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Land resource evaluation

Edited by
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PREFACE

INTRODUCTION

The expert group on land use and rural resources was established following a request of the Standing Committee on Agricultural Research (CPRA) to prepare an inventory of land use and rural resource problems in the Community.

In 1974 the member countries received a questionnaire about major land use problems, proposed steps to overcome these problems and present and proposed research in this field, as well as research fit for common action under the EEC 'Land Use and Rural Resources' study group.

The expert group met in Brussels on the 20th January 1977 in order to both screen a working document of October 1976 and discuss a report on land use and rural resource problems in the EEC prepared from the questionnaires by Dr. J. Lee (January 1977). During this meeting it was agreed that a good basis for further work in the sphere of land resource evaluation was available in the EC soil map of Europe and in the European part of the soil map of the world of FAO/UNESCO. Moreover, it was found that land capability studies with an agreed common methodology at both qualitative and quantitative levels needed to be developed. During this meeting a number of important other items were discussed eg, classification of land use potential; conservation of soil structure; erosion problems; land use competition; leisure and recreational land use pressures; land use planning and land use in connection with socio-economic relations. Other important and related subjects were also discussed, viz., water resources and sewage sludge.

It was decided to identify the following four major priority themes to be put forward to the CPRA:

1. Land resource evaluation
2. Hydrology
3. Disadvantaged areas
4. Soil degradation.

The Standing Committee concluded that the Land Use and Rural Resources Group should give priority to items 1 and 3 and they should endeavour to establish a co-ordinated research programme on the evaluation of land resources with regard to soil and water and research should also be co-ordinated on the problems of disadvantaged areas. Furthermore, the group would report to the CPRA on the areas identified as requiring common research efforts. Against this background the CPRA would take into consideration the setting up of a common research programme on Land Use.

ACTION STRATEGY

The report prepared by Dr. J. Lee for the January 1977 meeting on Land Use and Rural Resource Problems in the EEC contained information on research progress into the above themes in member countries. On the theme of land resource evaluation, it was apparent that there were major differences between countries in the intensity of map production and in the development of land evaluation systems as well as in the methodology adopted. It was therefore decided that a fundamental appraisal should be made of the scope and organisation of research programmes on land resource evaluation in the member countries. In view of this, it was decided by the CPRA that the next meeting of the Land Use and Rural Resources group should be combined with a seminar on 'Land Resource Evaluation'. The main objective of the seminar would be to review the state of knowledge on this subject in each of the participating countries with particular reference to a description of land classification systems capable of serving the interest of the Common Agricultural Policy of the EEC.

SEMINAR ON LAND RESOURCE EVALUATION

The Director of the Agricultural Institute of Ireland, (An Foras Taluntais), Dr. T. Walsh, invited members of the Land Use and Rural Resources group to hold their meeting at the headquarters of the National Soil Survey of Ireland, at Johnstown Castle, Wexford. He also proposed to hold the seminar in Johnstown Castle. Both the meeting of the expert group and the seminar took place on the 7th, 8th and 9th of November, 1978.

Invitation for contributions to the seminar were accepted by twelve specialists from eight member countries and from FAO. The conclusions of the seminar were discussed in the session of the expert group and adopted for further reference and presented to CPRA. It was agreed to publish a summary of each paper presented at the seminar, including a summary of discussions and recommendations made by the seminar participants.

FUTURE ACTIVITIES

On the basis of the available information as well as the conclusions reached at the seminar, the expert group decided to nominate four co-ordinators for four groups of experts in order to prepare proposals for co-ordinated and common research in four areas of high priority. The co-ordinators were invited to prepare and transmit a draft report about the decisions reached to the expert group early in 1979. The expert group could then decide about proposals for further research to be presented to the CPRA in 1979.

(a) Land resource evaluation

It was agreed that the appropriate use of land should include reference to conservation (including landscape) aspects of land use. The whole concept should be developed with reference to land use planning in order to incorporate the multipurpose use of land, including effects of urbanisation and the utility of work carried out to provide an input to regional modelling should also be considered. It was decided to prepare a land resource map and couple it with the standardisation of methodology for land resource evaluation. The time, cost and purpose for which the map would be used were important elements in arriving at a final decision. The need for standardised information on land resources in the EEC was emphasised. The development of a land suitability system for specific crops was considered important. The creation of a data bank and the production of basic data maps for the treatment of problems affecting land use at the regional, national and European scale was envisaged. This work could be accomplished by:

(i) Examining the many sided aspects of the system such as assessment factors, recording of data, etc. to ensure a systematic analytical appraisal;

(ii) Implementing a uniform system at EEC level;

(iii) Production of maps (commodity, economic data).

It was also proposed to select within each country a difficult area for case studies to test the system. Mr. M. Cornaert, of the Environment and Consumer Protection Service (ECPS), informed the group that case studies have already been carried out for the ecological mapping of the European Communities and these studies may contain useful guidelines (1, 2).

The eventual recording system would be required to respond at short notice so that the basic data can be supplemented as a result of technological changes. The system should be relevant to both farmers and policy makers. In this connection the scale of mapping was considered important. However, the soils map on a scale of 1 : 1 000 000 is the only one available if the mapping system is to be harmonised at a European level. Dr. R. Dudal informed the group that such maps are available from FAO for reproduction. Climatic data would also need to be compiled on this scale. The relevant soil and climatic requirements for specific crops, eg, forage, cereal, potato, sugar beet, would also require to be established.

The information thus obtained would be stored in a data base. The working group recommended that the data base system should be supported by research. Dr. Reiniger informed the group that ISPRA have provision plans (1980 - 1984) to further develop a methodology for the automatic classification of land by combining remote sensing data with data from other sources. If this programme is approved, the collected data would be computerised. The facility would be available to the land use group if they wished to use it for pilot study purposes.

(b) Disadvantaged areas

It was agreed to investigate the problems of less favoured regions through pilot studies in specially selected areas. These areas should be chosen on the basis of the data already available in such areas and also using the selection criteria applied in the physical case studies undertaken by the ECPS. However, for resource case studies in disadvantaged regions, the evaluation would include studies on both physical and socio-economic factors so that land development or management systems could be further progressed. An implementation strategy should also be considered, avoiding wherever possible the necessity for supporting legislation. It was agreed that a paper should be presented at the next meeting outlining the present position with regard to marginal land use policy in the individual Member states. The less favoured areas were recognised as being highly heterogeneous throughout the Community and the associated problem of land use as being very variable. It was emphasised that the use of better land in in the less favoured zones for purposes other than agriculture should be discouraged because of the complementarity in use of good and poor land in such regions. The work pertaining to this section of the programme should be harmonised with that of the beef production group, Mediterranean group and the ECPS. The forestry division (DG VI/E/5) would welcome involvement in this area. Co-ordination should also be effected with the Statistics and General Studies division (DG VI/G/2) as the report made available by them on "the structural socio-economic situation and evolution of agricultural regions in the Community, particularly less favoured areas" was very relevant to the work of the land use group.

(c) Soil degradation

The meeting was informed that the Council of Europe Committee had already expressed concern about soil degradation in Europe. This concern was shared by members of the expert group. Erosion and physical and chemical loading of European soils require urgent attention. Tolerance limits (eg for cultivation, minimum tillage, monoculture, pesticides, compaction, structure and permeability) should be established. The effects of animal effluents loading should be co-ordinated with the work of the existing working group on animal effluents. The influences of grassland and cultivation (including monoculture) degradation pressures on water resources, should be monitored and recorded by data bank methods. The FAO Soils Bulletin No. 34 on "Assessing Soil Degradation" was considered an important reference work.

(d) Hydrology

Hydrological aspects were common to the above priority areas and would be taken into account by the respective ad hoc groups charged with the further elaboration of these proposals. Measures to develop as well as to protect and maintain land and water resources would be included in the terms of reference of the soil degradation sub group.

(e) Rural environment related to man

Relationship between the individual and his environment was considered by the working group as warranting inclusion in the final proposals. However, in relation to it the group considered that a clearer definition of the proposal was required. A balance of all environmental interests was necessary, although the synchronisation of the various land uses in a generalised model was a difficult problem. However, the importance of the sociological impact and the quality of the environment in relation to rural development programmes were considered as very important aspects of the group's work. A possible method of approach would be to adopt a co-ordination programme on the problems arising from the intensification of agriculture. The importance of such co-ordination in relation to less favoured and urban areas was important. It was agreed that the topic required further elaboration.

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PART I

LAND RESOURCE EVALUATION

EVALUATION OF SOIL SUITABILITY FOR THE PLANNING OF RURAL SPACE IN FRANCE

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1. INTRODUCTION

INRA has several research teams studying the problems of rural space planning:

- The 'Service d'Etude des Sols et de la Carte Pedologique de France' is publishing a pedological map of the country at a scale of 1/100 000. Soil suitability evaluation is based on a consideration of the physical characteristics of soils.

- Some research groups study in a general way the different types of land utilisation, taking into account not only physical criteria but also geographical and socio-economic factors.

- Some teams specialise in forestry problems.

2. STATE OF ADVANCEMENT OF CARTOGRAPHIC WORK

Maps are produced either on a scale of 1/50 000 directly by the SESCPF, or by the regional bodies for soil planning, in which case the scales vary from 1/5 000 to 1/100 000.

Many maps are published at different scales according to the different problems of management. Systematic publication is limited to a scale of 1/100 000.

A new draft of the soil map of France at a scale of 1/1 000 000, which would be useful at EEC level, has also been prepared.

3. EVALUATION OF SOIL SUITABILITY

The scope of land use planning is wide. Soils are assessed for agricultural purposes and non-agricultural purposes. Problems of soil and landscape conservation also require attention. The experience gained by INRA in this field is varied because of the diversity of the geographical environment in France and the variety of the agricultural production systems.

3.1. More favoured land zones

A methodology of suitability evaluation based only on physical characters has been used, when the socio-economic factors are relatively unimportant vis a vis the physical factors as in the following situations:

(a) Regions of intensive agriculture, eg the wide flats of the Paris Basin where the structures and the technical level of farmers are sufficiently homogeneous and near the optimum level.

(b) Regions of highly specialised cultures, eg, wine, fruit growing regions.

(c) Forestry zones.

(d) Regions where the agricultural productivity of soils is limited by certain constraints (drainage of hydromorphic soils and irrigation of sandy soils).

(e) Regions where urbanisation requires the necessity to protect the best agricultural lands.

The approaches chosen in the many studies dealing with these questions vary according to the scale of the problem district, region, etc.) and to the type of soil utilisation. However, despite this the general approach is similar. It consists in the first place of assessing factors relevant to the principal types of land utilisation, and in the second place of assigning a weighting for these factors.

The classification system in analagous to classifications used in other countries and to that proposed by FAO. At the highest level, the suitability classes are defined according to the range of crops that can be grown and the degree of intensification of the cropping system. There are four classes for cultivation. Class V consists of those soils where mixed grassland type cropping is possible, and class VI comprises soils where neither cropping nor grassland are possible.

The sub classes within each class contain suitability groups which have similar limitations when cropped at the same intensity.

The classification of the soils within this general framework is the result of the application of a system of numeric rating based on the semi quantitative evaluation of a certain number of factors linked to the elementary soil and environment parameters. With this in mind one starts by selecting, through enquiries, the most relevant physical factors for the growing and the cropping of plants. This is based on the most common and remunerative crops. The weighting given to the factors is based on the importance attached to each. Each factor is evaluated in accordance with a certain number of criteria which characterise the physical environment, eg, the factor 'water availability' is evaluated by reference to the useful depth and the stoniness of the soil etc.

Every elementary criterion affects the rating of the corresponding factor according to its importance. The sum of the points given to each factor permits finally the rating of any soil so as to characterise its suitability for a specific type of utilisation.

This parametrical approach gives rise to a classification of the different soil units; in this context it becomes necessary to highlight the limits of the capability classes. For this purpose one refers to certain criteria particularly well defined called the diagnostic criteria. For these criteria, one takes the thresholds of variation corresponding to significant variations in the cropping behaviour. In this way one defines the limits of the classes. If the criteria for defining the classes are not explicitly linked to some notion of suitability or profit, they are anyhow linked to the notion of diversity of a certain biological productivity based on the most remunerative cropping. One of the advantages of this approach is the possibility of computerising the information.

The applicability of such a system is limited for the moment to the production system in force in regions of intensive cropping. That means nearly half of the French land surface. Furthermore, such a system is available within a region with homogeneous climatic conditions. So the application of such a system at the inter-regional level implies the setting up of a comparative method between different regions with the introduction of climatic parameters. That is the reason why, at this level (inter-regional), a research team of INRA has attempted to elaborate suitability maps using some indices of theoretical production calculated by means of inter-related climatic and production data. In this particular case it concerned the cropping of maize in south west France.

But the application of such a system becomes difficult in regions with diversified semi-mountainous and mountainous environment where the structures are small and where the cultivable lands are scattered. In these cases the above method is not applicable in the short or medium term.

3.2. Mountainous and semi-mountainous zones

Some research teams of INRA have studied some methods applicable to such regions (Vosges, Corse). In these regions, which are more common in the soutn of Europe, one must introduce a potentiality notion applicable to such situations and to the evolution of agriculture.

With this perspective the potentiality of land cannot be evaluated without considering its inclusion in a particular production system and in the context of precise socio-economic structures. It becomes indispensable to use such an approach in studying those regions, where it is necessary to maintain an agricultural activity which is disappearing or is rapidly transforming.

With this approach the choice of a particular type of land utilisation or planning is the result of analysis of those systems where physical and socio-economic criteria are involved. Some of these are structural, eg, field pattern, accessibility, size; demographic composition of the family; socio-economic circumstances, eg, possibility of sale of farm products or product processing. The introduction of socio-economic criteria implies the choice of a time scale, during which there is an alteration of the retained criteria and an evolution of the system as a consequence of technical progress and economic circumstances.

The analysis is carried out at both farm and territorial level. The interaction between the different elements of the same system permits complementarity:

(i) technical complementarity, for instance between grassland for cutting situated in valleys and mountainous areas for sheep grazing.

(ii) economic complementarity between several activities, for instance small scale rearing - forest - handicraft.

4. CONCLUSIONS, RESEARCH PERSPECTIVE

The dominant problem is obviously the classification of the agricultural capability of soils, but it is important to make a choice between a classification of physical suitability or a classification taking account of both the physical and socio-economic criteria.

At national level it is possible to conceive suitability maps at small scale taken directly from soil maps and, when possible, with the aid of remote sensing. Parametrical maps such as those concerning soils affected by excess of water or those establishing the available water of soils could constitute a first step in this direction.

It is also possible to conceive suitability maps simultaneously integrating physical, geographical and socio-economic criteria. Such an approach, if applied, should take in account the production systems so as to permit a comparison between very different regions.

Consequently it would be useful to establish first of all a classification of agricultural regions which should take into account the diversity of the actual types of systems of production. One could then think of studying cases where the physical, socio-economic analyses would be associated in order to finalise proposals for the planning of the actual systems.

Because of its priority character, we would propose for instance to consider firstly the problems of the breeding zones, especially in disadvantaged areas.

TABLE 1

RELATIONS BETWEEN THE CONDITIONS OF PRODUCTION AND THE CONSTITUENT CHARACTERISTICS

Major characteristics	Conditions for Plant Development				
Constituent Factors	Availability of water	Germination and establishment of vegetation (plants)	Quality of the root system	Conditions of aeration	Availability of nutritive elements
Texture) Calculation Stoniness) of utilisable Utilisable depth) reserves Capilliary rise)	+ 350				
Stability of structure in surface horizon; caking of surface		+ 50			
Profile Development			+ 100		
Solum stoniness			+ 50		
Depth and degree of gleyification in relation to the moisture conditions of the surface horizon				+ 150	
Base exchange capacity					+ 80
pH					+ 20
Texture Slope					
Moisture conditions of surface horizon (In terms of field capacity and Atterberg limits)					
Stoniness of surface horizon					
Total points = 1 000	350	50	150	150	100

Note: Climatic variations have little significance at the regional level

TABLE 1 (Continued)

Major characteristics	Conditions governing the carrying out of cultivations		
Constituent Factors	Tractive effort	Feasibility of cultivation	Obstacles to mechanisation
Texture) Calculation Stoniness) of utilisable Utilisable depth) reserves Capilliary rise)			
Stability of structure in surface horizon; caking of surface			
Profile development Solum stoniness			
Depth and degree of gleyification in relation to the moisture conditions of the surface horizon			
Base exchange capacity pH			
Texture	+ 40		
Slope	+ 30		
Moisture conditions of surface horizon (In terms of field capacity and Atterberg limits)		+ 70	
Stoniness of surface horizon			+ 60
Total points = 1 000	70	70	60

Note: Climatic variations have little significance at the regional level

TABLE 2

QUANTITATIVE ESTIMATION (BY CLASS) OF THE FACTORS PLAYING A PART IN THE ESTIMATION OF THESE CONDITIONS (SEE TABLE 1). TWO EXAMPLES OF THE ESTIMATION OF CONDITIONS 'AVAILABILITY OF WATER' AND 'AERATION'

AVAILABILITY OF WATER

Classes of Utilisable Reserves (in mm of water)

(Evaluated from the aspect of capacity for retention and wilting point and weighted as a function of depth)

(1) - > 250 mm) (2) - 250 - 200 mm)	350
(3) - 200 - 150 mm:	325
(4) - 150 - 100 mm:	250
(5) - 100 - 50 mm:	150
(6) - < - 50 mm:	25

AERATION CONDITIONS

Drainage Classes

(greater of less capacity to dry-out)

(1) Presence of gleying at depth of more than 80 cm:	Rapid drying of surface:	150
(2) Gleying between 40 & 80 cm:	Drying out in one week:	125
(3) Gleying at less than 40 cm:	Drying out in 2-3 weeks:	75
(4) Gleying at surface (temporary submersion):	Drying out in more than 3 weeks:	5
(5) Semi permanent submersion or risks of frequent flooding:		0

LAND SUITABILITY EVALUATION IN MAJOR AGRO-ECOLOGICAL ZONES

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In order to obtain a more precise assessment of the production potential of the world's land resources, and so provide the physical data base necessary for planning future agricultural development, FAO has recently initiated a study of potential land use by major agro-ecological zones.

The methodology to assess the agricultural potential of the world's land resources uses five basic principles:

i. land suitability is only meaningful in relation to a specific use, eg, land suited to the cultivation of cassava is not necessarily suited to the cultivation of pearl millet;

ii. the evaluation of production potential needs to be made in respect of specified input levels, eg, whether fertilisers are being applied or not, if pest control is effected, if machinery or hand tools are being used;

iii. suitability must refer to use on a sustained basis, that is the envisaged use of land must not result in its depletion, eg, through wind erosion, water erosion, salinisation or other degradation processes;

iv. evaluation involves comparison of more than one alternative type of land use, eg, suitability for millet or sorghum or maize, and not just for a single crop;

v. different kinds of land use are compared at least on a simple economic basis, that is, suitability for each use is assessed by comparing the value of the produce to the cost of production.

It appears that the concept of land evaluation is wider than the appraisal of soil qualities to which previous suitability classifications were sometimes limited. Land is defined geographically as a specific area, the attributes of which relate to soils, geology, hydrology, plant and animal population, climatic conditions and the results of past and present human activities to the extent that these attributes exert a significant influence on present and future uses. Furthermore, a multi-disciplinary approach is required which uses a physical resource base in a social and economic context.

The global appraisal of land suitability in major agro-ecological zones is based on a world-wide soils and climatic inventory.

The climatic inventory used in assessing land suitability takes into account the crop's climatic requirements including rainfall, soil moisture, temperature and radiation.

The globalland suitability assessment will give areas of land very suitable, suitable, marginally suitable, not suitable for the production of each crop at two levels of inputs. The four classes will be related to the anticipated yield as a percentage of the maximum attainable under optimum agro-climatic and soil conditions, and will therefore provide the necessary data for calculation of the production potential of any given area. This methodology could also be applied at regional and country levels.

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SOIL RESOURCE INVENTORIES AND THEIR APPLICATION IN THE NETHERLANDS

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1. INTRODUCTION

Low-lying soils developed on fluvial or marine alluvium and peat soils cover about half of the area of the Netherlands. Also important are soils developed on 'cover sand' (wind deposited material of late Pleistocene origin): these too are usually low-lying. In addition there are relatively small areas of soil developed on loess, on sand dunes and on coarse sandy material (Figure 1).

The surface of the alluvial and peat soils is very flat with less than 1 m height difference per 100 m. In the cover sand soil slopes may attain 2 - 3 m/100 m. Significant slopes only occur on the loess soils, on the sand dunes and on the coarse sandy material of the ice pushed ridges.

Because they are low-lying, most of the soils used for agriculture have groundwater in the top metre of the profile for at least part of the year. Thus the depth of the mean groundwater level in summer and in winter is an important feature of soil conditions. It is indicated on soil maps by groundwater depth classes (Van Heesen, 1970).

The small differences in climatological conditions over the country are insignificant as far as the interpretation of soil surveys is concerned.

