Sustainable, healthy, and resilient: Practice-based approaches to land and soil management

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Contents

IES ▶ REPORT Practice-based approaches to land and soil management

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Executive summary

The difference between a world which cares for its soil and one which neglects it is colossal. Currently, inaction is increasing the risk of climate change, food insecurity, flooding, biodiversity loss, and the collapse of the natural systems on which we rely. The benefits of healthy soil are poorly understood, yet play a key role in many areas of our lives. Decisive policy intervention could create a positive future: one where we have a sustainable climate, healthy food, and resilient communities.

Soil and land which is sustainable, healthy, and resilient can store more carbon to offset changing climates. Soil can improve the yields and nutritional content of our food. Soil can hold more water to manage the risk of flooding. Soil can support many biological processes, including habitats and ecosystems. It can quite literally become the ground on which our economic, social, and environmental wellbeing is built.

This report consolidates knowledge from the environmental sciences on the interactions between land management and soil resources, both from a natural capital perspective, and in terms of the range of benefits which can be achieved by approaching land and soil as an integrated system with consequences for the whole environment. The aim of the report is to share that consolidated knowledge with policymakers and decision-makers.

The report goes on to explore potential solutions. The first concerns how to measure and address the health and quality of soils, without needing to make difficult and subjective decisions about which properties of soil are more or less valuable, across multiple contexts and functions.

The other recommendations form the basis of different approaches to translate those measurements into policy and decision-making. The significance associated with healthy soil and an area of land will be contextual and interactive with other societal and financial constraints. It is therefore crucial that the wider benefits of good practice are understood, rewarded, and spread.

This has immediate consequences for Government target setting, where a long-term target on soil health would be made immediately realistic by this approach to assessments. The same system could also be used for regulation, oversight, or forming the basis of payment of 'Public Money for Public Goods', ELMS, and other CAP successor systems. Sustainable finance and agro-ecology present opportunities for private actors to improve and measure sustainability, keeping ahead of Government policy changes.

One approach takes a lesson from experiences of land contamination, where land purchase relies on assessing for contaminants. Requiring a direct assessment of the overall health of soil before land purchase would provide the basis of a system which values the inherent benefits of land and soil, removing short-term incentives and giving direct financial value to historically undervalued aspects of soil.

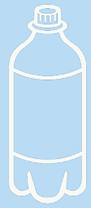
The challenges linked to soil are likely to affect all of society in the very immediate future. The answers to those challenges can only be found by better management of soil that improves its sustainability, health, and resilience.

Summary of recommendations

1. We must take a holistic view of soil and land as an integrated system with consequences for the whole environment, working at the same scales that nature works on, with a goal of promoting soil which is sustainable, healthy, and resilient.

2. We must recognise the nexus of crises we are facing – climate change, biodiversity loss, soil depletion, and others – and how our management of land and soil could provide solutions.

3. We must ensure research is supported to drive awareness of emerging issues, such as the effects of microplastics on land, soil, and human wellbeing, avoiding new crises developing.



4. Assessments of soil for policy purposes would be made more successful by taking a practice-based approach, using an evidence-based list of supported practices and local risk registers.

5. Assessments should be used as the basis of a long-term governmental target for more widespread adoption of appropriate management practices for soil resources, aligning with current UK governmental policy approaches in other areas.

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6. ELMS, 'Public Money for Public Goods', and equivalent systems in the devolved administrations must go beyond the CAP to provide clarity for farmers, rewarding sustainable management of land and soil, while providing a platform to showcase best practice for peer-to-peer learning.

7. One approach would use assessments as the basis of an 'OFSTED for soil' approach, using oversight or regulation to ensure widespread compliance with basic standards of practice in how land and soil are managed.

8. Another approach would use assessments as a required part of the process of land sale, removing short-term incentives associated with re-selling land for commercial gain, and ensuring long-term land sustainability is rewarded for both landowners and tenant farmers.

9. Sustainable finance and agro-ecological approaches provide effective means for businesses and land managers to improve their practices in the short-term, staying ahead of government regulation and gaining a competitive advantage by increasing sustainability.

10. In devolved administrations and other countries, though the policy landscape may differ, Governments should still adopt the aspirations for soil set out in this report, and would also benefit from specific policies, such as the report's system for assessing soil health holistically, which applies across contexts.

Background to the report

The Institution of Environmental Sciences (IES) is a membership organisation that represents professionals from fields as diverse as air quality, climate, land contamination, water, waste, ecology, and education. The organisation leads debate, dissemination, and promotion of environmental science and sustainability, and supports an evidence-based approach to decision and policy making. The Institution stands up for science, scientists, and the natural world.

"Everybody ... needs to live with the consequences of poor management of soil and land. Everyone has a personal stake in their food, their community, and their climate"

Most importantly, the IES is an interdisciplinary organisation, representing specialisms from across the environmental sciences, so the IES has a unique ability to identify trends and bring together the best evidence from across the scientific community. Soil, and the land it is part of, have begun to rise on the scientific agenda, though more needs to be done to raise them on the policy agenda. Change has been incremental and atomistic, rather than systematic and transformative.

With high stakes and strong scientific backing for action, the IES has consolidated the work of the sector to help support the level of change needed to revitalise the UK's approach to land and soil. This report brings together expert knowledge from across disciplines, draws on progress already made, and identifies where best practice can be used to find solutions which work across urban, agricultural, and other land management contexts.

An interdisciplinary view reveals a simple but important truth: land, soil, and the risks attached to them are problems for everyone. Land managers, farmers, and ecologists all have special interests in the land, but everybody in society needs to live with the consequences of poor management of soil and land. Everyone has a personal stake in their food, their community, and their climate, so a positive way forward for land and soil has the potential to help all corners of society.

The report was developed as part of a process which incorporated the best available evidence from a range of existing reports, articles, and publications from across the environmental sciences, government, and international organisations. This evidence was considered in discussion with a working group of expert members, and IES members were consulted.

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Policy context

Understanding

Our understanding of the natural environment has never been greater, but neither has the level of challenge we face. In an environmental policy context with many urgent and complex threats to our lives and livelihoods, we increasingly need approaches which can address multiple issues simultaneously.

