WOODLAND TRUST

Wood Wise

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SECRETS OF THE SOIL

UNDERSTANDING A VITAL FOUNDATION OF LIFE

FASCINATING SOIL CREATURES REVEALED

MANAGING WOODS FOR SOIL HEALTH

INTIMATE RELATIONS OF SOILS AND TREES

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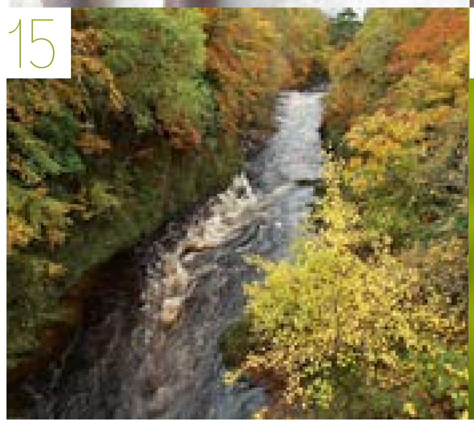

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Cover photo: Earthworm - Natural History Museum

WTPL - Rosey

Moles are soil architects

Soils: cryptically captivating

Soil is often overlooked and undervalued. Yet it is a vital resource teeming with life that underpins the terrestrial ecosystems we humans and many other species depend on for survival.

With so much visible natural beauty around us, it is unsurprising that the invisible realms, like the soil beneath our feet or the dark depths of the oceans, do not attract interest in the same way, and as a consequence are less understood. Equally, we tend to have an affinity towards things we find visually appealing, like colourful birds and butterflies. Those that initially look drab or ugly attract less interest, both from the media and from researchers. But this does not mean they are less important. In fact, it could be argued the importance of soils and the critical need to protect them outstrips a number of higher profile subjects, such as the photogenic panda. And delving deeper reveals a fascinating world that is far from dull.

Extreme erosion events

Soils are a multifunctional but finite resource. One centimetre of topsoil can take over 1,000 years to form, but this is the vital, fertile section of the soil profile that plants need to grow their roots. Worryingly, soils can be lost or degraded all too quickly with dire consequences. The United Nations says around 40 per cent of the world's agricultural soils are seriously degraded. This not only poses a risk to food production, it also results in greater impacts from droughts and floods.

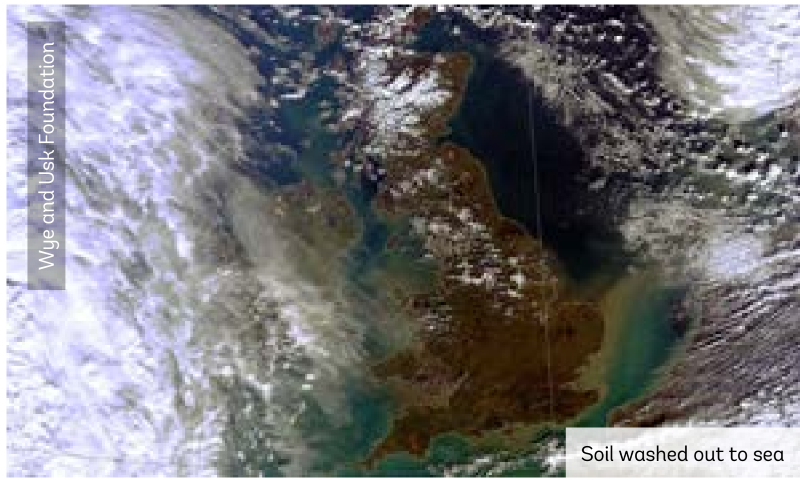
The loss of tonnes of topsoil washed off fields, clogging waterways and carried out to sea during heavy rainfall events is a major issue we must address. A Government report states we lose 2.2 million tonnes of important topsoil each year from the UK's land. Estimates put the cost to the economy at £45 million annually and some hillside agricultural areas can lose more than 100 tonnes per hectare per year. As agricultural land covers around 70 per cent of the UK this is a major concern.

Super soils

'Ecosystem services' simply means the multitude of benefits the natural world provides us. Key functions delivered by soils include: production of biomass; storage, filtration and transformation of nutrients, substances and water; provision of habitat, species and genetic biodiversity; provision of the physical and cultural environment for humans and their activities; provision of raw materials; carbon storage and cycling; and protection of archaeological heritage.

Without soils, humans and millions of other species would seriously struggle or be unable to survive. Many of the processes carried out by soils cannot be effectively replicated by human activity or technology, therefore we need to preserve them and ensure their health. This in turn helps to ensure our own health and longevity, as individuals and as a species.

The following articles highlight the fascinating, if cryptic, world beneath our feet and offer advice on best practice to protect and enhance our precious soils.



Wye and Usk Foundation

Soil washed out to sea

Woodland soils explained

Dr Peter Shaw

Next time you walk through a wood, pause for a moment to pay attention to the soil beneath your feet. Not just watching out for muddy patches, but trying to visualise the layers that cover the whole site like marzipan on a cake.

Often you can see the soil exposed in small cliffs by paths or streams, but a little scraping with a trowel can also help. By understanding the soil profile you gain a deep insight into the wood's history and can often predict flora and fungi found there.

