PRINCIPLES AND OBJECTIVES OF LAND CLASSIFICATION -

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Motto : "The good farmer must always be an intelligent man of parts, knowing perhaps more about more things than any other citizen. He must know something of markets, the weather, distribution, machinery, economics, history, ecology, disease, bacteriology and many other things, but most of all he must understand the earth and the laws which govern its maintenance and productivity. This last is a vast field, much of it still open to experiment and research".
(Louis Bromfield: Malabar Farm).

I. GENERAL PRINCIPLES

a. General

The words "land classification" only mean the arrangement of land in classes. This may be an arrangement in a certain sequence, from the best to the poorest land, but this is not strictly necessary. The arrangement may also give groups that have, at a certain moment, the same value, but that may differ on account of the treatment the soils must get. All this depends on the goal to be reached.

We distinguish six categories of classification (cf.LEWIS, 1952)[x)]

1. Land classification in terms of inherent characteristics (Soil Classification, Topographical Classification).
2. Land classification in terms of inherent qualities (Soil Quality Classification).
3. Land classification in terms of present use (Soil Use Classification).
4. Land classification in terms of use capabilities (Soil Suitability Classification).
5. Land classification in terms of recommended use.
6. Land classification in terms of program effectuation.

Of these six categories, the first four belong to research, number 5 is on the border between research and administration, whereas number 6 belongs to administration. Generally speaking, both number 5 and number 6 are based on a choice, made on administrative considerations, from the inventory of use capabilities provided by the "land classification in terms of use capabilities". The latter, which we prefer to call "Soil Suitability Classification" in its turn rests largely on the data provided by the first two categories of land classification.

In the following paper we are dealing mostly with the Soil Suitability Classification in its various aspects and with the Soil Quality Classification.

x)The author wishes to express his thanks to Ir. J.M. Verhoog (Suriname) and other participants of the 1957 Seminar on Land Development for their suggestions. These made us formulate the new Category 2: Soil Quality Classification. Also the paragraph on Transfer of Knowledge (IVa) was a result of suggestions made by Mr. Verhoog.

LEWIS (1952) also mentions the following kinds of land classification, namely:

a. Soil Classification
b. Land capability Classification
c. Economic Land Use Classification
d. Mapping of Major Agricultural Regions.

Soil Classification (a) is a purely scientific matter. It arranges the soils according to their morphological, their genetical or other inherent characteristics. It corresponds with category 1, which we mentioned previously. If a Soil Classification is to be of any definite and practical use, it should be expressed in the form of soil maps. The soil classification units will, however, not always be the same as the mapping units. Dependent on the scale of the map, the composition of a certain amount of Soil Associations, containing various soil-classification-units soil types will be necessary (KELLOgg, a.c. 1949).
Also, for an efficient practical use, the soil map should be composed with a view to those soil boundaries that are important for agriculture. This does not mean that only such boundaries should be found on a map, as are only important for one special project. In this way we would make a too limited use of our knowledge of the soil. But the soil is of such predominant value for human society, that any responsible scientist mapping soils must always keep in mind that his maps must be as useful as possible for as many purposes as may be thought of, now and in future.

Land capability Classification is the same as what was called "Category 4: Land classification in terms of use capabilities", the same as, what we prefer to call: Soil Suitability Classification. This classification indicates for which types of farming, rotations, crops etc, a soil is suitable under certain circumstances of climate and hydrology on the one side and of general economics on the other. These factors of economy, climate and hydrology may, for a certain project within a certain length of time, be calculated as constant factors, or more accurately as parameters. These parameters may differ largely, however, between various projects and also within the same project in a certain length of time, for instance within a century. If the parameters are changed, the suitability classification must also be revised. Both Land Capability Classification (Soil Suitability Classification)and Soil Quality Classification belong to a range of various "interpretive Soil groupings". (KELLOGG, 1951).
The Economic Land Use Classification studies basically the same factors as are studied in the Land Capability Classification. The difference between the two kinds of classification is that the economic factors which we use as parameters in our Soil Suitability Classification are the principle objects of the Economic Land Use Classification. It may result in a classification of farm business units, as in the Cornell system of Economic Landclassification (CONKLIN, 1957), which gives an "income appraisal" per farm for groups of farms.

The classifications that are described as the Mapping of Major Agricultural Regions mostly belong to category 2: Land classification in terms of present use. Although these classifications are basically records of the present land use, they may contain very useful information. The research of WEAVER (1954) has as its primary goal "to get a systematised and enlarged understanding of the dynamic forces that both initiate and give impetus to change in the patterns of crop land use". The work of HOU, CHANG and TSENG (1956) demonstrates how soil classification, soil survey and research into present land use may be combined very usefully into a general account of large regions in an immense country.

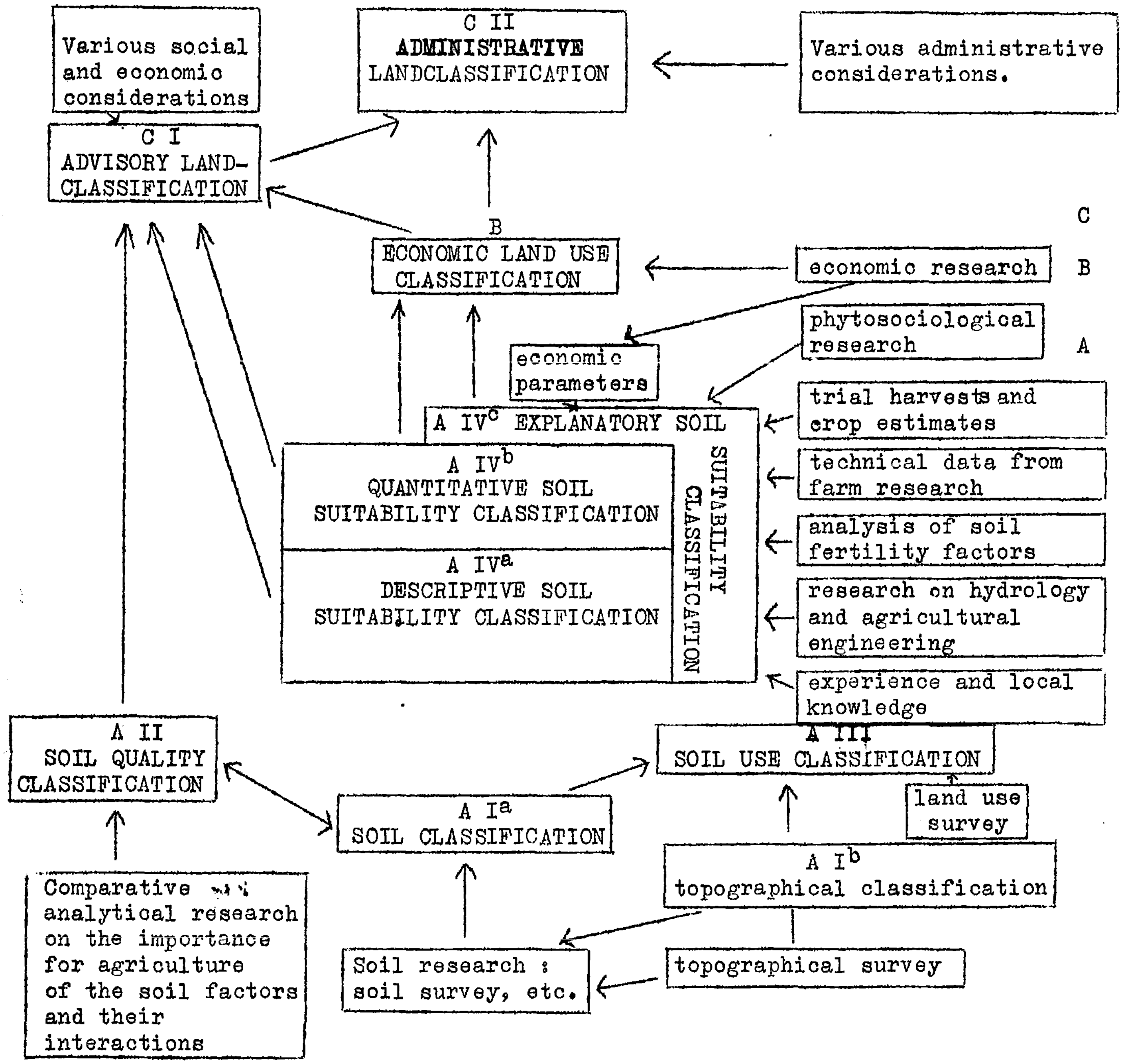


Fig. 1. Categories of Landclassification, and the information needed for them.
A = Soil Classification and interpretive soil Groupings
B = Economic Land Use Classification
C = Advisory and Administrative Landclassification.

Figure 1 shows an effort to represent in a schematic way the various categories of landclassification and their relations. Also a rough designation is given of the various aspects of research necessary to establish these classifications.

b. Soil Quality Classification

The category called "Soil Quality Classification" is a new one. This kind of classification regards the inherent qualities of the soil. Therefore, it is without any economic bias, whereas the Soil Suitability Classification can not be developed without the use of certain economic assumptions. Soil Quality Classification differs also from Soil Classification. In the latter, the characteristics of the soils are considered from a purely scientific standpoint, whereas in Soil Quality Classification soil qualities (fertility, permeability) that have already some interpretive meaning (cf. KELLOGG, 1956), are used. Sometimes, characteristics may also have the meaning of qualities. Rapid (slow) permeability is a soil characteristic, useful for soil classification. Good (bad) permeability is an interpretive designation belonging to soil quality classification.
A quality may consist of a group of characteristics, together influencing some aspects of soil use. In the following table, some examples of these classifications are given.

