The Wildlife Trusts

Digging into our soils

How healthy soils underpin our food systems, climate and natural ecosystems

Introduction

Since the UN officially designated the 5th December as 'World Soil Day' in 2014[1], each subsequent year has seen more and more soil-inspired campaigns, events, and media attention. The increasing popularity of World Soil Day reflects the growing recognition amongst scientists, policymakers, and NGOs of the importance of soils for both human societies and natural ecosystems. Internationally, soils are seen as critical for achieving a number of the UN Sustainable Development Goals, particularly SDG 2 'Zero hunger', SDG 13 'Climate action' and SDG 15 'Life on land'. In the UK, soils underpin many of the ambitions set out in the 25-year Environment Plan, 2021 Environment Act and 2021 Agriculture Act.[2]

However, despite growing recognition of the importance of soils they are still underappreciated by many, and there has been very little meaningful action to tackle the problems facing them. Soils are under increasing threat from factors such as climate change, soil degradation brought about by unsustainable farming, and land use change. As a result of these threats, across the globe we are losing an estimated 36 billion tonnes of soil every year. This means that if more urgent action is not taken to protect and restore soils going forward, it is thought that it will be almost impossible to achieve our food security, biodiversity, and climate change targets.

In The Wildlife Trusts' recently adopted Strategy 2030, we have set out a vision of "a thriving natural world, where our wildlife and natural habitats play a valued role in addressing the climate and ecological emergencies, and everyone is inspired and empowered to take action for nature." Soils already underpin much of the successful work we do across our wildlife sites, and protecting and restoring our soils will be critical if we are to make this vision of a thriving and connected wild landscape a reality. But to do so, we need to transform the way we think about our soils and build a wider appreciation of all the important services they provide, across our movement but also in policy circles, with farmers, retailers, and the general public. Considering the ongoing development of the Environmental Land Management Scheme in England, alongside other developing land use policy schemes in the devolved nations that will shape our countryside for years to come, there has never been a more important time to raise the profile of UK soils.

This briefing sets out what soils are and how healthy soils function, outlines the threats acting upon them, and explores the role they play in achieving sustainable food systems, mitigating and adapting to climate change, and the protection of natural environments. It finishes with a discussion of possible actions that may be implemented to tackle soil degradation and restore soil health across agricultural and natural environments. It is hoped that this briefing will facilitate further discussions on soil policy, promote wider awareness of the importance of soils within The Wildlife Trusts, and aid the development of future actions to push soils further up the land management agenda.

MOLE © JUEFRAPHOTO / SHUTTERSTOCK

What is soil, and what makes it 'healthy'?

Soils can be extremely varied and diverse, as their structure and makeup are determined by several factors such as the parent material they formed from, their age and geographic location, and the climatic, topographic, and biological conditions that have acted upon them[3]. In general soils are made up of a mixture of the following components:

- **Organic matter (residues from plants, animals, and microbes)**
- **Minerals (including sand, silt, and clay)**
- **Living organisms (from microbes to macrofauna and flora)**
- **Gases and water**

A soil is not just a medium for plants to grow in, but also a precious resource that provides the habitat, nutrients, and biological interactions that countless organisms rely on. It can also be described as a finite resource[4], given that they can often take hundreds or thousands of years to form yet can be lost in a fraction of that time. However, as well as describing soil as a resource, most scientists and agricultural practitioners now consider soil to be a complex and dynamic ecosystem in its own right, which can be vulnerable to external pressures acting upon it. This recognition has led to the development of the concept of 'soil health', which is defined as:

"The continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, promote the quality of air and water environments, and maintain plant, animal, and human health."[5]

There are a range of physical, chemical, and biological attributes that are typically used as indicators of soil health[6]. Physical attributes provide an insight into the structure of the soil and include bulk density, texture, porosity, and aggregate stability. Chemical indicators of soil health include pH, soil organic matter levels, and nutrient concentrations (particularly Nitrogen and Phosphorus concentrations, due to their importance in agriculture). Biological indicators of soil health recognise the important contribution of biodiversity to soil processes. These are often measured using soil microbial activity, diversity, and biomass as indicators, but other attributes including the abundance and diversity of soil meso (nematodes, mites, collembola etc.) and macrofauna (earthworms, beetles, ants, and other larger arthropods) are also key considerations[7].