What is soil?

Most people know what the word soil means in a loose sense, but pinning it down in a way that covers all eventualities is surprisingly tricky. For example, are accumulations of leaf litter up trees a true soil? They pass all the tests apart from actually touching the ground, and are usually known as 'suspended soils'. What about material in freshly dumped industrial wastes?

For this purpose we will use a simple definition: soil is the medium plants grow in. Woodland soils are usually well structured, so as you dig down into them a characteristic sequence of changes in the colour and composition of the soil occurs. These show up as bands running through the soil at a (roughly) constant depth. These bands are the 'horizons'. Good soil surveyors can see a freshly excavated soil pit and name each horizon based on colour, texture and position.

Brown earth soil

It is important to understand that the soils are usually much older than any of the trees in the wood, because the upper metre has been broken up by root growth/death over millennia since the last ice age ended. Some chemicals in wood decay so slowly that they persist for centuries after falling to the soil. Some woodland bulbs and fungi in the soil also live longer than the trees – but that is another article.

Soils with broadleaved trees

We can distinguish between two extreme types of UK woodland soils, differing in the types of trees and underlying geology. Over much of the UK, anywhere the soil is neutral to slightly acid (roughly pH >5.5) we expect broadleaved trees (dominated by oaks) growing in a soil traditionally called a brown forest earth. The topmost layer of the soil carries the remains of last autumn's dead leaves and twigs, along with anything else that might land there. This layer can be picked up in your fingers – this is the L (for litter) layer.

A few millimetres deeper down are the fragmented remains of earlier autumns, mixed up with old faecal pellets from soil invertebrates that chew up litter fragments. Books assure us these can be divided into an upper F horizon (for fermentation) and a lower H horizon (for humus), though this is not easy to see. If you try to lift this entire organic layer with a trowel it tends to separate from the underlying mineral soil along the H horizon. Always these upper three layers are brown – the colour of dead leaves and humus - and together make up the O horizon (L+F+H = O).

In a brown forest earth this brown colour extends smoothly down into the soil, fading gradually with depth until ending maybe 20-40cm deep; the underlying mineral soil is usually paler. This is due to the endless burrowing of the larger species of earthworms, pulling organic material down and excreting subsoil at the surface. Here soil scientists distinguish an upper A horizon overlying a deeper B horizon, which itself overlies the bedrock, but these are not always easy to see. The old forestry system classifies these as mull soil.

Soils with coniferous trees

Acid soils (pH <5) with conifers growing have a very different soil profile – this is another very common pattern, especially in the north or at altitude. In these systems there are few if any earthworms, as they cannot cope with such acid soils. So organic matter falling on the soil simply lies there and decays slowly through the action of fungi and soil arthropods. Because there are no worms to pull organic matter down, the boundary between the organic layer and the mineral soil (where the litter layer meets the A horizon) is sharp, easily seen and teased apart. Older foresters call this a mor soil.

Podsol with black iron-pan

Coniferous needles decay more slowly than most broadleaves, creating a soft spongy layer of decaying needles 10-20cm thick. This tends to be heaving with vast numbers of tiny animals, mainly mites and springtails. A common variant, especially in upland areas, is where the site has been an acid mor soil for thousands of years. In this case the upper 10cm or so have the iron washed out by a chemical reaction called sequestration, in which complex organic molecules effectively kidnap metallic ions inside their molecular structure. This leaves a clean white upper layer overlaying a thin, hard, black iron-pan. Such soils are called podsols and, although attractively coloured, are well known for chronic infertility.

Differences in soil fauna

Along with these obvious differences in forest soil types come many differences in their associated biota. Just as botanists will tell you there is hardly a plant species in common between a lowland oakwood and a highland pinewood, so mycologists will tell you that the great majority of their fungi are equally different. The same is true for many life forms. The group of soil insects called springtails seem less fussy. But there are certainly some species that specialise in cold acid upland sites and at least one, *Lipothrix lubbockii*, seems to be an indicator of ancient woodlands.

Soils are dynamic, although slow to respond, and can easily be altered by changes in forest composition. If you can find a place where native woodland has been replaced by a coniferous plantation, compare the soils. The usual pattern is that the coniferous soil will have a deeper, more acid litter layer than pre-planting, and there will be a different selection of soil animals in the two sites. The expected response is to have fewer earthworms and more arthropods in the coniferous areas, but each case is different. These changes can take upwards of 30 years to become apparent – a brief blip on ecological timescales.

So next time you are in a wood, spend a few moments poking at the soil to see what you can learn from it. It has many stories to tell.

Lipothrix lubbocki inhabits ancient woodland soils

Earthworms in woodlands

Emma Sherlock & Keiron Brown

Earthworms are probably not the first creatures you think of when out on a stroll in your local wood. With all the leaf litter, you often cannot see them or even their telltale signs, such as casts and middens. Hopefully this article will mean although they might be out of sight, they will no longer be out of mind.

Many of us know the positive impact earthworms have on gardens and vegetable patches; such as breaking up the soil, converting nutrients to a form plants can take up more readily and generally making the world fertile and green. However, people may not think as much about the role they play in less 'green' areas. Their importance as decomposers cannot be underestimated; recycling nutrients back into the soil and breaking down dead organic matter.