Table 1. EXAMPLES of characteristics, qualities and suitability designations of soils (cf. KELLOGG, 1953).

Category of Classification:	Soil Classification	Soil Quality Classification (or: Soil Property Classification)	Soil Suitability Classification
Groupings according to:	Characteristics	Qualities	Suitability
	Clay content, Structure	Ploughability	Suitability for wheat
	Slope, structure etc.	Erosion hazard	Suitability for intensive cultivation
	Depth of solum	Hazard of grading	Suitability for arable farming
	Loam content Clay content Humus content Depth of profile	Water storage capacity	Suitability for oats, sugarbeet, etc.
	Clay content, structure, profile: permeability (rapid or slow)	Permeability (good or bad)	Suitability for flax, beans, peas, etc.

Soil Classification arranges the soils according to what can be seen, be it in the field or by chemical, physical or mechanical analysis
Soil Quality Classification arranges the soils according to qualities that can be measured without taking into account the land use, though with a view to the practical use of the data in a purely technical (non-economic) sence. It is based on the Soil Classification.
Soil Suitability Classification arranges the soils according to the suitability for growth of crops, which is always done within some system of land use. It is also based on the Soil Classification.

Soil Quality Classification is a useful means of extracting the essential data for a certain project, from the many-fold information given in the legend of a soil map. It is also the means of making "single value maps" out of a soil map. The soil map however, should not be forgotten. It remains in the background and should always be referred to in the case of more full information being wanted. Also, for every special objective, new Soil Quality Classification maps and other kinds of interpretational maps can always be derived from the original soil map. There is an essential difference between the single value map based on a good soil map and the single value map made without regard to the other characteristics and qualities of the soils.

Soil Classification is usually done with more or less definite objectives but in its outlook and methods, it has many aspects of fundamental research. Soil Quality Classification is in many cases the first step to facilitate the applications of soil maps. Soil Suitability Classification is a typical example of "applied Soil Science" (see also pages 15, 17 and 23).

c. Soil Suitability Classification

When making a soil suitability classification, one should always define the management class within which the suitability is considered. Soil only becomes important as an economic object when used by man. The use made of it is of course influenced by the type of soil, but when once this has been decided, the actual data of crop production of the soil depend largely on the management. First of all a distinction should be made between general types, such as: forestry, horticulture, agriculture or range-farming. Secondly, it may be necessary to distinguish between mixed farming, ley farming and other types of farming with a different management of organic matter. Within each of these types, the levels of management, as defined by the SOIL SURVEY MANUAL (1951) are very useful:

"Level 1. The most common combinations of management practices followed by the majority of successful farmers using the soil dealt with".

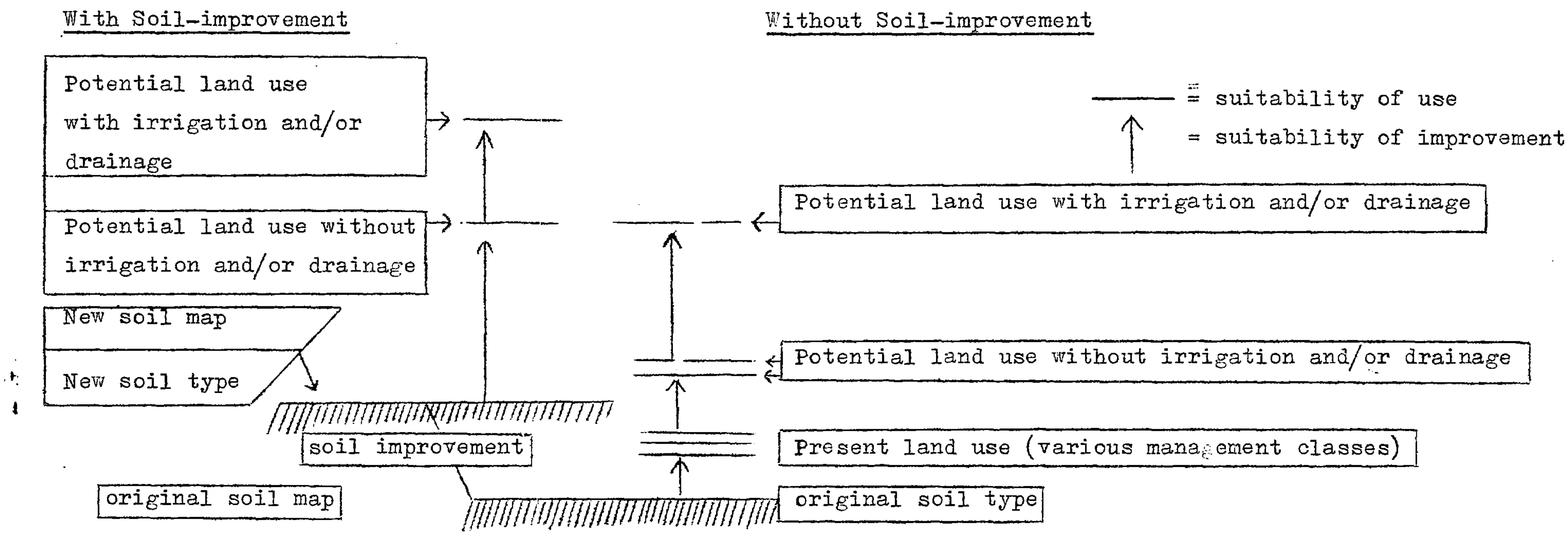
"Level 2. The superior combinations of management practices followed by the leading farmers using the soil, perhaps 1 per cent or perhaps over 10 per cent".

"Level 3. The optimum combinations of management practices developed on pilot research farms, or on other farms that represent the best(" or "ceiling") that can be done in the present state of the agricultural arts".

But also the possibility to change the use-capabilities of a soil by means of agricultural engineering should be considered. This may first of all be done by irrigation, drainage or technical methods of soil conservation, or combinations of these. In many cases, however, there are also possibilities of changing the soil profile itself by deep ploughing, land levelling etc. The influence of these measures on the suitability classification may be demonstrated in the following figure (fig. 2).

Thus, there are two kinds of suitability classification to be made:
a. those that indicate the suitability of the soils on the various (horizontal) levels (="suitability of use").
b. those that indicate the "improvement capabilities" (suitability of improvement).

Fig. 2. Soil and potential Land use.



SUMMARY

Principles and objectives of land classification - 2
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the Netherlands.

I. General principles

1) In executing a landclassification, a division into six categories (cf. LEWIS, 1952) may be made (see figure 1).
2) For a soil suitability classification (= landclassification in terms of use capabilities), the factors of economy climate and hydrology may for a certain project within a certain length of time be calculated as parameters.
3) A good landclassification should always be based on a modern soil survey.
4) A Soil Quality Classification gives interpretive groupings of soils without economic bias (see table 1).
5) When making a soil suitability classification, one should always define the system of farming and the management class within which the suitability is considered.
6) There are two kinds of suitability classification:
a. "Suitability of use",
b. "Suitability of improvement" (see figure 2 and 3).
7) The suitability of a soil for a crop is the possibility to cultivate that crop over long periods within a certain type of farming with good management in such a way, that the farmer makes a profit on it.
8) The risk of bad harvests is, on certain soil types and in certain regions, the principal factor limiting the suitability (see table 2).
9) The preparation and combination of field work with the analysis of aerial photograps is a time and money saving device of primary importance for soil survey and landclassification.
10) In comparing the characteristics of soils, the physical and the chemical characteristics have a different influence according to the farming system in which the soils are used, (see figures 4a and 4b).

II. Types of Land Classification and their limitations

11) A landclassification for a landdevelopment project should be based on a good soil survey; its data should be transferable and the evaluation of the data should be quantitative.
12) The amount of the various use capabilities of a soil is a characteristic of landclassification which is not easily influenced by changes in the economic parameters (see table Soil S. Cl. in the Netherlands).

III. Objectives and Methods of Determination and Evaluation of the Physical Conditions in a Land Development Area

13) In making a landclassification one should never lose contact with the reality of the farmer, who must run his farm in the circumstances provided
14) For landclassification in relatively unknown regions, pilot projects are the best tools of research.

IV. The application of landclassification

15) Soil survey and landclassification take a large part of their importance in recent agricultural science from their usefulness as tools for transfer of knowledge.
16) For comparing knowledge and experience with comparable soils in other countries it may be usefull to work with a rough system that takes into account soil, climate and systems of farming.
17) Landclassification is essentially teamwork. To plan an effective land-development project, a Regional Land Development Team should be established.

ZUSAMMENFASSUNG

Prinzipien und Ziele der Bodenbonitierung - 2

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I. Allgemeine Prinzipien.

1) Bei der Aufstellung einer Bodenbonitierung sollen immer die sechs Kategorieën betrachtet werden.
2) Für eine Bodengeschicklichkeitsklassifikation (Kategorie 4) soll man die Faktoren der Economie, des Klimas und der Hydrologie für ein gewisses Gebiet und eine gewisse Zeit Parameter betrachten.
3) Eine gute Bodenbonitierung soll immer begründet werden auf eine moderne Bodenkartierung.
4) Die Soil Quality Classification (Kategorie 2) gibt interpretative Anordnungen der Böden one ekonomische Annahmen (sehe Tabel 1).
5) Wenn man eine Bodengeschicklichkeitsklassifikation macht sollen immer die landwirtschaftliche Bedingungen für welche die Klassifikation gilt, genau definiert werden.
6) Man unterscheidet zwei Typen der Bodengeschicklichkeitsklassifikation :
   a. Geschicklichkeit der Bodennützung
   b. Geschicklichkeit der Bodenverbesserung. (sehe Fig. 2 und 3).
7) Die Geschicklichkeit eines Bodens für ein bestimmter Frucht ist die Möglichkeit um dieser Frucht über längere Zeiten in ein gewisses Landwirtschaftliches System mit Gewinn anzubauen.
8) Das Risiko von Miszfrüchte ist auf gewissen Böden und in gewissen Gebiete der vornehmste Faktor der Geschicklichkeitshemmung.
9) Die bodenkundliche Auseinanderlegung der Luftbilde gibt eine gute Möglichkeit für schnellere und billiger Fortschritt der Bodenkartierung und der Bodenbonitierung.
10) Die physikalische und chemische bodenfaktoren spielen eine verschiedene Rolle bei der Bodenbonitierung, abhänglich von der landwirtschaftlichen System (sehe Fig. 4a und 4b).