Our collective understanding of how soil is interconnected with all natural systems has developed considerably over successive decades. Soil plays a crucial role in buffering other natural systems, and its health has direct or indirect consequences across the environment. However, whereas public understanding of climate and ecology has expanded massively, the same appreciation of land and soil has yet to become mainstream, and we are yet to see decisive policy action to make the most of land and soil.

Current issues

UK policy-making is also in a unique position of strain and opportunity. Following the UK's exit from the European Union, the Government has rightly acknowledged the importance of good land management in its 25 Year Environmental Plan, Environment Bill, and Agriculture Bill. These set out a framework under which environmental considerations need to be made going forwards, including how we manage land and soil resources. Furthermore, COVID-19 has given us cause to reflect and reconsider the future of food security, land use, and soil. These changes provide a window of opportunity, during which the creation of a positive and sustainable vision for the future of UK land is a real possibility.

Government policy and business practices in the UK do not yet fully represent the interconnected benefits or opportunities which can flow from our management of land and its constituent soil. The risks are not abstract: degradation of soil has been taking place for a long time without proper recognition, and the cross-cutting role soil plays has impacts on human life which should be better recognised by the way we value soil resources, and the way our policy seeks to address them.

Most importantly, we must take proactive steps to address issues from the ground up, starting with soil. Policy for air and water quality has begun to recognise that we must address these issues at the source, and that multiple stakeholders need to be involved in making solutions effective. The same approach must now be taken to the problems associated with land and soil.

Past solutions have worked downstream to respond to flooding, obesity, and climate change, but future solutions must better address their causes if our goal is long-term sustainability.

Goal 1: Creating an aspiration for soil

Our first goal is to resolve the historic question of what 'healthy soil' should look like, with a view to supporting beneficial policy outcomes which do not displace risks onto other natural systems which are unable to cope with them. In order to do so we have consolidated definitions and perspectives from across the environmental sciences.

Whenever we interact with the natural world, we must work at the same scales which nature works on, taking a holistic view of soil and land as an integrated system with consequences for the whole environment. For the purposes of our aspiration of promoting and maintaining soil that is sustainable, healthy, and resilient, the IES has produced definitions of these three key characteristics:

Sustainable soil is soil which can be reliably sustained for future generations. To achieve this, the ways in which we use soil should themselves be sustainable; they should allow for the maintenance of ecological balance, and should not directly or indirectly cause unsustainable outcomes elsewhere. The burden of risk should not be unduly shifted to other aspects of the biosphere which lack the capacity to sustainably absorb that risk.

Healthy soil is soil which possesses the salient qualities and properties needed to allow it to remain functional and viable. This should be understood in the context that soil has inherent value, even when it is not being actively utilised by humans as a natural resource, and that the protection of soil is itself a desirable outcome.

Resilient soil is soil which has been safeguarded against all potential risks and dangers, in terms of both soil erosion and the wider causes of degradation. These risks should be addressed across multiple potential purposes for any given soil, in line with the precautionary principle and the way that land use may change over time.

Our aspiration has a clear tripartite goal: we should address the way we use soil, we should address the soil itself, and we should address the risks and opportunities associated with soil. **Box 1** works through some applications of this approach.

Box 1. Goal 1 in practice.

Flood risk
Where use of soils leads to an increase in flood risk which would not be able to be managed, that risk would be an unsustainable outcome of our management of soils and the land they are part of, so it would not be 'sustainable'. Where soil lacks the porosity to effectively store water, it would have lost that function and its viability as a means of addressing flooding, so it would not be 'healthy'. Where soil has not been sufficiently protected from water erosion or levels of compaction that might increase flood risk, it would no longer be 'resilient' to those risk factors.

Ecology
Where soil is sealed as a result of infrastructure development on land, there are consequences for the potential to create functioning ecosystems, and an approach to land use which seals, erodes, or contaminates too much soil in a given area would not be 'sustainable' in terms of the need for ecosystems and their services. Where soil loses biota and micro-organisms as a result of contamination or intensive practices, it would lack the salient qualities needed to buffer other systems or cycle nutrients effectively, so it would no longer be 'healthy'. Where soil has been contaminated by pollutants, it may no longer be able to serve as a habitat or functioning ecosystem, meaning it would no longer be able to be 'resilient' to the changing needs of the land and risks of collapse across the wider ecosystem.

Agriculture
Where intensive farming techniques are used, such as heavy machinery which compacts soil, the soil is increasingly put at risk of degradation and erosion, meaning that these techniques cannot be considered 'sustainable' in the long-term. Reductions in nutrients and organic matter over time also remove the salient qualities needed for the soil to be considered 'healthy'. These processes leave behind soil which lacks porosity and so cannot store as much water or carbon, increasing its risk to run-off and reducing its adaptability to changing land use. In this case, the soil would no longer be 'resilient'.

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Goal 2: Stopping immediate crises linked to soil

While our first goal set out the ideal for what our soil resources should look like, our second goal confronts the less than ideal reality of the challenge ahead.

In order to make progress for land and soil, we first need to recognise the immediate crises we are facing, the role that human treatment of soil plays in causing those crises, and the role it could play in providing solutions.

"Without action, we face clear and serious socio-economic consequences. Mitigating negative outcomes downstream is not enough."

There is some public awareness of environmental crises, particularly those relating to changing climate and ecology, though there is still only limited understanding of the ways that these crises are caused, buffered, or mitigated by natural systems. There are also crises which have not historically been viewed as environmental, but where land and soil have a crucial role to play in finding solutions, such as obesity which is linked to the provision of healthy and affordable food.

In addition to the climate crisis and the ecological crises linked to biodiversity loss, we need to find solutions to challenges such as flood risk, soil loss via erosion, loss of resilience in natural systems, and the sustainability of our food security.

These issues warrant direct interventions at the source of the problem. Without action, we face clear and serious socio-economic consequences. Mitigating negative outcomes downstream is not enough. We have rightly begun to address the harms of poor management of air and water at the source, and the same approach must be taken for land and soil.

As we become aware of other urgent and emerging issues, we should ensure that sufficient research is available to determine the full extent of their effects on land and soil. One example is microplastics, their long-term presence in natural systems, and the consequences they might have for the contamination of land and soil, as well as food and human health. This may have been exacerbated by the transfer of plastics into food waste recycling systems, and eventually into agricultural compost. Research into such issues should be prioritised to prevent new crises emerging while we continue to grapple with existing ones.