As woods have so much organic matter sitting on the surface, there is a huge amount of work for them. They are also a hugely important part of the food chain, being a major food source for other species such as foxes, badgers, birds and a number of invertebrates.

A clew of worms

The role earthworms play in recycling and decomposing depends on their type. Earthworms tend to be split into four ecological groups:

- **Compost worms**: these would only be found in woods with lots of rich organic matter, such as manure.
- **Epigeic worms**: small red worms found on or near the surface of the soil, or in rotting logs and tree hollows. They breakdown organic matter directly on the woodland floor.
- **Endogeic worms**: pale grey, pink or greenish worms. They are usually found a few centimetres below the soil surface and are soil feeders. They consume the soil itself, break it down further and convert the nutrients to an accessible form for plants.
- **Anecic worms**: large worms that are deep red or black in colour dorsally.

Woodlands can house earthworms from all these groups. They may not support the greatest biomass of earthworms, but they often have the biggest diversity of species. This includes the rarer species, so woods are a great place for some earthworm spotting.

Aporrectodea caliginosa

Diverse and diverting

A common misconception is the belief there is only one species of earthworm. In fact, there are about 30 species living freely in the UK's soils. Other species can be found here, but these are confined to tropical greenhouses having been introduced to them from hotter regions. Some of them are found all over the UK and in most habitats, whereas others are far more specific.

Over half of the free-living earthworm species can be found in UK woods. These are unlikely to all be encountered in one survey. However, if different habitats are explored, every sampling visit is likely to be fruitful.

Dendrobaena octaedra

Here are some of the best methods for surveying different habitats and encountering the UK's many different earthworm characters:

Soil:

Unsurprisingly, one key method of earthworm sampling is to dig a small pit. It is best to use standard sized pits, for example 25cm x 25cm x 10 cm, and try to dig out an entire soil block. Then sort through the soil to carefully remove and identify any worms. The groups most encountered here are enogeics and epigeics. *Aporrectodea caliginosa* is a common worm found here and beneath many lawns.

Leaf litter:

Brush away a layer of the leaf litter and have a good look within and underneath it. Here the little red epigeic worms can be found busily working away. *Dendrobaena octaedra* is not very common across the UK, but in certain woodland areas it can really thrive.

Trees:

Look under the bark of trees and in hollows in the trees – yes earthworms can and do climb trees. Rotting logs are also good to explore; the worms can be found within the logs or directly under the bark and even in the organic matter collected within these areas.

Last summer Britain's smallest earthworm, a worm not seen in the UK for 32 years, reappeared in our woods in rotting logs. *Dendrobaena pygamea* was thought to be extinct in this country, but was recorded four times in 2015.

Dendrobaena

Microplana scharffi

Other methods:

- Use a dilute mustard solution on an area of cleared soil. This will help to bring to the surface any deep burrowing anecic species, but will not hurt the worms.
- Look under metal sheeting, rocks and old, fallen fence posts. Worms are often found lurking beneath them.

With all these methods, other types of worms may also be encountered. For example, in very waterlogged soils leeches may be found, or colourful flatworms under sheeting and rocks.

Their work is never done

The UK's earthworms are crucial to the health and vitality of our woods. So next time you are out in woodland, spare a thought for them actively working away beneath and around your feet, and even up in the trees.

Earthworm Society of Britain
DIG INTO THE WORLD OF EARTHWORMS

The Earthworm Society of Britain (ESB) is devoted to the study and conservation of earthworms. Despite being a favourite species of Darwin's, relatively little is known about UK earthworm distribution – compared with mammals, birds, butterflies and bees.

Therefore, in 2014 the ESB launched the National Earthworm Recording Scheme. So far, results show current thoughts about some species' habitat preferences, distribution and rarity are not entirely correct. Gaps are being filled, but much more information is needed. If you want to become an earthworm recorder you can attend an ESB Earthworm ID Weekend. For more information go to: www.earthwormsoc.org.uk

Ancient woodland soils

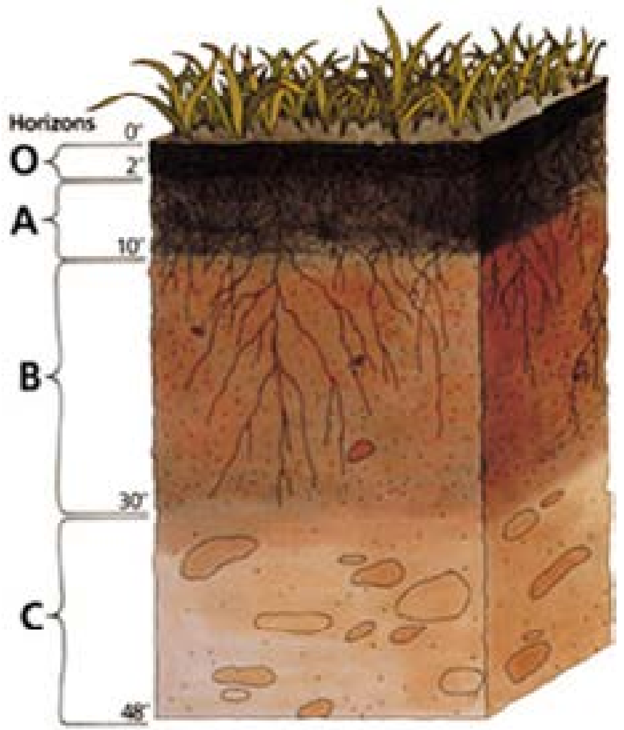
Kay Haw

Ancient woods are irreplaceable habitats and essential biodiversity reservoirs that provide important ecosystem services. Ancient woodland covers a tiny fraction of the UK's land mass and soils are a vital component, as the time (centuries or millennia) these soils have taken to form and their relative lack of disturbance means they are hugely complex and diverse.

