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WITH SPECIAL REFERENCE TO EXPERIENCES IN THE NETHERLANDS

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APPLICATIONS OF SOIL SURVEY IN LAND DEVELOPMENT IN EUROPE

WITH SPECIAL REFERENCE TO EXPERIENCES IN THE NETHERLANDS

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FOREWORD

The subject "Applications of Soil Survey in Europe" was discussed during the meeting of the F.A.O. European Working Party on Soil Classification and Survey held at Bonn on 23rd to 27th September, 1957. The Netherlands delegation to this meeting prepared an extensive report dealing with all aspects of the applications of soil survey in their country. Several other delegations also presented reports or notes about their experiences in this subject.

The author was invited to submit for this meeting a general statement on the applications of soil survey in Europe. After the discussions the author was asked to draft a more comprehensive report on this subject for the next meeting of the Working Party to be held in the United Kingdom in 1959. This meeting was held at Oxford from 6th–11th September, 1959, as the Second Session of the Working Party on Soil Classification and Survey. A report entitled "Applications of soil survey in land development in Europe", served as the basis of a discussion. After this discussion the author was asked to prepare his report for publication after including a number of additions.

The present text could not have been prepared without the kind help of a great number of colleagues. The author would particularly like to thank: –

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In spite of all this generous help nobody but the author bears any responsibility for opinions expressed in this text.

The International Institute for Land Reclamation and Improvement expressed its willingness to undertake the publication of this study.

THE AUTHOR

1. SOIL SURVEY IN RELATION TO CROP PRODUCTION

1.1. INTRODUCTION

Soil-crop relationships form the basis of all applications of soil survey to agriculture. This statement is so important that it will be fully discussed in this report.

Soil-crop relationships cannot be studied by soil surveyors only since no soil surveyor has a sufficient knowledge of all crops grown in his area. Basically, soil-crop relationships should be the subject of joint research by soil scientists and crop scientists. Important results of such co-operation can be reported from all countries where successful soil surveys have been carried out. Examples of these results will be discussed below.

The relationships between crops and soils are most obvious in the case of monocultures of such expensive products as fruit, flowers, vegetables, wine- or table-grapes, etc. In most European countries such crops are called horticultural crops. A survey of fruit or other horticultural crops in most centres of production will reveal great variations in yields per hectare in different places. Differences in a proportion of 2:5 are usual and a proportion of even 1:5 is no exception. In a number of cases low yields are due to poor management. When the soil-crop relationships are studied, poorly managed holdings should be left out of consideration.

1.2. HORTICULTURAL CROPS

1.2.1. *Special position of horticultural crops*

There are several reasons why the soil-crop relationships of horticultural crops are more stimulating to the soil scientist than those of ordinary field crops.

1. Horticulture occupies only a small part of the total cultivated area. Even in the Netherlands, where more than 50% of the horticultural production is exported, the land utilized for horticulture is only 6% of the total. In the most intensive branch of horticulture, greenhouse crops, the proportion is only 0.15%.

Hence from the point of view of area it would not seem difficult to locate all horticultural holdings on perfectly suitable soils, but it should be borne in mind that this does not apply to the usual field crops, which occupy the entire available area, including very good, average, poor and even very poor soils. Although a soil suitability classification for agricultural soils is also important, as will be shown in § 2.3, it is a simpler matter to apply knowledge of soil-crop relationships to horticulture than to agriculture.

2. Most branches of horticulture are characterized by a great demand for labour. If this labour is to be paid according to the standards of a modern progressive society, it is not only essential to employ the most effective technical methods, but also to ensure that yields are as high as possible. Such high levels of production can only be achieved on soils that are pre-eminently suitable.

3. Several branches of horticulture require large capital investments. These are most profitable where crops pay the highest returns. This stimulates the demand for the more suitable soils and increases their value. It is therefore in the interest of both the individual owners and society to discover such areas. The discovery of good sites for horticultural crops is as important to the national economy as the discovery of ore, oil or coal deposits. The exploration of such sites with hidden prospects acts as a stimulus to soil scientists.

4. European horticulture as a whole comprises the cultivation of several hundreds of crops, each of them exhibiting its own reaction to soil conditions. Moreover, methods of cultivation vary considerably and in some cases crops succeed each other in rapid rotation. Horticultural crops afford the most varied opportunity for studying the relations between crops and soils.

1.2.2. *Methods applied in the study of soil-crop relationships in horticulture*

The methods of studying soil-crop relationships, employed in various soil surveys of horticultural regions in the Netherlands, are fairly simple. They are not offered as original methods, as they equally well form the basis of successful surveys in other countries. It is a remarkable fact, however, that they are not discussed in the leading European manuals and textbooks of soil science.

The chief consideration in a study of the relationship between a horticultural crop and soil conditions is to start in a district where the crop in question is grown on a large scale. It will soon be noticed that the crop produces more on one field than on another. The difference may be apparent in the yield, the quality of the produce, or the harvesting date. There may be many reasons for these differences and the main problem is to select cases in which the phenomenon noted is caused by soil conditions and not by differences in management. To do this, attention should first be given to the places with the highest yields. If the yields are much above the average of the whole district it can be assumed that both soil conditions and crop management are above standard. This means that the soil conditions in question represent the local optimum, and this forms the starting point of an effective classification of the soils in the district concerned. It is hardly necessary to state that such a classification should be based on the permanent characteristics of the soil profile. In this classification the soil units showing optimal conditions for the crop in consideration quite obviously occupy an important position.

After these soil units have been identified and defined a study of the other soils can be begun. All other soil units represent deviations comparing unfavourably with the optimum soil units.

This is most evident with regard to the poorest soils in the district which are in such a state that they should not, in fact, be used at all for the crop in question. Further difficulties occur when dealing with intermediate soils. As a rule only fair crops are found on intermediate soils, but they may also be encountered on good soils under poor management. Here the soil scientist will fail in his task if he does not co-operate with a crop specialist who is able to assess the quality of the management of holdings which are often complex. In the Netherlands it has always been possible to enlist the services of the local assistants of the Government Horticultural Advisory Service who are often very well informed about local conditions. In a number of cases these persons have been included in the survey team for a considerable period. Their experience has been very valuable for obtaining a good appraisal of soil profiles in connection with the crop in question. In this way the essentials have been consciously sorted from the often confusing abundance of phenomena. These essential facts represent the effect of proper management on the soil in question. With this procedure it is possible to define the soil units in such a way that they also represent stages of productivity.

To avoid confusion it should be stated that a soil classification in itself is morphological. The characteristics adopted for the definition of the soil units should be measurable. But in adopting such criteria the soil surveyor has a certain freedom and there is no reason why he should not make use of characteristics which have a bearing on the quality of the soils for an important crop. The scale of the maps compiled during this kind of investigation will rarely be smaller than 1:10,000, so that a very detailed classification of the soils is appropriate.

When the classification of the soils in the area has been completed by continual study and comparison of both soils and crops the mapping can be finished, but it is still necessary to express statistically the relationship between crops and soil conditions. The most successful method of obtaining such statistics is termed the "best holdings" method in the Netherlands. Only particulars of well-managed holdings are recorded, exceptional conditions being omitted which might result in an exaggerated picture.

To exemplify this method, part of the work done by VAN LIERE (1948) on grape soils in the Westland (Netherlands) will be discussed. The grapes (Black Alicante on its own root) are grown in greenhouses on very different soils.

1. The first subject of study is the development of the root system in relation to the soil profile. In suitable soils the root system is able to develop properly. It can penetrate to a great depth and spread regularly through the soil profile. Soils with unfavourable

water conditions are less suitable. If the profile contains impervious layers causing waterlogging in wet periods, this can be seen from the appearance of the roots of the vine which may rot and even kill the entire vine. In less severe cases the vines are stunted and produce lower yields. By applying this simple technique it is possible to obtain a clear picture of the manner in which the subterranean parts of an important variety of grapes reflect soil conditions (Figs. 1 and 2).

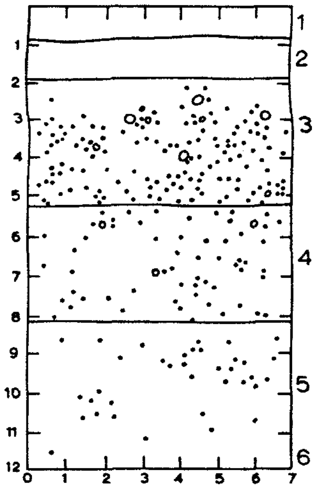


Fig. 1 Distribution of 'Black Alicante' vine roots (Van Liere 1948. Soil type 2). Excellent rooting.

1 Topsoil
2 The same with efflorescence of gypsum
3 Dark greyish-brown sandy clay
4 Brown sandy clay
5 Bluish-grey silty clay with rust
6 Watertable. Depth in decimetres

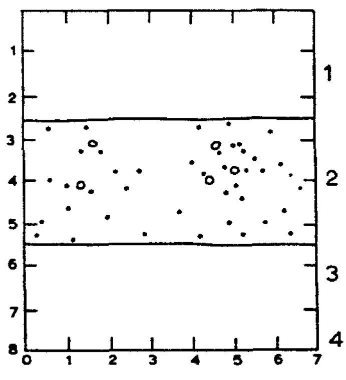


Fig. 2 Distribution of 'Black Alicante' vine roots (Van Liere 1948. Soil type 6). Shallow rooting.

