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METHODS OF SOIL SURVEY IN USE IN THE GOLD COAST

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Introduction

Whilst it has long been realised by those responsible for the administration of the African colonial dependencies that soil inventories should form the basis for well-planned schemes of development, exceedingly little has been achieved to-date in the matter of formal soil surveys. This has been largely, if not entirely, due to lack of knowledge concerning the methods by which soil surveys, characterized by an adequate degree of precision, could be carried out in country covered by tall forest and high-grass savannah. Many colonial governments would have provided the necessary funds for systematic soil mapping had they felt assured that reliable methods existed for carrying out such work and that, in consequence, the money furnished would be wisely expended.

In the past, in the British dependencies, at least, attempts at soil mapping have been almost wholly due to the efforts of individual enthusiasts who have had neither the time nor the resources at their command to carry out systematic and precise surveys. Due to the nature of the terrain and the immense areas that need covering with some rapidity if soil surveys are to form the basis for agricultural development in the near future, it is considered that work of this nature is unsuited to individualist enterprise and cannot be efficiently and speedily prosecuted by increasing the number of independent workers or the means at their disposal. If the extensive territories that need mapping are to be surveyed with adequate precision and this work to be accomplished sufficiently rapidly to serve as an enduring foundation for future schemes of land utilization and agricultural development, the services of a well-constructed organization, in which different aspects of the work are carried out by separate sections and their results subsequently co-ordinated into a whole, is required.

During the past three to four years, the investigations of the Soil Science Division of the West African Cacao Research Institute have been directed towards the elaboration of precise and reliable techniques for carrying out soil surveys under conditions obtaining in the humid parts of tropical Africa and the devising of a form of

organization suited for putting them into effect. Satisfactory methods have now been worked out and given extensive trial both in forest and savannah country. This paper briefly outlines the field techniques evolved and describes the form of the organization considered most suitable for putting them into operation.

The Gold Coast is fortunate in possessing many enlightened chiefs and other informed persons and, largely as a result of their realizing what an important part soil surveys could play in the agricultural development of the country, a Soil Survey Division has recently been added to the Department of Agriculture. During the next few years, this Division will be engaged on the systematic mapping of the Gold Coast Colony, Ashanti and the southern part of Togoland under British Mandate using the methods and the type of organization with which this paper deals. Since the chief agricultural product of the territories mentioned is cocoa, the Cocoa Marketing Board in the Gold Coast has generously donated the sum of £150,000 towards the cost of the work.

General principles underlying Detailed Reconnaissance soil surveys

Under the conditions that prevail throughout the greater part of the Tropics, it is impracticable, except over very small areas, to map individual soils, i.e. soil series or soil types, as has been successfully done in the United States of America and other more or less well-settled temperate countries. The dense cover of vegetation, the absence of permanent fields and the frequent inadequacy of means of communication preclude this, save over those relatively small areas that comprise European-controlled plantations.

It is possible, however, to recognize in most territories areas where the same individual soils are repeated time and time again in which the constituent soils are associated with one another in an irregular but, nevertheless, typical pattern. Under similar climatic conditions, such patterns are determined, where the underlying parent rock is the same throughout, by differences in relief and drainage. Soil patterns of this nature are, apparently, very characteristic of large parts of tropical Africa, and

many people besides soil scientists must have noticed the constantly recurring succession of soils found from hill crests to the valleys below: red soils in the summits of undulations, brown and greyish yellow soils on the slopes and grey, water-logged sands and clays in the bottoms. Other, more complicated, soil patterns may occur, too, such as where the country rock consist of two or more constantly occuring types and here differences in lithology, as well as in topography, are responsible for the association of soils that is found. Elsewhere, as well, areas exist where variations in the nature of the parent rocks are almost solely responsible for the soil pattern that exists and the effects of relief and drainage in determining the character of the associated soils are reduced to a minimum.

Areas of the sorts described, characterized by recognizable associations of soils, very often form well-defined units of the landscape and are generally sufficiently extensive to render the accurate mapping of their boundaries within a reasonable period of time a practical proposition.

Soil associations determined by differences in relief and drainage were first investigated scientifically by G. Milne (1). Milne termed the succession or sequence of soils to be found in an area of undulating country underlain by the same sort of rock a "catena". Milne also described soil associations where differences in the nature of the parent rocks, as well as differences in relief and drainage, contributed to determining the soil pattern. Subsequent to Milne's work, several American soil scientists, notable Jenny and Bushnell, have devoted considerable attention to different types of soil sequences.