Soils house a significant amount of the Earth's biodiversity and a sizeable percentage of life-supporting ecosystem services provided by them are actually delivered by soils' biotic community, which itself takes time to develop. This is found in the active rhizosphere of a soil profile, the section that most intimately interacts with plant roots and soil microorganisms.

Soil profiles

The image of the soil profile shows different horizons: O, A, B and C. There is another, R, beneath these which is the solid rock layer. Rhizosphere densities are highest in horizons A and B, as they are an oasis of organic matter and bioavailable nutrients that flora and fauna can use. However, the rhizospheres of many soils extend into



US Department of Agriculture-Wikimedia Commons

Soil profile

C to take full advantage of the lesser but still present resources there.[1]

The loss of soil profiles through ancient woodland destruction is a serious issue, as they cannot be recreated or translocated (discussed further below). For example, large scale land disturbance can irreparably damage the intricate networks of mycorrhizal fungal strands (key elements of the soil biotic community) that run through ancient woodland soils (see the *What lurks beneath your feet?* article on page 16).

These types of networks are essential to over 90per cent of plant life in the world, benefiting their growth and assisting in adaptations to altering climatic conditions.[2] They are also crucial in the recycling of nutrients in woodland ecosystems. Fungi are key decomposers and among the few organisms that can break down the tough structures of lignin and cellulose that give trees such robust structural support (see the *Fabulous Fungi* issue of *Wood Wise*, available online).

The translocation debate

Habitat translocation is described by Anderson (2003) as "the process of moving soils with their vegetation and any animals that remain associated with them, in order to rescue habitats that would otherwise be lost due to some kind of development or extraction scheme."[3]

There are other definitions and they all have subtle differences. For example, the Joint Nature Conservation Committee (JNCC) says "habitats translocation is here defined as the movement of assemblages of species, particularly plants (including the substrates, such as soil or water, on and in which these species occur) from their original site to a new location."[4] The key difference between the two is that Anderson refers to the movement of soil as the primary focus of translocation, whereas JNCC's emphasis is on the movement of plants.

A Woodland Trust literature review suggests those attempts to translocate ancient woodland have involved the removal of soil, and sometimes coppice stools or deadwood. However, whole trees and the vegetation associated with them have not been moved, and only certain protected species (e.g. dormice, *Muscardinus avellanarius*) rather than the huge wealth of species that do inhabit ancient woodland.[5]

To translocate soil it is generally scraped off the donor site and spread onto the receptor site. This causes great disruption to the soil profile and may render it an unviable habitat for target species to grow in. Disturbance of the

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Ancient woodland soil bank

soils also damages or destroys the complex interactions and associations within them, such as between the soil microbial communities. This disruption may well be a significant reason for the difficulties in viable habitat translocation. For example, as plants rely so heavily on their mycorrhizal partners the loss of these intimate relationships could have serious consequences for their survival.

No substitute for the real thing

None of the recorded ancient woodland translocation attempts have proved to successfully recreate the diverse and complex habitat that has been destroyed, and in no way compensates for the huge loss it results in. There is also a serious lack of published and peer-reviewed evidence around translocation. Therefore, the Woodland Trust argues for a precautionary approach and advocates no further loss of the dwindling concentration of ancient woodland we have left.

The argument that ancient woodland can be translocated is often put forward by developers keen to develop the land it grows on into roads, quarries, railways, etc. But Natural England states: "ancient woodland as a system cannot be moved". The complex communities found in ancient woodland are a product of the interaction between unique geographical and historical factors, which cannot be replicated. Current guidance is that habitat translocation is never an acceptable alternative to in-situ conservation.[6]

Ancient woodland restoration

Plantations on ancient woodland sites (PAWS) are those that were historically cleared and replanted with (in general) non-native tree species and/or invasive woody shrubs. This had an understandably negative effect on native woodland biodiversity. However, many of the planted tree crops are now coming to marketable maturity and there is a window of opportunity to restore these sites back to native woodland.

A key advantage of PAWS restoration over secondary woodland creation is that the land remains wooded and the soils relatively undisturbed. This retains some of the soil communities, networks and interactions that would be lost if the land was, for example, cleared then ploughed for agricultural use. So the essential foundations remain intact to enable the restoration of healthy and diverse ancient woodland ecosystems.

