Soil Science in the Twentieth Century*

By Prof. J. Hendrick

MOST of our scientific knowledge of the soil has been built up during the past century. It was only with the development of modern science, and especially of chemistry and geology, that such knowledge could advance, and it was about a century ago that our early knowledge of the chemical composition and mineral constitution of the soil was built up. This knowledge has been advancing ever since but with particular rapidity during the present century.

Soil science in Great Britain was in a comparatively stagnant state at the beginning of this century. Britain had done much in the development of the fertilizer industry, though even in this, while other countries were advancing rapidly, we had been falling somewhat into the background during the last quarter of the nineteenth century.

A comparison of the text-books on agriculture and agricultural chemistry of the beginning of the century with those of the present day will illustrate the great change in outlook on soil science. There were no British text-books on soil science in 1900. Any text-books on this subject in English were American. Our knowledge of what was being done by soil investigators abroad was not extensive; of what was being done in Russia we knew nothing.

Britain is a comparatively small country falling within ten degrees of latitude, with a climate which is in all parts temperate and humid and with a rainfall which is well distributed throughout all seasons of the year and which varies from moderate to high. The soils of Britain had not been studied even over the whole limited range of the country, but almost entirely in a small region in the south-east and mainly at Rothamsted and Woburn. These were looked upon as typical soils, and all others were supposed to be more or less similar. If that was not definitely stated, it was tacitly assumed. It may be said that until the present century, and even until the second decade of the present century, our view of soils was narrow and insular. All others were expected to conform to "This blessed plot, this earth, this realm, this England", and it was a most blessed plot of the south-east of England which was the standard.

We did ourselves no good service from an imperial point of view by taking such a narrow and insular view of soils. While Britain is a small country of limited latitude and climate, the British Empire exists in every latitude and every kind of climate. In agricultural science and not least in soil science, great sections of the British Empire, not merely Canada, but Australia and South Africa as well, came to look to the United States rather than to Britain for information and guidance.

There are two great countries which, unlike Britain, extend through wide ranges of latitude and climate. These are Russia and the United States. Russian territory extends from arctic tundra to the subtropical, and embraces every kind of climate from warm humid and cold humid to arid and desert. The same is true of the United States, especially if we include Canada, which, in this respect, is in very close association with the United States, whose workers keep in view the soils of the whole North American continent.

The scientific work of the United States is published in English and is therefore always easily accessible to us. Russia, on the other hand, is cut off from us by the barrier of a language which few can read, and the remarkable soil work which was going on in Russia and has now produced such a great change and widening of the views of soil investigators throughout the world, was unknown in Great Britain until after the Great War, when it began to filter through to us from America, Germany and other countries.

What are these fresh views which we all sat at the feet of the Russians to learn? They treat the soil as an independent natural object worthy of study for its own sake and not merely as a useful medium in which to grow crops, or as a subsidiary branch of geology or chemistry or any other science. The branch of science which deals with soils they treat as an independent branch, which they call pedology. Many people in Great Britain and in America have now adopted this term and prefer to be pedologists—a word not in the dictionary—rather than soil scientists. My own preference is for a term which is readily understood by ordinary people.

Next, the Russians insist that the soil is the natural product of a number of soil-forming factors of which the most important is climate, and that its nature is not determined by its geological origin. Their great primary classification of soils is into a number of climatic zones. The most notable feature in the whole Russian philosophy of soils is the insistence on the importance

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of climate as a soil-forming factor. Climate plays the central part in their system of soil classification. This recognition of climate is not entirely a new idea. Hilgard in America, and others, had already shown that climate has a great effect on the nature and composition of soils.

In the old Russian Empire, and the modern union of Soviets, there are soils which have been produced in a great variety of climates in Russian Europe and Asia. The Russian soil workers set themselves to collect these and to examine them critically, and came to the conclusion that soils produced from a geological formation in a cool climate were very different from those produced from the same geological formation in a hot climate, and that those produced in a moist climate were very different from those produced from the same parent materials in an arid climate. In fact they showed that soils cannot be classified and characterized on a geological basis. Possibly some of them, and still more some of their enthusiastic converts in other lands, go too far in excluding geological origin altogether as a factor in soil formation.