The overall health of a soil will depend on a combination of its physical, chemical, and biological attributes, so gaining an accurate picture of soil health typically requires an integrated approach that takes into account a suite of different indicators. Although there are often common features that are broadly applicable to healthy soils, it is also important to note that the specific features of healthy soils can look different depending on their classifications and corresponding ecosystems. For example, a 'healthy' boreal forest soil will typically be acidic, nutrient poor and show distinct layering, in contrast to 'healthy' grassland soils which can be pH neutral or alkaline, nutrient rich and exhibit much more subtle layering.

Box 1. 'Soil quality' vs 'soil health'

The term 'soil health' was first coined over 100 years ago but did not gain wide recognition until recent decades. A similar term, 'soil quality', also became very popular in the 1990's. These two terms are often used synonymously with each other, but some consider soil quality to focus more on specific soil functions and chemical or physical attributes, whereas soil health includes biological interactions and views soil as a dynamic living resource.[5]

SOIL © LAUREN HEATHER

What is threatening our soils?

Recently, soils have been gaining more headlines due to once healthy soils losing their physical structure, becoming depleted of carbon and nutrients, and losing the biodiversity responsible for regulating and maintaining this precious resource[8]. Referred to as 'soil degradation', this process can lead to soils becoming infertile, being blown away, or washed into water courses, and can ultimately end with the decline and collapse of both agricultural and natural ecosystems alike[9]. Across the globe, an estimated 25% of the total land surface is classed as 'highly degraded or experiencing high degradation', 8% as 'moderately degraded or experiencing moderate degradation' and 36% as stable but 'slightly or moderately degraded'[10]. As a result, a large proportion of soils across the globe can be considered to be in poor environmental condition.

The total amount of soil lost globally in 2012 was thought to be around 35.9 gigatons.[25] The social and economic costs of these losses are profound, especially as 1.5-3 billion people are dependent on soils that are classed as degrading[11]. In a recent study, it was estimated that accelerating soil degradation was reducing global food yields by 33.7 million tonnes every year, with an associated economic cost of eight billion US dollars[12]. Significant costs of soil degradation are also seen in the European Union[13], and in England and Wales[14] £1.2 billion is lost each year primarily because of declines in soil organic matter and compaction.

Intensive agriculture is one of the leading causes of soil degradation, and a number of conventional farming practices have been shown to cause soil health declines. The physical structure of soils can be degraded by excessive ploughing, which breaks up the soil aggregates and exposes organic matter to the elements, in turn depleting the soil carbon pool and releasing carbon dioxide to the atmosphere[15]. The action of heavy machinery and trampling caused by unsustainably high stocking levels of livestock can also harm the soil's physical structure, causing compaction that removes the soil pores and channels that are important spaces for plant roots, soil biodiversity, and water retention[16]. Intensive agriculture can also alter the chemical attributes of soils in ways that negatively affect soil health, particularly through the removal of soil carbon and the additions of large amounts of chemical inputs, such as pesticides and fertilisers.

Since the 1950's, crop rotations have typically become less diverse and focused on producing profitable, high yielding crops repeatedly in a relatively short timeframe[17]. Whilst this can maximise short-term profits, this practice also reduces the levels of important nutrients and depletes the soil organic carbon pool, which threatens the soil's ability to continue to produce crops in the longer-term[18]. To compensate for this, the amount of chemical fertilisers and inputs has sky-rocketed, allowing farmers to maintain plant yields even in nutrient-depleted soils[17]. However, this high rate of inputs is unsustainable in the longer-term[19] and only serves to undermine soil health further, by disrupting soil chemistry and altering the dynamics of the wider soil ecosystem[20].

Alongside the negative effects on the physical structure and chemical profile of soils, intensive agriculture can also be extremely harmful to soil biodiversity. For example, ploughing the soil can cause death and injury to many soil animals and destroy their burrows and refuges, making them more vulnerable to predators[21]. The widespread application of large amounts of chemical inputs can also have unintended negative consequences for a range of soil organisms, and many pesticides have been shown to have lethal and sub-lethal effects on soil fauna that can destabilise the balance of the wider ecosystem[22]. Soil animals are not the only organisms that can be harmed by intensive farming however, as the prophylactic use of antibiotics and veterinary medicines for livestock often leads to these compounds leaching into the soil profile[23]. Once there, they can persist for a long time and cause significant changes and disruptions to the microbial community also[24].

