# SOILS OF COLD AND TEMPERATE REGIONS

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## Contents





## Summary

This chapter focuses on soil development and properties in regions with temperate and cold climates. The factors which influence soil formation are briefly discussed with a recognition that the relative importance of many of these varies depending upon the climatic conditions at the site. Whilst local soil variations are often due to the specific influence of a single or a combination of soil forming factors, broad soil patterns are determined by climatic conditions. The major climatic influences are: temperature and amount and distribution of precipitation.

In temperate regions the principal soils are: Luvisols, Podzols, Cambisols, Fluvisols, Gleysols, Leptosols and Anthrosols; the latter are very common because of the

prolonged human occupation and intensive soil use in this area. In cold regions the principal soils are: Cryosols, Podzols, Histosols, Gleysols and Leptosols. Albeluvisols and Regosols are also found extensively in both regions, and Histosols may be locally important in temperate areas. Many soils in these zones are subject to intensive use and, therefore, careful management is required to ensure that they are not degraded.

Because of the increasing evidence of global climatic change, the soil forming conditions in the region may change rapidly. In particular soils which are frozen for most of the year may be subject to marked changes if temperatures continue to increase. A number of soils in these zones contain large pools of carbon within the profile. Carbon pools are increasingly recognized as a significant component of global carbon budgets and, therefore, due care must be taken to maintain or increase the size of this pool. Urban and associated developments in these regions are resulting in more and more soils being sealed. This process is normally irreversible and leads to the loss of soil.

## 1. Introduction

Soils are the product of the interaction of climate, vegetation and fauna (including Man), and topography on the soil's parent material over time. These five 'influences' are widely known as the soil forming factors. Their interactions and relative importance give the distinctive suite (vertical sequence) of soil horizons into a soil profile at a particular site, and the distinctive spatial pattern (horizontal sequence) across a landscape.

Depending upon the spatial scale at which soils are observed, one or more of these factors may appear to have a major or in some cases a dominating influence on the soil profiles and on the suite of soil properties distinguished. For example, over the scale of a few meters or less there may be distinct soil variations because of differences in the activity of soil fauna such as ants, termites or earthworms. Where the activity of soil animals is focused on below- ground chambers the soils will be different from those where such chambers are absent. The result is often a complex mosaic of soils. Similarly under individual trees or shrubs there may be differences in soil properties directly below and outside the influence of the canopy.

Within an area there are frequently distinct patterns of soils linked to the position in the landscape. These patterns often reflect the reworking of soils in the landscape through erosion, transport and deposition processes. Additionally there will be patterns linked to the movement of water and associated solute loads in the soil mantle and to the periods when soils in different parts of the landscape are at different soil water capacities.

At a broader scale there will be soil differences reflecting the pattern of underlying geological materials, although in many environments the soil's parent material may not be the underlying solid rock, but a veneer of glacially derived materials, river borne alluvium or colluvium transported within the landscape.

The influence of climate on the nature and pattern of soils is frequently viewed at a much broader spatial scale, with patterns exhibited over hundreds of kilometers. This is the underlying principle of the zonal concept of soil distribution, where soil patterns are distinguished at a continental scale broadly linked to climatic zones (see also *Soil Geography and Classification*). Within these zones there will also be clear evidence of many soils and soil properties which do not match the predicted relationship between soils and climate, this reflecting the relative dominance at particular sites of the other soil forming factors, either singly or in combination.

All these interactions and the consequent processes of soil formation have been taking place through time. There is evidence, globally, of some sites where soil formation has not been interrupted, possibly for millions of years, although not necessarily in response to the same combination of soil forming factors. In other cases soil formation has been of relatively short, and there is often little evidence of organization of soil materials and development of soil profile characteristics. In both these extreme situations, however, the soil is not static and continues to be subject to change. Whilst time is a useful shorthand term and one which is widely understood, the rate of changes which occur over a period of time under one combination of soil forming conditions may be very different from that under a different set of environmental conditions.

The rate at which processes operate to bring about these changes in the soil vary in response to the environmental conditions and may also vary at different stages of soil development, often being more rapid in earlier than at later stages. It is in the context of the broad climate – soil relationships that this chapter will seek to review the soil conditions which prevail under temperate and cold climatic regimes.