The next great feature of the Russian system is the classification of soils according to what is found in the soil profile. The profile, as is now well known to all of us, though that was not so twenty years ago, is a section of the soil from the surface down to the parent material. If such a section is examined, it is almost invariably found to consist of a number of different layers, called horizons, which are generally easily distinguishable from one another. When a great many such profiles are examined from different parts of the world it is found that they fall into a number of definite types characteristic of the different types of soil. The profile is an expression of the results of the different soil-forming factors, and therefore characterizes the different types of soils as produced by the action of these factors. This is expressed by saying that the profile is the resultant of the pedogenic processes. The modern soil surveyor studies morphology of soil profiles and classifies his soils accordingly.

This is in outline very simple; in practice it is often very difficult, and is apt to give rise to differences of opinion, especially when those accustomed to the profiles of one part of the world are introduced to a new region with conditions different from those to which they are accustomed. It will be seen, too, that this scheme of a profile made up of horizons is a development of the old division of the soil into soil and subsoil. But there is an important difference; the terms soil and subsoil were applied to cultivated soils mainly, and the soil was, generally speaking, the layer which had been mixed and influenced by the implements and processes of cultivation, while the subsoil was the layer which was not touched by instruments of cultivation. Such a division is of no use to the modern student of soil morphology and genetics. The processes of cultivation have turned over and mixed the surface layers and have also modified those below the region reached by the plough. The modern soil investigator, therefore, insists that the profile must be studied in undisturbed soil which has existed in its natural condition for a long period of time. To him the profile is the soil unit which must be studied as a whole, unmodified by artificial operations of man. This of course introduces difficulties in old settled countries of dense population, like our own, where most of the soils which are worth cultivation have been broken up and cultivated at one time or another. In the extensive, lightly populated areas of Russia or North America there are plenty of natural soils; but in applying modern methods of soil study to the soils of much of western and southern Europe and other regions of ancient civilization, modifications have to be introduced to allow for the influence of cultivation which, in many cases, extends over long periods of time.

The whole of the processes of soil formation are very complex and require much more study before we can hope to reach, I will not say a final, but a sound system of soil classification. The soil itself is, from every point of view, a very complex and variable material; and our present methods for its study and classification, though a great advance on what went before, are of very recent origin, and no doubt further great progress will be made as a result of the intensive studies to which soils are now being subjected in many lands.

In the above sketch I have merely referred to one or two features of the Russian soil philosophy which appear to me to be outstanding. Much of the Russian soil science is at present remote from agricultural practice. It is curious that in spite of their theories of Government and of five-year plans for the rapid practical improvement of the condition of the people, the Russians are the champions of pure soil science, of the view that our study of soils should proceed without reference to any use that may be made of such knowledge for the service of agricultural practice, or for the production of wealth from the soil.

The fundamental importance of soil moisture has been known for ages. Without water, crops cannot grow, and with excess of moisture we get marsh or swamp and our ordinary crops are drowned out. A proper supply of moisture is more important to crops than all the fertilizers put together. In the modern theory of soil formation and classification the important part played by water is recognized. The two important factors in climate, those which do most to determine what the soil is to be, are the supply of water and the temperature. In considering water supply it is not sufficient to consider the rainfall—the humidity, the distribution of the rainfall and the topography all enter into the picture. A rainfall which is sufficient to wash through the soil and leach away soluble constituents in a cool humid climate may all be re-evaporated and leave nothing to wash through the soil in a warm climate with a dry atmosphere. Again, if all the rain falls at one season of the year a part of it may seep through the soil and escape as drainage water, while if the same rainfall is distributed throughout the year so much may be re-evaporated that there will be none to escape as drainage.

