 1: Land use in England Historically).[89]

Supporting the natural capital of the environment to produce multiple ecosystem services does not preclude trade-offs occurring. The focus on the provision of specific ecosystem services, like regulating services (i.e., soil generation), or provisioning services (i.e., crop production), may have trade-offs with others (i.e., cultural services; see Culture and Heritage Landscapes) through modification of habitats. Though the nature of these trade-offs is difficult to measure, as they are not always comparable. [90]

The Dasgupta Review, a global review of the economics of biodiversity highlighted the importance of multifunctional land that provides benefits for people and biodiversity, as part of a portfolio of natural assets for promoting the co-existence of people and wildlife.[15] The concept of multifunctionality is aligned to sustainable land management in seeking to deliver multiple outputs from land (food, biodiversity, climate related services, clean water, protection of human health, wellbeing and recreational enjoyment) but it goes wider than this to include energy generation, waste absorption and recycling, space for habitation and materials for construction, textiles and other societal purposes.

However, in England planning systems are highly fragmented. For instance, there is disjuncture between the National Planning Policy Framework and the Environmental Land Management scheme, which may be the key means of delivering ecosystems services.[91] If the appropriate governance processes for addressing this fragmentation aren't created, it will limit the development of multifunctional landscape approaches that deliver better environmental, social and economic outcomes without a means of managing trade-offs between them. The Planning Bill (developing from the Planning for the Future White Paper 2020) announced in the Spring 2021 Queen's speech will require local authorities to classify all land in their area into zones that are "protected", for "renewal", or for "growth". While this presents opportunities to protect areas important for wildlife and ecosystem services, it is not clear if such an approach to zoning can deliver integrated spatial planning for land use multifunctionality or be informed by the concerns and needs of local communities.

Box 2. Land-sparing or Land-sharing?

A common debate addressing the nature of trade-offs for SLM in a global context is how the spatial extent and intensity of agricultural production affects wildlife. Although intensification and technologies offer opportunities to meet the demands of the global food system, conventional analyses suggest that farmed land will likely continue to expand (POSTnote 589).[92] The issue of how to achieve of "sustainable intensification" through spatial arrangement of farming areas in conjunction with conservation areas is captured in the debate over land sparing vs land sharing.[93,94] Land-sparing promotes large areas (>10 km²) of unfarmed natural habitat to improve biodiversity [95,96] compensating for reduced area of farmland by more intensive farming per unit area.[97,98] By contrast, land sharing involves lower-yielding, wildlife-friendly farming, with these lower yields compensated for by a larger area of farmland (and so less natural habitat).[99] The National Food Strategy recommends that Defra produce a Rural Land Use Map that is freely available to land managers to help all stakeholders decide how best to use land and where the environmental priorities are.[56] The map would help inform which land is most appropriate for semi-natural land, low-yield farming, and high-yield farming as well as for economic development and housing

This debate is typically considered in a global context of developing

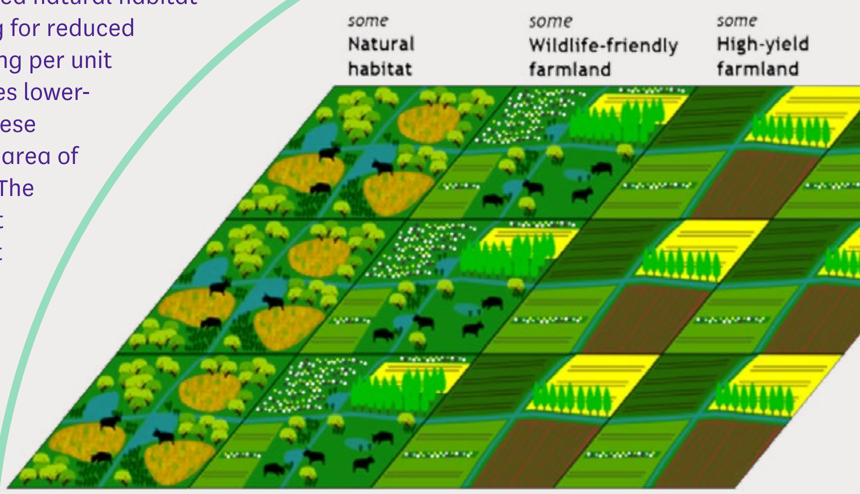

Figure 2.

Land sharing vs Land sparing management dynamics as three categories from Finch et al.[111]

countries where biodiversity is more intact, unlike the UK where landscapes have historically been more degraded. Studies show that "sparing" areas of native vegetation and intact habitat has benefits for wildlife.[100] Yet, the benefits of creating new wildlife friendly farming by "sharing" could compromise wildlife and affect yields, and may be limited in heavily-modified landscapes or intensive systems.101 Sustainable intensification (SI) is defined as a process or system where agricultural yields are increased without adverse environmental impact and without the conversion of additional non-agricultural land.[102] Some forms of relatively intensive land management – for instance permaculture or traditional flood-meadow management – can have also have measurable benefits for nature (e.g. for soil ecology and for the particular species associated with a non-chemically enriched aquatic system, respectively), when managed correctly.103 However, some studies have suggested that there is a risk, if yields decrease as a result of land sharing, the burden of production would be shifted to farmers in other countries with more intact biodiversity.[104,105]

Studies comparing these approaches have mostly been conducted in tropical countries where most insects, birds and wild plant life do better under land sparing.[106] Though typically considered in a more global context, this debate has been considered by Natural England as having merit within a UK land management strategy.[107] The long history of agriculture in Europe and in particular the UK, means that species have co-evolved with management, so conservation is focussed on both protecting species using natural habitats and farmland species largely dependent on semi-natural habitats (not purely natural, nor highly intensively managed, but used by people for producing food or fibres, for many centuries). This presents challenges to the binary "spare or share" model for deciding over the degrees to which patterns of farmed land affect which kinds of wildlife. Modelled evidence suggests that the land spare vs. land share framing may be too simplistic. For example, landscape multifunctionality could function more enabling a mosaic of management types along a spectrum between classic types of sharing and sparing.[108–110]

A recent study from the RSPB comparing scenarios in England shows that an in-between category may be useful where some spared land is managed not as natural habitat but low yielding wildlife friendly farmland, with high yield farming delivering the most of food production.[111] The authors call this "compartment sharing" which includes three, not two land management compartments 1) high yield farming (to spare land elsewhere) 2) natural habitat (spared land) 3) low yield or wildlife friendly farming (shared land). The challenge involves finding the optimum balance between the three compartments while recognising the trade-offs and would potentially require more detailed land use planning than the status quo. The study shows there is potential to use a similar model to examine other environmental outcomes including butterfly conservation, greenhouse gas emissions, nature-based recreation and diffuse pollution.

Landscape resilience

Broadly speaking, sustainability has been traditionally connected to ideas of biophysical resilience defined as “the capacity to create, test, and maintain adaptive capability” of a system.[112] Ecological resilience can be described as a measure for how far an ecosystem can be perturbed without shifting to a new regime (POSTnote 543).[63] Coined in the 1970s, resilience replaced ideas of ecological balance in use since the Second World War across complex systems.[113] Definitions of resilience differ between academic disciplines concerned with complex adaptive systems but can be understood as “Systems are resilient if they have the capacity to adapt to changing circumstances and challenges while maintaining their core functions, including the delivery of their vital goods and services”.[114]

Today the concept has been expanded to include social as well as ecological system dynamics[112] and refers to multiple variables and their thresholds at different scales.[115] For example, a ‘social-ecological’ definition of resilience has increasingly been applied to food systems (Box 3a). This describes a system in which humans and the environment are interlinked, where resilience is the system’s ability to absorb change, adapt or transform, and then return to a steady state (which may differ from its original state) (POSTnote 626).

Net biodiversity declines may lead to the erosion of the resilience of certain ecosystem functions, increasing the risk of failure in their delivery under future environmental perturbations. Loss of species richness in functional groups means that there is a weaker ‘portfolio’ effect (independent fluctuations of multiple species leading to a more stable ecosystem function provision), as well as lower functional redundancy. Therefore, the ‘insurance’ capacity provided by biodiversity is weakened leading to higher risk of ecosystem function deficits.[116]

Resilience has been adopted as an objective in several policy frameworks, such as the Environment (Wales) Act 2016, Section 6 of which places a biodiversity and resilience of ecosystems duty on public authorities.[117] The 25 Year Environment Plan for England stated the need to increase the resilience of wildlife habitats by implementing the Nature Recovery Network in line with the Lawton principles (see Principles in Practice: Climate Change Mitigation from Land Net Zero), with the measures for implementing this set out in the Environment Bill and the Environmental Land Management scheme.[118]

While resilience is useful for thinking about complex systems,[119,120] some consider it insufficient to address the social and political dynamics between people.[121] For others it is prone to decoupling human and natural systems[113] and therefore driving technical policy approaches rather than participatory ones.[122] Models of resilience which can account for human dimensions (those outlined in The Principles of Sustainable Land Management) are better able to model dynamic change and understand how the framework can interacts with social institutions.[123,124]

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Box 3a. Social-ecological systems

Social-ecological systems (SES) reflect a highly interconnected relationship between society and ecosystems. The concept was developed to broaden our understanding of how "to match the dynamics of institutions with the dynamics of ecosystems for mutual social-ecological resilience and improved performance."[125]

Resilience of such a system of systems depends on a wide range of factors stemming from the linkages between human societies and ecosystems. The factors include changes in the social, political and environmental situations. The interaction between actors of both systems further complicates the matter and increases the vulnerability of the system.[126]

Over its 20 years' course of existence the SES concept still lacks a more unifying definition. A social-ecological system can be defined as the following:
"a system of people and nature"[127]

- a system "where social and ecological systems are mutually dependent"[128]
- "interdependent and linked systems of people and nature that are nested across scales"[129]
- "a system that includes societal (human) and ecological (biophysical) subsystems in mutual interactions"[130]
- a system that "includes the entities of common-pool resource, resource users, public infrastructure, infrastructure providers, institutional rules, external environment and the links between these entities"[131]
- "complex adaptive systems with key characteristics such as: integrated biogeophysical and socio-cultural processes, self-organization, nonlinear and unpredictable dynamics, feedback between social and ecological processes, and difficulties in extrapolating information from one SES to another"[132]
-

Researchers and engineers adopting the social-ecological perspective of intrinsic resilience hope that "properties such as diversity, efficiency, adaptability, and cohesion" reduce the vulnerability of engineered systems in the event of unforeseen and unanticipated disruptions. [133]

Whereas most scholars may have a pretty good understanding of what a social-ecological system entails, the lack of a more detailed definition is a drawback when communicating it to a broader multidisciplinary audience.[134]
Within the Food and Farming sector, SES can include the interactions between farmers, researchers, extension agents and the supply chain/food system; essentially the people that make up the levels of food production.[135]

Ecosystem integrity

Biological diversity across genetic, species and ecological processes supports ecosystem services like pollination and pest control. In general higher biodiversity enhances the resilience of ecosystems, but low biodiversity systems can also be resilient.[136–138] The integrity (or intactness) of ecological systems is assessed by measures related to the ecosystem's capacity to support energy flow, mineral cycling and water cycling.[137] This is affected by the physical structures of ecosystems and their habitats, and the interactions between the species, habitats and processes (structure, composition and function). When an ecosystem has integrity, it should be able to withstand and recover from most disturbances that occur naturally, such as droughts, or impacts from human disruption. [44]

However, ecosystem integrity is not the same as resilience, though higher levels of integrity are related with a higher resilience, varying at an ecosystem[140] but also landscape level.[141] Ecosystems can lose their integrity before their resilience reflects this loss.[142] On the other hand, the ecosystem may have a relatively high level of integrity but may lose its resilience all at once. For example, disturbances such as disease or new predators that affect a unique species in a specific functional group could reduce or eliminate the ecological process supported by this species.[140] Higher levels of biodiversity in agricultural landscapes are spoken of as a form of insurance in the context of incomplete understanding of relationships between production processes and ecosystem processes.[71,143,144] Studies suggests a precautionary approach should be taken to maintaining ecosystem functions through the preservation of biodiversity.[145]

THE PRINCIPLES OF SUSTAINABLE LAND MANAGEMENT

The implementation of landscape approaches to environmental management has been embraced widely in the conservation and policy fields, accompanied by an emphasis on multifunctional landscapes and area-based conservation. [146] Although many of the concepts and principles have been relatively well summarized (see Defining 'sustainability' in the context of land management), [147] a cross-sectoral (i.e. integrated) approach to these issues has only recently been proposed. SLM can be described within 10 principles that reflect the prevailing views in across academic, policy and grey literature. [19] Representing a consensus view of attendees, these principles were discussed by the Convention on Biological Diversity (CBD) during the 15th Meeting of the Subsidiary Body on Scientific, Technical and Technological Advice in 2011. [38]

1. Shared Visions

Sustainable landscape management approaches are shown to be effective when they attain legitimacy, so actors are willing to accept risks and uncertainties. How much can and will be done will depend on the benefits on offer and perceptions of risk.[148] This relies on building shared visions [89] and a common understanding of the issues.[149] Multifunctional land use involves shifting perceptions over what land is for and building capacity to recognise and value things not traditionally produced as part of a food and farming business (i.e. healthy, productive soil systems). Without this change in perceptions, counter-productive outcomes may occur, such as land managers rejecting payments for environmental benefits and instead further intensifying food production up to regulatory limits.[150]

Communication strategies working through professional associations, participation in bridging institutions (Principle 2), public events or using various media can help build the awareness and understanding to contribute to shared visions.[151] Evidence from behavioural social science studies of farmer motivations indicates that, although financial incentives are sometimes necessary, they are not always sufficient on their own to get farmers to engage in environmentally sustainable activities.[152–154] Internal motivations, community engagement or local "good practitioners" leading the way (Principle 2) often play a key role in engaging individuals and in aligning a common objective across groups. These social factors may not be enough to ensure widespread implementation and should not be relied upon in the absence of financial incentives.[154,155] Voluntary initiatives can achieve substantial outcomes in the short term, though sustaining efforts over longer periods of time remains a challenge.[153]

In addition to their business needs, land managers' perceptions and values are shaped by their cultural and social networks and other historical factors.[156] Education, shared knowledge and awareness of the benefits of SLM will shape the conditions for participation.[151] Investing in processes to establish joined-up visions and co-designing schemes which work along-side established farming practices will build legitimacy.[155] A shared vision is also key to any participatory strategic planning process, and included in the first stage of applying a natural capital approach in the natural capital evidence handbook.[157]

2. Bridging Institutions

Finding a common entry point that contributes to a shared vision can build trust between stakeholders. National policies are often supported through local initiatives and institutions. [19,158] Bridging institutions are organisations, usually working collaboratively at the local level, which can mediate between different knowledge systems, actors, and institutions across larger scales (a process sometimes referred to as polycentric governance, defined by the Stockholm Resilience Centre as a governance system in which multiple bodies interact to make and enforce rules).[89,159,160]

Polycentric governance systems allow for multiple governing units may take initiatives at the same time, but not necessarily in an integrated manner.[161,162] Though there is significant critique that polycentric governance may result in enabling poor behaviour and complications in power-sharing dynamics.[163]

Bridging institutions can support SLM or integrated landscape initiatives if operating at a landscape scale, involve coordination across sectors, and support multi-stakeholder and participatory processes for multi-functional landscapes.[164,165] They can be used to build trust and shared visions (Principle 1) and foster social learning,[166,167] and should enable cooperation or partnership among state and nongovernmental

conservation organizations, communities, and private landowners and managers.[168]

SLM bridging institutions help to foster a broad range of landscape values and support issues of local heritage and culture, tourism, rural livelihoods improvements, promoting local food networks, protection of biodiversity and protected areas, and strengthening the sense of community.[169,170] The Natural Capital Committee says that multi-stakeholder work across agencies, councils, landowners, charities and individuals will be essential for the delivery of the 25 Year Environment Plan. [171] Partnerships will often need support by institutions that are competent and enabled through funding, government policies and local expertise (Principle 8).[19,168]

In 2014, a review of integrated landscape initiatives across 23 EU countries identified the UK to have more such institutions than other European countries, though it is likely more institutions will have evolved since publication of this study.[165] Coordination of such institutions and partnerships, however, presents novel challenges.[168] Actors need adequate capacity, skills and the ability to participate collaboratively. Yet arrangements to support these capacities entail higher transaction costs and potential complexity.[172] The European study showed that in general farmers and producer associations were not well represented compared with other groups. This is despite most institutions they explored having arable land or pasture within the land covers in their target area. Publicly supported institutional initiatives may be one way to strengthen the role and participation of farmers.[173]

3. Negotiation and Equity

Co-management is not merely about resources; it is about managing relationships. Developing processes that allow actors to negotiate and work through trade-offs as they occur can build legitimacy and compliance as well as improve justice, equity, and empowerment. Sustainable land management relies on supporting people whose livelihoods are affected by management decisions having a say in how those decisions are made.[159,166] Polycentric systems of governance allow for negotiation, information flow, as well as collaborative planning, participation and coordination.[156] Because management systems are not merely the product of governments but rather of all societal actors, realising sustainable management systems will require coordination amongst many different actors, including those who frequently do not cooperate.[174]

Negotiation processes should be participatory and not favour particular actor groups, and as such contribute to a shared vision (Principle 1).[175] The multiplicity of interests requires flexibility and negotiation which, in turn requires functioning institutions for collaboration and participation (Principle 2).[19,176]

When actors have different values, understandings and priorities for their land, there will often be no single best management option at a landscape scale where actors have different values, understandings and priorities for their land. [177,175] Failure to engage people in equitable decision making will undermine the interventions decided at any scale. Similarly, the benefits and incentives for land use changes and activities need to be distributed fairly. [19]

4. Adaptive co-management

Ecosystems are made up by complex interactions across time and geography. Managing the outcomes of these interactions requires flexible multilevel management that can respond to environmental feedbacks.[167,178] Adaptive and flexible management approaches that iterate and learn as they go are better suited to this complexity of and unforeseen interactions, often fostering a 'learning by doing' approach.[120] Adaptive management has been defined in various ways since its development in the 1970s. Broadly it is a form of integrated co-learning with stakeholders, focusing on using the results of monitoring systems, to account for the surprising and unpredictable nature of a systems' responses. [179,180]

Adaptive management arises when the dynamic learning is combined with collaboration and cooperation in management (Principles 2 and 3). [181] This relies on strong institutional linkages and networks between actors (Principle 2), participatory processes (Principle 3), good knowledge exchange (Principle 9) and monitoring (Principle 10) and requires collaborative processes for consensus (Principle 1) among the parties, before feedback-based problem solving can proceed.