Milne, in writing of catenary and other forms of soil associations stated:

"In the undeveloped countries of the tropics, the method of detailed surveys is rarely practicable, and one has to depend on the investigation of sample localities and the discovery of a key that will in a general way enable the soil distribution to be predicated for the rest of the area".

Milne and his collaborators published a soil map of British East Africa on a scale of 1:2,000,000 which showed areas under different soil associations and indicated what the characteristics were of the individual soils which made up each association. This work, however, was never systematized: the boundaries of the associations recognised were not arrived at by formal methods of survey and little or no detailed mapping of sample areas was apparently undertaken. But for Milne's untimely death, precise work along these lines could have been anticipated, however.

The type of soil survey that has been elaborated in the Gold Coast, and which is considered suitable for all tropical territories where extensive tracts of undeveloped or little developed country need to be covered with a minimum expenditure of time and effort, is a systematization of the method suggested by Milne. It consists of mapping the natural geographical soil associations as much by means of reconnaissance methods and in carrying out detailed soil surveys of small, representative areas of each soil pattern occuring to show the distribution of the individual soils, their relative extent and their topographical and other relationships to one another.

If the soil associations are well-defined and if sufficient sample areas are investigated within each association, it should prove possible to form a reliable estimate of the proportionate areas occupied by the individual soils that together make up the pattern.

This type of survey, since the expanses covered with different soil associations are mapped by reconnaissance methods, whilst the distribution of individual soils within sample areas representative of each association is determined by the methods of detailed survey, can be conveniently termed: Detailed Reconnaissance soil survey.

Under favourable circumstances, where sufficiently detailed topographical and lithological maps exist, it may be possible to project the information obtained from the detailed survey of sample areas over the whole expanse of country covered by a particular soil association, and to prepare a soil map showing the approximate distribution of the individual soils. Such a map, although it could not be expected to be accurate as to detail, would, nevertheless, present a true enough picture to be of considerable

aid in planning schemes of land utilization, in drawing up programmes of agronomic investigation and in assisting in the carrying out of agricultural advisory work.

Detailed Reconnaissance soil surveys are relatively rapidly carried out and form a useful basis for further more detailed mapping as this is called for. By their means practically all the soils of a region can be distinguished and described, their relationships to one another worked out and their general distribution and areal significance determined. They provide a convenient framework within which more detailed surveys of particular areas can be undertaken when occasion demands and supply all the preliminary information that such projects require.

Field and other techniques employed in Detailed Reconnaissance soil surveys

Subdivision of the territory to be surveyed

Surveys of various sorts are perhaps most frequently carried out on the basis of administrative divisions, i.e. county by county, or district by district. Although this may often have very decided advantages it is considered that Detailed Reconnaissance soil surveys can be more efficiently conducted by being carried out drainage basin by drainage basin. In favour of this method is the fact that relief and drainage play such an important part in determining soil distribution so that carrying out the survey along these lines focusses attention of two of the principal factors responsible for soil differentiation. Further, and this applies to large areas of Africa, soil surveys are needed as a basis for schemes of soil and water control so that conducting the work in this manner forms a most useful preliminary where conservation work of this character will be undertaken at a later date. Over large parts of tropical Africa, too, development is inhibited by the presence of tsetse fly, and since the distribution of these insects in savannah country is largely determined by the drainage pattern, utilization of such areas has to be planned taking this into account.

Preliminary soil survey

Before undertaking Reconnaissance soil surveys to determine the distribution of soil associations within a drainage basin, and before initiating Detailed soil surveys of sample areas within soil associations, a Preliminary soil survey is necessary. This type of survey consists of two parts: firstly, it comprises study of all the relevant information existing concerning the basin being investigated such as is contained on topographical maps and in meteorological, geological, forestry and agricultural reports; and, secondly, it comprises traversing the basin in as rapid a manner as possible making use of the main lines of communication, roads, the more important trails, navigable rivers, railway lines, etc., in order to get a general idea of the soil associations occurring, and of the particular soils that make up each soil pattern. Of particular importance during this survey is the securing of information by means of which particular soil associations and particular soils occurring in them may be easily and rapidly identified, what are known in systematic botany and zoology as "spotting characteristics". No formal field mapping is attempted during the preliminary surveys, although a rough sketch map may be produced in the office at the conclusion of the work. On the basis of the Preliminary surveys, the Reconnaissance and Detailed soil surveys within the basins are subsequently planned. Work of this character needs to be carried out by an experienced officer who is thoroughly acquainted with the morphology of the various soils occurring in the territory being surveyed. When Detailed Reconnaissance surveys are first commenced, Preliminary surveys will entail much hard work, but as the soil associations, and their constituent soils, become familiar to the officer engaged on this section of the work, rapid investigation of the basins to be surveyed will present less and less difficulty.