As a result of the impacts of intensive agriculture, 50.5% of all the soil erosion that took place globally in 2012 occurred in croplands, despite them only accounting for 11.2% of the total land area[25]. This amounts to a soil degradation rate that is 77 times higher than in forests. However, intensive agriculture is not the only cause of soil health declines, and climate change and other land use practices are also key drivers. Climate change and soil degradation are intricately linked, and changes in our soils can change how much carbon is emitted and absorbed, as well as determining how resilient our future systems are in adapting to a changing climate (see 'Healthy soils for tackling climate change' below). Climate change itself is thought to have a mix of future impacts on soil health through increasing temperature and carbon dioxide. It will also affect soil degradation, particularly through reduced soil moisture during periods of drought and extreme weather events causing more soil to be lost through wind and water erosion[26].

With regards to other land use practices, forestry activities can also threaten soils, particularly when large areas of trees are clear felled to harvest the timber. The removal of the trees disrupts the soil ecosystem that will have taken a substantial amount of time to develop[27], and the lack of living tree roots to anchor the soil mean it is more likely to be eroded and washed away[28]. When heavy machinery is used to harvest the timber, this can also cause soil compaction, which exacerbates the problem further[29].

Finally, the wider development of towns and cities can also be a threat to soil health due to 'soil sealing', which is the action of covering soils with a layer of concrete or other non-permeable material[30]. When soils are sealed, they lose the ability to provide the ecosystem services that are typically attributed to them, and their ability to take up carbon, store water and provide a home for wildlife are all lost. This means they effectively become wasted resources and lost ecosystems[31].

DEGRADED SOIL © DAVID TIPLING/2020VISION

Why should we care about soil?

Declines in soil health and increasing rates of soil degradation are bad news for both people and wildlife. This is because soils provide essential ecosystem services and underpin many of the activities that human society depends on, and they are an integral part of most terrestrial ecosystems. As the rates of soil degradation increase both in the UK and further afield, the ability of soils to continue to provide these ecosystems services becomes threatened. Reversing degradation and restoring soil health will be particularly important for ensuring the long-term sustainability of food production, tackling climate change, and restoring natural environments. The contribution of healthy soils to these areas are explored further below.

Healthy soils for sustainable food systems

An estimated 98.8% of all the food calories consumed by humans are currently derived from soils[32], so maintaining soil health is crucial to food security and the sustainability of our food systems. However, we know that across the world declines in soil health are being observed, and these declines have repeatedly been linked with subsequent declines in crop yields. For example, one study suggested that across the globe at least 20 million tonnes of grain are lost every year as a result of soil degradation[33], while another estimated that global food production was being reduced by 15-30%[34].

In the EU, areas that are experiencing high rates of soil degradation have been reported to be losing around 0.43% of their crop productivity every year, equating to the loss of around 1.25 billion Euros annually[35]. If these worrying trends in agricultural productivity are to be halted and reversed, more action to protect and enhance soil health is required. But how does increasing soil health increase the productivity of our food systems?

In agriculture, healthy soils can directly increase crop yields by providing crops with more of the space, resources, and biological associations that they need to grow. For example, when compared with unhealthy compacted soils, healthy soils have more structural pores that facilitate root growth, in turn supporting greater aboveground plant growth[36]. These pores are also important for increasing the water retention capabilities of healthy soils, which can particularly benefit plants and maintain higher yields when water is scarce[37]. Healthy agricultural soils usually have greater amounts of soil organic matter, which provides the key building blocks and nutrients needed for plants to grow and increase their biomass. This means that healthier soils can be less reliant on human inputs of fertilisers like nitrogen and phosphorus[38] (which typically limit plant growth in intensively farmed soils), saving farmers the economic and environmental costs of applying them. The greater soil biodiversity associated with healthy agricultural soils is another feature that can boost plant growth. This can occur via many different pathways, including through the indirect actions of animals in the soil environments (such as the burrowing and casting of earthworms, which provides space for roots and makes nutrients more readily available[39]), or through the plants direct associations with organisms that enable them to access more resources (such as mycorrhizal fungi, which when present form associations with plant roots and provide nutrients in exchange for carbon and sugars[40]).

