The UK Forestry Standard

The governments' approach to sustainable forestry

Forestry Commission
Scottish Forestry
Coilltearachd na h-Alba
Cyfoeth Naturiol Cymru
Natural Resources Wales
FOREST SERVICE

8. Forests and Soils

Soil is a fundamental component of the forest ecosystem. It is a complex and variable medium comprising mineral particles, organic matter, water, air and living organisms. The characteristics of the forest's soil largely determine the nature of the flora and fauna that live in it, sustaining its biodiversity and its productive potential. It is a vital but fragile resource that must be used in a sustainable way by knowing and working to soil type and condition.

Soils in the UK

Geology, topography, historic human activity and climate all play a part in creating the many different soil types found across the British Isles, which often vary within short distances. The physical, chemical and biological properties of soils are continually modified by a number of natural processes, which include leaching, waterlogging and the addition and decomposition of organic matter. Soil is a valuable habitat in itself and it forms a living system that includes organisms belonging to many plant, animal and microbial species.

The actions and complex interactions of soil biota help to maintain the nutrient, energy and water flows that support the forest ecosystem. Soils provide an important filtering and buffering action that protects other parts of the ecosystem from pollution and damage, and they can be a major source or sink of carbon dioxide and other greenhouse gases. Some of the least disturbed soils in the UK are found in ancient woodlands, untouched by agriculture for hundreds of years.

Forest soils

For the purpose of the UKFS, 'forest soils' are defined as those soils supporting forests, including post-industrial, or brownfield, soils that are being restored. Historically, UK forests tend to have survived on, or have been planted on, ground of generally poorer quality than agricultural land, for example, steep slopes, peats and gleys subject to periodic waterlogging, and low nutrient podzols and ironpan soils (see Glossary). A smaller proportion of forests are located on better, well-drained brown earth soils, particularly in England and Wales. Forests created in recent decades for social and environmental reasons have often been established on a wider range of soil types.

Forest soils are usually slightly acidic, unless underlain by calcareous rock or sediment. Inputs of atmospheric pollutants, particularly sulphur and nitrogen, can have significant impacts on acidity and nutrient status. Forest soils naturally have a high organic or carbon content, on average about 75% of total organic carbon contained in the forest. Climate change has the potential to affect forest soil function both directly and indirectly. Rising temperatures can accelerate mineralisation rates and soil nutrient availability, while nutrient leaching may be enhanced by higher winter rainfall. Increasing soil moisture deficits in summer could decrease both nutrient uptake by trees and leaching losses. The risk of physical soil disturbance and erosion may increase as a result of greater run-off, waterlogging and windthrow, especially if the frequency of storm events increases. All of these effects will have implications for the nutrient and carbon balance of forest soils.

In general, forest soils have low and infrequent levels of disturbance, particularly under a LISS such as continuous cover forestry. However, some forest management activities, such as cultivation, drainage, harvesting and engineering works, can impact on forest soils or expose them to greater risk, for example, erosion after intense rainfall. More subtle changes to forest soils can be induced by species choice, stocking density and brash management.

Some practices may also result in a short-term loss of soil carbon until this is replaced over the rotation as the forest grows. Deep peat is particularly vulnerable to disturbance and the process of woodland creation will generally result in a net loss of stored carbon.

Some high impact forestry practices, such as excessive ground preparation and regular applications, are no longer acceptable within modern forest management standards. Identifying the extent and distribution of different soil types is essential to help make decisions about which tree species are ecologically suited to the site under a changing climate – meaning that the ecological requirements of different tree species and woodland communities can be met by the site, and thus sustainable forest management practised. Managers should seek to match the species to the site rather than alter the site to suit the tree species.

Cultivation should only be used where it is clearly demonstrated to be the most effective means of providing a favourable environment for tree survival and early growth. Where soil cultivation is required, the least intensive method possible should be used to successfully establish woodland.

