SOILS BULLETIN

22

APPROACHES TO LAND CLASSIFICATION

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Foreword

The papers presented here formed a part of the background documentation of an Expert Consultation on Land Evaluation for Rural Purposes which was convened by the Food and Agriculture Organisation of the United Nations in co-operation with the University of Agriculture and the International Institute for Land Reclamation and Improvement, Wageningen, Netherlands. The meeting was held at the International Agriculture Centre, Wageningen, 6-12 October 1972.

The Consultation, which climaxed two years of preparatory work, was aimed at encouraging the standardisation of land evaluation methods as a means of improving communication between resource surveyors and those who need to make use of resource survey information. More specifically, it was planned to develop a framework of land evaluation that would be widely acceptable to survey and planning organisations alike and which would meet the needs of the widest possible range of users. Proposals for such a framework were developed, prior to the consultation, by two multidisciplinary committees; one in the Netherlands the other within FAO. A document describing these proposals is included in a report on the Consultation which has been published by, and may be obtained from, the International Institute for Land Reclamation and Improvement, Wageningen. 1/

Also included in the documentation of the Consultation but not previously published was this series of papers which describe many of the approaches to the classification of agricultural land developed or adopted in the past by different countries or by different organisations throughout the world. They are reproduced here since, together, they are thought to provide a valuable comparison of the diversity of existing methodology and, individually, they record methods which have proved their worth in different environments. It is hoped that a wider distribution of these papers will assist the many who, concious of the importance of understanding the wise alternatives of land use, are presently engaged in developing improved systems for evaluating land.

The reader will appreciate that the views expressed in these papers are those of the respective authors and do not necessarily represent the views of FAO.

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1/ "Land Evaluation for Rural Purposes", Publication No. 17, International Institute for Land Reclamation and Improvement, P.O.Box 45, Wageningen, The Netherlands. (Price: 9 Dutch Guilders).

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INTERPRETATIVE LAND CLASSIFICATION IN ENGLISH-SPEAKING COUNTRIES[1/]

(a working paper on some of the systems in current use and some of their adaptations)

INTRODUCTION

Many different kinds of land classification schemes and systems have been used in English-speaking countries, and a number of them have been adapted in other places. Land classification systems have evolved in response to the need for the classification of landscape units to help solve land use and land planning problems. Each system has been developed, usually over long periods of time (decades), with considerable amounts of effort and evaluation going into the formulation and philosphy of the classification systems. Different environments have different land problems, of course, and different resources to meet the needs. Land classification itself is not an end - it is a means toward an end. The desired end for which land classifications are created is an improved physical and economic environment in which people can live more productive and satisfying lives.

Jacks (1946) reviewed land classification as it "relates to the grouping of lands according to their suitability for producing plants of economic importance." The definition of land classification as now generally used includes practically all aspects of uses of areas of land, including comprehensive and alternative uses of land. Former viewpoints of soil conservation and production maximizations have been influenced increasingly by concepts of ecological efficiency and environmental quality. New techniques in inventory of components of land (some are discussed in Stewart, 1968) include remote sensing, aerial photographic interpretation, mechanical and soil strength measurements, and computer technology (e.g: data banks, map printout systems, retrieval programmes, systems analysis, mathematical simulation models). The computer promises to be a useful tool in increasing quantification of description of land class units, and in putting together, collating, and correlating large amounts of data on soils, land use, slope, elevation, vegetation, climate, geology, drainage, and other natural resource and social attributes. Increasingly, many different disciplines are being called together in task force efforts to solve land use problems. In the future, land classification will probably become more comprehensive as well as more quantitative, and will be increasingly used as a basis for making both high-level planning and low-level implementation management decisions.

In this paper some of the systems and applications of land classification are examined. The land-capability classification of the U.S. Department of Agriculture has perhaps been most widely used and adapted. The U.S. land-capability classification is basically a system of aggregation of soil map units (from detailed maps) into groups of soils showing similarities in responses to management, and similarities in hazards, limitations, or risks in use. The land-capability system is used in the United States at the lowest levels on farmers' fields, to help plan conservation practices and crop rotations for individual management objectives; on the national level the land-capability classification is used to group soils to summarize conservation problems and needs for solution on a national scale. The soil surveys of England, Wales, and Scotland have adapted the principles of the U.S. system, but regionalized it to fit local conditions; along with other changes, the British adaptation eliminated the Class V of the U.S. system, and added climatic criteria relevant to Britain. In Canada, the U.S. system has been modified to provide a soil capability classification which forms part of the Canada Land Inventory; the revisions made in Canada are in several respects similar to those introduced in Britain. In East Pakistan, the principles of this U.S. classification were utilized, but the environmental situation of land resources and use in East Pakistan was so drastically different from the conditions under which the classification is applied in the United States that rather wide revisions were necessary for adaptation.