The next section outlines how these crises are inextricably linked to our management of soil resources, and how an approach to land which produces sustainable, healthy, and resilient soil would help us to mitigate and overcome them.

What can soil do for us?

Over the past two decades, there has been an increasing recognition that many of the environmental resources we take for granted are capable of providing massive benefits for human health and livelihoods. Despite this, soil still remains a vastly underappreciated and undervalued resource. In order to appropriately manage land and its interactions with soil resources, we must begin to recognise the full set of opportunities and risks which are associated with land, soil, and the ways in which human activity interacts with them. **Figure 1** below shows the full range of functions and benefits which are associated with soil in the UK.

Providing healthy and sustainable food

Soil has a crucial role in producing food. Around 95% of global food production relies on soil, and soil plays an especially important role in producing food which is sustainable, nutritious, and affordable.[1,2,3] As food security and access to food become increasingly important considerations, soil has the potential to provide a consistent domestic supply of food which is sustainable, healthy, and reliable.[4,5,6] Soil also plays an important role in the production of other resources, including plant-based products and biological materials with significant industrial and medical applications.[7]

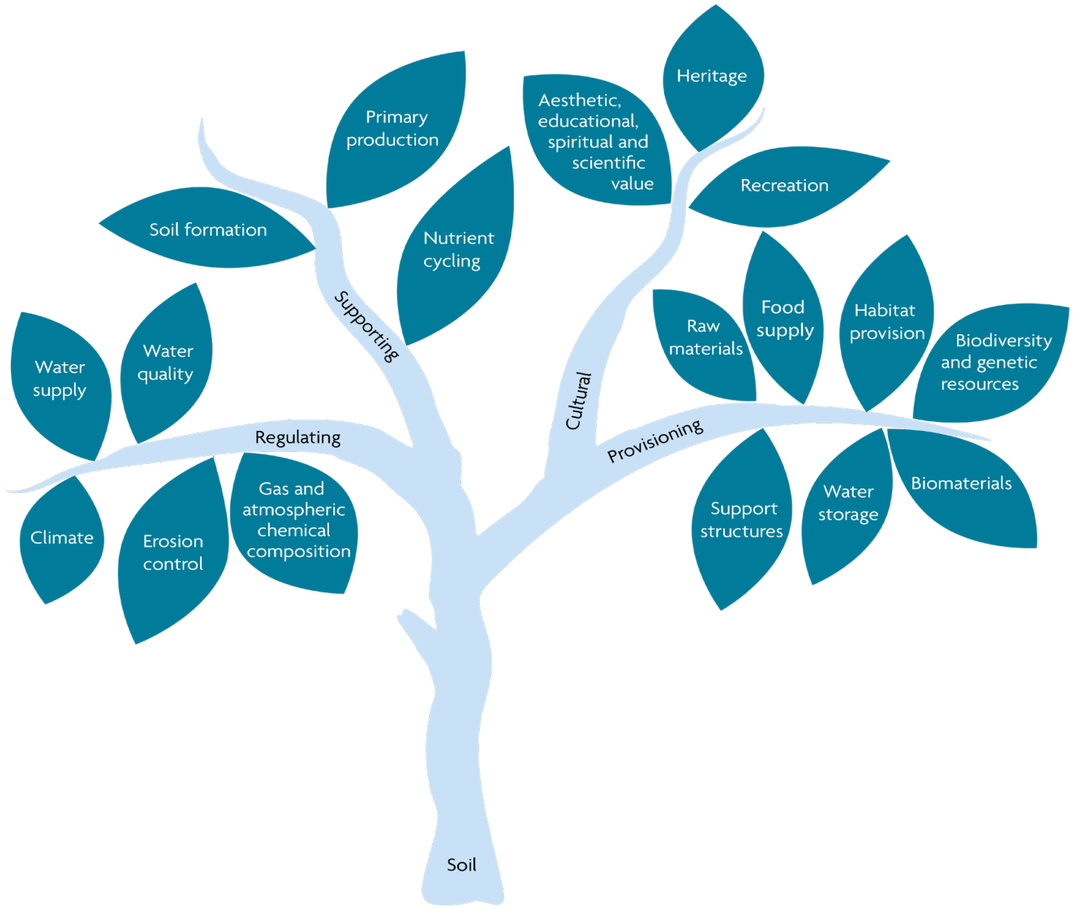

Figure 1: Visual representation of ecosystem services and functions associated with UK land and soil. Adapted from Haygarth, P.M., and Ritz, K. (2009). *The future of soils and land use in the UK: Soil systems for the provision of land-based ecosystem services.* Land Use Policy. 26S. S187-S197. DOI: 10.1016/j.landusepol.2009.09.016

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Mitigating and defending against floods

Flood risk management is becoming increasingly important in our interactions with the environment.[8] Soil has the potential to reduce flood risk, while mitigating the extent of flooding which does occur.[9,10] Healthy soil can store greater amounts of water, reducing peak flows and the risk of flooding to downstream communities.[11,12] This water storage function plays a key role in managing the risk of flooding. Agricultural run-off has been associated with increasing flood risk by 14%, with soil erosion and degradation directly linked to a 7% increase in the risk of flooding.[13]

Conversely, if soil is made more impermeable through compaction, or if it is sealed by infrastructure, water flows are more likely to lead to increased flood risk.[14] Soil also plays a role in regulating the quality of water through filtration and buffering, helping to mitigate the transfer of pollution.[15]

Carbon and climate

One of the most overlooked roles of soil is the storage and cycling of carbon, which has an enormous impact on global emissions and their effect on the climate.[7,12] **Figure 2** shows where carbon is currently stored in directly accessible natural systems, including the 1600 billion tonnes of carbon stored in soil. There is a fundamental opportunity to store carbon within organic matter in soil, dramatically displacing the burden of carbon storage from the atmosphere and hydrosphere which have a limited capacity to absorb it without creating unsustainable consequences for the climate and human health.[9,16]

Equally, when organic matter in soil is degraded, it can lead to significant amounts of carbon being released into the wider biosphere, including in the form of carbon emissions.[17] For example, peatland decomposition alone contributes to 5% of annual global carbon emissions, and peatlands also contribute more to carbon storage than all global forests combined.[18]