Reconnaissance soil surveys

Reconnaissance soil surveys differ from Preliminary surveys in that actual mapping is either done in the field, or precise information is collected, on the basis of which, subsequent mapping is carried out in the office.

The object of Reconnaissance soil surveys is to map the boundaries of the soil associations recognized during the Preliminary soil survey of a basin. This is achieved by covering the area being surveyed with parallel traverse lines. Soil observations are made at regular intervals along these and the points where soil association boundaries cross the traverses are determined and then the boundaries are drawn on a suitable base map by means of interpolation. No attempt is made to survey association boundaries along their course, although their position may be more accurately fixed by means of offsets to the main traverse lines where such a procedure is considered advisable.

The parallel traverses consist of lines cut through the forest, bush or savannah along definite compass bearings. As far as possible, these traverses are so laid out that they cut the soil association boundaries at right angles, information regarding the direction they should take being one of the objects of the Preliminary survey. Suitable base lines such as main roads, railway lines, or rivers are chosen for the starting points of traverses and a small party of land surveyors has the function of locating and marking such starting points in advance to the reconnaissance soil surveyors. Where good topographical maps are lacking, a great deal of useful information regarding relief and drainage can be collected for insertion on the base maps at the same time as soil data are obtained and without much additional trouble.

In the Gold Coast soil survey, traverse lines for the purpose of Reconnaissance work are being run at a distance of 100 chains (approximately 2,000 metres) apart. These traverse lines are cut and appropriate observations made along their course by Reconnaissance soil survey parties comprising the following technical officers:

A <u>direction giver</u> supplied with a prismatic compass and six labourers to cut bush and hold ranging poles;

A <u>distance measurer</u> supplied with a Gunter's chain (66 feet or 20 metres approximately) and three labourers to carry the chain and cut and insert pegs;

Three soil surveyors, including the party leader, supplied with a labourer and auger, etc. each to make soil observations and to collect soil and rock samples; and

A vegetation surveyor who records the principal types of vegetation encountered along the traverse and, when necessary, takes notes on topographical features.

On an average, a party so constituted can traverse three to three and a half miles a day (approximately 5 kilometres).

Auger borings, or inspection holes, are made at every furlong (approximately 200 metres) along the traverse. Borings are normally carried to a depth of $3\frac{1}{2}$ feet (just over 1 metre), but extensions to the augers are provided enabling borings to be made to a depth of 6 feet (2 metres) where necessary. The topography at the site of each boring is carefully recorded and notes are taken, using standard abbreviations, of the soil profile disclosed by augering. The following data are recorded for each horizon: depth; colour; content of organic matter, based on colour; texture, based on feel; consistency, based on ease of augering, etc.; presence of concretions; etc., etc. In addition to this, the soil surveyors also collect specimens of the parent rock, or rocks, of the soils encountered along the traverses. The leader, besides general supervision of the party under his charge, has the task of carrying out borings in each type of soil encountered and collecting horizon samples for examination at the field base.

The records of the soils investigated and the rock and soil specimens collected are brought in daily to a mobile field base which accompanies the reconnaissance soil survey parties. Here the data collected are critically examined and the boundaries of the various soil associations traversed plotted on specially-prepared base maps. Such work needs to be carried out under the personal supervision of a trained and experienced soil worker.

It is to be noted about the field procedure described above that the positions of all traverse lines and the sites at which all auger borings are made and rock specimens collected are accurately ascertained and recorded. This enables the work to be checked and provides a firm

basis for future operations of a more detailed character should these prove necessary. Further, all operations performed in the field are of a routine character and have been carefully planned so that each officer knows precisely what his functions are and so that there is no need for hasty and, perhaps, ill-considered improvisation.

Detailed soil surveys

In Detailed soil surveys the boundaries of individual soils, i.e. soil types and soil phases, are mapped. These boundaries are plotted by means of interpolations between borings so closely spaced that for all practical purposes the boundaries can be considered surveyed throughout their course.

The sample areas over which Detailed soil surveys are conducted are in the form of long, narrow strips sited as far as possible at right angles to the prevailing relief and drainage channels. These strips may be 10 chains (approximately 200 metres) wide and 200 chains (approximately 4,000 metres) long or 20 chains (approximately 400 metres) long or 20 chains (approximately 400 metres) wide and 100 chains (approximately 2,000 metres) long. Experience has shown that strips of these dimensions provide an adequate picture of the distribution of and relationships between, the individual soils that together make up a soil association.