1/ Condensed from a document prepared by Dr. G.W. Olson, Cornell University, NY, U.S.A.

Land classification methods for irrigation suitability, as developed by the U.S. Bureau of Reclamation, depend upon large scale maps of soils, topography, and other factors applied in an environment that is economically feasible for irrigation development. Supplementary studies in the laboratory, greenhouse and field may also be carried out. The U.S. Bureau of Reclamation irrigation suitability classification is a good example of a very intensive land classification scheme into which considerable investments are put for implementation of large scale projects. The irrigation suitability classification has a very specific purpose, but has been used in environments as diverse as the U.S., Thailand and Brazil.

The Storie index is of interest as being one of the earliest examples of a quantitative approach to rating land potential based primarily on properties of the soil and climate. To fit local conditions, different values can be substituted for the various factors considered in the formula.

The land systems approach to land classification, developed in Australia, aims at an integrated evaluation of the total environment and the approach has been mainly applied to the broad evaluation of large areas in both Australia and in parts of Africa. Terrain evaluation parametric methods offer some of the most exciting prospects for the future in land classification. Much of the work presently done on the mechanically-measured landscape values have been of an experimental or research nature. A great deal of work in this area has been done by military research organizations in the fields of aerial photographic interpretation, remote sensing, satellite information relay, terrain evaluation, trafficability studies, and computer programming for military intelligence. In the future much of this technology will probably become available for civilian use, so that land classification can use some of these methods to improve the quantitative aspects. Computer technology is already being applied, however, in large scale programmes of land use inventory in Canada, New York, Puerto Rico, and several other places. In Canada, the land use inventory is tied in with capability ratings of the lands for agriculture, forestry, recreation, and wildlife.

Each land classification scheme tends to adapt itself to the local environment, resources, and problems. The Cornell farm area classification is one example of a system which has proved very useful in New York State, and which has been adapted, in part, in several areas in Latin America and other places. The Cornell farm area classification gives heavy emphasis to economic considerations, but also considers soil, climate, and other elements of the natural environment.

LAND-CAPABILITY CLASSIFICATION

One of the most widely used systems of land classification, commonly called land-capability classification, is that of the Soil Conservation Service of the U.S. Department of Agriculture. The classification is summarized in Klingebiel and Montgomery (1966). A bulletin and set of 50 slides introduce the concepts of the classification (SCS STAFF 1969).

This land-capability classification is based on a detailed soil survey, usually published at scales of about 1:20 000 or 1:15 840 in the United States. The classification consists essentially of grouping the various soil mapping units "primarily on the basis of their capability to produce common cultivated crops and pasture plants without deterioration over a long period of time." The soil mapping unit is defined as the "portion of the landscape that has similar characteristics and qualities and whose limits are fixed by precise definitions", and is the unit about which the greatest number of precise statements and predictions can be made.

Capability units, into which soil mapping units are grouped, have similar potentials and continuing limitations or hazards. Soil mapping units put into a capability unit are sufficiently uniform to (1) produce similar kinds of cultivated crops and pasture plants with similar management practices, (2) require similar conservation treatment and management under the same kind and condition of vegetative cover, or (3) have comparable potential productivity. Use of capability units condense and simplify soil mapping unit information for planning use and management of individual areas of land, as small as several acres in size. A capability unit is designated by a symbol such as III e-2. The Roman numeral designates the capability class where the land has the same relative degree of hazard or limitation; the risks of soil damage or limitation in use become progressively greater from class I to class VIII. The lower case letters designate subclasses which have the same major conservation problem: e (erosion and runoff), w (excess water), z (root zone limitations), and c (climatic limitations). The Arabic numbers indicate the capability unit within each capability class and subclass.

Land capability classes are used as a means of introducing the map user to the more detailed information on the soil map; the classes show the location, amount and general suitability of the soils for agricultural use, the subclasses provide information about the kind of conservation problem or limitation involved in land use. Both classes, used together, provide the map user with general information about the limitations and problems involved for broad programme planning, conservation studies, and similar purposes. The capability unit indicates soil areas that are enough alike to be suited to the same crops and pasture plants, to require similar management, and to be similar in productivity and in other responses to management.

The land capability classes are as follows:-

Class I

Soils in Class I have few limitations that restrict their use.

