Soil Survey in Ireland with particular reference to Forestry.

By Pierce Ryan

Introduction:

A recent Government White Paper on an extensive programme for economic expansion laid special emphasis on increasing production from the land of Ireland. It is rational to concede that our soils must play a fundamental role in any form of improved productivity from our land resources. The extent to which production can be increased to meet the targets of an economic expansion programme, depends ultimately on the potential of our soils to meet this demand, on the manner in which they are used and on the manuring and management practices that can be applied to them toward greater out-put. Proposed targets can only be met by better use of all the resources at our disposal, principal of which is the soil itself, by the application of the best possible scientific techniques, and by the greater over-all effort on the part of all concerned.

The limitations inherent in our soils and militating against certain forms of production can best be remedied on a sound scientific basis when the soils themselves are thoroughly studied and known. In the more advanced agricultural countries of the World a survey of soil resources is regarded as basic to and an integral part of all land use planning and improvement. It is not surprising therefore that the agricultural research programme formulated by the Institute of Agriculture for this country, should include as a fundamental primary project a complete survey of Irish soils.

Procedure and Functions served:

This survey is being made to determine and record the more stable, slow-to-change characteristics of soils, the similarities and differences amongst soils, their distribution and extent and their behaviour under different cultural treatments. Such a survey makes possible the segregation and classification of soils on the basis of parent geological material and of other physical and chemical properties within the soil profile and of relevant landscape features of the soil. Each soil therefore can be fitted into a particular category and as a result the more important properties amongst soils are distinguished and comparisons between soils can be made. From time to time a number of surveys for drainage planning, settlement planning and for various other purposes depending on the current requirement, can be drawn from the basic soil survey. These surveys may group together for a specific project, certain soils segregated on the soil map, but the soil survey remains the basic survey designed to serve many purposes, for although the combination of soil use and management practices may change periodically, the soils themselves undergo little change so that the basic soil map is lasting in its interpretation and use for many years.

Modern soil survey and classification is based fundamentally on a study of the soil profile (vertical section of soil from surface down to parent material inclusive) which reflects the influence of the various factors of soil formation, including climate, vegetation, drainage and type of parent material from which the soil was derived. The morphology of each soil is expressed in its profile, reflects the combined effects of the particular set of genetic factors responsible for its development. This concept, first established by the Russian soil scientists at the end of the last century, is now generally accepted. Detailed examination and description of soils in the field is then an important part of the surveyor's procedure. The soil profile is thoroughly studied and for different depths or horizons (layers) such important characteristics as colour, texture, structure, consistence, occurrence of lime, gypsum or soluble salts, occurrence of iron or manganese concretions or pans, nature and distribution of organic matter including plant roots and other soil fauna, thickness and arrangement of the horizons (layers) and their definition in the profiles, internal and external drainage status and the presence of a water table, nature of parent material and so on are noted and described. Field findings are checked and supplemented by physical and chemical analyses in the laboratory of samples selected from representative profiles. By this means all existing knowledge of soils is collected and may then be arranged in a systematic way in a soil classification. In this manner the nature of any particular soil may be specified and further, it may be compared or contrasted with any other particular soil.

Soil survey has a vital role to play in the many facets of land use and development including soils research and field experimentation, research application and advisory work, management and manuring, cropping and rotation practices, delineation of problem areas toward improved animal and crop production, horticulture and forestry planning and practice, land reclamation and drainage, land settlement and reallotment, consolidation of fragmented holdings and others. First and foremost a soil survey provides a valuable inventory of the soil resources of the country as regards inherent character, potential and extent. In the planning and conduct of research and experimentation in the field, proper selection of most representative sites and rational extension of experimental findings to large areas can be made with far greater confidence when the soils are surveyed and classified. It is obvious that all experimentation related to the soil assumes far greater value when the soil as a variable factor is recognised in full.