Auger borings to depths varying between 3 and 6 feet (1 and 2 metres) are evenly distributed throughout the sample strips at a distance of 5 chains (100 metres) apart. Under average condition in the closed forest zone, i.e. in tall forest and in cocoa farms, visibility extends to about $2\frac{1}{2}$ chains (50 metres) on either side of the traverse lines. Under savannah forest conditions the extent of visibility is, of course, much greater, approximating to 10 chains (200 metres) on either side of the traverse lines. In areas of dense secondary bush in the forest zone, and in swampy areas in both the forest and savannah zones, visibility is frequently nil to right and left of the traverses; this, however, cannot be helped. So with borings 5 chains (100 metres) apart, all of the territory being surveyed, except for the particular formations mentioned, comes under observation.

A draft soil map is first prepared showing the boundaries of the individual soils encountered by means of interpolations between the regularly-spaced auger holes 5 chains apart. Using this draft map as a guide, additional borings are made in order to determine the course of the boundaries more accurately. This involves the running of short offsets to the main traverse lines and the cutting of additional traverses in the areas covered by dense vegetation.

In addition to the soil map, a topographical map of the strip is prepared by the use of an Abney level along the traverse lines. Such topographical maps show the courses pursued by drainage channels and contour lines at vertical intervals of 5 feet (150 cms).

As well as soil and topographical maps, a vegetation map of each strip surveyed is also prepared.

After the draft soil map of the sample area has been completed and whilst the final soil map is being prepared, profile pits are sunk in areas representative of each soil occuring in the strip. The profiles disclosed are very carefully described and samples of each horizon are taken for future comparison and for analysis in the laboratory.

A detailed soil survey party consisting of a party leader, 2 land surveyors, 3 soil surveyors and a vegetation recorder is employed on the work described above. Such a party can complete the survey of a sample strip of the dimensions stated in the course of two or three days.

Sample strips are surveyed at the rate of one for every ten miles of traverse carried out during the Reconnaissance soil survey. This means that one per cent. of the area so covered has its soils surveyed in detail.

Reconnaissance maps are being produced on scales of 1 inch = approx. 4 miles (1:250,000), 1 inch = approx. 2 miles (1:125,000) and 1 inch = approx. 1 mile (1:62,500). Detailed soil survey, topographical and vegetation maps of sample strips are produced on the scale of 10 inches = approx. 1 mile (1:6,250).

Soil analyses

It is intended to carry out routine analyses on horizon samples collected from representative profiles of all of the principal soils occurring in the regions being surveyed. These analyses will comprise mechanical analyses and determination of reaction, base status, organic carbon, nitrogen, phosphorus, etc. Analyses of the clay fraction, in order to determine the molecular ratio of silica to sesquioxides, will also be undertaken.

Owing to difficulties of supply during the past few years, laboratory investigations have very considerably lagged behind field investigations. Laboratories have now been constructed, however, and consignments of chemicals and equipment have commenced to arrive.

Compilation of maps and the production reports

A central office for the compilation of the final Reconnaissance and Detailed soil maps and for the preparation of reports on the regions surveyed is being established.

A standard form of report has been devised and this aims at describing the soils encountered in the surveys in relatively simple language so that descriptions of the soils and their agricultural uses can be readily understood by the non-specialist.

The organization adopted for Detailed Reconnaissance soil surveys

The method of carrying out Detailed Reconnaissance soil surveys outlined above lends itself admirably to a division of labour such that different officers are each responsible for certain aspects of the survey whilst the data they collect are finally co-ordinated into the form of maps and reports by an officer responsible for this section of the work alone.

As mentioned earlier in this paper, this type of organization is likely to produce more rapid and more comparable results than one consisting of numbers of officers carrying out complete and more or less independent surveys of various parts of the territory.

In the organization adopted in the Gold Coast three categories of work are involved:

1. Unskilled labour:
   cutting and clearing traverse lines, chaining, digging inspection and profile pits, etc.

2. Routine technical work:
   (a) laying out traverse lines, levelling, etc.;
   (b) recording soil observations from auger borings and pits, collecting soil and rock samples, recording vegetation types, etc.;
   (c) carrying out routine soil analyses in the laboratory;
   (d) draughting base and final soil maps.

3. Skilled technical work:
   (a) carrying out Preliminary soil surveys of drainage basins;
   (b) supervising Reconnaissance and Detailed soil surveys;
   (c) supervising laboratory work;
   (d) compiling soil maps and preparing reports from the data collected in the field and obtained in the laboratory.