One problem for PAWS soils can be their acidification due to the build-up of dropped conifer needles. Surface soil acidification is associated with a reduction in the

PAWS management at Cadora Woods

species richness and abundance of vascular plants. It was also linked to increases in moss cover. This can have an impact on restoration of the habitat and must be taken into consideration.[7]

Gradual and careful restoration is key to effective management of PAWS back to native woodland. This ensures the protection of remnant features and the reduction of threats (see the *Ancient Woodland Restoration* issue of *Wood Wise,* available online). It is important that any restoration work, such as timber extraction, causes as little damage and disturbance to the soils as possible in order to protect the soil profile and biotic community.

Valuable but vulnerable

Soil is the foundation of an ancient woodland, the base from which all else grows and thrives. Yet there are still big knowledge gaps in our understanding of its processes and needs, and constant threats to its health and survival. To achieve total protection for ancient woodland may sound like a tall task, but when there is so little of it left can we really afford not to save it all?

[1] *Richter, D.D., et. al. (2007). Chapter 8-The rhizosphere and soil formation. In: Cardon, Z.G., Whitbeck, J.L. (Eds), The Rhizosphere, Academic Press, Burlington, p.p. 179-IN2.*

[2] *Amaranthus, M. (2013). Mycorrhizae: Are they right for me? Available online: http://mycorrhizae.com/wp-content/uploads/2013/03/Mycorrhizae-are-They-Right-for-Me-PDF.pdf*

[3] *Anderson, P. (2003) Habitat Translocation – A Best Practice Guide, Construction Industry and Research Information Association (CIRIA).*

[4] *JNCC (2003). A habitats translocation policy for Britain. Joint Nature Conservation Committee, Peterborough*

[5] *Ryan, L. (2013). Translocation and ancient woodland. Woodland Trust. Available online: http://www.woodlandtrust.org.uk/publications/2013/04/translocation-and-ancient-woodland/*

[6] *Natural England (May 2012) Standing Advice for Ancient Woodland, Version 3*

[7] *Forestry Commission (2003). Restoration of Native Woodland on Ancient Woodland Sites. Available online: http://www.forestry.gov.uk/pdf/fcpg014.pdf/$FILE/fcpg014.pdf*

Movers and shakers:

adaptation and survival in soil ecosystems

Thom Dallimore

There is a philosophical question that has plagued biologists since the formation of the idea of soil as a unique biological horizon. How do you define the soil ecosystem and what are its boundaries?

This may sound like a trivial question, as soil is very obvious as a material in itself and as children we are taught it is the stuff beneath our feet plants need to grow in. However, scientists, agronomists and conservationists are now testing these basic assumptions, and are discovering how fundamental these systems are across a multitude of scales.

Many of the functions of soils are unknown and those we do know about are too numerous to mention here. But they cover everything from atmospheric regulation to supporting vast food webs for larger creatures such as ourselves. It is the latter that brings us to a discussion about the complex adaptations that exist within these systems, and this is where the blurry definition of a "soil ecosystem" comes into play. It would seem nobody told the creatures that live in the soil they have been given their own ecosystem now.

An evolutionary dance

It would not be ridiculous to describe the special adaptations of soil fauna as a cross between the great creatures of the African savanna and the creative genius of the surrealist HR Giger (who designed the alien for the Alien movies). However, where plains mammals inhabit a relatively two-dimensional space with the boundaries of their existence pretty well defined, this is not so for plenty of our soil dwelling species.

The world of soil is complex and three dimensional, and where soil animals can live depends upon a great many factors. The structure and composition of soil is important. Therefore the types of plants that grow in these areas and the impact of larger creatures (such rabbits and humans, which are aptly referred to as 'soil architects') also affect the types of creature that can inhabit certain places. Most plants and architects require a soil ecosystem to live, and most soil ecosystems require architects and plants to provide structures to inhabit. Neither are mutually exclusive and both worlds are locked in a carefully intertwined dance for existence.

Where do soil fauna live?

The majority of soil species are small, such as springtails, mites and pseudoscorpions whose sizes can range from a tenth of a millimetre to the tiny giants who can reach several millimetres in length. Many of these species live an extremely wide-ranging existence, with some spending only a portion of their life within the soil itself. It is not unusual for soil fauna to be found floating at 50,000 feet in the air; ballooning in a similar fashion to spiderlings, hitching a lift on other more mobile creatures, or floating on the surface of seas and rivers. Many soil species are

Springtail, *Orchisella villosa*

Notiophilus germinyi

Leistus mouth

not as sedentary as first presumed but are indeed some of the most pioneering, being the first to inhabit barren lands.

Even creatures completely restricted to the soil live a very three-dimensional existence, and this is not surprising. Soil is often waterlogged after heavy rain or frozen on the surface during winter. The water table too can move up and down depending on the season. So the ability to survive complete submersion or to move freely between the different layers of soil can be vital for survival. The architecture of the soil is therefore also incredibly important for these animals who can be exceptionally vulnerable to soil compaction. Our great soil architects such as moles and worms provide important air pockets beneath the surface to provide channels for many soil species to move freely.

Adaptations for movement

The pseudoscorpions closely resemble their much larger namesake, but the poison-tipped stinger is absent and the resemblance is coincidental as they are only distantly related. At a grand 2-4 mm in size, they are voracious predators of the soil savanna and use their large (relative to body size) pincers to capture their prey of springtails and mites.