Soils in this class are suited to a wide range of plants and may be used safely for cultivated crops, pasture, range, woodland, and wildlife. The soils are nearly level or only gently sloping and erosion hazard from wind or water is low. They are deep, generally well drained, and easily worked soils. They hold water well and are either fairly well supplied with plant nutrients or highly responsive to inputs of fertilizer.

The soils in Class I are not subject to damaging overflow. They are productive and suited to intensive cropping. The local climate must be favourable for growing many of the common field crops.

In irrigated areas, soils may be placed in Class I if the limitation of the arid climate has been removed by relatively permanent irrigation works. Such irrigated soils (or soils potentially useful under irrigation) are nearly level, have deep rooting zones, have favourable permeability and water-holding capacity, and are easily maintained in good tilth. Some of the soils may require initial conditioning including levelling to the desired grade, leaching of a slight accumulation of soluble salts, or lowering of the seasonal water table. Where limitations due to salts, water table, overflow, or erosion are likely to recur, the soils are regarded as subject to permanent natural limitations and are not included in Class I.

Soils that are wet and have slowly permeable subsoils are not placed in Class I. Some kinds of soils in Class I may be drained as an improvement measure for increased production and ease of operation.

Soils in Class I that are used for crops need ordinary management practices to maintain productivity - both soil fertility and soil structure. Such practices may include the use of fertilizers and lime, cover and green-manure crops, conservation of crop residues and animal manures, and sequences of adapted crops.

Class II

Soils in Class II have some limitations that reduce the choice of plants or require moderate conservation practices.

Soils in Class II require careful soil management, including conservation practices, to prevent deterioration or to improve air and water relations when the soils are cultivated. The limitations are few and the practices are easy to apply. The soils may be used for cultivated crops, pasture, range, woodland, or wildlife food and cover.

Limitations of soils in Class II may include (singly or in combination) the effects of (1) gentle slopes, (2) moderate susceptibility to wind or water erosion or moderate adverse effects of past erosion, (3) less than ideal soil depth, (4) somewhat unfavourable soil structure and workability, (5) slight to moderate salinity or sodium easily corrected but likely to recur, (6) occasional damaging overflow, (7) wetness correctable by drainage but existing permanently as a moderate limitation, and (8) slight climatic limitations on soil use and management.

The soils in this class provide the farm operators less latitude in the choice of either crops or management practices than soils in Class I. They may also require special soil-conserving cropping systems, soil conservation practices, water-control devices, or tillage methods when used for cultivated crops. For example, deep soils of this class with gentle slopes subject to moderate erosion when cultivated may need terracing, stripcropping, contour tillage, crop rotations that include grasses and legumes, vegetated water-disposal areas, cover or green-manure crops, stubble mulching, fertilizers, manure, and lime. The exact combinations of practices vary from place to place, depending on the characteristics of the soil, the local climate, and the farming systems.

Class III

Soils in Class III have severe limitations that reduce the choice of plants or require special conservation practices, or both.

Soils in Class III have more restrictions than those in Class II and when used for cultivated crops the conservation practices are usually more difficult to apply and to maintain. They may be used for cultivated crops, pasture, woodland, range, or wildlife food and cover.

Limitations of soils in Class III restrict the amount of clean cultivation; timing of planting, tillage, and harvesting; choice of crops; or some combination of these limitations. The limitations may result from the effects of one or more of the following: (1) moderately steep slopes; (2) high susceptibility to water or wind erosion or severe adverse effects of past erosion; (3) frequent overflow accompanied by some crop damage; (4) very slow permeability of the subsoil; (5) wetness or some continuing waterlogging after drainage; (6) shallow depths to bedrock, hardpan, fragipan, or claypan that limit the rooting zone and the water storage; (7) low moisture-holding capacity; (8) low fertility not easily corrected; (9) moderate salinity or sodium, or (10) moderate climatic limitations.

When cultivated, many of the wet slowly permeable but nearly level soils in Class III require drainage and a cropping system that maintains or improves the structure and tilth of the soil. To prevent puddling and to improve permeability, it is commonly necessary to supply organic material to such soils and to avoid working them when they are wet. In some irrigated areas, part of the soils in Class III have limited use because of high water table, slow permeability, and the hazard of salt or sodic accumulation. Each distinctive kind of soil in Class III has one or more alternative combinations of use and practices required for safe use, but the number of practical alternatives for average farmers is less than that for soils in Class II.

Class IV

Soils in Class IV have very severe limitations that restrict the choice of plants, require very careful management, or both.

