Geo Factsheet

Number 35

Forests and Soils

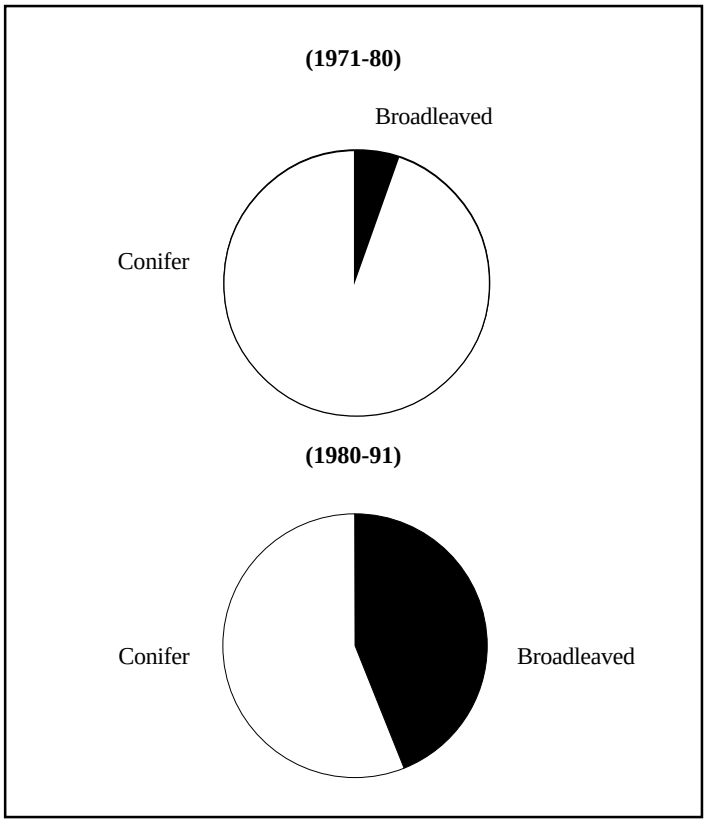
Forests may have a dramatic effect on the characteristics of the soils on which they are grown. However, different types of forests and different management practices exert very different effects.

1. The impact of conifer plantations in the UK

Between 1945 and the early 1970s, the vast majority of afforestation involved the planting of exotic conifers, rather than our native broadleaves. Such conifers were often planted on the poorest land (since greater profits could be made from agriculture on all other types of land) and involved the growth of coniferous species such as Sitka spruce and Norway spruce. Coniferous species were used because, keeping their needles all year round, they were potentially able to photosynthesise all year round and hence, showed greater productivity. Such trees were also more tolerant of the nutrient deficient soils, low temperatures and high wind speeds of the uplands in which they were often grown.

Since the 1980s this trend towards conifer afforestation has been reversed. The environmental harm caused by such plantations, along with the changing objectives of UK forestry has resulted in a decline in conifer afforestation and a rapid increase in the use of native broadleaves such as oak (Fig 1).

Fig 1. Broadleaved/conifer mix of planting Great Britain



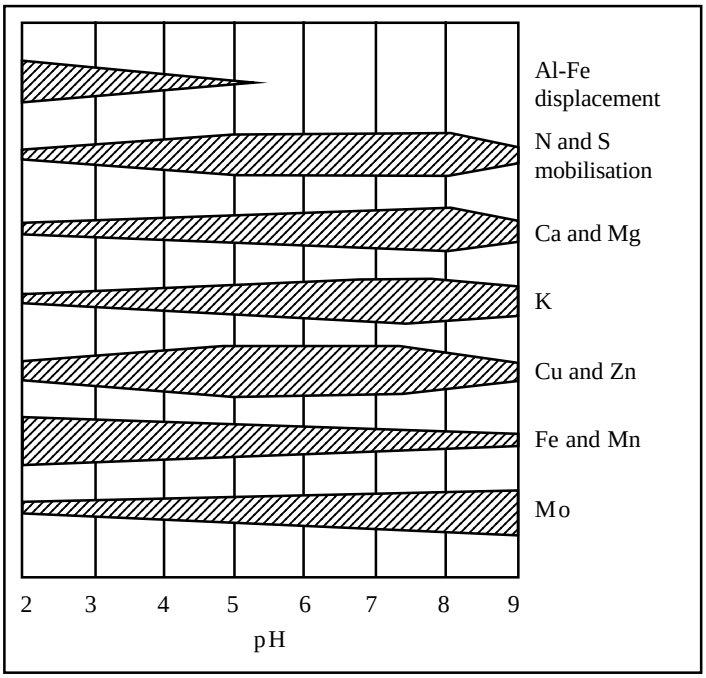
However, since large areas of the Welsh and Scottish uplands remain covered in coniferous monoculture, it is well-worth considering the effect such plantations have on the underlying soils, the consequences this may have for their future productivity and their implications on, for example, water quality within catchments.