5. Scaled frameworks

Outcomes at any scale are shaped by processes operating at other scales – so called "scaled frameworks" adapt to this. Aggregations of different land uses, and decisions give rise to emergent properties which shape landscapes. Landscape thinking in sustainable land management means addressing the complex interactions between different spatial scales.[19,182] Ecosystems are complex adaptive systems, where patterns at higher levels emerge from localised interactions at lower scales. It is not always clear who will benefit from the services at different scales. Land management outcomes are not only shaped by numerous ecosystem feedbacks but are also influenced by external influences and constraints.[19] One particular difficulty is that, in the UK, local level choice of habitat will be based on cultural factors, public choice and heritage. Aligning these factors emphasises the necessity for negotiation and equity (Principle 3).

Scaled frameworks help resource management move towards effective cooperation and self-organisation by relying less on a top-down approach,[148,177] but national governance systems should be aware of local conditions (Principle 6 and 7) so that they do not undermine them. [156] Landscape properties associated with sustainable land management cannot be delivered from a single farm or wood and need long term commitments and working relationships, partnerships and collaboration (Principle 2). Root Cause Analysis (RCA) is a technique for problem solving that can be used to identify the real source of an undesirable ecosystem outcome, which derives from another spatial or governance scale. It identifies where in the land management chain an intervention would prevent the problem from occurring to address the causes rather than symptoms of the problem strategy.[183]

6. Local specificity

The success of many SLM initiatives is contingent on interactions at the local level,[184] and all local factors must be considered to tailor approaches. In this respect, the most effective SLM begins at the local level. This is both in terms of using the local expertise and knowledge of that area, democratic legitimacy and participation.[185] What works in one area to produce positive outcomes across food production, climate mitigation and wildlife benefits may differ in another, where rainfall, microclimate, soil structure and social governance are different.[186]

Deciding on what to do, where and how to do it depends on a series of different factors and contingencies, which are not only biological, but also geophysical, socio-economic, institutional and cultural.[41] Higher levels of local expertise, awareness, buy-in and vision (Principle 1) can support better tailored local interventions that take account of ‘what works’ in the given context.[187]

Highly political issues such as land ownership, rights and tenancy arrangements shape the parameters of natural resource management.[40] Decisions taken locally, through the other principles of SLM by local land managers,

communities, local authorities, statutory bodies, businesses and wildlife agencies working together may help shape approaches in accordance with local issues.[145]

7. Spatial Planning

To achieve sustainable land management, decision-making needs to be spatially explicit,[188] and sensitive to the local socio-political dynamics of the areas.[189] Spatial planning is more than regulating land use but an integrated way of engaging with complex problems and can be used to nurture strategic visions of shared futures at larger than project scale.[190] While it will inevitably be shaped by national and local government, planning for SLM must accommodate the local users' needs and priorities for living landscapes. The National Food Strategy calls for Defra to produce a National Rural Land Map within a National Rural Land Use Strategy to provide detailed assessments of the best way to use any given area of land.[56]

England is presently the only country within the UK without a specific land use planning strategy. Any spatial planning system implemented needs to be flexible enough to accommodate multiple and changing perspectives, as SLM is non-linear compared to single sectoral interventions (Principle 8). Spatial planning can help integrate different land use sectors and support cooperative governance.[169] In English landscapes, there will be many interests, high environmental pressures with potential conflicts, highlighting the important role of partnerships and participatory processes in seeking to resolve them (Principles 1, 2 and 10). SLM initiatives are demonstrably more successful when they seek out complementary land uses and take a spatial approach to landscape planning.[191]

For strategic planning, a good understanding is required of the likely ecosystem services outcomes of different management approaches and their synergies and trade-offs with farming and biodiversity goals. [192] A spatial orientation can help inform the changing demands for ecosystem services that will occur under climate change.[158]

8. Joining up Governance: Policies, Markets and Regulation

SLM involves moving beyond fragmented policy frameworks and governance bodies. To strengthen alignment and integration of land-use policy across departments, the roles and mandates of government institutions would need to be clearly defined. Creating a coherent and connected policy for land-use on a national scale means recognising the factors that connect different uses, finding complementary beneficial outcomes, managing trade-offs and addressing competing demands and conflicting visions.[193]

Stronger horizontal co-ordination between ministries and vertically (e.g. between national and local governments) would be needed to ensure linkage across land management fields and to facilitate the coherent design and implementation of policies.[194] The OECD highlights how governments can facilitate the creation of coherent policies for sustainable land use at three important points in the governance process:

- through relevant national strategies and action plans;
- via institutional co-ordination;
- the design and implementation of policy instruments (which involves comprehensive spatial planning).[195]

One key challenge England still faces is to adequately align the Agriculture Act 2020 with the Environment Bill 2019-21 and the Planning White Paper. Commentators such as The Wildlife Trusts and Wildlife and Countryside Link suggest there are presently unresolved trade-offs relating to the allocation of new homes and plans for delivering the Local Nature Recovery Networks.[196,197] The Dasgupta review highlighted the flaw in financing harmful activities that degrade ecosystems, which exacerbates the costs of other conservation activities that seek to reverse the degradation (for example: regenerative agriculture).[15,198] Financial mechanisms in subsidies, taxes, regulations and trade policy can be aligned to deliver SLM, such as halting environmentally harmful agricultural subsidies.[40] Environmental taxes are comparatively under-used in land-use policy, despite being shown to be effective in reducing pollution from agrochemical inputs.[199] Trade policy and regulation alignment prevents "leakage" of adverse impacts such as exporting avoided domestic GHG emissions or deforestation overseas.

9. Changing research, evidence and knowledge transfer

Closer relationships of user-oriented knowledge between academics and research users – co-production – is one approach to develop and apply new knowledge and insights to address big societal challenges.[200] SLM requires research to take a more interdisciplinary and participatory approach. Implementation-oriented research centres such as the Agriculture and Horticulture Development Board (AHDB), Rothamsted Research, LandScale and the N8 Food for Future group have begun to develop interdisciplinary research programmes that address this rapidly evolving field.

Co-production approaches all seek to break down the barriers between knowledge producer and user, whether this is a government actor, developer or a sheep farmer.[201] SLM seeks to elevate the reflective process over the role of the technical expert (Principle 2).[202] While evidence-based decision making is vital, it also has limitations, since evidence is not always widely accessible, oriented towards implementation or used to facilitate stakeholder participation.[203]In cases where there is mistrust or tension between the role of experts and non-experts, improved transparency, collaboration and the ability to work with and acknowledge uncertainty are central.[204]

10. Collective monitoring

One of the main tasks for support of SLM is to produce monitoring evidence of its effects on natural resources and to assess the implications from such outcomes on society, the economy and policy.[205] Effective monitoring programmes engage progress of SLM initiatives with communities at the local level.[184] Since 2019 monitoring has transformed into a NERC-funded research platform (The Countryside Survey) that utilises an annual rolling program to measure soils and vegetation that will repeat every 5 years.[206]

Engagement with local interventions on the part of both academic researchers and policy development has been discussed as a key pathway to effective implementation,[201] with provision of new technologies or support for local innovations for implementation of SLM often taking place at the local level.[184]

When stakeholders agree SLM outcomes (Principle 2) there will also be an interest in assessing progress. This also provides a chance for both users and local government or NGOs to work out how to adapt together (Principle 3). Monitoring the impact of SLM programmes can be technically difficult due to funding constraints, time lags and confounding effects between interventions.[207,208] However, an overabundance of monitoring can also impede progress, sometimes being seen as “a pointless use of resources”, when used in well-established initiatives.[209]

PRINCIPLES IN PRACTICE: FOOD AND FARMING

The financial status of current models of agricultural production in England may not be viable in the long term as the costs of inputs into agricultural systems continue to increase. Growing costs are connected to the environmental and human pressures on the global food system. For example, many low-productivity upland farms have become reliant on government subsidies for financial viability. The following chapter discusses how the previously established principles of sustainable land management can be applied to the food and farming sector, the potential impediments that exist inherently within the sector, and explores some examples of where SLM aligns with current practice. Providing a broad overview of the food and farming sector, this chapter also signposts other meaningful reports that cover areas in more specific detail.

Food systems, Production, Business and Intensification

Under the Agriculture Act 2020, the UK Government is required by Parliament to report on and manage food security for the UK. Food security means a great many things, most commonly revolving around the stability of a country's food system. The Department of Environment, Food and Rural Affairs (Defra) defines food security as "access at all times to sufficient, safe, sustainable and nutritious food, at affordable prices", in terms ranging from of global production, supply chain resilience, to household spending. [210] Self-sufficiency on the other hand refers to the ability for a nation to source the goods it needs without relying on imports. Government statistics in 2018 showed that the UK is approximately 61% self-sufficient (in terms of food imports) and UK self-sufficiency has been declining for the past 30 years.[211]

Food security challenges

Food security depends on three main factors — availability, access, and utilisation, all of which are directly underpinned by ecosystem services. Meeting the food security and sustainability challenges of the coming decades is possible, but will require considerable changes in soil, nutrient and water management.[212] Global agricultural production may have to double in the next 30 years if estimated projections on increasing demand need to be met.[213] Four crops, maize, rice, wheat and soybeans, currently provide nearly two-thirds of global calorie intake. [212] However, yields in these four crops are increasing at less than the 2.4% per year required to double global production by 2050. (POSTnote 589). However, this is only one issue with global food security. A focus on yield per hectare does not reflect the environmental costs of increases, nor that this harm will limit whether they can be sustained. Approaches like this are successful only for a short time before the environmental costs "catch up".

The "Food System"

Farming outputs are part of a global 'food system'. A food system is "the interconnected system of everything and everybody that influences, and is influenced by, the activities involved in bringing food from farm to fork and beyond." [214] It is an inherently global system. Food systems constitute producing, processing, retailing and consuming food.[215] The food system comprises smaller complex systems that feed back into whole system in response to factors such as social, economic, environmental and political fluctuations, resulting in unpredictable outcomes, such as fluctuations in the affordability of food. This creates challenges for transforming the system to achieve the UN SDGs and resilient long-term beneficial outcomes. [216]

Factors affecting the food system include urbanisation, climate change, population growth, changes in diet, unsustainable agricultural production systems, and competition for land and water (POSTnote 626). Agricultural economic systems have also become globalised, such as the trade in animal feed. For example, the import of soya for animal feed, has exported some of the environmental impacts of UK agriculture to other countries, where it may result in poor environmental outcomes.[217,218]

The current National Food Strategy is the first independent review of England's entire food system for 75 years. Part 2 of the review is due to be published in July 2021 and will set out both ideas for transforming the food system and a vision for the future of the system. [210] This will include considering food security through the three lenses of environmental sustainability, healthy food and resilience.

Box 3b. Status of English Agriculture (2020)

Agricultural land use and ownership

- Farming comprises 74% of English land use, [13] with the agricultural area in England totalling just over 9 million hectares.
- Total "croppable" area covers 54% of land, and had increased by 0.8% to just over 4.9 million hectares from 2018 to 2019.
- Permanent grassland accounts for an additional 41% of land.
- The area of owned land in England increased by 1.3% to just under 6.2 million hectares in 2019. Land rented in for a year or more decreased by 1.5% to just over 3.0 million hectares.

Crops

- The total area of arable crops has increased by 1.0% since 2018, and now stands at almost 4 million hectares in 2019.
- Cereals and oilseed crops account for the majority (82%) of the total arable crop area.

Livestock

- The total number of cattle and calves in England was 5.3 million in June 2019; the number of pigs in England increased by 0.5% to just under 4.1 million animals; the number of sheep and lambs stood at almost 15.4 million from 2018 to 2019.
- The total number of breeding and laying fowl in England increased by 0.4% between 2018 and 2019 to just under 33.8 million. The number of table chickens (broilers) decreased by 0.7% in 2019 to 95.1 million.

Agricultural workforce

- The total number of people working in agriculture in England was 309,000 in 2019. Farmers, business partners, directors and spouses account for over half (59%) of the total workforce.

Data from Defra Accounts[219]

The State of Farming Economy in England

The Agriculture and Horticulture Development Board (AHDB) have suggested that increased labour costs are a more pressing matter in the immediate future, rather than the long term detrimental effects of climate change.[220] For example, the cost of farming labour may increase with the cessation of Freedom of Movement to the UK from the EU.[221–223]

Farming is a business practice and profitability remains the primary goal (Box 4). The NFU have stated that a farmer's sustainability goals typically revolve around making as little impact on the land while making a profit with acknowledgment that damage is inevitable and should be matched with attempts to restore the damage (Principle 1 Shared Visions).[153,221]

Box 4. RSPB Haweswater Farming Accounts

Although the term a "typical upland farm" represents a range of farming systems, publicly available accounts suggest that this type of farming only continues with the support of payments through the Higher-Level Stewardship and Basic Payment Scheme. In upland areas, research has suggested agri-environmental subsidies are positively associated to short-term farm profitability.[224]

For example, the Naddle and Swindale Farms run collaboratively by United Utilities and RSBP at Haweswater (around 750 hectares of directly managed land) are in a Higher-Level Stewardship (HLS) agreement that started in 2013. In addition, Basic Payment Scheme (BPS) is claimed for all eligible land and United Utilities provide capital grant funding through their Sustainable Catchment Management Programme (SCaMP).

The tenancy agreement with United Utilities is for 45 years. The RSPB pays an agricultural rent for the land. Infrastructure works are carried out on the farms including boundary work, tree planting and building improvements to enable more sheep to be wintered off the commons. This was part of a package to improve how the catchment acts as the primary filter for raw water quality. Financial accounts from the farms show that on average, even accounting for agricultural produce coming from the land, the business is consistently run at a loss. The RSPB believe that without continued support payments through Higher Level Stewardship and Basic Payment Scheme, it would be very difficult to continue farming under the current model. Large losses are not unusual, as total livestock sales often reach only 25% of the costs of production. [225]

Previous agri-Environment Schemes and the New ELM scheme

An estimated 72% of the payments for agri-environmental measures under CAP in Europe compensated farmers for the costs of providing public goods and services,[226] while only about 17% of the basic direct subsidy support was considered as compensation for these. However, maintaining ecological integrity was not the focus of the funding provided by funding from schemes including, but not limited to: CAP, ELS and HLS.[226]. Shifting subsidies to more targeted forms of payment may improve the provision of public goods (Principle 3 Negotiation and Equity).[227]

The importance of the Basic Payment Scheme (BPS) varies between agriculture sectors. In some sectors when BPS subsidies begin to decline, intensifying production may be seen as the only option to replace lost revenue. [221] However, if this intensification fails to be financially competitive within the global food system, it has been predicted that up to 25% of smaller farm businesses will become financially unviable. [228]

Price fluctuations can impact the motivation of a farmer to engage in agri-environment schemes when they are seen as less profitable than food production.[229] Funding under CAP may also have disproportionately benefitted larger landowners, in a non-scaling manner than the area of land owned.[226,230] The complexity of existing systems like Countryside Stewardship and the HLS arguably put off smaller farm businesses. [221] Future replacement systems may continue to fail to engage smaller landowners without simplification or appropriate facilitation (Principle 1 Shared Visions). Given the number of smaller landowners that would be needed to work collaboratively to achieve the same area, engaging with larger landowners may result in greater gains in environmental benefits. However, not engaging with smaller landowners could lead to an avoidable loss of large areas of land for ecological restoration. [229]

Food production is not the only motivation for farmers, particularly in areas where farm incomes depend on agricultural subsidies for profitability.[220,229] Maintaining the trust of farming communities is key for the long-term viability of environmental schemes (Principle 3 Negotiation and Equity). A range of NGOs, LNPs and various other cooperative bodies have spent the duration of CAP working with farmers, building trust and understanding to effect change in how land is managed. There is a risk that a new system and administrative approach may lead to a loss of trust built up previously. [229]

Tenancy, land ownership and cooperative farming

Land Tenancy in agricultural systems is widespread across England, further adding to the complexity of the mosaic of governance. Most farmers (the NFU estimates 80% of farmers in England) have some sort of arrangement involving tenancy, be it as a tenant or a landlord. Tenancies are highly bespoke in nature, encompassing grazing agreements, cropping agreements, land swaps, annual tenancies, biannual tenancies, lifetime tenancies (etc.). Tenancy duration (~3.7 years currently) has steadily shortened since the 1980s (see Annex 1: Land Use History); making long-term planning in environmental policy is harder to implement.[221]

Farmers are not just economically rational actors. A farmer's sense of ownership over land will often affect the outcomes of regulation and incentives seeking to influence agricultural management (Principle 1 Shared Visions).[26] For example, a sense of ownership can guide sustainable use of the land, by thinking about long term impacts of present-day actions. A sense of "self-determination" is important for farming communities[229], the sense of caring for the land for the local community and wider public good is a common motivator for good environmental practice on farmland.[221] "Public goods" (see Background) are a potentially valuable classification of outcomes from agricultural land produced without profit, which include environmental benefits such as carbon storage public goods.[231]

Short-term tenancies may limit the ability of tenant farmers to work collaboratively, such as with what may be required within an ELMS agreement.[229] Tenancy influences the connection between the farmer and their land. A tenancy to let out land to pastoral farmer may see priorities shifting away from environmental stewardship on the part of the farmer, as their primary source of income (e.g., the cattle stock) is disassociated from the land. Tenancies also provide a difficulty in whether SLM policy should be directed towards the landowner or the tenant. Typically, paying the landowner to manage the environmental aspects of the land would be the normative choice, but this would continue to increase the disconnection between farming and the environment in tenants (Principle 3 Negotiation and Equity). Some existing tenancies, such as those employed by United Utilities or the National Trust, are highly prescriptive agreements that require higher standards of environmental stewardship of their tenants. By putting the burden of environmental stewardship on tenants, this rewards landowners more than tenants, while delivering the objectives of the landowners (e.g., clean water production for United Utilities). There are not currently any strict legislative frameworks governing environmental stewardship that these contracts must agree to, such as environmental standards, but implementing them could be one option to enforce and encourage uptake of SLM.