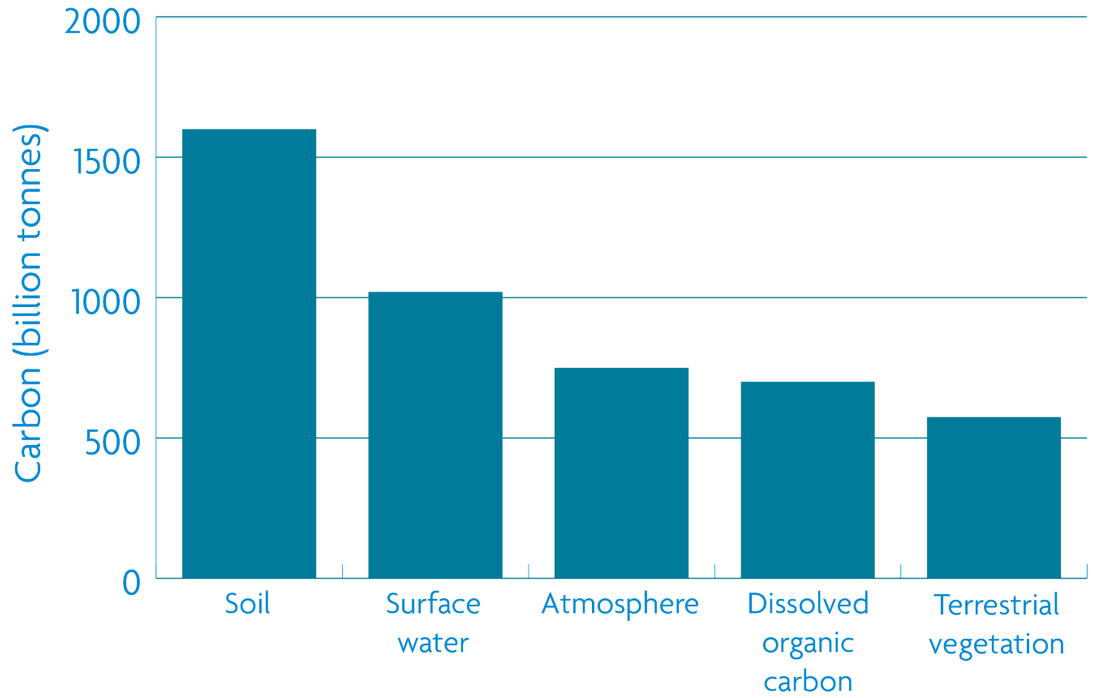

Figure 2: Chart of carbon storage in directly accessible natural systems (excludes carbon storage in coal, oil, and gas deposits, intermediate and deep water, marine sediments/sedimentary rocks, and surface sediments) in billions of tonnes of carbon. Based on 2009 figures. Adapted from Rekacewicz, P. (UN Environment Programme/GRID-Arendal). (2009). *The present carbon cycle: volumes and exchanges in billions of tonnes of carbon.* Available at: https://www.grida.no/resources/5390 (Accessed 9th September 2020).[19]

Soil manages nitrogen and phosphorus cycles, storing them as important nutrients for soil health, while preventing their release in forms such as nitrogen dioxide or ammonia which can have harmful effects on people and the planet.[4]

Ecosystems and biodiversity

Soil's role in providing ecosystem services, the contributions made by ecosystems to human wellbeing, is both direct and indirect. As well as the micro-organisms living within soil, the soil itself is fundamental to the sustainability of a wider system of ecosystems such as forests, which support biodiversity as well as providing benefits for humanity.[20,21,22] As we seek to combat biodiversity loss, we need to be mindful of the importance of soil to maintaining functional ecosystems.[23]

Whilst the range of services provided varies and covers a wide variety of benefits for human wellbeing, soil plays an especially important role in buffering other natural systems to protect them against risks, for example by processing and cycling nutrients which are vital for maintaining the conditions of life on Earth.[7,24]

Cultural benefits

There are wide-reaching cultural, social, and economic benefits to maintaining the quality of soil resources. Recreation often relies on soil, including eco-tourism and sport, both of which make substantial contributions to the economy.[7]

There are additional indirect benefits to culture from soil's role in buffering other natural systems such as filtration for water quality, with consequences for recreational fishing, open water swimming, and other water-based activities.[13] These are beneficial to human wellbeing, and also support a significant section of the UK's tourism and leisure economy. The natural landscapes provided by soil are also linked to heritage and provide aesthetic, educational, and spiritual value.[15]

Soil at risk: degradation

These benefits can be put at risk if soil is degraded, where the functions it provides can be significantly impaired through a number of processes. These have increased over time in the context of pressures on soil health from the food, forestry, textile, and biofuels industries, as well as the consequences of other human activity.[16,18]

Though soil can be degraded in a number of ways, there are a number of common issues associated with the degradation of soil:

- Soil can become sealed in by infrastructure, preventing it from performing any functions and increasing the likelihood of run-off, creating a greater risk of flooding and peak flows;[11]
- Soil can be compacted by heavy machinery and livestock, reducing the porosity of soil so that less water can be contained within. This leads to increased run-off, less capacity for water storage, and less room for plant roots to grow through the soil, directly affecting soil ecosystems;[14]
- The organic matter in soil can be lost as a result of cultivation and the use of inorganic fertilisers, impairing all the functions of soil and increasing soil's vulnerability to erosion or further degradation. This also releases carbon dioxide and risks reducing the yield of crops and their nutrient content;[15,25]
- Soil ecosystems and biodiversity can be broken down, removing the micro-organisms which support the functions of soil, including organic matter content for carbon storage and porosity for water storage;[12]
- Soil can be contaminated by toxic elements or pollutants, damaging biodiversity and polluting groundwater which resides within soil;[13]
- Soil can become salinized by salt build-ups from irrigation water or coastal flooding, reducing the fertility of the land, becoming toxic for plant-life, and increasing the long-term risk of desertification;[2] and
- Soil can be subject to acidification or nitrification caused by pollutants, fertilisers, or the draining of wetlands, leading to a reduction in the overall fertility and functionality of the soil, and potentially to the release of nitrogen-based emissions.[4]

Soil at risk: erosion

Soil is a finite and threatened resource. Soil forms at slow rates, measured at around 1 tonne per hectare per year, or taking hundreds of years to form a few centimetres.[4] In many areas, soil is being eroded far more quickly than it is being formed, and we are losing important soil resources which put all the essential services soil provides at risk.[9]