The restrictions in use for soils in Class IV are greater than those in Class III and the choice of plants is more limited. When these soils are cultivated, more careful management is required and conservation practices are more difficult to apply and maintain. Soils in Class IV may be used for crops, pasture, woodland, range, or wildlife food and cover.

Soils in Class IV may be well suited to only two or three of the common crops or the harvest produced may be low in relation to inputs over a long period of time. Use for cultivated crops is limited as a result of the effects of one or more permanent features such as (1) steep slopes, (2) severe susceptibility to water or wind erosion, (3) severe effects of past erosion, (4) shallow soils, (5) low moisture-holding capacity, (6) frequent overflows accompanied by severe crop damage, (7) excessive wetness with continuing hazard of waterlogging after drainage, (8) severe salinity or sodium, or (9) moderately adverse climate.

Many sloping soils in Class IV in humid areas are suited to occasional but not regular cultivation. Some of the poorly drained nearly level soils placed in Class IV are not subject to erosion but are poorly suited to intertillable crops because of the time required for the soil to dry out in the spring and because of low productivity for cultivated crops. Some soils in Class IV are well suited to one or more of the special crops, such as fruits and ornamental trees and shrubs, but this suitability itself is not sufficient to place a soil in Class IV.

In subhumid and semi-arid areas, soils in Class IV may produce good yields of adapted cultivated crops during years of above average rainfall; low yields during years of average rainfall; and failure during years of below average rainfall. During the low rainfall years the soil must be protected even though there can be little or no expectancy of a marketable crop. Special treatments and practices to prevent soil blowing, conserve moisture, and maintain soil productivity are required. Sometimes crops must be planted or emergency tillage used for the primary purpose of maintaining the soil during years of low rainfall. These treatments must be applied more frequently or more intensively than on soils in Class III.

Class V

Soils in Class V have little or no erosion hazard but have other limitations impracticable to remove that limit their use largely to pasture, range, woodland, or wildlife food and cover.

Soils in Class V have limitations that restrict the kind of plants that can be grown and that prevent normal tillage of cultivated crops. They are nearly level but some are wet, are frequently overflowed by streams, are stony, have climatic limitations, or have some combination of these limitations. Examples of Class V soils are (1) soil of the bottom lands subject to frequent overflow that prevents the normal production of cultivated crops, (2) nearly level soils with a growing season that prevents the normal production of cultivated crops, (3) level or nearly level stony or rocky soils, and (4) ponded areas where drainage for cultivated crops is not feasible but where soils are suitable for grasses or trees. Because of these limitations cultivation of the common crops is not feasible but pastures can be improved and benefits from proper management can be expected.

Class VI

Soils in Class VI have severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture or range, woodland, or wildlife food and cover.

Physical conditions of soils placed in Class VI are such that it is practical to apply range or pasture improvements, if needed, such as seeding, liming, fertilizing, and water control with contour furrows, drainage ditches, diversions, or water spreaders. Soils in Class VI have continuing limitations that cannot be corrected, such as (1) steep slope, (2) severe erosion hazard, (3) effects of past erosion, (4) stoniness, (5) shallow rooting zone, (6) excessive wetness or overflow, (7) low moisture capacity,

(8) salinity or sodium, or (9) severe climate. Because of one or more of these limitations these soils are not generally suited to cultivated crops. But they may be used for pasture, range, woodland, or wildlife cover or for some combination of these.

Some soils in Class VI can be safely used for the common crops provided intensive management is used. Some of the soils in this class are also adapted to special crops such as sodded orchards, blueberries, or the like, requiring soil conditions unlike those demanded by the common crops. Depending upon soil features and local climate, the soils may be well or poorly suited to woodlands.

Class VII

Soils in Class VII have very severe limitations that make them unsuited to cultivation and that restrict their use largely to grazing, woodland, or wildlife.

Physical conditions of soils in Class VII are such that it is impractical to apply such pasture or range improvements as seeding, liming, fertilizing, and water control with contour furrows, ditches, diversions, or water spreaders. Soil restrictions are more severe than those in Class VI because of one or more continuing limitations that cannot be corrected, such as (1) very steep slope, (2) erosion, (3) shallow soils, (4) stones, (5) wet soils, (6) salts or sodium, (7) unfavourable climate, or (8) other limitations that make them unsuited to common cultivated crops. They can be used safely for grazing or woodland or wildlife food and cover or for some combination of these under proper management.