1 Topsoil mixed with moss peat
2 Stiff clay
3 Rusty stiff clay
4 Groundwater. Depth in decimetres

2. The development of the above-ground parts of plants differs considerably on good and poor soils and consequently afford an index to soil conditions. In this way it is also possible to compare soils and crop.

3. VAN LIERE took advantage of the fact that records of yields for over ten years were available for a number of greenhouses on well-managed holdings. His diagrams show the

vast differences in yield obtained on various soil units in the Westland area. The regional average is equal to the yield on soils where conditions are far below the optimum. What used to be satisfactory to growers in the region is barely acceptable today, after the soils have been classified and the best soils are now taken as the standard. It is hardly necessary to state that this change of outlook has had important economic consequences on the production of grapes and other well-studied horticultural crops.

4. It has also been possible to study the revenues of a number of well-managed holdings on different soils in the Westland area. Revenues depend on the yields, the quality of the crop and the date of auction. In the case of grapes the latter greatly depends on management, especially upon the heating of the glasshouses. Output in terms of money can only be compared when conditions are identical. In cases where a comparison was possible it was found that grapes from the most productive soils fetched higher prices than those from poor quality soils. The great difference in weight is even more emphasized by the higher price paid per kg. This difference in price is due to the fact that grapes from the more productive soils are more suitable for cold storage. (Figs. 3 and 4).

The "best holdings" method cannot always be used and in this case a different method can be adopted which is called the "poor patches" method. This method has been severely criticized and should only be used in a qualitative way. Despite its limitations it can yield valuable indications.

The "poor patches" method is based upon the observation that a crop is rarely uniform and that the poorer patches have suffered from unfavourable divergencies in soil conditions. In such cases it is possible to compare a crop on two different soil units, one favourable and the other unfavourable, under identical management.

In orchards the effects are often quite spectacular. The trees in an orchard are usually planted according to a definite system and are all given the same treatment. Fruit being a perennial crop, it is possible to verify a description of a poor patch after several years in order to ascertain how the trees have behaved.

DE BAKKER (1950) measured and described a number of orchards having a poor patch. In most cases the reason for the poor growth was the presence of a coarse sandy subsoil causing excessive drainage. Trees on such soils suffer periodically from drought and their growth is inhibited. By comparing them with trees on adjacent soils it is possible to verify the unsatisfactory growth by different means, e.g. by recording the diameter of the trunk and crown, the length of the annual shoots, etc. It is obvious that a large healthy tree gives a higher yield than a backward one so that the stronger or weaker growth is reflected in greater or smaller production. Useful observations have also been made on poor patches where the subsoil consists of heavy impervious clay causing waterlogging (Figs. 5, 6 and 7).

A large number of orchards have been assessed by this method. It has become possible to observe trees of most varieties on various rootstocks on all kinds of soil units.

The present knowledge of the adaptation of varieties to soil conditions in the Netherlands was obtained by this simple and inexpensive method. This knowledge has been

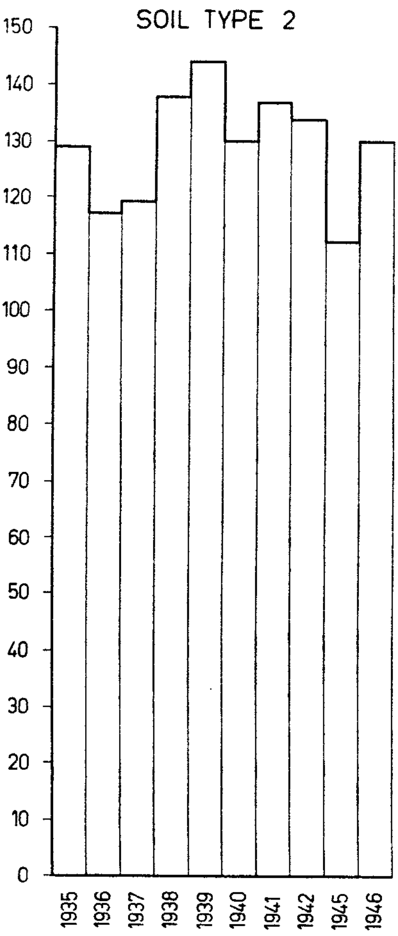


Fig. 3 Yields of 'Black Alicante' table grapes grown on soil type 2 during the period 1935 to 1946 in kilograms per 40 sq. ms (Van Liere).

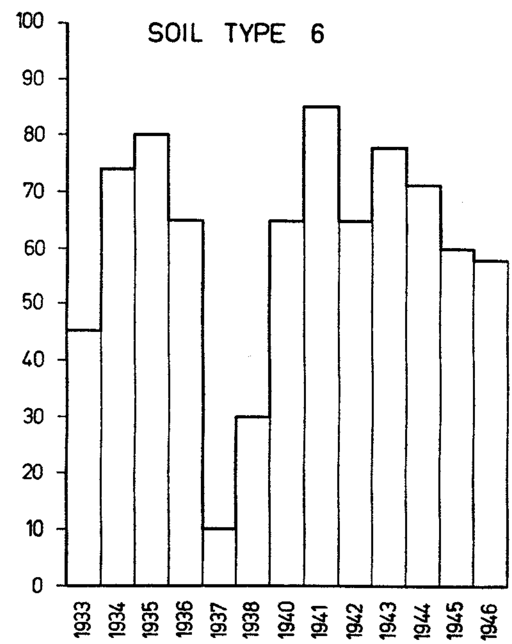
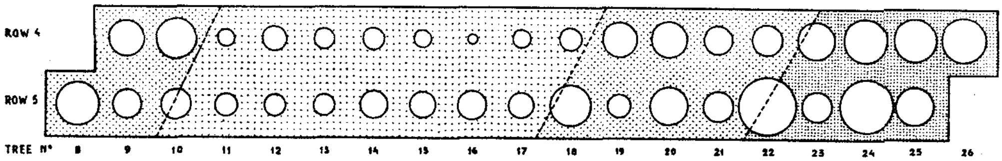


Fig. 4 Yields of 'Black Alicante' table grapes grown on soil type 6 during the periode 1933 to 1946 in kilograms per 40 sq. ms (Van Liere).



1 Sandy loam with a loamy sand layer from 38–52 cm and a subsoil of sandy loam

2 Sandy loam with a fine sandy subsoil

3 Sandy loam with a coarse sandy subsoil deeper than 35 cm.

4 ○ Diameter of the crown

Fig. 5 Very detailed soil map showing the diameters of the crowns of an apple orchard (according to De Bakker). Compare Fig. 6.

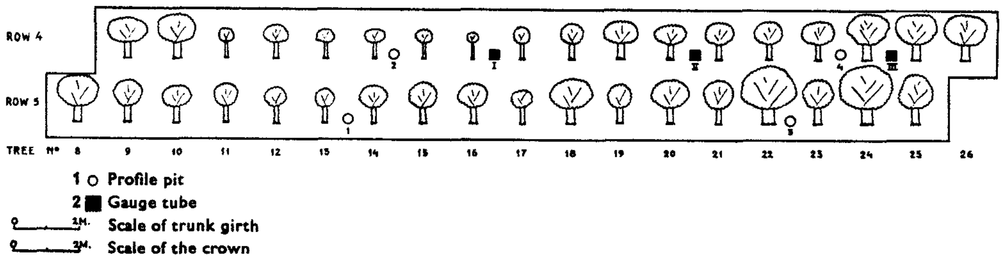


Fig. 6 Graph of the trunk-girth, the height of the top and the diameter of the crown of apples. Compare fig. 5.
Row 4 'Perzikrode Zomerappel' Variety
Row 5 'Cox's Orange Pippin' Variety

applied by the Extension Service all over the country and since the second world war there are few orchards that have been planted on unfavourable soils.

But the "poor patches" method is open to criticism. The choice of varieties and the management of crops are adapted to conditions prevailing on adjacent good soils. If a field had solely consisted of an unpropitious soil unit a different method of management would probably have been applied with better results. In other words the quality of a poor patch is underestimated. Despite this warranted objection, the "poor patches" method is both interesting and instructive. When used by experienced persons it can furnish important evidence.

