SOME ASPECTS OF SOIL CLASSIFICATION

BY P. H. GALLAGHER, D.Sc.

The classification of soils must necessarily be of very considerable interest to the forester if only for the reason that he is so often expected to make some practical use, not only of an assortment of crumbs, but also of the more or less indigestible bones that may, so to speak, fall from the agriculturist's table

Numerous as are the soil problems of ordinary farming, it is in cases where the farmer is fully convinced that these problems are economically insurmountable that you are apt most frequently to find land on offer to the forester. The latter, we will admit, has at his disposal a crop capable of giving an economic return on many classes of soil which may reasonably be considered unsuited for normal farming use. It is the character of the soil which ultimately decides whether a particular district be economically plantable, just as it is the character of the soil which chiefly decides the tree species which will likely give the most profitable return.

Vegetation as an Indicator of Soil Conditions.

Many foresters rely to a considerable extent on evidence derived from existing vegetation when assessing the value of a plantation site. There is unquestionably a relationship between the vegetation established on a given site and the local soil conditions. Experience and caution are, of course, necessary if the inferences to be derived from one type of vegetation are to serve as a universal guide in forecasting the growth of another. Consideration of the whole plant community or association serves as a more reliable guide to soil conditions than does the presence or absence of any single plant. Some plants require fairly specific soil conditions in order to establish themselves. but the absence of a plant is no proof that the soil is unsuited to it. The general plant association, on the other hand, will sometimes be found to vary with change of environment, even where soil conditions may not be materially different. Elevations and wind exposure have a notable influence in this respect. We have examples of plant associations in the Survey of the Vegetation of South Co. Dublin carried out by Petherbridge and Praeger some years ago. Fraser, of the Macaulay Soil Research Institute, has in recent years given considerable attention to the plant associations as a means of assistance in forestry development in Scotland.

Relationship of Soils and Geology.

In the course of the many attempts which have been made to formulate a comprehensive system of soil classification in the past, geology has figured very prominently. So much was this the case that at one time the scientific study of the soil was frequently regarded as being exclusively within the province of the geologist and the mineralogist. When the Irish Geological Survey was established over a century ago, it was set the task of accomplishing a soil survey in conjunction with the solid or rock geology. The project of soil classification was abandoned, however, at quite an early stage, the reason stated being that it was considered preferable to devote the full resources of the organisation to the more fundamental solid geology.

Looking back at the position which existed a century ago, one may question whether a useful survey of Irish soils was at that time really feasible, and whether a realisation of the true position after some little experience may not in fact have determined its abandonment. For some reasons which I shall refer to at a later stage, no direct relationship can be said to exist generally in this country between the soil and the solid geology. The theory of glaciation, which goes far in explaining the displacements of our soils from their parent rocks, was not formulated until considerably later than the period at which the Irish Geological Survey commenced its work. Moreover, there did not exist, a century ago, any proper realisation of the climatic or weathering processes which have a fundamental influence on the character of a soil.

The Climatic Soil-forming Process.

The study of the weathering processes which impart to the soil most of its individuality was first developed in Russia towards the close of the nineteenth century. Making due allowance for the ability and initiative of the Russian investigators concerned, it will be seen that a country so vast, and possessing such diversity of climate, offered a unique opportunity for the study of a problem of this kind. Throughout most of Central and Western Europe the climatic soil-forming process is substantially so uniform that it was perhaps, pardonable that persons studying the soils in these regions tended to forget the existence of any specific weathering process at all. In Central and Western Europe, attention was in great measure confined to factors connected with local geology. The Russian investigations to which I have referred, showed that where you had sufficient differences in climate, the effects of climate superimposed themselves on local geology in different ways. A particular rock situated in one climatic region would, for instance, give rise to the relatively infertile soil-type known as the "podsol," in another climatic region the same rock would yield the very fertile "black earth" or chernozem. The same geological formation in the tropics would give rise to a lateritic soil, which is totally different from the other two. These interesting and important facts have given rise to a somewhat deplorable consequence. They have led nowadays to a rather common belief that the geological parentage of a soil is of little or no practical significance. From your own practical experience of Irish soils, I doubt very much if you will be disposed to agree with this view. At the same time it is true that each species of climatic soil-type occurring in this country is to be found on quite a variety of geological materials. The essential point is that the climatic factor can be superimposed on a geological material without entirely obliterating the individual qualities of that material. There are, moreover, qualities inherent in our several geological formations which have determined the extent to which each has reacted in the past to climatic influence.