As well as by directly increasing plant productivity, healthy soils can also indirectly boost crop yields by making them more resilient to factors that would otherwise threaten them. A good example is crop pests and diseases, which are some of the major causes of crop loss worldwide. Insect pests alone have been estimated to destroy around 18-20% of annual crop production and cost over $470 billion worldwide[41], whilst diseases caused by fungal pathogens and other microorganisms can also decimate crops and can be responsible for up to 15-20% of annual wheat yield losses[42]. Managing agricultural soils to boost soil health has been shown as an effective tool in boosting the resilience of crops to many pests and diseases, as the increased microbial activity, biomass, and diversity associated with healthy soils can act as a biological suppressant that prevents diseases taking hold[43]. Alongside microbes, the greater abundance and diversity of larger soil organisms has also been shown to have disease suppression benefits[44], and the presence of more natural insect predators in healthy soils can be an effective way to keep pest numbers at tolerable levels[45]. The valuable pest and disease control services provided by healthy soils are particularly important when considering The Wildlife Trusts aims to reduce the amount of pesticides and fungicides applied to crops, which can have widespread negative effects on our ecosystems and act as a further barrier to achieving soil health increases[46].

Climate change is another threat facing food production that healthy soils can help to mitigate against. Over the next few decades, climate change is expected to lead to significant reductions in major crop yields across the globe, even under modest warming scenarios[47]. This is not just a problem for the future as the negative effects of climate change are already being seen, particularly the increasing frequency and severity of extreme weather events which have already been linked with global yield declines[48]. Improving the health of our soils could be part of an effective management strategy to increase the ability of agricultural systems to be resilient to these extreme weather events going forward, which will be critical as we adapt our food production systems to a future climate. This is because healthy soils tend to have a much greater water holding capacity, which means they can effectively act as a sponge, holding more moisture and releasing it more slowly[49]. In times of drought this means that plants are able to access water for a longer period of time, while in times of severe rainfall it means that soils are less likely to waterlog and produce damaging flood conditions[50]. The fact that healthy soils are more likely to give rise to healthy plants is also an important consideration, as healthy plants will be more likely to withstand temporary adverse conditions than unhealthy ones[51].

Box 2. Soil health and livestock

The relationship between soils and livestock is very complex and intertwined. Maintaining soil health is important for the long-term viability of livestock systems as they rely on soils to produce the food that grazing animals consume, whether this is the grass in pasture-fed systems or the crops that are grown as feed for livestock[a]. But depending on how livestock systems are managed, they can also play a critical role in either promoting or reducing soil health.

On the one hand, livestock can be beneficial for soil health as their manure can provide an important input of carbon and other beneficial nutrients to soils, whilst also providing an important microhabitat for many invertebrates and microbes[b]. In some places grazing by livestock can also prevent one species of plant dominating the ecosystem, which helps to maintain biodiversity and the benefits this brings for soils[c].

However, livestock can also have negative impacts on soils. For example, overgrazing can deplete soils of their protective plant cover and leave them more vulnerable to erosion[d]; and trampling by large numbers of animals can cause compaction or 'poaching' that severely damages soil structure[e]. When liberal amounts of unnecessary antibiotics and antifungal treatments are also applied to livestock, these substances often find their way into soils. This can harm soil animals and disrupt the balance of the microbial community[f]. In the UK, the current approach to livestock management also relies on 'improved grasslands' that require large amounts of added fertiliser to function.

Whether livestock have an overall positive or negative effect on soil health will ultimately depend on the circumstances involved and the management practices employed.

CONSERVATION GRAZING CATTLE © MATTHEW ROBERTS

Healthy soils for tackling climate change

In the coming years, soils will play a major role in determining whether or not we are successful in addressing the climate emergency. Soils are a huge store of global carbon and are estimated to contain around 2,500 billion tonnes[52]. There is more carbon in the soil than there is in all the aboveground living organisms and atmosphere combined, and soil is second only to the oceans in terms of quantity of carbon stored[53]. However, because of the growing problems of soil degradation and declining soil health associated with intensive agriculture, it is estimated that soils have already lost around 8% of their carbon stocks globally, and around two thirds of this carbon has ended up in the atmosphere[54]. Tackling soil degradation and boosting soil health will therefore be crucial to reducing future greenhouse gas emissions and removing more carbon through natural systems. This is because in general, improving the health of soils often corresponds with increasing the levels of stored carbon in them, so managing land in ways that boost soil health will contribute towards helping us drawdown carbon and achieve our net-zero carbon ambitions. One study has shown that managing our soils to boost soil health could increase carbon storage and avoid around 5.5 billion tonnes of carbon emissions every year, which is just under the total annual emissions of the United States[55].