There are large differences in natural chemical fertility between different soils. However, agriculture is very intensive, with high inputs of fertiliser and therefore any nutrient deficiencies that might limit productivity can be remedied

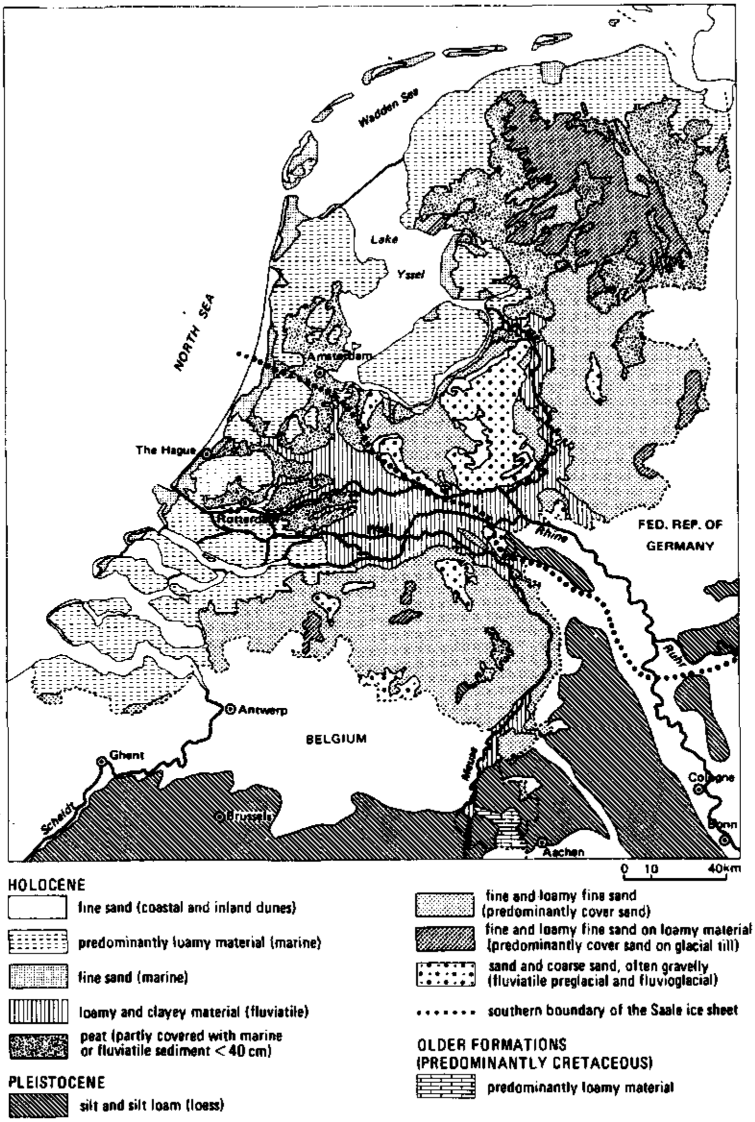

Fig. 1. Generalised distribution of the various kinds of parent materials in the Netherlands, differentiated according to geological age, texture and origin. In Belgium and the Federal Republic of Germany only the loess is indicated to show that the Dutch loess region is part of the West European loess belt.

From De Bakker, 1978.

relatively easily. This largely obliterates any original differences in fertility level.

Of the total area of the country (37 000 km^2), 68% is used for agriculture (22% arable land, 42% grassland and 4% horticulture); 8% is forests; 15% roads, built-up areas, public parks, etc; and 9% is water.

Population density is high and land is scarce. The land is used intensively. Not only soil conditions but also socio-economic and historical factors have determined to a high degree present day land use. The land use continues to change, especially from agriculture to non-agricultural uses. In the 1960s much arable land was converted to grassland.

The circumstances described above have given rise to the development of an intensive system of soil resources inventory that emphasise the features and detailed distribution of the soils and groundwater and the main potentials and limitations of soils for various types of land use. This approach reveals how the soils can be managed and how they can best be modified if necessary for the kind of production that is envisaged. Figures 2 and 3 show the coverage to date of the surveys.

2. THE DUTCH METHOD OF SOIL SURVEY INTERPRETATION

2.1. The need for interpretation

Users of soil maps are not usually interested in the soil map itself but rather in its applications. They require accurate and precise predictions about soil performance under different forms of land use and about the measures required to obtain the desired results. They want to know the function of the soil properties in the processes and site conditions affecting a specific land use. Moreover, map users often require a more comprehensive description of soil performance in the form of soil suitability. Soil suitability is defined as the degree to which a soil, according to its properties, meets the requirements for a particular type of land use (Vink

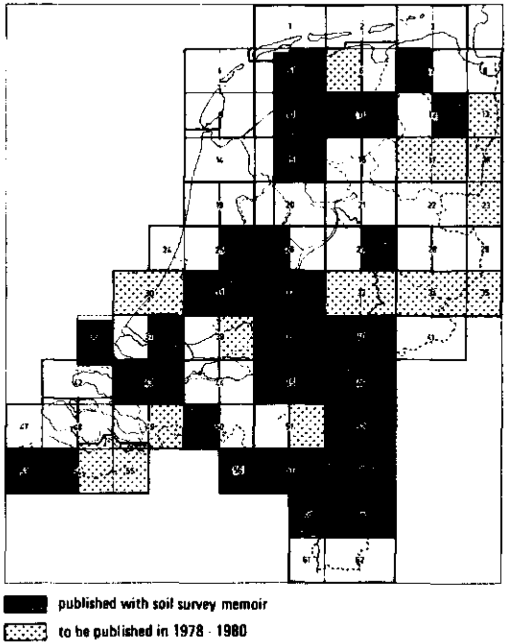

Fig. 2. State of 1 : 50 000 soil survey

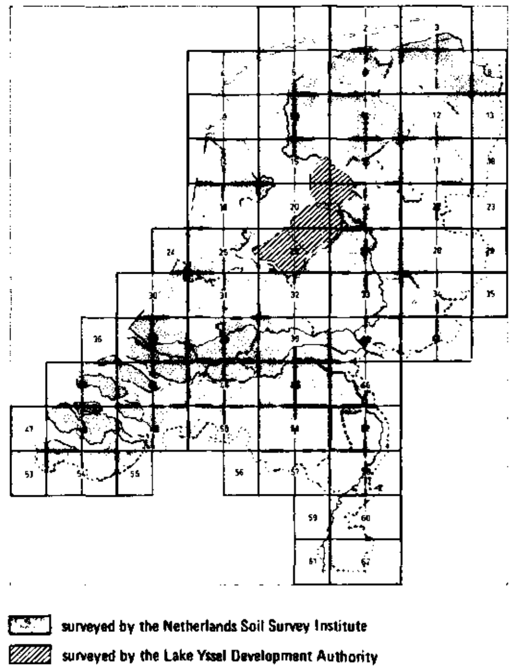

Fig. 3. Soil surveys published at 1 : 25 000 and larger

and Van Zuilen, 1974).

The Dutch system of interpretation of soil maps provides quantitative data on specific aspects of soil performance in the form of assessment factors, and it contains suitability classes for different land use.

Before interpreting, it is necessary to define precisely the various land use forms and to identify the soil-dependent processes and site conditions involved. Required levels of performance and productivity must be ascertained for each land use. Furthermore, the relations between the mapped properties and the soil-dependent processes and conditions have to be ascertained, as well as the influence of all these on soil performance and productivity (Gibbons and Haans, 1976).

2.2. Assessment factors

The relations between soil properties and processes are expressed in terms of defined assessment factors constructed according to current understanding of land qualities (FAO, 1976; Beek, 1978; Haan and van Lynden, 1978). An assessment factor is a soil attribute, formed by combining several soil properties, and sometimes environmental properties). It describes a specific process or condition (site condition) important for land use and indicates its level. Assessment factors are inferred from observed soil properties. Their identification requires therefore some explanation. Figure 4 presents a number of assessment factors important in the Netherlands for assessing various forms of land use. For example, the assessment factor 'moisture supply capacity' gives the quantity of moisture that a soil can supply to the plant roots in a dry summer. It is the sum of the available moisture in the root zone plus that supplied by capillary rise to that zone. This factor is very important for all land uses involving plant growth. Levels of moisture supply capacity may be inferred from observed soil properties or calculated from these properties using a model (Rijtema, 1978).

Assessment factor	Land use form				
	arable farming	grassland farming	forestry	recreational land use	low rise housing development
Drainage status	×	×	×	×	×
Moisture supply capacity	×	×	×	×	
Bearing capacity topsoil		×		×	
Workability	×				
Structural stability	×				
Bearing capacity subsoil					×
Fertility status			×		

Fig. 4. Assessment factors and their use for various land use forms in the Netherlands

Some assessment factors apply to more than one form of land use (eg drainage status and moisture supply capacity), others only apply to one type. For instance, workability is an important factor in arable farming, but not in grassland farming or forestry. Fertility status (ie the natural fertility of the soil) is important in forestry where no fertilisers are used. In arable farming and grassland farming with high fertiliser application, differences in natural fertility are hardly important. There are usually five, sometimes three, levels of assessment factors.

Relevant assessment factors for grassland farming are drainage status, moisture supply capacity, and bearing capacity of the topsoil. Drainage status determines the aeration of the soil, the oxygen supply to the roots, and the soil's consistence and trafficability. There are levels of drainage status (Table 1). Drainage status is strongly governed by the groundwater regime. The most important soil property determining it is the mean highest groundwater level. Moisture supply capacity strongly governs soil productivity, because during the growing season evapotranspiration exceeds rainfall. In principle this factor can be calculated as explained above, from the available moisture content of the root zone and the quantity of moisture supplied to the base of the root zone by the capillary rise. There are five levels of moisture supply capacity (Table 1). The assessment factor 'bearing capacity of the topsoil' is important because in modern grassland management, soils must be trafficable during the whole year; during the grazing period the sod must be sufficiently firm to resist poaching even when wet. Bearing capacity levels are defined by values for soil strength of the topsoil measured with a penetrometer, when the soil is at field capacity (Table 1). Factors determining levels of bearing capacity are: organic matter content, texture and mean highest groundwater level.

TABLE 1

LEVELS IN ASSESSMENT FACTORS

Drainage status	
Level	Mean highest groundwater level in cm below surface
1	> 80
2	40 - 80
3	25 - 40
4	15 - 25
5	< 15
Moisture supply capacity	
Level	Moisture supply in mm
1	> 200
2	150 - 200
3	100 - 150
4	50 - 100
5	< 50
Bearing capacity of topsoil	
Level	Soil strength in kgf/cm^2 (standardised penetrometer readings)
1	> 7.5
2	5 - 7
3	< 5

2.3. The suitability classes

The interpretation proceeds in three steps (Figure 5). The first step is the derivation of the necessary knowledge about soil properties from the mapping units. The second step is the determination of the levels of the relevant assessment factors. The last step in the interpretation is scaling the mapping units into suitability classes. This is done by comparing the levels of the relevant assessment factors with the land use requirements. The requirements are formulated in consultation with experts on the appropriate land use. The kind of land use and the objectives of the land use determine which assessment factors are constraining and which are critical (threshold) values. It is the latter that determine the levels of assessment factors.

A certain combination of levels of assessment factors results in a specific suitability class. Keys have been constructed to help do this (Figure 6). There are three main suitability classes (well, moderately and poorly suited), each of which may be subdivided. When assigning soils to suitability classes certain assumptions are always made. For instance, for arable farming and grassland farming, it is assumed that certain conditions regarding land parcellation and accessibility, size of holding, farm management, skill of farm operator, economic situation etc. are fulfilled.

2.4. The interpretation system in practice

Working with assessment factors has various advantages. Firstly, assessment factors have an important independent function because they are used directly by many users. For example, the assessment factors 'drainage status' and 'moisture supply capacity' are used to plan and implement drainage and water management schemes.

Assessment factors lend themselves easily to quantification. By comparing actual and required levels of assessment factors, limitations may be identified.

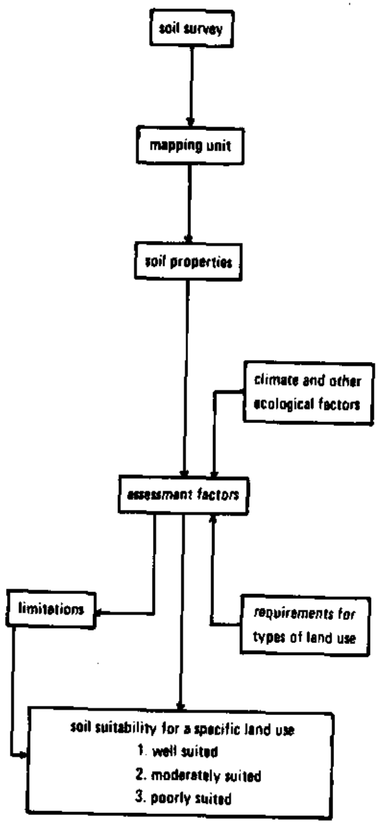

Fig. 5. Schematic diagram illustrating stages in the interpretation of soil maps

Drainage status / Moisture supply capacity	1 + 2		3		4			5	
Bearing capacity	1	2	1	2	1	2	3	2	3
1	1.1	1.2	1.1	1.2	1.2	2.1	3.1	2.1	3.1
2	1.3	1.4	1.3	1.4	1.3	2.1	3.1	2.1	—
3	2.2	2.3	2.2	2.3	2.2	2.3	3.1	3.1	—
4	3.2	—	3.2	—	—	—	—	—	—
5	3.2	—	—	—	—	—	—	—	—

Fig. 6. Simplified key for grassland suitability classification, derived from the levels of the following assessment factors: drainage status, moisture supply capacity and bearing capacity. 1.1 = suitability main class and sub-class

Equally important is the function of assessment factors as a means of deriving suitability classes for different kinds of land use. The explanatory tables accompanying the soil maps contain the values of the most important properties of each mapping unit, the levels of the assessment factors, and the suitability classes for different land uses. Therefore the map user can follow every step from soil properties through assessment factors to suitability rating. The underlying interrelations between mapping units, assessment factors and suitability classes have been demonstrated, and can be checked. The older systems of soil survey interpretation were mainly based on farmers' experience and the general know-how of regional specialists to define descriptive suitability classifications in terms of well, moderate and poor. However, a given suitability can result from combinations of many different factors and considerations, and lack of a specific analysis of the determining factors often made such classifications not very informative by not elaborating on causal relations between soil factors and the suitability ratings (Bouma et al., 1979).

Because they are observed during survey, soil properties are more specific and can be more accurately presented than can assessment factors and suitability classes.

Assessment factors are not observed directly; they are concepts derived from soil properties and other environmental factors. They clearly form the framework of the interpretation system. Though less tangible than soil properties, it is possible to quantify them. This depends on the availability of successful models linking assessment factors to soil properties. At present, such models are not always available, and if models are available, suitable soil data may be lacking. Therefore at present levels of assessment factors are partly determined by informal procedures based on experience and empirical research. However, when more formal procedures become available, they can easily be incorporated into the framework.

The suitability classes are broad and descriptive and have a higher level of abstraction than soil properties and assessment factors. They are less quantitative. For instance, the statement that a soil is moderately suited for land use form 'arable farming' is based on the fact that the soil has a certain combination of levels of assessment factors that are considered to be relevant. To verify this (which has rarely been done to date), it is necessary to have objective criteria to define 'moderately suited'.

The interpretation data are incorporated into the Information System for Earth Sciences. It may be that in the future this will offer many more possibilities for using soil survey data. With the help of the Information System for Earth Sciences all the computations necessary for interpretation can be done automatically and maps showing the interpretations can be made directly by automated cartography.

3. APPLICATION OF SOIL INVENTORIES

Examples of the use of soil inventories for various land use purposes are given in the references.

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LAND EVALUATION IN BELGIUM

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1. SOIL MAP AND SUITABILITY CLASSES

A detailed soil map of Belgium has been prepared covering about 95% of the territory and the remainder will be completed within about three years. Soil mapping is made on cadastral plans at a scale of 1 : 5 000 (approximately two borings/ha). The map is printed in several colours on a topographical map base at a scale of 1 : 20 000 (one sheet = 8 000 ha). For each type of soil the following properties are recorded on the map by a set of colours and superimpositions in black or in colour:

- texture
- natural drainage category
- development of the profile
- thickness of the soil
- nature of the substratum
- kind and quantity of stones
- other characteristics.

Each sheet at a scale of 1 : 20 000 (8 000 ha per sheet) is accompanied by an explanatory booklet of about one hundred pages. One chapter devoted to soil suitability gives the suitability classes of each type of soil for the principal crops and plantations of the region (meadows, wheat, sugar beet, different types of forest or fruit trees, etc) in the following way:

Class 1: very suitable soils
Class 2: suitable soils
Class 3: moderately suitable soils

Class 4: poorly suitable soils
Class 5: unsuitable soils.

These suitability classes are determined on the basis of observations made during the soil mapping, by questioning cultivators and forestry staff and by certain studies carried out by various organisations on different crops in different regions. The combination of these information sources gives a fairly good idea of the suitability of a specific soil for a particular use. In certain fruit-growing and forestry regions the capabilities are better known, since studies have been carried out on the behaviour and economic efficiency of the different varieties.

2. CAPABILITY OF FOREST SOILS

The work carried out in forests can be attributed principally to three specialised centres: the Centre of Forest Ecology at Gembloux, the Centre of Forest Biology at Bokrijk and the Centre for Studies of Forest Soils of Haute Belgique at Gembloux.

Belgian research concerning the capability of forest soils relates to three essential points:

(a) diagnosis of the forest zone being studied;
(b) suitability of the site for tree growth and productivity;
(c) suitability of the site with regard to the choice of species.

Several capability maps for the different economic species have been prepared at a scale of 1 : 20 000 for the sandy region of Limbourg and other maps at a scale of 1 : 25 000 have been prepared for the Ardennes region.

CAPABILITY OF HORTICULTURAL SOILS

Over the last fifteen years the suitability of soils for the most important market-gardening products, grown in the open as well as under glass, has been systematically studied.

After a preliminary study, restricted sites are chosen in cultivated fields. The pedological, physical and chemical variables are determined directly or after laboratory analysis; plant development is observed during the vegetation period and the yield is determined both quantitatively and qualitatively.

The data obtained undergoes thorough statistical analysis by computer, including analysis of variance, the computation of the correlation matrix and factorial analysis.

In this way one can point out the specific influence of different factors and their interaction, which determine the soil suitability and capability. As a rule, a descriptive table is made of the soil series by suitability classes, so that it is easy to draw suitability maps with the help of existing pedological maps.

4. REALLOTMENT OF LAND

In the framework of reallotment of agricultural land, all the land lying within the reallotment zone must be assessed in order to conduct a fair exchange. This land evaluation is carried out by a group of cultivators (farm owners and tenants) under the presidency of a state agronomist.

The best land in the area to be reallotted is worth 1 000 points per ha, and the least favourable one 50 points. The evaluation is based upon the cultivators' knowledge of the land they cultivate, often for many years. As a rule this evaluation is not based on specific crops, but the number of points awarded is a global appreciation of the lands for the usual cultivations in the region being reallotted.

Very often pedologists and cartographers are requested to give their opinion regarding the classification of land for the settling of litigious cases.

LAND RESOURCE EVALUATION IN THE FEDERAL REPUBLIC OF GERMANY

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1. INTRODUCTION

In the Federal Republic of Germany soil survey activities are being carried out under the control of the individual Lands which maintain their own geological surveys. In contrast to most other countries, the Pedological Services in the Lands of the Federal Republic are integral parts of the Geological Surveys of the Lands. The work of the Geological Survey of Northrhine-Westphalia includes the following activities:

- pedological investigation of the Land territory;
- production of soil maps;
- advisory functions on a scientific basis; expert opinions;
- scientific reports and papers reflecting the results of these activities.

Notwithstanding the existing diversity at the administrative level, the soil scientists of the Geological Surveys of the Lands, joined together in a 'Pedological Working Group', have endeavoured to use identical descriptions for identical soil conditions in the individual Lands in order to arrive at a soil atlas of maximum uniformity.

As early as 1965 the 'Pedological Working Group' published, as a co-operative effort, a Guide to the Preparation of Soil Maps to serve as a standard for all future projects on soil mapping. In 1971 the second edition of the Guide was published. Presently the Pedological Working Group are preparing the third, markedly extended and amended, edition of the Guide. For the purposes of pedological surveying of forest areas a specific Guide for Forest Surveying ('Forstliche Standortsaufnahme') was published in its second edition in 1978.

2. SYNOPTIC SOIL MAPS

2.1. The Soil Map of the Federal Republic of Germany, on a scale of 1 : 1 000 000 was published in 1963 by the Federal Geological Survey at Hanover and was produced by the teamwork of the soil scientists of the Geological Surveys of the Lands. On this map the common soils of the Federal Republic are classified according to soil types and subgrouped according to soil textures and geological parent materials. This concept paid due consideration to modern soil type theories as well as to the grain-size composition of the soil and to the soil-forming underground rock. The small scale of this map allows only a relatively rough classification of the soils.

2.2. The Soil Quality Map of the Federal Republic of Germany on a scale of 1 : 1 000 000 was published in 1958 by the Federal Institute for Areal Studies (Institut für Landeskunde in der Bundesanstalt für Landeskunde und Raumforschung, Bad Godesberg). The map shows the soil qualities of the areas under agricultural cultivation on the basis of mean yield index numbers as established by the fiscal authorities.

'Soil quality' in this context means the whole complex of natural conditions of yield (soil, relief, climate) which, for the purposes of land valuation, is expressed in terms of 'yield index numbers' (German abbr.: EMZ = Ertrasgsmesszahl). These index numbers reflect the classification of soils according to their natural productivity.

This map was produced by order of the Federal Ministry for Food, Agriculture and Forestry and subsidised by the Federal Ministry of Finance. It is of particular importance since it presents a global inventory of soil resources in the Federal Republic.

The yield index numbers fall under quality levels as follows:

Below 21
21 to 26
26 to 33
33 to 41
41 to 51
51 to 64
64 to 80
80 and above

Moreover, different colour shadings on the Soil Quality Map indicate whether the grass land covers more or less than 60% of the entire agricultural area of a rural community. However, in recent years the grass land has been markedly reduced in favour of arable land.

Soil mapping schemes at 1 : 5 000 carried out by the Geological Survey of Northrhine-Westphalia for the purpose of investigating agricultural regions were aimed primarily at developing optimum land utilisation and land improvement systems. The large-scale transformation of grass land into arable land, particularly after the completion of soil consolidation schemes, may be largely due to the detailed pedological investigations made for this purpose.

2.3. Generalised Pedological Maps of the Lands on scales ranging from 1 : 600 000 to 1 : 100 000 cover nearly the entire territory of the Federal Republic. Below is a list of these general maps of the individual Lands:

- Pedological Map 1 : 500 000 of Schleswick-Holstein (1955)
- Pedological Atlas of Lower Saxony 1 : 100 000 (1940)
- General Pedological Map of Northrhine-Westphalia 1 : 300 000 (1953)
- General Pedological Map of Hesse 1 : 300 000 (1951)
- General Pedological Map of Rhineland-Palatinate 1 : 500 000 (1965)
- General Pedological Map of Baden-Württemberg 1 : 600 000 (1965)
- General Pedological Map of Bavaria 1 : 500 000 (1955).