II. Typen der Bodenbonitierung und ihre Beschränkungen.

11) Eine bodenbonitierung soll immer begründet werden auf eine Bodenkartierung; die Ergebenheiten von die beide sollen übertragbar und kwantitativ sein.
12) Die Anzahl der verschiedenen Möglichkeiten eines Bodens ist ein wichtiger Faktor der Bodenbonitierung. Dieser Faktor ist ziemlich unabhängig von der wechselenden ekonomischen Lage.

III. Ziele und Methoden der Bestimmung und Bonitierung der Physischen Umstände in ein Entwicklungsgebiet.

13) Wenn man eine Bodenbonitierung macht soll man sich immer den Bauern erinnern, der schlieszlich sein Betrieb in der bestimmten Lage treiben muss.
14) Wenn man eine Bodenbonitierung in unbekannten Gebieten machen muss, sind Experimentalprojekte ein sehr wertvolles hilfsmittel.

IV. Die Anwendung der Bodenbonitierung.

15) Die Nützbarkeit für praktischen Zielen der Bodenkartierung und der Bodenbonitierung liegt für ein groszes Teil in die möglichkeit der Übertragung von Kenntnis und Erfahrung von einem Gebiet nach einem anderen.
16) Um diese Ubertragung aus sehr verschiedenen Gebieten der Welt für ein bestimmtes zu ermöglichen könnte man schon ein einfaches System nützen, das die Böden, das Klima und die landwirtschaftliche Systeme in betracht nimmt.
17) Bodenbonitierung ist "teamwork". Für ein bestimmtes Entwicklungsgebiet sollte man eine regionale Entwicklungsgruppe machen.

RÉSUMÉ

Principes et objets de la classification des terres - 2
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I. Principes généraux

1) En exécutant une classification des terres, il faut se rappeller qu'il y a au moins six catégories (cf. LEWIS, 1952 et fig. 1).
2) Une classification d'appropriation des terres (catégorie 4) se fait en considérant les facteurs d'économie, de climat et d'hydrologie comme constants paramétriques, pour un certain cas dans une période certaine.
3) Une bonne classification de terres doit avoir comme base scientifique une étude cartographique du sol.
4) La "classification qualitative des sols" (catégorie 2) donne des groupements pratiques des sols sans préjugements économiques (voir table 1).
5) La mise en oeuvre d'une classification d'appropriation des terres (catégorie 4) doit être accompagnée par une détermination des systèmes agriculture et des classes d'exploitation pour lesquelles la classification a été faite.
6) La classification d'appropriation des terres est divisée dans
   a. appropriation d'exploitation
   b. appropriation d'amélioration (voir figures 2 et 3).
7) L'appropriation d'un sol pour une culture est la possibilité de le cultiver dans un certain système d'agriculture dans des périodes d'aux moins quelques dizaines d'années de sorte que le fermier y enlève des profits.
8) Les risques de récoltes insuffisantes est, sur certains types de sols et dans certains régions, le facteur principal limitant l'appropriation.
9) L'analyse pédologique des photographies aériennes est très importante pour économiser sur les frais et la durée d'un projet de cartographie des sols.
10) Les propriétés physiques et chimiques des sols ont une valeur différente pour l'utilisation des terres dans des différents systèmes d'agriculture (voir fig. 4a et 4b).

II. Types de Classification des terres et leur limitations.

11) Une classification de terres pour un projet de dévéloppement doit être basée sur une bonne carte pédoloque; les données doivent être transférables d'une région à une autre et l'appréciation des données doit être quantitative.
12) Le nombre des possibilités différentes d'un sol est une propiété de classification de terres très importante parce qu'il est peu influencé par les variations des paramètres économiques.

III. Objets et Méthodes de détermination et d'appréciation des conditions physiques dans une région de dévéloppement.

13) En faisant une classification de terres, on ne doit jamais perdre le contact avec la réalité du fermier qui doit exploiter sa ferme dans les circonstances données.

14) Pour une classification de terres dans des régions vides ou peu connues, les projets expérimentales sont un des meilleurs méthodes de recherches.

IV. La mise en oeuvre pratique de la classification de terres.

15) Le transport de connaissances est un des aspects plus importants de la classification des sols et de la classification de terres.
16) Pour le transport de connaissances et d'expériences pourvues par d'autre régions du monde, un système global utilisant les données des sols, des climats et des systèmes d'agriculture peut être très utile.
17) La classification des terres est un travail d'équipe. Pour un projet de dévéloppement il faut établir une équipe régionale de dévéloppement.

In exceptional cases the suitability of improvement may be so very clear that it is possible to indicate the capabilities of the soils in this respect without considering the "Suitability of use" to be reached by the improvement on various soils. This may also be the case if a project is not put forward primarily for economic reasons, but for social reasons. In all other cases, however, it will be useful to make three classifications namely: 1) the present suitability of use, 2) the suitability of improvement, 3) the suitability of use to be reached if the classification of improvement is put into practice.

As an example we take a region with a tropical monsoon climate where, somewhat schematized, the following soils occur:

1. moderately weathered latosols, without hardpan
2. moderately weathered latosols with slight hardpan
3. heavily weathered and eroded latosols with thick hardpan
4. severely eroded latosols, predominantly consisting of lateritic hardpan.

In figure 3 schematic profiles of these soils are given. Above these profiles are noted: (from bottom to top):
1) present suitability of use, 2) suitability of improvement, 3) suitability of use after improvement.

No explanation should be necessary for the careful reader.

The suitability of a soil for a crop is the possibility to cultivate that crop over long period within a certain type of farming with good management in such a way, that the farmer makes a profit on it. This suitability of a soil type is determined by the following physical factors:

1. The productivity in lbs/acre.
2. The amount of working hours, kilograms of fertilizers, etc., necessary to get the above mentioned productivity on a certain soil type.
3. The quality of the product.
4. The risk run with the crop on the soil type due to inevitable changes of weather and other uncontrollable physical variations.
5. The relative area of the suitability class to which the soil type belongs, in the region concerned (soil pattern).

There are also economic factors, such as the relative prices of the products, the cost of labour, fertilizers etc., that have an important influence on suitability. These factors are taken as constant for a certain type of farming in a certain region. The study of these factors as variables should be done by the Economic Land Use Classification.

The risk of bad harvests is, on certain soil types and in certain regions, the principal factor limiting the suitability. The influence may be seen even in a country with a rather mild climate such as the Netherlands. An estimate of the risks can be calculated from yield data taken from the same crops on the same soil types over a series of consecutive years. We made some estimates of risks in a sandy region in the Netherlands, (table 2).

Figure 3. Suitability of use and suitability of improvement; schematized example.

x) 3 is based on the new soil types, after improvement (cf. fig.2). By way of simplification, these are not given in this table.

	Soils 1	2	3	4
3 suitability of use after improvement x)	suitable for most crops with good yields	suitable for most crops with good yields	suitablity dependent on methods of improvement applied; if hardpan is fully removed and humus-status restored, suitable for most crops	not suitable for agriculture
2 suitability of improvement	no improvement necessary, but humus-status should be watched	to be improved with relatively simple methods: breaking of hardpan and improvement of humus-status	to be improved, but only with complicated methods	not suitable for improvement
1 present suitability of use	suitable for most crops, with good yields	only suitable for the less exacting crops; but these also with lower yields	only moderately suitable for a few crops, with poor yields	not suitable for agriculture
Soil Classification	Latosols, moderately weathered, without hardpan	Latosols, moderately weathered, with slight hardpan	Latosols, heavily weathered and eroded, with thick hardpan	Latosols, severely eroded, predominantly consisting of lateritic hardpan