1.2.3. *Vineyard survey in Germany*

The vineyard survey of the Rhine-Hessen area is a good example of a very detailed soil survey with special reference to soil profile characteristics influencing the wine grape

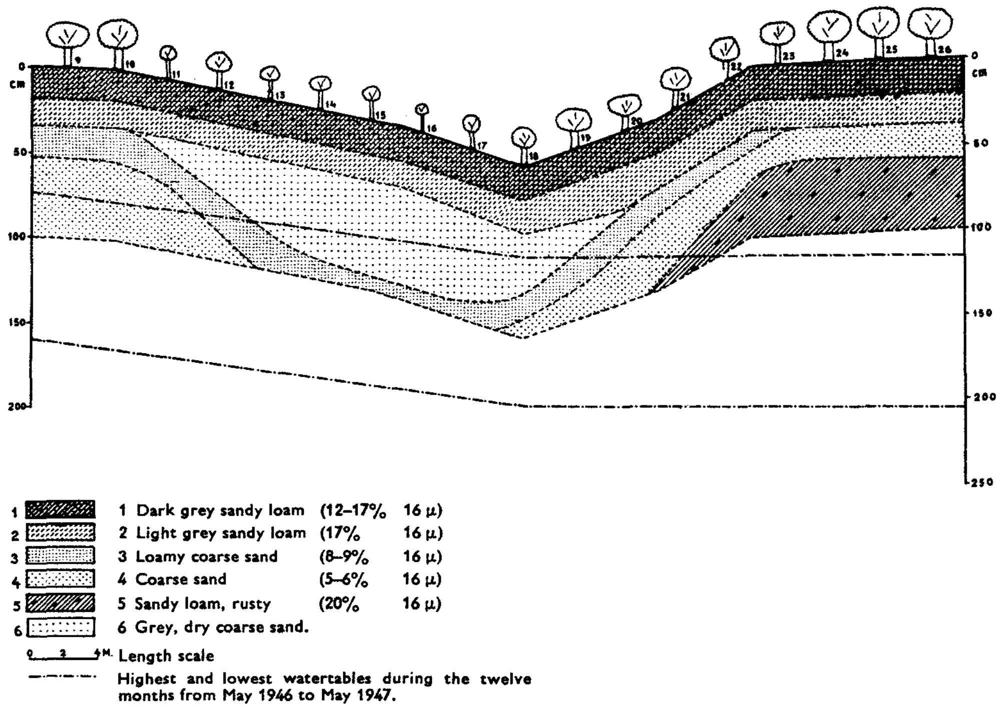


Fig. 7 Cross-section of the soil along row 4 of Fig. 5. Depth below the surface in centimetres.

(PINKOW, 1951; ZAKOSEK, 1957). The vineyard soils of this district are man-made soils developed by the very deep mixing of the soil materials several times a century. On these occasions all kinds of soil improvers such as shale, loess, clay, slag, ash, sand, forest litter, etc. are mixed into the soil.

Under these conditions soil profile descriptions distinguish two profile sections viz. the mixed cultivated layer and the subsoil. In some respects the latter section is a remnant of the natural soil profile.

The description of the cultivated layer is greatly influenced by the part played by the soil improvers. The description of the subsoils is normal.

Special reference is given to water conditions, pH and lime content and structure of the surface soil. The maps are drawn on a scale of from 1:1,000 to 1:5,000 and based on an average of 5 borings per ha and one profile pit per 3 ha.

The principal use of this very detailed map is the adjustment of adaptation of rootstocks to soil conditions. This decision was always a very difficult one before the soil maps were available. A second use is soil improvement. Liming may also create difficult problems. Some soils need lime and others are already overlimed. The maps are not printed, but a copy of the local map with explanation is available in every village, where wine growers can consult it.

The completed map of the whole district is also important for Government planning work. The map will be very valuable in case of future farm consolidation. There are also plans for irrigation.

Similar work is reported from other parts in Germany.

The slight differences between this German project and the work done in Holland are due to the different organization of the Government Services. In the Netherlands very detailed soil maps of single holdings are compiled by the extension services. Extension officers discuss the findings with the farmers and give the necessary advice. The extension officers concentrate on farmers interested in receiving advice, so that soil maps on cadastral scales are only made incidentally and on request, and not maps of whole districts.

1.2.4. *Work in other countries*

The fruit soil surveys of Great Britain should first be mentioned. Some of the earlier investigations were undertaken to provide information on soils where specialized cropping had produced problems of plant growth, cultivation and management (WALLACE et al.). Such surveys had a marked practical bias and since they were carried out in districts where special crops had been grown for many years, they pointed the way to further utilization of similar soils in the district. Although soil series maps were not made, the soil profiles were described sufficiently well to enable them to be identified in other areas. In 1949 sufficient information was available on the behaviour of many kinds of tree fruits, bush fruits and market-garden crops growing on a diversity of soils under very varied cultural conditions.

With the background provided by this and older surveys it is possible to forecast the performance of many classes of fruit plants on most soils likely to be used for their culture.

In Ireland similar work on fruit soils has been done since 1943.

In France soil scientists started investigations in the Sarthe orchards in 1958. From the very beginning this survey has given interesting indications on the influence of certain soil horizons on the development of the fruit-trees. It has been possible to relate the choice of the varieties and other cultural facts with the characteristics of the soil profile.

In Belgium research has been on much the same lines as in the Netherlands and some striking results have been obtained. A recent peach and early strawberry district illustrates the benefits which a country can derive from studies in soil crop relationships. Another outstanding achievement was the detailed survey of the greenhouse district south of Brussels. It would be interesting if the Belgian soil scientists were to publish a detailed report on this and other successful work.

In Germany the success of the vineyard soil surveys (§ 1.2.3.) has led to similar fruit soil surveys. In the Rheinland-Pfalz area the soils of the important fruit districts are now being surveyed on scales of from 1:1,000 and 1:5,000. The maps will be used in advisory work in connection with fruit growing. Similar surveys have been planned in other parts of Germany.

In Portugal several detailed soil surveys have been made at the request of the Olive-Tree and Vineyard Departments for studying certain problems with which they were concerned, e.g. root development, adaptation of varieties and adjustment of the choice of root stocks to soil conditions.

The present programme of development of orchards included in the Second National Plan of Development for Agriculture, is based on information provided by detailed soil maps.

1.2.5. *Concluding remarks*

Since soil science is in a state of rapid progress, the relationships between crops and soils have to be periodically revised. In particular, since soil profile descriptions have improved so much of late, new profile characteristics have to be taken into account, some of which are very important in connection with plant growth.

In the Netherlands the first important steps towards the recognition of the relationship between plant development and soil conditions, reported in this chapter, date from between 1943 en 1948. Only recently an important improvement has been possible as the result of a much more accurate description of soil structure. The root distribution in the various soil horizons can now be better understood. Differences in yield, hitherto unexplained, are now properly understood. Such an improved diagnosis has immediate consequences for extension work on the suitability of certain soils for sensitive crops.

1.3. FIELD CROPS. SOIL SUITABILITY CLASSIFICATIONS

Like horticultural crops, ordinary field crops bear a close relationship to the soils on which they grow. The methods of studying the soil-crop relationships, discussed under 1.2.2., can also be applied to ordinary field crops. Root systems, above-ground development and yields are influenced by soil conditions in much the same way as horticultural crops.

One difficulty of using the results of such investigations is that ordinary field crops are grown in rotation. The response of one crop to soil conditions is only part of the farm-soil relationship. The minimum requirement is to study the relationship between all the crops of the rotation and the soil.

Even an inventory of the crops found on the various soil units, together with a rough appraisal of their development, will produce results which are more important than studies based on single crops. When a farmer decides which crop to grow on a certain field he subconsciously makes a forecast of results. Since forecasting is one of the aims of scientific research, a student of soil-crop relationships in ordinary farming is on firm ground if he begins bij studying the crop rotation on various soils on well-managed farms. The results will be surprising.

On the light sandy soils of the Netherlands soil classification is closely associated with the moisture characteristics of the soil profile, water being the limiting factor in plant growth since chemical fertilizers are available. On the driest soil units no root crops are found and only rye and oats are grown. On soils with medium water conditions all crops of the region are found. During dry summers the lowest soils of this category give the best results, and in wet summers the higher soils. Since the weather of a given season is unpredictable, the rotation within the various soils of medium water conditions is the same. Soils with abundant water supply are usually laid down to grass and good arable crops can only be produced during a dry year.

A careful study of the reasons why capable farmers grow certain crops and not others has shown that the farmer's decision is mainly based on the hazards to which certain crops are exposed on certain soils. These hazards reduce the possibilities of certain crops and mean a more limited crop rotation.

Drought-sensitive soils are not attractive for root crops. Soils with a poor topsoil structure in spring are not good enough for such crops as flax, which require a very regular seed-bed. Root crops grown on heavy clay soils may cause trouble when harvested during a very wet autumn.

A soil suitability classification of arable land for ordinary farm crops should be based on what competent farmers consider to be the best crop rotation.

Improved permanent pastures are found on moist to wet soils in the Netherlands. Despite the abundant water supply most pastures show depressed growth during the mid-summer period. Certain pastures show a marked mid-summer depression but produce abundant herbage in early spring and autumn. "Cold" or "late" grassland usually has a limited mid-summer depression.

An important characteristic of pastures is the suitability for grazing. The topsoil structure of some pastures is destroyed by the weight of the animals during wet summers. If a soil surveyor can find soil characteristics that run parallel with such practical features of the land he will succeed in making a very useful soil suitability classification for ordinary field crops.