The different levels of advancement of the pedological investigations are reflected by the variable publication dates of these maps. However, they all provide a generalised overview of the natural fertility of the soils which is of value for all agricultural and forestry purposes.

3. SEMI DETAILED SOIL SURVEY

3.1. A systematic pedological survey of the Federal Republic is being carried out on a scale of 1 : 25 000 or 1 : 50 000. The Geological Surveys of several Lands have had an appreciable number of sheets of the 1 : 25 000 Soil Map prepared and printed. For instance, in Schleswick-Holstein, 20 soil maps on a scale of 1 : 25 000 were published; in Lower Saxony about 80; in Hesse 20; and in Bavaria some 25 maps. In Northrhine-Westphalia about 20 soil maps on a scale of 1 : 25 000 with explanatory details have appeared so far. Because of the sizeable land area involved the entire survey programme was changed to the 1 : 50 000 scale about 10 years ago.

<u>3.2.</u> To date 19 sheets of this Soil Map (1 : 50 000) have been published; field work for 10 more sheets has been completed and five sheets are being prepared for printing. In addition, the soil maps 1 : 50 000 of the former administrative districts of Wiedenbrück and Iserlohn were published. Before the end of the next decade it is hoped to have finalised a complete compilation of soil maps for the Land Northrhine-Westphalia. The 1 : 50 000 soil maps are well suited for the purposes of regional planning.

4. DETAILED SOIL MAPS

For detailed planning, however, the Soil Map 1 : 50 000 is not sufficiently accurate. This would require surveying on a larger scale and the establishment of large scale special maps which allow delimitation of areas down to individual plots and allow purposeful interpretation of the soil conditions for single lots of land.

<u>4.1.</u> For the purpose of pedological surveying of agricultural areas, in the Land Northrhine-Westphalia, soil maps are produced on a scale of 1 : 5 000; these are needed particularly for areas under soil consolidation and are therefore put to the disposal of the Chambers of Agriculture and dependent institutions ('Ämter für Agrarordnung', 'Bezirksstellen für Agrarstruktur'). Under this programme some 40 000 hectares are surveyed each year to provide detailed working material for the authorities concerned, including data on soil and water conditions in a particular region, on optimum soil utilisation and possibilities of land improvement. In Northrhine-Westphalia some 335 soil consolidation projects on a total area of about 600 000 hectares have been dealt with in this way.

<u>4.2.</u> For pedological surveying of forest areas which may be under public or private ownership, soil maps on a scale of 1 : 10 000 are prepared. These special maps are indispensible for all aspects of forest planning, eg selection of

types of trees, clear-cutting potential, questions of afforestation and melioration. So far 115 000 hectares have been surveyed, which is about one seventh of the forest area of the land; the maps were put to the disposal of the authorities of the forest administration and to the Northrhine-Westphalia Institute for Ecology (Landesanstalt für Okologie, Landschaftsentwicklung und Forstplanung). Since forest areas play an increasingly dominant role in an environmental and recreational context, and considering the demands resulting from recent legislation, the Northrhine-Westphalia Minister for Food, Agriculture and Forestry recently charged the Geological Survey of this Land to undertake pedological surveying of the entire wood area of the Land (850 000 hectares).

4.3. In several Lands of the Federal Republic soil maps of different scales have been produced for very specific planning purposes, eg for suburban areas, vineyards, hop-culture areas, outline plans for the management of water resources, etc.

5. SOIL MAPS AS AN AID TO STUDYING SOIL/PLANT RELATIONSHIPS

For all studies relating to the soil as the habitat of plants, soil maps of 1 : 5 000 scale prepared for land purposes are to be used. Maps of this scale represent the results of a soil valuation for every parcel under tillage with due consideration of recent pedological research. Some 6 000 sheets of the 8 638 basic maps of the Land Northrhine-Westphalia have been subject to scientific investigation; 5 300 sheets have been published to date. In other Lands the soil valuation maps are being interpreted in a similar way.

6. FURTHER ACTIVITIES ON LAND RESOURCE EVALUATION

6.1. Land valuation

In 1934 legislation on the valuation of agricultural land was introduced. The aims of the legislation included an equitable basis for distribution of taxes, a basis for land use planning and an improved basis for the distribution of grants and loans to agriculture.

The soil valuation embraced:

(a) The precise identification and description of the soil and its nature and character. The results were represented on maps.

(b) The establishment of the productivity of the soil based on natural conditions of yields (soil properties, relief and climate). Differences in the yields depending on economical conditions were not included.

(c) Representative soils were selected for comparison to ensure a uniform soil valuation. A group of experts valued these and compared soils throughout the country by homogeneous terms of reference. Soil profiles were examined to a depth of 1.5 m.

(d) The soil valuation of the whole agricultural area of the Federal Republic of Germany was completed in 1952. It is important to remark that this soil valuation was carried out by a uniform method and therefore the results are comparable in the whole Federal Republic of Germany. The soil valuation is updated constantly by, eg, modification of land use, drainage, irrigation, impoldering and others. The heavy clay soils are undervalued 30% more than 25 years ago.

(e) A board of valuation consisting of four members was responsible for the soil valuation. Borings were made at a density of four/ha. All the soil profiles were recorded in a valuation book.

The soil value was based on:

Bodenart	(soil texture)
Entstehungsart	(geological origin)
Zustandsstufe	(degree of soil development)
Klima	(climate)
Oberflachengestaltung	(relief)
und noch andere Faktoren	(and other factors).

An arable evaluation framework (Table 1) was evolved. In this scale the best soil has a valuation index of 100 (Chernozem by Halle/Saale) and useless land has an index of 18. By using the arable evaluation framework the value figures are defined as soil base figures and the arable figure is obtained by considering other yield conditions, eg, slope, exposure and aspect.

The pasture index is estimated by a valuation framework for pasture. In this valuation the following factors are important:

Bodenart	(soil texture)
Zustandsstufe	(degree of soil development)
Klima	(climate)
Wasserverhaltnisse	(water conditions).

Using these factors it is possible to derive the pasture base figure by considering other yield conditions, eg, slope, exposure and aspect.

(f) The soil climate figure results from the arable figure, pasture figure and relief. The soil climate figure is useful for a regional comparison of the natural productivity in different areas. In Northrhine-Westphalia the soil climate figures for the communities have been represented on maps (Figure 1).

TABLE 1

VALUATION FRAME FOR ARABLE LAND

Soil Texture	Geological origin	Degree of soil development 1	2	3	4	5	6	7
S	D		41-34	33-27	26-21	20-16	15-12	11- 7
	Al		44-37	36-30	29-24	23-19	18-14	13- 9
Sl (S/lS)	D		51-43	42-35	34-28	27-22	21-17	16-11
	Al		53-46	45-38	37-31	30-24	23-19	18-13
	V			42-36	35-29	28-23	22-18	17-12
lS	D		59-51	50-44	43-37	36-30	29-23	22-16
	Lö		62-54	53-46	45-39	38-32	31-25	24-18
	Al		62-54	53-46	45-39	38-32	31-25	24-18
	V			50-44	43-37	36-30	29-24	23-17
	Vg				40-34	33-27	26-20	19-12
SL (lS/sL)	D		67-60	59-52	51-45	44-38	37-31	30-23
	Lö		72-64	63-55	54-47	46-40	39-33	32-25
	Al		71-63	62-55	54-47	46-40	39-33	32-25
	V		67-60	59-52	51-44	43-37	36-30	29-22
	Vg				47-40	39-32	31-24	23-16
sL	D	84-76	75-68	67-60	59-53	52-46	45-39	38-30
	Lö	92-83	82-74	73-65	64-56	55-48	47-41	40-32
	Al	90-81	80-72	71-64	63-56	55-48	47-41	40-32
	V		76-68	67-59	58-51	50-44	43-36	35-27
	Vg				54-45	44-36	35-27	26-18
L	D	90-82	81-74	73-66	65-58	57-50	49-43	42-34
	Lö	100-92	91-83	82-74	73-65	64-56	55-46	45-36
	Al	100-90	89-80	79-71	70-62	61-54	53-45	44-35
	V		82-74	73-65	64-56	55-47	46-39	38-30
	Vg				60-51	50-41	40-30	29-19
LT	D		78-70	69-62	61-54	53-46	45-38	37-28
	Al		82-74	73-65	64-57	56-49	48-40	39-29
	V		78-70	69-61	60-52	51-43	42-34	33-24
	Vg				57-48	47-38	37-28	27-17

TABLE 1 (Continued)

Soil Texture	Geological origin	Degree of soil development						
		1	2	3	4	5	6	7
	D			63-56	55-48	47-40	39-30	29-18
T	Al		74-66	65-58	57-50	49-41	40-31	30-18
	V			62-54	53-45	44-36	35-26	25-14
	Vg				50-42	41-33	32-24	23-14
Mo				45-37	36-29	28-22	21-16	15-10

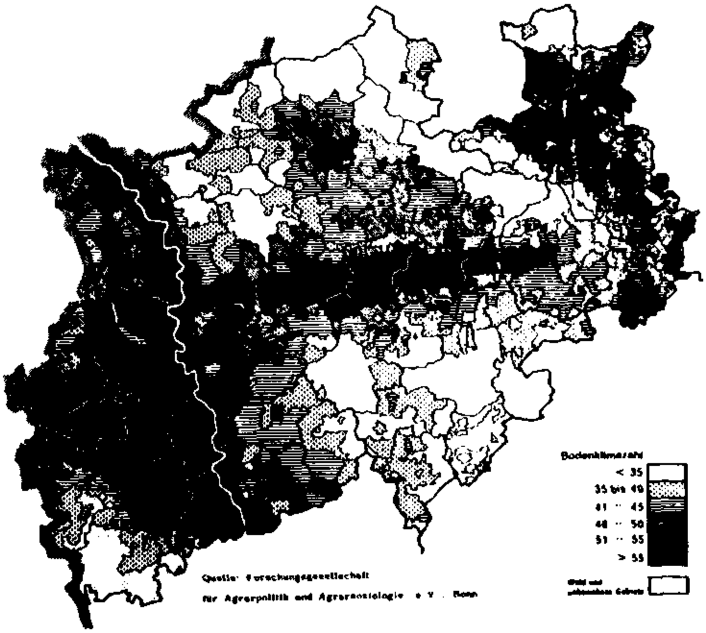

Fig. 1. Soil climate figures for Northrhine-Westphalia

6.2. The reallotment of land

The reallotment of land aims for improvement of agrarian structure.

Since the law on the reallotment of land was enacted in 1976, land reallotment is carried out uniformly by all states in the Federal Republic of Germany. Soil maps (1 : 5 000) are prepared by the Geologisches Landesamt, NRW, for this purpose. The improvement measures required for particular soils and their use suitability are described.

6.3. Research work in disadvantaged areas

There are two examples of such work:

(a) Soil mapping of the Ems-land

In the area of the River Ems, sand and bog soils are frequent. Before 1945 these soils were only cultivated to a small extent. After 1945 the area was made accessible for agriculture, to give the peasants coming from Eastern Germany new land. In a short time (1953 - 1963) the soil mapping of this area (240 000 ha) was completed by the Niedersächsisches Landesamt for soil science on a scale of 1 : 5 000 (584 sheets). The whole work was published and is useful for reclamation purposes, especially for podzols and bogs. This soil map is the basis for a land improvement map with information on drainage by ditches or drains, distances of the drains and deep ploughing.

(b) Geological-pedological mapping of the marsh land at the North Sea coast (scale 1 : 5 000)

In connection with a plan for coast protection at the North Sea the Niedersächsisches Landesamt for soil science made a geological-pedological map of the marsh soils at the coast of Niedersachsen (scale 1 : 5 000). Marsh soils must be drained, but the drainage is complicated. At the same time soil physical and chemical studies were carried out. Through soil mapping and supporting laboratory research a land improvement map was prepared: for example, drain depth and drain distance were represented. The most suitable land use for these difficult soils is shown on the map. A similar soil map (1 : 5 000) of the marsh areas at the west coast of Schleswig-Holstein and of the river low ground was produced by the Geologisches Landesamt Schleswig-Holstein. This map is useful for the improvement of the important agricultural soils.

6.4. Planning maps

For many years some states of the Federal Republic of Germany have produced planning maps.

Recently land use maps have been prepared for some states, eg, Württemberg and Hessen. At present Hessen is preparing such a map (1 : 50 000). The following aspects are represented:

1. areas of different agricultural land use;
2. areas with land use regulations (zoning);
3. areas requiring protection (nature conservation);
4. reclamation areas.

These are examples; there are also other land use maps.

SOIL SUITABILITY FOR HORTICULTURAL CROPS IN BELGIUM

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1. INTRODUCTION

With the financial support of the Institute for Encouragement of Scientific Research in Industry and Agriculture (Brussels), the Study Centre for Horticultural Soils of the Catholic University of Leuven for more than 10 years has made systematic investigations on soil suitability, *sensu largo*, for the most important field and greenhouse crops.

The principal basis of the investigations is information from production units under normal cultivation conditions. The procedure includes three steps.

2. PRELIMINARY SURVEY

This is needed to obtain information on specific phytotechnical aspects of a given crop and on the parameters for an appropriate quantitative and qualitative description of the final product. It provides a preliminary screening of fields to be selected for study.

Tomato parameters for example, are easily recorded and weight, size and colour determined. However, for crops such as strawberry or asparagus this is not the case. For strawberries the final production is estimated from the number of flowers; for asparagus, production is predicted from the summation of stem diameters. The procedure includes statistical analysis of data from a limited number of plots.

3. FIELD SURVEY

A large number of fields are surveyed (100 and more per year). On each of them a small plot is chosen at random. The soil series, as indicated on the soil map, is examined by means of a hand auger to a depth of 120 cm. Classes of texture and drainage, and other relevant profile characteristics are recorded; a sample is also taken for analysis.

With the help of the growers, plant development is observed. The data for the quantitative and qualitative characterisation of the harvested crop are collected, including results of chemical analysis of the plant. This investigation is done for at least four consecutive years to include climatological effects.

4. STATISTICAL CALCULATIONS AND INTERPRETATION

The data are processed statistically, which includes regression analysis, factor analysis and computation of the correlation matrix.

It is possible to elucidate the influence of different soil properties on yields and to establish soil suitability classes with a list of the soil series as represented on the soil maps.

It is also possible to calculate optimal soil fertility conditions and optimal plant chemical composition for improving yields. An example is given of a correlation matrix for tomatoes grown in an open field on sandy soils (Tables 1 and 2); of the factor analysis and the optima (Tables 3 and 4); the productivity classes (Table 5) and of the optima (Table 6).

TABLE 1

CORRELATIONS BETWEEN PRODUCTION AND CHARACTERISTICS OF SOIL AND CROP (135 PLOTS).
$r = 0.222$ for $p = 0.01$; $r = 0.169$ for $p = 0.05$; + or - indicates positive or negative slight correlations for $r = 0.100 - 0.168$; ns = not significant for $r < 0.100$

Characteristics of soil and crop		Real production	Quality production	Production per class			
				AA	A	B	C
Quality production		0.936					
Production per	AA	0.517	0.714				
size class	A	0.810	0.919	0.529			
	B	ns	-0.259	-0.592	-0.384		
	C	-	-0.413	-0.513	-0.542	0.583	
Texture		+	0.281	0.293	0.312	-0.313	-0.252
Drainage		ns	ns	-	ns	ns	0.199
Profile development		ns	+	-	-	0.204	0.171
Nutrient status	K	-	-0.199	-0.323	-	0.254	0.278
of the soil	Ca	-	ns	ns	ns	ns	ns
	Mg	+	0.177	+	0.236	-0.234	-0.184
	P	ns	-0.190	-0.264	-0.232	0.290	0.425
	pH	+	ns	ns	ns	ns	+
	Salt concentration	+	0.228	0.170	0.316	-0.254	-0.325
Mineral composition	K	ns	-0.201	-	-0.280	0.203	0.327
of the fruit	Ca	0.313	0.440	0.416	0.447	-0.267	-0.493
	Mg	+	0.193	0.199	0.186	-	-0.253
	P	+	-	-0.201	-0.243	0.492	0.486
	Na	-	ns	ns	+	-0.224	-0.384
	Mn	-	-0.262	-0.284	-0.335	0.401	0.362
	N	0.299	0.271	+	0.201	ns	ns

TABLE 1 (Continued)

Characteristics of soil and crop		Real production	Quality production	Production per class			
				AA	A	B	C
Mineral composition of the middle leaves	K	+	+	0.175	+	-	ns
	Ca	ns	ns	ns	ns	ns	+
	Mg	ns	-	-	-	0.195	0.265
	P	-	-0.243	-0.214	-0.321	0.284	0.374
	Na	-0.276	ns	+	ns	-0.444	-0.392
	Mn	ns	-0.184	-0.227	-0.254	0.345	0.331
N content of the leaves	Lower	+	0.218	0.255	0.271	-0.343	-0.291
	Middle	+	+	+	+	ns	-
	Upper	ns	ns	ns	ns	ns	-

TABLE 2

CORRELATIONS BETWEEN QUALITY ASPECTS AND CHARACTERISTICS OF SOIL AND CROP (135 PLOTS)
r = 0.222 for p = 0.01; r = 0.169 for p = 0.05; + or - indicates positive or negative slight correlations for r = 0.100 - 0.168; ns = not significant for r < 0.100

Characteristics of soil and crop		Colour		Appearance of diseases	
		Lycopene	Carotene	Botrytis	Phytophthora
Real production		0.219	ns	-0.245	-
Quality production		0.258	-0.190	-	-
Production per size	AA	+	-0.260	+	ns
class	A	0.278	-0.239	ns	ns
	B	ns	0.321	-0.389	-
	C	-	0.356	-0.292	-
Texture		+	-0.241	0.227	ns
Drainage		ns	ns	-	-
Profile development		ns	ns	+	0.221
Nutrient status	K	+	ns	-0.261	-
of the soil	Ca	ns	ns	0.206	ns
	Mg	0.178	-0.171	ns	ns
	P	+	+	-0.413	-0.209
	pH	ns	ns	ns	ns
	Salt concentration	0.214	-0.365	0.266	ns
Mineral composition	K	-0.386	+	0.294	+
of the fruit	Ca	0.287	-0.289	ns	ns
	Mg	ns	-	+	+
	P	-	0.380	-0.494	-
	Na	+	-0.243	0.255	0.190
	Mn	-	0.372	-0.187	ns
	N	+	ns	-0.391	ns

TABLE 2 (Continued)

Characteristics of soil and crop		Colour		Appearance of diseases	
		Lycopene	Carotene	Botrytis	Phytophthora
Mineral composition of the middle leaves	K	-	-0.178	0.341	0.175
	Ca	ns	0.177	-0.229	-
	Mg	ns	+	ns	ns
	P	-	+	-0.188	ns
	Na	-	-0.228	0.685	0.310
	Mn	-0.194	0.210	-	ns
N content in the leaves	Lower	+	-0.276	0.225	ns
	Middle	ns	-0.195	+	ns
	Upper	ns	ns	ns	ns

TABLE 3

RESULTS OF THE FACTOR ANALYSIS. FACTOR-LOADINGS FOR THE 7 COMPUTED FACTORS ACCORDING TO THE METHOD OF THE PRINCIPLE COMPONENTS (135 OBSERVATIONS)

Main variables		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Real production		-0.225	0.118	0.670	-0.059	0.546	-0.141	-0.073
Quality production		-0.498	0.095	0.671	-0.092	0.445	0.053	-0.092
Production per	AA	-0.608	-0.043	0.407	-0.221	0.298	0.210	-0.115
size class	A	-0.597	0.112	0.594	-0.037	0.291	-0.081	-0.083
	B	0.714	0.046	-0.021	0.139	0.089	-0.343	0.129
	C	0.770	0.104	-0.201	0.115	0.178	0.016	-0.030
Colour value	Lycopene	-0.210	0.395	0.409	0.174	-0.295	0.129	0.063
	Carotene	0.495	-0.145	-0.117	-0.291	0.180	-0.047	-0.141
Number of fruits	Botrytis	-0.530	-0.318	-0.536	0.104	0.036	0.156	0.028
affected by	Phytophthora	-0.191	-0.211	-0.303	0.078	0.014	0.023	0.212
Soil texture		-0.512	0.304	-0.140	-0.006	0.155	-0.126	-0.135
Nutrient status	K	0.265	0.582	-0.096	0.514	-0.018	-0.164	0.082
of the soil	Ca	-0.144	0.496	-0.529	-0.065	0.302	0.190	-0.098
	Mg	-0.344	0.615	-0.096	0.028	0.124	0.165	0.148
	P	0.500	0.568	0.064	0.076	-0.130	0.329	-0.097
	pH	0.020	0.528	-0.254	-0.444	0.352	0.044	0.030
	Salt concentration	-0.498	0.267	-0.065	0.554	0.122	-0.106	0.053
Mineral composition	K	0.197	-0.193	-0.471	0.171	0.586	0.046	0.026
of the fruit	Ca	-0.511	0.051	0.377	-0.020	-0.102	-0.131	0.130
	Mg	-0.230	-0.229	0.242	0.065	0.042	-0.088	0.390
	P	0.715	0.039	0.316	-0.048	0.209	0.073	0.073
	Na	-0.449	-0.017	0.093	-0.050	-0.413	-0.210	0.082
	Mn	0.562	-0.451	0.008	0.053	0.132	0.033	0.067
	N	0.145	0.096	0.533	-0.108	0.104	-0.112	-0.050

TABLE 4 (Continued)

Main variables		Mean M	Factor 1 M - 2S	Factor 2 M + 2S	Factor 3 M + 2S	Factor 5 M + 2S	Deduced optima
Mineral composition	K	99.2	111.1	87.4	95.4	118.1	105.4
of the middle leaves	Ca	242.6	219.0	293.1	237.1	233.1	233.8
(see fruit)	Mg	50.8	40.8	60.5	52.3	49.7	48.7
	P	54.4	72.8	51.3	57.8	54.0	60.8
	Na	8.3	16.9	5.8	0.6	6.6	7.2
	Mn	24.1	6.3	4.3	29.4	25.5	20.2
N content in the leaves	Lower	161.4	184.2	152.7	169.2	157.6	169.6
(meq)	Middle	230.0	239.2	210.9	239.8	236.3	237.1
	Upper	283.2	287.9	280.9	289.2	274.7	284.5
Factor weight			0.498	0.095	0.670	0.445	