Considering the importance in soil formation of water which passes through the soil, and of the amount and nature of materials in solution and suspension which are washed away by such water, or removed by it to lower layers of the soil, and the importance to soil fertility of the relations of the soil to water, and of the economic importance of drainage in connexion with the loss of nitrogen, lime and other manurial constituents from the soil, it has always been a matter of surprise to me that more use is not made in soil studies of drain gauges or lysimeters, or instruments of a similar kind.

The first drain gauges, so far as I am aware, were made by Lawes and Gilbert at Rothamsted more than sixty years ago. They were designed to study evaporation and percolation in relation to depth of drainage, and were therefore of different depths, 20, 40 and 60 inches respectively. They were also used to study the amount of nitrogen washed away from uncropped and unmanured soil. The blocks of soil enclosed in these drain gauges were never broken up, they were built with as little disturbance as possible into the water-tight structures which enable the drainage to be measured. They consist therefore of real soils which have been formed by a long course of natural soil-forming processes. Similarly the drain gauges which I have had built at Craibstone, near Aberdeen, have been formed by enclosing, without disturbance, in water-tight boxes of Caithness slate, blocks of natural soil which have never been broken up. My drain gauges are intended to study the changes which take place in cultivated soil, and the losses which take place in the drainage water during ordinary processes of cropping and manuring.

Such drain gauges are not easy to construct. I suppose that is why this method has been so little used in the study of soils. It is much easier, and cheaper, to build a water-tight box and fill subsoil and soil into it, than it is to enclose a block of natural soil, weighing several tons, in a water-tight structure. If the easier method is adopted, as has been done to a large extent in America and elsewhere, its limitations must be recognized. The soil, once it is broken up and filled into a lysimeter, is no longer a natural soil, and it is difficult to say how long it will take under the influence of the soil-forming processes of the locality to become once more a real soil such as is provided in Nature.

The development of our knowledge of soil colloids and base exchange during the present century is second in importance only to the advance which has been made in the science of soil formation, structure and distribution. The beginnings of our knowledge of this subject can be traced back to the middle of last century when Way showed that the ammonium of ammonium sulphate, or the potassium of potassium sulphate, was retained by the soil while an equivalent amount of calcium went into solution and could be washed away as sulphate. He also showed that this power resided in the finest mineral part of the soil, the clay, and he regarded the action as an ordinary case of double decomposition between clay and the soluble, neutral salt in solution.

Though there was much discussion about these phenomena, which were regarded as of the greatest practical importance because they showed that valuable manurial bases when applied in a soluble form could be absorbed and retained in the soil, and though soil investigators of last century were divided into two camps, one regarding this fixation of bases as a chemical precipitation by double decomposition and the other looking upon it as a physical process of absorption, little further advance was made until the present century. By that time, considerable advance had been made in our knowledge of colloid chemistry, and we also knew that there were two types of colloid complexes found in soils, one mineral and the other organic.

We now know that this process of base exchange is a colloid phenomenon, and follows the laws of colloid chemistry. It is not confined, as Way supposed, to the fine mineral matter of the soil, but is a property of the organic colloids also. The old controversy as to whether this is a chemical or a physical phenomenon is thus cleared up and both sides are shown to be right or both wrong, according to taste, for both sides knew nothing of that border-line field of colloid phenomena where physics and chemistry blend, and, in the best modern manner, tend to become indistinguishable.

Our knowledge of the chemistry of humus, in spite of the great amount of work which has been done upon it in recent years by workers in many countries, is still in a state of doubt and darkness, but in the last few years we have learned a great deal about the chemical structure of clay. The application of X-ray methods of analysis has shown that much clay material exhibits a definite lattice structure, and that there are several different minerals, showing at least two different types of lattice structure, to be found in clays. Some light has also been thrown by this work on the nature of the base exchange capacity of clay and on the great differences in base exchange capacity which are found in different types of clay substances.