Depending upon the soil characteristics and local climate, soils in this class may be well or poorly suited to woodland. They are not suited to any of the common cultivated crops; in unusual instances, some soils in this class may be used for special crops under unusual management practices. Some areas of Class VII may need seeding or planting to protect the soil and to prevent damage to adjoining areas.

Class VIII

Soils and landforms in Class VIII have limitations that preclude their use for commercial plant production and restrict their use to recreation, wildlife, or water supply or to aesthetic purposes.

Soils and landforms in Class VIII cannot be expected to return significant on-site benefits from management for crops, grasses, or trees, although benefits from wildlife use, watershed protection, or recreation may be possible.

Limitations that cannot be corrected may result from the effects of (1) erosion or erosion hazard, (2) severe climate, (3) wet soil, (4) stones, (5) low moisture capacity, and (6) salinity or sodium.

Badlands, rock outcrop, sandy beaches, river wash, mine tailings, and other nearly barren lands are included in Class VIII. It may be necessary to give protection and management for plant growth to soils and landforms in Class VIII in order to protect other more valuable soils, to control water, or for wildlife or aesthetic reasons.

The assumptions on which the classification is based are:-

1. That a combination of permanent soil characteristics and climate effects only are taken as determinant;
2. That within a class similarities are based on the range limitation for use;
3. That a favourable overall long term investment ratio is one of the criteria used for inclusion of a soil in a class;
4. That a moderately high level of management is assumed, based on local norms. But that the most favourable economic use is not implied in the allocation of a soil for cropping capability;

5. That while Classes I to V define soils suitable for long term cultivation there may be greater within class variation in management requirements for perennials than between classes;

6. That water, stones, salinity problems etc., are not considered permanent factors for the purpose of (1) above unless their extent or nature makes amelioration uneconomic;

7. Soils capable of amelioration are classified according to the probable subsequent results, limitations, potential reversion etc. The economics of amelioration are not a criterion;

8. Soils already ameliorated are grouped according to their continuing potential;

9. The assignment of specific classifications in an area can be changed following major reclamation projects, the effects of which are assumed to be consistent for the foreseeable future;

10. Groupings may be changed on the basis of new soil capability information;

11. Socio-economic factors are not criteria;

12. Soils I to IV require that mechanical cultivation is economically and practically feasible;

13. Suitability for cultivation does not exclude use for pasture, range, forest etc., and a classification for these latter will not be coincident with the present one;

14. Specific assignment of classification indices is done on the basis of research, current practises and experience. Lacking data on current practise, soils are assigned indices through experience with similar soil/climate conditions elsewhere.

The capability grouping of soils is designed (1) to help landowners and others use and interpret the soil maps, (2) to introduce users to the detail of the soil map itself, and (3) to make possible broad generalizations based on soil potentialities, limitations in use, and management problems.

A publication by Brown (1963) illustrates how the land-capability classification is used to help landowners and others use soil maps. Soils of the Flat Top Ranch in Bosque County, Texas, were grouped into capability classes and the minimum conservation treatment was specified for each class to meet the management objectives of the landowner. Deep rooted legumes or perennial grasses were to be grown one year out of every four on Class I soils, one out of every three on Class II, one out of every two on certain Class III soils, and four out of five years on Class IV. Grasslands on the ranch in the higher capability classes, not suitable for farming, were to be managed for better root development and plant vigor by (1) leaving at least one-half of the annual growth and (2) providing timely rest periods to maintain the vigor of desirable adapted plants.

Almost all soil survey reports currently published by the co-operative soil survey in the United States have sections explaining classification of the soils of the areas into land capability units - to introduce users to the detail of the soil map itself.

Land-capability classification also assists in making possible broad generalizations based on soil potentialities, limitations in use, and management problems in the United States. Broad areas of land resource regions have been delineated (Austin, 1965) with data from the land-capability classification and other sources. The national conservation needs inventory, utilizing detailed soil and land use maps of 100 . and 160 - acre blocks from a statistical sampling of about two percent of the privately-owned lands in the United States, made extensive use of the land-capability classifiation, particularly in summarizing acreages and future projections on conservation problems and land use relationships (Co-operative Committee, 1965). Farm planning, urban planning, and regional planning in the United States also makes extensive use of the land-capability classification.