TABLE 4

RESULTS OF THE FACTOR ANALYSIS. MEAN (M), TABULATED OPTIMA PER FACTOR (M ± 2S) AND DEDUCED OPTIMA VALUES (135 PLOTS AND 65 VARIABLES)

Main variables		Mean M	Factor 1 M - 2S	Factor 2 M + 2S	Factor 3 M + 2S	Factor 5 M + 2S	Deduced optima
Production (kg/10 plants)							
Real production		21.913	24.237	23.132	28.847	27.555	26.845
Quality production		18.687	24.401	19.957	26.377	23.794	23.660
Production per size class	AA	2.385	5.377	2.188	4.396	3.847	4.421
	A	10.905	16.616	11.952	16.521	13.675	15.551
	B	5.693	2.313	5.932	5.598	6.117	4.793
	C	2.568	0.176	2.879	1.947	3.121	1.788
Colour value	Lycopene	76.0	79.0	82.5	82.7	71.0	78.5
	Carotene	13.8	6.8	11.7	12.2	17.3	11.9
Number of fruits affected by	Botrytis	3.4	10.0	0	0	3.4	3.8
	Phytophthora	0.3	0.8	0	0	0.3	0.3
Soil texture		1.98	2.65	2.38	1.80	2.19	2.18
Nutrient status of the soil (mg/100 g)	K	39.7	29.5	62.4	35.8	39.0	36.3
	Ca	70.0	79.8	105.0	32.8	91.5	65.8
	Mg	11.1	15.8	19.6	9.7	12.8	12.8
	P	48.1	28.7	70.0	50.4	43.1	43.3
	pH	5.70	5.70	6.10	5.50	6.05	5.71
	Salt concentration	202	335	274	187	234	238
Mineral composition of the fruit (meq/100 g DM) (Mn in mg)	K	93.6	88.1	88.4	80.8	109.5	90.8
	Ca	7.3	10.5	7.6	9.6	6.6	9.0
	Mg	11.3	12.0	10.6	12.0	11.4	11.8
	P	47.4	32.1	48.2	54.2	51.8	46.8
	Na	1.8	2.4	1.7	1.6	1.2	1.7
	Mn	2.2	0.6	0.9	2.2	2.5	1.7
	N	172.2	165.8	176.9	196.8	177.0	181.5

TABLE 3 (Continued)

Main variables		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Mineral composition of the middle leaves	K	-0.282	-0.275	-0.086	0.518	0.446	0.112	-0.061
	Ca	0.206	0.453	-0.046	-0.334	-0.085	-0.174	-0.308
	Mg	0.331	0.321	0.052	-0.132	-0.038	0.160	0.435
	P	0.599	-0.095	0.113	0.132	-0.038	0.515	0.011
	Na	-0.625	-0.180	-0.561	0.027	-0.125	0.085	-0.078
	Mn	0.509	-0.568	0.146	0.335	0.041	-0.054	-0.163
N content in the leaves	Lower	-0.443	-0.172	0.146	0.221	-0.073	0.289	-0.011
	Middle	-0.165	-0.568	0.170	0.384	0.109	0.264	0.065
	Upper	-0.091	-0.052	0.126	0.261	-0.184	0.053	-0.014

TABLE 5

DISTINCTION INTO PRODUCTIVITY CLASSES, AVERAGE NUTRIENT CONDITIONS PER CLASS AND SIGNIFICANCE OF DIFFERENCES

Classes		1	2	3	4	F-value
Quality production in kg/10 plants		> 25 kg	20-24.999	15-19.999	< 15 kg	
Number of plots		12	32	46	48	
Average quality production		27.845	22.020	17.110	12.247	
Nutrient status (mg/100 g) of the soil	K	25.0	39.0	38.6	46.8	3.58 x
	Ca	71.2	64.2	67.5	77.5	0.70
	Mg	16.1	9.8	10.9	11.1	2.65
	P	33.1	49.8	48.3	50.5	1.74
	pH	6.03	5.63	5.64	5.75	2.42
	Salt concentration	237	232	190	185	1.07
N content (meq)	Middle leaves	236.4	239.1	223.7	229.3	2.67 x
	Fruit	181.0	179.3	167.2	168.0	2.70 x

For d.f. 3 and 134, $F_{.01} = 3.93$; $F_{.05} = 2.67$

TABLE 6

COMPARISON OF THE OPTIMA OBTAINED FROM PRACTICE AND THE CALCULATED OPTIMA

	Nutrient status of soil						N content	
	K	Ca	Mg	P	pH	Salt concentration	Middle leaves	Fruit
Mean (Table 4)	39.7	70.0	11.1	48.1	5.70	202	230.0	172.2
Deduced optima (Table 4)	36.3	65.8	12.8	43.3	5.71	238	237.1	181.5
Top data from practice (Table 5)	25.0	71.2	16.1	33.1	6.03	237	236.4	181.0

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LAND EVALUATION RESEARCH IN IRELAND AND A TENTATIVE EVALUATION OF EEC LAND FOR FORAGE PRODUCTION

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INTRODUCTION

The basic programme of land resource appraisal in Ireland has operated at three levels of organisation:-

1. Detailed studies of experimental stations and also extension experimental sites (1 : 2 500).
2. Detailed reconnaissance studies of counties (1 : 126 720) where the soil series is the unit of mapping.
3. A combination of detailed reconnaissance and general reconnaissance to arrive at a national picture (General Soil Map of Ireland, 1969) (1 : 575 000). The soil association is the unit of mapping.

The major emphasis in the soil survey programme is directed to detailed reconnaissance mapping on a county basis. Soil mapping is carried out on maps of 1 : 10 560 scale, which are reduced to 1 : 126 720 for publication. In the absence of air photos, they were not used in the past. However, these are now becoming available and increasing use will be made of them in the future, particularly in the hill and mountain zones.

Some 40% of the country has been surveyed and mapped to date. Complete reports on seven out of twenty-six counties have been published together with reports on a number of regions and districts. Some field work has also been carried out in seven other counties.

SOIL PRODUCTIVITY ASSESSMENT

Three essentially different approaches are adopted in assessing productivity:

(i) Sample harvestings on well managed farms (Table 1);

(ii) Study of accurate yield records on well managed farms (Table 2); and

(iii) Extrapolation of pasture dry matter and animal production data from experimental sites to analagous areas (grassland) thus enabling the preparation of grazing capacity maps.

TABLE 1

GRAIN YIELDS OVER FIVE YEARS FROM EACH SOIL SERIES (t/ha)

Soil Series	1964	1965	1966	1967	1968	Mean	CV (%)
Clonroche A	3.35	3.57	3.85	4.61	5.32	4.16	20.2
Clonroche B	2.99	2.78	4.16	4.94	5.81	4.13	30.4
Screen	2.68	2.80	3.62	4.66	5.48	3.84	31.3
Rathangan	2.36	2.79	3.28	4.22	4.86	3.50	33.0
Macamore	2.23	2.90	3.10	5.16	5.68	3.81	39.7

TABLE 2

SUGAR YIELDS (t/ha) BY SOIL SERIES 1964 - 1965

Soil Series	1964		1965		Mean sugar yield
	Sugar yield	Sugar percent	Sugar yield	Sugar percent	
Broadway	8.28	18.0	8.03	16.4	8.16
Clonroche A	7.00	17.4	7.08	16.4	7.04
Clonroche B	5.15	16.2	5.30	15.9	5.23
Screen	5.60	16.2	5.62	16.0	5.61
Rathangan	4.84	16.9	5.55	15.8	5.20

RELATIONSHIP BETWEEN SUGAR BEET YIELDS, SOIL ASSOCIATION AND CLIMATIC FACTORS

The Irish Sugar Company provided the average sugar beet yield for each sugar beet loading area in Ireland for 1966 - 1968 and maps showing the boundaries of the loading areas. These enabled yields to be studied in relation to soil distribution as shown on the Soil Map of Ireland (1 : 575 000) (Table 3).

The yields presented in Table 3 are an index of the performance record (average yield) of each soil association.

TABLE 3

NUMBER OF SUGAR BEET LOADING AREAS IN EACH SOIL ASSOCIATION WITH AVERAGE YIELDS AS INDICATED (AVERAGE 1966 - 1968)

Soil Association		Yield Category (t/ha)				
Soil assoc. No.	Principal soil in the association	< 37.2	32.7 to 35.2	35.2 to 37.7	37.7 to 40.2	40.2 to 42.7
7	Acid Brown Earths (Dystrochrepts)	-	-	-	5	3
9	Brown Podzolics (Normorthods)	-	-	3	9	4
8	Acid Brown Earths (Dystrochrepts)	-	-	7	4	1
23	Shallow Brown Earths (Eutrochrepts)	-	2	4	2	-
24	Grey Brown Podzolics (Hapludalfs)	2	8	11	5	-
21	Grey Brown Podzolics (Hapludalf-Eutrochrept)	-	-	11	1	2
20, 22	Grey Brown Podzolics (Eutrochrept-Glossudalf)	5	5	-	-	-
13	Gleys (Umbraquepts)	6	-	-	-	-

Figure 1 shows the geographic distribution of yields in the country and Table 4 lists a number of climatic parameters representative of the yield zones.

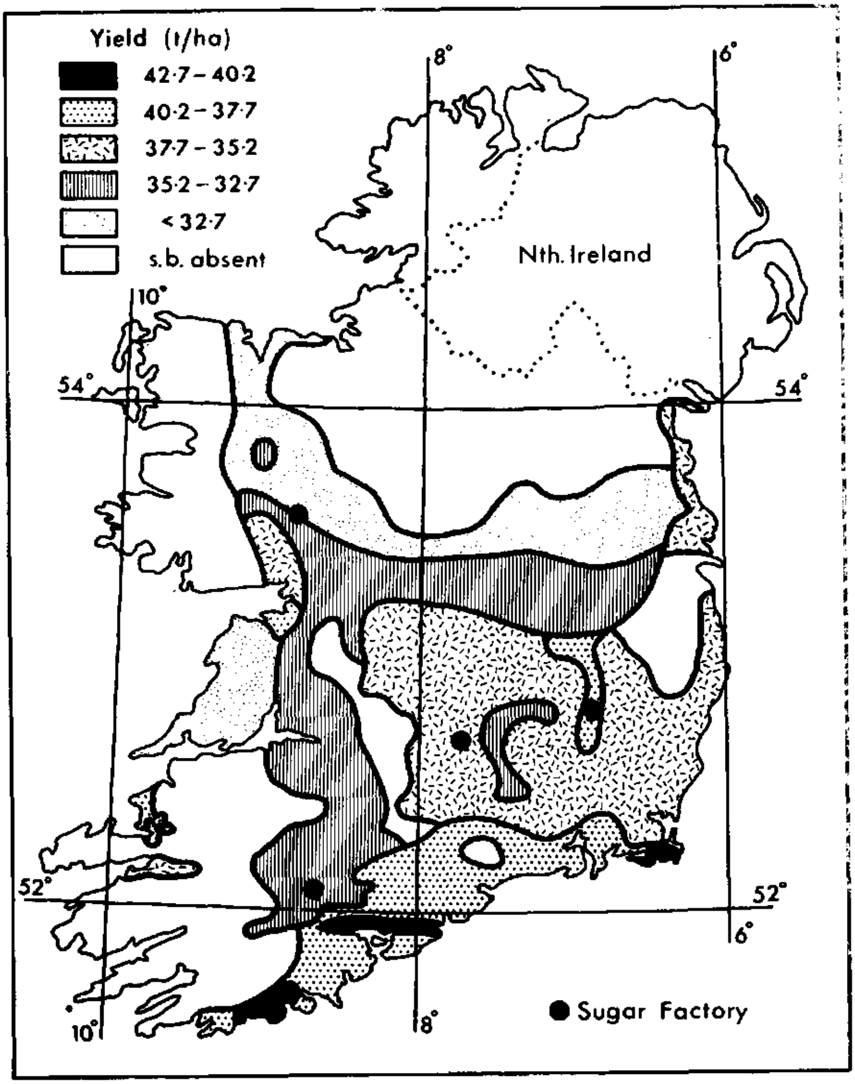


Fig. 1: Geographic distribution of sugar beet yields in Ireland (average 1966 - 1968)

TABLE 4

CLIMATIC PARAMETERS OF MAJOR YIELD ZONES

Climatic parameter	Yield zone (t/ha)				
	< 32.7	32.7 to 35.2	35.2 to 37.7	37.7 to 40.2	40.2 to 42.7
Accumulated degree days above 40°F (Feb-Apr)	430	480	-	-	520-570
Accumulated degree days above 40°F (Mar-Sept)	2625	2780	-	-	2900-2945
Mean daily global solar radiation (cal/cm^2) June	430-440	440-460	450-500	450-500	490-520
Mean daily global solar radiation (cal/cm^2) June-Aug	370-390	380-400	400-420	410-430	420-450
Average growing season rainfall (mm) (Mar-Sept)	470-600	440-500	440-500	440-600	440-560
Mean date of last spring frost	May 15	May 1 - May 15	Apr 1 - May 15	Mar 15- Apr 1	Mar 1- Mar 15

PASTURE PRODUCTION

In pasture production it was shown that soil wetness is a major limitation in livestock intensification and at the other end of the scale, soil moisture stress is also a limitation but of lesser magnitude. The average grazing capacity of the three categories of lowland mineral soils is shown in Table 5.

DIFFICULT LAND AREAS

The extent of difficult farming land in the country is shown in Table 6. These areas are included under EEC Directive 268 (Disadvantaged Areas).

TABLE 5

AVERAGE GRAZING CAPACITY OF MAJOR CATEGORIES OF LOWLAND

	Grazing capacity LU/100 ha	
Major land unit	48 kg N/ha	230 kg N/ha
Dry	217	272
Wet A[1]	173	212
Wet B[2]	143	-

[1]Wet A = Wet components of the Carboniferous Limestone, Sandstone and Ordovician Shale soils

[2]Wet B = Wet soils occurring on drumlins and Carboniferous Shales.

TABLE 6

EXTENT OF DIFFICULT FARMING LAND IN IRELAND

Land Unit	Extent (million ha)	Percent of country
Wet mineral lowland (Wet B)	0.74	11.1
Mountain and hill	1.47	22.1
Lowlevel peat	0.78	11.7
Total	2.99	44.9

The problems of these areas were highlighted and research into land improvement described with particular reference to land improvement capability classifications.

SOME EXAMPLES OF SOIL SURVEY APPLICATION

Examples of soil survey application were cited under the following headings:

1. Regional agricultural planning.
2. Quantifying the land reclamation requirements of the country.

3. Delineating disadvantaged areas (EEC Directive 268).
4. Cost/benefit analysis of arterial drainage.
5. Assessing technical capacity of farms for livestock production.
6. Basis for forestry/farming comparison in difficult land areas.
7. Improving understanding of soil fertility problems.

INITIAL WORK ON EEC LAND EVALUATION

Using a similar methodology to that used in the preparation of a grazing capacity map for Ireland, a similar approach was adopted to derive the first approximation to an EEC Land Capability Map for Forage Production. In preparing the map (1 : 5 000 000) existing land use and land utilisation types were not considered and socio-economic factors were also excluded.

The forage output data from experimental sites throughout the EEC were extrapolated to analagous areas defined by soil and climate. Obviously experimental data were not available for all the ecologic zones of the EEC, but this problem was overcome by the process of interpolation. The major climatic parameter used was annual maximum precipitation deficit. This information was available in cartographic form and by superimposing the soil map, topographic map, climatic map and by taking into consideration the productivity data, it was possible to derive the land capability map. Ten land classes were shown on the map which attempted to place in focus regional land capability for forage production.

Existing limitations were implicit in the classification system. The classification did not take into account the improved productivity that is possible in many areas through irrigation or reclamation. The main exception here was in Italy, where dry matter yields for well fertilised maize of

15 000 - 18 000 kg/ha were recorded in well irrigated or in natural water regions. Thus the Po Valley was included in the best land capability class because of the exceptional quality of the land and the presence of irrigation infrastructure which must contribute to the exceptionally high yields attainable in this region. In Ireland and the UK drainage of wet land was assumed. The map accompanies this summary report.

EVOLVING A LAND USE RESEARCH STRATEGY

A conceptual representation of the many interacting components in an analytical approach to evolving a future research strategy for the Land Use and Rural Resources Group was attempted (Figure 2). It was pointed out that while the Group already had a mandate to quantify the land use capability of the EEC's land resources, consideration of the other components in Figure 2 was considered necessary to provide guidelines on the other activities which the Group might profitably undertake to meet the socio-structural objectives of the EEC's CAP and also other objectives of the EEC relating to environmental and regional planning.