However, in reality the situation may be more complex, as boosting soil health does not automatically mean that soils will become greater carbon sinks. Even healthy soils have the potential to act as both sources and sinks of carbon dioxide and other greenhouse gases, and it can be hard to distinguish their overall contributions to the carbon cycle due to the complex mechanisms and ever-changing conditions involved. For example, increasing soil microbial activity is often seen as a reliable indicator of improving soil health, but in some cases the higher rates of organic matter breakdown associated with this can cause more carbon dioxide and methane to be released into the atmosphere before it can be stored[56]. However, the same increase in microbial activity can also lead to the overall sequestering of carbon if certain types of fungi are more dominant in the soil microbial community[57]. For this reason, it is also very difficult to determine what effect future temperature and atmospheric CO_2 rises will have on soil carbon cycling.

The overall potential for larger soil organisms, like earthworms, to help with climate change mitigation is also unclear. Many studies have shown that earthworms can both sequester carbon (by feeding on organic matter and locking away the carbon in their casts)[58] and release it (by stimulating microbial activity that increases carbon emissions)[59], and there is still considerable debate among the scientific community as to which process dominates[60]. Unravelling the complexities that determine the role soils can play in climate change mitigation will require more research, but the importance of tackling existing greenhouse gas emissions from degrading soils should not be ignored.

We also know that healthy soils are crucial to making our food systems and natural places more resilient to climate change, helping to buffer them against extreme weather events and rising temperatures (see 'Healthy soils for sustainable food systems' above). This means improving the health of our soils will be

Box 3. What does the soil carbon pool consist of?

Carbon in the soil is broadly split into two groups: inorganic and organic carbon. Soil Inorganic Carbon is stored as carbonate minerals and tends to remain stable in the soil for long periods of time. Soil Organic Carbon makes up the bulk of the soil carbon pool (around two thirds) and consists of decaying vegetation and other dead organisms, fungal and bacterial growth, living organisms and the products they metabolise[g]. A breakdown of what contributes to soil organic carbon is included opposite[h]:

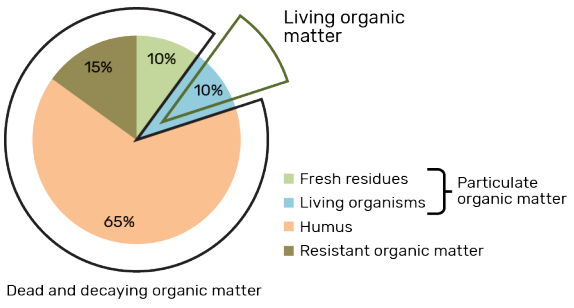

IMAGE COMPILED FROM THE EU SOIL BIODIVERSITY PARTNERSHIP WEBSITE

hugely important for helping us adapt to a warming world, especially as the latest predictions from the COP26 Glasgow summit held in November 2021[61] suggest that we are currently headed for around 2.4˚C of warming. The vital role that soils will play in climate change adaptation has been recognised in the 2021 UK Climate Risk Independent Assessment (CCRA3), which identified the risks to soil health as one of the highest priorities that requires more action. The report also highlighted the urgent need for policy mechanisms that promote improved soil conservation, and called for more comprehensive monitoring of soils.

Healthy soils for nature and wildlife

Although they are rarely given a thought when people picture a diverse ecosystem teeming with life, soils are actually home to more than 25% of all the biodiversity on earth[62]. Healthy soils provide the habitat for a staggering array of wildlife, including millions of species of plants, animals, and microbes. This means that considering the health of our soils will be critical for achieving The Wildlife Trust's goal of managing 30% of land for nature's recovery by 2030.