The process of erosion begins with soil particles being detached by erosive forces. They are then transported elsewhere by water and wind, where they are deposited, risking sedimentation or reduced water quality. Erosion is typically caused by one of three factors. Firstly, exposed soil can be physically displaced by wind.[14] Secondly, water can carry soil away through run-off, eroding the soil and potentially increasing pollution of watercourses.[11] Thirdly through agricultural practices. Some erosion takes place through harvesting when soil adheres onto crop roots and farm machinery, though much more is caused by intensive agricultural practices such as inversion ploughing, overgrazing, and inadequate water management which increases the risk of run-off.[15] These risk factors are also enhanced in the context of land use change away from natural systems.[9]

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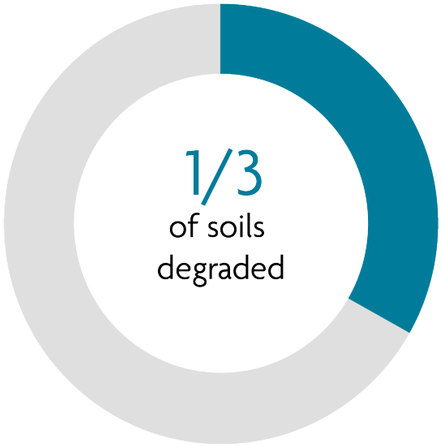

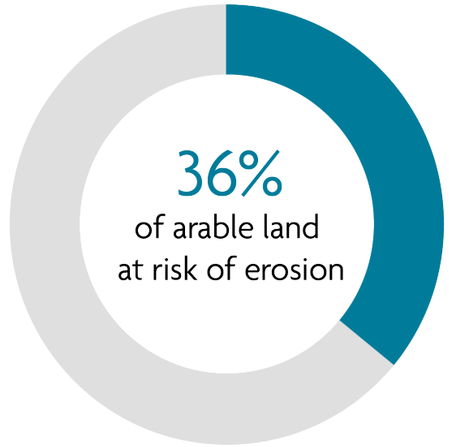

225,787

tonnes of carbon lost per acre to soil erosion

18,026

tonnes of nitrogen lost per acre to soil erosion

2.9 million

tonnes of topsoil lost annually to wind and water erosion

Figure 3: Chart demonstrating percentage of UK soils estimated to be degraded; percentage of UK soils estimated to be at risk of erosion; estimated quantity of UK topsoil lost each year to wind and water erosion (million tonnes per annum, excludes topsoil lost to agriculture and other causes); and estimated tonnes of carbon and nitrogen lost per acre each year in England and Wales (tonnes per acre per annum). Adapted from CPRE. (2018). *Back to the land: rethinking our approach to soil.* Available at: https://www.cpre.org.uk/wp-content/uploads/2019/11/CPRE_FF3_Soil_26Nov_web.pdf (Accessed 9th September 2020);[2] and Graves, A.R. et al. (2015). *The total costs of soil degradation in England and Wales*. Ecol. Econ. Volume 119. 399-413. DOI: 10.1016/j.ecolecon.2015.07.026.[13]

As **Figure 3** demonstrates, erosion of soil is widespread in the UK, with an estimated third of soils degraded, 1 million hectares at risk of erosion, and nearly 3 million tonnes of topsoil being lost every year to wind and water alone.[2] There are means of mitigating these losses through erosion control and targeted interventions, though these techniques are not currently being used sufficiently to offset losses from erosion.[7] The results of erosion are clear, but potentially devastating: not only does erosion remove soil, it can reduce the overall organic matter of the soil that remains, selectively taking the most important components first, and leaving behind soil which only has a third of the nutrients contained in the eroded soil.[13]

When this happens, all the good which land and soil can do is put at risk, but erosion is associated with a number of specific problems:

- Erosion causes lower yields of crops, reducing food supplies and creating financial risks for agriculture, with increased risk where crops are prone to erosion due to their slow establishment or the extensive disturbance of soil involved in their cultivation, such as for maize or potatoes;[14]
- Erosion jeopardises crucial ecosystems in the topsoil with cyclical effects on the health of the remaining soil;[2]
- Erosion can directly lead to the release of stored nitrogen, expelling it into the atmosphere;[13] and
- Erosion also increases risks during heavier rainfall, leading to more sediment run-off and reduced land fertility.[9]

The issues associated with the erosion of soil are especially critical as in many cases they may reach the stage of becoming functionally irreversible.[25] The slow formation of soil and the rapid rates of erosion could pose a crisis which will be incredibly difficult to reverse.[4] These issues must be addressed before that tipping point is crossed.

An economic perspective

The environmental and societal costs of eroded and degraded soil are clear, but there are also substantial economic consequences for failing to protect the long-term sustainability, health, and resilience of soil resources.

In 2014, an article by researchers from Cranfield University estimated these costs to be more than £1 billion every year in England and Wales alone.[13] Primarily, this figure is associated with loss of organic soil content, compaction, and erosion, with some of the harms of degradation not quantified in that figure. It is important to recognise that the actual number is likely to be significantly larger for three reasons:

1. The figure is likely to be compounded and increased, both by inflation as well as the cyclical and accelerating degradation of soil resources. As soil is eroded and degraded it becomes increasingly difficult for natural functions to continue, so costs associated with degradation are likely to have increased significantly since 2014. As one example, ONS data suggests that CO_2 emissions associated with the agricultural industry rose 16% between 2014 and 2018;[26]
2. Since the article was published in *Ecological Economics*, our understanding of how soil relates to the interconnected crises facing the UK and the wider world has continued to progress. Estimations of soil's contribution to these crises were made conservatively in the article, and our current understanding indicates these may have been under-estimations; and
3. Even within the calculations used to reach that figure, there are many factors which are not able to be quantified, including many of the social benefits lost when soil is degraded, so there are still many unknown factors which are likely to substantially increase the economic costs associated with soil degradation every year.

The logical conclusion of this is that the exact cost of soil erosion and degradation is unknown, but is likely to be substantially higher than the 2014 figure, potentially stretching into billions of pounds in England and Wales alone, with an even higher figure for the UK as a whole. CPRE also estimate that the social costs of abating carbon emissions could more than triple the figure associated with soil degradation's impact on greenhouse gases.[2]

Further research in this area could help to provide a clearer understanding of the full economic impacts of poor management of land and soil. However, even in the absence of complete economic figures, it should still be clear that the social and environmental costs are too great to ignore: increased flooding, lower yields on the provision of healthy food, collapsing ecosystems, and unchecked release of carbon into the atmosphere.