A major function of the soil survey will be the identification of a soil in a local area such as a farm, or a forest unit, for the purpose of applying results of research applicable to that area. At the present time soil analyses are being used as a guide to balanced manuring for various crops. However, different soils have, for instance, different powers of "fixing" phosphate or variable ability to release potash from potash-rich minerals of the soil itself. Thus, whereas our present soil test is a very useful guide in planning manurial treatments, it becomes a much more formidable guide when supplemented by survey information on the soils themselves. Several aspects of liming problem in soils can best be investigated and remedied with the help of soil survey. Soil survey also discloses the level of organic matter in soils—a highly important factor. Problems of soil management, such as the most desirable cultivation practices to adopt, or most suitable seeds mixtures or tree species to grow, or best rotation to follow and such like, can best be tackled on a soil survey basis.

In the course of carrying out a soil survey, areas where certain nutrient elements are either deficient or present in toxic quantities in the soil for plant or animal needs, can be effectively delineated. The condition can usually be associated with recognisable soil features which are recorded in the course of the survey. Thus, extensive areas can be treated for the condition rather than sporadic occurrences. Besides the prediction possibility is extremely valuable. Such a survey to delineate areas deficient in cobalt for ruminant nutrition was carried out in Ireland in 1954-'55 with very satisfactory results. Similar surveys for like purposes have proved their usefulness in New Zealand, Australia and elsewhere.

Soil survey information relative to soil-crop relationships is most pertinent in horticultural enterprises for different reasons. Horticulture usually occupies only a small proportion of the total cultivated area and production is on the intensive rather than the extensive margin. With the relatively high labour content and capital investment involved in horticultural enterprise and with the limited degree of rotation and diversification of cropping possible, it is most important to have the other factors of production as optimum as possible so only the most suitable soils should be selected. A soil survey to determine the areas most suitable for orchard crops was carried out in this country in 1943 and has since proved of great value to horticultural instructors and orchard owners in locating and managing orchards. At present also the guidance of soil survey is being used in the proper selection of the most suitable soil areas for soft fruit production and other horticultural projects.

In land reclamation and drainage, the nature of the soils themselves and more particularly of the subsurface layers may be the deciding factor in determining whether certain reclamation procedure may be successful or perhaps even too costly relative to the economic value of land. A soil survey for instance, would indicate the presence of subsurface layers such as an ironpan or hardpan which might render drainage uneconomic. The question of whether mole drainage or subsoiling could be substituted for the more expensive tile or stone drains or what combination of both systems could be adopted, or what the optimum depth and spacing of drains should be, can be decided with far greater confidence with the aid of soil survey information. Before any large scale reclamation is undertaken for development of alluvial or marine areas, a thorough survey should be carried out to assess the nature of the deposits, their potential as soils when reclaimed, the variability within the area which may affect the economic feasibility of the project.

Many other facets in the development of our land resources should properly be aligned with sound soil survey information. Foremost is that of land resettlement—a very salient problem in Ireland. All the noteworthy land reallotment schemes and those for the consolidation of fragmented holdings in the Netherlands, for instance, are built around soil survey data of the lands involved.

Soils of Ireland—Their Variability:

In Ireland the need for a soil survey is accentuated by the fact that our soils are more variable in general character than those of most other countries. The reasons for this great variation are related to some major factors influencing the genesis, formation and development of our soils. Foremost is the extent to which our country was glaciated throughout Ice Age times, leaving a great variety of mixed glacial drifts as parent materials from which our soils have formed. Our soils are more directly related to these superincumbent drift materials than they are to the solid geological formations. Although the glacial drifts of themselves are related in geological composition to the local solid geology of any area, nevertheless they also include extraneous materials and their physical fabric is quite variable from that of the parent formation. Besides a solid geological formation as mapped may comprise a mixture of geological types rather than a uniform type. For instance, *Old Red Sandstone* may include impure limestone, quartzite grits and clay shales. But even on a uniform and common parent geological material, soils display wide variations amosgst themselves due to other factors that influence them in their genesis, formation and development from the geological parent material.