## 2. Climatic Regions

### 2.1. Temperate Region

The connotation ‘temperate’ is used to describe a broad range of climatic areas where there are no extremes in temperature and precipitation and where there are distinct summers and winters, although the changes between seasons may sometimes be rather subtle, warm or cool rather than extreme hot or cold. In most temperate climates, whilst there are seasonal differences in rainfall, there is a tendency for there to be precipitation all year round. In broad terms the average temperature of the coldest month in the temperate zone is between 18 $^{o}$C and -3 $^{o}$C, and the average temperature of the warmest month >10 $^{o}$C.

Variation within this broad climatic region includes areas with the driest part of the year in the summer, others with the driest part in the winter and still others with no relatively dry period (precipitation <30mm/month). There are frequently further subdivisions in terms of the average temperature of the warmest month; above or below 22 $^{o}$C. In parts of the temperate zone there are areas with cool summers, where there are less than four months with temperatures in excess of 10 $^{o}$C.

Although the temperate regions account for only 7 % of the surface area of the earth, approximately 40 % of the global population is found in this region. For this reason many soils in this part of the world show distinct evidence of use by man, and in some situations man has even become the dominant soil forming factor. Where the influences of man are over-riding all other soil forming factors the soils are known as Anthrosols. Before the present extensive human occupation this region would have had an extensive cover of rich mixed forested landscapes, with a predominance of deciduous trees such as oak and beech.

### 2.2. Cold Region

Whilst there are many areas in this region which are permanently covered with snow, the focus here is on soils that are free of snow for part of the year. The areas where soil development is taking place have an average temperature of the warmest month above 10 $^{o}$C, whilst that of the coldest month is less than -3 $^{o}$C. Subdivisions within this region are recognized on the basis of the occurrence of a dry season in winter and on the amount of rainfall (>30 mm) in the driest month. Major subdivisions are furthermore based on the temperature of the warmest and coldest months.

## 3. Soil Forming Environments

### 3.1 Temperate Region

In addition to contemporary climatic conditions, there might be a number of significant previous influences on the nature and properties of soils in the temperate region. A substantial part of the current temperate region was covered for a relatively long time by continental ice sheets at their maximum extent during the Pleistocene. During this time extensive deposits of glacial and fluvio-glacial materials were laid down. These sediments and those in non-glaciated areas frequently show signs of cryoturbation, ice crystal formation and many other features that are characteristic of contemporary conditions in the cold zone. In addition to glacial and fluvio-glacial deposits there are often extensive areas covered by wind blown fine sands and silts, commonly known as *cover sands* and *loess*, respectively. Many contemporary landscapes and parent materials in this region retain features developed during the Pleistocene.

Under the current cool and sub-humid climatic conditions of the temperate region there are often three broad groups of landscapes within which soil development is taking place:

- Pleistocene sedimentary lowlands, with glacial and fluvio-glacial deposits, periglacial reworked materials and eolian deposits.
- Uplifted and dissected sedimentary basins, principally with Mesozoic limestone and sandstones, often with variable thickness of veneers of cover sands and loess.
- Uplifted and dissected Caledonian and Hercynian massifs.

### 3.2. Cold Region

In many respects the soil forming conditions within the cold region reflect those experienced during the Pleistocene in the current temperate region. Geomorphologically the landscape has a substantial proportion of mountains and glaciers. In glacier free zones terrigenic calcareous stony and marine sediments predominate. During winter months the soils are frequently snow-covered and frozen. In higher latitudes the soil may remain frozen at depth throughout the year with only a relatively shallow upper part being unfrozen during the warmer summer months. As the latitude increases the period and depth of freezing tends to increase.

The dominant soil forming processes here are strongly influenced by the occurrence of frozen soil affected by *cryoturbation* and in some areas by *gleying* in the unfrozen zone. The latter process occurs in the soil material above the frozen subsoil because water is unable to drain vertically. If, during this period of water logging, the soil temperature is sufficiently high for biological activity, the available oxygen will be rapidly consumed and reducing conditions will prevail. Under these conditions characteristic features of grey matrix and ochreous mottling will develop, the exact patterns depending upon the duration of the period of water logging.