Typically, the soil community is split into four broad groupings based on the size of the organisms in question. Although smallest in size, the microbes are the most numerous and diverse members of the soil community, and include bacteria, fungi, and archaea. A single teaspoon of healthy soil is estimated to contain around 1 billion individual microbes and around 10,000 different species[63], although it is thought that only 1% of all soil microbe species are known to science[64]. Going up in size the next group of organisms is the 'microfauna', which have body widths of <0.1mm and include protozoa and nematodes[65]. The next group is the soil 'mesofauna', which have body widths of 0.1-2mm, such as enchytraeids (also known as 'potworms') and microarthropods like springtails and mites. There are over 6,500 species of springtails alone, which can be described as living fossils given that they are considered to have first evolved over 420 million years ago[66]. The largest organisms are known as the soil 'macrofauna', which includes earthworms, millipedes, termites, and other organisms with body sizes over 2mm.

Together, the soil community is an integral part of terrestrial ecosystems, and most would quickly collapse if this community was to disappear. Ecosystem engineers like earthworms and ants shape their physical environments and the soil profile, which dramatically effects the structure and composition of the aboveground habitat[67]. Soil detritivores such as millipedes, isopods, and worms feed on dead and decaying matter which stops it building up on the soil surface and recycles the nutrients back into the ecosystem, and soil predators like spiders, beetles, and centipedes keep herbivores in check that could otherwise decimate the plant community[68]. Many soil animals are also an integral part of the wider food web and have a range of aboveground predators that rely on them as a source of food. Maintaining healthy soils is therefore crucial to not only protecting the abundant and diverse wildlife found belowground, but also the natural habitats and wildlife above it.

As well as providing a home for wildlife and supporting the ecosystem that they reside in, improving soil health can also benefit surrounding ecosystems, particularly by reducing pollutants and waste runoff from the land. This is particularly important for improving the water quality in rivers and seas, where pollutants running off the land can unbalance the ecosystems and lead to eutrophication[69] and marine dead-zones[70]. This problem is exacerbated by unhealthy soils, which may require more fertilisers and pesticides to be applied in order to achieve the equivalent crop yields of healthier soils[71]. When these applications are made to less healthy soils, the fertilisers are also more prone to being quickly washed away into the surrounding environments, as the degraded and compacted soils are less able to absorb them[72]. By improving the health of our soils, we can therefore reduce the amount of chemical fertiliser applied to the land in the first instance, and the improved soil structure can limit the amount of remaining fertiliser that does runoff into surrounding water courses[73].

How do we move towards more sustainable, healthy soils?

If we are to fully realise the substantial benefits that soils provide and tackle the many problems that threaten them, we will need to make fundamental changes to the way we manage our land. This will not only require a swathe of new actions and policy changes to transform our food and land management systems, but it will also require a substantial shift in the way we think about our soils in the first place. As the Wildlife Trusts we are used to leading the way in changing the perceptions of previously neglected habitats and places, so we can play a key role in bringing about the move to more sustainable and healthy soils too. Some of the key actions, policy changes, and perception shifts that will be needed to make this a reality are discussed below.

Firstly, more soil health and biodiversity monitoring is urgently needed, both across agricultural production systems and the wider landscape. Monitoring the existing status of soil health is essential to fully understand the extent of soil health declines, establish baselines, and assess the success of management interventions. However, particularly when compared to the monitoring of certain aboveground habitats, the coordinated monitoring of soil health has historically been severely lacking[74]. As more policymakers begin to realise the extent of the problems facing our soils, there have been renewed efforts to establish new systems that encourage the uptake of more widespread soil health monitoring and reporting, including the FAO's SoilSTAT programme[75] and the EU's recently established Soil Observatory[76].

In the UK however no such scheme has yet been put in place, despite the opportunity that leaving the Common Agricultural Policy has given to reshape the way we govern our land. The recently announced Soil Health Action Plan for England (SHAPE) may prove to be a promising development in this area, but details on what this framework will involve are currently scarce and the draft outline is already delayed[77]. It is possible that the development of soil health monitoring programmes has been slowed down by the complexity of soils and the need to track multiple chemical, physical, and biological indicators to gain an accurate understanding of the full picture[78]. However, the science surrounding soil health has continued to advance and standardised approaches for monitoring are now being developed[79], so it is important that our movement continues to push for the wider rollout and uptake of these techniques.