In considering these other factors, let us recast our thoughts on the process of soil formation. In studying a soil profile, what we really see expressed in its morphology is a reflection of the combined influence on the parent geological material of a climatic factor, biotic factor, a time factor and a location on the landscape or relief factor. This is true for all mineral soils. Variations in the relative degree of influence of each of these major factors cause variations in the soils themselves.

Climate in its role in soil forming processes can be considered under two independent headings—*humidity* and *temperature*. The main climatic factor operative in this country is the rainfall-evaporation regime. With the ratio balanced well in favour of rainfall most of our soils tend to occur in the leached to podzolised categories. Apart from those we have extensive areas of gleyed soils where high water table gives ground-water gleys. The former may be a function of the physical constitution of the profile, probably inherited from the parent material, as in our Drumlin soils. The latter is most often a function of relief or position of the soil on the landscape topography where such soils occur in low relief or depressed sites. Temperature is an interdependent agent with humidity since the higher the temperature the greater will be the surface evaporation and the lower the rainfall-evaporation ratio, thus reducing the leaching tendency. Temperature also affects the rate of decomposition or organic residues in the soil resulting in the formation of either the mull-like humus of our better mineral soils or the mor-like humus of our strongly developed podzols.

A major component of the operative biotic factor in soil formation has been the vegetation influence. For instance, on similar parent materials with all other factors being equal, two soils may show variable profile character as a result of vegetation history. The broad distinctive influence of forest versus grassland on soil profile character is well recognised, but even more impressive is the general difference between coniferous and deciduous species. More impressive still is the specific action of beech litter as distinct from that of other hardwoods in this respect. Beech litter accumulation is conducive to podzolisation in the underlying profile with formation of a raw surface humus, whilst oak litter tends to maintain a brown forest soil and a mull humus. Dimbleby and Gill [1] claim that Holly litter brings about the conversion of raw humus—even *Calluna* raw humus—to mull humus. Even within the conifers variation in influence occurs. It has been suggested [2] that whereas very active mor-forming species such as spruce or pine will maintain a mull only on very fertile soils, there may be marginal species such as larch and Douglas fir able to maintain a mull on appreciably less fertile sites. Of course ground flora is equally variable in its influence on soil forming processes. Especially interesting here is the drastic action of *Vaccinium, Calluna* and Ericaceous species in inducing podzol conditions.

The influence of time or age is not so apparent in our soils, except in the extreme case of young alluvium in comparison with mature soils, but nevertheless it has played its part too. Relative to other areas of the world, few if any of our soils could be considered as very mature. Nevertheless, some of our more mature soil profiles may be twin profiles with a "fossil" profile underlying a more recent profile. Finally, in thinking of variable soils, we can never discount man's interference over the years with the "natural" trends of soil development.

Soil Survey with particular reference to Forestry:

When planning a new forest, the forester must endeavour to take into account those ecological factors that may affect the growth, health, yield and quality of his trees. So closely are soils and forestry related, one to the other, that their influence is mutual. Cases of where the influence of different species causes specific differences in soil profile character have been instanced. Likewise, different tree species are selective with regard to optimum soil conditions. In an enterprise so closely related to the soil, surely soil survey must have a major role to play. Besides the forester has very often to contend with land that may be considered unsuitable for agricultural use and this limits considerably his latitude in soils. Although forestry as a crop is capable of producing economically over a wide range of soils, nevertheless it is the soil that determines in many cases the economic feasibility of planting an area. Likewise, it is the soil which chiefly influences decisions on the species to plant for most profitable return.

Soils affect trees principally through soil, air and soil moisture. Seasonal available soil moisture commonly determines what species persist in any forest and their rate of growth. Four general soil characteristics affect the air and moisture supply—depth, surface porosity, subsoil permeability, and aspect. These factors then are all-important in a forest soil. Too much soil moisture is equally a problem as too little where tree growth and especially seedling establishment is concerned. Enough water at the right time is the all-important thing.