The general effects of conifer plantations in the UK uplands are as follows:

(a) Soil Acidification.

This is the result of the interception or scavenging of acidic pollutants by the forest canopy. Coniferous forests are more efficient pollution scavengers than deciduous forests, simply because most coniferous species (excluding larch) retain their needles all year round. Dry deposition, (eg. sulphur particles) can be filtered out. These may then dissolve in rain water and reach the soil beneath the canopy through stem flow or leaf drip. As soil pH decreases, the solubility of cations such as Al^{3+}, Ca^{2+}, Mg^{2+}, Pb^{2+} and Mn^{2+} increases (Fig 2) and this, in turn, may cause a number of environmental problems.

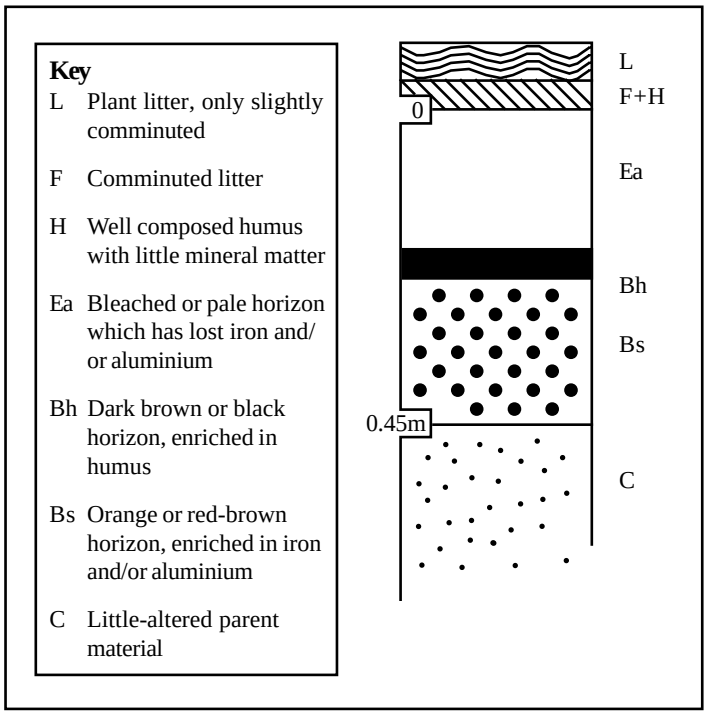
Fig 2. Influence of soil pH on the solubility of ions
(the wider the bar, the greater the solubility)



Heavy metals, such as aluminium, may be leached out of the soil and into water courses where they will rapidly prove toxic to fish and many fresh water invertebrates. High levels of aluminium in drinking water for human consumption causes problems since aluminium is implicated in Alzheimer's disease. High concentrations of this, and other, heavy metals may prove toxic to the root hairs of trees and reduce the ability of tree roots to form symbiotic relationships with ectomycorrhizae. In turn, this will reduce the ability of tree roots to absorb nutrients and decreases their resistance to diseases. Acidified soils become dominated with acid-tolerant plant species and the species diversity of flora and fauna decreases. In particular, detritivores such as earthworms are unable to tolerate acidified soils and are increasingly replaced by mites and springtails. This is one of the reasons why the rate of decomposition beneath coniferous plantations is much slower than under deciduous woodlands.

In areas of high rainfall, **podsols** often develop on permeable parent materials such as sandstones and gravels. Coniferous leaf litter produces an acidic, **mor** humus containing both carbonic and humic acids. These contribute to the rapid leaching of ions such as iron and aluminium from the Ea layers which, as a result, becomes bleached (see Fig 3). A siliceous residue remains thus, as leaching continues the Si:(Al + Fe) ratio increases and humus and sesquioxides are deposited in the Bh and Bs horizons. The leaching of basic ions from surface horizons results in a base-deficient, acidic soil.