Climatic Factors Influencing Soil Formation.

To gain an understanding of the essential characters of Irish soil-types it is necessary first to consider the climatic factors which have affected their formation. Soils, of course, originate from the crumbling down of the rocks which form the solid core of the country. Mere disintegrated rock, however, does not in the true sense constitute a soil. It is merely the raw material from which, through the combined operations of climate and vegetation the soil is fashioned. The features of climate which are of importance from the point of view of soil development are temperature and humidity. These are interdependent, since for a given rainfall, the higher the temperature, the greater will be the surface evaporation, and consequently the lesser will be the effects of rainfall as a leaching agent in the soil. The higher the temperature, the more rapidly and completely also will the residues of vegetation tend to decompose. Where you have excess of rainfall over evaporation, and where also the temperature is such that growth is good, but the decomposition of vegetation residues is comparatively slow—in such climatic circumstances soil formation becomes dominated by a leaching process of acid character, resulting ultimately in the soil-type known as the podsol. The climatic circumstances necessary for podsolisation are found in what the geographers term the moist temperate zones, which is precisely the type of climate that we occupy.

Sources of Soil Acidity.

I have referred to the process which gives rise to the podsol as a leaching process of acid character. Although the geologists speak of certain rocks, such as granite, as being acidic, very rarely does one find a freshly disintegrated rock to be actually acid. Even quartz, though chemically acidic, is not an active acidifier. The primary source of acidification in the soil lies in the residues of vegetation. This is not necessarily the so-called "humic acid" that one frequently hears about. Plant tissues themselves are acidic. They contain various comparatively simple, soluble, well-defined organic acids, such as oxalic and tartaric. Plant residues reaching the soil not only contain such acids, but they further produce them on decomposition. Simple organic acids of this kind, however, are somewhat readily decomposed by bacterial action They consequently exert their influence in the portion of the soil not far removed from the region of plant residue decay.

Soil Impoverishment Resulting from Leaching.

Acid leaching inevitably results in soil impoverishment. Loss of lime, is, perhaps, the most prominent starting point, a notable result of which is that the deterioration process becomes accelerated through the establishment of a calcifuge vegetation which tends progressively to produce a more acidifying vegetable residue. The soil thus becomes generally depleted of its base reserves, while at the same time phosphate deficiency tends to become pronounced, not because this latter fertiliser is easily lost in drainage, but because the acidified soil acquires the power of rigidly precipitating phosphate and withholding it from the plant. The persistent drainage to which soils are subjected in our climate is a primary source of loss of fertility and it is, perhaps, the principal reason why manuring is so very important in our agriculture. In South-Eastern Europe, where the climate is not podsolising, crops such as wheat and maize, which we are apt to regard as exhausting, are normally grown successfully year after year without intervening fallows or green crops and with little or no attention to livestock production or to manuring as we know it.

The Mature Podsol.

One of the most noticeable features of advanced podsolisation is the manner in which the soil becomes zonated, as it were. Beneath a variable depth of peat or raw humus, which frequently forms a cover, there lies first of all the original surface soil. In the fully developed podsol, this is normally blackish in colour, due in the main to organic matter. This is succeeded in depth by a comparatively bright coloured layer resembling grey ash in the most typical instances. The comparatively bright colour of this layer is due to severity of leaching of the mineral particles and to comparative freedom from organic matter. Leaching of mineral constituents is well-nigh equally severe in the overlying darker layer which I have referred to, except that in this case organic matter somewhat obscures the mineral particles. The bleached layer is succeeded in depth by a reddish-brown layer which is usually referred to as the B horizon. This in turn overlies the more or less unaltered or unweathered parent material. The B horizon is, in fact, the receptacle of some of the soil constituents which have been removed from the layers which overlie it. It is enriched in iron and aluminium, often also in organic matter, and even in phosphate, although the latter is not necessarily present in an available form. The B horizon is also frequently the seat of iron-pan.

The Alkaline Podsol.

It should be noted that there are numerous instances on comparatively fertile soils on limestone drift in this country in which one meets with some of the salient features of the podsols which I have described. There is ample evidence to show that a downward migration of iron and aluminium occurs in practically all our soils, but the deposition of these elements in a definite B horizon in the subsoil is only apparent either where leaching has gone to an extreme, or alternately, where the parent material is exceptionally rich in lime. These two manifestations of podsolisation are readily distinguishable with a little experience, and they should on no account be confused. It would be a very serious error to plant the one with tree species suited only to the other. The normal acid podsol is definitely infertile, and one must be content to plant it with Scots Pine and similar conifers. Where the formation of a B horizon is due to lime, fertility will rarely, if ever, be found to be seriously impaired.