The key lesson for environmental policy should be clear: there is a big difference between the world which looks after soil and the world which neglects it. If we want our society to be one which thrives with a sustainable climate, healthy food, and communities which are resilient to flood risk, then our approach and attitude to land use and soil resources needs to change dramatically.

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What are the solutions for land and soil?

Challenges for land and soil are context-driven. There is no 'one-size-fits-all' approach to improving soil health and there may be some degree of subjectivity in selecting techniques from among those known to drive positive outcomes, particularly where there are trade-offs between different soil types and functions. In light of this, any solution to the problems facing soils should be designed to work towards the goals established earlier in this report: creating sustainable, healthy, and resilient soils, while mitigating and alleviating current crises.

This section contains a selection of policy solutions which could be adopted to support those goals.

Land management practitioners will be in the best position to make tactical choices about managing a local soil resource in line with these aspirations, especially where they are empowered by best practice and environmental science. The role of policy makers is to create a landscape that facilitates and rewards sustainable management.

The following should be viewed as a menu of choices, rather than as a list of prescriptive recommendations:

Assessing soil quality

Assessing the quality of soil faces serious practical challenges from a policy perspective. There are an expansive and diverse range of properties of soil which can be used to evaluate it, some of which also have multiple methods of measurement. Within these, there is no 'universal measure' of what it means for soil to be healthy or high quality, and too many individual factors for all of them to be given full consideration, especially in policy spaces which demand guaranteed outcomes.

Evaluations depend fundamentally on the functions which are being sought from the soil, and the context within which that soil resides, both of which have the potential to change over time. There are two potential solutions, and a robust process of assessment should make use of both of them in order to produce the best outcomes, as indicated in **Figure 4**.

Best practice: Produce a list of supported practices which the best available scientific evidence shows are well-positioned to contribute towards positive environmental impacts for soil across contexts and individual properties.

Many of these techniques are already well understood, with considerable evidence demonstrating which practices lead to positive outcomes for soil. This list would need to be comprehensive, cut across contexts, and provide relevant case studies which practitioners could use to enable peer-to-peer learning. The list would need to be properly maintained in light of emerging scientific evidence and evolving best practices, learning lessons from implementation.

The creation of a list of supported practices should draw on the expertise of academics and practitioners who have relevant understanding of the wider environmental systems affected by soil. In particular, case studies should be drawn from agricultural, land contamination, and other land management contexts, and prior assessments of the wider applicability of techniques should be established through consultation with academic sources.

Figure 4: Flowchart of the two mechanisms for 'Solution 1: Assessing soil quality' demonstrating (a) method of assessment, (b) action by land managers, and (c) the combined outcome of assessments for sustainable, healthy, resilient soils.

Examples of well-evidenced techniques include:

- Applying organic amendments (manure, crop residues, etc.) to increase soil organic matter;
- Implementing cover crops (such as green manures) to reduce bare soil, while returning more organic matter and nutrients to the soil system and reducing erosion;
- Minimising tillage to maximise organic matter and soil biology;
- Reintroducing mixed farming and rotational grassland within arable systems; and
- Using precision agriculture for smart targeting of inputs.[25]

Risk register: Maintain a risk register, setting out existing challenges and risk factors for an individual piece of land and how soil on that land is contributing to or mitigating against those challenges.

Depending on the level and scope of implementation, these risk registers could be voluntary evaluations by land managers, or managed by relevant oversight bodies, including the proposed Office for Environmental Protection (OEP), Environmental Standards Scotland, or other equivalent bodies. In any case, registers should take note of the interactions between soil and other natural systems, including the ability for soil to have on-site and off-site consequences of the types described earlier in this report.

With these two key mechanisms in place, assessments could be conducted simply, producing effective outcomes which would not be reliant on differentiated and limited property indicators. This would also allow for contextually-appropriate and subjective management of land, rather than prescribing a 'one-size-fits-all' approach to evaluating the quality of soil. Relevant assessors, land managers, or farmers could demonstrate the techniques they have used which align with the list of supported practices, as well as identifying the risks and issues currently associated with their soil and how they are being addressed.

Long-term targets for soil

DEFRA's Environmental Targets paper sets out the desire of the Government to set a long-term target on the basis of soil health.[27] The IES agrees that this will be an important environmental goal, and that setting a long-term target in this area has the potential to massively benefit the UK's future sustainability.

Putting a target in place will require a means of effectively assessing progress; the policy paper notes that "*only when [indicators] are completed can we consider whether this advanced data could inform the development of outcome based targets*". While the Government develops this indicator, the form of assessment outlined above could provide the basis of a target which measures the rate of adoption of best practice and proper evaluation of risks stemming from the management of soil. This approach would achieve many of the same goals as the target currently being considered, and would not involve the challenges of evaluating soil on the basis of individual properties or the need to develop further indicators.

The result would be akin to the policy paper's suggested approach to habitat quality, where DEFRA notes that "*We should not wait to take action on habitat loss, so propose first to consider developing targets that focus on actions to restore and create habitats and bring habitat into appropriate management*." That approach could be mirrored for soil, where appropriate management of land and soil is seen as a first step while more detailed indicators are developed.

Regulatory approaches

Another approach would be to use the above system for assessing the quality of soil as the basis of active regulatory approaches to land. Under this approach, a requirement for regular reporting on the state of land and soil would address gaps in data about soil quality, giving an indication of wider crises while allowing for specific issues of individual degradation to be addressed by land managers or land owners.

There are many forms which this regulation could take, subject to specific regimes of payment and oversight. In England, this is likely to be subject to the full implementation of the OEP, and how it operates in practice. A heavier system of oversight would take an 'OFSTED for soil' approach in which the OEP conducts its own assessments to ensure that high standards of practice are being maintained, and that land managers or owners are properly addressing risks associated with their land and soil. Alternatively, a lighter approach to regulation would operate on the basis of land managers making their own assessments to feed into broader oversight, where the OEP would monitor emerging issues or lapses in best practice and take action where required to address risks.

ELMS and public money for public goods

One of the important questions about the current policy landscape for land in England is how the Environmental Land Management Schemes (ELMS) regime is going to function in practice, as well as how a system of 'Public Money for Public Goods' will reward the right kind of practices to lead to better outcomes for our natural environment. Fundamental to these questions is how best practice will be understood and incentivised for land where these practices are not currently widespread.