Brownfield soils

Brownfield soils are those that have been used for industry or development in the past. They are likely to have been substantially modified physically, chemically and biologically by their previous use. Forests provide a way of reclaiming post-industrial areas and establishing a productive and environmentally beneficial resource. However, the restoration of brownfield sites can present a range of challenges: the soils can be very acidic or very alkaline, contain toxic compounds or low levels of organic matter, and be either too compact or too loose. Successful restoration often requires intensive management and the importation of soil or soil-forming materials from elsewhere. Brownfield site restoration is thus a complex task and one that requires specialist input. The UKFS takes the remediation of brownfield land to be a specialised arena and beyond the capacity of the forestry sector to address without appropriate expertise.

Forest soils and ecosystem services

The term 'ecosystem services' describes how ecosystems and the biodiversity contained within them produce a range of resources useful to people. Forest soils provide a number of ecosystem services, including:

- A store of carbon: organic matter is accumulated in the soil itself and in the wider forest ecosystem that soil supports.
- A growing medium for trees: forest soils provide physically, chemically and biologically for tree growth and forest products.

- Water management: the high infiltration capacity of most forest soils helps to reduce rapid run-off, with potential benefits for managing local flooding and controlling or abating diffuse pollution.
- A historical archive: forest soils may contain archaeological and palaeo-environmental evidence of the past.
- Revitalisation of derelict or neglected land: woodland creation and the development of forest soil on derelict or neglected land can play a vital role in economic regeneration.
- Habitat creation and restoration: forest soils support the creation and restoration of habitats for flora and fauna and soil biodiversity.

Maintaining these ecosystem services remains a challenge, and work is underway to develop methods for assessing the specific role of soils in their delivery.

UKFS Requirements for Forests and Soil

Waste management

Country waste management regulations apply to sewage sludge and other waste materials (such as waste soil, bark, wood or other plant material) that may be applied to forest or other soils. Any operations covered by these regulations must be registered with the relevant authority. Exemptions may apply for the application of materials not considered to be 'waste', such as approved or acceptable use of brash and some composts, providing these ameliorate the soil. Sewage sludge may be applied to forest land, providing this results in ecological improvement and does not cause levels of potentially toxic elements in soils to exceed those permitted under the regulations.

1 The regulatory authority must be consulted prior to the application of wastes to forest soils, including sewage sludge, waste soil, waste wood, bark or other 'listed substances'; conditions applied to permissions or licences, including 'relevant objectives', must be complied with.

Soil protection

The physical structure of a soil affects the movement of gases, water and nutrients. A good structure is vital for soil fauna and the growth and reproduction of trees and other flora. Ancient woodlands in particular are a valuable resource of relatively undisturbed soils, which are likely to be of high biodiversity value. The nature and structure of soil is strongly influenced by the amount and quality of organic matter present and by the inorganic constituents of the soil matrix. These also determine the chemical properties of soils and soil fertility.

Soil fauna and microorganisms play a vital role in the retention, breakdown and incorporation of organic matter and influence soil structure and porosity. Soil microbial activity is also directly linked to carbon and nutrient cycles and breakdown of pollutants. A decline in levels of soil organic matter can lead to an increase in the susceptibility of soil to compaction, lower infiltration rates and, possibly, increased run-off or erosion. Climate change projections of rising temperatures suggest that these could accelerate mineralisation rates and soil carbon loss.

Woodland creation and forest management, as well as changes in environmental conditions, can have impacts on soil structure and fertility, including influencing the availability of nutrients and the capacity of soils to buffer adverse effects. Forests can increase soil organic matter and ecosystem carbon through large inputs of decomposable material such as foliage, woody material and fine roots. However, soil disturbance, erosion, forest fires and harvesting or burning brash and stumps can impoverish soil organic matter, in turn reducing soil carbon stocks and increasing greenhouse gas emissions. Cultivation and drainage pose a particular risk of depleting the organic content of peaty soils through soil drying and oxidation, and the carbon cost of different cultivation and drainage methods is increasingly recognised.