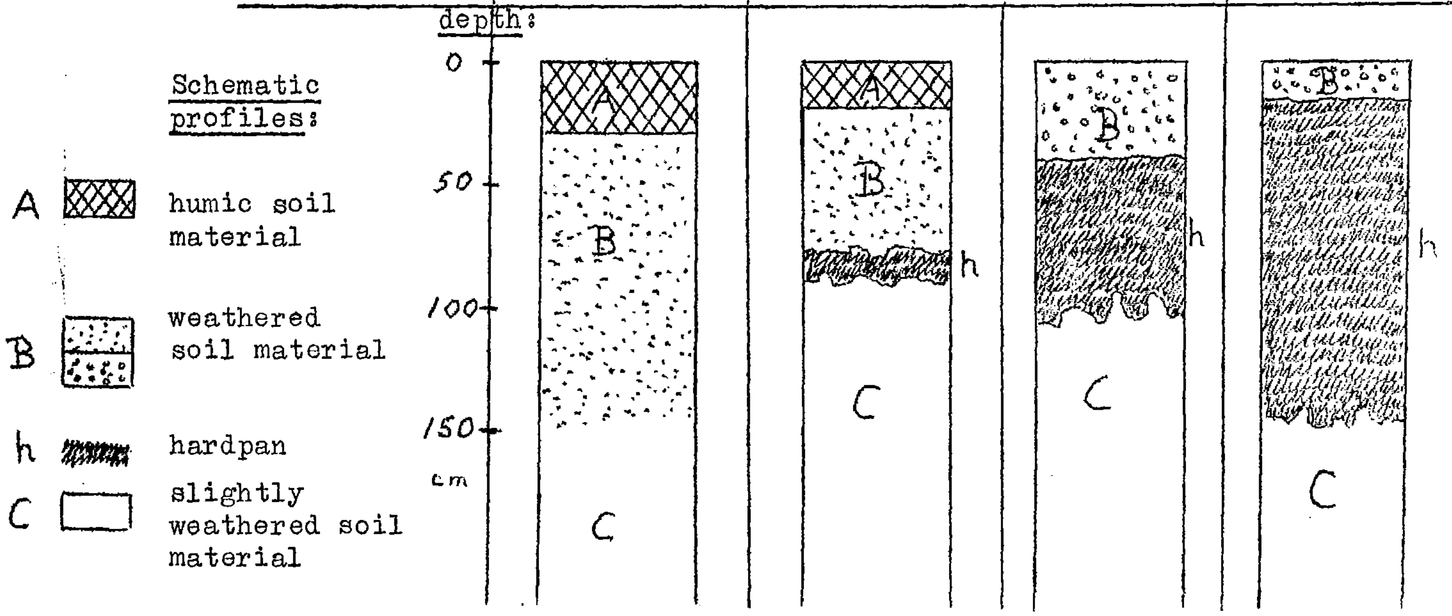


Table 2.
Estimate of risks on 7 soil types with rye.

Percentage of yields considered good (more than 3200 kg/ha year), normal (2500-3000 kg/ha year), poor (less than 2500 kg/ha year) in the municipality of Venray during the period 1951/53.

Soil type	Qualification of yields good	normal	poor
Q = deep humic loamy sandy soil	27	57	16
B = deep humic sandy soil	6	71	23
H = dry sandy podzolic soil	8	37	55
M = moist sandy podzolic soil	13	66	21
L = wet sandy soil	33	50	17
A = moist loamy sandy soil	29	47	24
S = dry regosol	3	42	55

The relative surface of a land class is a result of the soil pattern. It has a very marked influence on the possibility to put certain theoretical use capabilities into practice. For the cultivation of a crop a certain minimum area is necessary. This applies to every region as well as to every single farm unit. If 95% of a region is only suitable for pasture, it is in many cases not feasible to use the other 5% as arable land. This is certainly true if this 5% is dispersed in small bits over many farms. This is an extreme case. We know many examples in the Netherlandswhere a more or less marked influence of this factor can be found.

d. Comparing soils for practical use.

Land classification is the outcome of the comparing of many soils both as regards their inherent characteristics and their use capabilities. Without a sound basis of knowledge of the inherent characteristics of the soils, a land classification remains uncertain, because the transfer of knowledge and experience from other regions in which the same soils occur is not possible. In a land development project one most certainly should "use the soil according to its capabilities and treat it according to its needs". Therefore,any useful information gained from the experience of others should be placed on a sound basis. This means, that a soil survey of sufficiently detailed character, accompanied by a good soil classification is one of the basic steps in planning a land development project. The soil classification should first and foremost rest on field observations of the soil profile, combined with a sufficient amount of analyses of well-taken samples. The morphology of the soils should take precedence in the classification over more theoretical considerarions such as pedogenesis, geology etc. A good example of modern soil classification is the "Fifth Approximation circulated among the soil scientists concerned by the U.S. Soil Survey. It is impossible to compare the use capabilities of various soils, if one can not compare the soils themselves i.e. the inherent characteristics of the soils, with objective means.

In this respect special importance should be also attached to research of the soil mineralogy as mentioned by VAN BAREN (1956). This concerns the mineralogy of the clay fraction as well as that of the sandy fraction of a soil. The first gives an insight into the physico-chemical reactions to be expected from the soils. The second gives an estimate of the riches of the soil, e.g. the amount of minerals that will contribute to soil fertility during the process of weathering.

A soil survey consists of a lot of interesting field work. Especially in those countries where the number and the quality of field roads is poor, this work takes a long time. Even if the costs are not very high, this may mean that the planning of a project takes considerable time. Therefore, one should look for as many time saving devices as possible. The best of these is the preparation and combination of the field work with analyses of aerial photographs. These analyses should be done with the special aim of interpreting the characteristics of a region that are important for the soil survey. The staff of the International Training Centre for Aerial Survey at Delft play an important role in the development of these methods (BURINGH, 1954, 1955, 1956). This method makes it possible to reduce the time necessary for the soil survey to approximately 25% of that needed with field work alone. A certain amount of field work will always be necessary. This must be done by very competent Soil Scientists.

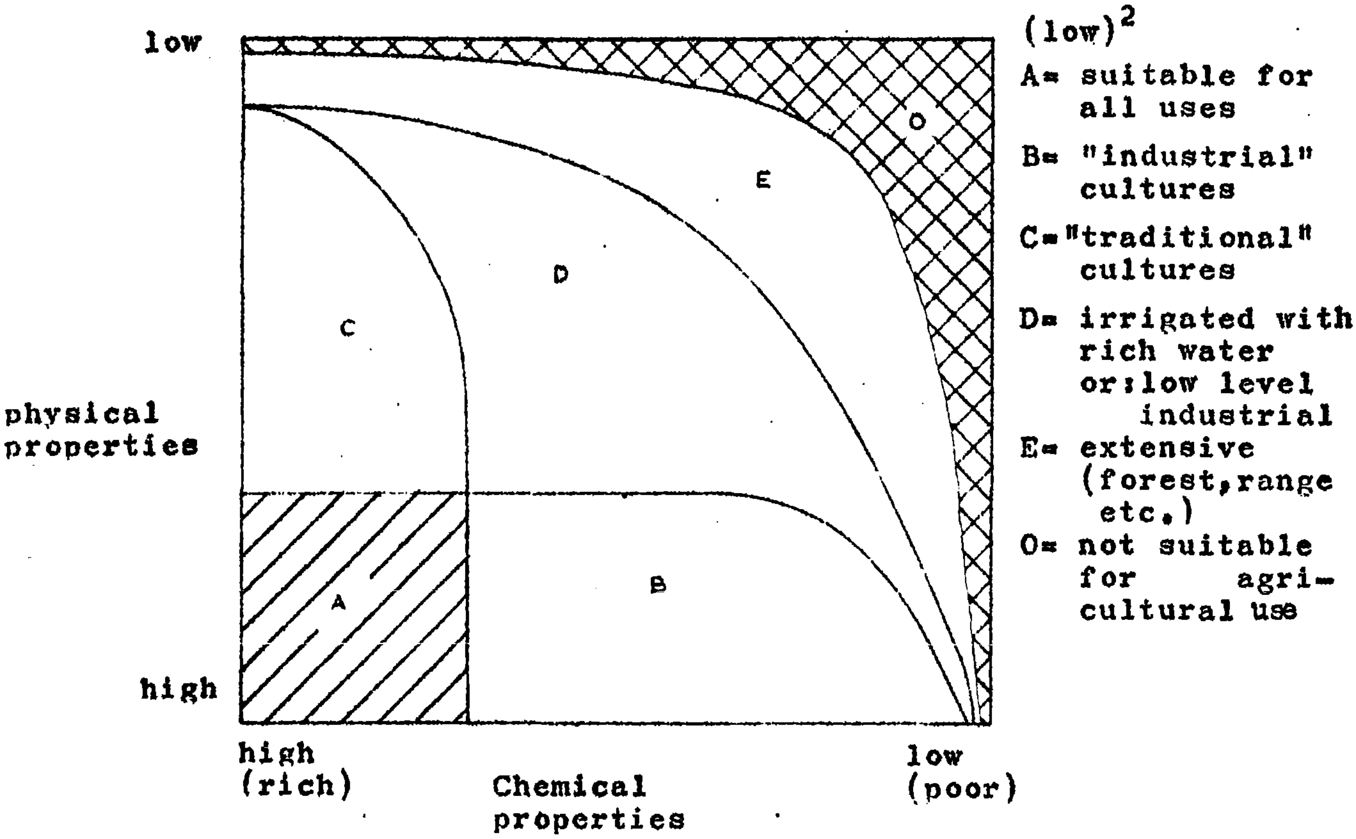
In comparing the characteristics of soils, it is useful to distinguish between the physical and the chemical properties of the soil types. In doing this, one should always regard the soil type as a three-dimentional unit, viz. a soil profile with a certain amount of surface and topography. The figures 4a and 4b give an idea of the comparative importance of soils that have a high or a low value as regards chemical and physical proper... respectively. The relative importance changes according to climate, hydrology and type of farming. Figure 4a demonstrates the use capabilities of the soils under good climate and hydrology. The amount of soils not suitable for any kind of farming is then very limited. Figure 4b shows these soils under poor conditions of climate and hydrology. In this figure the unsuitable soils (0) have a predominant place.

The soils that have both good chemical and good physical properties are suitable for almost any kind of farming. The soils that have good chemical properties are preferred by the "traditional" systems of agriculture, e.g. those systems that do not use industrial products such as chemical fertilizers and pesticides. The soils with good physical properties, whether rich or poor in chemicals, are preferred by the systems of agriculture using industrial products. In between lies a region in which the use depends on the quality of irrigation water and on economic considerations. These figures should be helpful in discussing and comparing the possibilities of various soils and regions. Owing to the limited scope of this paper, we do not have time to discuss the consequences more fully.