Farming cooperatives in England

Economic pressures are likely to increase on smaller farms in England. These pressures may lead to greater consolidation, such as in UK dairy cooperatives. There are over 600 agricultural cooperatives currently trading in England. The top 10 highest economically performing cooperatives encompass nearly 9000 farmers, comprising a total annual turnover of £3.9bn (Table 1). Agricultural cooperatives are comparatively underdeveloped in England. By comparison, there were over 2600 cooperatives in France in 2018, representing nearly €85bn in turnover and encompassing nearly 85% of farming SMEs. [232] In England, informal collaboration and cooperation within everyday farming practices has declined over the past 40 or 50 years [26] as most CAP schemes did not provide sufficient incentives to do so. [229]

Table 1. UK Agricultural Cooperative companies (2016).

Data sourced from Farmers Weekly.[233] *figures taken from company websites

Rank	Co-op	Turnover (£m)	Number of farmer members	Financial year end
1	Openfield Group	749	2,700	30/06/2015
2	Fane Valley Co-operative Society	553.9	2,020	30/09/2014
3	First Milk	460.1	1,317	31/03/2015
4	Arla Foods UK	454.3	3,200*	31/12/2013
5	United Dairy Farmers	421.5	1,619	31/03/2015
6	Mole Valley Farmers	407.8	-	30/09/2014
7	Anglia Farmers	247.4	3,500*	31/01/2015
8	Berry Garden Growers	212.9	59	31/12/2013
9	Fram Farmers	184.5	1,126	29/06/2014
10	GrainCo	165.6	-	30/06/2014

Larger agricultural cooperatives have both significant positives and negatives when it comes to implementing SLM approaches (Principle 5 Scaled frameworks). AHDB predicts that big agricultural companies may come to dominate farming management in England, with only a few smaller, more specialised businesses (such as those providing unpasteurised organic milk straight from the cow, and those that deal exclusively in local farmers markets or a very specific segments of the market). From a landscape perspective, larger farms (both cooperatives and single business) may be advantageous for implementing appropriately scaled conservation approaches (see Principles in Practice: Biodiversity, Ecosystems and the Nature Recovery Network). Using coordinated approaches across farms, mandated by cooperative leadership, (e.g. Arla Foods UK's Sustainable Dairy Farming Strategy), landscape scale approaches may be more likely to succeed (Principle 1 Shared Visions).

They are also likely to attract international investors, which could pose challenges for policies seeking to maintain animal health and welfare standards, environmental standards. Rigorous regulatory standards will be necessary to ensure continued trajectory towards biodiversity net gain. [220]

Sustainable Farming Interventions

Farmland has the capacity to produce the widest diversity of SLM outcomes but requires a diversified portfolio of interventions from farm-level to wider landscapes. The portfolio covers crop diversification, crop rotation, regenerative agriculture, zero tillage, agroforestry (trees and shrubs grown amongst crops), planned (or mob) grazing (short duration, high density grazing with a longer than usual grass recovery period), silvo-pastoral systems (incorporating trees and shrubs into grazing systems), seen as promising in terms of sustainability.[13]

To identify the right portfolio of interventions, soil, water, air quality (and GHG emissions), biodiversity and cultural values of the landscape of agricultural systems need to be considered in combination to assess the sustainability of outputs. Agriculture is a highly variable industry, not only between production sectors (i.e., arable, horticultural, pastoral), but also within geographical contexts (i.e. north-western or south-western hill farming). Innovation to improve sustainability in one sector will not necessarily be transferable to others across the agricultural industry (Principle 6 Local specificity). Arguments can be made for moving away from the dependence of agricultural productivity on chemical inputs given the environmental impacts of this approach.[234] For example, United Utilities suggest the production of clean water (one of the key soil functions – see above), may be more financially worthwhile than agricultural outputs of certain upland regions (see Principles in Practice: Water).

The complexity of these variables has the potential to hamper communication about implementing sustainable land management nationally (Principle 5 Scaled frameworks). Conversely, taking a generic approach to sustainable land management results in tools that fail to consider sectoral and geographically specific requirements. [235] Considering interventions designed for agriculture across all sectors, within a local, landscape and national context requires spatially-integrated approaches across these scales (POSTNote 627).[236] Addressing this complexity may also require a decisive shift in how landscapes are managed and the development of novel technologies, to implement this shift (POSTNote 628). Defra is launching a £12m fund as part of a Future Farming & Countryside Programme to bring together farmers, growers and businesses to develop new technological solutions (Principle 1 Shared Visions). The project sits within a £90m science and technology funding opportunity under Transforming Food Production Challenge from the UKRI.[23]

Soils: A One-health systems approach

The One Health approach encapsulates the idea that individual, population and ecosystem health are linked. One Health shares characteristics with holistic approaches like sustainable land management, incorporating socio-ecological, cultural and economic elements (Box 5).

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Box 5. The One-Health Concept

The One-Health concept has been discussed since the mid-2000s, as an initiative linking between the medical and veterinary fields, acknowledging the need for a greater focus on zoonoses in the wake of the SARS outbreak and avian influenza outbreaks.

Adopted by the WHO, FAO and Office International des Epizooties, 238 the concept emphasises the interconnectedness of human, animal and environmental health, noting that human health depends on healthy and functioning ecosystems. [239]

Although there are discussions about the different terms describing this interconnectedness (for example 'One-Health', 'EcoHealth', 'Planetary Health')[240], they share a common focus on encouraging collaborating across disciplines like medicine, veterinary science, ecological and environmental science.

Although the focus has been on zoonotic diseases, the One-Health approach emphasises a holistic understanding to tackle challenges, [239] and is therefore highly relevant for discussions about sustainable land management.

Within the Ecosystem Services framework, there is focus on food security and disease regulation under a One Health approach. The One-Health concept has been applied to both bovine livestock and pollinators (POSTnote 619), acknowledging the spectrum of factors respectively impacting their health and the approaches that have to be undertaken to protect their environments and contributions to people. [241]

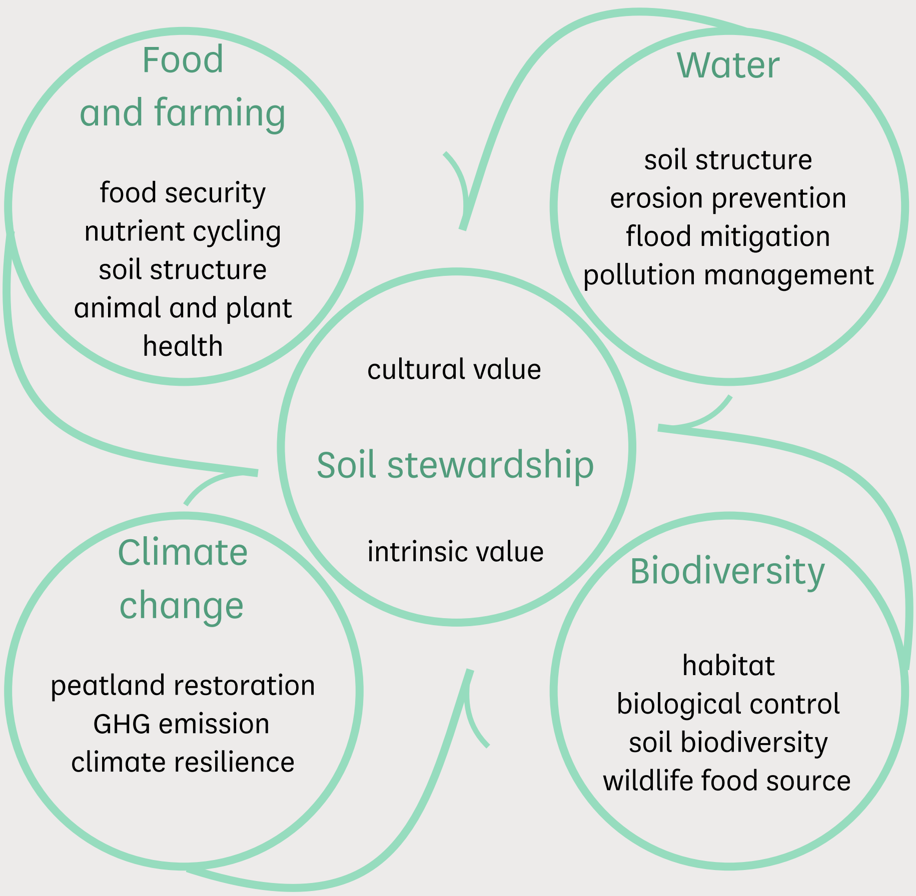
Soil is a complex system at the intersection of the atmosphere, the water cycle, geological processes and biodiversity, which support a range of essential benefits such as food provision, water quality and reducing flood risk that are critical to environmental sustainability. [242,243] Soils can be seen as a centre-point for many global environmental sustainability challenges (Figure 3). [244] There is clear overlap between the Ecosystem Service and One Health approaches, [18] particularly when considering its role in soil stewardship.

Similarly, soils contribute to various environmental and cultural services including intrinsic values and education, and as a habitat containing a diverse array of lifeforms (Principle 1 Shared Visions). Studies examining the effects of land management and its change on a range of soil services are becoming familiar, but the linking across these sectors required by SLM is still scarce. [18]

Quantification is important in managing soil-health and soil-ecosystem services, and the multifunctionality. Each soil stewardship goal requires a different set of parameters be monitored, compared with reference states when appropriate and managed. [243] Soil health indicators, whether organismal (biological), molecular (chemical) or structural (physical), are not adequately included in or integrated into soil health frameworks. Biological diversity has been recognised as important for soil and human health, [245]appropriate soil-health indicators and methods for soil biota diversity have not yet been developed (POSTnote 601).[246] Natural Capital Indicators, developed by Natural England, aim to include indicators for measuring soil-sediment processes.[247]Molecular and soil structural diversity are not yet explored but are important for soil organic carbon. [248] Next-generation sensors could provide the much-needed platform to monitor changes in soil health over time. [249]

Figure 3. The position of soil stewardship within a "nexus" of management applications not solely within food production.

Soil stewardship has an important role in each of the key "principles in practice" detailed in this report, SLM emphasises thinking across each of these classically sectoral areas. [243]



The LANDMARK project has developed models to quantify the potential supply of soil functions based on a meta-analysis of European datasets.[250] Soil functions include biomass transformations (productivity), water partitioning and reservoirs, geological filters and buffers, biological habitats, direct uses, and cultural support.[251] These functions vary according to farm type, soil type, environment and management. [252] Their degradation through poor management, water and wind erosion threatens their capacity to provide benefits such as carbon storage and food provision, as does the poor capacity of soils to recover once degraded. [253,254] The German Centre for Integrative Biodiversity Research (iDiv) have also produced a toolbox for novel sampling, molecular identification, functional approaches, environmental variables, and modelling techniques within soil.[255]

Agricultural soils

The factors impacting sustainable use of soil in agricultural systems include (but are by no means limited to), soil organic carbon loss, soil erosion, and conventional tillage.

Most arable soils have lost 40 to 60% of their organic carbon since 1973; in England and Wales, 2 million hectares of soil are at risk of erosion and 4 million hectares at risk of compaction. Microplastics are wide spread in soil with unknown consequence along with other contaminants from sewage sludge application to agricultural soils.[256]

Erosion is the process by which topsoil is carried away by wind and, above all, water, and is accelerated by human activities such as removal of vegetative cover, ploughing down sloping fields and overgrazing with impacts on the benefits soil provide such as carbon storage. [257,258]

Soil erosion alters and changes soil C stocks (organic and inorganic) causing the loss of significant amount of relatively stable soil organic carbon (SOC) that has been retained in the soil system for millennia, and adversely affecting net primary productivity and use efficiency of inputs.[259] One possible measure for increasing the amount of carbon stored as soil organic matter may be zero tillage depending on soil type and other factors. Conventional tillage disturbs the soil microbiome, can impact soil structure through compaction, [260] increasing GHG emissions relative to alternatives like reduced or zero-tillage systems. [261] Existing systematic reviews suggest reduced tillage increases organic carbon stored in upper soil (top 10cm).[262,263] The evidence is limited that it makes any overall difference to stored carbon in the full soil profile. [264] The effectiveness of no till agriculture (not ploughing between crops) also depends on soil type and weather, and while it may be beneficial for improving soil structure and some other benefits that arise from the soil, it may reduce others. [265]

Greenhouse gas (GHG) emissions from soil systems are positioned similarly at a nexus of factors around food security and climate change mitigation. Arable cropland occupies just 7% of the UK's peat area, but has the highest GHG emissions per unit area of any land-use as a result of drainage and fertilisation.[266]

Zero-tillage systems may become a soil carbon store for as long as it is practiced, but resuming conventional tillage may result in rapid loss of this carbon to the atmosphere. [261] Carbon-loss from soils may continue to occur as because of climate and land use change, but there are opportunities to increase soil carbon as part of wider climate change mitigation strategies. [267,268] Similar to carbon sequestration by woodland creation (see Principles in Practice: Climate Change Mitigation from Land Net Zero), these methods may have to be maintained in perpetuity to be an effective climate change mitigation strategy. Minimum or no-tillage may shift the soil microbial community to one that actively sequesters carbon. [269] Evidence suggests this is highly susceptible to variation in soil types, climate, crop residue management, cover crops (POSTNote 601). [270] Evidence also suggests that deep rooted crops and diversification in grassland can increase fine roots, which bind soils and improve soil structure and that diversification can bring benefits for soil health without compromising yield. [271,272]

Soil biodiversity monitoring and conservation can support the achievement and tracking of many SDGs, targeting areas such as climate, food and biodiversity protection, [273] but there is a lack of internationally recognised standard which sets out what is to be recorded about soil biodiversity and its ecosystem functions and how.

Delivering Sustainable Farming Interventions

Understanding farmer motivations and poor engagement in previous AES will be key to future SLM schemes in England. Standard economic analyses typically fail to explain how family farms, which are not financially viable at various points through time (and in some cases continue to not be very financially viable), persist. They do not take account of the culture, history, tradition of the farm, how farm-owners carry on, through reducing expenditure, getting alternative farm employment, and self-sacrifice in terms of quality of life.[274] They also do not take into account how farmers will adapt or respond to these changes.[63] The existing policy focus on economic stimulus may need to be realigned to take account of these other factors. Social science research, specifically aimed towards understanding farming communities have identified that treating farmers as 'economically rational actors' is a key impediment to environmental restoration.[26]

Although all these factors influence farmer decisions, farmer surveys conducted by researchers at Cambridge indicate that financial incentive is always one of them.[275] Social factors are also key, evidence suggests uptake from the first individual in a farming community will inevitably result in rapid uptake across the community (Principle 8 Joining up Governance: Policies, Markets and Regulation).[186] Advice and engagement are equally important in helping to understand farmers existing intrinsic (e.g. self-determination and connection to their land) and extrinsic motivations (e.g. productivity and market competition) and encourage sustained behavioural change on the ground.[153] However, the origin of advice and information available to farmers may hamper trust and willingness to adopt novel approaches and techniques. The AHDB are developing an evidence base to underpin recommendations for sustainable land management strategies (Principle 9 Changing research, evidence and knowledge transfer). Providing this information, along with the costs, the degree of evidence that it works and effective linkage to other approaches may influence decisions,[220] but more active forms of knowledge exchange may have greater influence (see Knowledge Exchange Networks).

Changing farmer behaviour also requires understanding their intrinsic motivations to undertake these activities (Principle 1 Shared Visions). Shifting motivations may require a change in farmers' underlying values and beliefs, influenced over time by societal norms. To achieve this shift there is the need for a coherent policy and advice framework in which regulations and incentives are important elements for signalling societal norms and expectations. Shifting farmers' extrinsic motivations for undertaking environmental management activities to more intrinsic ones is necessary to ensure sustained and widespread environmental improvements (Principle 1 Shared Visions). [276] Public campaigns aimed at helping farmers to redefine their identities as environmental stewards have been effective in Eastern Europe (Belarus, Bulgaria, Romania, Russian Federation, Ukraine). [277]

In the UK, there is increasing interest in the use of social/voluntary approaches to encourage behavioural change. [153] If behaviour change leads to voluntary action then it tends to persist over time, as it is more likely to become embedded in social norms. [278]

Market Demand

Engaging with the public, developing awareness and changing consumer behaviour are all potential steps that may need to be taken in conjunction with changing the agricultural economy. Providing context for the carbon cost of a supermarket purchase has been suggested as an effective engagement technique, though the practical application of such an approach is still in early stages.[279] Market demand may further modify allocations of funding to support water, climate change and biodiversity management (see Principles in Practice). A consistently applied system of in-store labelling that takes into account the environmental impact of food and farming may be one way to influence consumer spending.[234] Corporations may be required to audit their supply chains and adhere to Environmental, Social, and Corporate Governance (ESG) principles to be more effective, rather than putting the focus on the individual farmer. This system quickly becomes complex when considering anything other than direct farm produce. Most produce comes from a cluster of farms, multiple farmers providing grain, meat, vegetables, fruit (etc.), combined with the factories and processors. Calculating the environmental impact of something as simple as a sandwich requires a significant investment in technological development, as previously experienced by supermarket companies like Tesco in partnership with the WWF.[280]

The degree of carbon label understanding, acceptability of carbon labels, credibility of carbon labels, attitudes toward purchasing low-carbon products, perceived effectiveness of low-carbon consumption, social norms are all highly variable across markets (Principle 2 Bridging Institutions). Engaging with consumers on sustainability in food and farming has been consistently suggested by NGOs, academics and policy writers as a method for encouraging long-term SLM approaches to be taken up by the agricultural sector. Recent evidence suggests that the efficacy of measures such as labelling is limited since much of consumer behaviour does not result from choices based on knowledge, but is shaped by habits, social norms and expectations and physical surroundings.[281,282]

Payments for Ecosystem Services

ELMS will provide public payments to managers for the provision of public goods arising from land use and management changes, also known as "public money for public goods". There is also private market demand for ecosystem services, for example with clear beneficiaries seeking specific goods like clean water or carbon sequestration within the Landscape Enterprise Networks business partnerships team.[283] It is expected that private investments in ecosystem services also known as payments for ecosystem services (PES) can also work in combination with public payments and mechanisms and will supplement government funding.