Comparative Immaturity of Irish Soils.

The condition of infertility which characterises the normal acid podsol represents what might be expected to be the ultimate condition which all our soils would attain in our prevailing climate. The mature podsol occurs here, however, to but a limited extent, and it is to be found for the most part in mountainous districts. Its frequency in the latter is to be attributed to geological factors rather than to elevation. The materials arising from different geological formations vary very considerably in power of resisting what one may describe as the degradation to which the podsolising process subjects them. The highlands in this country, especially where they are covered by coarse materials, are generally speaking of poor resistance to weathering as compared with the lowlands. At the same time the comparative immaturity of so many of our soils from the point of view of podsolisation is doubtless attributable to the glaciation of the country which would have had the effect of setting back the process of superficial weathering to a new beginning in relatively recent geological times.

Brown Earths.

I wish now to refer to the features of two very important groups of immature soils which occur in the podsol climatic zone on virtually all geological formations. The first of these is termed the "brown earth" and the other the "gley." The brown earth is a soil which shows in its profile none of the zonation of constituents which is characteristic of the podsol. The colour is a nearly uniform brown to a very considerable depth, the upper portion being usually somewhat darker than the remainder owing to accumulation of organic matter. While the podsols which occur in this country are nearly always light in texture, being either sandy or gravelly, the brown earths are usually loams. From the point of view of fertility the brown earth is definitely superior to the podsol, and it is suited to the growth of the more exacting tree species, including the hardwoods.

The "Humus Podsol."

The brown earth owes the characteristic colour of its profile to an even distribution of iron in a comparatively full state of oxidation. There occurs on many geological formations in this country a soil type which, though materially different from the brown earth in many important respects, is very liable to be confused with it. This is the more or less immature humus podsol, which is normally distinctly inferior to the true brown earth in fertility. The humus podsol owes most of its characteristic brown subsoil colour to a peculiar variety of organic matter. The presence of this organic matter to a considerable depth in the subsoil is quite evidently the result of podsolic leaching, as a result of which it has migrated in a soluble form from the upper layers of the soil, to be finally fixed in position through absorption by the oxides of aluminium and iron which already have accumulated in a podsol B horizon. The resulting coffee-brown subsoils are distinctly soft and crumbly, possessing none of the plastic or cohesive properties which are displayed by both peat and clay.

Gley Soils.

While all of the foregoing soils owe their origin to free drainage, we have a climatic soil-type known as the "gley," which owes its essential characters to defective drainage, associated with either permanent or periodic water-logging. Where the water-level in the soil is high and substantially permanent in position, the subsoil displays substantial uniformity. Crumb or aggregate formation is noticeably absent below the organic surface layer. When the subsoil is allowed to dry, it merely cracks as a result of shrinkage. Gley soils are very frequently regarded as being heavy clays, although the percentage of clay material in them, as distinct from sand or silt, is frequently not high in comparison with well-drained soils possessing good structure. The colour of permanently water-logged subsoils is most frequently a somewhat uniform yellowish-grey. There are cases, however, where bluish or even black colours may be met with.

The most common class of gley soil, however, is that in which the water-level fluctuates periodically with seasonal changes. The soil in this case acquires a characteristic variegated appearance in the portion in which the rise and fall of water occurs. The body of the subsoil is usually yellow-grey, but in the channels resulting from the decay of roots, and in the site of old shrinkage cracks, the colour is a rustry brown. This distribution of colour gives the soil a mottled or semi-marbled appearance which serves for the diagnosis of drainage conditions even during a period of drought. The distribution of colour in these soils is due to the fact that when air is excluded owing to the presence of stagnant water, iron present in the soil becomes reduced to a relatively soluble and colourless form. As the water-table falls, air gains easiest access through cracks and old root channels, on the walls of which the dissolved iron is precipitated through oxidation.

While gley soils have not been subjected to the severity of leaching which has been the fate of the podsol and even of the brown earth, and while they thus may be expected to contain a relatively greater reserve of plant nutrients, they none the less possess many undesirable features from the point of view of fertility, owing to the asphyxiating influence of ground-water. They frequently contain notable amounts of sulphide. When artificially drained, they are exceedingly slow in acquiring a desirable structure, while in the absence of drainage, they are suited only to the growth of species which are tolerant of a high ground water level. One must also bear in mind that a high ground-water level restricts the effective depth of soil from which the plant can acquire its nutrient supply. Althougn gley soils are at present seldom classed as arable, some of them are subject to extremely high Poor Law Valuations in this country, a fact which is probably to be ascribed to their apparent heaviness and to their productive capacity as meadows.