One cannot give a very hopeful account of the progress of our knowledge of humus. We have not yet found any clear method of unravelling its structure and of showing what is the nature of the colloid molecules which build up the main part of this very important soil constituent.

In many other directions, fundamental soil science has made in this century, and is making, marked advances. Fertilizers, for example, we may class along with the soil, for they are substances used to increase the productivity or make up the deficiencies of the soil. From small beginnings a century ago, the fertilizer industry has grown to be one of the world's greatest chemical industries. In the early days of the industry Great Britain played a notable part, but in the latter part of last century and the early part of this one, when the whole of our soil science was in a somewhat backward position, our fertilizer industry also fell into the background. We have recently seen a great revival consequent upon this industry again becoming scientific instead of depending merely upon commercial and business ability. For this change and improvement we may, I think, give much of the credit to Imperial Chemical Industries, Ltd., who are now our greatest fertilizer manufacturers, and who make the manufacture of manures an important section of their business. The older type of fertilizer manufacturers may have employed a few works analysts, but they did not pay for the best scientific brains to help them to introduce new processes and to improve old ones. That has been changed by I.C.I., and we have a new spirit in the fertilizer industry and we are regaining something of the great position we once held in that important branch of chemical manufacture. It is to be hoped that this will continue. If we are not to fall back into the old state of lethargy we must continue with long-range research, as the Germans and Americans are doing, carried out by educated and competent persons. That is the only way if we are to continue to advance and keep in the front.

Physics is not the only branch of science in which revolutionary changes have been made in the twentieth century. Even in soil science we have seen a structure built up which the agricultural chemists of a generation ago would find strange. In the British Isles at the beginning of the century there was almost no soil science ; now we are taking our due part in building up and nurturing this branch of knowledge. We have now not only the great station at Rothamsted but also the Macaulay Institute at Aberdeen, which is engaged in the study of soils of different types from those of the south-east of England and is approaching soil study from a somewhat different angle. There are also in our universities and agricultural colleges quite a number of soil investigators of distinction who are dealing with the soils of many other parts of the country. At the same time, it is probably true to say that in Britain the fundamental attitude towards soil study remains the same. It is difficult for us to achieve the complete detachment of the Russians and study soils entirely apart from any practical agricultural applications which our studies may have.

But to what are we heading ? Of what use is it all ? Are we only increasing sorrow by increasing knowledge ? Our increased knowledge should give us increased power to use the soil, and that surely means increased production. We are told there is already over-production and that what is required is restriction of production. We read in our papers of crops being destroyed because they cannot be used, or because it does not pay to harvest them. In the United States, and elsewhere, the growth of fundamental food crops, like wheat, has been restricted. In Great Britain arable land is decreasing while at the same time the import of foodstuffs is being restricted.

Has everybody in this country, and in every other country, too much, or even enough, food ? Do we not, at the same time as we are crying out about over-production, hear an equal outcry about malnutrition and under-feeding even in this comparatively prosperous country ? The two things do not fit together. They cry out against one another. They cannot both be right. But we all know that there are many people, forming quite a large section of the population, who have not over-abundance, who have not even enough. This, which is true of Great Britain, is, unless we are strangely misinformed, true in a much higher degree of the world at large. This is not a problem of soil science, but a problem for the statesman, the social reformer and the economist. The soil scientist can safely go on and increase our knowledge of soils, and hope that, in the long run, it will increase production and lessen labour. Increased wealth, especially in the essential things produced from the soil, is a blessing, not a curse, and if it can be obtained more easily, and more certainly, through the power and control provided by increased knowledge, that is all to the good.

The solution of our difficulties must be looked for by the increase of impartial scientific knowledge in other directions. It is our social organization, our statesmanship, our economic system which are at fault when the abundance which is produced cannot be brought to the many who are in need of it. Social and political sciences and even economic science are no doubt applying themselves to this problem, and let us hope they will be able to remove it from an atmosphere of social prejudice and party bias to the calm, truth-seeking atmosphere of pure scientific investigation. Agricultural science can go forward fearlessly to increase knowledge in the good hope and belief that increased knowledge will be in itself a blessing.