The Dasgupta Review highlights that the flow of capital into nature restoration is far below what is required.[15] It argues that transformative funding mechanisms that create new investment opportunities and markets for nature and nature-based solutions are critical. It also highlights multiple barriers to investment that need to be identified and worked through.

However, research suggests a spatially targeted approach to land use that considers the value of both marketed goods and ecosystem services could increase the net benefits society derives from land by 20% in terms of farm profitability and carbon sequestration value (Principle 3 Negotiation and Equity). This increase may be even higher if it includes factors that may be harder to accurately quantify the benefit of, like biodiversity.[284]

Where clear beneficiaries of ecosystems can be identified, public and private market-based mechanisms known as Payments for Ecosystem Services (PES) enable beneficiaries to directly pay the land stewards who are the providers of the ecosystem services under demand.[285] In 2010, Defra's natural environment white paper: "The Natural Choice: Securing the Value of Nature"[286] promoted the valuation of natural capital (POSTNote 542) and compensation for the provision of biodiversity and ecosystem services through voluntary offset arrangements and other payment mechanisms (POSTBrief 34). It also catalysed the creation of The Ecosystems Market Taskforce which was a coalition of UK business that recommended the expansion of green goods, services, products, investment vehicles and markets which value and protect ecosystem services.[287] Defra outlined a number of regulatory, accounting and institutional principles in a Best Practice Guide for PES in 2013 and commissioned three rounds of PES research pilots to test practical application of the concept in new contexts.[288] PES outcomes must be additional to what would have occurred without the payment and avoid perverse incentives. Public and private market PES require appropriate reference levels for the environmental standards that land managers deliver and these should be in excess of legal baselines. While the position for water quality has been clarified over the past decades,[37] expectations with regard to other standards like carbon stored in soil or the qualities of soil itself are less clear.[285]

There are a variety of PES schemes in operation in the UK covering both single environmental outcomes and multiple ecosystem benefits which can be "stacked". There are however, unresolved complications arising from market distortions associated with subsidies, taxes and regulations in different areas of land policy.[289] Managing land for environmental benefits (POSTNote 627) also requires also cultural shifts. Social science analysis of farmers' perceptions of PES show that policies will need to be compatible with food provisioning and other ecosystem services, since cultural norms mean many farmers may remain committed to food production (Principle 1 Shared Visions). [290] But offering payments for environmental outcomes under a competitive approach may support the self-determination and competitive business-oriented processes that land managers desire.[226] However, there is scope to expand the range of beneficiaries of environmental goods to support the development of multifunctional landscapes and avoid management for the narrow delivery of just one or two ecosystem services.

Other barriers and challenges also exist including knowledge and data gaps, still developing methods, tools, metrics and standards, regulatory constraints, uncertainty around commercial returns and issues relating to awareness (Principle 9 Changing research, evidence and knowledge transfer).[291] PES business models will need to be scaled up to provide increased liquidity and certainty for investors and land managers if they are to be widely attractive to private funding and finance.[292] There are evidence gaps over understanding which interventions can deliver which public goods that will affect the development of both ELMs and private PES.[290] Some public goods have robust indicators and good evidence around the efficacy of interventions, such as Natural England's Managing Ecosystem Services Evidence Review (MESER) tool.[293].

Knowledge exchange networks

Establishing a network of (pre-existing) sites of good practice that are geographically specific would allow for the simultaneous collection of new local knowledge and dissemination of sustainable land management procedures using practical existing examples, which can be articulated experimentally, experientially and sometimes even nonverbally (Principle 2 Bridging Institutions).[152,229]

Demonstration farms

"Demonstration farms" are an ideal environment that show farmers what to do, how it works and the agricultural and environmental benefits, but require follow-up offsite or troubleshooting opportunities. The Eden Demonstration Test Catchment (Eden DTC) project run in the Eden Valley Catchment in Cumbria (see Principles in Practice: Water) has provided a service comparable to this, in collaboration with academic researchers across multiple universities.[294,295] Providing geographically specific locations for demonstration can be usefully combined with local charismatic individuals to spread information and engage with the community. However, a potential barrier to fulfilling this is the need to identify and recruit these people.[152,229]

Examples of demonstration farms, community projects, academic research projects and farmer engagement programs exist across England. These sites (such as the Knepp Estate [198]) bridge the environmentally-focused organisation with the agricultural, as well as those that bridge the academic and agricultural (such as the EdenDTC).[296] The Rivers Trusts are also running the Pinpoint project[297], which provides advice and support to farmers to help reduce diffuse water pollution from agriculture. Community co-design of research outcomes or experimental design is well established as the most effective method for distributing novel SLM (Principle 4 Adaptive co-management).[201]

There has been a reliance on volunteers to provide this service. Reliance on volunteers is not tenable for the duration required of environmental restoration at a national scale. For example, the Ullswater CIC,[298] which works with farmers in and around the village of Glenridding in the Lake District to help improve flood resilience and restore nature in a way that complements sustainable farming (Principle 2 Bridging Institutions). This started as a voluntary effort and persists presently only due to financial support from facilitation grants and charitable donations. [204]

Cooperation with other networks

Environmentally focused organisations have the potential to cause social friction between the agricultural industry and demonstrators of environmental practices (Principle 3 Negotiation and Equity). Discussing ideas on best practice "off-farm" (specifically meaning, not on the farmer's land) in a context outside of a farmer's land may be less problematic. Organisations, like the RSPB, Buglife or Open Spaces Society, are more likely to test novel and unconventional approaches. Facilitating these connections between practitioners and land managers may be necessary to establish novel approaches.[220] Existing social networks (auction houses, church communities, etc.) may also provide a secondary non-formal pathway to engagement. [229]

Top-down and bottom-up

Previous attempts through the Countryside Stewardship Schemes were more prescriptive with "top-down" delivery of policies that were not received as flexible enough to work in site specific strategies. Alternatively, a system that engages in a "bottom-up" structure that collects, enhances and facilitates funding of locally developed and adapted sustainable land management is likely to have a greater degree of uptake from land managers. Though the latter is accompanied by a sense of "being listened to" by the landowners, this is likely far more complicated to implement and in particular to monitor (Principle 8 Joining up Governance: Policies, Markets and Regulation). [299]

Monitoring (see Principles in Practice: Biodiversity, Ecosystems and the Nature Recovery Network) provides another interesting contrast in function and perception from landowners (Principle 10 Collective monitoring). They can serve as an important signal to other landowners that a particular management strategy is effective, as well as justifying the continued funding of that management (particularly in the case of a "bottom-up" policy development strategy). However, monitoring also comes at a significant financial burden to the landowner, and may be perceived as a waste of time and money, particularly when repeating management techniques within a local system or in an equivalent geographical setting. [299]

Local Environmental Governance Organisations (LEGOs), Local Nature Partnerships, AONB management boards, farming cooperatives, local government, parish councils and more are all currently existing bodies that deliver environmental outcomes in a locally adapted manner (Principle 8 Joining up Governance: Policies, Markets and Regulation).[300] However, there are few formal institutional connections between these bodies and national Government policy goals relevant to SLM, such as those in the 25 YEP. Developing a system that allows for employment of local expertise, engagement with communities in "bottom-up" management, while also coordinating these smaller scale schemes and mosaics of governance within any potential national objectives for SLM, is inherently complex (Principle 6 Local specificity).

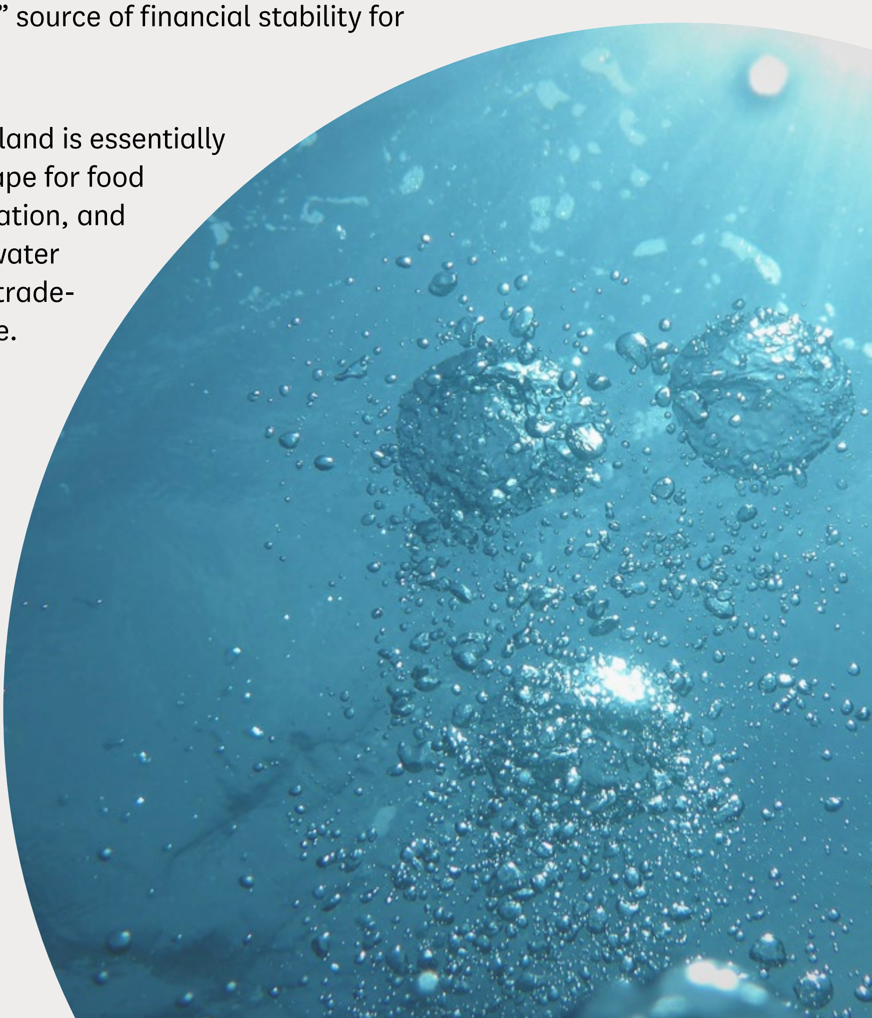
PRINCIPLES IN PRACTICE: WATER

Water management considers all aspects of the water cycle, as poor land management has impacts on water quantity and water quality. Agricultural activities are a major pressure on England's freshwater bodies, due to nutrient and chemical pollution, water abstraction and physical changes in habitats, including through water storage and land drainage.[301]

The following section discusses how the principles of sustainable land management are reflected by how we are managing water in England. Providing a broad overview of the water sector, which occurs at the meeting point between land management (primarily farming) and public utility companies, this chapter signposts key interactions between sectors and examples of current practice working at this nexus point.

As with Biodiversity, Climate change, and Food and Farming, successful implementation of government policies aimed at promoting sustainable land management requires consistent long-term funding to achieve meaningful outcomes. Without guarantees of long-term funding for restoring environmental features to improve water management, the potential for successful uptake may be limited. This may result in a drive towards intensification as a more "guaranteed" source of financial stability for some farmers.[204]

The water management system in England is essentially layered over a highly modified landscape for food and farming, biodiversity and conservation, and urbanisation. As such, implementing water management measures may come at trade-offs within a multifunctional landscape.



Box 6. Major threats to water management in England

Flooding: The UK Government's 2017 Climate Change Risk Assessment report identified increased flood risk as one of the UK's top climate change risks. [302] Over 5.2 million homes and properties in England are at risk from flooding and coastal erosion. The Environment Agency estimates that for every household directly affected during a large flood, about 16 people suffer knock-on effects from losses of utility services.[303]

Drought: Over the past thirty years, droughts have dramatically increased in number and intensity in the EU and at least 11% of the European population and 17% of its territory have been affected by water scarcity to date, including droughts occurring in South England (POSTBrief 40).[304] Traditionally, drought is usually considered to not be an issue in the Northwest because of high rainfall. Southeast England is comparatively more prone to drought, due to higher population density, urbanisation and average annual rainfall differences.[305] Under climate models, flows of rivers, aquifers and surface discharge are prone to disruption.[306] This disruption is highly geography specific. Prolonged periods without rain have a bigger or distorted effect in places where rivers and the hydrology are largely surface driven (for example: the Lake District)[307], because there are limited buffers of groundwater in the system to keep flows high.

Pollution: Agriculture is the source of around a third of diffuse pollution of water (DPW).[308–311] In 2020, only 16% of England's waters - and only 14% of rivers - currently meet the criteria under the Water Framework Directive for "good ecological status", and none of England's surface water bodies meet the current criteria for "good chemical status".[312] Agricultural DPWs (including nitrogen, phosphate, pesticide drift and particulates from soil erosion) are a substantial source. [313] Defra's Demonstration Test Catchments (DTCs) have found reducing agricultural DPW requires actions by land managers across entire catchments (POSTNote 478). [294,309] Trade-offs occur over imposing changes to environmental stewardship on farmers (see 3. Principles in Practice: Food and Farming), while not addressing economic pressures that drive environmental degradation. [314]

Central to any discussion of water in England and its management within the context of SLM is the EU Water Framework Directive (WFD) (2000/60/EC), some of which under the EU Withdrawal Act became part of UK law.[315] The WFD took the stance that "Water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such". There is growing concern that the UK Government objective of good ecological status, or higher, in all UK waters by 2027 is a long way from being achieved [316]. Though legislation and policy are supportive of cleaner water in England, the effectiveness of compliance and monitoring has been criticised by NGOs. This has resulted in the widely reported "200 year wait" between farm compliance inspections on average.[317]

Each water company has a duty under the "guaranteed standards scheme" to maintain security of its water supplies and this is assessed by Ofwat using the security of supply index (SOSI).[318] The water industry in England is also working collaboratively to restore the environment through the WINEP platform (Box 7).

Box 7: Water Industry National Environment Programme (WINEP)

Water as a public utility is handled by 20 water companies, distributed across their own river catchments throughout England. Establishing a sustainable landscape for the production of clean safe water necessitates not only working with landowners, but also these private firms.

The Water Industry National Environment Programme (WINEP) encompasses a set of actions requested by the Environment Agency for all 20 water companies operating in England, to complete between 2020 and 2025, in order to contribute towards meeting their environmental aims set out in the 25YEP.

WINEP is supported through up to £5 billion of investment by water companies in the natural environment through 2020 to 2025. The program specifically aims to:

- Protect and improve at least 6000km of our waters
- Protect and improve 24 Bathing Waters and 10 Shellfish sites
- Protect and improve 1800 hectares of protected nature conservation sites
- Enhance nearly 900km of river and 4276 hectares through wider biodiversity improvements

Scaling of approaches

"Catchment scale" approaches to water management are consistently agreed as most appropriate. The Catchment Based Approach (CaBA) project, funded by the European LIFE and Interreg Projects, The Prince of Wales's Charitable Fund and the Natural Environment Research Council,[319] are the driving force behind river management in England, maintaining demonstration test catchments as well as the main institutional framework.