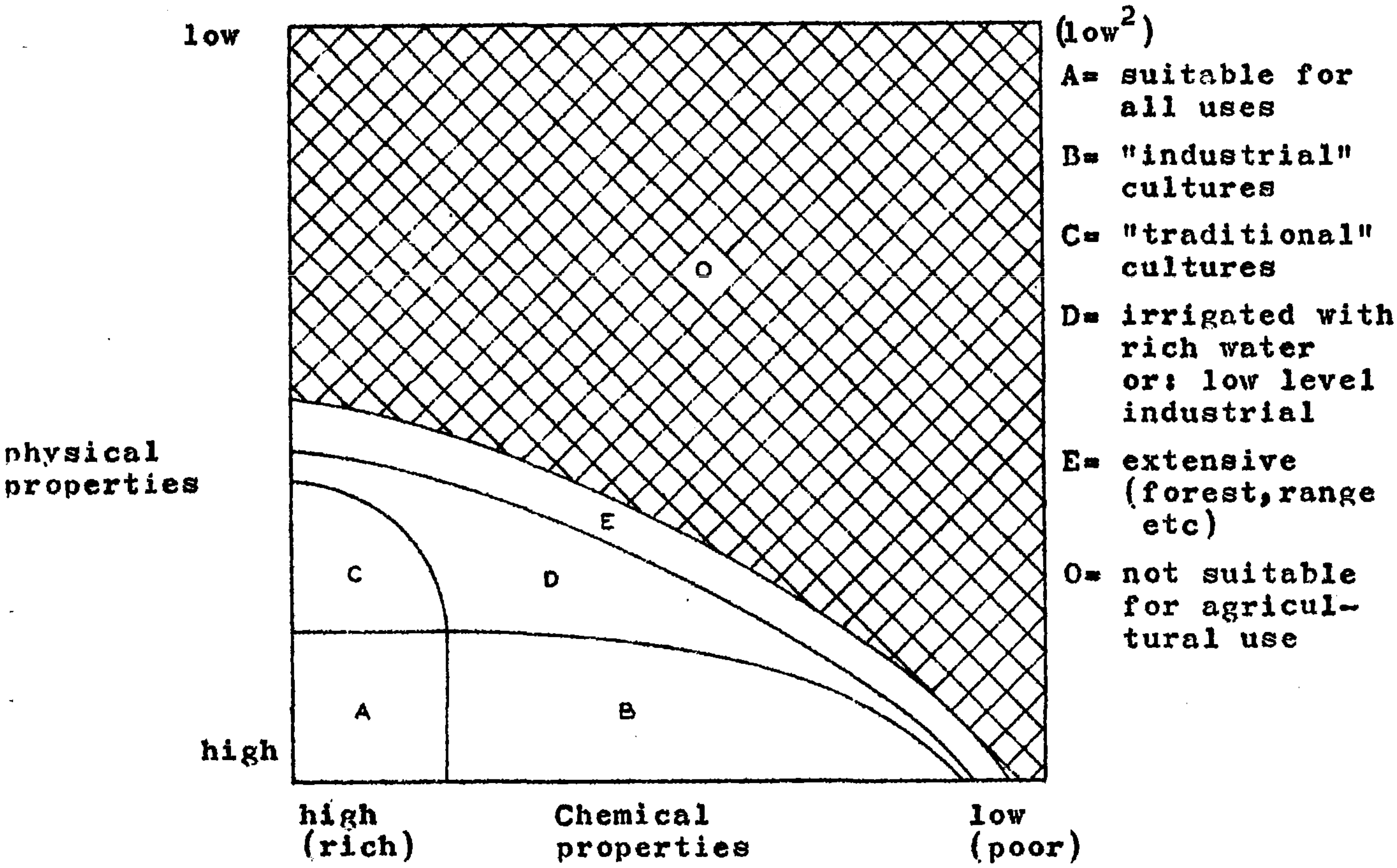
II. TYPES OF LAND CLASSIFICATION AND THEIR LIMITATIONS

The activities called "Land classification", "Soil Quality Classification", "Soil Suitability Classification" lie in the border zone between soil science and agricultural practice. The soil scientist, knowing most of the basic facts, should also develop the science of soil suitability and provi.. the classifications. He should do this, however, in cooperation with o.. experts. Often the interest that soil scientists take in the application of their science is too limited. This should be remedied, but every cure takes some time.

1. good climate and hydrology



2. poor climate and / or hydrology



Furthermore, in the past the preparation of a project within reasonable time limits often required the development of systems of land classification that are based on a very limited knowledge of basic facts.

In future, with our present knowledge of time saving methods such as aerial photography, this should not happen any more. Also, as we are now more intimately acquainted with the problems arising in land development projects, more careful planning is possible. In criticising projects of the past, one should therefore be careful not to assume a knowledge that was not available at the time when these old projects were undertaken. This means, however, that the systems of land classification of the past have only a limited signifance for the development of our present plans, because the basic data provided both on the soils and on the other factors are scientifically vague and incomplete.

This applies not only to the development of projects in other countries but also to the development of new projects in those regions in which the old classifications were made. Even in these, new soil surveys and other research will be necessary. This again stresses the importance of starting with the maximum amount of data for the first project in a region, in order that in the further development a lot of basic work need not be repeated. This is also very important in view of the possibility of transferring experience from the first project in a country to later projects.

In general, the available land classifications should be tested for the following principles.

1. The object of the classification and the goal to be aimed at;
2. The possibility of using the classification as a help for the general way of thinking with regard to the problems occurring in a certain project;
3. The possibility of transfer of the knowledge and experience and of the exact data from the old classification;
4. The more or less quantitative evaluation of the data;
5. The usefulness and readability of the classification for the people who are going to use it.

It is not possible for us, within the limited scope of this paper to give a more or less extensive treatise on the various land classifications. It should be useful, however, to consider some well-known systems of land classification with regard to the abovementioned criteria. For further descriptions the reader is referred to the literature.

Two of the more or less well-known land classification systems have as their goal to provide an objective basis for government taxes. These are Storie's indexes (California, U.S.A.) and the German "Bodenschätzung". The indexes, also called "productivity ratings", developed by STORIE (1954) are based on the soil data of the U.S. Soil Survey. Separate indexes are given for cropland, pastures and forest respectively. The indexes are calculated with standardized formulas. The standards are probably very well adapted to Californian circumstances. The whole way of treatment looks like a fair system for dividing the burden of the government taxes resting on the soils. For other projects this system does not seem to be very useful. The "Bodenschätzung" in Germany is a very expensive project, with a lot of special fieldwork based on the science of about 1930. The developme of scientific knowledge has been wholly sacrificed by the wish to develop a uniform system of land-taxes on a disciplinary basis. Because of the very detailed survey made for this purpose and the fair knowledge of the /ors survey/, employed this work gives a reasonable amount of data for other purposes within the region thus surveyed.

This system should, however, never be taken as an example for research in land development projects. Both the "Bodenschätzung" and the indexes of Storie look attractive by their conclusions, given in arithmetic figures. They are, however, not truly quantitative, as their calculations are only based on estimates and assumptions.

Both the Storie indexes and the estimates of the "Bodenschätzung" are very useful as first estimates of the relative productivity of the soils within the existing systems of agriculture and with roughly the same relative prices of production and of labour and capital. It is often neglected, however, to point out that these assumptions have been made. This is also where the danger lies for the use of these classifications unless the classifier himself points out that these assumptions have been made. These two systems rightly belong to category 6: "Administrative Landclassification". They are alike based on accurate soil surveys. Storie's indexes have a more or less well considered system of soil classification and of soil suitability classification. These two are not in evidence with the Bodenschätzung. This system reaches its administrative stage by way of some rather arbitrary tables, based on practical experience, together with some assumptions.

The same holds for the observations on suitability made by MÜCKENHAUSEN (1957) on 60 key soils of Germany. These observations evidently have been taken from practical experience within the existing types of farming and with a given intensity of cultivation. The idea of Mückenhausen, to describe exactly a number of key soils, is a very helpful one. The systematic research of key soils is also going along in the U.S.A. It would be very helpful also for the research in less developed regions as a "follow-up" to soil surveys. The study of key soils without the background of a soil survey is dangerous, in that too many chances are offered for the research team to forget the relative importance for practical agriculture of the various soil characteristics. The data provided by Mückenhausen could easily be arranged to a Soil Suitability Classification by an expert with enough local knowledge. As it is it still lacks the classifying element.

The land use classification of L.D. STAMP (1953), developed during the war in Great Britain, has all the defects of a project made without enough scientific foundation. The results are, however, based on a very great deal of common sence. It gives some interesting ideas about general land use planning. There is also a seemingly quantitative part to this classification, but this should not be taken too seriously. One should study this classification for interesting remarks on the problems met with in land use planning anf for sound general ideas. The classification is not transferable as it lacks an exact scientific basis. This classification has proved to be very useful during the war years for developing agriculture in Britain. It is also rather easily read even by comparative outsiders. Although it is called a "land use classification", it has a marked tendency to provide data on the potential use. It is in many respects a landclassification in terms of use capabilities.