Regarding unskilled labour, all that need be remarked is that the only advantage that soil surveys in the Tropics have over similar projects conducted in more advanced temperate lands is the ready supply of relatively cheap labour that is available.

Work of the second category, being of a routine technical character can be efficiently performed by African staff that has been locally trained. In the Gold Coast soil survey, great use is being made of assistance of this nature. In case the value of results obtained by this means is doubted, examples of similar work that has been and is being carried out by locally-trained African operatives will be given.

The survey departments of most colonies employ locally-trained African surveyors who are, under skilled supervision, responsible for the vast majority of the field and cartographic work. The one-inch-to-the-mile topographical maps of colonies such as Sierra Leone and the Gold Coast are evidence to the high standard of work that operatives of this sort can produce. For a long time, the

laboratories of sugar factories in various parts of the Tropics, e.g. the West Indies, have employed locally-trained personnel, many of them Africans, to carry out routine analyses. Locally-trained workers have, also over a large number of years, been successfully used in the soils laboratory of the Imperial College of Tropical Agriculture. Forestry departments in the Tropics, too, have made successful use of locally-trained African assistants in the mapping of vegetation; excellent work has been done by this means, for example, in British Honduras.

There is no reason, therefore, why African officers should not be trained locally to carry out equally good field work where soil mapping is concerned. This would involve training them in the elements of soil morphology and genesis and in the methods of describing and sampling by means of profile pits and auger borings. During the past few years, a number of African personnel have been given tuition in the field examination of soils, and not only have they shown considerable interest in such work, but the results have been most encouraging.

The great advantage of being able to employ locally-trained operatives for the routine technical work of soil surveys means that more ground can be covered in a given period of time and that European-trained soil specialists, whose numbers at the present time are severely limited, can be released for more skilled work and for supervisory duties. Under the climatic conditions that obtain in the African Tropics, there is no doubt in my mind whatsoever that European specialists are most efficiently employed when engaged on work of a non-routine character: such work is usually performed with a higher degree of accuracy by members of the indigenous population.

In a soil survey organised along the lines described, the services of six officers who have received special training and have some experience in soil work, is desirable, if not essential: one to carry out Preliminary surveys of the drainage basins to be surveyed by Detailed Reconnaissance methods, one to supervise the Reconnaissance work, another to take charge of the Detailed investigation of sample strips, an officer to supervise the initial co-ordination of the field data at the mobile base, an analyst to superintend the laboratory work, and lastly an officer to be responsible for the compilation of the final maps

at the main base and to undertake the work of producing reports on the regions surveyed.

Extensive soil survey of the type being undertaken in the Gold Coast involve long periods under canvas and the victualling of large numbers of technical officers and labourers whilst engaged on field work. Efficient transport facilities and camp organization are essential if good work is to be carried out without delays and discomfort occasioned by irregularities in the arrival of supplies, etc. The successful prosecution of projects of this character demands capable administration if costs are to be kept at a reasonable figure. Much experience has already been gained on these matters in the Gold Coast, largely whilst engaged on the survey of land suitable for the large-scale production of groundnuts.

Conclusion

A soil survey is not an end in itself; it is a means to an end: it aims at ensuring that different soils are employed for the purpose for which they are most suited. For this end to be achieved, it is essential that the people who are actually engaged in tilling the soil and raising crops should themselves understand what soil surveys are and what purpose they serve, and that they, as well as administrative officials, should become soil conscious. There is no surer method of achieving this than by a training and employing large numbers of local workers to take part in the surveys, for by this means the aims of such investigations and the elementary principles involved in the correct use of soils will be widely disseminated.

The form of soil survey designed to suit conditions in the forest and savannah lands of the Gold Coast, not only allows for the mapping of large areas of different terrain in a minimum of time, but affords opportunity for the technical training of considerable numbers of locally-recruited personnel. Approximately 120 African staff will receive training in the recognition, description and mapping of soils when the Gold Coast soil survey is operating at full strength.

Colonial dependencies to-day are rapidly becoming more and more politically conscious and their peoples are anxious to take an increasing part in the task of developing these territories. If the latter is to be accorded them, greatly increased numbers of trained technical workers will be required. Since agriculture is the major industry of the colonies, and is likely to remain so, it is in this sphere that local technical knowledge will be most needed if their inhabitants are to progress towards higher standards of prosperity. One of the officially-recognized features of the Gold Coast soil survey, therefore, is the opportunity it will present for training African staff in the basic principles of correct land use.

Reference

(1) MILNE, G., and collaborators, "A Provisional Soil Map of East Africa". Amani Memoirs, 1936.

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