According to American research findings [3] soil temperature affects

(1) Dimbleby, G. W. and Gill, J. M. "Forestry" Vol. XXVIII, No. 2, 1955.
(2) Johnston, D. R. "Quar. Jour. of Forestry" Vol. XLVIII, No. 4, Oct. 1951.
(3) U.S.D.A. Yearbook of Agriculture, p. 723. 1957.

the germination of seeds, establishment of seedlings, and growth of trees. Best for germination is reckoned to be between 68°—75° F. Heavily shaded soils, cool northerly slopes and "cold" soils that warm slowly because of excessive moisture therefore may retard both germination and development. Certain forest diseases likewise can be related to soil conditions.

The fertility requirements of trees would seem to vary greatly, especially among the pines, but in any case these too are directly related to the soil. Fertilisation with potassium, phosphorus, magnesium and nitrogen has markedly increased growth in some areas. The quantities of nutrients taken up by forest crops are relatively large as indicated by Rennie [(1)]. But he points out that the quantities absorbed do not necessarily indicate the actual requirement for vigorous growth. Nevertheless, soils of very low inherent fertility may fail to supply the needs of the forest crop in which case they must be supplemented with fertiliser amendments for best results. Besides the essential major plant nutrients, certain tree species in particular respond to trace element application, e.g. Monterey Pine in Australia sdffers from Zn deficiency and Cu deficiency may be a distinct problem in different species on peat areas. According to American findings [(2)] "germination is inhibited and growth prevented on excessively acid or alkaline soils and by high concentrations of soluble salts". For example, "extreme acidity from oxidation of iron pyrite occasionally prevents both natural and artificial restoration of spoil banks and strip mines". The soil reaction and other chemical properties however, usually affect the development rather than the germination of seedlings. American workers [(2)] for instance have found that conifers will germinate over a wide range of pH 2.0 to pH 11.0, whilst seedlings in general develop best between pH 4.5 and 6.0, but species differ widely in their adaptability to soil reaction.

The supplies of nutrients and moisture that affect tree growth are closely associated with effective soil volume and its physical makeup. For this reason the presence of a pan or substratum such as occurs extensively in our podzols and soils with fragipan that limits these two factors, is one of grave moment. Texture, consistence and mottling of the subsoil and other factors, have all been related to growth rate frequently.

In forestry operations soil surveys have been used in a number of ways. Cropping problems of the soils present are made known in the course of a survey. In forest plantations, according to Stephens [(3)] "soil surveys have been used in the study of the relative productivity of various soil types, to study the instances of nutrient element deficiencies and to correct them by the application of suitable amendments. Both the latter operations are most readily carried out initially on sample plots and these should be located with regard to soil type. Furthermore,

(1) Rennie, P. J. "Plant and Soil" No. 7, 49-95, 1955.
(2) U.S.D.A. Yearbook of Agriculture, p. 723-724. 1957.
(3) Stephens, C. G. "F.A.O. Agricultural Studies" No. 20, p. 21, March, 1953.

soil maps of unplanted areas can be used for the selection of soils suitable for plantation purposes and to define those areas of soils which may be made suitable by such means as drainage, cultivation and the addition of mineral nutrients". Where natural forests have been cut over decisions whether to regenerate the area to forestry perhaps to assist watershed control, or to complete clearing to develop for agricultural purposes can be made with greater confidence with the aid of soil mapping and classification.