Note that the hydrological continuity of peat soils, not just peat depth, should be adequately accommodated in planting proposals. This is especially important in areas where adjacent peatland restoration and woodland planting is simultaneously proposed.

1 At planning and operational stages, the quality of forest soil in terms of its physical, chemical and biological properties should be protected so that it is maintained and, where appropriate, enhanced.

2 Forest operations should be planned and managed to minimise compaction and damage to soil structure and function by using appropriate measures. Should damage occur, reinstatement should be undertaken and adverse effects mitigated.

3 The environment adjacent to forests should not be subject to adverse effects due to soil disturbance associated with woodland creation or forest management practices.

4 New forests should not be established on soils with peat exceeding 50 cm in depth – or a depth specified in country guidance – or on sites that would compromise the hydrology of adjacent bog or wetland habitats.

Note: woodland creation on certain sites where deep peat soils have historically been highly modified may be considered, provided that it complies with the relevant country policy.

UKFS Guidelines on Forests and Soil

Acidification

Forests in the UK tend to occur on poorer soils that, particularly in the uplands, are often characterised by their natural acidity. Long-established forests on neutral soils usually develop a marginal acidity of surface layers due to the enrichment of the soil with organic matter. This natural acidity reflects normal forest processes and rarely leads to any adverse effects.

However, the addition of acidity to the environment, largely from atmospheric pollution, can result in soil acidification. This leads to a gradual depletion of calcium and other soil base cations from the surface layers and a reduction in the natural ability of soil to neutralise or buffer acidic inputs. Enhanced soil acidification generally has adverse effects, leading to:

- decreased pH of water draining from the soil, which can harm aquatic organisms;
- increased aluminium and heavy metal mobilisation, which can be harmful to tree roots and aquatic organisms;
- a reduction in tree growth and changes to the ground flora;
- a change in the predominant groups of soil organisms.

Whole-tree harvesting and the removal of harvesting residues can further reduce the ability of soil to buffer acid deposition. Repeated cropping for short rotation forestry or coppice could also lead to the acidification of sensitive soils if base cations are not replaced by soil treatments. Artificial and non-permanent measures can be taken to combat soil acidity, including the controlled application of liming materials.

1 On soils classified as at high risk of increased soil and water acidification, avoid short rotation forestry or short rotation coppice, and the harvesting of whole trees, forest residues and tree stumps.

Contamination

Contamination arises when soils become contaminated from the introduction of waste or polluting substances that cause instability and harm. Potential contaminants of forest soils include fuel oils, lubricants, pesticides and other chemicals, sewage sludge and inorganic nutrients. Pathogens such as faecal coliforms (from sewage sludge) can be a source of microbial contamination. Contaminants can have a range of adverse impacts on soil function and tree growth, water quality and public health. For all operations involving the use of potential contaminants, a risk assessment should be undertaken when planning operations to eliminate or minimise the risk of soil contamination.

It is a requirement of the UKFS that a plan is in place in case of spillages, to help limit incidents and ensure clean-up procedures are effective. It is also a legal requirement to have permission before some potential contaminants (e.g. sewage sludge) are applied or the aerial application of pesticides takes place.

On brownfield sites, forests offer a beneficial land-use option for site restoration, but some industrial sites have high levels of contaminants and dealing with them requires specialist advice beyond the scope of the UKFS.

2 Plan and use risk assessments to eliminate or minimise the risk of contamination of forest soils; have contingency plans in place to deal with accidental spillage and pollution.

3 Place any waste or recovered oil in an impermeable container and remove from the site for disposal at a suitable licensed site.

4 Where it is necessary to store fuel oils on site temporarily, use double-skinned or bunded lockable tanks and place them well away from watercourses.

5 When restoring brownfield sites, seek specialist advice, especially if measures are needed to ameliorate excess soil acidity.