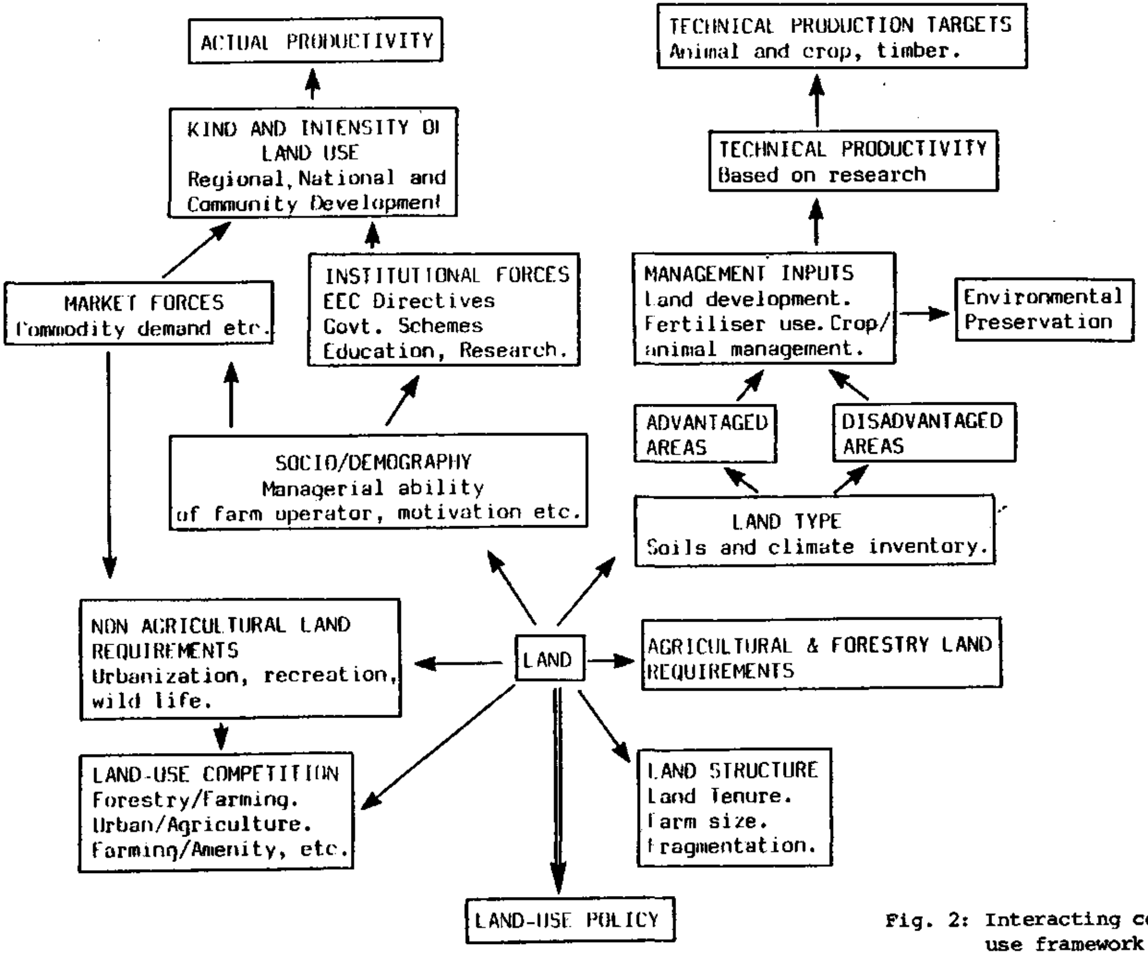
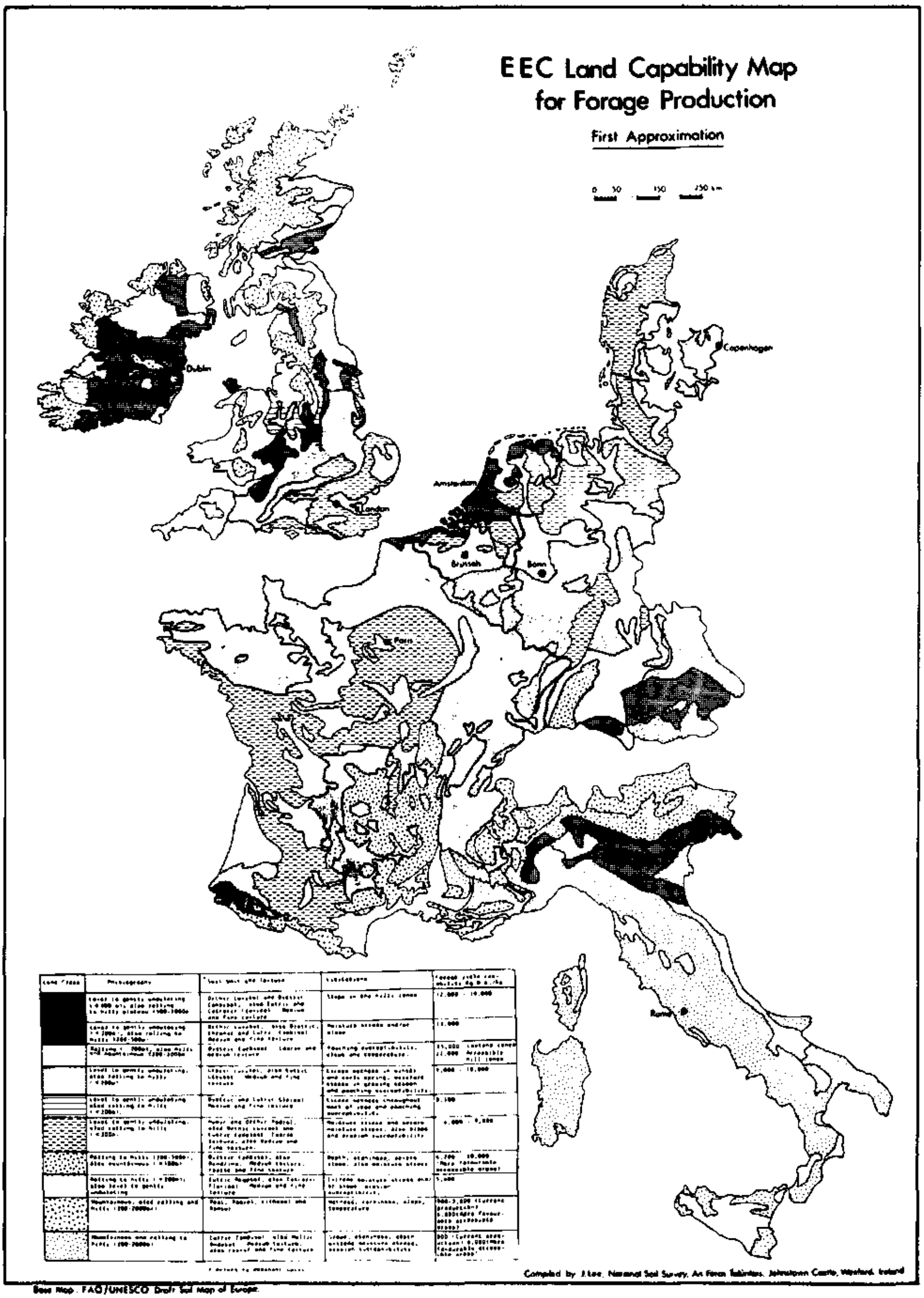
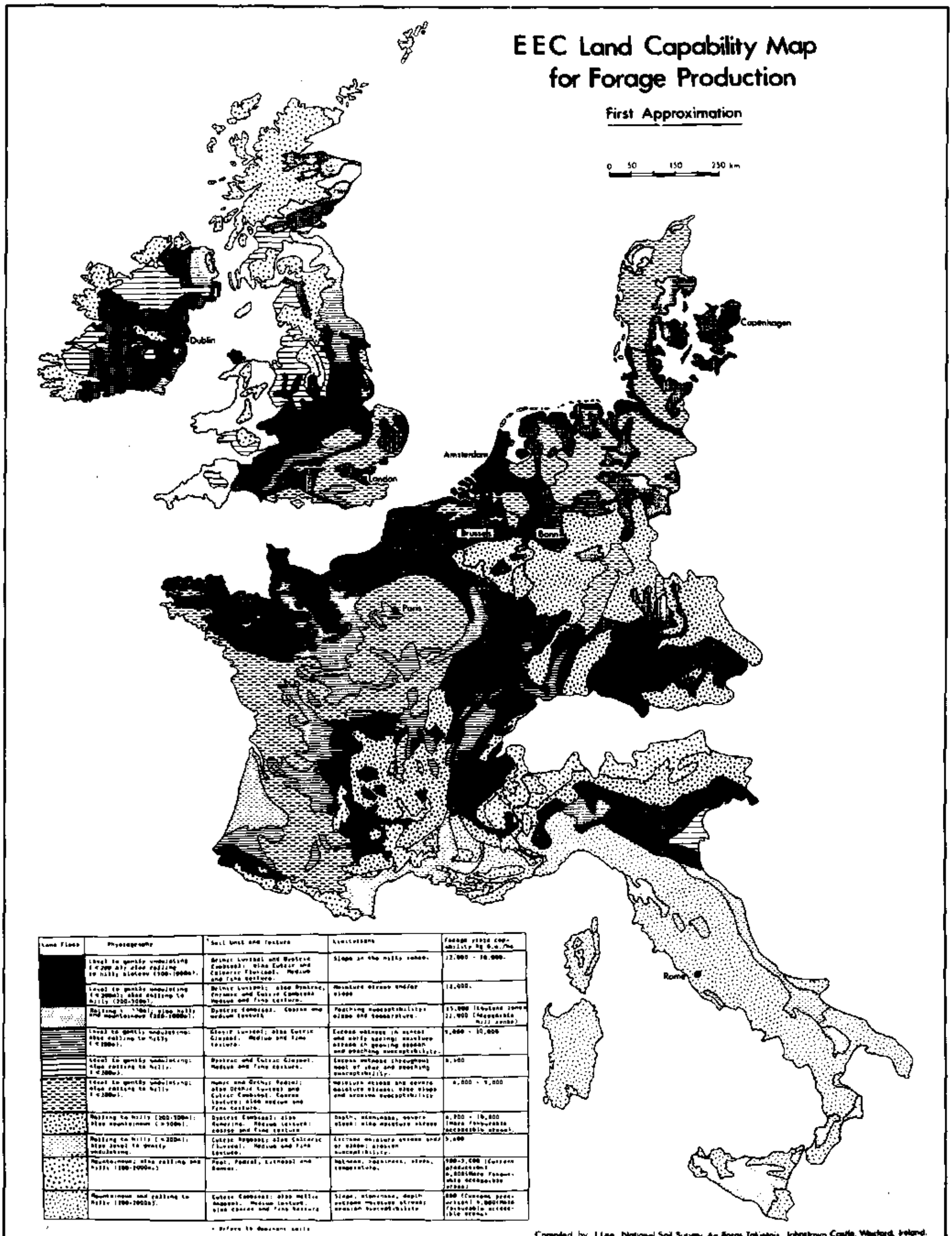


Fig. 2: Interacting components in a land use framework



Base Map: FAO/UNESCO Draft Soil Map of Europe.



Base Map: FAO/UNESCO Draft Soil Map of Europe.

LAND SUITABILITY EVALUATION SYSTEM FOR IRELAND

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QUANTITATIVE SUITABILITY CLASSIFICATION

A widely used system for the interpretation of soil survey data from the point of view of land classification consists of assessing the capacity of each soil unit for permanent sustained production and arranging the units according to the USDA System of Land Capability Classification. This is a standard eight class system in which classes I to IV are suited to cultivated crops, classes V to VII are suited to grazing and forestry and class VIII is suited only to wildlife.

The USDA system emphasises the adaptability of a soil for a range of uses and implies a hierarchy of use capacity, viz. cropping, grazing, forestry. In relation to land use practice in Ireland this hierarchy is not relevant as the priority use of land is dairy livestock production which has a large grazing component. Since economic priorities change with time, value judgements based on economic criteria should be excluded as far as possible from a technical land classification.

The system recently adopted in Ireland is to evaluate the degree of suitability of each soil unit for a set of uses, viz. cultivation and grassland, where all types of use have equal rank. This system could be extended to include suitability for forestry or urban development where appropriate. Choice of optimum use of a soil unit could be derived at any time from the suitability classification by assigning a weighting to each type of use based on the prevailing economic circumstances.

Soil suitability depends largely on the physical properties of the soil and the environment. These are rarely ideal and the limitations affect productivity and cultural practices. The degree of limitation is assessed from such factors as wetness (w), drought (d), liability to flooding (f), slope (s), rockiness (r), boulders (b), textural and structural properties affecting tilth and susceptibility to poaching (p). On the basis of these factors the soils are grouped in five classes designated A, B, C, D, and E for grassland, and I, II, III, IV and V for cultivation. Productivity is the dominant criterion in the ranking of suitability for grassland and the suitability classes A, B, C, D, and E parallel the grazing capacity of the soils. There is an implied quantitative hierarchial order in the grassland suitability classes intuitively derived from productivity information from bench-work experimental sites. In the case of cultivation, the dominant criterion is the effect of soil properties on the ease of cultivation.

In the legend the suitability classes are divided into sub-classes by principal limiting factor. Sub-classes are indicated by a subscript which indicates the type of limitation, for example, w = wetness, s = slope, etc. The degree of limitation increases from the higher to the lower categories.

Every map separation can be represented by the class letter for grassland, the class number for cultivation and the subscript letter for kind of dominant limitation, eg, (i) A I d indicates class A for grassland, Class I for cultivation and liability to drought as the dominant limitation; (ii) C III w indicates class C for grassland, Class III for cultivation and wetness as the dominant limitation.

SUITABILITY CLASSES

The approach adopted is illustrated in Table 1.

Although there may be diversity in the type of limitation applicable to soils within any suitability class, nevertheless the soils in any one class have sufficient important characteristics in common in their use potential to warrant their

TABLE 1

SOIL SUITABILITY FOR GRASSLAND AND CULTIVATION - CO. WESTMEATH

Suitability class		Sub-class	Mapping unit
Grassland[1]	Cultivation[2]	Principal[3] limitation	
A	I	d	Patrickswell (part of)
	II	s	Baggotstown, Patrickswell (part of)
	II	t	Elton, Mortarstown, Rathowen, Rathowen Cherty Phase, Patrickswell-Rathowen Complex
B	II	s	Patrickswell-Baggotstown Complex, Patrickswell-Baggotstown-Elton Complex, Ladestown, Patrickswell-Ladestown Complex, Ladestown-Rathowen Complex
	III	s	Baggotstown-Crush Complex (part of), Rathowen-Ladestown-Rathowen Complex
		f	Milltownpass
C	III	w	Mylerstown, Howardstown, Howardstown-Baggotstown Complex, Clonaast, Banagher, Gortnamona
	IV	w	Ballyshear-Patrickswell Complex, Camoge, Howardstown-Patrickswell Complex
	V	s	Baggotstown-Crush Complex (part of)
		b	Patrickswell Bouldery Phase
D	IV	w	Ballyshear, Street, Coolalough, Drombanny
	V	r	Ballinacurra
E	V	r	Burren, Knockeyon
		w	Allen, Turbary, Pollardstown
Variable			
BII & CIV		s, w,	Ladestown-Rathowen-Banagher Complex
BII & EV		s, w,	Finnea-Banagher-Allen Complex

[1]Grassland: A = very good, B = good, C = moderate, D = poor, E = very poor
[2]Cultivation: 1 = very good, 2 = good, 3 = moderate, 4 = poor, 5 = very poor
[3]d = drought, w = wetness, s = slope, b = boulders, f = liability to flooding, r = rockiness, t = textural and structural properties affecting tilth and susceptibility to poaching

inclusion in the same class. The type of limitation is specified at sub-class level and the geographic distribution of the sub-class is shown in the soil suitability map (1 : 126 000). Implicit in the classification is that the degree of limitation becomes more pronounced as one progresses down the scale of suitability classes.

The climatic factor is also taken into account where relevant. For example, in Westmeath relatively low solar radiation militates against crops such as sugar beet and results in late ripening of wheat crops.

QUANTITATIVE SUITABILITY CLASSIFICATION

For tillage crops such as sugar beet and wheat the approach adopted was to select 10 farms under a good level of management on each soil series and make sample harvestings to estimate yield (cereals) or study accurate yield records (sugar beet).

For grassland, estimates of potential productivity are obtained from stocking rate experiments at the experimental stations of An Foras Taluntais and from pasture dry matter output from cutting experiments on selected soils throughout the country.

The output data necessary for evaluation are extrapolated from these sites to analogous areas defined by soil and climate. The evaluation is based on the hypothesis that land or soil classes similar to those occurring on the experimental sites will respond similarly to management techniques for animal production. The method, therefore, is based upon the concept of transfer by analogy.

Figure 1 shows the relationship between stocking rate and percentage dry land under experimental conditions. Figure 2 shows the relationship for the range of soil drainage classes in the country.

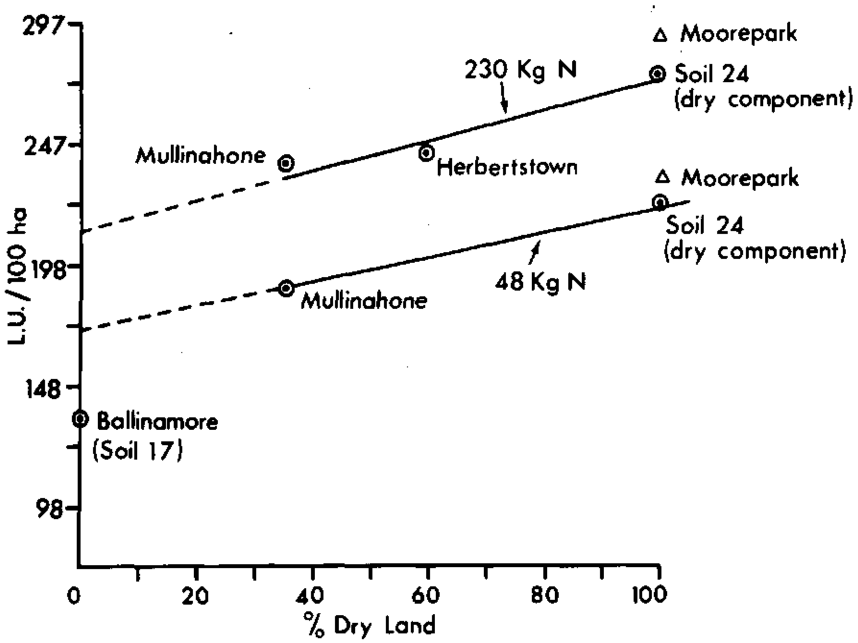

Fig. 1: Stocking rate achieved under experimental conditions in relation to percentage dry land

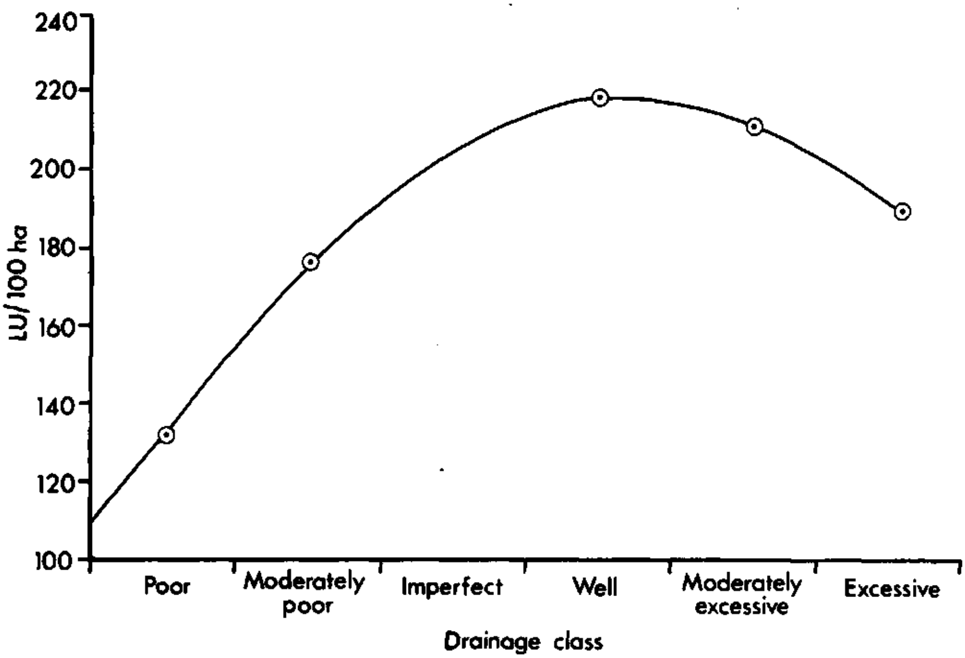

Fig. 2: Effect of drainage status of soil on stock carrying capacity

Table 2 shows the legend accompanying the grazing capacity map of Ireland.

TABLE 2

LEGEND FROM GRAZING CAPACITY CLASSIFICATION OF IRELAND[1]

LU/100 acres		Grazing	LU/100 ha	
43 lb N/acre	206 lb N/acre	Capacity class	48 kg N/ha	230 kg N/ha
≥ 90	≥ 112	A_1	≥ 222	≥ 276
85-90	107-112	A_2	210-222	264-276
80-85	102-107	B_1	197-210	252-264
75-80	92-102	B_2	185-197	227-252
70-75	82-92	C_1	173-185	202-227
65-70	72-82	C_2	160-173	188-202
60-65	-	D_1	148-160	-
55-60	-	D_2	135-148	-
< 55	-	E	< 135	-
		Unclassified	-	-

[1] Source: Lee, J. and Diamond, S., 1972. Soil Survey Bulletin No. 26. An Foras Taluntais, Dublin.

Table 3 is a short description of the approach to soil suitability assessment as outlined by Pons in FAO Soils Bulletin No. 29.

TABLE 3

SHORT DESCRIPTION OF ASPECTS OF SOIL SUITABILITY CLASSIFICATION IN IRELAND

Source	1. Socio-economic and physical assumptions	2. Type of land use	3. Soil and land characteristics or qualities	4. System of classification
Land evaluation research in Ireland and a tentative evaluation of EEC land for forage production. Lee, J. - EEC Seminar on Land Resource Evaluation. Johnstown Castle, Wexford (1978)	High level of management. Two levels of fertiliser use (grassland). Present national socio-economic conditions.	Arable land with broad groups of crops. Pasture production. Forestry. Drainage or reclamation assumed.	Soil wetness, susceptibility to drought, liability to flooding, slope, rockiness, texture and structural properties affecting tilth and susceptibility to poaching.	Categoric system (Class and sub-classes). 5 classes based on degree of use limitation (arable use) and potential (*grassland*).

PRESENT STATUS OF LAND EVALUATION IN ITALY AND A PROPOSED SYSTEM OF LAND SUITABILITY CLASSIFICATION

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1. LAND CLASSIFICATION METHODOLOGY IN ITALY

In Italy, land classification for agronomical purposes has been conducted since the 1960's by following essentially two different methodologies of research. In effect, both categoric systems of classification, based on limitations, and parametric systems have been used. Included in the first group are the classification systems derived from the American Land Capability and the Land Classification of the Bureau of Reclamation, which are still applied with a certain success even in surveys on a relatively large scale. The use of parametric methodologies in order to determine the current potentiality of the soils involves a different approach to land classification.

The method used in Italy was perfected in 1966 by applying criteria and suggestions offered by FAO (Bramao, 1962, 1964). It takes into consideration some of the measurable or estimable features of the soil; assigning to each of them a numerical variable between 0 and 100, which defines quantitatavely the influence of a certain characteristic of the soil on its theoretical potentiality. The potentiality rating is obtained by multiplying the various numerical factors pertaining to the different characteristics of the soil. Applying this method, Mancini and Ronchetti (1968) published a map of the potentiality of the soils in Italy on a scale of 1 : 1 000 000.

2. A PROPOSED SYSTEM OF LAND SUITABILITY CLASSIFICATION

Following in general the outline and definitions on land evaluation proposed by the FAO (1976), and keeping in mind the criteria observed by other procedures for classification of the land resources, the authors and some other Italian colleagues are experimenting with a new methodology of assessment for Italy.

2.1. The socio economic and physical assumptions. The evaluation procedure for the time being takes into account only physical assumptions; the inclusion of socio-economic assumptions in addition to the physical assessment is visualised.

2.2. Types of land use. The land mapping units of the FAO Framework on Land Evaluation are the objects of assessment. The suitability of the land mapping units is established for the following major types of land use:

- agricultural use
- forestry and grazing use.

The agricultural use includes the following broad land utilisation types:

- annual crops
- perennial crops
- irrigated farming.

The forestry and grazing uses include:

- forestry
- grassland.

2.3. Land and soil characteristics and qualities. The proposed system of classification is based on two consecutive phases. Firstly, only the limitations (characteristics and qualities) of the land are considered, and secondly, the soil limiting factors (mainly soil characteristics) are examined. This procedure allows a preliminary subdivision in land for agricultural or forestry and grazing use. The subdivision can

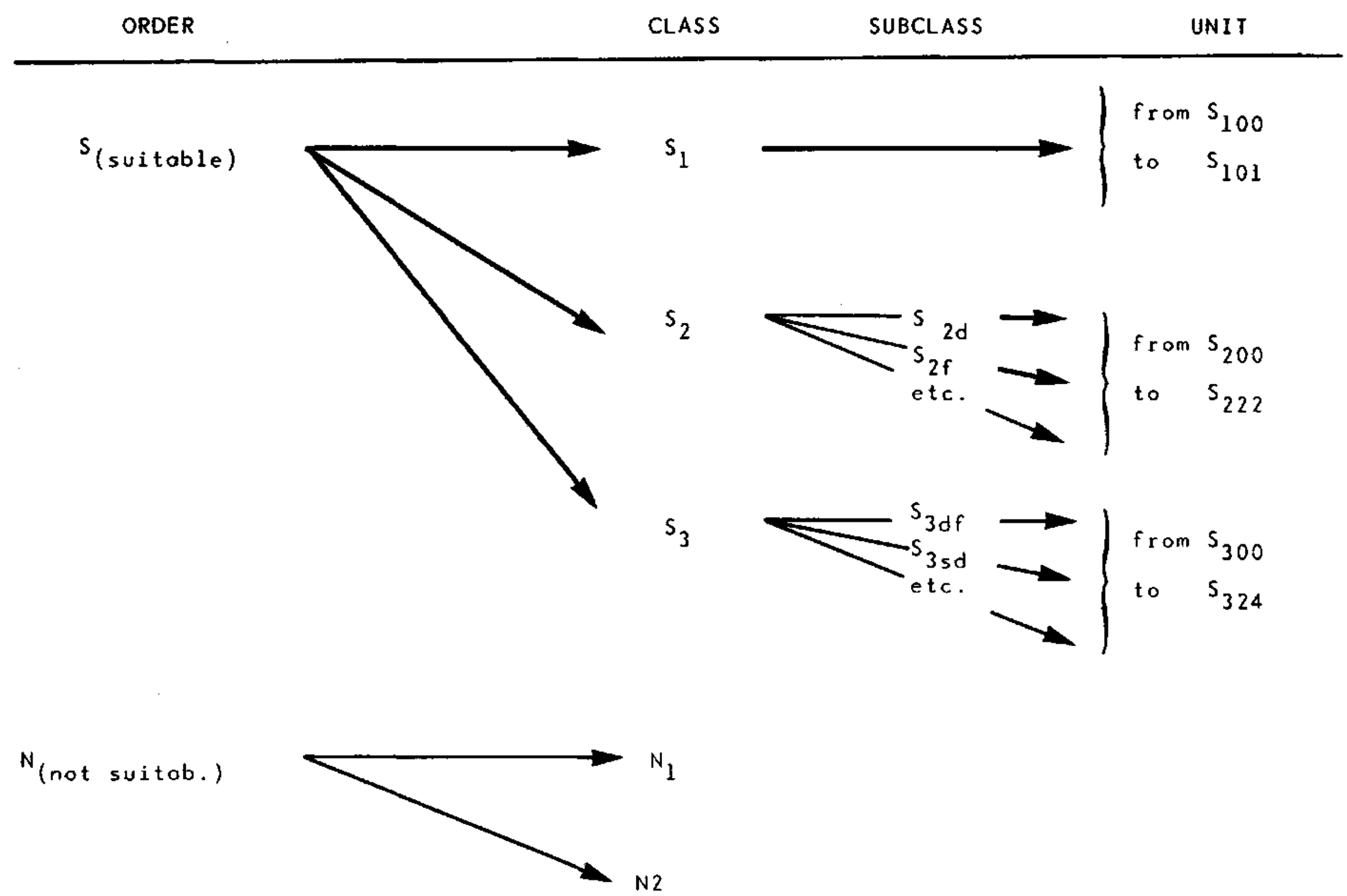

Fig. 1: Structure of the suitability classification

be carried out also in small scale maps (eg 1 : 100 000) without taking the soil into account.