Practitioners in the field suggest there is a far greater return on investment from applying a "holistic catchment scale approach" to water management.[204] A catchment is simply defined as an area contributing water to a river and its tributaries, with all the water ultimately running off to a single outlet (POSTnote 484). The catchment partnerships in all 100+ river catchments across England and cross-border with Wales are the main policy framework for delivering improvements[320] in water quality and integrated catchment management.[319]

Integrated Catchment Management

Effective management of water requires understanding of pressures on water resources at an appropriate scale - large enough to take account of all the relevant information, but small enough to ensure that people who live in the area can easily relate to their catchment (Principle 5 Scaled frameworks). Climate change is projected to significantly alter UK precipitation patterns over the coming decades, having significant impacts on extreme rainfall events. [321] Climate change further exacerbates regional water stress due to increasing temperatures and altered and less predictable precipitation patterns. Extreme rain events as a result of climate change increase the transport of nutrients and chemicals from farm soils into streams.[301] Climate models predict the need to adapt agricultural practices to reduce pollution runoff (Principles in Practice: Climate change mitigation). [322]

Evidence suggests an integrated approach to managing land and water use in individual catchments can protect and improve water resources (POSTBrief 40). In 2012, the House of Lords EU sub-committee highlighted the key challenge for catchment management is to develop institutional structures that match hydrological, ecological, social and economic processes operating at different spatial and temporal scales and to address the linkages between those scales (Principle 7 Spatial Planning). [323] This is referred to as taking a polycentric governance approach to water; it is increasingly seen internationally as essential to successful water management. [29]

Natural Flood Management

Natural Flood Management (NFM) is an approach to managing flood risk that aims to create, restore or alter landscape features to reduce flooding (for examples, see POSTnote 396). Traditionally, flood risk management approaches are usually centred on structural defences such as floodwalls, which aim to keep floodwater away from vulnerable areas. Deployment of structural defences is restricted by high capital, maintenance and upgrade costs, and the EA have stated that they cannot be raised indefinitely in response to increasing risk. [324] NFM measures implemented at the catchment scale may compliment engineered flood defences – such as walls and weirs – in populated areas (POSTnote 623). However, at this stage there is limited empirical evidence available to judge the efficacy of NFM against extreme events (Principle 9 Changing research, evidence and knowledge transfer). [325] A 2017 evidence review by the Environment Agency reported on 65 different UK NFM case studies [326]. Measures are currently being applied or considered in over 236 areas throughout the UK. [327] Evidence from these areas shows NFM can contribute to reduction in flood risk, but has limited effects on its own against extreme flooding. It can also achieve multiple benefits for people and wildlife, helping restore habitats, improve water quality and helping make catchments more resilient to the impacts of climate change. [325]

Polycentric governance

Polycentric governance (Figure 4) is the governance over an issue from multiple centres which range in scale. [328] It requires public participation across a diverse set of interest groups operating at different scales, from local beneficiaries, to local government, to regional and national organisations (Principle 4 Adaptive co-management). In the HoL Committee's recommendations it stated: 'Behaviour will only change by linking communities back into their rivers, the surrounding catchments and the ecosystem services that the catchment supplies, such as water. This will help to address issues such as water consumption and the impact of food production on water.' [323]

Polycentric governance (Figure 4) is particularly applicable to water management; for instance, decisions for implementation of Natural Flood Management (NFM) are influenced by multiple scales of governance.

- **At the largest scale**, EU legislation[315] has influenced greater working with natural processes and required that multiple benefits such as ecological gains are sought. [329]
- **At a national scale**, the need for new scientific evidence of NFM as an effective flood risk management method is driving funding up to £15 million between 2017 and 2027.
- **At a local authority scale**, the Lead Local Flood Authority (LLFA) or Internal Drainage Board (IDB) has governance over and responsibility for sub-channels of major rivers termed "Ordinary Watercourses." An IDB is a public body with a mix of elected and appointed members; it is concerned with managing water levels in lowland areas, including reducing risk from flooding. NFM is often most impactful within the upper catchment, so is most likely to be installed by LLFAs localised in the upper catchment area.
- **At a smaller scale,** decisions for NFM implementation can also be promoted and implemented through community action. [330] Local flood action groups can influence NFM uptake though active cooperation with land managers, the LLFA, NGOs and the EA. [331]

CaBA have consequently argued for the need for improved collaboration within catchment management partnerships and flood action groups.[30]

Other effective area-based conservation measures (OECMs) are conservation designations for areas that are achieving the effective conservation outside of protected areas. OECMs offer a significant opportunity to increase recognition and support for long-term conservation that is taking place outside currently designated protected areas,

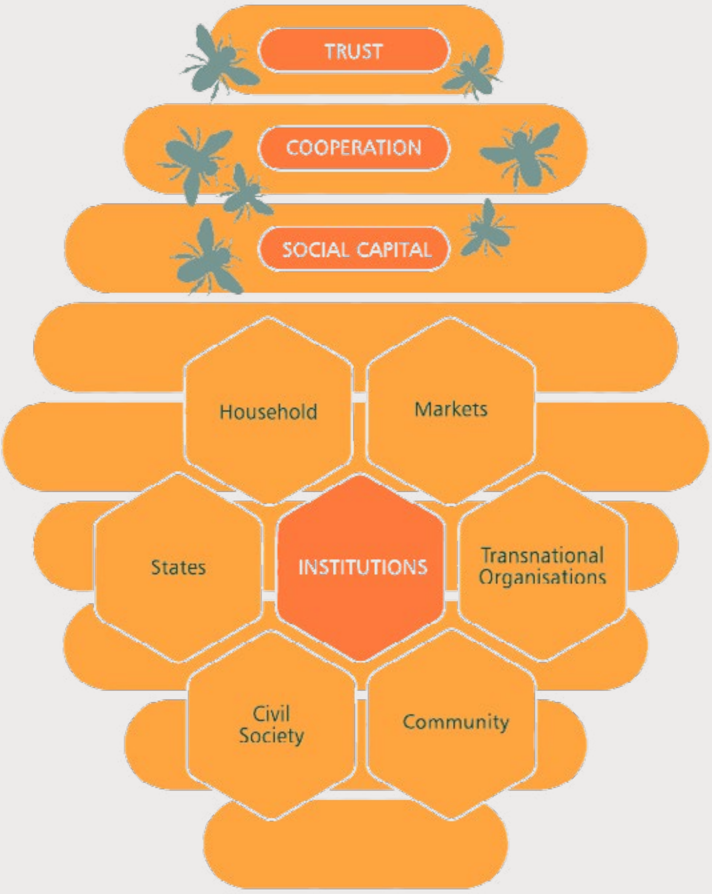


Figure 4. Framework for a polycentric governance approach to land management, developed as part of the Dasgupta Review.[15]

implemented by a diverse set of actors, including by Indigenous peoples and local communities, the private sector and government agencies.[332]

Challenges to SLM for water

"Unsustainable" land management practices (see Defining 'sustainability' in the context of land management) pushes further exploitation of land and water. Long-term damage of landscapes through (for instance) agricultural intensification impacts sustainable use of water. The modification and degradation of UK floodplains and uplands for agriculture and human infrastructure, and the resultant disruption of geomorphological processes (flooding, drought, pollution; see Box 7) highlights the important consequences of poor land management.

Water usage: agricultural environments

Agricultural intensification may increase in response to changes in environmental stewardship or fluctuations in the agricultural economy (see Principles in Practice: Food and Farming). This intensification of agriculture results in changes in land management that have direct effects on water management, such as:

- loss of hedgerows and larger fields (thus increasing slope lengths);
- cultivation practices causing deeper compacted soils (with reduced storage);
- land drains connecting the hilltop to the channel;
- cracks and mole drains feeding overland flow to drains and ditches;
- unchecked wash-off from bare soil;
- plough lines, ditches and tyre tracks concentrating overland flow;
- tramlines and farm tracks which convey runoff quickly to water courses;
- channelised rivers with no riparian buffer zone. [333]

These factors collectively change surface runoff rates (e.g. the extent of soil compaction, the efficiency of land drains and the connectivity of flow paths). Soil compaction is likely the greatest factor impacting runoff. By influencing the soil structure, storage capacity and hydraulic conductivity, land management can significantly affect these factors. [334] Localised measures of surface runoff in Europe suggests farmland has have generated more than any other land type.[335]. This is particularly the case for small-scale flood events caused by intense storms.[333] Local flood events may cause even more damage if these consist of muddy floods caused by erosion on farmland. [333] For arable farming systems, novel irrigation strategies can improve soil fertility and crop yields.[336]

In terms of land productivity (especially in the northwest), clean water could be considered more important than food production, United Utilities argues. [225,337] Pastoral farming systems have to contend with a net loss of over 60% of input energy, drawing criticism over their role in global food security. [337] Upland hill farming may have significant economic constraints (Box 4), in terms of meaningful produce from these landscapes, United Utilities consider clean water a more meaningful produce of the natural capital of these systems (Principle 2 Bridging Institutions). Equally though, the RSPB and United Utilities both consider recreation and public access to the countryside is also a key land use benefit (see Principles in Practice: Cultural and Heritage Landscapes).

Loss of wetland and restoration

Some 90% of wetland area in England has been lost since the industrial revolution. [338] In England, wetland areas such as fen, marsh, swamp and bog have been lost from lowland floodplains (Figure 5), with 64% converted to arable farming.[339] 85% of rivers in England have no associated wetland restoration, continued degradation and a lack of progress in restoring catchments may mean they will remain vulnerable to both drought and flooding. [340]

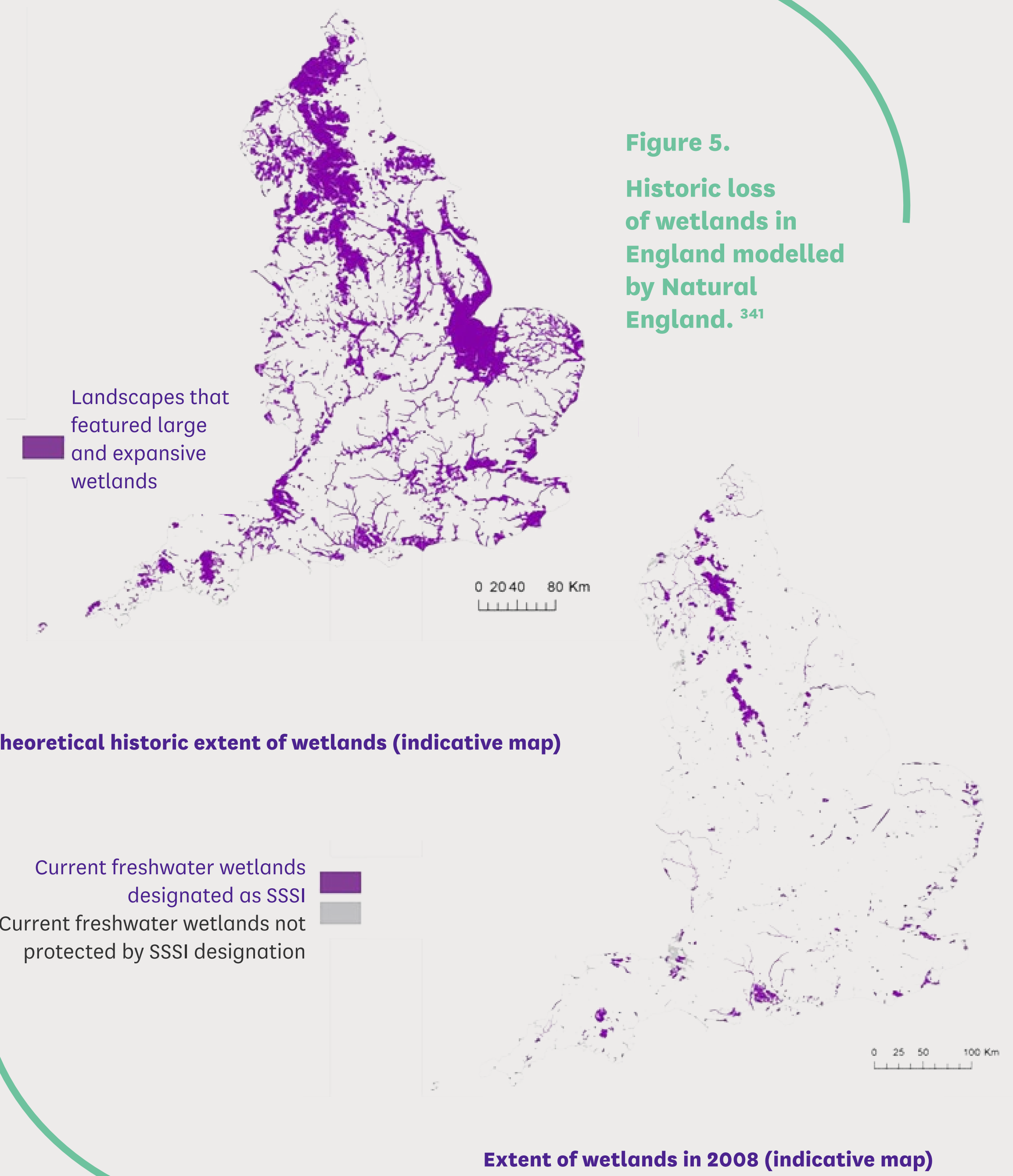


Figure 5.

Historic loss of wetlands in England modelled by Natural England. [341]

In the UK, the Natural Capital Committee has classified freshwaters as having deteriorating environmental status given the lack of progress towards restoration targets set out in the 25YEP, and have noted that currently, w assessments do not include data on streams, small lakes, ponds and ditches and wetland habitats outside protected areas that are integral components of river catchments. [171] The Blueprint for Water Coalition have called for a programme of restoration of these areas, in conjunction with regeneration of peatlands (see: Principles in Practice: Biodiversity, Ecosystems and the Nature Recovery Network) in the Nature Recovery

Network. [342] For a detailed report of wetlands conservation refer to Natural England Research Report "A Narrative for Conserving Freshwater and Wetland Habitats in England" [338]

Increasing demand

Managing water resources to meet the needs of society, the economy and the environment is a difficult task (POSTBrief 40). Increasing demand from population growth and housing developments has increased the risk of water shortages, particularly in the south. [343] Water is perceived publicly as a "silent service", meaning an uninterrupted service is seen as the only option for suppliers. Consumer behaviour in terms of quantities and patterns of consumption is disconnected from the environmental consequences of providing clean water.[337,344] As well as public and commercial water consumption, objectives for the natural environment like wetland restoration also place demands on the water resources (Principle 9 Changing research, evidence and knowledge transfer).[345]

Monitoring and Enforcement

Although water companies like Anglian Water or United Utilities can incentivise landowners to protect water courses through management measurements, they rely on statutory agencies to respond to activities that degrade water resources within their catchments.[337]

Outcome-based payments for measures to reduce water pollution or flooding through land management or recreation of landscape features could result in failed environmental restoration schemes that leave landowners with financial losses (Principle 10 Collective monitoring). There is also limited incentive for small landowners to undertake measures if funding is withheld due to failed outcomes (e.g. increasing the risk on small landowners in undertaking measures), or to adapt to situations resulting from damage caused by other landowners in the local area. [346]

Opportunities in SLM for water

Practical demonstrations

Several ongoing projects are being run across England to demonstrate the efficacy of SLM techniques for water management. Including the Ripon Multi-Objective Pilot (Ripon-MOP [333]), the Eden Demonstration Test Catchment (EdenDTC [347]) (Box 8), as well as evidence reviews by the Environment Agency. [326] NERC is also funding three major NFM research projects, due for completion in 2021. These projects (Landwise NFM, Protect NFM, Q-NFM)[348–350] are collecting real-world observational data to improve modelling and reduce uncertainties about NFM impacts on flood risk (Principle 9 Changing research, evidence and knowledge transfer).

Public responsibility and landowner accountability

RIPON-MOP (Box 8) public participants were of the opinion that if land owners took measures beyond good farming practice to reduce runoff from farmland for the public good by implementing runoff retention measures such as water storage ponds, they should be compensated for the extra costs involved.[333] Some academics have argued that farmers have a moral responsibility to prevent externalities caused by agriculture that negatively impact society, such as diffuse pollution, soil erosion and soil degradation.[333] United Utilities work collaboratively with farmers and charities (e.g. the South Cumbria Rivers Trust). Over time, this has built the necessary public trust in this system, resulting in positive perception of monitoring and long-term funding of environmental works (Principle 3 Negotiation and Equity; Principle 4 Adaptive co-management). [351]

Box 8. NFM Projects

The Ripon-MOP project was started in 2004, and is run by a local advisory group consisting of multiple stakeholders. Ripon-MOP aims to demonstrate integrated solutions to a range of issues within the catchment including flood management, biodiversity, resource protection, land management and public amenity. [352]

The EdenDTC is a Defra funded research project, aimed at cost effective mitigation of diffuse pollution from agriculture whilst maintaining agricultural productivity. The project joins up work done across England within the Eden river catchment in Cumbria, the Avon catchment in Hampshire and the River Wensum catchment in Norfolk. [353]

By monitoring the stream water quality and biology, the project looks at how catchments respond to storm events. This work includes measuring many properties of the water including the amount of nitrogen, phosphorus, sediment and total amount of water leaving the catchment.[353] Key to the project's success is the close relationship built with farmers in each catchment, which greatly increased the impact of the research. The EdenDTC team demonstrates the advantages of collaborative work with stakeholders in terms of enabling rapid uptake of novel management strategies. [295] Other projects, like the Cotswolds NFM project similarly demonstrate the beneficial role of working with multiple stakeholders to implement natural flood management on a catchment wide scale.[354]

Working with stakeholders

Consumer behaviour is complex, driven by factors including the level of consumer awareness of a water shortage issue, social and cultural narratives regarding how people perceive and value water, and the environment and perceived barriers to making positive change (Principle 4 Adaptive co-management; Principle 6 Local specificity).[355,356] Barriers to continued active engagement with water conservation and climate change occur at three levels.

- **Informational** (a lack of accessible information on environmental water demands, the links to climate change, incomplete understanding of land use trade-offs).
- **Institutional** (a lack of understanding between the water industry and the public and a perceived lack of political will to engage in water conservation).
- **Social** (habitual behaviour and a lack of resources to implement sustainable technologies).

Habitual behaviours are difficult to change, as they are not seen by those engaging in them as having a direct negative impact. [357]

PRINCIPLES IN PRACTICE: BIODIVERSITY, ECOSYSTEMS AND THE NATURE RECOVERY NETWORK

State of Biodiversity in the UK

As well as having intrinsic existence value, biodiversity underpins human life support systems. [358] Nature is declining at a global level [15,359,360]. In the UK, assessment reports including the 2019 State of Nature Report and the 2020 UK Biodiversity Indicators show ongoing declines across many taxa and species. [2,361] The UK did not achieve its international commitments to reverse the decline of wildlife by the Autumn of 2020, missing all the targets set out a decade before at the UN Convention for Biological Diversity. [362] Academic studies have suggested the risks arising from the loss of biodiversity and the degradation of ecosystems are often underestimated in comparison with threats of climate change, which is also driving losses in biodiversity (POSTNote 617). [358,363,364] The Dasgupta review has set out how global economic growth has driven this degradation and subsequent risks. [15]

Biodiversity is affected by different natural and human drivers, such as changes in land use, climate change, invasive species, overexploitation and pollution.[365] Averting and adapting to a changing climate at all geographic scales and reversing biodiversity loss can be addressed through restoring the natural environment. [360]

Direct links between pressures and biodiversity may be unclear as the relationships can be complex and non-linear. Impacts may occur over varying time scales, can be intermittent or permanent, and their magnitude is location-specific.[366] Uncertainty in indicators raises challenges for achieving desired biodiversity outcomes (POSTNote 644).