Compaction

Soil compaction is an increase in soil bulk density and a reduction in pore space due to compression. This affects the movement of water and air through the soil, reducing water infiltration and storage, and increasing the risk of water run-off and erosion. Compaction may also affect the growth and functioning of roots and soil organisms, which in turn can adversely affect tree stability and growth. Natural processes such as freeze–thaw cycles, wetting–drying cycles and root penetration can mitigate compaction and, in some situations, these processes can restore soils to their original condition over time. However, on some soil types, compaction is virtually irreversible.

The ground pressure of heavy machines used for harvesting or forwarding timber can compact the soil and cause rutting and puddling (peaty and clayey soils being the most vulnerable), particularly with frequent passes over a sustained period and when logs are skidded along the ground. Compaction to topsoil can usually be ameliorated, but damage to the subsoil (greater than 20 cm depth) is more difficult to rectify. Brownfield sites are often subject to repeated vehicle traffic during restoration, leading to severe compaction. Soils with a previous history of intensive grazing can be compacted and agricultural ploughing sometimes leads to a compacted layer just below the reach of the plough. Soil stacked temporarily, for example, for road construction and mineral extraction, can become compacted and degraded if it is stacked too high and for too long.

Compaction, leading to rutting and erosion, can be minimised by good planning and management of forest operations, such as using extraction routes made from layers of fresh brash to spread the load. A well-designed road infrastructure, with stacking and turning areas, will help minimise skidder haul tracks and other incidental causes of compaction on forest soils. Machine choice and working method affects the ground pressure and the risk of damage. Wheeled vehicles pose the greatest risk, but the use of lower tyre pressures and controls on the frequency and speed of vehicle movements can reduce this. Tracked vehicles exert less ground pressure, while cable extraction poses virtually no risk of compaction and is the least environmentally disruptive for particularly sensitive sites. Dry soils have a greater bearing capacity than wet soils and so harvesting in dry periods reduces the risk of compaction. Compacted soils may require remedial treatment, such as subsoiling, carefully matched to the depth of compaction, to minimise the extent of disturbance.

6 Minimise compaction, rutting and erosion during forest operations by selecting the most appropriate working method for site conditions; monitor operations and modify, postpone or stop procedures if soil damage starts to occur.

7 On sites vulnerable to compaction and erosion, consider the weather and avoid working during periods of heavy or exceptional rainfall; plan ahead for changes in the weather that could affect site conditions, and suspend operations if necessary.

8 Maintain adequate brash mats throughout extraction where operations provide this material. If brash is not available, use other techniques to protect the soil.

9 Where compaction has occurred and will affect tree growth or lead to other detrimental effects, apply remedial treatment, but minimise the soil disturbance involved.

Disturbance

Soil disturbance is defined as any activity that mixes or moves soil material. Disturbance affects a wide range of soil characteristics and processes by altering the continuity of soil pores and the relative position of soil material. Various forest operations and engineering works disturb the soil, including cultivation and drainage, and these operations are now considered alongside species choice at the planning stage so that soil disturbance during site preparation for afforestation or restocking is minimised.

Cultivation is used to improve tree survival and growth by preparing a favourable, elevated planting site above the water table (it does not, nor should it be used to, lower the water table). This can increase permeability, rooting and nutrient availability. Drainage is carried out to collect and remove excess water, to reduce the local water table and provide greater rooting depth.

Although soil disturbance can assist with forest management, it can also have a range of detrimental effects, including:

- releasing greenhouse gases through the oxidation of soil organic matter, damaging soil structure, and increasing the risk of erosion, leaching of nutrients and contaminants;
- water pollution;
- destroying palaeo-environmental and archaeological remains;
- subsidence/shrinkage of peat soils.

Removing tree stumps disturbs and can damage forest soils; there is a presumption against this, and it should not be carried out unless a site assessment has been undertaken. However, on some sites stump removal may be necessary for tree health reasons (e.g. controlling the fungal pathogen *Heterobasidion annosum*) or for the restoration of formerly afforested peatlands.