However, these tools are not just for dining, as pseudoscorpions are well known to clamp onto the legs of anything that moves faster than they do; flies, beetles and even tiny parasitic wasps. This is a method of dispersal known as phoresy and has allowed species of pseudoscorpion to disperse around the globe. Like a 1940s tram system, they simply hop off when they reach their stop.

Like the pseudoscorpion, the majority of soil fauna is small (less than 5mm) and with good reason. As you move through the litter and into the soil the available head room for the inhabitants becomes lower than a country cottage, and many species have taken on novel forms to deal with the lack of space.

Springtails that live mostly in the litter have relatively long legs and antennae, and use a long spring-like ornament called a 'furca' to evade predators. Their method of escape is by speed rather than strength. Deep soil springtails live in among the tiny soil pores and have adapted to this environment perfectly by having shortened antennae, stumpy legs and losing the ability to spring.

Like cave-dwelling invertebrates, many are blind and instead of eyes they have developed the use of chemicals such as pheromones as the main method of communication. Members of the *Onychiuridae* can produce noxious toxins that are ejected through a small circular organ called a pseudocellus to repel attack from predatory mites.

Springtails have also developed a special water repellent exoskeleton, which under a scanning electron microscope shows a wonderful hexagonal, waxy ridge that holds a layer of air against the body when submerged. This allows the springtail to breath under water when it is not possible to escape waterlogging. Humans are now trying to synthesise this unique ability to develop a new lightweight waterproof material.

Eat or be eaten

The predator-prey relationship of creatures that live within the soil is dynamic to say the least. Depending on whether you are predator or prey, you will almost certainly have a specialised weapon within your arsenal.

A group of small beetles known as *Notiophilus* have developed large eyes to allow them to gain a sensory advantage over their prey, usually springtails or mites. Indeed beetles show remarkable adaptations to capture their prey, which are often fast moving. Some springtail species are able to accelerate faster than a formula one car. *Leistus* beetles have developed a solution to this problem, mouthparts underneath their heads that form a basket of sharp inward pointing bristles. When a *Leistus* spots its springtail prey it pounces using its mouth as a sort fishing net to ensnare a wriggling dinner.

The tiny rove beetle *Stenus* has chosen a different method of predation. At first glance it looks much like any other rove beetle, however it is also has a taste for fast food. On spotting its dinner it ejects a long tongue-like apparatus from its mouth with all the unswerving accuracy of a chameleon. The end of the mouth is an intricate instrument with thousands of tiny sticky pads that adhere to its prey, preventing any escape. Once captured it draws its dinner back to its mandibles where it is subsequently devoured.

Oribatid mite

The mites, or Acari, are some of the most numerous of creatures on the planet and some of the most diverse. The oribatid mite is one of the plentiful of all and has a simple survival strategy. It is small (0.2-1 mm), round and has a hard sclerotized exoskeleton that is almost impenetrable by predators. It is a gentle, slow and long-lived grazer of organic material within the soil; the pigmy tortoise of the soil world.

Some mites are less benign than the oribatid, being swift predators that move rapidly through litter and soil pores. For example, gamasid mites (Mesostigmata) are quick and agile; in litter and soil they predate other small invertebrates such as springtails, nematode worms and other mites. Their mouth and digestive system only allows them to drink fluids, so they inject their prey with a digestive enzyme that turns their innards into microarthropod smoothie. The gamasid then sucks this up with a barbed, tube-like apparatus. Like the pseudoscorpion, gamasids are known to hitch a ride to aid in their dispersal. Despite being found all over the world, species numbers appear to be greatest in woodland soil ecosystems where their diversity can be a strong indicator of woodland health.

Significance of the small

Despite the fuzzy boundaries around soil ecosystems one thing is abundantly clear, whether it be a waltz or a Danse Macabre ('Dance of Death'), the interplay between soils and the more visible world should not be underestimated. New ideas about how to care for these micro-worlds will affect how we survive as a species. But take solace when you next walk through a UK wood - there are places secure for these worlds to jive and hopefully thrive.

The essential foundation:

caring for soils in woodland management

Sian Atkinson

Soil is a natural resource, an essential component in nutrient cycling in forest ecosystems. In managed forests, soil should be treated with care. It is the raw material on which the future of the forest depends, and while it is not renewable, it is sustainable if correctly managed. In ancient woods particularly, the relatively undisturbed soils are one of the key reservoirs of biodiversity, having developed over hundreds or thousands of years, and should be maintained or enhanced.

The UK's woods and forests are varied, from vast expanses of secondary conifer plantation across the uplands to small pockets of remnant native woodland in river valleys, to well-walked urban woods to small shelterbelts and copses on farms. Woodland owners and managers have almost as wide a range of different objectives in managing their woods, from nature conservation to recreation, or game management to timber and woodfuel production. Often it will be a combination of several objectives. Whatever the aims, though, it is essential to follow the principles of sustainable forest management, to guard and nurture the wood's biodiversity and the ecosystem services it provides.

Guiding soil sustainability

In the UK, the UK Forestry Standard sets out the requirements of sustainable forest management; practical guidance accompanies this in the form of guidelines on biodiversity, climate change, historic environment, landscape, people, water and soils .[1] Following the soils guidance will enable site managers to take all possible steps to keep their soils in good health, ensuring a sustainable future for their forest or wood.