PRELIMINARY SOIL SUITABILITY CLASSIFICATION FOR ORDINARY FIELD CROPS AND PASTURE IN THE NETHERLANDS TO BE USED IN CONJUNCTION WITH THE SOIL MAP 1:200,000 (cited after A. P. A. VINK)

MAJOR CLASS BG: SUITABLE FOR ARABLE LAND AND PASTURE

Class BG 1 with very wide use capabilities
„ BG 2 with wide use capabilities
„ BG 3 with certain limitations
„ BG 4 with limited use capabilities
„ BG 5 with very limited use capabilities
„ BG 6 complex with wide variability of use capabilities
„ BG 7 complex with limited capabilities

MAJOR CLASS GB: SUITABLE FOR PASTURE AND OFTEN FOR ARABLE LAND AS WELL

Class GB 1 with certain limitations
„ GB 2 with limited use capabilities
„ GB 3 complex with limited capabilities

MAJOR CLASS B: SUITABLE FOR ARABLE LAND ONLY

Class B 1 with fairly wide use capabilities
„ B 2 with limited use capabilities
„ B 3 with very limited use capabilities

MAJOR CLASS G: SUITABLE FOR PASTURES ONLY

Class G 1 suitable soils with solid sod but with certain hydrologic limitations
„ G 2 suitable soils, late in spring
„ G 3 suitable soils with weak sod and with certain hydrologic limitations
„ G 4 soils with varying suitability
„ G 5 mediocre soils

MAJOR CLASS O: UNSUITABLE SOILS

Class O 1 mostly too dry soils
„ O 2 mostly too wet soils

Land with wide use capabilities has many advantages over land with a limited crop rotation. Some crops, e.g. certain vegetable seeds, can only be grown on very homogeneous land having a soft topsoil. In some years the farmer can make substantial profits from such crops. Farmers on average land, with a limited crop rotation, never have such advantages and never earn more than a modest income per hectare.

What is discussed above is no more than a first step. The second step is the consideration of cost prices and profits of the various crops, taken both separately and together.

Since prices of ordinary farm products are low, it is both important to know whether a good crop can be produced and what such a crop costs. This is the main difference between horticultural crops and ordinary field crops. If we compare apples and wheat, both of which are limited to good soils in western Europe, we find that the production per hectare of apples is about ten times that of wheat, the price per kilogram being about the same. A proportionally small increase in yield may mean a substantial profit in the case of apples and a negligible profit in the case of wheat. The costs might be of no real importance in the case of apples and prohibitive in the case of wheat. Hence in the case of horticultural crops the highest production per hectare is nearly always economic; in the case of ordinary farm crops this is by no means certain.

A comparison of different soils might show that their yields are the same but that the cost prices differ considerably. Such differences in cost price are often due to higher tillage and fertilizer costs. In this way the soil suitability classification for ordinary farm land is given a quantitative basis.

It will be obvious that this part of the study of ordinary farm soils can only succeed provided a farm economist is called in. (Note the difference from horticultural crops, where the soil scientist needs the help of a crop specialist).

The applications of the soil suitability classifications to ordinary farm soils is not so direct as in other applications of soil surveys. It is fairly difficult to tell a competent farmer something new about the suitability of his soils for ordinary crops. He and his ancestors have found out about this subject many years ago. But leaders and advisers can still benefit greatly from the new evidence, and farmers will derive important benefits from their improved work.

Until recently the only approach to the question of farm income was via economic research. It is an important achievement that it is now possible to make a sound use of soil classification and surveys for this purpose.

To avoid any misunderstanding it may be as well to state that the ordinary farmer benefits from soil surveys in other ways, especially with regard to soil improvement (chapter 3) and possibly through his interest in horticultural crops. This report is divided into chapters to facilitate the discussion, not because the subjects of the various chapters are separate.

Excellent work on the value of agricultural soils has been reported from Belgium. The yields of the major crops to be expected with good management are known for all soil units.

In Finland soil maps are successfully used for general agricultural planning and guiding the cultivation of various field crops, including related industrial activities.

In Greece a special soil survey of the Thessaly area was carried out in connection with the establishment of a sugar-beet industry in order to indicate the most suitable land for the cultivation of sugar-beet.

In Portugal both the soil maps and a 1:50,000 Land Capability map are being published. The latter map has not been compiled for individual farmers direct but is mainly intended for regional planning.

The soils are grouped into five capability classes. Classes A, B and C are suitable for cultivation and other uses. Class A is suitable for intensive cultivation. Class B is suitable for moderate cultivation. Class C is only suitable for limited cultivation. Classes D and E are unsuitable for cultivation and only suitable for grazing and forestry.

Capability classes are subdivided into subclasses according to the kind of dominant limitations.

The Extension Service for Agriculture is increasingly basing its programmes of work on the soil maps and the Land Capability map.

1.4. FORESTRY

The applications of soil survey to forestry are clearly based on soil-crop relations, the crop in this case being timber. Relationships between tree species and soil conditions can be studied in a similar way as in the case of fruit (chapter 1.2). Good results require close co-operation between soil scientists and foresters.

The productive tree species differ widely in their soil requirements. Some will only grow well on fairly good soils, others are more tolerant and do as well on poor as on good soils.

By carefully studying existing forests it is possible to compile a soil suitability classification for forestry purposes which gives valuable information to any forester about to make decisions on management. An example of this kind of soil suitability classification can be derived from a Dutch report on the soil survey of an inland dune sand district by J. SCHELLING (1956).

Detailed maps of forest areas are required in order to apply such knowledge of the relationships between forest tree species and soil conditions. A scale of 1 : 10,000 is suitable for such maps, although in some countries scales of even 1:2,000 or 1:5,000 have been used.

In some countries foresters also make use of the information given by vegetation surveys. In this report it is not intended to discuss the relationships between soil maps and vegetation maps. Recent experiences show that they often supplement each other in a most interesting way.

In some countries, e.g. Sweden, much good research work has been done on forest soils, but no soil maps have been produced.

In France also excellent work on forest soils does not lead to what might be termed modern soil survey work. French foresters rely on a forest site survey which in addition to climate includes soil, parent material, topography, exposition and vegetation. Since the vegetation is considered to be the result of all other factors, phytosociology is regarded as the most useful science in connection with the forest site survey, although the survey team also includes a forester trained in soil science.

Since foresters tend to organize their research work separately from other land users, the question arises as to whether forestry soil surveys should be carried out by a national soil survey group or by a special forestry group. This question is discussed by the German expert F. E. EIDMANN (1957). According to this writer, the survey of forest sites in Nordrhein-Westphalia was started in 1949. The surveyors were foresters specially trained in soil and vegetation survey before starting field work. But this method produced unsatisfactory results and since 1951 the survey of the basic facts has been carried out by specialist institutions. The State Geological Department produces the soil maps and the Federal Institute for Vegetation Mapping the maps of the vegetation types. A forester then produces the forest site map in close co-operation with the soil and vegetation specialists and with the additional use of climatic and historic data. The site types of the district are then classified and grouped according to their silvicultural values and potential productivity. Forest sites have an economic and dynamic character. Soil, vegetation, climate, etc, are basic facts. Thanks to the sound professional work of the specialized Institutes, forest site mapping has now reached an entirely new phase.

The separate mapping by soils and vegetation specialists has an important advantage. Each specialist group has an opportunity to produce its own most important evidence. If the surveys were combined the surveyor would emphasize one technique more than the other according to his personal predilections.

One final good reason for entrusting the soil survey of forest areas to a specialized institute is that soil science in general and soil classification and survey in particular are making rapid progress. Specialist organizations are well aware of this progress and contribute to it. They can give foresters the full benefit of the latest achievements of soil science. A separate forestry group would be at a disadvantage in this respect.

Experiences and methods in various countries differ considerably.

In Austria the work in question was begun in 1958 so that no important results could be reported yet. The work is carried out by the Soil Survey Institute at Vienna.

In Belgium a programme of study of forest soils has begun by two specialist institutions, one of which is closely associated with the National Soil Survey group.

As pointed out above, France has not developed soil survey work in connection with forestry. Work on forest soils is more directed towards ecology.

In Germany not all "Länder" take the same view as Nordrhein-Westphalia, discussed above. An example of the opposite view can be found in Rheinland-Pfalz. This forest site mapping takes into consideration climate, soil, vegetation and production. The survey is carried out by foresters specially trained in soil science and employed by the Forest Service (BENINDE & WALLESCH, 1959).

In the Netherlands soil survey work for forestry purposes is carried out by the Soil Survey Institute.

In Norway detailed soil maps of two areas operated by the Norwegian Forest Research Institute have been prepared for experimental forestry work. The results of the investigations carried out jointly by the State Soil Institute (at the Agricultural College of Norway) and the National Forest Survey, have been useful in practical forestry, e.g. in afforestation work.

In Portugal the Forestry Service has an extensive programme of reafforestation of many areas of low capability as defined by the National Soil Survey. The Forest Service has a special Centre of Soil Studies which gives advice on the reafforestation projects.

In Scotland the soil survey group gives advice on tree species and soil types in the planting programme of the Forest Commission.

In Spain special surveys are undertaken in connection with the planting of Pinus halepensis.

1.5. USE OF FERTILIZERS

It may be useful to state that there is one aspect of soil surveying important to agriculture that has not been greatly developed in Europe, viz. the relationship between soil classification and the fertilizer needs of the soils. Moreover soil chemists rarely make use of soil survey data.