The land-capability classification of the Soil Conservation Service of the U.S. Department of Agriculture, of course, is seldom used in other countries exactly as it was developed in the United States. Generally workers in other countries adapt the principles of the classification, and come up with a modification more suitable to local plant and management situations. In East Pakistan, for example, the classification as used in the United States was not well suited;1/ the environmental conditions at hand were such that crops were grown throughout the year, soil erosion is not a major problem, much of the land is flooded for about half the year, and wetland rice is the principal crop grown. Classes developed were Class I (Very good agricultural land), Class II (Good agricultural land), Class III (Moderate agricultural land), Class IV (Poor agricultural land) and Class V (Very poor and non-agricultural land). Subclasses included t (toxic materials), z (flood hazard), and x (hazard of river erosion or alluvial burial).

LAND USE CAPABILITY CLASSIFICATION

The land use capability classification used by the Soil Survey of England and Wales is basically an adaptation and revision of the U.S. land capability classification, modified to fit conditions in Britain. Bibby and Mackney (1969) have summarized the classification in a technical monograph. Some of the philosophy and history of land classification is put forth in a Technical Report on classification of agricultural land in Britain (Ministry, 1962). Class V land, as defined for use in the United States, is not used in Britain. Definitions of land use capability classes used in Britain are as follows.

Class 1

Land with very minor or no physical limitations to use.

Soils are generally well drained deep loams, sandy loams, or silt loams, related humic variants, or peat, with good reserves of moisture or with suitable access for roots to moisture; they are either well supplied with plant nutrients or responsive to fertilizers. Sites are level or gently sloping and climate favourable. A wide range of crops can be grown and yields are good with moderate inputs of fertilizer.

Class 2

Land with minor limitations that reduce the choice of crops and interfere with cultivation.

Limitations may include, singly or in combination, the effects of (1) moderate or imperfect drainage, (2) less than ideal rooting depth, (3) slightly unfavourable soil structure and texture, (4) moderate slopes, (5) slight erosion, and (6) slightly unfavourable climate. 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 or demand careful management, or both.

Limitations may result from the effects of one or more of the following: (1) imperfect or poor drainage, (2) restrictions in rooting depth, (3) unfavourable structure and texture, (4) strongly sloping ground, (5) slight erosion, and (6) moderately unfavourable to moderately severe climate. The limitations affect the timing of cultivations and range of crops which are restricted mainly to grass, cereal, and forage crops. While good yields are possible, limitations are more difficult to overcome.

1/ Personal communication to the author from H. Brammer, FAO Deputy Project Commissioner.

Class 4

Land with moderately severe limitations that restrict the choice of crops or require very careful management practices, or both.

Limitations are due to the effects of one or more of the following: (1) poor drainage difficult to remedy, (2) occasional damaging floods, (3) shallow or very stony soils, (4) moderately steep gradients, (5) slight erosion, and (6) moderately severe climate. Climatic disadvantages combine with other limitations to restrict the choice and yield of crops and increase risks. The main crop is grass, with cereals and forage crops as possible alternatives where the increased hazards can be accepted.

Class 5

Land with severe limitations that restrict use to pasture, forestry, and recreation.

Limitations are due to one or more of the following defects which cannot be corrected: (1) poor or very poor drainage, (2) frequent damaging floods, (3) steep slopes, (4) severe risk of erosion, and (5) severe climate. High rainfall, exposure, and a restricted growing season prohibit arable cropping although mechanized pasture improvements are feasible. The land has a wide range of capability for forestry and recreation.

Class 6

Land with very severe limitations that restrict use to rough grazing, forestry, and recreation.

Of the following limitations one or more cannot be corrected: (1) very poor drainage, (2) liability to frequent damaging floods, (3) shallow soil, (4) stones or boulders, (5) very steep slopes, (6) severe erosion, and (7) very severe climate. The land has limitations which are sufficiently severe to prevent the use of machinery for pasture improvement. Very steep ground which has some sustained grazing value is included. On level or gently sloping upland sites, wetness is closely correlated with peat or peaty or humose flush soils.

Class 7

Land with extremely severe limitations that cannot be rectified.

Limitations result from one or more of the following defects: (1) very poorly drained boggy soils, (2) extremely stony, rocky, or boulder-strewn soils, bare rock, scree, or beach sand and gravel, (3) untreated waste tips, (4) very steep gradients, (5) severe erosion, and (6) extremely severe climate. Exposed situations, protracted snow cover, and a short growing season preclude forestry, although a poor type of rough grazing may be available for a few months.

The American subclass system is used, but an additional subclass (indicated by lower case letter "g") has been introduced for gradient and soil pattern limitations on land use. Effects of climate (c) have been carefully studied in Britain, and also related to land use capability classes.

