SOILS OF COLD AND TEMPERATE REGIONS

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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.

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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