The reason why this connection has not been systematically investigated is that the study of soil fertility and soil chemistry had already attained a high level of perfection in Western Europe before modern soil surveying started. Since soil surveying and classification have also reached a certain level in a number of European countries it would be appropriate to revise the relationships between the two subjects.

Not all European countries can be considered as highly developed. In Greece and Turkey and parts of other Mediterranean countries the use of fertilizers is still in its infancy and very little is known about fertilizer needs. Since both soil fertility and soil survey studies have recently been introduced in these countries it may be useful to make some comments on the relationships of soil classification and soil fertility under the conditions involved.

Under more or less natural conditions soil fertility is closely related to the results of the processes of soil formation. Weathering of parent material produces the mineral nutrients required for plant growth. Under a virgin vegetation topsoils always contain a great deal of plant food, owing to a rotational movement of mineral matter and nitrogen through the vegetation and topsoil. This fertility is only slightly affected by the soil-forming processes, that are continually in progress in the subsoils (Fig. 8).

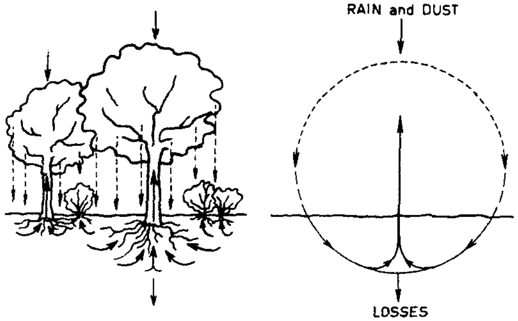


Fig. 8 Diagram showing the movement of plant nutrients in a soil and its vegetation in a natural environment. Origin of initial fertility.

After reclamation of a soil covered by a more or less virgin vegetation, the accumulated fertility becomes available. This fertility may be termed initial fertility. The proverbial fertility of certain tropical forest reclamation areas or the legendary fertility of steppe and prairie soils are examples of this initial soil fertility accumulated by the original vegetation and only slightly affected by the soil formation.

After reclamation this initial fertility is of short duration; in some cases it only lasts a few years, in others up to half a century. It is a temporary soil characteristic. After this period soil fertility approximates to the natural soil fertility viz. the production of plant nutrients by continual weathering.

This natural fertility may be considered as a function of the soil profile, and where it is important there is no reason why it should not be included in soil survey activities.

It should be realised, however, that the soils of most of Europe and the adjacent parts of Asia and Africa (the Old World) have been farmed for a very long period (up to 8000 years). Farming practices of the ancient inhabitants radically altered the fertility conditions of the various tracts of land. A simple form of the processes involved is caused by the grazing of farm animals on idle land. Grazing animals consume part of the natural fertility of rough grazing areas and some of this fertility reaches the homesteads, and also, via manuring, the arable land near the villages. In many cases the proportion of this arable land was (or still is) no more than 1/3, 1/5 or even 1/10 of the whole area. Agriculture on this arable land may have been maintained for many centuries by means of grazing animals. The idle lands have been impoverished and the arable soils enriched by this process. The idle lands are now less fertile than their natural fertility would suggest, while the old arable lands are more fertile. This situation is indicated by the term traditional fertility (Fig. 9). It is the major difference in soil conditions between the old world and the new. It has so greatly influenced certain soils that they must be termed man-made soils. Traditional fertility has a pronounced regional character and where it is still important it can be studied by soil surveyors.

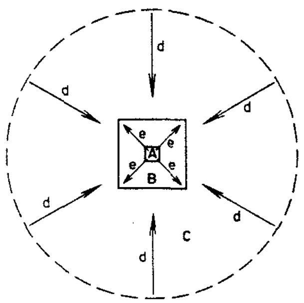


Fig. 9 Diagram showing the movement of plant nutrients on a farm under traditional conditions.

- a Farmstead;
- b Arable land;
- c Rough pasture;
- d Transport of plant nutrients by the grazing animals towards the farmstead;
- e Transport of plant nutrients in the form of manure. Area B is being enriched at the cost of area C, origin of traditional fertility.

In the parts of Europe developed at present traditional fertility was of predominant importance up to the time of introduction of industrial fertilizers. Ideas on soil fertility have been revolutionized by this development and fertilizers are only a part of the story. The productivity of land has now become dependent on the application of a large number of scientific and technological findings. The basis of soil fertility now largely lies outside the soil itself. It may be termed technological fertility.

Technological fertility is still connected with real soil properties, but to a lesser extent than the traditional or natural soil fertility of the past. It can only be considered by a soil survey insofar as it is influenced by soil characteristics of a permanent nature.

Although the relationship between soil classification and soil fertility has not been systematically studied in the developed parts of Europe where soil fertility has reached the stage of the technological fertility some attempts and results of this kind have been reported.

In England and Wales an investigation has been begun into the possibility of correlating soil survey mapping units with the records of soil fertility made by the National Agricultural Advisory Service in order to increase the value of both sets of data to the agriculturist.

In another case a detailed soil survey in Central Somerset showed the cattle disorder known as "teart" to be associated with certain soil series (on other soils the trouble had never appeared) (B. W. AVERY, 1955). The disorder was caused by uptake of molybdenum by the cattle, due to their consumption of certain pasture plants containing it in excess. It was also found that cattle could be kept on "teart" fields if they were given an adequate supply of copper in their diet. As a result of these findings a more intensive use of this land is now possible.

Surveys of soils and plants show that plants grown on particular soils are prone to certain of the "deficiency" diseases e.g. of boron deficiency in sugar-beet and of manganese deficiency in oats.

In Finland soil surveys have been used to locate areas where liming was required.

In Ireland cobalt deficiency in ruminants is associated with certain soil groups. (WALSH, RYAN and FLEMING, 1956).

In Scotland under conditions of rolling relief hydrological sequences of soils tend to occur, and wherever possible hydrological sequences of soil profiles are collected for analysis. It has been found that on arable land the phosphate relationships of naturally freely drained soils (mainly derived from iron podzols) differ from those of poorly drained soils (non-calcareous groundwater gleys). In the freely drained soils the total P_2O_5 is higher in the surface soils than in the surface soils of the poorly drained soils. Acetic acid-soluble phosphate is the reverse of this, being higher in the poorly drained soil. Organic phosphate, amorphous sesquioxides, are also different.

This finding has implications for the subject of phosphate fixation, fixation being greater in freely drained than in poorly drained soils. Consistent trends have been observed in the distribution of calcium, magnesium, carbon and nitrogen. Certain trace elements viz. cobalt, nickel and molybdenum, extractable in acetic acid or ammonium acetate, have been found to vary under hydrological conditions in which high values consistently occur in the non-calcareous gley and peaty gley soils. This finding has been confirmed for soils of widely differing geological origin and composition.

The finding of these differences in the chemical composition of soils were a direct result of soil survey studies of soil profiles undertaken in co-operation with the chemists concerned, so that detailed studies of these differences are now being made at the Macaulay Institute for Soil Research, Aberdeen.

The consequences of this interesting experience are that before soils are subjected to costly chemical and physical analyses it should be insisted that the sample material used should be competently assessed in the first instance by means of a soil survey.

In Portugal fertilizer and liming experiments are only being made on representative points of the main soil units as defined by the soil map.

Investigations have been begun into the possibility of correlating soil survey mapping units with the records of soil fertility of the agricultural laboratories.

In various countries very detailed soil surveys have been made of experimental farms and important experimental fields as part of the fertility research programme.

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2. SOIL SURVEY IN RELATION TO LAND RECLAMATION AND IMPROVEMENT

2.1. Introduction

Although it may seem an obvious fact that soil maps are essential documents for land reclamation and improvement, co-operation between soil scientists and engineers presents many difficult problems. The subject is discussed with regard to conditions in Western Europe.

In connection with the desired co-operation between soil scientists and engineers, the soil scientist should realise that although he may be an expert in his own field he is an outsider as regards engineering problems. If he acts the part of a super-expert in land improvement he will find it extremely difficult to persuade engineers to co-operate.

Engineers responsible for land improvement schemes often distrust soil science and it is important to understand their reasons for doing so. Soil survey results are often presented in a form which is not in keeping with engineering traditions. Soil maps are inaccurate documents from the engineer's point of view. Engineers are much more used to quantitative thinking than are soil scientists. If a soil expert is content to call a soil impermeable, the engineer concerned with the drainage projects wants to reduce this property to a figure which suits his formulas. Most soil scientists agree that single value mapping is poor soil science, but they must express their results in quantitative figures if they are to satisfy the land improvement engineers.

Not all the engineers' criticisms of soil maps are warranted. Some engineers take too much for granted and have little liking for research. Often they know even less about soils than soil scientists know about engineering and it is hard to convince them of the value of even a good soil map.

It is one of the achievements of the scientists engaged on the Zuyder Zee Works in the Netherlands to have bridged the gap between agricultural and engineering traditions from both sides, viz.: –

a. by adapting soil data to the engineers' requirements
b. by introducing research into engineering techniques

Other Dutch groups have adopted similar methods in order to obtain the necessary co-operation between soil scientists and engineers. In the following discussion special attention is given to experiences in the Netherlands.