In Britain, land gradient (g) has a marked effect on mechanized farming. Slopes of 3–7° may cause problems with some gapping machines or mechanized weeders, precision seeders, and some root crop harvesters. Slopes of 7–15° restrict the use of a combine harvester. Two-way ploughing encounters difficulties at about 11° slopes. Above 15° loading on trailers is difficult. Slopes greater than 15° are not suitable for normal rotations and remain in grass for long periods. Gradients above 20° are difficult to plough, lime, and fertilize. Above 25° some soil movement and the formation of paths across slopes by animals starts, and no mechanized operations are possible without specialized machinery.

Climate (c) is also an important consideration in the land use capability classification in Britain. Climatic land use capability groups have been designed where rainfall – potential transpiration = $<$ 100 mm (annual) and mean daily maximum temperature is $>$ 15°C; where rainfall – potential transpiration = $<$ 300 mm and mean daily maximum temperature is 14–15°C; and where rainfall – potential transpiration = $>$ 300 mm and mean daily maximum temperature is $<$ 14°C.

In general, altitude and annual rainfall also separate land use capability into the following groups: (1) land over 2 000 feet is generally above the tree line and provides only poor rough grazing, (2) land between 1 000 and 2 000 feet with more than 60 inches annual rainfall provides rough grazing but pasture improvement is generally not feasible, (3) land between 600 and 1 000 feet with more than 50 inches annual rainfall allows pasture improvement but is not suitable for arable crops, and (4) land between 400 and 600 feet with more than 40 inches annual rainfall is mainly suitable for grass and limited arable cropping.

The report on soils of the Exeter district (Clayden, 1971) illustrates application of the land use capability classification to a specific area. Criteria of the classification of soils of the district are discussed in the report, and some classes and subclasses are illustrated with photographs. A table in the report lists placement of each map unit (scale of 1 inch = 1 mile) into classes, and land use limitations of the mapping units. Some earlier reports (Hall and Folland, 1970) assign grades to soil associations which are a bit more generally defined, but follow the same general principle of land use capability classification.

SOIL CAPABILITY CLASSIFICATION

Soil capability classification for agriculture is being used as part of the Canada Land Inventory (Department of Forestry, 1965). Soil capability classification is made from soil maps, and put into a computerized data bank system (Tomlinson, 1968). The soil capability classification is modified from the U.S. land-capability classification, and resembles the land use capability classification used in England and Wales, but has been adapted to Canadian conditions.

The Canadian soil capability classification (Department of Agriculture, 1970) has seven classes, briefly defined as under:

Class 1

Soils in this class have no significant limitations in use for crops.

Class 2

Soils in this class have moderate limitations that restrict the range of crops or require moderate conservation practices.

Limitations of soils in this class may be any one of the following: (1) adverse regional climate, (2) moderate effects of accumulative undesirable characteristics, (3) moderate effects of erosion, (4) poor soil structure or slow permeability, (5) low fertility correctable with consistent moderate applications of fertilizers and lime, (6) gentle to moderate slopes, (7) occasional damaging overflow, or (8) wetness correctable by drainage but continuing as a moderate limitation.

Class 3

Soils in this class have moderately severe limitations that restrict the range of crops or require special conservation practices.

Limitations of soils in this class are a combination of two of those described under class 2 or one of the following: (1) moderate climatic limitations including frost pockets, (2) moderately severe effects of erosion, (3) intractable soil mass or very slow permeability, (4) low fertility correctable with consistent heavy applications of fertilizers and lime, (5) moderate to strong slopes, (6) frequent overflow accompanied by crop damage, (7) poor drainage resulting in crop failure in some years, (8) low water holding capacity or slowness in release of water to plants, (9) stoniness sufficiently severe to seriously handicap cultivation and necessitating some clearing, (10) restricted rooting zone, or (11) moderate salinity.

Class 4

Soils in this class have severe limitations that restrict the range of crops or require special conservation practices, or both.

Limitations of soils in this class include the adverse effects of a combination of two or more of those described in classes 2 and 3 or one of the following: (1) moderately severe climate, (2) very low water holding capacity, (3) low fertility difficult or unfeasible to correct, (4) strong slopes, (5) severe past erosion, (6) very tractable mass of soil or extremely slow permeability, (7) frequent overflow with severe effects on crops, (8) severe salinity causing some crop failures, (9) extreme stoniness requiring considerable clearing to permit annual cultivation, or (10) very restricted rooting zone, but more than one foot of soil over bedrock or an impermeable layer.

Class 5

Soils in this class have very severe limitations that restrict their capability to producing perennial forage crops, and improvement practices are feasible.