It is important to note that gley soils very frequently occur in other than low-lying positions. Where soil structure is so imperfectly developed as to interfere with proper drainage, gley conditions will arise irrespective of local topography.

Hybrid Types.

While refraining from chemical and physical details, I have sought to indicate the principal features of podsols, brown earths and gleys because these types represent definite landmarks in this country from the point of view of climatic development. While there are many soils which belong specifically, to one or other category, there are others which share the properties of two or more categories. Chemical analyses of the clay fractions from different positions in brown earth profiles frequently yield evidence that the migration and deposition of iron and aluminium, which is characteristic of the podsol, has already taken place to some degree. In profiles which are substantially of brown earth character, one sometimes finds visual evidence of such migration. These are the so-called "podsolised brown earths," the fertility of which tends to be somewhat depressed, as compared with the brown earth proper. Most of the brown earth soils of this country are in agricultural use, and it is possible that evidence of slight podsolisation in many of them may have been obliterated by tillage operations. Gleyed brown earths are also not uncommon, as well as the soil-type known as the gleyed podsol.

The existence of soils conforming to these hybrid types may at first sight seem surprising and a contradiction in terms, since both podsolisation and brown earth formation depend on freedom of drainage, while gley formation is due to defective drainage. But there are soils capable of maintaining a water-table at such a distance from the surface that while drainage may be sufficiently free through the upper levels to produce the essential features of the podsol or brown earth, the lower levels, being under ground-water influence, will display the properties of a gley. I would mention that the well-known indurated deposit known as iron-pan may conceivably be the result of gley conditions in podsols of coarse texture. The deposition of iron from ground-water in coarse soils would tend to take place at a comparatively uniform level, and not in the diffuse manner which is usual where loams and heavier soils are concerned.

Significance of Climatic Soil-type in Land Classification.

The question which now naturally arises is, whether in a country as limited in area as Ireland, the climatic soil-type in all its ramifications is capable of furnishing an adequate basis for a practical system of land classification. A classification of Irish soils on a purely climatic basis would unquestionably coincide with very important relationships between the potential fertility of various districts, but there will be found to exist a certain lack of uniformity within each climatic group of soils. This lack of uniformity is ascribable to variations in the soil parent material, which, of course, is traceable to its geological source. As an example, I would point out that the brown earths of our Silurian districts, while bearing many points of resemblance to those derived from Old Red Sandstone, are at the same time very noticeably different from them. Soils of brown earth character on limestone drift are in many important respects different from both the corresponding Silurian and Old Red Sandstone types. As I indicated at an earlier stage, climatic features are superimposed on the geological ones without by any means totally obliterating all of their individual qualities.

The climate of this country may be regarded as reasonably uniform in respect of temperature, rainfall and evaporation, but the effects of humidity on and within the soil will be determined, not only by the inherent drainage capacity of the soil material, but also to a very important degree by the character of the local site in which the soil has formed. Making allowances for a somewhat greater rainfall in the west than in the east, with a resultant tendency to greater podsolisation in western districts, it can be stated that from a given geological material, wherever it may occur, soils of practically identical characteristics have been formed where drainage facilities within the soil have been substantially similar. Where drainage facilities have differed, however, one or other of the climatic soil-types—podsol, brown earth, gley and intermediate phases—will result, depending usually on the circumstances of local topography.

If the geologist has in the past failed to evolve a satisfactory system of soil classification, this, I believe, is in the main due to lack of adequate reference to the facts of climatic weathering which determine the soil-type which a given geological product will evolve in any given location. It would be equally futile, in my view, to seek a comprehensive practical classification on the basis of climatic factors only, without reference to the parent material on which they operate. It will, I think ,be clear that it is in the interrelationships of both the geological and the climatic factors that the true solution may be said to lie.

Complexity of Irish Soil Geology.

The direct application of existing geological data to the classification of Irish soils is, however, by no means so simple as one might at first sight suppose. We possess in this country quite a variety of geological formations, the sites of which have been very fully explored as far as the solid geology is concerned. As a consequence of glaciation and erosion, the soils derived from these formations have, throughout most of the country, been transported over considerable distances; but the information available as regards the nature and extent of Irish soil displacements is meagre in the extreme. The position is further complicated by the fact that the soil material is very frequently a decided mixture from a geological point of view. A further complication is that a single geological formation is not necessarily comprised of a uniform rock or soil producer.