Alongside monitoring, farmers and landowners need to be supported to transition away from intensive agricultural practices that damage soils, towards more agroecological and regenerative farming methods. There is an ever-growing body of evidence showing that these methods can promote and maintain the long-term health and sustainability of our soils, whilst also bringing other benefits to food producers such as increased profitability and ecosystem-service delivery[80]. Some examples of regenerative and agroecological farming techniques that boost soil health include more diverse crop rotations and residue retention that allows carbon and other important nutrients to be returned back to the soil[81]; cover cropping and companion cropping to maintain soil cover and protect it from carbon loss and erosion[82]; reducing tillage intensity to preserve soil structure and protect soil biodiversity[83]; introducing grassland rest periods into rotations (also known as 'leys')[84]; reducing inputs of synthetic fertilisers and pesticides that disrupt ecosystems and instead moving towards Integrated Pest Management approaches[85]; tackling compaction by reducing livestock stocking densities[86]; and rearing native livestock breeds that are better suited to UK habitats and require less inputs[87].

Adopting practices that promote soil health makes long-term sense for farmers and growers, but they will need financial support to make the transition to regenerative farming a reality. The Government is currently unveiling the new 'Sustainable Farming Incentive' (SFI)[88], an agricultural payments framework that will replace the Common Agricultural Policy now we have left the European Union. It is vital that the SFI becomes an effective and supportive tool that adequately rewards farmers for taking ambitious steps to protect our soils, which underpin our food systems and provide so many other public goods. Offering payments to undertake the actions listed above and ratcheting up the transition to support more ambitious regenerative approaches over time would be a highly effective strategy to protect and enhance our soils, thereby achieving the Government's aims of providing public money for public goods. It is currently unclear whether the SFI will provide the ambitious and transformative framework that we need, but with the scheme due for wider rollout in 2022/23 it is imperative the Wildlife Trust movement continues to make the case for our soils.

Outside of agriculture, more consideration of our soils should be built into other forms of land management and planning, including in the development of Local Nature Recovery Strategies and urban construction projects. As described above, soil can be home to a staggering array of wildlife and provides so many ecosystem services that can improve the resilience of our towns and cities and help them adapt to a warming climate. Making sure these attributes are appropriately valued when designing future nature regeneration and urban development projects will be crucial to maximising the opportunities that soils provide. This will also help to keep activities like soil sealing and compaction to a minimum, which if left unchecked can lead to issues like flooding and pollution causing even more damage to our infrastructure[89].

Closer to home, more consideration of our soils should also extend to how we as Wildlife Trusts manage our own reserves. This could involve increasing the monitoring of soil health and soil animal populations in the sites we manage, and adapting our decision-making processes so that possible implications for the soil are taken into account when choosing conservation actions. If we are able to demonstrate best practice in natural soil management ourselves, we would be able to set a great example that other land managers could follow. This would also complement our new Strategy 2030, particularly Enabling Priority 1, which focuses on "Getting our own house in order".

Finally, it is imperative that we foster a greater appreciation of soils more generally, including a greater recognition of all the life they support and the services they provide. For too long soils have been overlooked and underappreciated, which has contributed to the huge problem of soil degradation that we now face. This neglect has also led to a substantial loss of soil knowledge, leading to gaps in understanding about how they function, what they provide, and how to manage them. There is also a worrying lack of soil content across all levels of education, from early education in schools right through to agricultural degree courses and professional development[90]. New initiatives to encourage more education and skills development for people working in agriculture, such as the recently launched Institute for Agriculture & Horticulture (TIAH), may go some way to addressing this, but it is still unclear whether there will be suitable provisions made for improving soil knowledge and promoting beneficial soil management techniques[91]. Even if this does prove to be the case, more emphasis on soils at other levels of the curriculum is urgently required, to build appreciation for soils among the wider public and change the narrative.

The Wildlife Trusts need to spread the message loud and clear that soils are complex, dynamic ecosystems that deserve to be protected and restored, so that we can effectively tackle the historical 'out of sight out of mind' attitude to soils. We have already achieved great success in doing this for marine ecosystems, and we should utilise this experience for the benefit of soils too. As this document has highlighted, soils have huge ecological, social, and economic importance, but we also need to recognise that they have inherent value and are worthy of conservation like any other habitat. Now is the time to seize the opportunity to change the way we see, think, and talk about soils, so that we can preserve this vital living resource for the benefit of future generations to come.

MUD PLAY © HELEN WALSH

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