2.4. The system of land classification. The process of evaluation is essentially based on the degree and quality of limitations arising for a determined type of agricultural use or forestry and grazing use. The classification system, which is a categoric type classification, consists of two orders (S = suitable and N = not suitable); five classes (S_1, S_2, S_3, N_1, N_2); sixteen sub-classes ($S_{2\ s}$, $S_{3\ fd}$, etc., where 's', 'f', 'd', etc. represent the most important limitations at the highest taxonomic level), and finally, 26 units (2 for class S_1, 9 for class S_2, 15 for class S_3)(Figure 1). The qualitative significance of the different categories is consistent with the FAO proposal, but their allocation to the various cartographic units results from qualitative and quantitative criteria established in an objective manner. This process may be carried out even by means of an electronic processor.

In the first phase of assessment, a preliminary classification is completed according to the 5 suitability classes for the two main utilisation groups (agricultural and forestry and grazing use)(Figure 2). The various land mapping units are assigned to the separate suitability classes and sub-classes in accordance with the severity of the land limitation, ie, rockiness (Ro), the average slope (Sl), the danger of flooding (Fl), the land degradation state (De). These are the four chief limiting factors of the land. The limitation is expressed by a conventional scale variable between 0 and 2 (and in one case, between 0 and 4), as follows:

rating	limitation
0	none or low
1	moderate
2	high

	Ro →			Sl →					Fl →			De			
	0	1	2	0	1	2	3	4	0	1	2	0	1	2	
S_1	•								•			•			
S_2	•			•					•				•		d
	•			•						•		•			f
	•				•							•			s
S_3	•			•						•			•		df
	•				•								•		sd
	•					•						•			ss
N_1		•					•						•		
N_2			•												

Fig. 2a: Land suitability classes and sub-classes (agriculture) (see Appendix)

	Ro →			Sl →			Fl →			De			
	0	1	2	0	1	2	0	1	2	0	1	2	
S_1	•			•			•			•			
S_2	•			•			•				•		d
	•			•				•		•			f
		•		•			•			•			r
	•				•					•			s
S_3	•			•			•					•	dd
	•			•				•			•		fd
		•		•			•				•		rd
		•		•				•		•			rf
	•				•						•		sd
		•			•					•			rs
N_1			•			•					•		
N_2			•			•						•	

Fig. 2b: Land suitability classes and sub-classes (forestry-grassland)(see Appendix)

For the scale from 0 to 4, the ratings are as follows:

rating	limitation
0	none
1	slight
2	moderate
3	severe
4	very severe

Designation of the rating and measurement of the various limiting factors are conducted according to different methodologies.

In the second phase of assessment each cartographic unit, assessed at the sub-class level (for example, $S_{2\ d}$ = sub-class of S_2 (FAO with chief limitation being land degradation)), receives a further definitive classification of the degree of suitability it presents for a specific utilisation (annual crops, perennial crops, grassland, forest, etc.). The degree of permanent and changeable limitations increases on the scale from 0 to 4 for a determined type of utilisation. According to the arrangement in Figure 3, a land mapping unit may remain in the taxonomic category resulting from the first phase of classification, or it may be de-classed due to the presence of limitations of a degree incompatible with that foreseen for each class. Therefore, during this step in the procedure, the land suitability unit is identified and characterised by a numerical index of three figures (for example, $S_{212\ df}$). This provides, although very roughly, a quantitative measure of the degree of suitability of the land mapping unit. The first number in fact represents the class, the second the severity of the permanent limiting factor, the third the changeable limiting factor, while 'd' and 'f' usually represent the sub-class.

The limiting factors for each of the five land utilisation types foreseen at this stage of research appear from appropriate cards (Figure 4) prepared for the three climatic zones[1] into which the Italian peninsula can be subdivided, and for two features of the pedological substratum or of the soil itself[2].

Consequently, 30 cards must be tested; these are periodically revised and updated in relation to the continually increasing knowledge of the relationships between characters and qualities of the land and productivity of the soils.

---

[1]Zones: 1 = from lauretum to castanetum
2 = from castanetum to fagetum
3 = from fagetum to picetum

[2]Features of pedological substratum (for annual crops, perennial crops, forestry, grassland): consolidated parent material, unconsolidated parent material.

Features of the soil (for irrigated farming): vertic characters of soil, no vertic characters of soil.

RATE OF CHANGEABLE FACTORS	RATE OF PERMANENT FACTORS: 0	1	2	3	4
0	S100				
1	S_{101}				
0	S_{200}	S_{210}	S_{220}		
1	S_{201}	S_{211}	S_{221}		
2	S_{202}	S_{212}	S_{222}		
0	S_{300}	S_{310}	S_{320}		
1	S_{301}	S_{311}	S_{321}		
2	S_{302}	S_{312}	S_{322}	N_1	N_2
3	S_{303}	S_{313}	S_{323}		
4	S_{304}	S_{314}	S_{324}		

Fig. 3: Land suitability classes and units (see Appendix)

CARD FOR LAND CLASSIFICATION

LAND UTILIZATION TYPE: Annual crops

CLIMATIC ZONE: Lauretum to castanetum

SOIL TEMPERATURE REGIMES: thermic

SOIL MOISTURE REGIMES: xeric to udic

PARENT MATERIAL CHARACTERISTICS: unconsolidated material

	LIMITING FACTORS	DEGREE OF LIMITATION 0	1	2	3	4
		none	slight	moderate	severe	very severe
PERMANENT FACTORS	Soil depth	> 70	70-40	< 40	========	===========
	" texture	C-CL-L-Si-SiL-SiCL	SC-SCL	LS - SL	S (wint.)	S (summer)
	" stoniness	< 10	10-25	25 - 45	45 - 70	> 70
CHANGEABLE FACTORS	Drainage	class 4	class 3 & class 5	class 2	class 1	class 0

CARD FOR LAND CLASSIFICATION

LAND UTILIZATION TYPE: Annual crops

CLIMATIC ZONE: Lauretum to castanetum

SOIL TEMPERATURE REGIMES: thermic

SOIL MOISTURE REGIMES: xeric to udic

PARENT MATERIAL CHARACTERISTICS: consolidated bedrocks

	LIMITING FACTORS	DEGREE OF LIMITATION 0	1	2	3	4
		none	slight	moderate	severe	very severe
PERMANENT FACTORS	Soil depth	> 80 cm	80 - 60	60 - 40	40 - 20	< 20
	" texture	C-Cl-L-Si-SiCL-SiC-SiL -	SC - SCL	SL - LS	$S_{(wint.)}$	$S_{(summer)}$
	" stoniness	< 10	10 - 25	25 - 45	45 - 70	> 70
CHANGEABLE FACTORS	Drainage	class 4	class 3 & class 5	class 2	class 1	class 0

APPENDIX

Explanation of Figure 2

Subdivision into land suitability classes (S_1, S_2, S_3, N_1, N_2) and sub-classes ($S_{2\ d}$, $S_{2\ s}$, $S_{3\ df}$, etc.) for agricultural (Figure 2a) or forestry-grassland (Figure 2b) use. The classes and corresponding sub-classes are defined on the basis of the degree of limitation determined by the degree of rockiness (Ro), slope (Sl), danger of flooding (Fl), land degradation (De), measured with a conventional scale variable between 0 and 2 (in one case, between 0 and 4). Designation of the class and sub-class takes place by examining the limiting factors in the direction specified by the arrows. The symbol '•' visualises the maximum value each limitation can take on within a determined suitability class.

The sub-classes are characterised by one or two letters representing the limiting factor or factors present:

s = limitation due to slope
f = " " " danger of flooding
d = " " " the land degradation
r = " " " rockiness
ss = " " " a strong slope
dd = " " " a strong land degradation
rf = " " " rockiness and danger of flooding.

etc.

Explanation of Figure 3

Subdivision into land suitability classes and units based on the maximum degree of the limitations caused by the permanent factors (horizontal scale) and the changeable factors (vertical scale) appearing on the various assessment cards prepared for the different agricultural and forestry and grazing uses. The maximum degree of the permanent and changeable factors compatible for each class is clearly shown in the table. The land suitability units are denoted by a numerical index made up of three figures, the first of which represents the class, the second the maximum degree of limitation of the permanent factor, the third the maximum degree of limitation of the changeable factor. Subdivision into units is not established for classes N_1 and N_2.

SOIL CLASSIFICATION IN DENMARK - ITS RESULTS AND APPLICABILITY

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1. ADMINISTRATIVE STRUCTURE AND MAIN OBJECTIVE OF THE SOIL CLASSIFICATION

The Danish soil classification has two main objectives; (i) use in connection with physical planning, and (ii) data collection on the land resources to estimate the value of a given area for agriculture and also for environmental planning purposes. Figure 1 shows the administrative structure of the project.

The technical-administrative work of the soil classification and its development is handled by the Bureau of Soil Classification under the Danish Ministry of Agriculture. The soil classification work has concentrated on constructing a data system consisting of two main components: the classification maps (the basic data maps) and the data base.

In the structure of the system great importance has been attached to:-

a. Preparation and publication of the necessary classification data (soil types, slope, etc.)

b. The requirement for quick data supply to the regional planning in progress and subsequent local planning.

c. Co-ordination of the classification work with physical planning in the counties.

d. Follow up and service with regard to supplying interpreted data, ie, descriptions of specific areas and problems.

Ministry of Agriculture
The department

Bureau of Soil Classification

Administrative structure

Guidance group

Ministry of Agriculture
Ministry of Environment
Agricultural organisations

Organisations involved

Danmarks Geologiske Undersøgelse
Statens Planteavls-Laboratorium
Hydroteknisk Laboratorium, Landbohøjskolen
Det faglige Landscenter, Aarhus
Konsulenttjenesten (145 konsulenter)
Det danske Hedeselskab
Amtskommunerne (primaerkommunerne)
Hovedstadsradet
Geodaetisk Institut
Laboratoriet for Geofysik, Aarhus Universitet
Grafisk Højskole
Statens Planteavlsudvalg

General method

1. Determination of classification area
2. Analysis of soil factors
   - Slope
   - Natural drainage state
   - Texture, including geology
   - Structure and porosity
3. Climate factors
   - Rainfall
   - Temperature

Data Collection Preparation

BASIC DATA MAP
Topographical basic map
Reference net (UTM)
Soil thematic elements
DATA BANK
Map plot
Data lists

Data Registration

INTERPRETATION

The physical planning - Agricultural Act/planning legislation
Environment matters in general
Water supply planning - need of field irrigation
Agricultural research and tests
Raw material mapping

Use

The follow up process has especially been initiated in connection with water resource planning.

Further preliminary work is carried out in connection with problems of wind erosion.

2. TECHNICAL STRUCTURE OF THE CLASSIFICATION SYSTEM

The soil classification includes the recording of a number of characteristics of the upper (approximately 1 m thick) loose layer of the solid earth crust. The topographic maps from the Danish Geodetic Institute in the scales 1 : 25 000 and 1 : 40 000 are used as the cartographic basis of the classification.

The analysis method includes three main elements:

(i) Determination of the classification area. The classification area corresponds to the total land area exclusive of existing urban zones, week-end cottage areas, woods, etc.

(ii) Analysis of soil factors

- (a) Slope
- (b) Natural drainage state
- (c) Texture and geology
- (d) Water capacity
- (e) Structure and porosity.

The slope analysis is given in degrees (360° system). There are three categories. Areas with 0°-6° gradient, areas with 6°-12° gradient and areas with more than 12° gradient. The natural drainage state is recorded and waterlogged areas are delineated where drainage involves a common measure for a considerable area. The classification area is divided into three state groups:

- meadow, bog and rush areas;
- 'wet land' areas (rush areas);
- other areas.

The principal element of the soil classification is the recording of the soil texture. Textures are recorded for the following:

(a) From soil samples taken at a depth of 0 - 20 cm.

(b) From soil samples taken at a depth of 35 - 55 cm.

(c) Geological samples from The Geological Survey of Denmark for evaluation of the character of the soil at a depth of 1 m.

(d) Other sources, including profile descriptions from the files of the Danish Heath Society.

The total number of soil samples for the whole country will amount to about 40 000. Twenty-five to thirty borings are made at a depth of 0 - 20 cm with a half-cylinder auger, diameter 15 mm. The volume of the soil sample is about 450 cm^3. The samples from 35 - 55 cm depth are taken within the same area as the samples from 0 - 20 cm depth. The density of augering is 25 - 30/5 000 m^2 (approximately).

Each test locality represents 50 - 80 hectares dependent on geological variation in the area. The number of samples from 35 - 55 cm depth depends on the geological variation and amounts to 30 percent of the number of test localities with samples at 0 - 20 cm depth. Each test locality is determined in consultation with the staff of local agricultural advisers in order to obtain a representative covering as regards the variations in geology and texture. For certain areas in Denmark there are no systematic data for the geological conditions. In these areas the texture recording is increased. The local advisers (total about 150) and the Heath Society assist in the texture recording and determination of the boundaries for the soil types.

In connection with the classification work, an investigation has been initiated with the aim of setting up a model (multiple regression) for systematic calculation of plant available water on the basis of the soil classification data material. Soil porosity is determined for special samples taken for determination of moisture retention curves. On this basis soil structure can be evaluated.

(iii) Climatic factors: the following are recorded:

(a) Average monthly rainfall

(b) Average temperature (May - October)

(c) Average yearly temperature.

3. THE DATA BASE OF THE SOIL CLASSIFICATION

The object of establishing the base has been to enable an organisation of data with the objective of making allowance for existing as well as future information needs about the land resources. The data base is specially made with the aim of handling data defined on a co-ordinate basis both quantitative as well as qualitative relating to the land resources. In the construction of the data system, it has been considered important to establish a method of data preparation which can by means of a co-ordinate system be referred to a point or a line. For each soil sample (test locality) the data base contains four main groups of values:-

(i) Values identifying the test locality

(ii) Content of the various particle size fractions and of humus and calcium carbonate in the soil sample.

For each sample percentage values can be found for the following:

A	Clay	< 2 μm
B	Silt	2- 20 μm
C	Fine sand	20- 200 μm
D	Coarse sand	200-2000 μm
E	Humus	58.7% Carbon
F	Coarse fine sand	63- 200 μm
G	Coarse silt	20- 63 μm
H	Calcium carbonate	

(iii) Values calculated from the values in group (ii), including the soil type

(iv) Values characterising the test locality, such as a code for geology and drainage state.

Through storage of the data in a data base, which can be developed by a computer, for which the necessary programme facilities have been developed, a great number of possibilities of handling data are obtained, eg:

(a) The individual values can be printed on a list in any combination and the analyses listed can be sorted out on the basis of an infinite combination of sorting criteria.

(b) Values or combinations of values can be drawn on an automatic drawing machine on any scale. The drawing can further be combined with values drawn from other data banks.

(c) Statistical preparation of the analyses become practicable in many different ways.

4. THE CARTOGRAPHIC REGISTRATION OF THE SOIL CLASSIFICATION

The object of the mapping of the soil classification is to provide the users with the results of the soil classification in a well-arranged graphical form. There are about 330 basic data maps (1 : 50 000). The map work consists of three main elements:-

1. A topographical map
2. A reference net
3. The soil thematic elements - basic data concerning the soil factors.

The maps are printed with the UTM co-ordinate system valid for zone 32 in a square grid with half-kilometre graduation. The UTM reference net constitutes the connecting link between the classification maps and the data base of the soil classification. The surface texture is indicated by a colour scheme on the basic data map. The vertical texture variation (profile) may be interpreted from the geological information on the map and/or the information in the data base.

5. TIME LIMITS OF THE SOIL CLASSIFICATION WORK

Publication of the 330 basic data maps and the primary construction of the data base will be finished during 1979 for Denmark. Of the special projects in progress, with the object of setting up models for use in further elaboration and interpretation of the primary data base, the calculation basis for the planning of water resources will be finished in 1978. The digitalisation of the basic data maps is expected to be finished for 60 percent of the country during 1979. Explanatory tables and diagrams are presented in the Appendix.

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Further sources have been used: unpublished notes worked out by Axel Nørr, S.W. Platou, Jens Kierkegård and Peter Munk Plum, Bureau of Soil Classification.

APPENDIX

SOIL CLASSIFICATION OF DENMARK

DEFINITION OF SOIL TYPES

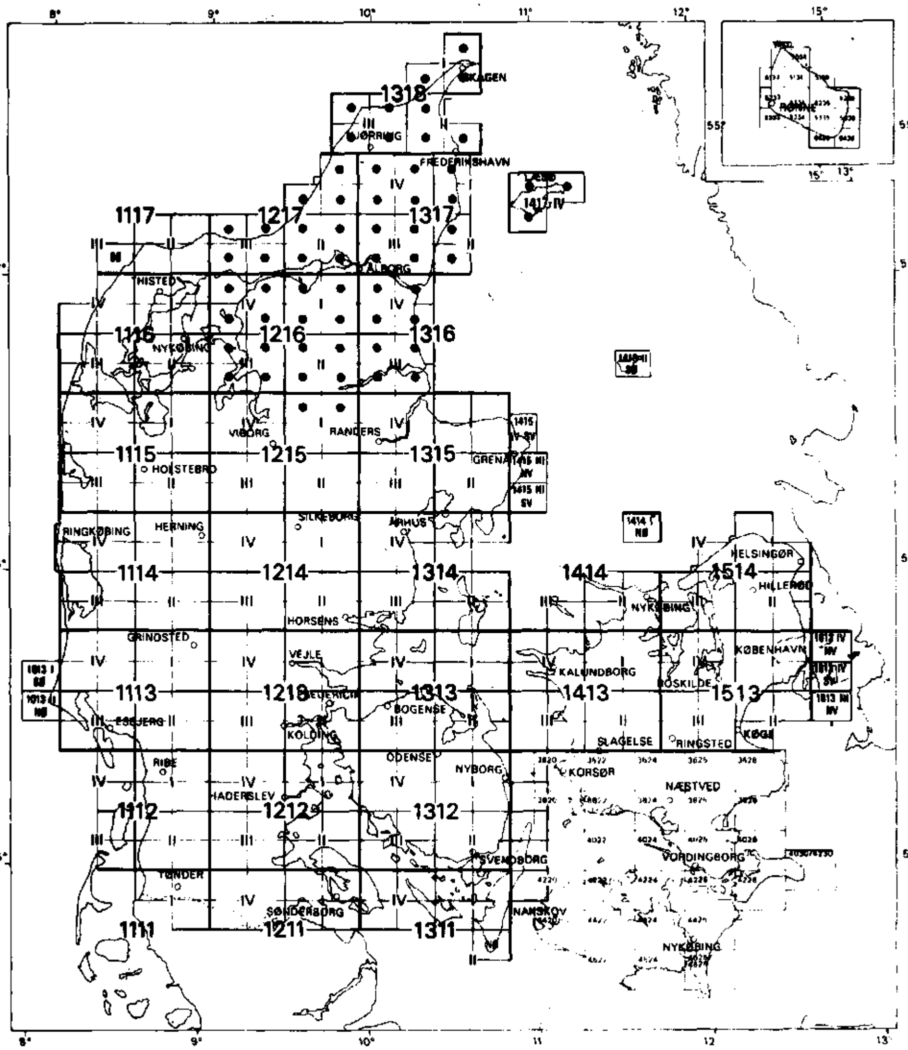
SOIL TYPE (Map Colour Code)	FARVE-KODE	TEKSTURDEFINITION FOR JORDTYPE	Symbol	JB-nr.	Clay Ler under 2 μm	Silt Silt 2-20 μm	Fine Sand Finsand 20-200 μm	Total Sand Sand, ialt 20-2000 μm	Humus Humus 58,7 % C
					Vægtprocent (Per Cent of Weight)				
Coarse Sand	1	Grovsandet jord	GR.S.	1	0-5	0-20	0-50	75-100	Under 10
Fine Sand	2	Finsandet jord	F.S.	2			50-100		
Loamy Sand	3	Grov lerblandet sandjord	GR.L.S.	3	5-10	0-25	0-40	65-95	
		Fin lerblandet sandjord	F.L.S.	4			40-95		
Sandy Loam	4	Grov sandblandet lerjord	GR.S.L.	5	10-15	0-30	0-40	55-90	
		Fin sandblandet lerjord	F.S.L.	6			40-90		
Clay	5	Lerjord	L.	7	15-25	0-35		40-85	
Heavy Clay	6	Svær lerjord	SV.L.	8	25-45	0-45		10-75	
		Meget svær lerjord	M.SV.L.	9	45-100	0-50		0-55	
Silt		Siltjord	SI.	10	0-50	20-100		0-80	
Humus	7	Humus	HU.	11					Over 10
Special	8	Speciel jordtype	SPEC.	12					

Note: Map Colour Code is a reference to the different colours representing the dominant soil types in the map series: JORDKLASSIFICERING DANMARK BASISDATAKORT 1:50.000.