Table 3. Various systems of Landclassification.

a. Major Classes of the U.S. Soil Conservation Service

I	"Few limitations. Wide latitude for each use. Very good land from every standpoint".
II	"Moderate limitations or risks of damage. Good land from all-round standpoint".
III	"Severe limitations or risks of damage. Regular cultivation possible if limitations are observed".
IV	"Very severe limitations. Suited for occasional cultivation or for some kind of limited cultivation".
V	"Not suited for cultivation, because of wetness, stones, overflows etc., Few limitations for grazing or forestry use".
VI	"Too steep, stony, arid, wet etc. for cultivation. Moderate limitations for grazing or forestry".
VII	"Very steep, rough, arid, wet etc.. Severe limitations for grazing or forestry".
VIII	"Extremely rough, arid, swampy etc.. Not suited for cultivation, forestr Suited for wildlife, watersheds or recreation".

b. Relative evaluation of the Classes of Land in Great Britain (Stamp)

Major	Category	Type	P.P.U. per acre	S.U. p.acre
I	Good Lands	1.First Class	2	--
		2.Good General Purpose	1	0,4
		3.First Class,high water table	2	0,8
		4.Good Heavy	1	0,4
II	Medium Lands	5.Light	0,5	0,2
		6.Medium General Purpose	0,5	0,2
III	Poor Lands	7.Poor Heavy	0,1	0,04
		8.Mountain	0,1	0,04
		9.Poor Light	0,1	0,04
		10.Poorest Land	---	---

c. Preliminary draft of a Soil Suitability Classification of the Netherlands, scale 1:200.000

Major Class	BC	: Suitable for arable land and pastures
class	BC 1	: with very wide use capabilities
"	BC 2	: with wide use capabilities
"	BC 3	: with certain limitations
"	BC 4	: with limited use capabilities
"	BC 5	: with very limited use capabilities
"	BC 6	: "Krijtland" - complex
"	BC 7	: complex with limited capabilities
Major Class	GB	: Suitable for pastures and often also for arable land
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 rather 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 stiff sod but certain limitations as to hydrology
" G 2	:	suitable soils, late in spring
" G 3	:	suitable soils, with weak sod and with certain limitations as to hydrology
" 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

d. Classification of land for irrigation purposes

U.S. Bureau of Reclamation, example of a specialized classification:

Class 1	:	arable lands with a potentially high production
" 2	:	lands of intermediate value that may be considered arable under general farming
" 3	:	lands of the lowest productive value that may be considered arable under general farming
" 4	:	lands which have marked deficiencies or restricted utility but which have been shown to be of limited arability as a result of special economic and engineering studies.
" 5	:	non-arable under existing conditions but have a potential value sufficient to warrant segregation for further study, or: lands in existing projects whose irrigability is dependent upon additional construction
" 6	:	lands of low productivity that are considered permanently non-arable.

The landclassifications developed by the U.S. Bureau of Reclamation should be useful for study by those people that are interested in irrigation projects. The transfer of basic data should however, be done with a very critical eye. The mapping prescriptions given by the U.S. Reclamation Bureau for making the basic soil maps are absolutely insufficient. This especially regards the minimum amount of observations per area unit prescribed for the various mapping scales. The classification resulting from these observations may be useful if made by a very competent team. The readability of the principal classification units enhances in such a case the use by the average agriculturist. As a classification, it belongs to category IV : Soil Suitability Classification (Lcl. in terms of use capabilities).

The capability classification of the U.S. Soil Conservation Service, using the well-known eight capability classes, was originally developed as a system for better organisation of individual farms This aim has been gradually widened to a more general system of land use planning. The original eight major classes have been divided into capability sub-classes and capability units. (HEDGE AND KINGEBIELL, 1957). The system is very useful for practical application, easily readable, but on its various levels (class, subclass, unit) it carries various assumptions that are not always sufficiently defined. Generally speaking, one should be very careful before applying it to other countries than the U.S.A., especially if social and economic circumstances are very different. Some of the best wine-producting areas of Southern Europe would be considered too rough for cultivation according to this system.

Table 4 demonstrates that this system consists partly of Soil Quality Classification (subclasses and units) and partly of Soil Suitability Classification (major classes).

Table 4. An example of capability grouping of soils in the U.S.A. : Oswego Country, N.Y. (data from KELLOGG, 1955).

Soil Classification	Soil Quality Classification		Soil Suitability Classification
Soil Mapping units:	Capability Units:	Capability Subclasses:	(major) Capability classes:
Alton gravelly loam, 0 to 3 per cent slopes	I Deep, nearly level, gravelly soils		I Nearly level, very good soils
Ricard gravelly fine sandy loam, 3 to 8 per cent slopes	IIe1 Deep, well-drained gently sloping gravelly soils	IIe. Soils sloping and subject to erosion	II Good soils that require easily applied practices because of gentle slope or some other minor limitation
Lucas silt loam, 0 to 6 per cent, slopes	IIw1. Well-drained, alluvial soils, subject to occasional floods		
Ottawa loamy fine sand, 0 to 8 per cent slopes	IIIs1, Deep droughty savely soils on lake-laid deposits, nearly level or gently sloping	IIIs. Soils with low moisture holding capacity	III. Soils moderately good for cultivation; slope or other limitations require special practices

Some authors have recently published quantitative data regarding the problems around this system of classification and, more generally about the feasibility of "Conservation farming". The data and farm budgets published by BALL, HEADY and BAUMANN (1957) are very interesting and should be studied by any one interested in land development. The reader is also referred to various publications in the 1957 U.S.A. Yearbook of Agriculture (Soil, 1957).

Various other interpretive groupings of soils, used in the U.S.A. merit attention. The establishment of Productivity ratings of the soil mapping units, or estimated average yields under various levels of management (table 5) should be a system useful for land development projects, even if only rough estimates can be provided. The productivity ratings themselves cannot yet be called a classification. They are, however, a big step in the direction of a quantitative Soil Suitability Classification.

Table 5. An example of estimated average yields per acre of adapted crops under alternative systems of management on the soils of Ontario and Yates Counties, N.Y. (from KELLOGG, 1955).

Map Symbol	Soil	Management level 1)	Corn (Silage)	Corn (grain)	Oats	Wheat	Alfalfa (hay)	Potatoes
			Tons	Bu.	Bu.	Bu.	Tons	Bu.
An	Arkport fine sandy loam 0 to 6 per cent slopes	A	10.8	49	49	32	1.6	175
		B	12.0	54	54	35	2.6	250
		C	12.6	57	59	38	2.7	312
Ao	Arkport fine sandy loam, 6 to 12 per cent slopes	A	10.3	46	46	30	1.9	140
		B	11.4	51	51	33	2.5	200
		C	13.0	54	56	35	3.0	210
Hd	Honeoye fine sandy loam, 0 to 3 per cent slopes	A	11.5	52	52	33	3.0	210
		B	12.8	58	58	37	3.0	300
		C	14.1	64	61	37	3.0	375
He	Honeoye fine sandy loam, 3 to 10 per cent slopes	A	11.5	52	52	33	3.0	210
		B	12.8	58	58	37	3.0	300
		C	14.1	64	61	37	3.0	375

1) Management level A is the common management on the majority of the farm of the county; the combination of practices does not maintain soil fertility, organic matter and tilth and prevent excessive erosion. At management level B the combination of practices does maintain soil fertility etc. and prevent excessive erosion. At management level C combinations of management practices exceed those needed for soil maintenance but some farmers have found these intensive practices profitable under economic conditions prevailing recently.

In the Netherlands we are now working on a project in which a certain minimum of data both from the technical and from the economic side of productivity in various regions, will be combined into farm-budgets, to be made for various soil-types within various farming-systems. In this way a more quantitative land classification will be possible. This land classification is based on the data of the soil survey, of pilot farms, of trial-harvesting projects and of general farming experience.

III. OBJECTIVES AND METHODS OF DETERMINATION AND EVALUATION OF THE PHYSICAL CONDITIONS IN A LAND DEVELOPMENT AREA.

A. General, Soil Quality.

The objectives of classification, which means both determination, evaluation and arrangement of the physical conditions, depend on the limits which the authorities concerned want to formulate for a land development project.
This may mean for instance:

1. Reallotment in its proper sense, i.e. the redistribution of the land without changes in system of farming or works of agricultural engineering.
2. Soil improvement, without other changes.
3. Hydrological improvements: irrigation, drainage, soil conservation.
4. Introduction of new crops.
5. Changes in the system of farming : more intensive or more extensive, introduction of ley-farming, etc.
6. Colonisation of waste lands.

Several of these objectives may occur together within one project. So for instance the combination of nos. 1, 2 and 3 within one Reallotment Scheme is quite common in the Netherlands. Often it is necessary to make combinations of these various aspects to develop an effective new land use system.

As a general principle one could argue that the new way in which the land is to be used should offer better possibilities both socially and economically, and should lead to a better use of the technical potentialities of the soils in a region. This means however, that the working unit of the region: the individual farm, should be put on a better foundation. The individual farm, after all, is the basic unit of agriculture. Up to a certain point, all regional development plans are abstractions. Only the farm is an ever present reality. In making a classification, one should therefore never lose contact with the reality of the farmer, who must run his farm in the circumstances provided. Every evaluation should therefore be put to the test of feasibility within a reasonable farm budget. Every determination of physical values should be made under circumstances that may, in the long run, be feasibly reproduced on the farms of the region.

The methods of determination of soil qualities are often based on the same analyses used for the determination of soil characteristics. In the case of soil qualities, the data from these analyses, however, is used in an interpretive sense. For other kinds of soil qualities, we still lack the necessary methods of determination, so for instance for the determination of ploughability of the soil. Systematized practical experience is in these cases a helpful means of getting a reasonable estimate. This kind of data can be obtained by methods as described for the determination of use capabilities : group conferences, inquiries etc.

b. Soil Suitability, Pilot Projects.

The methods of determination of the use capabilities (soil suitability) depend also very largely on the scope of the development project. To illustrate this, two extreme examples of development may be chosen.

