THE PHYSICAL PROPERTIES OF THE SOIL IN RELATION TO SURVEY WORK.

By G. W. Robinson, M.A., Adviser in Agricultural Chemistry, University College of N. Wales, Bangor.

Considerable difficulty has been experienced in the correlation of plant and soil surveys. This may be attributed to a large extent to the defects of existing methods of soil classification. In the classification of any material, whether soils, plants or animals, the method to be adopted is to a large extent arbitrary. For example, soils may be classified on a purely genetic basis and, from the geological point of view, this classification is the one naturally to be adopted. From the point of view of plant physiology, however, a genetic classification may be of little use.

In many regions the genetic classification proves quite satisfactory even from the point of view of plant physiology, and the properties of a soil may be closely correlated with the conditions of its origin. Geology and climate are the principal factors in soil formation. Under conditions such as obtain over most of England and Western Europe generally, the influence of geology on soil is well exemplified. Hall and Russell in their survey of the soils of Kent, Surrey and Sussex, were able to classify soils satisfactorily on a geological basis. Under more extreme conditions of climate as exemplified by the semi-arid regions of South-Eastern Europe and the extreme humid regions of our own islands the influence of geology on soil is much less marked. Accordingly, we find the Russian school of soil workers classifying soils largely on a climatic basis.

Working in North Wales, the writer has found the correspondence between geology and soil much less marked than in England. The rather extreme humid conditions may account for this to a large extent. Other observers have noted that under extreme conditions of climate, whether of temperature or rainfall, the influence of the parent rock is reduced to a minimum. The lack of correlation between geology and soil need not, however, prevent the investigator from establishing soil types. The question of course arises whether soil types always exist, or whether in some cases soils are unclassifiable. In some districts, the isolation of soil types is an impossible task. Among the glacial soils of certain districts of North Wales, it is possible to find a continuous gradation from sands to clays without any definite grouping. In other areas soil types do undoubtedly exist, and a large number have already been described.

This leads to the question of the criteria used in soil classification and the isolation of soil types. At present, mechanical analysis is the general criterion used for the characterisation of soils. In this country the soil is separated into six grades of particles, varying from fine gravel to clay. There are, however, throughout the world, a large number of different conventions as to the limits of the size of the different fractions. Uniformity is impossible as each country has accumulated too many data to

effect a change. It is thus impossible to compare an English soil with, say, a Hungarian or a Swedish soil. Even in the case of the clay fraction where the upper diameter limit is taken as ·002 mm., any comparison is vitiated by the different methods of separation in use. Another drawback to mechanical analysis, namely, the discontinuity of grouping, has been overcome by the elegant apparatus devised by Sven Odèn, whereby the mechanical analysis of a soil can be expressed as a continuous curve.

The main defect of mechanical analysis, however, as a basis for soil classification is that it only gives information as to the properties of the soil by inference. The mechanical analysis will tell us little about the properties of the soil beyond what is contained in the practical man's classification into sands, loams and clays. Indeed, within certain limits, the same information might be gleaned by the ordinary methods of silicate analysis. In other words the information given by mechanical analysis only differs in degree from that given by chemical analysis. The formula of an organic compound describes its constitution, but its properties are given by such constants as melting-point, boiling-point and refractive index. The mechanical analysis of a soil is analogous to the constitutional formula of an organic compound.

Mechanical analysis is of undoubted value from the point of view of the genetic classification of soils. It enables the investigator to group together soils of similar origin. Apart from its diagnostic value, it gives certain indications as to the actual properties of the soil, but these are only imperfect and indirect. Attempts have been made to correlate cropping with mechanical analyses. The correlation is, of course, complicated by climatic and economic factors, but even allowing for these, the correlation obtained is imperfect, and it may be doubted whether the mechanical analysis of soil can do more than standardise the practical man's classification of soils into heavy, medium and light.

It is probably this defect in mechanical analysis which is responsible for the disappointing results obtained from soil surveys. Soil survey work has been in progress in this country for fifteen years or more, while ecological studies have been carried on for an even longer period. Yet the actual progress in the correlation of plant and soil surveys is almost negligible.

In North Wales one frequently finds tracts where the edaphic conditions as indicated by the natural vegetation vary sharply from point to point without any apparent change of soil type. Differences in the air and water conditions of the soil are probably the main factors causing these variations, but there is no reliable quantitative method of expressing them. The mechanical analysis is almost useless, and can only occasionally be correlated with the natural vegetation. I am speaking, of course, of a province where the climatic conditions are somewhat extreme, but the same difficulty must frequently arise in districts of more moderate rainfall.

In the opinion of the writer, the only remedy for this and the only way to get a fresh impetus for the field study of soils is to examine the soil from the point of view of its actual properties. To say that a soil contains 20 per cent. of clay does not give a picture of the actual properties of the soil except by inference. In fact, certain materials, such as kaolin and finely ground slate, give as much clay by mechanical analysis as fairly heavy soils, although they lack the characteristic property of clays, namely, plasticity. Further, among the plastic clays the amount of clay by mechanical analysis cannot be correlated completely with the texture.