In general, however, the part played in forestry projects by soil survey in different countries is not so extensive as in Agriculture. For example, in New Zealand soil survey plays a lesser role in forestry than in agriculture. However, as Ward and Hocking (1) pointed out, "where there is a growing body of evidence that indicates that many of the cases of unthriftiness and mortality in forests can be traced to the soil, the forester has come to realise that the siting of trees without sufficient regard to soils can greatly affect the ultimate value of his forests. Thus any contribution made by the soil surveyor which extends the forester's understanding of the edaphic factor, enables him to utilise his soils more effectively." In a study of the application of soil survey to forest planning and practice, the same workers (1) have shown that the soil map and report are of real value to the forester: "they provide him with data essential to the proper understanding of sites and enable him to make the best possible use of his soils to establish a healthy and productive forest". Soil survey data also helps him to plan his forest in a shorter time and with greater confidence. The New Zealand forester, as is true for most countries, has little latitude in choosing his soils and consequently, must site his trees carefully on the soils most suited to their needs. The New Zealand studies of Ward and Hocking (1) at the Te Wara State Forest, stressed the need to strike a balance between the optimum use of each soil type and the limitations of forest management and economics. The soil survey there also made possible a workable compromise in land use where the more valuable soils agriculturally (recent soils and yellow-brown loams) were reserved for farming.

In the Netherlands, it has been found that productive tree species differ widely in their requirements with regard to soils. By careful study of existing forests a land classification for forestry purposes has been made for certain areas and is found most useful by foresters.

In Germany the State Geological Department produces the soil maps. These are used by the foresters in conjunction with vegetation survey maps and in co-operation with the soils and vegetation specialists to produce forest site maps. The site types of the district are then classified and grouped according to their sylvicultural values and their potential productivity.

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(1) Ward, W. T., and Hocking, G. W. "N.Z. Journal of Science and Technology", B.Vol. 38, No. 3. November, 1956.

In Norway, investigations on forest soils is part of the programme of the National Forest Survey. Characteristics studied mainly include depth and origin of soil material, thickness of humus layer, profile type, mechanical composition and content of stones on the surface. Distinction is made between podsols and brown earths and integrades of these two are mapped separately. Each of these three groups is further broken down on more detailed examination. Soil-vegetation relationships are given full recognition in all cases.

In the United States, survey of soils for forestry purposes has received a new impetus in recent years. The University of California at Berkeley is particularly active in forest soils research. This impetus was due in greater part to the realisation that forestry could not be dealt with as an economic problem, while involving an unknown value—the soil. Few commercial interests could afford to invest capital for tree planting and related forest enterprises on land of an undetermined productive potential. Wilde [1] discusses what he calls a *"forest soil survey"*. This survey supplies necessary information on site factors—climate, topography, ground water and *soil*. This characterisation of sites constitutes probably the most important step in the organisation of a forest project, and soil survey has a major part to play in this.

In Ireland the National Soil Survey can serve the interest of Irish Forestry, not alone by providing basic information on the soils themselves, but in many other aspects also. The basic survey of Irish soils is intended to serve as a foundation and source for various other surveys according to specific needs. Foremost amongst the latter will be land use capability surveys. Land will be classified on the basis of its relative ability to produce different crops and products under defined systems of management. Furthermore, a broad classification based on soil survey findings could segregate those soils not considered to be capable of high economic production under agriculture and then classify them in terms of their capacity ratings for forestry production. This would involve close collaboration between the forester and soil scientist. Perhaps a proportion of these latter soils may fall into land classes of but limited use for poorer type timber production or perhaps suitable only for wild life preserves and recration purposes.

Valuable observations on establishment and growth success of different species on certain soils in the country are available now no doubt, with many of our foresters. In how far can this valuable information be extended to other areas and be used with confidence in future forestry planning, until it is established that such areas have soils of similar nature to the observation sites. Likewise results of soil-tree species experiments, which of necessity must be confined to small areas can be projected with greater accuracy and confidence when the soil conditions are known. Furthermore, the productive capacity of different

(1) Wilde, S. A. "Forest Soils—Their Properties and Relation to Silviculture". The Ronald Press Co., New York, 1957.

species can be more accurately compared when allowance is made for soil differences.