National and Local Nature Recovery through Ecological Networks

Over 100 years, nature conservation in England has focussed on protecting nature and preventing its decline [367] through designated areas and reserves. Improving habitat quality through better protected area management has generally been regarded as the most important step for biodiversity conservation, [368–370] however this has not been enough to prevent species and habitat losses. [145]

John Lawton put forward recommendations in 2010 for restoring England's ecological network calling for space for nature to be bigger, better, more and more joined together (Principle 8 Joining up Governance: Policies, Markets and Regulation). Within a national (i.e. England) context, building a coherent ecological network would involve:

- improve the quality of habitat (better);
- increase the size of protected areas (bigger);
- increase the number of sites (more);enhance connectivity among sites for conservation (more joined up). [371]

The objective of these recommendations is to restore ecosystems reverse the fragmentation of habitats throughout landscapes by restoring features that allow species to disperse between them, such as hedgerows.[372,373] Academic studies have identified four main activities for addressing fragmentation to reverse biodiversity declines: [363,374]

- Reducing impact of farming on the environment (see Principles in Practice: Food and Farming);
- Extending the conservation network through protected reserves;
- Restoring degraded land;

The Government described plans to create an ecological network through a National Recovery Network (NRN) set out in the 25YEP,[3] and Local Nature Recovery Strategies (LNRS) to restore areas important for biodiversity set out in the Environment Bill.[375] It is not yet clear how the strategic planning for the NRN and LNRS will work with ELMs, the Agriculture Act 2020 and the Environment Bill 2019-21.[376]

Restoring ecosystems at a landscape and national scale will benefit human health and wellbeing [154,377–380] by enhancing the provision of ecosystem services.[381] For example, the national lockdown has highlighted how access to green space supports mental and physical health.[382]

The Glover Review [383] argues that "…our system of national landscapes should be a positive force for the nation's wellbeing" and suggests that a reform of England's designated areas and parks will contribute to the delivery of the Nature Recovery Network.[384] The Wildlife Trusts have suggested the Nature Recovery Network is renamed England's "Wild Belt" to foster public ownership of and engagement with the Nature Recovery Network.[367] In a related way, the IPBES argue that a widespread cultural shift in society's relationship to biodiversity towards transforming common practices and aspirations for all people and institutions is required. [365]

Commentators suggest technical approaches, such as assigning monetary values to ecosystem service benefits, have failed to engage with the emotions that motivate action towards alternative futures.[385] This includes the term biodiversity, with the late Dame Georgina Mace suggesting the "web of life" as a superior way of understanding the role of biodiversity in earth system processes and human society. [386,387]

Box 9. From the Natura 2000 Network to the National Nature Recovery Network.

As a result of the departure of the UK from the EU, Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) in the UK no longer form part of the EU's Natura 2000 ecological network. In the EU, the 'Natura 2000 network' was established to achieve long-term protection of habitats and species on the EU level. It consists of 25,717 terrestrial sites. [388]

A shortage of financial resources is one of the major management issues affecting Natura 2000 sites, as funding is needed for the establishment, maintenance, and management of the sites. 389However, Natura 2000 sites' importance in providing relevant social and -economic benefits to local communities, mostly related to tourism and recreation, is increasingly recognised, [390] and the identification and evaluation of Cultural Ecosystem Services and their benefits could foster the acceptance and support of the network. [391]

In the UK, the 2019 Habitats Regulations have created a national site network on land and at sea, including both the inshore and offshore marine areas in the UK. The national site network includes:

- Existing SACs and SPAs.
- New SACs and SPAs designated under these Regulations.
- Any references to Natura 2000 in the 2019 Regulations and in guidance now refers to the new national site network.
- The establishment of management objectives for the national site network (the 'network objectives').
- A duty for appropriate authorities to manage and where necessary adapt the national site network as a whole to achieve the network objectives.
- New arrangements with regard to the imperative reasons of overriding public interest (IROPI) test where a plan or project affects a priority habitat or species.

Nature Protection and Enforcement

An ecological network for England as envisaged by the Lawton Review has not yet been implemented. Institutional, political, and scientific barriers include:

- **Funding shortage**s and a lack of monitoring and enforcement for protected sites, and current farming practices (see Principles in Practice: Food and Farming).[393]

- **Inadequate management plans**, a fragmented system of coordination, lack of vision and awareness over the problems, clarity over responsibilities and inadequate institutional capacity at all scales to provide management all reduce the capacity for nature recovery. [384]
- **Shifting baseline syndrome** describes the incremental forgetting of what a healthy and living environment looks like. [394–396] There is a risk that visions to restore ecosystems become downgraded as nature gradually disappears and the landscape changes over time through degradation. [394]

National Parks and AONBs

In September 2020, the Government committed to protecting 30% of the UK's land for nature by 2037. [397] The combined designated areas currently make up 26% of land in England. However, some designated landscapes, such as Areas of Outstanding Natural Beauty and National Parks, have no statutory protections for nature. AONBs account for 18% of protected land in England. A further 400,000 hectares of land with conservation designations will need to achieve the 30% figure. The Glover Review 2020 [383] has recommended landscape designations should be combined with nature designations, to create a new system of "National Landscapes" that support the Nature Recovery Network. The Review found the current arrangement of National Parks and Areas of Outstanding Natural Beauty to be fragmented and with management structures in need of modernising. It suggests that National Parks can work more effectively together as a system and land managers should be supported by ELM to restore biodiversity and ecosystem services (Principle 8 Joining up Governance: Policies, Markets and Regulation). [384]

SSSIs, SPAs and SACs

Where nature protections have been designated at sites, such as Sites of Special Scientific Interest (SSSIs), SPAs and SACs, which all have the highest tier of nature protection in England, protections have often not been enforced in practice.[367,398,399] Many are in poor condition and have not been adequately supported to fulfil their potential.[398,399] The main bodies that oversee and enforce a wide range of environmental regulations to protect the natural environment are the Environment Agency, Natural England and Local Authorities. A report shows they have been subject to extensive funding cuts. [400] This analysis shows for example, that between 2009 and 2019, Natural England lost 72% of its funding and 20% of its staff. Spending on monitoring SSSIs has fallen by 64% between in this period and there has been a 148% increase in the number of response deadlines missed, meaning many of the existing SSSIs no longer have statutory protection.

SSSIs are considered England's best sites for nature with the highest level of protection. The status of a SSSI is determined by whether it has a Higher Tier Countryside Stewardship management plan in place. The number of Agri-environment agreements issued to farmers responsible for maintaining SSSI's in a favourable status has concomitantly been reduced by 80%: dropping from 2500 a year to just 500, between 2015 and 2020. There is likely to have been an effect on wildlife in areas with less legal protection. [401] The Forestry Commission has also lost 53% its funding over the same period and the Environment Agency 63% and local Authority spend on environmental and regulatory services has dropped by 31%.[400] Only 1 in 4 local authorities in England now have an in-house ecological expertise, [402] with many cutting parks, natural environment and countryside service budgets (Principle 6 Local specificity). [403] Studies show that local government capacity shortage risks weakening rather than strengthening environmental decisions in the planning system with the introduction of for mandatory biodiversity net gain (POSTBrief 34) for all developments by the Environment Bill. [404]

Office for Environmental Protection

The Environment Bill includes plans for creating a new Office for Environmental Protection (OEP) to monitor the UK Government's progress towards its environmental legislation.[397] It will also investigate potential failures of public bodies to comply with environmental law. Concerns have been expressed about whether the OEP will be resourced adequately to carry out its duties as promised by the Government, or with sufficient independence and powers to provide the scrutiny and accountability that legislation requires. [405]

Planning and Delivering the Nature Recovery Network

There is uncertainty over future land-changes and the effects of climate change, creating challenges for conservation strategy. The trade-offs in the choices for bigger, better or more joined up sites within a network can be mapped with sufficient evidence and modelling.[371] Understanding trade-offs will help translate evidence into practical and effective conservation planning for nature recovery (Principle 9 Changing research, evidence and knowledge transfer).[368] Relevant considerations include what kinds of species are targeted, their habitat needs; the degree of existing landscape fragmentation; and the vulnerability of sites to the effects of climate change and other risks.

The social and economic features of the land including ownership are also relevant to the design of local nature recovery strategies. A review of studies on reserve design found the priority should generally be on improving habitat quality and making areas larger while considering different climate, landscape, disease and economic factors, supporting the Lawton recommendations. The only exception was in highly fragmented landscapes, where area and connectivity may become more important than quality.[371]

Natural England published the Nature Network's Evidence Handbook in March 2020 to provide scientific evidence and guidance over how to design the network with ecological rules of thumb.[406] It provides a set of principles and decision-making tools, recommending that nature networks benefiting both biodiversity and people and are more likely to succeed if they work with the geography of the landscape and the needs of local communities and wider public. However, circumstantial factors, such as funding limitations, tend to always end up shaping the best approach to landscape scale conservation initiatives. [371]

Studies suggest trade-offs around food production and conservation requires sensitive engagement with local managers' needs and capacities. [23] Piecemeal projects with short term funding limit success and increase the risk that gains are simply reversed when money runs out, private owners shift priorities or land is sold. [168]

Spatial Planning of Networks

Natural England have outlined the pros and cons of different conservation planning approaches and decisions support tools with further references and examples of where they have been used. [406] Conservation planning uses a variety of tools and data to integrate scientific evidence into decision making, where the knowledge base is insufficient. [407,408] Good design of the local nature recovery networks requires spatial planning (Principle 7 Spatial Planning) and local data (Principle 6 Local specificity).[292] Targeted efforts using zoning, involving identifying multiple uses can prioritise and plan within landscapes. Debate around the Environment Bill 2019-21 is ongoing as to how public authorities should act in accordance with Local Nature Recovery Strategies, including statutorily required planning and spending decisions.[409] The National Food Strategy recommends that Defra work with the Local Nature Recovery networks to compile a National Rural Land Use Map that is freely available to land managers to help all stakeholders decide how best to use land and where the environmental priorities are.[56] The map would help inform which land is most appropriate for semi-natural land, low-yield farming, and high-yield farming as well as for economic development and housing (See Box 2 Land sparing or sharing). The National Food Strategy produced data analysis on the best places to concentrate efforts for tree planting, nature restoration and high-quality farmland to meet national targets for climate, biodiversity and healthy food production.

Systematic conservation planning is another form of spatial decision making [410] and can also be used to integrate conservation with food production and model the relationships, optimising outcomes for nature and minimising societal costs (Principle 7 Spatial Planning).[411] Maps and Geographic Information Systems supplemented with local knowledge are helpful to coordinate action in a participatory way and to assess ecosystem supply and demand.[412]

While there are many existing area-based or spatial lead approaches ranging from river basin management plans to nature improvement areas, nitrate vulnerable zones, biodiversity action plans, SSSIs and other designations, these all have limitations. The environment is often "siloed", with issues such as soil quality, flood mitigation and water quality separately addressed. These areas are often administered and financed separately, managed on short term timeframes, and are separate from local authority planning and development plans (Principle 8 Joining up Governance: Policies, Markets and Regulation).[413]

The Broadway Initiative which is a multi-sector stakeholder group, led by the Institute for Environmental Management and Assessment (IEMA) have called for a unified spatial framework as a single map to be included as a requirement in the Environment Bill. The map should integrate data from different sectors showing the current state and opportunities to improve the environment at different scales, which can be integrated into local development planning.[292]

The Local Government Association commissioned a series of studies into integration of strategic planning at the landscape scale for nature conservation.[414] They conclude that thus far "the overall policy approach has been characterised by fragmentation underlined by relatively weak policy wording in strategic/joint local plans and commitment when compared to other infrastructure and limited policy connections." Their studies reinforce the need for more integrated policy mechanisms as stated here (Principle 8 Joining up Governance: Policies, Markets and Regulation).

Data driven spatial planning is also helpful to manage trade-offs between the needs for biodiversity and the provision of ecosystem services, such as avoiding tree planting on habitats valued for their biodiversity (Principle 10 Collective monitoring). Spatial coordination can join up initiatives and investment, avoiding duplication and wasted effort. [378] While spatial tools for decision making are required, technical models can obscure from the local challenges involving people on the ground.[415] Successful restoration projects depend on collaborative engagement with local people and processes for managing conflict resolution.[176]

Data for Planning and Monitoring

Good quality data supports scenario developing and modelling and can help prioritise the benefits that landscape restoration can deliver.[416] Data is also needed prior to interventions being made, allowing comparisons to be made over time for evaluation of intervention success through monitoring. For example, the evaluation of conservation measures based on management undertaken and threat reduction rather than their outcomes suggests they have had limited effectiveness, such as the previous agri-environment schemes under the Common Agricultural Policy.[417]

The JNCC argue that an absence of detailed baseline data provides no way of tracking progress against goals in the 25YEP and recommended a national environmental census.[3] Commentators including the Natural Capital Committee [4] have argued a clear understanding over where natural assets lie is a first step towards ensuring that natural capital is no longer lost.[418] The Government has allocated £5m to support a Natural Capital and Ecosystem Assessment to create a centralised and accessible body of data on species populations and habitats.[419]

The United Kingdom has a rich tradition of citizen science initiatives. Citizen-science can also be enhanced through combination with technology such as the use of mobile apps, drones and acoustic monitors to increase the coverage and frequency of biodiversity data.[420,421] Remote sensing combined with grounded reporting of designated area management capacity can make outcome evaluations more accurate and reliable.[417]

The funding cycles which drive short term project deliveries constrains the long-term visions for landscape restoration projects.[422] There are examples of multi-generational visions for restoration projects, such as the Cairngorms National Park and the Wicken 100 Year Vision in the Cambridgeshire Fens. Institutional funding and policy instruments, such as conservation covenants can be designed to support long term restoration projects.[398] Blended finance can support long-term institutional arrangements, mixing public and private-sector funding.[423] Academic commentators have also proposed innovative financial mechanisms to address the conflicts between livelihood generation and environmental goals for those living in areas of high conservation value.[424,425]

Research Priorities for Landscape Restoration

Online facilities such as the Government's Enabling a Natural Capital Approach, the Ecosystem Knowledge Network and the website Conservation Evidence [270] are examples of open access knowledge transfer facilities that can be more widely promoted (Principle 3 Negotiation and Equity). Stronger integration across published research and policy planning may help overcome a disconnect between academic publishing and knowledge that is accessible and oriented to policy use, slow publishing times and intellectual property barriers.[426]

Commentators suggest the JNCC, CEH, Natural England and the non-governmental organisations such as the RSPB and the Wildlife Trusts could cooperate more. [393] For example, delivery of long-term landscape restoration projects will be affected by extreme events associated with climate change in unpredictable ways, compounded by other human pressures.[427] Natural England suggest spatial plans for conservation should be designed with climate change in mind [428] and biodiversity vulnerabilities need to be considered at an early-stage nature network development.[429,430] Making decisions over bigger, better or more connected reserves should also be in line with modelling and evidence predicting the impacts of climate change on the habitats and species populations present. [431]

Biodiversity, Natural Capital and Ecosystem Services

Biodiversity usually correlates to the delivery of ecosystem services, even though there are times when this is not the case,[432] for certain ecosystem services (e.g. pollination, control of agricultural pests, regulation of human disease risk), there is very good evidence for a positive effect of biodiversity, whereas for other ecosystem services biodiversity seems to be less important.[433]

NRN / LNRS needs to deliver multiple benefits as well as for biodiversity, but it only will if well planned, and the aim of delivering for people and wildlife is set out at the start.[376] SLM requires aligning social, cultural and political obstacles for effective translation of policy into actions and the necessary financial resources which benefit biodiversity (Principle 2 Bridging Institutions).[432]

Most ecosystem services are provided by the interaction of living and non-living components of nature, rather than by individual species,[434] but the causal link between biodiversity loss and impacts on ecosystem service provision remains poorly understood.[20] The government provides a series of frameworks to help mapping and decision making aimed at policy and decision makers in its Enabling Natural Capital Approach.[435] The Ecosystems

Knowledge Network also maintains an online resource with a wide range of tools for analysing ecosystem services, natural capital and green infrastructure. [436] Natural England's Natural Capital Evidence Handbook provides a best practice view of how to implement natural capital evidence in a strategic decision making process, as well as providing evidence which can be used.[157]

Natural Capital includes species diversity and ecological communities but also geodiversity, atmosphere, minerals, oceans and coastlines. Natural capital mapping can be layered over habitat data for example, through open access data for user friendly tools in landscape management (Box 10). However, natural capital has yet to be integrated into the work of all organisations and institutions that interact with land such as many utilities, highways and parks authorities. [437] Examples of those that have include Anglian Water, which now describes itself a natural capital company rather than a water company. [438]

Box 10. Trialling Natural Capital Mapping

The North Devon Pioneer covering the North Devon UNESCO Biosphere, is one of four projects tasked by Defra that trialled a natural capital approach. The project aimed to test using a natural capital approach, and to see how it could be used to improve the environment through building multifunctional ecosystems. Working in partnership with Natural England, the North Devon Biosphere partnership and other local sectors such as North Devon Council, Visit Devon, North Devon Homes and the NFU.