IES ▶ REPORT Practice-based approaches to land and soil management

For ELMS and the devolved administrations' successor regimes to payments under the EU's Common Agricultural Policy, there is an urgent need to create certainty for farmers and agricultural land managers. Where ELMS payments will not be in place for some time, the agricultural sector needs certainty that progress towards sustainable land management will be properly rewarded by the new system. Farmers should have confidence that they can begin to engage in the process of transition without concerns about whether their work will pay off.

Figure 5 demonstrates how land and soil play a direct role in all three tiers of the current plans for ELMS in the UK. To achieve sustainability, locally sustainable outcomes, and landscape scale change for environmental benefit, any plan adopted should consider the relationship between its goals and how land and soil are being addressed.

Crucially, the way funding is allocated through the principle of 'Public Money for Public Goods' must correspond to a definition of soil health which is likely to produce multiple benefits and long-term sustainability. It should not be based on isolated properties of soil, or on a single assumed function. Instead, it should be allocated on a basis which rewards farmers and land managers who produce soil which is sustainable, healthy, and resilient. Only by doing so will the best practice be rewarded, incentivising wider adoption of the most environmentally beneficial techniques.

ELMS tier	Why best practice on soil is essential
Tier 1 Encouraging environmentally sustainable farming and forestry	Soil management requires clear best practice to be successful
Tier 2 Locally targeted environmental outcomes	Habitat restoration, flood mitigation and other local goals require soils which are healthy across functions
Tier 3 Delivering landscape scale land-use change projects	Land-use change requires knowledge of interconnected systems and needs to be sustainability managed

Figure 5: Table demonstrating the three tiers of payments proposed by DEFRA for Environmental Land Management Schemes (ELMS), their stated objectives, and how best practice on soil is fundamental to supporting each of these objectives. ELMS tiers and their objectives are outlined by DEFRA. (2020). *Environmental Land Management: Policy discussion document*. Available at: https://consult.defra.gov.uk/elm/elmpolicyconsultation/supporting_documents/ELM%20Policy%20Discussion%20Document%20230620.pdf (Accessed 9th September 2020).[28]

Sustainable finance approaches

One of the key barriers to making progress for land and soil is securing investment. Despite the enormous benefits which can be achieved by properly managing land and soil, more capital will be required to achieve those benefits. Many of the positive outcomes which soil can provide are beneficial to everyone, though some are particularly beneficial to land-owners or producers, for example in the case of high or healthy yields of agricultural products. Soil may therefore be suited to multiple and diverse sources of funding to support projects.

For example, green bonds are financial instruments which allow investment with a fixed-income while also raising money for environmental outcomes. The International Capital Market Association sets out principles for what constitutes a 'green bond', and rightly evaluates 'environmentally sustainable management of living natural resources and land use' as a valid use of the proceed of those bonds, as well as several other categories where healthy soil could be beneficial.

Wider adoption of sustainable investment instruments such as green bonds can promote increased private investment in green outcomes. To maximise their effectiveness, the Government should do more to facilitate the creation of bonds or other instruments which link back directly to investment in land and soil. Similarly, there may be competitive advantages to private innovation in these kind of financial instruments, where soil is likely to have a significant impact on sustainability which the market is not yet fully capturing.

There are other sustainable finance approaches which would be beneficial, including through cost-related incentives in insurance premiums or planning stage incentives for healthy soil and land. In either case, Government policy could maximise this opportunity by introducing financial incentives to promote sustainable management of land across land ownership, development, and purchase.

Though there are likely to be more complex considerations involved for the market, costs to developers would be somewhat offset by sustainable practices, which would reduce risks such as flooding and other costs for those businesses in the long-term, while improving the quality of end products. These policies should be implemented in specific contexts where mutual economic benefits are likely to arise for both parties, but where a lack of regulation currently leads to poor competition and inaction.

Agro-ecological approaches

Agro-ecological approaches to land and soil provide a crucial toolset to help improve the health of soil and the land it is part of. There have already been considerable developments across the agricultural sector, providing a bedrock of best practice and case studies which can be used to apply general principles of agro-ecology to the subjective context of an individual piece of land.

Using approaches focused on agro-ecology, the Government would support these practices directly through financial incentives or pilot schemes. There may also be benefits to direct adoption of agro-ecology techniques by individual farmers and other agricultural land managers, especially where these are viable alternatives to their business models, helping to improve long-term yields and crop health in certain contexts. In such circumstances, land managers should consider the applicability of agro-ecological approaches to their context, even in the absence of direct government intervention.

Assessment as a condition of sale of land

Land is increasingly seen as more valuable when it is resold for development purposes, rather than being used for agricultural benefits. In some instances, this is currently leading to short-term agricultural tenancies, uncertainty for farmers, and the de-prioritisation of the health of soil and land.

An option for improving this situation comes from experiences of contaminated land law, which provide useful learning to bring to the context of soils and sustainable land management. Under this approach, prior to any sale of land taking place, it would be necessary to conduct a full assessment of the state of soil health on that land.

These assessments would be conducted in the manner set out above, with the potential to be integrated directly into systems of regulation or oversight. Once these assessments had been conducted, the sale would continue with the buyer in full knowledge of the state of the soil on their land, as well as the techniques historically used to manage that land and the risks posed as a result.

This would have three benefits:

1. Land with soil which has been properly maintained is likely to sustain a higher market value, rewarding those land managers who adopt best practices and incentivising others to do the same;
2. There would be incentives to look after the long-term sustainability of soil on land, even if that land is likely to be sold again in the short-term, addressing issues with short-term land purchase and its effects on tenant farmers and their ability to secure environmental outcomes; and
3. This would also go some way to closing data gaps, particularly for those parties who purchase land without a full awareness of the risks attached to soil or the full benefits which they could be achieving from their land.

IES ▶ REPORT Practice-based approaches to land and soil management

Adapting to the context of devolved administrations

While the goals and aspirations set out at the start of the report apply generally, there are important contextual differences between the policy regimes in the devolved administrations within the UK. Many of the solutions outlined in this report will also apply to devolved administrations, but this section outlines where adaptation may be required to make the most of the IES' recommendations.