Peat accumulation is also common in this zone, with up to 1 meter thick peaty surface layers on top of the mineral soil. The soils also show very little signs of distinctive soil development because of the limited time that conditions for soil formation are suitable. On deeper coarse textured soils where there is a snow free period of 4 to 6 months podzols may develop.

## 4. Soils of Temperate and Cold Regions

The variety of soils occurring in temperate and cold areas is high, and their classification in the world classification systems is widespread. Details on these systems, their structure, hierarchy and diagnostic criteria have been discussed at length in the section on *Soil Geography and Classification***.** A summary of the main and less common soils in temperate and cold regions, and their classification in the World Reference Base for Soil Resources (Deckers et al., 1998), is given in Table 1.

| **Climate Zone** | **Main soils** | **Important but less widespread soils** |
|---|---|---|
| | | |
| Temperate Regions | Luvisols | Histosols |
| | Podzols | Albeluvisols |
| | Cambisols | Regosols |
| | Fluvisols | Planosols |
| | Gleysols | |
| | Leptosols | |
| | Anthrosols | |
| | | |
| Cold Regions | Cryosols | Fluvisols |
| | Podzols | Albeluvisols |
| | Histosols | Regosols |
| | Gleysols | Planosols |
| | Leptosols | |

| | | |
|---|---|---|
| | Chernozems | |

Table 1: Soils of temperate and cold regions as classified in the World Reference Base for Soil Resources (Deckers et al., 1998).

### 4.1. Luvisols

Luvisols are widespread in temperate regions and found to a limited extent in cold regions. They are developed on a wide variety of unconsolidated materials including glacial tills, eolian deposits, alluvium and colluvium. The principal characteristic of Luvisols is the textural differentiation in the profile, showing an accumulation of clay in a deeper subsurface horizon (an argic horizon), often linked to a relatively shallow overlying horizon depleted in clay. The soils are generally well drained, although where the argic horizon is particularly strongly developed it may restrict internal drainage, producing gleying conditions in the upper part of the soil profile. Under most conditions the soils have a pH close to or just below neutral. They are generally considered naturally fertile soils.

The soil forming processes affecting the development of this soil essentially involve three components:

- mobilization of clay in the upper part of the profile (eluviation);
- translocation of clay to the horizon where accumulation occurs;
- immobilization in this subsurface horizon of the translocated clay (illuviation).

The profile which develops is A-Bt-C and there is a distinct contrast in the clay content of A and B horizons. Figure 1 is an example of a Luvisol developed on clay with flint deposits over calcareous cretaceous deposits  near Ashford , Kent, United Kingdom.

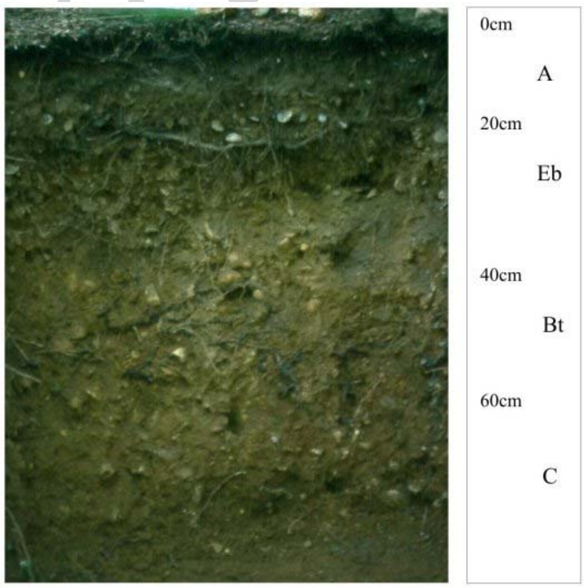


Figure 1: Luvisol developed on clay with flint deposits over cretaceous carbonate rich deposits near Canterbury, Kent, United Kingdom.

Where the argic horizon has distinct clay coatings (argillans) on ped surfaces, around coarse grains and coating fissures and pores, it is generally associated with conditions where there is a distinct dry season. The color of the argic horizon ranges from brown to red; more reddish colors normally indicate soil development in a contemporary or earlier warm climate.