2.2. LAND CONSOLIDATION WORK (OTTO, 1957)

Land consolidation has a different meaning in different countries and at different times. In the Netherlands it now means the reconstruction of an agricultural area in which the development of a modern rational and mechanized agriculture is hampered by old-fashioned conditions. A modern farm consolidation project comprises:

a. consolidation of scattered fields (consolidation proper)
b. enlargement of undersized holdings
c. improvement of water control
d. building of new roads
e. construction of new farmhouses outside the villages
f. building of utility works, e.g. water and electricity
g. improvement of the soil

Soil surveys can be used in many ways during farm consolidation operations, especially in connection with a, c, d and g.

– *Sub a. Consolidation of scattered fields* (consolidation proper).

Soil maps are required for the following purposes: –

1. The correct evaluation of the agricultural value of the land that each farmer contributes to the consolidation scheme. For properly preparing such evaluations and applying them in practice a detailed soil map is indispensable and is always used in the Netherlands.
2. The correct layout of new parcels with respect to soil conditions. No major differences in soil profile should occur inside a new parcel, which often consists of several small and irregularly shaped old parcels.
3. The correct allocation of new parcels of different soil types. Where the farming system is based on the use of different soils, e.g. mixed farming with pasture on peat soils and arable land on sandy soils, it is essential for every holding to be allocated on the right soil units in the right proportion.

– *Sub c. Improvement of water control*

A substantial part of the capital investment in most farm consolidation schemes in the Netherlands goes towards "the perfect control of the water table at the correct level." Under given climatic conditions this correct level depends on the soil and the crop.

Without soil classification and accurate soil profile descriptions no study is possible of the relationship between soil types and the correct depth of water table. Knowledge about this relationship cannot be applied without a soil map, nor can a drainage scheme be planned without such a map.

Sprinkler irrigation is spreading in some parts of the Netherlands on light sandy soils. Dry and wet soils alternate at short distances so that a detailed soil map is necessary for working out water supply projects for sprinkler irrigation.

Regions with deep peat layers respond to drainage by shrinkage and land subsidence. A drainage scheme that does not take this subsidence into account is not worth carrying out. With soil maps based on special surveys, the future shrinkage can be calculated provided a small number of laboratory tests can be made.

Owing to the very complex soil patterns drainage can often only be improved after very detailed mapping. The correct water table cannot be ascertained without such detailed maps.

– Sub d. Building of new roads

The construction of a new system of rural roads also requires a systematic use of soil maps, because: –

1. in many cases a soil map gives a rough forecast of the costs and problems of road construction and maintenance
2. a soil map indicates the possible location of such useful materials as sand and gravel
3. a soil map enables the number and sites of soil engineering tests to be properly selected and can also forecast the physical properties of other places without extensive testing being required
4. considerable capital investments can sometimes be saved by planning roads on soil units where road construction is cheap.

– Sub g. Soil improvement

Every new parcel within the new network of roads and watercourses should answer the following specification: –

1. a surface flat enough to allow mechanical operation
2. a soil profile uniform enough to allow a rational use of the parcel as regards crops and crop rotation.

In many cases these conditions can only be met provided: –

a. old ditches are filled in
b. old roads are cleared
c. the land is levelled
d. deep ploughing or subsoiling is carried out, e.g. in order to break up hardpans.

The need for these operations, especially alterations in the soil profile, cannot be determined without a detailed soil map, which also is indispensable for the planning and execution of such work.

Research into the need and results of these operations is not possible or transferable if it is not based on a detailed description and classification of the soils in question and on their distribution.

Summarizing, we may say that the great importance of soil surveying and classification for farm consolidation projects consists in its possibility of making forecasts about a wide range of problems directly related to the soil and its use.

These forecasts are possible because the soil map not only formulates these problems in terms of character, extent and geographical distribution, but also creates the only possible channel through which existing knowledge of these problems can be applied to the planning and execution of projects.

In Norway a land register is being planned which will cover each individual holding. It is being considered how soil survey methods can be used for this purpose. This work is regarded as being particularly useful for the future consolidation of farms.

In various other European countries soil maps are used in farm consolidation projects.

2.3. SEA-BOTTOM RECLAMATION IN THE ZUYDER ZEE WORKS (NETHERLANDS)

– *a. Introduction*

The primary object of soil surveys carried out in connection with the Zuyder Zee polders is to obtain results for practical application. Not only is the soil survey carried out on behalf of agricultural planning and operations and certain hydrological purposes, but a great deal of soil research is being done on dike construction, canal excavation, road and farmhouse construction and the erection of other buildings.

Three successive stages can be distinguished in the sea-bottom soil surveys viz.: –

– *b. Stage 1; underwater survey*

Data on soil conditions should be available before a dike is constructed since the actual work is preceded by the drafting of plans, and this cannot be done without a fairly thorough knowledge of the nature of the soil.

1. Situation and shape of the polder

Since the Zuyder Zee bottom varies extensively as regards soil conditions an attempt is made to reclaim good soils only and to keep the inferior ones outside the polders.

2. Settling (compaction) of the soil after empoldering

In their original condition the sea-bottom soils are very loose and have a large pore space. After emerging from the water the soils lose moisture through evaporation and transpiration. This drying-out is accompanied by a general shrinking of the soil which manifests itself in cracking and settling.

Settling is very important since the drainage system has to be designed for the future ground level, vz. the level after settling. With the aid of underwater samples a fairly reliable calculation can be made for design of the drainage system, including the pumping stations, since the polder water level determines the discharge height of the pumping plants. Under the conditions of the Zuyder Zee Works settling during the first century will vary between zero for sandy soils to over 100 cm for soils with thick layers of clay.

It is also necessary to make a seepage forecast since the amount of seepage has a great influence on the capacity of the pumping stations. This seepage forecast is also necessary for drafting the reclamation plan.

A polder of 50,000 hectares can be brought under cultivation in 10–12 years. Areas with seepage are developed last. The seepage also influences the spacing of field ditches and tile drains. The extent of seepage depends on the difference in level between the water inside and outside the polder and on the thickness and permeability of the soil layers down to a considerable depth. At some points it may be as much as 20 mm per day, but the average for larger areas is 1 mm per day.

3. Canal dredging

The principal canals are dredged before the polder has been pumped dry. The first rough soil map is also used for deciding where the spoil is to be dumped. This may consist of sand, peat or clay. Each of these materials is put to a different use. The sand is dumped at such depots as future road junctions or in the vicinity of future villages. If possible, peat is dumped outside the polder area. Finally, the clay is used to cover sandy soils with a view to their improvement.

4. Various purposes

Light soils are improved by sub-irrigation. In order to design such a plan it is necessary to know which areas require sub-irrigation. This is one reason why an underwater soil survey is needed.

The map is also used for a provisional determination of soil suitability and land use.

– *c. Stage II, general soil survey*

The second stage of the soil survey is carried out shortly after the polder has been pumped dry. This survey is used during the initial stages of reclamation.

1. Final land division

At this stage of the operations the final decisions on land division are made. This is the last opportunity to influence the planned network of main canals, subsidiary canals and ditches.

2. Canal excavation

All these canals are dug by private contractors. To enable a cost estimate to be made the works are described in great detail in the specifications. The data required are usually taken from the general soil survey.

3. Temporary field ditches

During the initial period the soils are still so impermeable that drainage has to be provid-id by means of temporary field ditches. The spacing of these ditches depends on the soil conditions as shown on the soil maps of stage II.

4. Fertilizer requirement

During the first years of reclamation only a limited number of crops can be grown irre-spective of soil conditions, but the amount of fertilizer required greatly depends on the soil conditions. With the aid of standards worked out on trial plots it is possible to indi-cate the amount of fertilizers required on the basis of soil maps.

– d. Stage III, detailed soil survey

The detailed soil survey is based on a very large number of observations. These maps are used for a large number of purposes. The provisional drainage system by means of field ditches has to be replaced by a permanent system of tile drains. Soil improvements are carried out whenever necessary and provided the cost is reasonable. Soils susceptible to drought and not earmarked for afforestation are given an artificial water supply. The final use of each parcel (arable land, permanent or rotational pasture, fruit, vegetables, forest) has to be decided upon, and the farm size determined. The rent of the farms also has to be settled. Finally, the soil maps have to serve the farmer. He will find on the map information useful for his management viz. tillage, choice of crops, fertilizer requirements.

– e. Final remarks

A study of experiences gained in applying soil surveys to the Zuyder Zee Works will show that the soil survey programme is closely adapted to the needs of the various stages of the engineering project. In other countries, under different conditions, the soil survey programme will be different but the adaptation to the needs of the engineers should be carefully planned, this being the only way in which full benefit can be derived from the soil survey.

2.4. COASTAL RECLAMATION WORKS

Conditions in coastal reclamation works differ from those in the Zuyder Zee bottom project (salinity, tides, etc). No underwater survey is necessary since the tidal flats are dry at low tide. During the soil survey it should first be considered whether reclamation is justified. This means that an estimate is required of the cost involved as well as an evalua-tion of the new land. The cost can only be estimated after plans have been drawn up with respect to land division, reclamation, drainage and construction of farm buildings. These plans depend on the soil conditions so that the soil survey has to be undertaken before-hand.