Bureau of Soil Classification

JORDKLASSIFICERING
DANMARK

BASISDATAKORT 1:50 000
KORTBLADSINDDELING



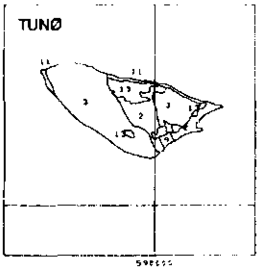
DANMARK 1:2 mill

0 10 20 30 40 50km

SOIL CLASSIFICATION OF DENMARK
SOIL MAPS 1:50000
Index to sheet lines and numbers.

JORDKLASSIFICERING DANMARK
AREALTYPEKORT 1 :50 000
SAMSØ OG TUNØ

Dominerende jordtyper 0-20 cm dybde og ikke-klassificeret areal



FREMSTILLING
Kortet er en EDB-udskrift fra jordklassificeringens databank under Sekretariatet for Jordbundsklassificering (SfJ).

Kortet er fremstillet af SfJ ved digitalisering, d.v.s. omsætning af kartografisk information til koordinater (talsæt) ved hjælp af elektronisk databehandling (EDB).

Grundmaterialet for digitaliseringen er Geodætisk Institute 4 cm kort 1 : 25.000 med jordklassificeringsdata, der er anvendt som grundlag for kortserien BASISDATAKORT 1 : 50.000 (klassificeringskort).

SfJ har foretaget beregninger og plotning, d.v.s. automatiseret, maskinel udtegning af det digitaliserede materiale, ved Det Regionale EDB-Center ved Aarhus Universitet (RECAU).

UTM ZONE 32 NET
Digitaliseringen er refereret til UTM zone 32-koordinatsystemet.

Der er angivet 5 km-netlinier. Tal ved kortrammen angiver zonekoordinater (øst-nord) i meter.

AREALTYPER - SIGNATURER
Digitaliseret grænselinie for arealtype.
Tal 1-13 refererer til arealtype.
jfr. nedenstående skema.

AREALTYPER - AREALBEREGNING
Med grundlag i digitaliseringen er der foretaget en arealberegning for arealtyperne, jfr. nedenstående skema:

AREALTYPE 1- 8: Domin. jordtyper 9-12: Ikke-klassificeret	AREALFORDELING SAMSØ og TUNØ ha.	 % af tot. areal
1: Grovsandet jord	732	6.2
2: Finsandet jord	1096	9.3
3: Lerblandet sandjord	4850	41.2
4: Sandblandet lerjord	3273	27.8
5: Lerjord	17	0.1
6: Svær lerjord, silt	0	0
7: Humus	142	1.2
8: Speciel jordtype	5	0.1
9: Byzone/sommerhusområde	270	2.3
10: Søer, vandløb m.v.	4	0
11: Restområde (skovlyen, m.v.)	673	5.7
12: Skov/plantage	709	6.0
TOTALT BEREGNET AREAL	11776	

[illegible]

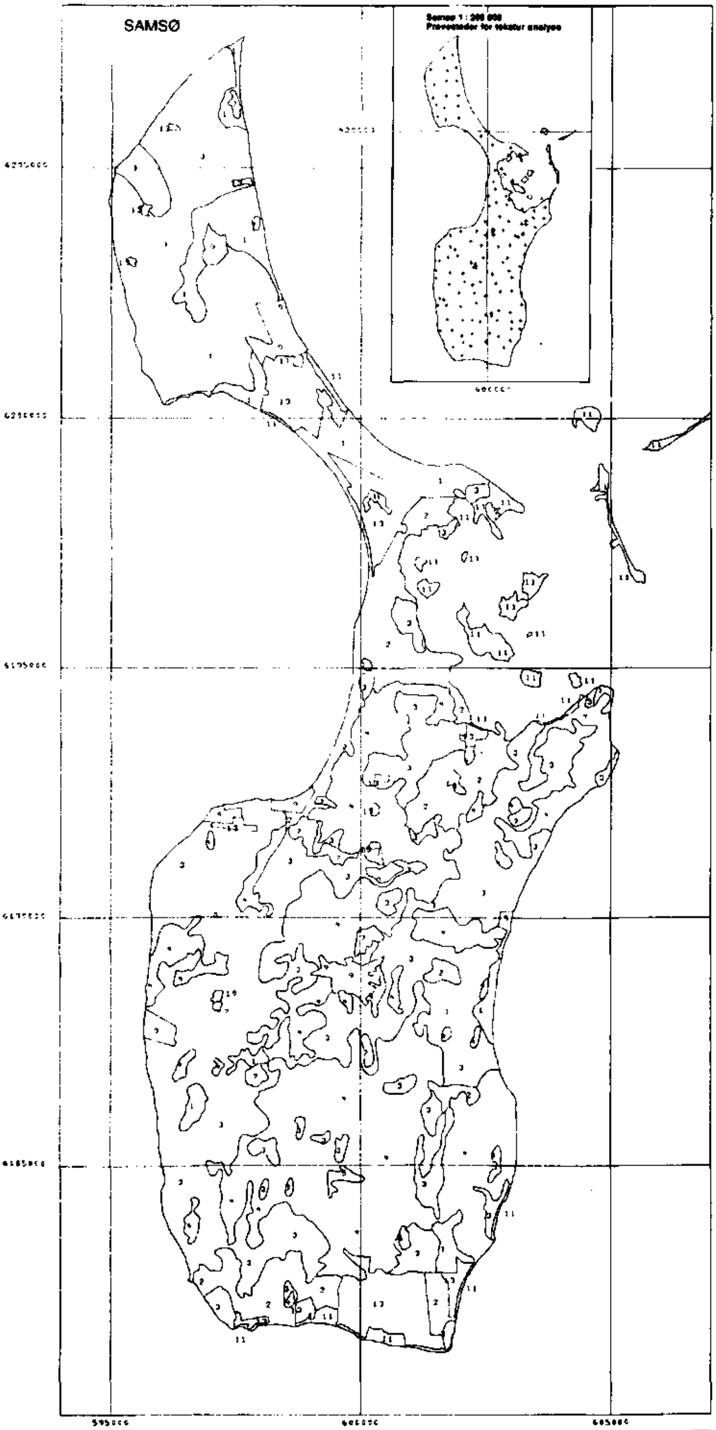
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	[illegible]	[illegible]	1	0-5	0-50	0-50	[illegible]	
2	[illegible]	[illegible]	2			50-100		
3	[illegible]	[illegible]	3 4	5-10	0-25	0-40 40-95	[illegible]	
4	[illegible]	[illegible]	5 6	10-15	0-30	[illegible]	[illegible]	Under 10
5	[illegible]	L	7	15-25	0-35		[illegible]	
6	[illegible]	[illegible]	8 9 10	25-45 45-100 0-50	0-45 0-50 20-100		[illegible]	
7	[illegible]	[illegible]	11					Over 10
8	[illegible]	[illegible]	12					

Udgivet af Sekretariatet for Jordbundsklassificering.

Trykt ved Vejle Amts Folkeblads Bogtrykkeri.
1978-10.

SOIL CLASSIFICATION OF DENMARK
Area type map 1 : 50 000
Samsø and Tunø

Bureau of Soil Classification
Borgvold 14
DK-7100 Vejle
Denmark



ASSESSMENT OF SOIL PRODUCTIVITY, USING CLIMATOLOGICAL AND SOIL PHYSICAL DATA

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ABSTRACT

A brief discussion is given on the effect of climate and soil physical conditions on evaporation and dry matter production.

The capillary properties and the soil moisture characteristics of a series of standard soils are given. These data can be applied in forecasting soil moisture conditions and capillary rise from the subsoil.

A scheme is proposed for a hydrological soil classification system depending on the physical properties of the soil and on the climatological conditions which can be applied under a large variation of the boundary conditions.

1. INTRODUCTION

A large number of guesses have to be made in many land resource programmes on the effect of climatological conditions and of the soil properties in the unsaturated zone on water balances and the influence of these guesses on derived productivity.

The accuracy by which soil moisture extraction can be forecasted depends completely on the accuracy by which the soil properties are known. The extraction pattern of moisture, however, is not only directly related to these data but is also dependent on the climatological conditions, given as frequency distributions of evaporation and precipitation totals with time, and on the depth of the groundwater table. A good forecasting of soil moisture extraction also results in fair estimates of groundwater losses by capillary rise and drainage.

Both capillary properties and soil moisture characteristics depend on the granular composition, the density and the pore size distribution of the soil. It is apparent that each soil will have its own properties. However, it is very often impossible to use for each soil its specific properties in forecasting procedures. For this reason data of capillary conductivity and soil moisture characteristics available from literature have been collected. These data were averaged for a number of soil groups, resulting in a series of standard soils (Rijtema, 1969b). When, for instance, a soil survey has been made with a classification of the soil types present, the physical properties of the corresponding standard soils can be used for forecasting the conditions in the unsaturated zone.

As the soil moisture conditions in the unsaturated zone are also determined by the climatological conditions, the depth of the groundwater table, the practice of farming and by the crop itself, it is apparent that a set of standard calculation rules for practical application will have to be used.

2. RELATIONSHIP BETWEEN CROP PRODUCTION AND WATER USE

For an analysis of the productivity of soils information on both maximum and actual dry matter production of field crops per unit of soil surface is a prerequisite. Since dry matter production is the result of net photosynthesis, production of other compounds than carbohydrates can be ignored quantitatively. Without limiting factors dry matter production is determined by the amount of light intercepted by the crop and by the diffusion of carbon dioxide from the external air to the chloroplasts of the plant. It has been shown by De Wit (1965) for standard crop conditions, and by Rijtema and Endrödi (1970) for actual crop conditions, that the dry matter production rate can be calculated by means of a formula which combines solar radiation, crop development and the CO_2-diffusion process.

The relation between evaporation and dry matter production is of particular interest in land resources programmes. Bierhuizen and Slatyer (1965) and Rijtema (1966) did show that this relation can be given as a linear function between total dry matter production and the total transpiration-vapour pressure deficit ratio. Periods of drought do not generally affect the relation between dry matter production and transpiration to a great extent, provided the dry matter of the wilted parts of the crop are also harvested. Generally, however, only the above ground parts of the crop are harvested. The relation between production and transpiration depends in that case on the quantity of dry matter present in the roots. When the sprout-root ratio is large and when the main quantity of the roots is formed during the early stages of growth, small fluctuations in the amount of dry matter present in the roots do not affect the linear relationship very much. The relationship might be affected to a great extent when the sprout-root ratio is small with continuous root production and several yields during the growing season (Rijtema, 1969a).

3. STANDARDISATION OF SOIL PHYSICAL PROPERTIES

A full discussion on the relations between capillary conductivity and suction used in literature has been given in a previous study (Rijtema, 1965). It appeared that the relationship between both factors in the low suction range can be given by the expression

$$k = k_o \, e^{-\chi(\Psi-\Psi_a)} \quad \Psi > \Psi_a \tag{1}$$

where k is the capillary conductivity, k_o conductivity at zero suction, Ψ the suction, Ψ_a the suction at the air entry point and χ a constant depending upon the soil.

The maximum value of the suction to which this equation is valid varies from soil to soil. The relation between capillary conductivity and suction in the high suction range can be expressed by the type of equation proposed by Wind (1955) and Wesseling (1957) as

$$k = a\Psi^{-n} \tag{2}$$

It has been shown (Rijtema, 1965) that the value of n for different soils is close to 1.4. The value of a varies from soil to soil.

The available data (Rijtema, 1969b) from literature were grouped for various types of soils. The mean relation between capillary conductivity and suction of each group is given in Table 1. Equation (1) has been used in the low suction range and equation (2) in the high suction range, with n equalling 1.4. The given value of Ψ_{max} in this table represents the suction to which the relations (1) and (2) can be used.

The data given in Table 1 are representative for the important groups of soils which are normally present. Within each soil group deviations of the given mean values will be present for each separate soil, but for forecasting purposes the mean values for each soil group will give a reasonable estimate of the capillary properties.

In addition to the capillary properties of the soil groups, information concerning the soil moisture characteristics of the various groups is necessary. Unfortunately the soil moisture characteristic data were not always given in the literature from which the data of capillary conductivity were derived. For this reason also, other data on soil moisture characteristics were used to obtain a mean characteristic for each group. The representative data of the soil moisture characteristic of each group are given in Table 2.

Expressing the available soil moisture between field capacity and wilting point as a volume fraction, results for a number of soils in an even more simplified standardisation are shown in Table 3 (Rijtema and Aboukhaled, 1975).

4. MOISTURE LOSSES FROM CROPPED SOILS

Soil moisture content changes during the course of the year under influence of precipitation, evaporation and drainage. The amount of precipitation during the growing season is generally not sufficient to cover the water requirements of crops. For this reason water supply of crops depends for a major part on the availability of soil moisture.

Though the effect of soil moisture on the reduction of transpiration has been described by the moisture conditions and soil physical properties in the effective root zone of crops (Rijtema, 1965; Feddes, 1971; Feddes and Rijtema, 1972), this does not mean that both the physical properties of the subsoil and the depth of the groundwater table do not affect the availability of soil moisture. Due to uptake of water from the root zone, a potential gradient is established below the root zone causing a rise of water from the subsoil and the saturated zone, which results in an additional water supply.

TABLE 1

VALUES OF K_o, α, Ψ_a, Ψ_{max} and a for the relations between capillary conductivity and suction

Soil type	K_o cm day^{-1}	α cm^{-1}	Ψ_a cm	Ψ_{max} cm	a $cm^{2.4} day^{-1}$	
Coarse sand	1 120	0.224	10	80	0.080	1
Medium coarse sand	300	0.138	0	90	0.63	2
Medium fine sand	110	0.0822	0	125	3.30	3
Fine sand	50	0.0500	0	175	10.9	4
Humous loamy medium coarse sand	1.0	0.0269	0	165	15.0	5
Light loamy medium coarse sand	2.3	0.0562	0	100	5.26	6
Loamy medium coarse sand	0.36	0.0378	0	135	2.10	7
Loamy fine sand	26.5	0.0398	0	200	16.4	8
Sandy loam	16.5	0.0737	0	150	0.24	9
Loess loam	14.5	0.0490	0	130	22.6	10
Fine sandy loam	12.0	0.0248	10	300	26.5	11
Silt loam	6.5	0.0200	0	300	47.3	12
Loam	5.0	0.0231	0	300	14.4	13
Sandy clay loam	23.5	0.0353	0	200	33.6	14
Silty clay loam	1.5	0.0237	0	300	36.0	15
Clay loam	0.98	0.0248	0	300	1.69	16
Light clay	3.5	0.0174	0	300	55.6	17
Silty clay	1.3	0.0480	0	50	28.2	18
Basin clay	0.22	0.0380	0	80	4.86	19
Peat	5.3	0.1045	0	50	6.82	20

TABLE 2

SOIL MOISTURE CONTENT IN VOLUME PERCENTAGE IN RELATION TO THE SUCTION

Soil type	Suction in cm									
	0	2.5	10	31	100	200	500	2 500	16 000	10^6
Coarse sand	39.5	36.7	21.5	10.7	3.2	2.4	1.8	1.5	1.2	0.3
Medium coarse sand	36.5	35.7	33.1	27.4	9.5	6.5	5.2	3.1	1.7	0.4
Medium fine sand	35.0	33.4	32.5	30.5	15.5	8.0	6.1	4.3	2.3	0.7
Fine sand	36.4	35.6	35.2	32.8	19.6	15.0	12.9	6.5	4.2	1.2
Humous loamy medium coarse sand	47.0	46.6	46.0	44.0	40.5	36.3	29.3	17.4	10.5	2.8
Light loamy medium coarse sand	39.4	39.0	37.4	35.3	28.0	24.2	20.5	15.1	10.0	3.0
Loamy medium coarse sand	30.1	29.3	28.2	26.5	20.9	18.1	14.1	5.6	2.1	0.5
Loamy fine sand	43.9	43.5	39.9	30.7	17.9	14.6	11.5	8.5	6.0	0.7
Sandy loam	46.5	45.9	44.2	41.9	26.0	19.5	14.2	9.2	6.1	1.5
Loess loam	45.5	44.8	43.6	38.5	34.0	28.3	23.2	17.0	11.0	3.5
Fine sandy loam	50.4	49.9	48.8	48.2	42.3	27.3	22.4	13.2	8.7	1.7
Silt loam	50.9	50.7	49.7	48.4	46.1	33.8	27.9	13.7	9.2	2.0
Loam	50.3	49.8	48.6	48.0	42.0	29.5	24.8	16.7	9.8	2.5
Sandy clay loam	43.2	42.5	40.7	37.6	33.8	31.7	28.8	24.0	18.0	6.0
Silty clay loam	47.5	46.7	43.8	41.0	37.2	34.5	30.5	25.0	18.5	6.0
Clay loam	44.5	43.7	42.9	42.1	41.1	39.3	36.6	34.2	25.5	5.9
Light clay	45.3	45.0	43.5	40.5	36.0	34.0	31.5	27.0	21.5	7.5
Silty clay	50.7	50.0	49.2	48.2	46.3	44.7	42.2	35.2	25.7	6.5
Basin clay	54.0	53.7	53.3	52.7	51.9	49.8	47.0	40.2	32.1	11.9
Peat	86.3	85.5	83.2	81.6	76.3	70.5	64.9	35.6	26.5	9.8

TABLE 3

RELATIONSHIP BETWEEN SOIL WATER POTENTIAL (Ψ_s) AND AVAILABLE SOIL MOISTURE EXPRESSED AS VOLUME FRACTION (θ)

	Soil water potential in			
	- 0.2	- 0.5	- 2.5	- 16.0
Fine textured soils				
Loam	0.197	0.150	0.069	0
Silt loam	0.246	0.187	0.045	0
Silty clay-loam	0.160	0.120	0.065	0
Silty clay	0.190	0.165	0.095	0
Basin clay	0.177	0.149	0.081	0
Mean value	0.194	0.154	0.071	0
Medium textured soils				
Loamy fine sand	0.142	0.105	0.051	0
Sandy loam	0.134	0.081	0.031	0
Sandy clay loam	0.137	0.108	0.060	0
Mean value	0.138	0.098	0.047	0

It is obvious that there will be great differences in moisture losses from the soil under humid conditions with a regular distribution of precipitation and small evaporation rates compared with farming under semi-arid conditions. Even under humid conditions large differences exist from year to year. For a good evaluation of moisture delivery to crops a frequency analysis of precipitation and potential, as well as actual evaporation totals with time, is necessary.

Though the soil moisture extraction pattern changes from region to region and from year to year, it remains possible to give general rules for the calculation of moisture extraction which can be applied for a large variation in boundary conditions.

With respect to production forecasting, it is necessary to schematise the extraction pattern by the crop. For this reason the effective root zone of the crop is introduced, which can be defined as that zone of the soil profile in which 80% of the roots is present. When the soil profile is not restricting rooting depth, the data given in Table 4 can be used for the effective root zone.

TABLE 4

TYPE OF ROOT SYSTEM AND CORRESPONDING EFFECTIVE ROOT ZONE

Type of rooting	Effective root zone (m)
Shallow root system	0.25
Medium shallow root system	0.40
Medium deep root system	0.60
Deep root system	0.80

It is assumed that in this effective root zone no vertical suction gradients are present, so water uptake from this zone is only by radial flow to the roots. It also means that a given value of the suction in the effective root zone holds for this whole zone.

The amount of water becoming available from the subsoil by capillary flow from the groundwater is taken up by the plant at the lower boundary of the effective root zone.

It is assumed that the precipitation fallen in balance periods with an evaporation surplus is used by the crop during that period for evaporation. The effective uptake from the soil equals under these conditions the evaporation surplus in that balance period.

In periods with a precipitation surplus, the top layer is firstly re-wetted to a suction of 100 cm and after that deeper layers.

The contribution of capillary rise from the groundwater and the moisture distribution in the subsoil at the times t_o, t_1.....t_n can be calculated using pseudo-steady state solutions of the flow equation in the unsaturated zone.

The depth of the groundwater table as well as its fall during the growing season are determined by both capillary rise and deep drainage under influence of the hydrological conditions.

The supply of water from the subsoil, with the groundwater table at very great depth, can be calculated with pseudo-steady state solutions of the flow equation, assuming initially a constant suction with depth at t = O.

Equilibrium conditions are assumed at t = O at the start of the growing season.

A computer programme has been developed, based on the preceding assumptions, which can be used to calculate the actual crop evaporation under any set of conditions concerning drought frequency distribution, soil physical properties and hydrological conditions.

5. REQUIRED BASIC DATA

Application of the model, described in the preceding section, in land resource programmes requires a series of basic data which can be derived from soil maps. From the soil survey data the following information must be obtained:

- depth and physical quality in terms of humus, loam and clay content of the effective root zone;
- depth and type of the subsoil, if necessary split up in different layers;

- the mean highest winter groundwater table and the mean deepest summer groundwater table, which are determined in many cases on the basis of hydromorphic characteristics of the soil. In other cases the mean data derived from observation wells can be used.

The data derived from the soil maps are transformed into soil physical data using the standardised data given in Tables 1 and 2.

The moisture supply capacity as derived from the interpretation of soil maps is used for many purposes (Haans, 1978). However, the evaluation of this factor in terms of soil productivity depends on the climatological conditions. For instance, a water supply capacity of 150 mm in a growing season with an evaporation surplus of 100 mm is sufficient, whereas it is insufficient under conditions of an evaporation surplus of 200 mm. The interpretation of this assessment factor has to be done in combination with the climatological conditions in the region. As precipitation is highly variable from year to year, the interpretation has to be done for a number of drought conditions, resulting finally in a frequency distribution of the evaporation surplus in the region.

For each drought condition the actual and potential evaporation, as derived from the available data, can be transferred into production data using linear relationships between dry matter production and evaporation, which results for the given region in a frequency distribution of soil productivity.