10 Base forest management decisions on an informed knowledge of its soil types.

11 Consider the potential impacts of soil disturbance when planning operations involving cultivation, harvesting, drainage and road construction; minimise the soil disturbance necessary to secure management objectives, and amend practices to manage the risks posed.

12 Avoid removing stumps unless for tree health reasons or the purposes of restoration, or where a risk-based assessment has shown that adverse impacts on soil carbon can be mitigated.

Erosion

Forests have an important role in helping to reduce the risk of soil erosion – risks that are likely to increase with climate change. This is because:

- tree canopies reduce rainfall intensity on the soil;
- windbreaks reduce erosion of agricultural soils;
- riparian woodland stabilises riverbanks and reduces soil erosion;
- buffer areas along watercourses reduce diffuse pollution from agriculture.

Conversely, care is required to ensure that the type of forest and choice of management regime do not increase the potential for erosion and landslips on vulnerable sites.

Soil erosion results in a loss of rooting medium, including nutrients and organic matter. This has several potentially detrimental effects to the forest environment, downstream water bodies and surrounding areas. These include the formation of erosion scars, water pollution through sedimentation and nutrient enrichment, and loss of habitat and greenhouse gases. Most soil erosion is caused by water flows, but wind can also erode soil. Trees can be useful as windbreaks in exposed areas with light soils and to stabilise windblown sands on the coast. Erosion can be increased by poor forestry practice and is likely to be worsened by the more frequent and severe extreme weather events as the UK's climate continues to change. By contrast, well-managed forests can stabilise soil and protect it from erosion.

Erosion is likely where the vegetation cover is lost, and ruts and water channels concentrate and accelerate water flows. These conditions often occur after clearfell or during site preparation for woodland creation, especially when creating steep gradients or linear channels, for example, by ploughing.

On steeper slopes, trees and shrubs have an important role in reducing the risk of landslip. The binding action of roots increases soil strength and the canopy helps intercept rainfall and reduces soil wetness. Employing a LISS will help to reduce the risk of slope failure and erosion by maintaining a protective cover of vegetation. Clearfelling has the opposite effect, by removing the protective canopy and causing the death of tree roots.

The risks of soil erosion, together with those of compaction and disturbance, can be minimised through effective forest planning, at both a forest and site level. The choice of silvicultural system, design of riparian areas and timing and arrangement of felling coupes, all affect the risks. At a site level, planning detailed arrangements and contingencies for operations such as forest cultivation and drainage, harvesting and engineering, will help ensure erosion does not become a problem.

13 Consider woodland creation to protect erosion-prone soils, stabilise slopes and intercept sediment run-off from upslope.

14 Address the risks of soil erosion as part of the forest and operational planning processes, ensuring mitigation measures are implemented when the soil will be exposed.

15 On steep slopes where there is a risk of slope failure or serious erosion, use native species and low impact silvicultural systems including continuous cover forestry where possible.

Soil fertility

Soil fertility is defined as the amount, availability and balance of nutrients required for plant growth. The availability reflects the soil conditions as modified by nutrient inputs and outputs, and the effect of soil micro-organisms. Nutrient inputs include the breakdown of organic matter, the weathering of mineral particles, water inflows, atmospheric deposition and the application of fertilisers. The principal losses are from the removal of timber and harvest residues from the site, soil leaching and erosion, and gaseous emissions.

Fertility has a major influence on the nature of forest ecosystems and their flora and fauna. The use of fertiliser in UK forests has generally declined in recent years because nutrient deficiencies are less common in the subsequent rotations of productive forests, and there is less new planting on marginal sites of low nutrient status. The UKFS seeks to minimise the use of chemicals such as fertilisers in forestry, and tree species should be selected based on their tolerance of existing nutrient levels rather than manipulating the site to support species with larger demands.