Although the original data of mechanical analysis are quantitative, the deductions from them are certainly not quantitative. The most valuable

data about the soil are those which give direct information as to the properties of the soil as they affect plant life. In the opinion of the writer, the data in question would be given by a series of physical constants comparable to those which are indispensable to the description of a newly discovered element or compound.

An example of this method of investigation is furnished by Atterberg's work on the plasticity of soils. From the agricultural point of view, information as to the working properties of a soil is highly desirable and the figures given by Atterberg's methods are of direct importance. His "Plasticity Number" gives the range of water content over which a soil is plastic, while the figures obtained by him for the cohesiveness of soils (festigkeit) give direct information as to the resistance of the soil to comminution by the ordinary operations of tillage.

Pore space as a physical constant for the soil would be of considerable use. Owing to the difficulties of obtaining a sample of the soil without disturbing its field structure, a satisfactory routine method for determining this value has not been devised. The methods of Kopecky and Trnka are instances of attempts to solve the problem. Could a satisfactory method be devised, it would be easy to determine to what extent it is specific for a given soil and to follow the variations due to season and soil treatment.

Closely connected with pore space is the determination of water-holding capacity. Here again some confusion reigns, partly due to the same difficulty of obtaining a sample with unaltered field structure. A constant to represent the permeability of soil for water and air would be of considerable value. Green and Ampt's methods, if they could be applied to investigation of natural soils, would be very suitable. The specific surface of soils has undoubtedly a physiological significance as a measure of the degree of dispersion. The methods of Mitscherlich, Hilgard, and others for the measurement of hygroscopicity are worthy of attention, and it ought to be possible to devise some rapid routine method applicable to the study of soils on an extended scale. The problem has also been attacked by measuring dye absorption. In the opinion of the writer this method is not to be recommended as it is liable to be complicated by chemical reactions between the dye used and soil constituents.

There are, of course, other physical properties of the soil on which quantitative ideas are needed, and it is to be hoped that the recognition of soil physics as a branch of investigation at Rothamsted will lead to a useful development of the work begun in this country by Warington.

Whatever physical measurements may be devised for the investigation of soils, there are certain desiderata if they are to be of use in field study. Firstly they must deal with the soil in its natural structure. The soil of the laboratory is an artificial product. Results obtained on it are apt to be misleading on the chemical side and even more so on the physical side. The methods devised should also be capable of being repeated in large numbers. The soil is such a complicated object of study that statistical methods must to a large extent remedy the unreliability of single observations. Methods to be devised for the physical investigation of the soil may have to sacrifice a little accuracy in order to make it possible to multiply observations in large numbers for the purposes of statistical treatment.

If reliable methods could be devised for characterising the physical properties of soils by a series of physical constants, the edaphic classification of soils might be placed on a much surer basis than at present and correlation with vegetation and agricultural conditions might be expected. The physical properties of a soil as expressed by such a series of constants would

be of importance from the point of view both of plant physiology and of practical agriculture, since they would give quantitative expressions for factors which directly affect edaphic and cultural conditions. Supplemented by a few chemical and economic data, the agricultural properties of a soil could be completely characterised.

The investigation of the physical properties of the soil must in future be one of the most promising lines of inquiry. The soils of our country do not as a rule show any striking deficiencies in plant food capital and such deficiencies as do occur are easily made good. The ultimate productiveness of our soils is largely a matter of physical properties. With the new impetus given to the physico-chemical study of soils of which this discussion is an evidence, it may be expected that the routine methods in use by field investigators will be more in the nature of physical determinations than of chemical analyses.

University College of North Wales,
Bangor.

April 27th, 1921.

Summary.

The classification of soils with the aid of mechanical analysis is of use mainly from the genetic standpoint. Apart from the defects of this method of examination and the lack of uniformity of procedure in different countries, the information given by such analyses is of comparatively little value in characterising the actual properties of the soil other than by standardising the ordinary practical classification into sands, loams and clays. Correlation with edaphic and cultural conditions is consequently imperfect. An edaphic classification should be based on actual soil properties, and for this purpose the soil might be better characterised by a series of physical constants comparable to those used in the description of a newly discovered element or compound. These constants might be supplemented by chemical data, but as it is easier to increase the amount of plant food in the soil than to change its intrinsic physical properties, physical constants would give a better definition of the inherent capabilities of a soil.

The soil is an exceedingly complicated material, and the lack of reliability of studies on individual soils necessitates the use of statistical methods. Determinations of physical properties must therefore be of such a character that they can be rapidly carried out on large numbers of soils. For many of these determinations, the soil must be examined without disturbing its original field structure.

Among the principal physical properties of the soil which affect edaphic and cultural conditions are pore space, water-holding capacity, permeability to water and air, plasticity and cohesion. Mechanical analysis must still be used as an aid to the genetic classification of soils.