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SUITABILITY MAPPING IN THE UK: TWO APPLICATIONS OF LAND USE PLANNING

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INTRODUCTION

Recently more stratification has been introduced into the 5-grade Agricultural Land Classification of England and Wales by sub-dividing Grade 3 - the central grade - and by amplifying the classification of those areas of Grades 4 and 5 which lie in the hills and uplands and constitute some of Britain's 'Disadvantaged Areas'. This 'Hill and Uplands Survey' is in effect a system of suitability mapping. An earlier example of this type of mapping was a survey carried out over a large part of England and Wales between 1957 and 1963, with the aim of defining areas potentially suitable for different branches of horticulture.

HILLS AND UPLANDS CLASSIFICATION

Agriculturally the hills are subject to severe physical restrictions and extensive tracts justify description as 'Less Favoured Areas'. Farmers in such areas are often constrained to make the most of every acre and this may involve land reclamation or improvement among other options. At the same time the hills are subject to increasing pressure from other land uses - particularly amenity recreation and conservation interests - as well as from established water catchment and afforestation. To assist in finding ways to reconcile these many interests while maintaining the output of store stock from the hills - so vital to the economy of many lowland farms - the Ministry considered it necessary to have a more detailed appraisal of the land resources of the hills and uplands.

This is provided by the 'Hills and Uplands Classification' in which a distinction is drawn between the 'hills' on the one hand, which are basically unimproved and covered by natural or semi-natural vegetation, and the 'uplands' on the other, which are enclosed and either wholly or partially 'improved'. The procedure followed in this classification is to analyse by field examination and reference to air photographs or maps, the factors of vegetation, gradient, irregularity and wetness.

Vegetation is taken as an index of how soil and climate interact to affect the feasibility of improvement: it also determines the present grazing value. Gradient is analysed from contour spacing and then allocated to three categories which reflect the degree of constraint imposed by slope on the operation of conventional machinery. Such operations are also inhibited by irregularity (ie, such surface features as large boulders or minor gullies), which may make improvement difficult and normal farming operations difficult or impossible. Wetness is assessed only in the uplands - the 'improved' land - and this analysis includes consideration of both atmospheric and soil wetness, with a view to separating those areas which are suitable for taking hay, silage or occasional fodder crops from land where such operations are not feasible.

Completion of the appropriate analyses enables land in the hills to be allocated to four classes according to the degree of potential for improvement they possess, with sub-classes in some cases to indicate present grazing value. These classes and sub-classes are:

H1A	Generally improvable - of high present grazing value
H1B	Generally improvable - of moderate present grazing value
H1C	General improvable - of low present grazing value
H2	Improvement limited by slope or irregularity

H3 Improvement severely limited but of some grazing value

H4 Generally not improvable and of low grazing value.

The uplands are also allocated to four classes (with sub-division to indicate the main limiting factor in one case). The upland classes are defined as follows:

U1 Generally suitable for grazing, mowing and occasional arable cropping.

U2 Suitable for grazing but mowing, conservation and arable cropping are limited by irregularity and/or wetness

U3S Generally restricted to permanent grassland which is primarily of use for grazing due to slope or irregularity

U3W Generally restricted to permanent grassland which is primarily of use for grazing due to wetness

U4 Rough or permanent pasture which, because of the extreme severity of constraints imposed by slope and irregularity, is very difficult to improve, utilise and/or maintain.

SURVEY OF POTENTIAL HORTICULTURAL AREAS

The original aim of this survey, carried out from 1957 to 1963, was to record all the land in England and Wales physically suited to horticulture; this was for use as a reference by horticultural advisers when approached by growers regarding suitable locations for a particular type of enterprise. Later the work was put to other uses in land use planning. It was used, for example, in preparing the agricultural case for the retention of land in the sunny areas of the West Sussex coast and South Hampshire - an early example of the application of a suitability mapping technique in land use planning.

This survey was essentially a land classification as opposed to a soil classification in that considerable weight was given by the multi-disciplinary survey team to climatic factors such as local frost risk, exposure and sunniness. Although the requirements of individual crops were necessarily considered, results were presented in terms of the needs of 7 types of horticultural enterprise, such as intensive vegetable production.

Suitability was defined from a practical viewpoint, defects being judged largely according to whether or not it was feasible for the individual grower to overcome them himself at a reasonable cost. Land was categorised into five suitability grades, the definitions of which are as follows:

(I) Highly suitable in respect of site, soil and climate.

(II) With minor defects which can be easily overcome.

(III) With minor defects which can be partly overcome.

(IV) With a serious defect which can be partly overcome or is partly offset by other physical advantages.

(V) With one or more serious defects, which cannot easily be overcome, but possessing some physical advantages.

The survey was selective in that not all land was classified but broad areas of suitability were defined and an indication was given as to whether most of the land within them was suitable for horticulture or merely parts or pockets.

CONCLUSIONS

Experience from these surveys and from the Agricultural Land Classification suggests there is still a need for further work to produce a satisfactory system for the economic classification of land or for the appraisal of overall agricultural significance. In such an appraisal, physical land qualities must receive considerable weight, but allowance must also be made for fractors such as farm structure and urban blight.

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LAND CLASSIFICATION SYSTEMS IN THE UK WITH PARTICULAR REFERENCE TO ENGLAND AND WALES

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ABSTRACT

Each country recognises the overriding importance of physical characteristics and to a marked extent adjusts the system used according to the dominant national physical characteristics.

The sequence of development of land classification systems in England and Wales has been from categorisation of land quality - deduced from land use information supplemented by local knowledge - to systems required for planning purposes (changes of user) based on analysis of physical characteristics.

The National Agricultural Land Classification (NALC) uses its five grades to indicate where changes of user would do most or least damage to the agricultural industry. Land Capability Classification (LCC) which, relatively speaking, is in its early days, lays considerable stress on soil characteristics and thereby would seem to have more practical application to giving advice in the area of soil management. The extensive soil information input of LCC can supplement that so far used in NALC and some derivative of LCC or combination of NALC and LCC may eventually become the accepted vehicle of land use advice. It is considered inadvisable however to switch over immediately to another system on a piecemeal basis: the completion of basic LCC surveys will take many years.

When planning negotiations centre round an area where all land is of a single uniform grade, supplementary information may be provided on overall agricultural significance. The latter includes such items as adequacy and standard of fixed equipment and farm size and structure. This effectively provides an economic overlay and is not a form of suitability mapping.

INTRODUCTION

The Ministry of Agriculture, Fisheries and Food (MAFF), through Research Officers of the Land Service, carried out during the period 1966 - 1974 an agricultural land classification of England and Wales. This is for use in planning negotiations and the coverage is by 115 separate map sheets published to a scale of 1 : 63 360.

The Department of Agriculture of Scotland has also built up a system of agricultural classification similar in approach and scope to that used in England and Wales. This too is used in planning negotiations, but the stratification is somewhat different, as are the descriptions of the types of land, and no maps have been published. Both surveys are not strictly designed as suitability surveys, though suitability may be inferred.

NATIONAL AGRICULTURAL LAND CLASSIFICATION (NALC)

The MAFF National Agricultural Land Classification assigns land to one of five grades. Grading is based on the way physical characteristics impose long-term limitations on agricultural use. The physical characteristics taken into account are:

(a) Climate. (Rainfall, transpiration, temperature and exposure)

(b) Relief. (Altitude, slope, surface, irregularity)

(c) Soil. (Structure, texture, depth, stoniness, wetness and available water capacity).

These, singly or in combination, impose long-term limitations which affect:

(a) The range of crops

(b) The level of yield

(c) The consistency of yield

(d) The costs of production.

Grading land by such means provides an indication of versatility for use and suitability. The grade assigned at the time of survey will remain valid in the future. Other and less permanent factors such as the standard and adequacy of fixed (farm) equipment, the level of farm management, farm structure and accessibility (to farm or market) are not taken into account. The method of survey is deliberately based on a wholly physical approach and socio-economic factors are ignored. Using the same technique large-scale maps can be prepared.

SUMMARY DESCRIPTION OF LAND GRADES 1 - 5

Grade 1

Land with very minor or no physical limitations to agricultural use. Soils are deep, well drained loams, sandy loams, silt loams or peat, lying on level sites or gentle slopes and are easily cultivated. They retain good reserves of available water and are either well supplied with plant nutrients or highly responsive to fertilisers. No climatic factor restricts use to any major extent.

Yields are consistently high and cropping highly flexible. Most crops can be grown, including the more exacting horticultural crops.

Grade 2

Land with some minor limitations which exclude it from Grade 1. Such limitations are frequently connected with the soil; for example, its texture, depth or drainage. Minor climatic or site restrictions may also cause land to be included in this Grade.

The limitations may hinder cultivations or harvesting of crops, lead to lower yields or make the land less flexible than that in Grade 1. A wide range of agricultural and horticultural crops can usually be grown, though there may be restrictions in the range of horticultural crops and arable root crops.

Grade 3

Land with moderate limitations due to the soil, relief or climate, or some combination of these factors which restricts the choice of crops, timing of cultivations or level of yield. Soil defects may be of structure, texture, drainage, depth, stoniness or water holding capacity. Other limitations may be due to increasing altitude, steep slopes, or an excess (or deficiency) of rainfall.

The range of cropping is comparatively restricted. Only the less demanding horticultural crops can be grown and, towards the bottom of the Grade, arable root crops are limited to forage crops. Grass and cereals are thus the principal crops; land in the middle range of the Grade is capable of giving reasonable yields under average management.

Grade 4

Land with severe limitations due to adverse soil, relief or climate, or a combination of these. Adverse soil characteristics include unsuitable texture and structure, wetness, shallow depth, stoniness or low water holding capacity. Relief and climatic restrictions may include steep slopes, short growing season, high rainfall or exposure.

The land is generally only suitable for low output enterprises. A high proportion will be under grass, with occasional fields of oats, barley or forage crops.

Grade 5

Land with very severe limitations due to adverse soil, relief or climate, or a combination of these. The main limitations include very steep slopes, excessive rainfall and exposure, poor to very poor drainage, shallow depth of soil, excessive stoniness, low water holding capacity and severe plant nutrient deficiencies or toxicities.

Grade 5 land is generally under grass or rough grazing, except for occasional pioneer forage crops.

A preponderance of land in Grade 3 has prompted a three part sub-division of the grade using a technique which:-

(a) Assesses physical criteria within the grade so that progressively from Sub-grade 3a - Sub-grade 3c the limitations become more serious.

(b) Analyses yield response in 'key' (or special) crops normally associated with Grade 3.

SUMMARY OF DEFINITION OF SUB-DIVISION OF GRADE 3

Sub-grade 3a

This land shares the moderate degree of limitation common to Grade 3, but has some physical advantages which lead to appreciably better performance than that of land in the remainder of the grade. These advantages may allow a wider range of crops to be grown, higher yields to be obtained from a narrower range of crops or 'usable' grass to be grown over a very long period, together with average yields of barley or oats.

Sub-grade 3b

Most of this land is capable of average production, typically of cereals and grass, although areas where yields are slightly below average are also eligible provided there is an advantage such as greater flexibility of cropping. In the case of land which is primarily suitable for grass, there must be the particular advantage of a long growing season.

Sub-grade 3c

This land has some physical characteristics which give a poorer production performance than that of other land in the grade. This poorer performance may be in the form of higher risks, higher costs, lower flexibility or lower yields.

In terms of its actual or potential production such land is usually characterised by below average yields in a narrow range of crops.

LAND CAPABILITY CLASSIFICATION (LCC)

More recently the Soil Survey of England and Wales, in consultation with members of the Ministry of Agriculture, Fisheries and Food, has begun the task of preparing land capability classification maps. So far only about 4 - 5% of land is covered by such maps, but in Scotland a similar classification covers a more extensive area.

This system has three principal aims:

(a) Simplification of soil maps so as to show their content in terms of land potential, and the limitations which restrict agricultural use.

(b) To provide information for farm planning and technical advisory work.

(c) To aid land use planning when some types of detailed soil information are required.

The capability of land is assessed on the knowledge of the behaviour of soil series or associations under different conditions of gradient, climate and land use. The seven classes of land are shown and these are defined as:

Class 1 Land with very minor or no physical limitations to use. A wide range of crops can be grown and yields are good with moderate inputs of fertiliser.

Class 2 — Land with minor limitations that reduce the choice of crops and interfere with cultivations.
A wide range of crops can be grown, though some root crops and winter harvested crops may not be ideal choices because of difficulties in harvesting.

Class 3 — Land with moderate limitations that restrict the choice of crops and/or demand careful management.
The limitations affect the timing of cultivations and range of crops, which is restricted mainly to grass, cereal and forage crops. Whilst good yields may be obtained, limitations are more difficult to overcome.

Class 4 — Land with moderately severe limitations that restrict the choice of crops and/or require very careful management.
Climate disadvantages combine with other limitations to restrict the choice and yield of crops and increase risks. The main crop is grass. Cereals and forage crops can be grown where the increased hazards can be accepted.

Class 5 — Land with severe limitations that restrict use to pasture, forestry and recreation.
High rainfall, exposure and restricted growing season prohibit arable cropping.
Mechanised pasture improvements are feasible.
The land has a wide range of capability for forestry and recreation.

<u>Class 6</u> Land with very severe limitations that restrict use to pasture, forestry or recreation. The limitations are sufficiently severe to prevent the use of tractors for pasture improvement. Very steep ground which has some sustained grazing value is included.

<u>Class 7</u> Land with extremely severe limitations that cannot be rectified. Exposed situations, protracted snow cover and a short growing season preclude forestry. Poor rough grazing may be available for very short periods.

Five sub-classes identify factors which influence production or need correction. These are:

Soil (s)
Wetness (w)
Climate (c)
Gradient (g)
Erosion (e)

In addition units within sub-classes can show soils needing different management and improvement practices.

A moderately high level of management is assumed and this includes such items as fertiliser application at or just below the recommended levels, good cultivation and grazing practice, economically feasible drainage improvements and suitable rotations.

As with the NALC system, assessment is made purely on the influence of physical characteristics.

PART II

DISCUSSION

DISCUSSION

The parametric approach to land classification described for France engendered a stimulating debate. The quantitative relationship between yield and specific soil properties was the central element in this approach. It emerged that there was an intuitive component in the classification system and that there was a clear need for further information on the relationship between yield and soil factors.

The agro-ecological zones of the world project of FAO required a multi-disciplinary input and the need for further information on the climatic requirements of specific crops was highlighted. FAO welcomed the work of the European Community on land resource assessment, particularly in regard to the development of a common system of land classification. The integration of EEC activities in land classification with those of FAO was considered important in the context of global land resource assessment, which in turn was basic for assessing the potential use of the world's land resources. In this context, the principle of comparative advantage in crop production would be important in land use policy development.

Discussion on the papers from the Netherlands centred on water management, soil moisture capacity and aspects of groundwater level and groundwater level changes, which are of vital importance in Dutch land classification. The need for the preparation of maps amenable to interpretation by people such as urban planners was emphasised and some concern was expressed on the predictive value of soil moisture capacity data in relation to the homogeneity of soil mapping units and levels of abstraction used in suitability classification. A quantification of the effect of climate and soil physical conditions on dry matter production was central to land resource assessment programmes. Some concern was expressed about the utility of meteorological data from stations in or near urban areas in relation to the elucidation of yield-soil-climate relationship. Similarly it was pointed out that the soil fertility factor must be considered in any analytical model of crop production.

In the context of the Belgian studies, the effects of agricultural technology and land development methods in the utility of the land classification maps was a matter of concern. It was important that these maps should be understood by farmer users. The quantitative approach adopted in Belgium to seek an understanding of soil factors influencing horticultural crop yields was welcomed and it was again accepted that there was a lack of information on this fundamental relationship.

The German system of land evaluation, which had been developed in 1934 for land taxation purposes, was updated when necessary to take into account changes in management and technology. The system was considered thorough and elaborate. However, the system did not take into account the economic position of the farmers or land tenure considerations. The use of farmer yields for land evaluation studies for tillage crops in Ireland was questioned, although these yields were recorded from well-managed farms. There was favourable reaction to the methodology used for land evaluation for pasture production and the application of the methodology for use at Community level emerged as a clear possibility. There was a need for a systematic approach to the question of land development practices, eg, drainage, irrigation in a land classification system for the Community.

From Italy concern was expressed at the lack of government support for land evaluation programmes of work. Research under this heading lacked co-ordination. The land suitability classification system being developed for Italy was commendable. The system had agricultural and non-agricultural applications and if adequately progressed, would have considerable application for Italian land use planning.

The possibilities and flexibility of the Danish approach to soil classification were recognised, although concern was expressed that the Soil Survey departed from the conventional pedologic approach. The system had the merit of the co-ordinated use of information from various agencies. Some concern was expressed about the computer based construction of soil boundaries. The application of the Danish methodology to complex soil areas could raise problems. The soil data storage system which was described was impressive and the development of such a system at Community level merited consideration.

The UK systems of soil and land classification were based entirely on physical characteristics and discussion centred on the possibility of developing an Economic Land Classification. This involves the estimation of output/acre attributable to the land, which would present major difficulties since farming systems may show considerable variation on similarly classified land. Other confounding factors included farm structure, adequacy of fixed equipment, location. Other points which emerged in discussion included the effect of land development including cost/benefit ratios on land categorisation, aspects of soil fertility and the utility of soil maps for land classification in the UK context.

In conclusion, the papers presented and the ensuing discussion set a very important basis for the further development of research effort which would have as a major objective the development of a common system of land classification for the European Community, which in turn would serve the interests of the Common Agricultural Policy.

APPENDIX I

PROPOSALS ARISING FROM THE LAND RESOURCE EVALUATION SEMINAR

The order of proposals is arbitrary.

1. A project should be started to investigate specific crop requirements both from a soil properties standpoint and a climatological standpoint in order to use such requirements in the land suitability classification system to be adopted.

2. The working group should adopt a data storing system for the member countries as a first step to the setting up of such a system for the Community. It should concentrate on the aspects of this system that may be similar to a certain degree to the present Danish data storage system.

3. The questions the EEC may ask should be considered at some length before setting up a data storage system or before producing a map or a set of maps in order to develop systems that can answer such questions. Questions of detail, scale or the type of data to be used for models should be considered. Moreover, the system must be able to respond to such questions at short notice.

4. A first step towards developing a land suitability system may well be the development of a set of proper assessment factors for this purpose.

5. A project could be developed to study for instance the total energy input in the production of a unit of beef in various areas of the various member countries.

6. Because of its priority character it was proposed to consider firstly the problems of breeding zones in disadvantaged areas.

7. At a national level it is possible to conceive suitability maps at a small scale, taken directly from soil maps and/or established maps and, if possible, aided by teledetection. Parametrical maps such as those concerning soils affected by excess water, or those quantifying the useful water reserve of soils, could constitute a first step in this direction. It is also possible to conceive suitability maps simultaneously integrating physical, geographical and socio-economic criteria.

   Such an approach, if applied, should take into account the production systems so as to permit a comparison between very different regions. Consequently, it would be useful to establish first of all a classification of agricultural regions, which should take into account the diversity of the actual types and systems of production. One could then think of studying cases where the physical and socio-economic factors would be associated in order to finalise proposals for the planning of the actual systems.

Apart from these proposals, the FAO requested the working group to assist in the development of land suitability systems and to contemplate the bringing of agricultural planning into accordance with that of the rest of the world.

In addition, comments were made on the properties of the land use or land suitability system to be adopted. Recommendations were as follows:

1. The system to be adopted for the classification of land use and/or land suitability by the Community should take into account the information provided by farmers and should be understandable to the farmers as well as planners and policy makers.

2. The system should be capable of responding in the interest of farming and agriculture to questions and pressures from the environmental, industrial and urban planning viewpoints.

Finally it was proposed to seek some strengthening of the Italian effort to set up national co-ordinated soil survey service.

APPENDIX II

LIST OF PARTICIPANTS AT THE MEETING OF THE LAND USE AND RURAL RESOURCES GROUP

Dr. T. WALSH (Chairman)	Ireland
Prof. A. NOIRFALISE	Belgium
A. HENRIKSEN	Denmark
Dr. M. LAPPLE	Federal Republic of Germany
M. JAMAGNE	France
J.P. DEFFONTAINES	France
Dr. M. GARDINER	Ireland
Prof. F. BONCIARELLI	Italy
Prof. G. RONCHETTI	Italy
Prof. A. PANATTONI	Italy
G.A. OOSTERBAAN	The Netherlands
D.B.S. FITCH	UK
J. GILLOT	EEC DG VI/E/4
A. COLE (Recorder)	EEC DG VI/E/4
J. KUYL	EEC DG VI/E/4
M. CORNAERT	Environment and Consumer Protection Service (EEC)
Dr. P. REINIGER	EEC, ISPRA
Dr. R. DUDAL	Director, Land and Water Division, FAO
Dr. L. VAN DER PLAS (Seminar Rapporteur)	The Netherlands
Dr. A. CONWAY	Observer - Ireland
Dr. J. LEE	Observer - Ireland

LIST OF PARTICIPANTS

Dr. J.C. BEGON	France
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M. BULFIN	Ireland
W. BURKE	Ireland
A. COLE	EEC
M.H. CORNEAERT	EEC
Dr. M. CONRY	Ireland
Dr. A. CONWAY	Ireland
J.P. DEFFONTAINES	France
S. DIAMOND	Ireland
Dr. G. DROVEN	Belgium
Dr. R. DUDAL	FAO
T.G. FAHY	Ireland
T. FINCH	Ireland
D.B.S. FITCH	United Kingdom
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Prof. E. GALLAGHER	Ireland
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J. GILLOT	EEC

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Dr. G. HEIDE	Federal Republic of Germany
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D.W. JEFFREY	Ireland
J. KIELY	Ireland
J. KUYL	EEC
Dr. D. LAMBERTS	Belgium
Dr. M. LAPPLE	Federal Republic of Germany
Dr. J. LEE	Ireland
J. LYNCH	Ireland
Dr. V. McALLISTER	United Kingdom
Dr. D. MAGALDI	Italy
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G.A. OOSTERBAAN	The Netherlands
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