The first step involved collating the natural capital assets and ecosystem services onto one spreadsheet. Ecosystem services were quantified, described and if possible valued economically. Technical evidence was combined with participatory evidence that was generated from partnership workshops to engender shared ownership of the evidence base, and increase the density of available evidence. A heat map of spending on conservation was used to assess how different stakeholders' investments in the region overlapped.[439]

The project performed a multi-criteria analysis to prioritise natural capital assets that were providing high value ecosystem services, but in poor condition and declining trend. A Root Cause Analysis (the process of discovering the root causes of problems to identify appropriate solutions) [440] tracked the source of ongoing problems. Visual root cause maps created through further partner workshops highlighted multiple sources and causes for the ongoing problems in the area. [183] The participatory process highlighted that people felt uncomfortable working with economic evidence, but engaged well with evidence about socio-ecological systems, such as the root cause analysis.

Solutions were developed along with actionable criteria across land management, land uses and the social and-economic understanding of incentives, motivations, capacities and governance. [385] Private sector investment opportunities identified include supporting local food networks, carbon offsetting, woodland management support hubs and ecotourism were.

385 However, the project showed that for many required actions, there was no clear financial return on investment, highlighting the role of public money or non-market sources of investment.[441]

The project produced a collectively owned natural capital strategy with the landowners and other sectors involved for action. It showed that the strategic changes become possible from not only knowing what to do, but from how the processes are worked out. The findings have contributed to the North Devon Biosphere's joint land and sea action plan. The project now comprises one of DEFRA's 55 "Test and Trial" commissioned projects to help inform the new ELMS. Lessons from North Devon has helped Natural England to develop the natural capital evidence handbook.[157]

Nature Networks, Urban Fabric and Planning Policy

Planning policy and urban development could also support the integrated delivery of LNRNs, Green Infrastructure and Nature Based Solutions. The Local Government Association has recommended setting up a joint local and central government taskforce on climate change and support a green recovery and the delivery of green infrastructure. However, they anticipate greater centralisation of planning decisions set out in the 2020 Planning White Paper will undermine Local Authorities' ability to shape urban development in a way that supports the nature recovery network. [403]

By contrast, a consortium of environmental NGOs has recommended strengthening the NPPF to promote a green recovery and climate adaptation in several ways. This includes empowering County Councils to:

- **Set** green infrastructure standards and refuse developments that fall short,
- **Ensure** plans to improve green infrastructure are adequately funded, and
- **Provide** stronger protection for all spaces that are important for nature including non-statutory wildlife sites. [403]

Urban nature, which can deliver benefits as part of a network is increasingly referred to as green and blue infrastructure (GBI) (POSTBrief 26). This includes parks, open spaces, playing fields, woodlands, street trees, allotments and gardens as well as rivers, canals and ponds. GBI can provide ecosystem services like flood protection, air quality and increased human health and wellbeing. Research has demonstrated it is possible to make a business case for local authorities to invest in GBI; [442] since strategic and local plans have had inconsistent coverage on green infrastructure for planning decisions. These could be strengthened through policy assessment tools [443] with prioritisation of natural capital, ecosystem services and green infrastructure in decision making. [444] The NPPF and National Planning Policy Guidance (NPPG) do not provide guidance on integrated approaches. Prioritisation and integration GBI and NBS could take place local environmental improvement plans along-side the national spatial environmental improvement plan. [413]

PRINCIPLES IN PRACTICE: CLIMATE CHANGE MITIGATION FROM LAND NET ZERO

In June 2019, the UK became the first major world economy to make a statutory commitment to end its contribution to global warming by 2050 and achieve net zero greenhouse gas emissions. [445] "Net zero" means reducing greenhouse gas emissions by 100% of 1990 levels. The target was established within the Paris Agreement in 2015 under the aim for keeping global warming to within a 1.5-degree limit (POSTnote 594). The UK Committee on Climate Change (CCC) have modelled scenarios that show how specific changes to the land use will be needed to meet the UK's net zero targets.[446,447] Widespread changes to land use and management are seen as an essential to meet the Paris Agreement goals.[448] The Royal Society with the Royal Academy of Engineers has produced guidance for land uses that may actively remove of greenhouse gas (GHG) removal from the atmosphere (POSTnote 549).[449]

Reaching net zero includes both changes to land use (like converting farmland to forest) and land management (climate friendly agriculture) (POSTnote 600). The CCC models show that emissions from agriculture can be reduced by 64% (from 58MT CO_2e in 2017 levels to 21MT CO_2e in 2050). [447] A further 25MT CO_2e reduction can be made from using timber from forests and bioenergy crops elsewhere in the economy instead of fossil fuels. The CCC recommends that one fifth of agricultural land be released for actions to reduce emissions and sequester carbon dioxide. This includes making space to grow up to 23,000 hectares of bioenergy crops and 30,000 hectares of forests a year.[446] Land management strategies may mitigate GHG emissions at a lower cost and faster rate than many other GHG strategies, but success will depend on the environmental and social context.[450]

The Committee on Climate Change has recommended that the UK increases its land cover of woodland from 13%-17% planting 30,000 hectares of woodland a year. [447] However, the amount of CO2 taken up and other benefits or negative effects of woodland creation depend on where and how woodland is established, tree species present, site conditions and management (POSTNote 636). The condition of a habitat and the soil and sediment processes will have an impact on its capacity sequester or emit GHG, and there is scope to improve carbon stocks of different habitats. Land of recognised conservation value stores a lot of carbon in the top 30cm of soil and work to create a net sink. Soil carbon could be increased by 75-87% a year with restoration management approaches, which is preferable to recreating habitats. [451,452] There is evidence on what management practices have the most benefit for sequestering carbon emissions in inland and coastal habitats. [453–455]

Managing agricultural and other land for climate services is integral to multi-functional landscapes (see The Principles of Sustainable Land Management). Farming practices that can reduce agricultural emissions such as improved agronomy, minimum soil disturbance and organic fertilisation can deliver co-benefits for yields (see Box 6).[456] The magnitude and range of results varies hugely between systems and context. Even small increases in soil carbon levels are likely to improve soil quality and functioning for sustainable crop production,[457] although the overall contribution to mitigating global climate change may be contentious. [458,459]

Actions for climate mitigation aim to enhance climate resilience, reverse land degradation, improve biodiversity and other environmental services as part of multi-functional and sustainable landscapes. For instance, land sparing (See Box 3) has the potential to be beneficial for biodiversity and other ecosystem services including carbon storage,[94] but benefits realised will depend strongly on the use of spared land (See: Principles in Practice: Biodiversity, Ecosystems and the Nature Recovery Network). Sparing could have knock on effects if high-yield farming creates further trade-offs detrimental for biodiversity and ecosystem services.[460]

The Government has defined land-based emissions reductions and natural forms of climate resilience as ‘public goods’ to be supported through the Environmental Land Management Scheme; [50] although forestry currently lies outside of Countryside stewardship and other Agri-environment schemes. Different kinds of land management and use can both remove and reduce GHG emissions. In this way land and its use is said to operate as both a carbon sink and a source.[151] Land based actions to address the mitigation of GHG emissions are therefore focussed on expanding land as a sink (when it is overall removing and storing or sequestering carbon from the atmosphere) and reducing it as a source of emissions (to the atmosphere on balance). In 2018, Defra implemented a smart GHG and ammonia emission inventory for UK agriculture in 2018. Changes have been implemented as part of Defra’s improvement programme to ensure that the UK inventory is more accurately representing the UK agricultural sector.[461]

Land as a greenhouse gas sink

Strategic changes in land use can minimise carbon emissions and create opportunities to sequester carbon. Carbon dioxide is removed from the atmosphere through photosynthesis and returned to the soil through the plant roots and the decomposition of vegetation. The carbon stock refers to carbon stored both in plant vegetation and in the soil as organic carbon

(SOC).[462] Carbon sequestration in soils or terrestrial biomass only remove carbon from the atmosphere until the maximum capacity for the ecosystem is reached, which may take 15–33 years, depending on management practice and system.[463,464] Wetlands, such as peatlands, are the most effective land use at capturing and storing carbon. Undrained peatlands accumulate organic matter because the decomposition of plants is slowed by permanently water-logged conditions. Over thousands of years, a large store of carbon is accumulated as peat soil. [266]

After wetlands such as peat, forestry is the next most effective land use at capturing and storing carbon (though only when managed appropriately), followed by pastures and grasslands, cropland and eventually urban land.[151] The net carbon sink effect of land between 1990 and 2016 in the England increased through growing forest cover, conversions of farmland to grassland and some less intensive agricultural practices.[465] Future sequestration is at risk due to the ageing profile of trees and the CCC has recommended increasing UK tree cover from 13% to 18%, improving woodland management and adopting agroforestry to contribute to the UK's net zero target.[466]. While there are economic, environmental and land tenure constraints on where woodland can be planted in landscapes (as well as optimal locations that provide other benefits such as recreation), trees can also be planted outside of woodland (such as in agroforestry systems, POSTnote 636). Increased protected area coverage, increased biofuel crop production and existing 74% of land used for agriculture, where and how these uses get integrated and placed is a challenging task.

Changing rain patterns and rising temperatures will limit the capacity of grasslands to absorb more carbon dioxide, meaning it is diminishing as carbon sink.[467] The rate land establishes a new equilibrium also depends on the nature of the land use change. Losses to soil organic carbon happen 'fast' (5 – 15 years in England) and gain happens 'slowly' (100 – 300 years in England).[461] When land use is changed, carbon can be sequestered or released until a new equilibrium is reached (when the rate of carbon accumulation and loss balance out). Carbon sequestration in soil increases with water levels in both organic and mineral soil types.[456]

The CCC's scenarios for changes to land use changes to increase the carbon sequestration and sink capacity of land involves work across:

- Expanding forestry (POSTnote 636).
- Planting bioenergy crops (POSTnote 618).
- Restoring peatlands.

Peatland Restoration and Paludiculture

In England, there are approximately 325,000 ha of lowland peatlands, with 240,000 ha (74% of the total stock) used for farming and food production. Much of this has been drained to maximise yields of high value produce crops. Two thirds of the cropped peatlands in England are in regular use for horticulture crop production, with the remainder being used for arable/cereal rotation.[468] Peat wastage (thinning of the top layer and land lowering) under cropland is typically 10 to 30 mm per year, and this land has the highest greenhouse gas (GHG) emissions of any UK land-use on peat (>10 times higher than emissions from upland peat). [469]

There is a growing interest in ameliorating peat wastage and CO2 loss through 'paludiculture', which are systems of farming and agroforestry using species typical of wetland habitats allowing managers to generate a commercial crop from these wetlands.[470] Findings from trials suggest that paludiculture could reduce CO2 (and overall GHG) emissions relative to conventional drainage-based agriculture or peat extraction.[471–473] The prospect of raising water levels to reduce emissions in farmed peatlands demands new ways of growing existing crops, or new crops suitable for elevated water tables. Most of the peat used in horticulture consists of decomposed Sphagnum moss and paludiculture could support this kind of production for growing media or potting soil.[474,475]

However, peatland management needs to take a full account of their historical status and the evidence concerning their development, changes in carbon dynamics and trade-offs in use and potential restoration. Essentially it is important to point out that bogs may be excellent sequesters of carbon as they grow and develop but that eventually they change naturally to sources of greenhouse gases. This is not a case for their accelerated degradation when carbon release is accelerated further but that practical and sustainable restoration of entire bog systems may not work in the present climatic envelop.[60]

There remain significant practical, economic and societal challenges for the large-scale implementation of paludiculture, including the need to support the opportunity costs of shifting production, maintain national food security, develop markets and supply chains, manage water within complex and heavily modified landscapes, and avoid displacement of emissions associated with food production to other areas. [476–478] Facilitating the wider adoption of paludiculture is likely to require the development of financial incentive schemes for farmers, landowners and investors, new regulatory approaches and investment in supporting infrastructure. This in turn requires a stronger evidence base, both to develop viable paludiculture systems and to accurately quantify the associated benefits and trade-offs (Principle 9 Changing research, evidence and knowledge transfer). [468]

Paludiculture offers a number of co-benefits for biodiversity and water storage within farmed landscapes although less than through full peatland restoration. The CCC recommends restoring 80% of upland and lowland peatlands.[479] The Government has committed to restoring 35,000 ha of peatlands by 2025 through the £640million Nature for Climate Fund and to publishing England's first comprehensive Peat Strategy (EPS). [51] The IUCN UK Peatland Strategy was launched in 2018 to co-ordinate large-scale action to conserve and restore the UK's peatlands. [480] The UK strategy aims for 2 million hectares of peatland to be in good condition, under restoration and sustainably managed by 2040. England's forthcoming Peat Strategy will provide incentives for restoration and sustainable management and initiatives to overcome non-financial barriers, particularly a lack of information. Regulatory measures to protect peat may also be introduced. [51] Defra ran five Peatland Pilots in preparation for the EPS. Evidence from these pilots show that the EPS will need to address external barriers such as tenure, farm business characteristics and provide sufficient financial incentives for making changes. It will also need to account for farmer perceptions of risk associated with management changes, regional and stakeholder specificities, and to overcome the problems of trust in Government advice to the farming community. [481] One of the important services of peat systems is the record of palaeo-environmental evidence and cultural artefacts undisturbed. This may not be consistent with a paludiculture approach.

Integrating Nature Based Solutions into Landscape Restoration

Habitat degradation creates carbon emissions and reduces ecosystem resilience, but restoring nature offers one of the best opportunities to mitigate and adapt to climate change (POSTNote 617).[482] Nature Based Solutions (NBS) is a framework for addressing the biodiversity and climate crisis in an integrated way.[483] The IUCN defines NBS as "actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits".[6,483]

In March 2020, the Government announced a £640m Nature Climate fund to restore peatland and plant trees. But two thirds of the carbon stored in the natural environment currently lies in land outside of protected sites suggesting challenges for mapping, protecting and restoring of ecosystems for aligning with the national Nature Recovery Network.[484] Joining together NBS and the ecological network in planning, through ELM and other local and national strategies, could help avoid conflicts and promote synergies in funding sources, partnerships and delivery (Principle 1 Shared Visions).[385] The nature recovery network will help both wildlife and society adapt to the effects of a changing climate, like increased rainfall, flooding and drought, hotter temperatures.[196]

The Committee on Climate Change has set targets under the 6th Carbon budget for restoring degraded peatlands to meet the UK's net zero targets. Evidence from Natural England's five Peatland Restoration Pilots suggests the term 'public goods' for peatlands may not connect with land managers. Instead, the pilots recommended policies should be framed in a way that connects with the identity, beliefs and immediate concerns of the land managers.[423] The messages must work with values and norms and support innovative land business practices. Financial incentives for peatland restoration need to sufficiently align with farmers identities and sense of business practice (Principle 3 Negotiation and Equity; Principle 4 Adaptive co-management).[423] Like the delivery of other conservation benefits, NBS projects should include stakeholders in co-design processes, understanding co-benefits and be sensitive to time frames which lead to increased costs in the short-term.[24]

- The British Ecological Society's Nature Based Solutions for Climate Change[91] in the UK report concluded that:
- Implementing NBS will require a multi-stakeholder governance framework that ensures integration and coordination across all relevant spatial and temporal scales, combining public and private sector inputs.
- NBS need to be integrated within wider policies across local and national government bodies and other key organizations.
- The need to develop and maintain the evidence base to inform a strategic spatial planning approach to NBS.
- Embed spatial planning which protects existing habitat networks and other high value natural capital assets.
- Stakeholder participation, collaborative action and the community voice are vital in planning NBS to equitably meet multiple needs.
- There is a need to support, develop and test approaches for designing NBS at landscape scale, taking into account trade-offs between different benefits. While approaches are emerging, there is a need to ensure these can assess the benefits and trade-offs for a range of intervention types.
- The multi-stakeholder governance framework needs to incorporate carefully designed monitoring systems, with a strong foundation of baseline data, in order to determine if the ambitions of the project are being met. This will require the inclusion of biodiversity and carbon, as well as human wellbeing metrics.
- An effective NBS assessment framework is required that enables transparent assessments at multiple spatial scales and can be utilised by all key stakeholders. It needs to be able to account for the multiple benefits of the NBS initiative for both nature and climate over time, in line with defined objectives, standards, criteria and metrics.

Delivering net zero

In the UK in 2016, total emissions were 467.9 Mt CO_2e, with agriculture accounting for 10% (POSTnote 600). Agricultural emissions are dominated by methane and nitrous oxide (57% and 32% of agricultural emissions respectively).[485] Broadly speaking, methane (CH_4) emissions are primarily derived from livestock farming (POSTnote 453), while Nitrous oxide (NO_3) is derived mainly from fertiliser use in arable farming (POSTnote 486). The Countryside Stewardship agri-environment scheme contributes an estimated emission saving of 1.1Mt CO_2e each year by working with land mangers on their holdings to deliver a range of options that benefit biodiversity and soil protection. [486] However, the UK agricultural sector is not on track to deliver a reduction of 3 Mt CO_2e in England by 2022, agreed under the CCC's carbon budget.[479] The CCC recommends three areas of policy to support land use and management changes:

- regulation;
- funding measures to incentivise further action;
- enabling frameworks to address non-monetary barriers.[479]

Regulation

Voluntary schemes have so far failed to deliver the rate of decarbonisation required to cut agricultural emissions in line with the CCC's recommendations.[487] The CCC recommends a stronger regulatory baseline accompanied with stronger enforcement to ensure compliance with land management goals for net zero,[447] which would include:

- New legislation under the Clean Air Strategy and existing regulation through the Nitrates directive to set standards for emission reductions.
- Banning peat and rotational burning (the Government announced a partial ban on peat burning in protected areas in England in January 2021).[488]
- Legal requirements for utility companies that own peatland within their estates, or other land owners with peatland as part of a SSSI to restore it in line with recommendations for net zero.[447]

The Green Alliance recommends additional standards, which the government should progressively increase over time.