Fig 3. Humo-ferric podzol



When coniferous or deciduous woodlands have been planted on less acidic, moderately well drained parent materials which possess higher earthworm populations, a **mull** humus often develops. The passage of leaf material through the guts of earthworms increases the pH, water content and surface area of the material, all of which, in turn accelerate its decomposition by microorganisms.

(b) Development of deep litter layer
Litter accumulates beneath coniferous woodland because:

(i) Temperatures are low since rapid canopy closure reduces incident light;

(ii) The chemical composition of conifer needles makes them resistant to decomposition and unattractive to decomposer organisms; and

(iii) Detritivores such as earthworms are not acid tolerant.

In combination, these dramatically reduce the rate of nutrient recycling.

(c) Reduction in species diversity of ground flora
This is largely a consequence of early canopy closure. However, following thinning of the plantation - the removal of some trees at various stages in the life of the plantation - invasive species such as birch may rapidly recolonise.

(d) Soil moisture content decreases
Interception losses may be high from coniferous plantations, particularly when canopy closure has been achieved. A large proportion of any rainfall will be intercepted and will evaporate from the canopy before it reaches the ground surface and this, along with high transpiration rates, has often meant that soils beneath coniferous plantation gradually dry out over the course of the rotation. On clay soils, such drying may lead to irreversible shrinkage which effectively destroys the soil structure.

(e) Increased soil erosion
This is usually associated with pre-planting and harvesting operations. Ploughing of soils to break up iron pans or to increase aeration and drainage prior to planting can lead to dramatic soil erosion incidents. Similarly, the extraction of trees at the end of the rotation leaves soils exposed to rainfall for the first time in perhaps eighty years and, particularly on slopes, the wheels of heavy extraction machinery can form channels and gullies which accelerate runoff and soil erosion.

2. The Impact of Plantations in the Tropics

Tropical plantations are often composed of monocultures of extremely valuable species such as mahogany, teak and rosewood etc. Such plantations have two important effects on the chemical content of the soil:

(i) Because they are monocultures, they deplete the soil of nutrients in exactly the same way that coniferous monocultures will deplete upland soils in the UK. The individual trees of a monoculture have similar rooting properties and require the same minerals and such plantations may rapidly deplete the soil of particular nutrients. However, it is also worth noting that some deep rooting species have been deliberately used to increase the nutrient content of tropical soils. Species such as *Prosopsis cineraria*, whose roots can extend to a depth of 30 metres have been used as pumps. The roots of such trees absorb deeply held nutrients and use them to synthesise their tissue, eg. leaves. Such foliage is then fed to livestock which are allowed to graze beneath the trees. The resulting faeces from these animals effectively represents recycled nutrients which are then made available to surface soil horizons. In addition, the root channels of deeply-rooted species allow air to enter the soil which accelerates chemical and physical weathering processes which releases more nutrients from soil minerals.

(ii) The litter layer becomes dominated by the leaves and twigs of the particular species and this leads to reduced species diversity of detritivores, uniformity of humus and uniformity in the chemical composition (ion content and pH) of the water that percolates through the soil.

Tropical plantations may also affect the physical properties of the soil:

(i) Very high transpiration rates may dry out soils, raising the water table. Plantations of species such as *Eucalyptus robusta* have been used to drain swamps which then allows the growth of more valuable tropical hardwood species. Similarly, leguminous species such as *Acacia mearnsii* (wattle) enrich the soil via nitrogen fixation and in **eastern and southern Africa**, this species has been used to prepare the land for the growth of valuable eucalyptus trees. In the **Philippines**, the nitrogen fixing species *Leucaena leucocephala* is often inter-planted with the extremely valuable mahogany (*Swietenia spp*) as a living source of nitrogen fertiliser. The harvesting of tropical plantations and natural tropical forests has dramatic effects on the long term productivity of the soil (see Factsheet 2 - Tropical Rainforest Management). Although vegetation debris left behind after felling may initially mean that the nutrient content of the soil increases, minerals are quickly leached or removed in crops and the resulting infertile soils may then be quickly abandoned.

(ii) As in temperate areas, the harvesting of tropical plantations using heavy machinery can dramatically increase soil erosion.

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