It would quite obviously be an error, therefore, to approach the subject of soil examination from simple considerations of solid geology, although in certain areas, where the geological formation is sufficiently uniform and extensive, it is possible to do so. Contrary to what one might be apt to suppose, however, the glaciation of our soils has not resulted in rendering their geology totally chaotic. It has subjected them for the most part to relatively limited lateral displacements. Within some miles of the geological boundaries, it is a frequent occurrence to find the soil composed of material totally different from that which the underlying rock would give rise to. The intermixture of materials in the neighbourhood of geological boundaries is a further complication, should one seek to classify soils from a purely geological standpoint.

Importance of Profile Examination.

Now if soil geology had been free from these various complexities; if, in other words, each geological formation were substantially uniform, and if the soil boundaries strictly agreed with it, the problem of soil classification would resolve itself into ascertaining the climatic variations in the soils within each formation. The existing geological complexities are such, however, that the only general practical approach to our soil problems is a direct one, depending on their individuality as soils.

If we therefore accept the soil as an object of independent individual study, in what manner are its individual qualities best expressed? To seek to judge a soil by the texture and other properties of its upper few inches constitutes a limitation in approach which has been materially responsible for the somewhat tardy advances in soil study which have characterised the work of the agriculturist and of the agricultural chemist for many years To ascertain the general character of a soil, one must consider its whole profile which comprises a vertical section to the depth to which roots and weathering influences have penetrated. Where you have substantial identity between whole profiles, there also do you find substantial similarity from the point of view of natural adaptability to one or other kind of vegetation.

In respect of adaptability to vegetation, one should bear in mind that soil type is properly decided by what may be regarded as permanent features of the soil, and it has no direct reference to artificial expedients for temporarily altering its productivity, such as in the case of ordinary manuring. But response to manure is undoubtedly influenced by the absorptive properties of the soil material which is largely determined by its type.

If we accept the soil profile as a standard of type—and a more comprehensive criterion is difficult to conceive of—what general features ought one to look for in characterising it ? You will discern a series of features which are systematically interrelated, including its climatic derivation, the nature of its parent material, its texture and structure, its drainage properties, its natural acidity and its depth. Two soils showing substantial agreement in these particulars are unlikely, except in very exceptional instances, to show lack of conformity in chemical properties, or in adaptability to vegetation. And when you meet with instances which are apparently exceptional, you ought to remember that it is by studying the exceptions to its rules that science accomplishes most of its advances.

Necessity for Reconnaissance.

There are many interesting aspects of classification which it would be impossible to touch upon in a brief review such, for instance, as those connected with the peats which the forester is frequently liable to encounter. I would like to refer to some general aspects of the subject in conclusion. In dealing with a product in the formation of which so many factors have had interplay, one might be led to suppose that soils are unduly complicated, and that the task of classification would be well-nigh insuperable. That they are in many respects exceedingly complex is, of course, to be admitted. It is none the less true that even when one specifies for classification purposes as comprehensive a degree of conformity in profile as I have indicated, the soils of this country are divisible into a not unduly large number of distinctive types, each of which possesses its individual adaptability for economic use.

The preliminary exploratory work on soils which has already been carried out in a number of agricultural areas is, I believe, capable of convincing anyone who is willing to go into the fields in order to examine it that in profile examination on the lines which I have outlined we have the clue to the solution of soil classification problems which in the past have baffled the ordinary practical man and the ordinary scientist, alike. Assuming that we, in this country, desire to acquire systematic comprehensive information on the properties and interrelationships of our soils, what then would be the logical method of approach ? One must first explore by general reconnaissance the broader features of the country as a whole, so as to gain a general knowledge of all our soils, the nature and extent of their actual types. On such a general knowledge alone can a framework for an ultimate detailed classification or survey be based. Our geological surveys would have been impossible without the systematic investigations on the nature and properties of rock formations which preceded survey work, but which subsequently enabled the geological surveyor to decide what each fundamental rock formation consisted of, where one ended and another began. A similar systematic and rational approach to the problem of soil classification is an obvious need.

I confess I have referred but little in this talk to the trees which are your primary concern. None of us is likely to forget that the most important feature of a soil is its natural purpose as a producer and supporter of vegetation. The assessment of the relationships between soil properties and productivity in the plantation is an important aspect of your work. I hope I have in some small measure succeeded in indicating to you the lines on which at least one phase of that work may some day be more fully systematised.