From the point of view of maximum economic production of timber products, it is essential to site trees on the most favourable soil conditions available for the species and to know beforehand what the inherent limitations of such soils are, so that they may be amended. These limitations in this country are more often of a physical rather than a chemical nature, involving impervious substrata, iron pans, textural limitations, resultant poor drainage or poor root development. But they also include limitations in essential plant nutrient supply, or due to toxic substances, soil reaction, trace element supply and so on. When introducing new species from abroad for trial under native conditions here, both in propagating them and siting them later on, a full knowledge of relative soil conditions involved is all-important.

Perhaps where soil survey can make a very special contribution in this country is in arriving at a rational compromise between forestry and agriculture, where the conflict arises in deciding on optimum land use in many areas. In Ireland with the ever current demand for agricultural produce, one must accept that in many cases only the less suitable agricultural soils will be devoted to forestry. These include the vast areas of Podzols, and associated climatic peats of Western Ireland and scattered mountain areas elsewhere, the poorer Brown-Podzolics, some of the Hydromorphic soils in the Drumlin and other areas, the blanket peats in the West and elsewhere, and the cut-away basin peats of the Midlands. Within these poorer soil groups the forester has to contend with a whole range of soil differences that will have an impact on his forestry planning and procedure.

However, in many hill-land areas, an agricultural system has been in operation for years, involving all gradations from mere hill-sheep ranching to small scale dairy farming or limited tillage farming. The ideal for such areas would seem to be to integrate forestry into the present system for more intensive economical land use. This would presuppose maintaining agriculture only on those soil areas most suitable for it and establishing forestry on the submarginal areas. But of course with the human element to be given foremost consideration in all such planning, the physical possibilities outlined must be modified in terms of the social desirability of such projects. Where hill-farming is concerned, it is desirable for winter food and shelter that a certain acreage of lowland accompany each stretch of hill grazing. With integration with forestry, it is usually possible to graze above the timber line in Summer and due to the forest shelter, utilise the lower slopes below the timber in the Winter, thus releasing lowland contiguous areas for a more conventional type of farming. It is better economically also to have an integrated grazing and forestry enterprise, as not only are they in part complementary, but they contribute toward better diversification of products. The information provided by soil survey is vital in the execution of programmes of this nature.

An integrated programme such as outlined above is perhaps the most desirable as a land use plan for many of our better hill areas, say on *Old Red Sandstones* that carry a mixture of leached Brown Earths, Brown Podzolics and Podzols. Equally well it should apply to the poorer Drumlin areas where a dairy industry based on grass production, under a very strict management system, integrated with well planned forestry, may quite conceivably be a solution to some of the problems there. But such an overall programme must be based on a knowledge of the soils since major profile differences occur amongst these soils even from one Drumlin to the next. More confident decisions can then be made on which soils should best be devoted to which enterprise, on how the individual soils must be managed toward greater output, on what drainage system to install to dispose of surplus water, on what grass seeds mixture or tree species that might best be planted, and on what manurial or liming procedure to follow for best results. With thorough soils knowledge, it is difficult to assess the most feasible procedure to adopt since economic and social factors enter the picture, but without such soils knowledge, it is well nigh impossible.

A few of the applications of soil survey in the field of forestry planning and programming have been covered. Nevertheless, it is certain that even these are adequate to assure us of the role that soil survey can play in this respect. Perhaps much more use will be made in future of the soils knowledge provided by Soil Survey in the forestry programme of this country. Greater collaboration and co-operation between the forester and the soil scientist should prove very rewarding to the efforts of both. It is hoped that such will be the case. Co-operation and co-ordination of effort are necessary to obtain, with the information available, the best possible practices of land use, management and conservation for every acre of land in the country, which coupled with current economic thinking, should achieve the most economic sustained output from our soil resources, on which the prosperity of this country as a whole, ultimately depends.