Cancer Research in Great Britain

THE thirteenth annual report of the British Empire Cancer Campaign was presented at a meeting held at the House of Lords on November 23. The report gives an effective summary compiled by institutions and individuals of the greater part of British research on malignant disease. The field of cancer research may be divided into three parts: the origin of the disease; the nature of malignant growths; and the effect of treatment in alleviating or curing the disease. Investigations in man, in animals and in cells growing outside the body in tissue culture have been made in all three directions during the last year.

Attempts to understand the nature of the processes which cause cancer in man have been made by studying cancer mortality according to the organ in which it occurs in different districts and different occupations. Observations of this kind have in the past indicated that coal tar and certain lubricating oils might be carcinogenic and so lead eventually to the isolation of the pure carcinogenic compound, benzpyrene. Previous investigation into the mortality from cancer in different countries has shown surprising differences, such as the high incidence of liver cancer in the East and its comparative rarity in Europe. In Switzerland, cancer of the œsophagus is more frequent than in the rest of Europe. Dr. Stocks, of the General Register Office, has examined the geographical distribution of 522,251 deaths occurring between 1921 and 1930 from cancer in the counties of England and Wales. He has calculated the "actual mortality per cent of that expected from the distribution of population by age and class of district". The results are depicted in a series of maps. Some of the more outstanding differences are shown in the accompanying table.

Death from cancer of all sites is more common than would be expected in North Wales and unexpectedly rare in Radnor and East Suffolk. In Wales, gastric cancer is frequent, and Carnarvonshire accounts for more than twice the expected number of deaths, but lung cancer is rather infrequent. The results show resemblances between the distribution of œsophageal cancer and rectal cancer, while the distribution of gastric cancer is quite different. The distribution of the ratios for breast cancer is much more uniform than for any other type of cancer shown. It is as yet impossible to determine whether these differences are due to genetical factors, to geological or meteorological conditions, to the different diets and habits of people, or to the difference in accuracy of diagnosis.

Prof. E. L. and Mrs. Kennaway have computed the incidence of death from cancer of the lung and larynx in a large number of occupations, for the years 1921–32. During the period 1919–34 there was an eight-fold increase in the mortality from lung cancer. The cause of this increase has not been identified, but it does not appear to be due to urbanization as the relative increase among agricultural workers is only slightly less than among the total population. Workers exposed to coal gas and tar and those engaged in tobacco and metal grinding trades show high susceptibility, while coal miners, cotton spinners and agricultural workers have a low susceptibility to lung cancer. This latter finding is reflected in one of Dr. Stocks's maps. Mortality from cancer of the lung is less

DEVIATION OF ACTUAL MORTALITY FROM THAT EXPECTED FROM THE DISTRIBUTION OF POPULATION BY AGE AND CLASS OF DISTRICT.

	High Incidence	Low Incidence
All sites (males)	Flint, London, Huntingdon.	East Suffolk, Radnor.
All sites (females)	Anglesey, Merioneth.	Radnor.
Stomach (males)	Ely, Anglesey, Carnarvon, Denbigh, Merioneth, Montgomery, Pembroke.	East Suffolk.
Stomach (females)	Anglesey, Carnarvon, Denbigh, Merioneth, Pembroke.	West Sussex.
Œsophagus (males)	Berkshire.	Durham, Lincoln (Holland and Lindsey), Northumberland, Nottingham, Merioneth, Monmouth.
Skin (males)	Lincoln (Holland), Anglesey, Cardigan.	Gloucester, Carnarvon, Radnor.
Lung (males)	Hertford, London, Middlesex, Essex, Nottingham.	Berkshire, Cumberland, Devon, Dorset, Durham, Gloucester, Lincoln (Holland), Northampton, Suffolk, all Wales except Flint.