In the specific context of agriculture, it will be especially important to ensure that high standards are reflected on both sides of internal UK borders, so that farmers are not incentivised to compete on lower environmental standards on one side of the border. The IES has long supported the innovation of devolved administrations raising environmental protections. These innovations should inform how the UK as a whole develops its environmental policies.

Scotland

Scotland will not adopt the ELM schemes proposed for England, with the Scottish Government proposing its own system to replace payments from the EU's Common Agricultural Policy (CAP). Rather than a system of 'Public Money for Public Goods', this will be based on two 'pillars' of funding: In Pillar I, environmental outcomes will be secured through 'greening' funding on top of an area-based Basic Payment Scheme (BPS). In Pillar II, environmental land management will be directly incentivised through agri-environment and forestry schemes.[29]

In both cases, the lessons about utilising best practice and aspiring for sustainable, healthy, and resilient soils remain vital, and the practical implementation of schemes will need to reflect that, going beyond the CAP to drive transformative change for how land and soil are managed. This may require a deeper interrogation of funding priorities to ensure that agriculture achieves multiple benefits for society and the environment, and will necessitate careful application of the BPS to avoid overly intensive agricultural practices.

The approaches to assessing soil health and promoting better outcomes through agro-ecology, green finance, and regulation are all applicable to that context, though in some cases Scotland has already begun to make more progress towards adopting those approaches.

Wales

The Welsh Government has stated its intention to present its own Agriculture Bill, though details of its proposed regime are yet to be fully set out.[30] On that basis, many of the mechanisms set out in this report could be adopted as the basis of that legislation, which should take a view of land and soil as central to its wider environmental objectives, rather than being purely based on food production. It will be especially important to consider these as part of any payment scheme for agriculture set out in the Welsh legislation.

Northern Ireland

While Northern Ireland is in a similar situation to other devolved administrations in the development of its own governance regime for agricultural land after the UK's exit from the EU, it also has specific recommendations set out by the Expert Working Group on Sustainable Land Management, which set out policy barriers to sustainable land management in the Northern Irish context.[31]

"It will be especially important to ensure that high standards are reflected on both sides of internal UK borders, so that farmers are not incentivised to compete on lower environmental standards."

The Expert Group's strategy sets out positive aspirations for evaluating the quality of soil across Northern Ireland, though this report's assessment mechanisms may prove to be more effective in the short-term at ensuring sustainability and resilience in line with the precautionary principle. In either case, Northern Ireland needs to ensure that its assessment process reflects the inherent value of healthy soil and multiple potential functions of that soil, including those which may arise in the future.

Adapting to the international context

Just like in the UK, many other countries will be able to achieve multiple ambitions simultaneously through their management of land and soil. This is especially important in the context of the Sustainable Development Goals (SDGs) and international targets such as the goals covered in the Paris Agreement under the UN Framework Convention on Climate Change or the Aichi Biodiversity Targets under the Convention on Biological Diversity. A sustainability-based approach to how we use land and soils could help make major progress towards all SDGs, but especially goals 2, 3, 11, 13, 14, and 15.

Though this will require a subjective assessment of the policy barriers which prevent progress towards sustainability, there are a number of recommendations in this report which can be applied universally:

1. We should aspire for all soil to be sustainable, healthy, and resilient;
2. We should seek to alleviate environmental crises as a priority, putting land and soil at the centre of our policies to work at the same scales as nature and find systems solutions which address the causes of crises rather than their symptoms;
3. We should promote greater research into, and awareness of, the interactions between land management and soil resources, both from a natural capital perspective but also in terms of the full range of integrated benefits which can be achieved from a systems approach to land and soil; and
4. We can solve challenges for assessing soil health by applying a two-step assessment process which evaluates the prevalence of proven techniques in land management, as well as the risk factors for a specific piece of land and its soil.

Innovations and other progress being made by countries which have already begun to recognise the benefits which land and soil can provide should inspire and validate the placement of land and soil at the heart of any strategy for sustainability.

Box 2. International case studies for land and soil

- France's '4 per 1000 Initiative', which seeks to increase the organic matter content of soils by 0.4% every year primarily through changing agricultural practices, with a goal to completely offset France's annual carbon emissions, aiming to halt the country's contribution to global CO_2 while improving food security and creating substantial job growth in sustainable development.
- The EU's Just Transition Mechanism, which provides financing, enabling, and practical support to help transition for sectors which are not currently climate-neutral. In the context of agriculture and other unsustainable land use, this kind of funding and practical support could be a crucial mechanism to help secure buy-in and overcome practical barriers which currently exist to the proper management of land.
- The UK may also be well-equipped to serve as a future case study and as a thought leader on land and soil. After the UK's exit from the EU, there may be an opportunity to take a leading role in re-imagining how the EU's Common Agricultural Policy could achieve environmental goals, with the UK serving as a blueprint for future innovation.

IES ▶ REPORT Practice-based approaches to land and soil management

Closing thoughts

Poor management of land and soil is a problem for everyone in society. Without action, we are likely to face crises for our climate, for our natural environments, for the resilience of our communities to flood risk, for our health and the security of our food, and for our ability to buffer natural systems against long-term vulnerabilities.

Where there has been historic disagreement over the importance of individual qualities or functions of soil, these can be resolved with a holistic approach. To achieve multiple benefits for society, we must look at the ways we use soil, the state of that soil, and the risks facing that soil.

To achieve these objective goals across contexts, we must recognise the subjective challenges facing land, rewarding best practice where it is known to lead to positive outcomes, and sharing that practice so that it can be replicated. We can only guarantee our success by ensuring good practice is in place while keeping sight of context-based risks for individual pieces of land.

There are several ways to achieve this, and it may be necessary to address the issues from multiple directions, in light of the different barriers to action. Several approaches have been outlined in this report, though the importance of continued research and innovation in the search for solutions cannot be understated.

Facing the UK is a significant series of challenges, but more importantly, there is the potential for a very bright and positive future. We can create communities which are resilient to risks associated with climate, biodiversity loss, and flooding. At the same time, those communities can benefit from secure food sources which are sustainable and nutritious, green land with immense cultural and recreational value, and a growing green economy which thrives through mutual societal, economic, and environmental improvement.

The key to unlocking that future is to build it from the ground up, and that requires us to start by looking at land and soil, ensuring that we have a foundation which is sustainable, healthy, and resilient.

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