In planning and carrying out woodland management, the following are important:

- Understand the soils on your site. What type of soil do you have, and is there variation across the site? What is the hydrology like? What types of species are appropriate for the soil, and are there areas of particular sensitivity?
- Take a long term view, thinking about the potential environmental cost of any activities throughout the life of the forest, rather than just the short term.
- How can you minimise soil disturbance during management activities? This might include through appropriate timing, where extraction routes are planned, types of equipment and machinery used, and so on.
- Consider the possible impacts of compaction and look to minimise this through appropriate choice of management techniques.
- Minimise contamination of soils through minimising use of pesticides and herbicides and following good practice in relation to storage and use of fuels.
- Look for positive opportunities to protect and enhance soils, for example through planting or appropriate management of riparian areas.
- Consider long-term fertility of the soil – removing all material from site can lead to depletion of fertility.

It is worth keeping up to date on the latest research. For example, Forest Research[2] carries out wide ranging research to understand how we can best protect and ensure the sustainability of woodland soils. This research underpins the development of guidance on woodland soil protection, and can provide soil analysis and advice on practical soil management.

Sustainable management - trees along watercourses stabilise soil


Poor soil health

[1] *Forestry Commission (2011). UKFS Guidelines on Forests and Soil. Available online: http://www.forestry.gov.uk/forestry/infd-8bvguk*

[2] *Forest Research (2016). Soil sustainability. Online content: http://www.forestry.gov.uk/fr/soilsustainability*

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What lurks beneath your feet?

Dr Fay Voller

When walking through woodland, many people do not realise the trees and most other plants they see are only able to grow due to their fungal partners.

These fungal partners spend all or nearly all their life underground, but they are nonetheless vital for the successful growth of the plant. This partnership is called mycorrhizal symbiosis and is the harmonic growth of specific fungi and plants together. Mycorrhizal simply means 'fungus-root'. At least 95 per cent of higher plants (vascular plants) form this symbiosis.

It is believed this mycorrhizal symbiosis was key in enabling plants to colonise land for the first time around 450-600 million years ago. The typical symbiotic structures plants and fungi form together have been found in early plant fossils from Scotland dating back at least 400 million years. Today, we know at least 6,000 fungal species form mycorrhiza with 240,000 plant species. Typically an individual plant will form mycorrhiza with several fungal species at the same time. In all mycorrhizal relationships there are benefits for both the plant and the fungus. Typically the fungus helps the plant obtain essential nutrients and water from the surrounding soil, while the plant provides carbohydrates (sugars) to the fungus to enable it to grow.

Plants and their fungal partners

Different groups of plants form slightly different types of mycorrhizal symbioses. The majority of woodland trees, including pine *Pinus* spp., birch *Betula* spp., beech, *Fagus sylvatica*, and oak, *Quercus* spp., and specific fungal species (mostly Basidiomycetes that typically form mushroom fruiting bodies) form ectomycorrhiza. Here the fungi grow around the tree's small root tips to form a sheath. Some hyphae (the long filaments that make up the true body of a fungus) grow between the root cells, while others spread out into the soil. In an ectomycorrhizal relationship fungi provide the tree with nutrients, water and protection against soil pathogens.

Hyphae

Common yellow russula, *Russula ochroleua*

Most plants, about 80 per cent, form a relationship called arbuscular mycorrhiza with a group of fungi (Glomeromycota) that do not produce the large fruiting bodies that add colour to woodlands in the autumn. In this relationship the fungi form specialist structures inside the plant's root cells.

The beautiful orchids seen in some woodland are only able to exist because of their relationship with fungi. Orchid seeds can only germinate if their fungal partners are present. The orchid seeds are so small that they do not have sufficient nutrients to allow the seed to germinate without the fungal partner providing the energy required in the form of sugars. Therefore, at the start of the relationship only the orchid plant benefits, but once the plant is mature enough it will start providing carbohydrates to the fungus from photosynthesis.

Fungi supporting tree survival

A tree can receive over 60 per cent of its nitrogen, an essential element for plant growth, via fungi. Fungi are also far better adapted at obtaining phosphorus from the surrounding soil than their plant partners; therefore the plant obtains most of its phosphorus via the fungi. In return the plant provides the fungus with up to a fifth of the sugars it has produced via photosynthesis.

An individual tree root can be colonised by several different species of fungi at the same time. Many of these ectomycorrhizal fungi are the typical woodland fungi such as *Amanita*, *Russula* and *Boletus* species. An individual tree species such as Scots pine can form the ectomycorrhizal relationship with 20-40 fungal species. It is not known whether different fungi perform slightly different roles for the tree. There is evidence that different fungal partners may be present at different times during a tree's development.

Within the soil, the mycorrhizal fungi also form underground networks between trees. These might be between seedlings and a mature tree, between a small group of plants of different species, or between a small group of plants that do not have the ability to photosynthesis their own sugar and a plant or plants that are photosynthetic. These non-photosynthetic plants, which are white rather than green, get all their carbohydrates through fungal links to other plants that they essentially steal from, such as the ghost orchid, *Orchis aphyllum*.