1. A region in which only a limited reallotment project will be carried out, which will also be used to stimulate the farmers to put their reallocated fields to a better use.
2. A region which consists solely of waste lands with totally unknown soils, and which, even after research and soil classification, gives no possibility of transfer of knowledge from other parts of the world.

In the first case, much may be learned when the region is compared with other regions in the world that have comparable soils, climates and hydrological and economic circumstances. But also within the region much is to be learned when the knowledge and experience of the region are systematised on the sound foundation of a good soil map.

In this case the following methods may be used :

1. Group conferences with good farmers of the region (ENGENE, 1951). These conferences shound be held with the soil map as an objective basis. The groups should not have more than 10 people each. For each region conferences should preferably be held with more than 6 groups. The method proved to be useful in various cases. It provides astonishing results showing the relative suitability of various soils for various kinds of farming. However, very few data are obtained on the absolute yield of product per surface unit (lbs/acre) and on the total costs of production.
2. Inquiries of individual good farmers. This should be done only by people that are known and trusted by the farmers of the region. This method takes more time and often gives less useful results than the above-mentioned one. For specified technical problems (choice of crops and varieties, amount of fertilizers) some very useful information has been obtained.
3. Judgement of the use capabilities of the soil types by local experts. These may be prominent farmers or local members of the agricultural extension services, teachers in agricultural schools, and various other persons that have an intimate but also critical knowledge of the land use in a region and of the use capabilities within the existing farming system. These judgements often take the form of rating the use capabilities per soil type and per crop.
   When all these ratings are combined a fair idea of the general use capabilities is obtained. Often this method is the foundation for more elaborate classifications. It is always an important supplement to other data of a more fragmentary character.
4. The use of all data from existing field experiments and pilot farms for various purposes. This method is only applicable, if the situation in the field of these experiments and farms is accurately noted, to make it possible for the soil scientist to assess the characteristics and soil types of the soils used in the experiments. As this has often been neglected in the past, this method often turns out to be both laborious and expensive. It gives, however, some absolute figures on yields, in combination with certain treatments. Often the best soils of the region predominate in the experiments. After all, everybody who has ever met with the difficulties of field experiments, prefers to have a good crop to begin with.
5. Crop surveys, i.e. surveys of every crop on every plot within the region and the statistical arrangement of these data according to soil types. The percentages of the plots with the various crops on the various soil types sometimes give interesting indications of the trends of use capability as indicated by the present land use.
6. Systematic projects of trial harvests and crop estimates. These projects if well planned and carried through for some consecutive years, are very important for supplying more quantitative data, directly measured. These projects are expensive and laborious. The choice of these projects should be made according to the various specific points in the classification expected. Per soil type and per crop at least 20 separate plots per year should be measured. This may be done partly by trial harvests and partly by eye estimates. For the annual crops, a surface of 50 m^2 per trial plot should be sufficient. For perennial crops the surface depends on the special characteristics of the crop and the varieties used in the research project. For cocoa, plots of 16 trees each give useful figures. For tea, plots of 100 m^2 are in many cases thought to be efficient.

The second extreme case is a land classification in a region of waste lands in which soils occur of which no transferable knowledge is to be found. One can of course still find some directives in the specific factors found in the soil, such as clay content, mineral content and the like. After assessing the possibilities derived from these factors and on the basis of the economic possibilities of colonisation in the region, one should, at the earliest possible time start one or more pilot projects.

The value of these pilot projects has been fully established in many cases. In the Zuiderzee-project, before the work on the main project was started, the "experimental polder" Andijk was established in 1926. This polder has an area of about 40 ha. A special research commission was formed and promptly started research on various problems. The first polder "Wieringermeer" was pumped dry in August 1930. Thus there were three years to do research on problems of drainage, ripening of the soil, desalination, microbiology, crops, fertilizers, cultivation and on all related problems. The Wieringermeer was again very useful as a large scale pilot project for the Northeastern polder and both these polders contributed to the plans made for the newest polder.

In other parts of the Netherlands use has also been made of pilot schemes. The first pilot farms were formed in 1936 for practical research on improvement of small farms. Afterwards, pilot farms have been established for many purposes such as : ley farming, mechanisation, high nitrogen dressings, rationalisation etc. Some pilot villages have also been established. This kind of research plays a predominant rôle in the Regional Development Schemes in various parts of the Netherlands.

In Surinam (formerly : Dutch Guyana) some very interesting pilot projects have also been established. The "Prins Bernhard-Polder" was established as a pilot project for mechanical rice farming and more generally for studying the various aspects of mechanisation of the Surinam agriculture, from a technical as well as from a farm economic point of view. This polder covers an area of 255 ha. The soils consist of heavy clays of the younger Surinam coastal plain. The polder has a system both for irrigation and for drainage. This project, which started less than 10 years ago, has already made important contributions both to the practical experience and to the scientific knowledge of the use capabilities of the Surinam soils.
Many difficulties have been encountered, which in previous centuries added to the disastrous results of colonisation in this country. Now it is possible in this pilot project to develop the proper methods to overcome the difficulties. Thus, there is a reasonable hope that good results will be obtained with the main project, which has started in the meantime.

An other pilot project in Surinam is the Lelydorp-project.
This project lies in the older part of the coastal plain of Surinam. The rather expensive operations of drainage and making a polder of the younger coastal plain are not necessary, but the soils in the older plain are not so fertile. The Lely-dorp project as a land development scheme started in 1950. Its ultimate purpose is to demonstrate the agricultural possibilities of independent middle-class mixed farms in this part of the country. The site of the project is at about 25 km distance from the capital : Paramaribo. A large variety of crops is included, e.g. oilpalms, cocoa, citrus, annual crops and pastures. Research on both the economic and the technical aspects of the settlement is carried on. The Lely-dorp project is an experiment, in which as many types of farming as possible should be developed. It is hoped, that the project will become a centre of rural development in the broadest sense of the word.

In the Netherlands New Guinea the Merauke scheme for mechanised rice-farming, combined with cattle into a system of mixed-farming is well on its way. Also in this country a pilot scheme was thought indisposable. Some more projects, for other regions, with other problems and other possibilities, are planned.

The pilot scheme or pilot project should always be based on as much comparative knowledge and experience as possible. Only then can it be directed according to the probable use capabilities of the soils and the possibilities and problems in a region. Thus started, the pilot scheme is the only way to get real experience and real results. First and foremost, this applies to the development of uninhabited or sparsely populated areas. But in many other cases this kind of practical research is also most useful.

Pilot schemes and other kinds of research should not only give technical data. These technical data ara very important, but they should always be accompanied by enough figures yo make possible their evaluation within the farm economy. This evaluation can be made through the composition of a series of tentative farm budgets on the basis of various economic assumptions. It will be found that some economic assumptions cannot be used under the given circumstances because of the technical limitations of the soils. In other tentative budgets there is a chance that some technical possibilities cannot be realized because of economic limitations. In this way, by eliminating the less feasible provisions, one arrives at some budgets from which one or more may be chosen according to existing preferences. In many cases the number of budgets from which a choice may be made will not be very large. As chapter IV will show, the budgets should be prepared by a Land Development Team.

e. Improvements, their feasibility.

The improvement capabilities form another important aspect of the development scheme. The improvements to be considered are to be classed as follows:

1. supply of mineral nutrients
2. supply of organic matter
3. drainage
4. supply of water
5. changes in the soil profile
6. desalination
7. changes in the microtopography.

If these changes are to be effective, they must be feasible within the system of farming that exists or will be developed. Also, it must be possible to maintain the changes for long periods with feasible methods.

The feasibility of the supply of mineral nutrients, especially in tropical and subtropical regions is also influenced by the possibility of combating pests and plant diseases. This applies particularly to the use of nitrogen. Often, the application of potassium and phosphates tends to strenghten the resistance of a crop against pests and diseases.

As an example we take tea cultivation in Java. Before 1949 a very dominant pest. Helopeltis spp., against which no effective pesticides existed, determined largely the feasibility of nitrogen-manuring. After 1949 the modern industrial pesticides, such as DDT and HCH came into general use. The consequences are that while before 1949 the optimum dressing of nitrogen on young volcanic soils was about 60 kg of nitrogen per ha per year, after 1949 a gift of 120 kg of nitrogen per ha per year had become still very effective.

The effect of supplying mineral nutrients differs considerably according to soil type. This means often, that the feasibility of the application is very different. In many cases, the best soils give also the highest effect of improvement. Therefore, by intensification there may be a tendency of a growing economic difference between the best soil types of a region and the poorer types. Although modern technology makes possible the technical improvement of our poor soils, it may well be, that the alternative application of the same amount of capital and labour to the better soils is much more feasible. In considering projects of land development both these sides: technical possibility and economical effect should be weighed. Apart from these, there may of course be social or political reasons for developing certain regions and certain soil types. But even if a decision is made on social or political grounds, one should have an insight into the technical and economical consequences. Table 6 gives a simplified example of the effect of supplying mineral nutrients on various soil types.

Table 6. Results of applying artificial fertilizers (N, P, K. in optimum amounts for each soil type) to tea crops on three different soil types in Java.

Soil type	Production without artificial fertilizers (lbs/acre)	Mean increase in per cent of production by artificial fertilizers (%)	Increase of product (lbs/acre)
1	2000	60%	1200
2	1400	70%	1000
3	1000	50%	500

The limited space of our paper prohibits the discussion of all the aspects of soil improvement. The extreme importance of organic matter must be stressed. The following means of supplying organic matter should be mentioned: root-rests of the crop itself, farm-yard manure, leys, various leguminous crops, mulching, town refuse. As an example of the importance of mulching we give some data from field experiments with coffee in Indonesia (table 7).