In many cases the polder water level is a very important matter. Any coastal reclamation area includes a certain amount of inferior soils containing too much sand in the profile. It is true that when the polder water level is raised the value of the soils susceptible to drought is enhanced, but the total area of reclaimable land decreases. The optimum result of the reclamation scheme can only be calculated provided an accurate soil map is available. But there may be interests other than agricultural or economic ones that conflict with such an optimum polder water level.

During the reclamation work the channels of the tidal flat are an important factor. What is to be done with the soil dug from the canals and ditches? Which creeks can be filled in, and how? The answers to these questions are important applications of the soil map.

Advice must be given on the construction of field ditches. The distance apart of ditches depends on soil conditions and the stage of ripening of the soil profile. The latter property can be observed during the soil survey and only a few supplementary investigations will be needed.

Another factor to be considered is the danger of wind erosion during the reclamation period. To control erosion certain protective crops or grass should be sown. The soil map shows where such soils are situated.

During the initial stage the new soils are saline. In order to ascertain at what stage the sowing of crops is warranted the degree of desalinization has to be investigated. Since desalinization is closely related to soil conditions and levelation, the soil map furnishes valuable indications on this subject.

The soil maps prove very valuable when advice has to be given on the manuring of crops during the first post-reclamation period or on soil improvement (mainly deep ploughing in order to mix soil layers).

The final land-use is closely bound up with soil conditions. As a result of various technical measures such as the filling-in of the channels or the mixing of soil layers by deep ploughing the ultimate soil conditions may be very different from those encountered during the initial soil survey.

In planning the farms an attempt is made to allot to each farm a certain minimum area of good soil which will ensure the future farmer a good crop and in addition an area of inferior quality. The rents also have to be fixed. These are based upon both the soil map and the general experience obtained on comparable soils in other parts of the country.

In Portugal many thousands of hectares of saline coastal soils are being reclaimed by the Portuguese Government. In all cases the first step is to compile a detailed soil map. Soil surveys in connection with such drainage projects have already been made in Greece and Ireland.

2.5. DRAINAGE PROJECTS

Soil surveys in connection with drainage projects should provide special maps giving additional information on certain facts not shown on ordinary soil maps, for example: –

the *hydro-geological characteristics* of the area;
the *permeability* of the various soil layers up to a depth of some metres;
the *location of the layer below drain depth* to be considered as relatively impermeable for the drainage scheme;
the *winter and summer* water tables; if the survey is carried out during the summer only the winter water tables have to be estimated from profile characteristics;
the amount of water available for plant growth, calculated over the whole profile, but without the contribution of ground water;
drainable pore space;
the need of drainage in relation to the water table, climate (rainfall, evaporation), crop and water storage capacity of the soil.

Drainage should be sufficient but not excessive. A small number of measurements may be sufficient for this purpose provided the soil classification used during the surveys is a sound one.

Soil maps providing this additional information will be gratefully used by hydraulic engineers.

In Belgium an extensive survey has been made of imperfectly drained soils (AMERYCKX & 't JONCK, 1957). The hydraulic conditions of the areas in question were studied at the same time. It is hoped to follow up this study with a large number of local drainage projects.

2.6. *Irrigation projects*

Soil surveys are very necessary in connection with irrigation projects. Too many costly mistakes have been made in attempts to irrigate soils which despite their favourable topography should never been irrigated owing to the unfavourable internal properties of the soil, or which should have received a specially adjusted type of management from the start.

Besides the various aspects of the topography and consequences thereof, soil surveys of irrigation schemes must take into account a number of hydrological and chemical properties of the soil, for example: –

- the *infiltration rate* under dry and wet conditions
- the *permeability*, especially of the subsoil
- the *water-retaining capacity* of the soil profile (field capacity, wilting point, readily available water)
- the *tilth* and *stability* of surface soils after being wetted
- the *chemical composition*, fertility level, pH and organic matter content.

In addition to such soil investigations for irrigation purposes, an intensive soil survey is particularly necessary when there is a salinity problem. It is also necessary to ascertain the extent to which salinization and/or waterlogging may be expected after some years of irrigation.

According to modern theories, irrigation should in many cases be combined with drainage. The drainage requirements should be based on the soil properties, the salt content of ground water and irrigation water, and the geo-hydrological characteristics of the area.

In France there is now a tendency to employ soil maps when preparing irrigation schemes. The first requirement is maps showing the suitability of the soils for irrigation. As a result, irrigation projects are now being adapted to soil conditions.

The French group recommends the study of soil conditions in existing irrigation schemes. This is a very important suggestion. Once the effects of irrigation on the soils are known it is easier to forecast the results of irrigation in new schemes.

In Greece large tracts of land have been studied according to the system of classification used by the U.S. Bureau of Reclamation.

In Portugal no irrigation project has been carried out without a previous soil survey since 1926. From these soil maps is derived an interpretative map showing the suitability of the soils for irrigation. These soil surveys are undertaken by soil scientists employed by the National Irrigation Board. The areas studied by this group are selected with reference to the soil maps compiled by the National Soil Survey.

In Turkey classification activities carried out according to the system of the U.S. Bureau of Reclamation are rapidly increasing as the construction of water storage dams progresses and irrigation is found to be necessary for obtaining higher yields.

In Spain soil surveys of irrigation schemes are beginning to assume importance.

2.7. RESTORING LAND TO AGRICULTURE AFTER MINING OPERATIONS

In the United Kingdom and Germany soil survey groups have successfully helped in restoring land after open lignite, coal or iron mining operations. In the United Kingdom it has been found that the productivity of such restored land is less than that of undisturbed land. Field drains subside; compaction causes failure of the early growth of crops and grass. Investigations of restored sites with these and other points in mind have enabled proposals to be submitted and regulations drawn up regarding the methods of restoration to be adopted.

Unsightly and unproductive land has often been made almost as productive as it was before the mining operations begun.

In the extensive lignite area in the Rhineland district of Germany the productivity of the land depends on the loess deposits and the soils developed on it. A careful inventory (1 : 10,000) has been made of these loess deposits. After the lignite has been excavated the loess material is used to restore the land. The loess inventory is made for this purpose.

2.8. RECONSTRUCTION OF AREAS DAMAGED BY FLOODS

In Belgium and the Netherlands soil maps have proved useful for the reconstruction work carried out after the flood disaster of February 1st, 1953. Thanks to the soil maps it was possible to make a rational sampling of the soils for laboratory analysis in relation to the dosage of gypsum. Where the land was covered by marine sand the soil map gave the necessary information on the possibility of ploughing-under the sand. Where the damage was extensive a new settlement plan was necessary and the plan could be based on existing soil maps.

2.9. RECLAMATION OF WASTE LAND AND SOIL IMPROVEMENT

In the densely populated parts of western Europe little wasteland has been left which could be reclaimed for agriculture. But even in Belgium it has been possible to start reclamation projects on wasteland after the soil surveyors had studied the district.

In Norway land suitable for reclamation has been studied by the Soil Survey and by the Norwegian Bog Association.

Where there are considerable areas of wasteland, soil surveys might be very useful for locating land where reclamation would be successful and for assembling the data required for the preparation of a reclamation plan.

Much land is in use of which the soils are of a fairly poor quality. The farming population of such areas is usually very poor and they are unable to improve their condition by applying modern techniques.

Situations such as these are intolerable in a modern welfare state. The areas should either be abandoned by agriculture or their soils improved.

The part played by soil improvement in modern farm consolidation projects has been discussed earlier in this chapter. Drainage is another soil improvement measure we have discussed above. Other methods are the mixing or interchanging of soil horizons and the breaking of hardpans.

In Belgium and the Netherlands acid marine soils are improved by deep ploughing (up to more than 1.50 m) thereby bringing up to the surface subsoil material rich in lime.

It will be obvious that soil improvement should be based on a detailed soil survey.

2.10. SOIL CONSERVATION

In the temperate moist parts of western Europe soil conservation, in the sense of protection of the soils against soil erosion, is not considered to be a serious problem, although it would seem that there was fairly active soil erosion in the 17th and 18th centuries.

Important research work on soil erosion and conservation has been carried out by Prof. Dr. H. KURON of the Soil Science Institute of the University of Giessen (Germany). In the German hill districts the arable soils have undergone important changes since the land was reclaimed. Modern farm consolidation methods tend to lay out large fields and this creates new soil erosion hazards on sloping land. In the studies of Professor KURON five types of hazards are distinguished and soil conservation methods are adapted to this classification.

In Greece the soil capability classification of the U.S. Soil Conservation Service has been applied in several places. Land use has been adapted to the findings of these surveys.

In Portugal a soil survey has been completed of the southern part of the country which has a Mediterranean climate and serious erosion problems. A Land Capability map is also being published. This clearly indicates the main soil conservation problems.

Both maps have drawn the attention to problems requiring investigation and some soil conservation research work is already being carried out. Several soil conservation projects now in progress are based on the soil map and the Land Capability map. In Portugal the Director of the Soil Survey is a member of a group in charge of studies on protection from soil erosion of the watersheds, including areas to be irrigated.