As well as being essential for plant growth, there is evidence that mycorrhizal fungi are involved in soil formation, plant community structure and plant diversity maintenance. However, despite their vast importance there is still a lot we do not know about the mycorrhizal relationship. Surveying trees in a woodland is relatively simple, but for the more cryptic fungi they associate with we still do not have answers to some of the basic questions.

Trees will have several different species of fungi colonising their roots at any one time, do different fungal species do different jobs for the tree? How are the different fungi distributed over time and space in a woodland? What will be the impact of climate change upon the fungal species present?

So next time you are enjoying the flora of a woodland, spare a thought for the fungi efficiently working below ground to keep the plants alive.

Common spotted-orchid, *Dactylorhiza fuchsia*

Decomposition of leaf litter returns nutrients to the soil

Soils and trees:

a win-win situation

Dr Judith Garforth

Trees depend heavily on the soils they grow in, but trees are also beneficial for soils and the flora and fauna that live in them.

Soils supporting trees

It is thought that trees need 16 essential elements for healthy growth. Trees obtain two of these elements, carbon and oxygen, from carbon dioxide in the atmosphere during photosynthesis. The remaining 14 essential elements, such as potassium and calcium, are sourced from the soil in which the tree grows.

For example, trees take up nitrogen and phosphorus from the soil and use them to build amino acids and proteins, the building blocks of DNA. Trees also take up magnesium from the soil; a key component of chlorophyll - the pigment that creates a leaf's green colouration and its ability to photosynthesise to generate energy.

Soil is a complex mix of mineral particles, organic particles, water, air and living organisms. Essential elements are taken up by trees through their roots, dissolved in the soil water, or transferred to the tree by mycorrhizal fungi. These fungi particularly enhance the uptake of phosphorus, which can otherwise often be a limiting factor in tree growth.

Generally, woodland trees rely heavily on nutrients that build up in the soil through natural processes. Most of the essential elements come from the mineral particles in the soil (the broken down rock from which the soil was formed). Others come from the decomposition of dead, organic materials. Nitrogen is 'fixed' in the soil as a result of the activity of soil bacteria, which can convert the unreactive nitrogen gas in the atmosphere into a plant usable form in the soil.

There can also be some human influence, because fertiliser run-off from agricultural land can increase the concentrations of nutrients entering woodlands soils. However, high concentrations of fertilisers can suppress the formation of important mycorrhizas.

Trees also rely on soils to anchor their roots into the ground, providing structural stability to the trunk and branches to help prevent them falling during high winds. Roots of mature trees are thought to extend to as far as two and a half times the radius of the tree crown.

Nutrient recycling

In natural environments, such as woodlands, many of the essential elements taken up during the life of a tree are returned to the soil when the tree dies. When a tree falls to the ground and is broken down and decomposed, the nutrients are released back into the soil. These will then be taken up by living trees, in a continuous nutrient cycle.

Alder trees have a symbiotic association with nitrogen fixing bacteria *Frankia alni*, which are found in their root nodules. These bacteria can fix atmospheric nitrogen into a plant-usable form.

Soil being washed from fields during heavy rainfall

Trees may help with nutrient cycling in agroforestry – the growing of trees in association with food crops. It is thought the trees may bring nutrients from deep in the soil (only accessible to the deeper tree roots) to the surface layers, which benefits the shallow-rooted crop plants, when leaf litter is deposited on the soil surface and decomposed.

However, the benefits of agroforestry are an area of on-going research and experimentation, as there are also potential drawbacks and it is important to strike the right balance. For example, the trees will compete with the crops for nutrients and water, and nutrients will be removed from the site if they are harvested for wood, much like crop plants.

Providing essential stability

Strong and intertwining tree roots help hold soil together, providing structural stability. This is especially important in hilly areas and along riverbanks, where heavy rainfall events can wash away and seriously erode soil layers.

Trees can be used to help prevent loss of soil from agricultural land. A staggering 2.2 million tonnes of topsoil are thought to be eroded from the UK's land every year. Soil can be washed off bare fields by surface water runoff and along drainage channels. This affects the soils ability to support plants, as, like trees, crops also require many of the essential elements found in soil for healthy growth. So erosion reduces the long-term fertility of soil by removing the nutrient-rich topsoil and organic matter.

In the right places, trees provide a physical barrier to the movement of soils. For example, hedgerows can trap soil on the land and prevent it entering it waterways. Also, trees can improve the rate of water infiltration into the soil, as their roots create channels along which the water can run and penetrate the soil more rapidly. This can reduce the amount of surface water during heavy rainfall events, which can help reduce flooding and erosion through runoff.

The soil stabilisation benefit of trees may prove useful in the remediation of sites with contaminated soils. If trees can be planted to reduce wind erosion, leaching and surface water runoff they may help to stabilise the soil in contaminated sites. This reduces the movement of soil pollutants from the site into waterways and other areas.

A game of winners

Trees and soils have an intimate relationship that has evolved over millennia. We are only just starting to fully appreciate its importance and complexity. But one thing is clear, there are winners on both sides.

Soil erosion from an arable field that becomes a watercourse in heavy rain

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