The loss of nutrients can undermine the long-term productivity of some forest sites. Most nutrients in a tree are contained in the crown and foliage and these are normally left on site after harvesting. However, whole-tree harvesting and the removal of forest residues such as brash and tree stumps can contribute to a net loss of nutrients and impoverish the soil, particularly where naturally nutrient-poor and shallow soils coincide with high rainfall. The removal of forest residues by burning or harvesting of woody biomass under short rotation coppice and short rotation forestry systems can similarly deplete nutrient levels.

In general, forests are effective at retaining nutrient inputs but problems can arise if fertiliser run-off or nutrient leaching leads to eutrophication or enrichment of watercourses. This is most likely when heavy rain follows fertiliser application, especially on steep topography. Atmospheric nitrogen deposition can sometimes exceed the absorption capacity of a forest, leading to soil nitrogen saturation and nitrate-enriched run-off.

16 Unless the site is part of an approved peatland restoration project, ensure the removal of forest products from the site, including non-timber products, does not deplete site fertility or soil carbon over the long term and maintains the site potential.

17 Choose tree species and silvicultural systems that are well suited to the site and, with the exception of short rotation forestry or short rotation coppice, do not require continuing inputs of fertilisers.

18 Minimise the use of fertilisers and confine these to areas where analysis clearly shows management benefits; if they will be used, plan applications to minimise the risk of nutrient loss.

Organic matter and soil carbon

Soil organic matter is made up of compounds that originated from living organisms and is distinct from inorganic or mineral material. It includes plant and animal residues at various stages of decomposition, substances produced by plant roots, roots themselves and living soil organisms. The organic matter content of soil affects:

- Physical properties – including structure and water-holding capacity.
- Chemical properties – including carbon content and the retention of nutrients and contaminants.
- Biological properties – including the nutrients and energy available for plants and animals.

In general, forest soils contain high levels of carbon and maintaining forest cover will help ensure these stocks of carbon are protected. Forest management methods that minimise intervention and create less soil exposure (e.g. LISS) will help preserve soil carbon stocks, and the continual input of organic materials from decomposable material such as foliage, woody material and fine roots will gradually increase the soil carbon content.

However, soil organic matter can be impoverished through disturbance, erosion, forest fires and the harvesting or burning of brash and stumps. Cultivation and drainage pose a particular risk of depleting the organic content of soils, especially peaty soils, through soil drying and oxidation. This causes the soil organic matter to decompose, which releases carbon dioxide. This effect is most marked in deeper organic or peat soils, although it is important to consider the fluxes of all the greenhouse gases, especially methane.

On most soils, long-term carbon gains from woodland creation are likely to outweigh initial carbon losses due to soil disturbance. The carbon benefits associated with woodland creation are generally greatest on soils with low levels of organic matter, such as mineral soils. On some peat soils the magnitude of soil carbon losses due to cultivation can be greater than carbon uptake by tree growth over the long term. Oxidation and degradation can also result from changes to the local hydrology by planting adjacent to these sites. For this reason, and for reasons of habitat and biodiversity value, there is a general presumption against woodland creation on deep peat soils. More detailed policies on this are determined at a country level.

The decision to restock (or regenerate) forests on deep peat should be carefully considered, taking into account the balance of benefits for carbon and other ecosystem services. In some situations, for example, on sites with certain conditions of soil type, peat depth, area, slope or tree growth, restocking on deep peat can lead to positive ecosystem gains – including for carbon. Decisions will be taken on a site-by-site basis in line with the detailed policies for restocking on peat soils that are determined at a country level.

19 To minimise soil carbon loss, employ techniques for ground preparation that create the minimum amount of soil disturbance but are still adequate to ensure successful establishment.

20 Consider, informed through tools such as a peat assessment, the balance of benefits for carbon and other ecosystem services before making the decision to restock (or regenerate) on soils with deep peat, ensuring the decision complies with relevant country policies.