- Legal requirements to improve soil management, which are to be included under the sustainable farming incentive. [489] This would include maintaining soil cover, limiting soil erosion, maintaining the level of organic matter in the soil. [490] They also suggest the decarbonisation of farming should be central objective of the ELMS. [487]
- Mandate nutrient management plans for arable farmers to ensure optimal fertiliser use and better use of organic residues. [487]

Funding for actions above the baseline

The CCC recommends funding actions above the regulatory baseline to support more costly measures:

- Carbon and other ecosystem service markets for forest planting
- Public money for non-carbon benefits of forests.
- Public funding for low carbon farming
- Public funding for peatland restoration.[446]

Changing management practices or land use can incur additional costs that reduce farm income. Participating in new ecosystem or carbon markets may also entail high transaction costs.[491] In the long-term, however farm businesses may benefit through improved private investment natural capital markets. [492]

Enabling frameworks

Other challenges to climate friendly land management include lack of skills or knowledge, data, monitoring, the invisible nature of carbon sequestration, financing and subsidising and the difficulty of coordinating with multiple-landowners. [493]

Markets and Taxes

There are actions that Government can take to informing consumer choices and a stronger business case for the changes required for decarbonising land use. Commentators have highlighted a range of options including:

- Establishing a cross departmental strategy for dietary change and to promote the consumption of less and better meat, and an increase in plant-based food.[212]
- Ensure supply chains drive local and low carbon food production.[494]
- Align trade policy with domestic land use policy to ensure the highest environmental standards and reward farmers and land managers who invest in low carbon solutions. [495]
- Support the scaling up of capacity for the domestic forestry supply chain from nurseries to sawmills and wood processors (POSTnote 636).
- Requirements for low carbon building using timber material (POSTnote 636)[495] in combination with bioenergy and carbon capture and storage (BECCS) infrastructure (POSTnote 618).
- Review contract issues with tenanted farms or common land.
- Tax review of woodland, and helping a conversion of land to forestry (CCC 2020).

Global trade in agricultural commodities, the pressures and costs on food processors and the prices food retailers are willing to pay farmers for their products affects what changes farmers are able or willing to make in their management practices.[401] This has led to perceptions among farmers they cannot be 'green' if they are in the 'red', highlighting the challenges of creating an enabling market framework and fair prices for producing sustainable and climate friendly food and other ecosystem services .[401] This would involve understanding and addressing the systemic drivers of farming and land management practices (Principle 1 Shared Visions).[26,346,496]

Aligning Stakeholders and Policies

Managing land for climate mitigation will involve hundreds of decisions by different actors: farmers, government, banks, land agents, industry and the public; which will need to interact to deliver significant emissions reduction in land (Principle 4 Adaptive co-management). Their behaviour and interaction can be understood through approaches such as agent based modelling, and reviewing the actions of actors regularly as new evidence of 'learning by doing' emerges can support adaptive management.[446] Agent based models identify patterns in data to analyse large quantities of data and identify complex patterns or relationships. Research suggests that agent based models may provide an efficient pathway to integrating these hundreds of decisions into a workable format. [497–500]

The National Farmers Union have called for net zero policies for land to be supported by cross departmental policies such as the Clean Growth Strategy, the Industrial Strategy and the Clean Air Strategy and Defra's Farm Emissions Reduction Plan, the Peatland Strategy, England's Tree Strategy and the 25 YEP. [501]

Knowledge and Capacity

Sustainable farming practices require extensive knowledge to implement effectively in different contexts and farmers will need support to develop new skills and capacities,[502] such as advisory and extension services. [503]

The CCC recommends public support for training, and market commercialisation of low carbon farming as well as awareness raising and training (Principle 9 Changing research, evidence and knowledge transfer). While farmers often have technical understandings they might lack of in-depth knowledge of complex practices, like evaluating better use of nutrients and changes in cultivation practices for restoration and management of lowland peat. [503] This may require advisors and extension services providing specialised climate knowledge, capacity to shaping farmer learning and business support to account for trade-offs and synergies of multifunctional land demands (Principle 2 Bridging Institutions). In general, farmers are more inclined to adopt mitigation practices that can be proven to be effective and could allow greater money saving. [504] The lack of publicly-funded extension services in the UK reduces coverage of holistic low carbon farming advice. Instead there is a focus on private siloed advice for different elements of farming.[505–507]

Cultural capital also affects how farmers perceive their role in climate mitigation, especially if this has been traditionally to produce food as a business (see: Principles in Practice: Cultural and Heritage Landscapes).[508] For example, social capital, such as strong networks, peer relations, community trust and power influence farmer's capacities to engage in sustainable soil farming.[509] Evidence suggests participatory extension services, networks based on voluntary collectives between farmers, researchers and rural experts, are effective for supporting changes towards climate friendly management.[156,278,510] For instance, Farming for a Better Climate was initiated in 2010 by the Scottish Government and involved a series of focus farmers to share and try out new practices within a platform across different actors.[511] The NFU proposes that farmers should develop strong understanding of proxy indicators of changed management practices that are likely to increase carbon storage, which could be coupled to models that are supported by actual field testing on a network of 'climate friendly' demonstration farms.[511]

Spatial Modelling

Spatial planning that combines food production, biodiversity and emissions accounting can be used to allocate climate measures like woodland creation in optimal locations (POSTnote 636). Spatial mapping could support ELMs for the delivery of climate friendly farming alongside other public goods. [495] Spatial planning could also be used more widely to align climate change mitigation, other environmental benefits and avoid negative impacts on existing ecosystems for net zero. For example, priority areas for woodland creation and ecosystem restoration could form part of the Nature Recovery Network or of an expanded set of Forestry Investment Zones, while being consistent with biodiversity objectives (see: Principles in Practice: Biodiversity, Ecosystems and the Nature Recovery Network). [512] Appropriate spatial mapping would also help avoid the negative effects of damaging carbon storage of peatland habitats associated with wind turbines and windfarms infrastructure, which are often optimally located in upland areas where peatlands are widespread. [513]

Combining national spatial strategies with local, bottom-up consideration of possible interventions would provide a tool for democratic engagement and decision making (Principle 8 Joining up Governance: Policies, Markets and Regulation). Maps can also be useful ways to communicate information between stakeholders at farm or landscape level. For instance, local engagement processes that use farmers' knowledge can enhance understanding spatial opportunities for high carbon soil storage and barriers to success.[514,513] Combining national spatial strategies with local, bottom-up consideration of possible interventions would provide a tool for democratic engagement and decision making. Maps can also be useful ways to communicate information between stakeholders at farm or landscape level. For instance, local engagement processes that use farmers'

knowledge can enhance understanding spatial opportunities for high carbon soil storage and barriers to success [514]

Spatial planning can help optimise benefit provision and manage trade-offs, since intervention success varies according to geographic differences in climate, soil, or the way the practice is adopted (Principle 7 Spatial Planning). [491] For example, it could also help avoid 'leakage' of effects where changes to land use in one place create undesirable effects or in another location, such as downstream flooding. Converting farmland to forest or bioenergy that displaces food production could lead to further intensification of farming practices elsewhere.[449] An example includes the project 'Tree Suitability Modelling – Planting Opportunities for Sessile Oak and Sitka Spruce in Wales in a Changing Climate'. The study showed that by combining detailed soil, topography data and climate projections while accounting for other land constraints, it may become possible to locate areas most suitable for the measures in the CCC scenarios and produce detailed maps of them.

Decision Support Tools and Monitoring

Many tools have been developed to assess sustainability performance at farm level that can help assess the impacts of changes, but tools vary considerably in terms of their usefulness.[515] For example, IMPACCT, which stands for "Integrated Management oPtions for Agricultural Climate Change miTigation" was developed for the European Commission and combines climate mitigation with economic and other environmental impacts for a holistic and integrated perspective.[515] A variety of tools and data is also available to help planners optimise decision making (e.g. the Sustainable Intensification Research Platform (SIP), the Outdoor recreation valuation tool (OrVAL) and the Natural Environment Valuation Online tool (NEVO).

If land management is to contribute to mitigation of climate change, the carbon storage potentials of soils and vegetation have to be taken into account and impacts of different management on carbon sequestration rate and total storage capacity should be known.[151] For example, supporting decisions on soil carbon management requires an improved understanding of the spatial variation in SOC stocks and how these interact with carbon stored in trees and plants (Principle 9 Changing research, evidence and knowledge transfer).[462] Technology like aerial photography and remote sensing can also be used to monitor activities as well as soils and vegetation patterns to predict the changes in carbon stocks (POSTnote 628).[516,517]

Where local decisions take account of the suitability of land for different uses now and in the future, a framework that captures these changes in practices could boost farmer confidence.[509,518] For example, the Sustainable Farming Trust have proposed a single integrated measure such as a 'sustainability metric' to capture a range of agronomic and environmental factors, which is supported by the NFU (Principle 2 Bridging Institutions).

PRINCIPLES IN PRACTICE: CULTURAL AND HERITAGE LANDSCAPES

In addition to the previously covered "environmentally-focused" outcomes from landscape use in England, the Agriculture Act 2020 provisions support including powers to provide financial assistance supporting "public access to and enjoyment of the countryside, farmland or woodland and better understanding of the environment". The objectives of these provisions were previously set out in the 25 Year Environment Plan. [519] The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experience have been broadly classed into the frameworks of "cultural and heritage ecosystem services" (CES)[520] or by the IPBES as "nature's contributions to people (NCP)" [61] (see Defining 'sustainability' in the context of land management). (Hereafter CES refers to both frameworks).

Examples of cultural ecosystem services are: appreciation of natural scenery; opportunities for tourism and recreational activities; inspiration for culture, art and design; sense of place and belonging; spiritual and religious inspiration; education and science.[521]

Understanding how cultural landscapes might change under alternative futures is important for identifying where to target actions towards persistence of cultural landscapes.[522] Cultural landscapes are valued for their landscape character and cultural heritage, for example the upland hay meadows in the North Pennine Dales;[523] examples like these: often low-intensity, multifunctional landscapes, are at risk of disappearance.

Despite their importance, CES have received less attention in ecosystem services research than other common categories such as provisioning or regulating ES but are equally important and diverse (Principle 1 Shared Visions). [524] Rural cultural landscapes are particularly threatened by abandonment and urbanisation. [525] These threats to cultural landscapes and dependence on societal demands may complicate the design of measures targeted at maintaining and strengthening cultural landscapes. Threats to cultural landscapes are also related to the interaction between social and-economic conditions and implementation of government policies. [522] Appreciation of CES can be classified into direct "outdoor recreation" and remote "through the window".

Outdoor recreation

Outdoor activities span from having a walk in the closest green urban area, to a short bike ride in a local nature park, to a day trip with the sole purpose to experience nature.[526] Based on public survey data, factors affecting accessibility and value of ecosystems for outdoor recreation include:

- Ecosystem function, with higher weightings towards more "natural" and high biodiversity ecosystems, such as rivers or forests.[527]
- Accessibility: for the ecosystem service benefits to be realised, recreation sites should be accessible to the greatest number of people possible, infrastructure (i.e. public transport, cycling networks) is needed to make sites accessible.
- Community culture, home environment, age, social status. [528]

Public surveys across England, highlight that on average the distance people are willing to travel for outdoor recreation is relatively short (approx. 8 km), though they are keen on travelling longer distances to reach more natural habitats. On average a visit to the natural environment lasted for just under 2 hours.[529] Specific habitat types also exert greater attractiveness (water, grassland and forest sites), whereas arable land is not recorded as being particularly attractive for recreation.[528]

- 19% of visits were to sites close to water (river, lake, canal, beach, coastline);
- 14% to path, cycleway, bridleway;
- 13% to forest;
- 3% to mountain, hill, and moorland.[529]

CES related to local practices, have substantive material aspects, such as gathering of wild products.[530]

Public access to rural land and nature is highly valued.[531] The value of urban green spaces for stress reduction and impact on quality of life is a very active research area[532,533] as well as a developing policy area.[382,534] Increasing public usage to land has been reported by the Ordnance Survey has growing across the United Kingdom, primarily in the South Downs and New Forest.[535]

For measurable "quality of life" improvements, facilitating contact with nature, not only public green areas, but also private green areas, such as domestic gardens or small elements such as street trees are important.[536]

Urban green spaces may contribute to physical health and mental well-being (POSTnote 538) [527,537], through buffering noise pollution [538], improving air quality[539] and collectively improving psychological well-being.[540] Numerous observational studies support the idea that having access to a garden or shared green space has positive effects on mental health.[541,542] Viewing nature through a window, [543] living in environments with a high percentage of green space[544] and having access to nearby green areas and parks [545] have been positively associated with health aspects. However, relatively little attention has been paid to how the choice of outdoor space affects the relationship with health . [536]

Cultural agricultural landscapes

The cultural importance of traditional agriculture landscapes has been widely recognized in Europe and the world. As of 2018, 87 of the 1,121 UNESCO world heritage sites are in the "cultural landscapes" category, and 32 of those because of traditional or symbolical agricultural practices. [108] Examples include the Mont Perdu in the Pyrenees or the Lake District National Park in North England. As much as 15 to 25% of the European farmland can be classified as High Nature Value farmland. [546] Of the 231 habitat types listed in the European Habitats Directive, 41 are associated with low-intensity agricultural management, including semi-natural grasslands and hay meadows. [547] Several AONBs in England occur on High Nature Value Farmland (i.e. the North Pennines AONB), emphasising the cultural value of such landscapes. Many protected landscapes in the UK include a high proportion of the country's High Nature Value Farmland (for example, traditional hay meadows in the North Pennines Area of Outstanding Natural Beauty), demonstrating the cultural heritage value of such landscapes.

Common land is an excellent example of cultural and heritage rich landscapes. Common Land, although only 3% of England, is critical to the delivery of public goods. For instance, 21% of England's SSSI area is registered common land and 12% of all Scheduled Ancient Monuments are on common land. Commons are critical for Open Access with 39% of all such land common land and 82% of common land is in National Parks. The collaborative pastoral grazing system and its biocultural processes, the future are a living example of cultural landscapes.[548]

CES motivates management

There is evidence that CES motivates use, managing, or protecting land, and often for amenity-related purposes. [549] For example, the growth of private and public nature reserves, tourism facilities, second homes, hobby farms, and residential homes in the countryside can all be understood as land uses stimulated by CES. [550]

Figure 7. Cultural ecosystem services and their influence on landowner decision-making, community engagement, and landscape planning. [31]

Understanding culture and heritage

As they are difficult to quantify, qualitative research plays a stronger role in studying CES than in the assessment of other ecosystem services.[524] CES's are generally enjoyed in bundles and can typically be captured through social-cultural valuation techniques.[530] A central assumption of the concept is that human well-being depends on CES, and that assessment and acknowledgement of these services will lead to more sustainable management of ecosystems.[551] Most existing valuation models are poorly equipped for quantifying CES. Their intangible nature, lack of suitability or appropriateness for monetisation, and the limited collaboration between ecologists and social scientists other than economists have limited the opportunities for cultural services to inform decision making.[552,553]

As a result, the current framing of CES has been criticised for separating humans and nature, and much like criticisms of the ecosystem services model, being an oversimplification (see Defining 'sustainability' in the context of land management).[87,552] Typically, all natural environments have been considered generically and aggregated into a measure of so-called 'green space' or 'green infrastructure' without further qualification as to type or quality.[554] For example, green space research has often effectively classified aquatic (blue space) environments, such as rivers, lakes and the coast, as a form of green space.[555] While it can be challenging to disentangle the benefits of blue and green spaces, it is now recognised that they have their own set of risks and benefits for human health and well-being,[556] with the term blue-green infrastructure now used in policy.[557]

IMPLEMENTING SUSTAINABLE LAND MANAGEMENT IN ENGLAND

In 2006, Natural England published a policy discussion document "Strategy for Sustainable Land Management (SLM) in England".[558] The UK Government has since published the 25 Year Environment Plan in 2018 with policies for the use and management of landscapes sustainably. [171]

Though the concept of SLM has existed for many years, first appearing in the Brundtland Report, published in 1988, [46] the complexity of SLM and the requirement for a non-sectoral approach to land management has been a constraint to its implementation in developed countries. Though the Welsh Government have adopted SLM as a central framework for restoring countryside economy.[12]

Policies affecting land uses in England are developed by different government departments in isolation without engaging at a localised scale. This fragmentation has created challenges for executive agencies, local authorities and NGOs at the local level.

As defined in chapter 2, SLM is predicated on 10 key principles. Although the basic principles of SLM are not complex when considering each in turn, implementing SLM in accordance with each of the ten principles together may be needed to address the diverse land use pressures currently facing England. [88]

Collective and sustained action to transform the centralised systems that underpin our engagement with landscapes could contribute to halting ongoing destructive activities (such as changes to financial incentives and government policies).[15] However, the principles of SLM also require working with, understanding and exploiting local knowledge systems, forming an adaptive network and building a system of collectivised knowledge to implement sustainable land use.

Research over the past 50 years has clearly shown that the environmental outcomes of land management actions (such as tree planting, natural flood management, farming subsidisation) are always multifaceted and often location-specific, resulting in trade-offs between different benefits and objectives.

SLM can provide a framework for both integrating different objectives to minimise trade-offs and to negotiate trade-offs at different administrative and geographical scales. Negotiation and institutional capacity for managing trade-offs are important to defining ideas of success and failure in a multiple-stakeholder context, where "someone's gain is someone else's loss".[94] The nature of these trade-offs means SLM also would need to find a way to prioritise different stakeholder perspectives, ensuring a sense of local-ownership and equity; for example, within systems of polycentric governance.[19] Partnerships bring together otherwise diverse interest groups who agree to work together to solve problems that are of common concern and that cannot readily be resolved individually without incurring conflict.[64] These changes may only happen in the "real-world" if we engage with the land managers whom we are asking to make these changes.

SLM seeks to integrate nature restoration with other benefits produced by landscapes (food, water, climate, biodiversity and heritage), while allowing consideration of historical and cultural factors that have shaped and continue to shape our land. Without adopting a multifunctional landscape approach, evidence suggests it will be challenging to catalyse the necessary transformative change to avoid the predictions made in the Dasgupta review.[15]

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