Table 7. Effect of organic matter

object	relative production of coffee
clean weeded	100%
id. + NP fertilizers	130%
mulched	280%
mulched + NP fertilizers	480%

In the Netherlands, the importance of town refuse for the reclaiming of sandy regions is well known. Another important way of improving organic matter conditions is ley farming. Both the technical and the economic aspects of ley-farming are now studied in our country in various experimental fields and on some twenty pilot farms.

The effect of drainage as a factor for improving the physical conditions in a land development area is sufficiently known. One should remember the following aspects :

1. The construction of a good drainage system in water-logged areas makes it necessary that the suitability of the soils for the new drainage-phases of the soil types should be reconsidered. This suitability may change to a large extent with a change of a foot in the depth of the ground water level. If one wants to keep a large part of the area for grazing, the system of drainage should be sufficiently differentiated to prevent the higher and drier soils of the area to become too dry for pastures.
2. Drainage is a necessary part of any irrigation system.
3. In many soil conservation projects drainage forms an integral part. This is especially true for those regions with a high rainfall intensity.

Water may be supplied by irrigation, by infiltration or by means of artificial rain. Apart from the general conditions in a region, it also largely depends on the characteristics of the soil types which kind of supply should be preferred. One should also keep in mind, that the quality of the water plays an important rôle. Irrigation water with a large content of mineral nutrients may play an important rôle as a fertilizer. Irrigation water with a too high salt-content may be dangerous in forming saline soils. Even if no saline soils are formed, irrigation water has a marked influence on the weathering processes of the soils. Irrigation water may also serve as an efficient weed killer.

Changes in the soil profile may be an important means of enlarging the possibilities of a land development project. Some remarkable examples may be shown in the Netherlands, such as :

- the upturning of underground layers rich in lime to improve the topsoil.
- the mixing of B-horizons of a podzol through the profile.

In both cases it is often better to keep the original A-horizon, or at least part of it, on top to retain the biologic activity of the soil which is indispensable to the growth of crops.

It is difficult to give general pedologic directives for these improvements. The planning of their application should proceed in some phases:

a. the soil scientist classifies the soils with regard to their needs and theoretical capabilities of improvement;
b. the agricultural engineer considers the practical possibilities to arrive at the improvements desired;
c. the economist studies the financial effect of the improvements;
d. after considering all these aspects, a more definite improvement-classification may be made.

The desalination is of extreme importance in regions of saline soils. A good drainage is the most important factor for this improvement. The use of gypsum or other soil-improving salts may be of very great help in these projects. This was fully demonstrated after the great floods in the Netherlands in 1953. Some very useful remarks on these problems are to be found in recent Russian literature.

Improvement of the microtopography may serve various purposes, for instance that of irrigation. The terracing for soil conservation could also be reckened to belong to this category of soil improvements. This kind of improvements falls primarily within the province of the agricultural engineer, working on basic data provided by the soil scientist. Of course the economic effect should also be considered.

IV. THE APPLICATION OF LANDCLASSIFICATION

a. Systematic Transfer of Knowledge

To provide a sound basis for land development, the knowledge extant about the use capabilities of comparable soils in all parts of the world should be studied. It never pays to leave aside the knowledge already gathered by others over more or less long periods of time and with considerable costs. Soil survey and landclassification take a large part of their importance in recent agricultural science from their usefulness as tools for this transfer of knowledge. It should be useful therefore, to try and systematise our methods for comparing soils,their qualities and their use capabilities.
In doing this, it must be realised that :

1st. the available data are often rough and incomplete, but nevertheless they may be very helpful,
2d. the time available for the planning of development projects is often very short even in the absolute sense; relative to the complexity of the problems to be met with, it is almost always too short.
3d. the people who are going to decide on the execution of a project need al essential information, but it must be easily interpretable.

The methods for comparing soil characteristics belong to the field of Soil Classification. They consist in comparing descriptionsand analyses as carefully as possible. The use of standardized analytical methods and a standardized colour scale (Munsell Colour Scale) are essential for this procedure.

For comparing the soil qualities from various parts of the world, it is also necessary to use standardized analytical methods. The chemical and physical analyses of soils in land development projects should be done first and foremost with the aim to obtain a basis for comparison and transfer of knowledge. The fundamental research on these questions should be planned at the same time, but it takes much more time and money to get reliable results. This second part of research could also be left to well equipped laboratories in other parts of the world. Research hobbies of local experts should take third place in these projects.

Many of these qualities are derived from field characteristics. For these the descriptions and definitions given in the SOIL SURVEY MANUAL(1951) should be used. If necessary, local adaptations may be made to this system. For many development projects, precedence should be given to the following:

topography
drought susceptibility
erosion hazard
stoniness
drainage
salinity

For each of these, a Soil Quality Classification may be made. It is often not necessary to distinguish many classes. This depends on the variation of the soils occurring within the region and on the amount of detail needed for further planning.

At the end of this paragraph a system will be described to combine all these classifications together with data on soil suitability, into one formula.

The methods for comparing the use capabilities od soils have never been developed systematically. The following tries to give an outline for developing methods for this purpose. The reader is referred to fig. 4a and 4b (par.Id).

The factors to be certainly distinguished in this case are :

soil
climate
system of farming

In many cases, it is already difficult to obtain enough workable data on these three factors. Necessarily our system should be rough. It is only meant to estimate in the gross, the use capabilities to be expected in our development plan. Further research (see chapter III) is needed to obtain more exact information.

First of all, from the existing literature and reports, soils should be selected that seem to have approximately the same characteristics and qualities as those soils of which the use capabilities are to be estimated. After that, or at the same time, all available data on climates, systems of farming, crops, crop yields, etc are gathered together. For a systematic study of the climates, the system of KÖPPEN (1931) is very useful. In his publication are also found a lot of climatic data of various countries.
A description of farming systems should perhaps be limited to the designation of (cf.fig.4):

industrial systems of agriculture
traditional systems of agriculture
irrigated agriculture.

This is an example of frequently occurring systems of agriculture. If necessary for various conditions, other systems of agriculture could be included.
The description of crops may in many cases be restricted to:

arable land (A)
pastures (B)
specialized crops (fruit, cocoa, tea, rubber, etc.) (S)
forestry (F)

A rough estimate of a certain soil under a certain climate for a certain group of crops may thus be made : (Table 8).

Table 8. Schematic basis forestimatesof suitability for planning in a landdevelopment project.

Climate: ') (group of) crops: / Suitability	Systems of farming: industrial	irrigated	traditional	designation of suitability
3	+	+	+	almost certainly suitable
2	+	+	-	probably suitable, but possibly with restrictions
	-	+	+	
1	+	-	-	perhaps suitable, but almost certainly with restrictions
	-	-	+	
	-	+	-	
0	-	-	-	probably not suitable, or with heavy restrictions

') designation according to Köppen

Table 8 gives only a schematic basis for the estimates to be made. It may be used for various soils, crops and climates. By using a system like this, it becomes possible to systematize in a rough way the knowledge derived from study, traveling etc. It is based on the assumption, that the amount of various use capabilities is the best general estimate of the soil potential.

According to IR. J.M. VERHOOG (Surinam) the combination of soil suitability and soil quality classification in one formula, may be done in the following way:

$$\text{Soil potential of soil } x = SP = \frac{Aa.Pp.Ss.Ff}{t_k.d_m.e_n.s_u.w_v.y_w.z_x}$$

This formula is not a calculating formula. It is a code for designating the various data that are essential for estimating the soil potential and its limiting factors. Aa, Pp, Ss and Ff give the suitability of the soil as estimated according to table 8. The letters t_k, d_m etc. designate the soil quality classes repectively for : topography (t), drought susceptibility (d), erosion hazard (e), stoniness (S), drainage (w), salimity (y) and various othe limity factors (z).

b. Land Development Teams

Land classification is essentially teamwork. Cooperation of all persons, in every bureau or service connected with a land development project is the only way to obtain results that will really improve farming conditions or that will lead to the sound development of new regions. This teamwork has various aspects :

1 soil scientist (suitability-expert);
1 economist (farm-economy-expert);
1 agricultural engineer.

This team should have the full cooperation of all other specialists, e.g.:

experts on soil fertility
experts on plant breeding
experts on cultural techniques
experts on plant protection

It may be advisable to include some of these experts into the team, or to include at least one general agriculturist to represent the point of view of the "planting-experts".

A special function of this cooperation in a team is the necessity to provide reasonable estimates in all cases in which not enough exact quantitative data can be provided. This will be the case in most land development projects. Only a team that is sufficiently "all round" to be able to combine all the technical and economical aspects of a project can be said to be able to take decisions on:

a. Whether the available data are sufficient to make the necessary calculations and classifications.
b. Whether the gaps in the knowledge can be filled by reasonable estimates (and such a team can provide these estimates).
c. Whether for certain gaps no reasonable estimates can be made, and in this case the team can advise to make researches to provide the data.

The members of the team can also do very valuable work as "liaison-officers" of their branches of the agricultural services. They should have the full cooperation of their respective institutes. This they can only have, if they discuss the problems of the team within their institutes. In this way it is also possible for these institutes to take into account at the earliest moment any special wishes with regard to their work that may further the progress of the Land Development Project.

If possible the team should be formed at the moment that plans for a project are considered. Only then it is possible to find enough time for correlating all kinds of researches. The team should never make the decisions on the execution of the project. These decisions must be reserved for the authorities in charge. The team is a combination of people working in applied research in its broadest sense. The application within pilot projects which is a kind of research, could partly be controlled by the team. But in general scientists should never be made administrators, nor should administrators be necessitated to do research work.

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