The soils are characteristically developed on stable landscapes. Following disturbance, for example due to the intervention of man, erosion of the eluviated surface layer may expose the clay-illuviated subsurface horizon close to or at the surface. Table 2 provides brief analytical information for a Luvisol.

| Horizon | Depth | pH | % Org Matter | CEC cmolc/kg | Exch Ca cmolc/kg | Exch Mg cmolc/kg | Exch K cmolc/kg | % Sand | % Silt | % Clay |
|---|---|---|---|---|---|---|---|---|---|---|
| Ap | 0-16 | 6.6 | 3.95 | 20.5 | 12.5 | 5.5 | 0.7 | 59.7 | 12.3 | 28.0 |
| Eb | 16-35 | 6.3 | 1.85 | 8.9 | 5.8 | 2.3 | 0.2 | 73.5 | 8.6 | 17.9 |
| Bt1 | 35-48 | 6.7 | 1.65 | 16.0 | 9.8 | 4.1 | 0.2 | 54.6 | 8.5 | 36.9 |
| Bt2 | 48-77 | 6.9 | 1.10 | 17.8 | 12.5 | 3.6 | 0.2 | 42.7 | 9.1 | 48.2 |
| BC | 115-170 | 7.2 | 0.20 | 22.3 | 15.3 | 6.1 | 0.2 | 49.9 | 11.6 | 37.5 |

Table 2: Analytical characteristics of a typical Luvisol developed on alluvium.

Luvisols may also be found in situations where contemporary climatic conditions are not considered conducive to the translocation of clay. In this case it is probable that these features developed under different climatic conditions, possibly during the Pleistocene or early Holocene periods.

**4.2. Albeluvisols**

Albeluvisols are quite similar to Luvisols, with a diagnostic argic horizon within 1 meter of the surface but with a distinctive bleached eluvial or albic horizon (similar to that found in podzols, but developed in finer textured parent materials). The albic horizon in these soils is particularly well developed and may extend into an argic horizon. These soils are widespread in cool temperate and cold regions, but are more characteristic of cold climates, developing on medium textured unconsolidated glacial tills, or materials of glacio-lacustrine or fluvial origin and fine textured loess, covered by a taiga vegetation or coniferous or mixed woodland. Albeluvisols are often found in close association with podzols.

Albeluvisols have been extensively modified by agricultural activity and their profile forms are now often identified as Luvisols, or in complex patterns with Luvisols. Where the landscape has a mosaic of arable land and adjacent natural woodland, Luvisols are often found in arable land and Albeluvisols in woodland. Many Albeluvisols are associated with a limited soil faunal or floral activity. Consequently, the organic material is only slowly broken down and incorporated into the soil, and a distinctive mor or moder horizon may develop at the surface.

The profile development is typically A-Ea-Bt-C. In this sequence the Ea horizon is distinguished as a surface horizon from which clay has been eluviated, often identified in the field by a distinctive lighter color than both the organic enriched surface layer and the underlying clay enriched B horizon.

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**Biographical Sketch**

**Stephen Nortcliff** is a Professor and Head of the Department of Soil Science, University of Reading, United Kingdom. He holds a B.A. in Geography (1969), and a Ph.D. in Soil Science (1975).

He has been active for more than thirty years both in the academic world, as a professor in soil science and land development, and as a technical and scientific advisor for a wide range of matters linked to soil quality and related policy issues, most recently in Europe. His initial interests were in soil variability and how this information should be incorporated in routine soil survey. Subsequently he has worked in the tropics of South America, Africa and Asia in a wide range of topics involved with clearance of natural vegetation and the establishment of agriculture. Much of this work has focused on the need to recycle organic matter if low input systems are to be sustainable. In the context of temperate soils he has worked extensively on the use of composts and other organic waste materials as soil amendments or as potential soil forming materials in the manufacture of artificial soils.

He was appointed Secretary General of the International Union of Soil Sciences in 2002, and in this role he has taken an active involvement in the incorporation of soil issues in land development and broader environmental development and legislative programs within the United Kingdom, Europe and globally