The importance of soil and water conservation is well recognized in Turkey. Activities in this sphere are based on examples and experiences of the U.S. Soil Conservation Service. Land capability maps have been compiled at many places and the results applied to numerous reclamation schemes. In the Mediterranean area bare limestone slopes can be terraced and economically planted with olives or other perennial crops. Water conservation is at least as important as soil conservation, since under the prevailing conditions water is the minimum factor in crop production. Many other activities, usually designated in the U.S. as soil and water conservation, are also being tried out in Turkey.

There are some other Mediterranean countries in which no soil surveys are being undertaken, despite the importance of soil erosion.

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3. SOIL SURVEY IN RELATION TO TOWN AND COUNTRY PLANNING

In most European countries the soil survey groups have important duties in connection with Town and Country Planning. These countries have a rapidly expanding non-agricultural land use; land is required for various purposes (towns, industries, airports, military authorities, recreation, highways, natural reserves) and in many cases agricultural land will have to be given up.

An interpretative map for both agricultural and non-agricultural land use, derived from a detailed soil map, can be used as a safe guide by the authorities who decide on such changes in land use.

As far as concerns horticultural land and agricultural uses, soil suitability classification maps of the kind discussed in chapter 2.2 and 2.3 of this report will specify which land is valuable for horticulture and farming. Maps showing the suitability of land for non-agricultural uses can be derived from detailed soil maps after consultation with soil engineering experts and other technicians.

Since the loss of good land has serious consequences to agriculture attempts should be made to locate urban and other non-agricultural sites on poor agricultural land. In some cases this can be done.

In Belgium and the Netherlands some agricultural land is too dry for optimum production, although the same land is excellent for building development. It is not always possible to find such a good solution, but with the interpretative maps available the authorities can make the best possible decision under the circumstances.

It is interesting to note that this application of soil surveying has had a different development in the countries concerned.

In Belgium the soil survey group works in close co-operation with the "Administration de l'Urbanisme" (Town and Country Planning Department) of the Ministry of Public Works. A number of reports have been published on important regions. One dealing with the Courtray region (in Flemish by 't JONCK) first discusses the soil conditions of the region and the suitability of the various soils for agriculture and horticulture. Since the region is rapidly becoming industrialized the report contains an interpretative classification for building purposes. The report also gives an inventory of natural resources. Plans for the extension of towns and agricultural development projects including improvements in drainage and changes from ordinary farming to market gardening, can be safely based on studies as these.

Soil scientists have also made an essential contribution to the very interesting report entitled "Le plan d'aménagement de la région Liègeoise", published by the Town and Country Planning Department of the Ministry of Public Works. The Liège region is one of the most industrialized districts in Europe and it also includes areas of very productive land. The interpretative grouping of soils as worked out by the soil scientists and based on a very detailed soil map (1 : 5,000) enables the regional and national authorities to pursue an efficient land use policy and to safequard agricultural interests on the very good soils.

In Finland it is fully recognized that country planning and knowledge of soils is generally needed for settlement, industry, traffic and land utilization. The lack of this knowledge may lead to errors which are impossible to correct at a later date. On the other hand without soil maps the planner is in complete ignorance of the land utilization possibilities of the district. Soil mapping in Finland has therefore been applied to all regional planning and all workers available for soil mapping are concentrated on these areas.

All culturable land should be saved for agriculture as there is plenty of land in Finland which is unsuitable for agriculture but quite suitable for other purposes.

In France the urgent need for information on soil conditions around the main towns was the main reason why soil surveying could be begun in a modest way. The chief aim of these surveys of the vicinities of towns is to ascertain the suitability of the land for agriculture so that new towns, industrial sites and other non-agricultural land could be sited with the least possible damage to agriculture.

The first 1 : 50,000 map was of the Paris district (350,000 hectares) where it was possible to safeguard the famous market gardening zones. The vicinities of other rapidly growing towns have also been surveyed, in all 180,000 hectares. It is estimated that about 50% of the work was of real importance.

In Germany similar work has been reported from the North Rhine-Westphalia region. The vicinities of many towns have been surveyed on scales of from 1 : 10,000 to 1 : 5,000. In addition to the soil map a hydrological map is compiled and a map indicating soil engineering data for building purposes (Baugrundplanungskarte).

One difference between this work and that done in other western-European countries is that the German maps essentially serve the town and its interests, and not agriculture. This is because the only areas considered are those which have in any case been lost to agriculture.

In the Netherlands the contribution of the soil survey group to town and country planning has been mainly to safeguard horticulture. About half of the Dutch horticultural production is exported and horticulture is obviously just as important to the national economy as industry. Such products as hyacinth bulbs are even a world monopoly. Since only a very restricted acreage can produce such crops the land available deserves to be protected from other land users. Comparable cases are found in greenhouse districts as the Westland area, which is surrounded by big towns and the great port of Rotterdam.

The interpretative maps, based on detailed soil maps and indicating the suitability of the various soils for the crops in question, have drawn the attention of many authorities to the unique value of certain soils for the national economy.

Most horticultural centres have been surveyed in great detail and the relationships between the soils and the most important crops have been studied at the same time. Soil suitability maps are the essential results of this activity.

The vicinities of about 100 towns have been mapped in connection with plans for their development and this has always resulted in soil suitability maps. Wherever possible, agricultural interests have been safeguarded.

The important development plans for the ports of Amsterdam and Rotterdam have also been drawn up with the help of soil maps and interpretative maps. These have given the authorities a good idea as to the value of the land that has to be destroyed or can be saved.

The work discussed under this heading has become widely known in the Netherlands. It has become one of the channels viz. which soil survey work has gained in popularity and become a greatly respected profession for a soil scientist.

In Norway, where agricultural land is very scarce, discussions between town planners and soil scientists have recently begun.

In Portugal the soil survey group works in close co-operation (by means of soil maps, land capability maps and the giving of proper advice) with a number of town planning committees, viz. in Lisbon and other towns near the capital.

In the United Kingdom similar activities have been reported. A detailed survey, mainly for planning purposes, was made of the coastal district between the rivers Arun and Adur in West-Sussex. It is an area mainly consisting of first-class soils chiefly developed on brick earth, and this fact, combined with its high amount of winter sunshine, has led to its development as an important horticultural district. At the same time land is in great demand for residential and non-agricultural purposes, and as the survey was made in detail it should assist in formulating a land-use policy.

4. CONCLUDING REMARKS

It follows from the discussions in the preceding chapters that a soil survey institute should include the applications of soil surveys in their programme. It is not feasible to leave the applications entirely to outsiders.

It is very useful to both parties that there should be a close connection between the basic soil survey and classification and the applications. Soil classification now moves in the direction of a much more accurate morphological definition of soil units. This development will serve the applications. Moreover, modern methods of compiling soil maps and legends can be usefully adapted to the needs of the applications.

It is a disadvantage if the applications have to be developed without the support of a strong soil survey group. In this case the application will soon suffer from a lack of experience in modern soil science. On the other hand, soil survey groups not interested in applications will suffer as well. Soils can be studied as subjects without reference to their environment, but one of the most inspiring aspects of soils is that they bear a vegetation. If this vegetation is composed of an economic crop, the soil student also touches on economic problems of the kind discussed in chapter 1.3. The whole complex of soils, crops and mankind should be the subject of inspiration to soil surveyors.

Some will excel in theoretical aspects, others in the more practical ones. It would be a tragic misunderstanding to think that these practical aspects are only secondary research subjects. On the contrary, they require a wide knowledge of soil science and a good understanding of the land-use problems involved. This is equally necessary when the soil scientist has succeeded in obtaining the close co-operation of specialists in other branches of agricultural science or engineering.

Soil survey groups should maintain the closest possible connections with other agricultural research bodies. Part of their research programme should be a joint programme with other institutions. Good co-operation cannot be based on goodwill only but it must be carefully organized.

The branches of soil science discussed in this report form a rapidly advancing sector of soil science. Soil survey groups cannot expect the agronomists, foresters, economists, engineers and other technicians who may use the soil maps to be familiar with this rapid progress. Soil survey groups should always be prepared to explain their work to those using their scientific results. In some countries soil survey groups organize special courses for the personnel of agricultural extension services and other bodies interested in soils. Although this work is very time-consuming and a strain on soil surveyors, the results are very rewarding as regards the application of soil maps.

Many European Agricultural Colleges have no facilities for instructing agricultural students in soil survey methods and results. This is one reason why soil surveying has not yet been started in certain European countries. This situation can be tolerated no longer.

The agricultural applications of soil surveys are so important that it is hardly possible to have a successful soil survey group that does not include associates with a background knowledge of agronomy.

In Germany the soil survey groups are sections of the Geological Survey Departments, owing to the interests of the survey work proper. This is an exceptional situation. In all other countries where soil survey work is in progress it is organized as a part of agricultural research. This can be recommended in countries where modern soil survey work has not yet been started.

The applications of soil survey discussed in this report are all related to agriculture. Other non-agricultural applications could have been mentioned, e.g. highway construction. This application is more highly developed in Michigan (U.S.A.) than in any part of Europe. The discussion of this and related subjects has been expressly omitted from the present report.