Limitations of soils in this class include the adverse effects of one or more of the following: (1) severe climate, (2) low water holding capacity, (3) severe past erosion, (4) steep slopes, (5) very poor drainage, (6) very frequent overflow, (7) severe salinity permitting only salt tolerant forage crops to grow, or (8) stoniness or shallowness to bedrock that make annual cultivation impractical.

Class 6

Soils in this class are capable only of producing perennial forage crops, and improvement practices are not feasible.

Limitations of soils in this class include the adverse effects of one or more of the following: (1) very severe climate, (2) very low water holding capacity, (3) very steep slopes, (4) very severely eroded land with gullies too numerous and too deep for working with machinery, (5) severely saline land producing only salt tolerant native plants, (6) very frequent overflow allowing less than 10 weeks effective growing, (7) water on the surface of the soil for most of the year, or (8) stoniness or shallowness to bedrock that makes any cultivation impractical.

Class 7

Soils in this class have no capability for arable culture or permanent pasture.

Soils in this class have limitations so severe that they are not capable of use for farming or pasture. These soils may or may not have a high capability for trees, native fruits, wildlife, and recreation.

Soil areas in classes 1-4 are also capable of use for perennial forage crops. Soil areas in all classes may be suited for forestry, wildlife, and recreation.

Subclasses are divisions within classes that have the same kind of limitations for agricultural use. Limitations and subclasses are (1) adverse climate (C), (2) undesirable soil structure or low permeability, or both (D), (3) erosion (E), (4) low fertility (F), (5) inundation by streams or lakes (I), (6) moisture limitation (M), (7) salinity (N), (8) stoniness (P), (9) consolidated bedrock (R), (10) adverse soil characteristics (S), (11) topography (T), (12) excess water (W), and (13) cumulative minor adverse characteristics (X). Guidelines have been prepared for placing soils in classes and subclasses at the national level, but some of these will require modification for regional applications in eastern, western, and west coastal Canada. Sections in soil survey reports and maps describe the soil capability classification as well as productive ratings (Reeder and Odynsky, 1969).

The Canada Land Inventory also results in maps of land capability for forestry, recreation, and wildlife (McCormack 1971); the same classification principles used for agriculture apply also to the other land uses. Subclasses for recreation include: (1) angling or viewing of sport fish (A), (2) family beach activities (B), (3) canoe tripping (C), (4) swimming or boat mooring or launching (D), (5) vegetation possessing recreational value (E), (6) waterfall or rapids (F), (7) significant glacier view (G), and (8) historic or prehistoric site (H).

IRRIGATION SUITABILITY CLASSIFICATION

The land classification system of the Bureau of Reclamation of the U.S. Department of the Interior has been used or adapted in many places for irrigation projects.

A good general summary of the Bureau of Reclamation's land classification is given by Maletic and Hutchings (1967). Detailed aspects of the method are given in the Bureau of Reclamation <u>Manual</u> (Bureau of Reclamation, 1953).

The selection of lands for irrigation involves social, economic, and physical factors, and construction of irrigation projects is generally very costly. Consequently, the selection of irrigable lands depends basically on economic criteria; the feasibility of a project is determined by overall costs and benefits, which vary from project to project. According to the concepts of the Bureau, lands to be irrigated should have a favourable 'payment capacity' which is defined as the residual amount of funds available to defray the cost of irrigation water after all other costs have been met by the farm operator. Institutional factors, managerial levels, farm practices, cost-price relationships, markets, social conditions, climate, and other factors are considered in determining the payment capacity for each project and part of a project. In general:

$$Y = -a + bX_1 - cX_2 - dX_3$$

where

Y = Payment capacity (dollars)

X_1 = Productivity rating (percent)

X_2 = Land development cost (dollars)

X_3 = Farm drainage cost (dollars)

a, b, c, and d = Constants derived from farm budget analyses

A large investment may be made to reclaim a saline-sodic soil which after improvement would yield a net farm income of $200 per acre; in another climate and economic setting where net income after improvement would only be $30 per acre, a soil having similar saline-sodic conditions would be regarded as non-irrigable.

Physical, chemical, and biological evaluations of project areas are very important in the Bureau of Reclamation procedures, particularly for characterization of climate, soil, topography, and drainage. In a given climatic setting:

$$E = \int (S, T, D)$$

where

E = Economic parameter

S = Soil characteristics

D = Drainage characteristics

T = Topographic characteristics

The factors S, T, and D are everywhere considered, but the individual characteristics of each, such as texture, structure, horizon arrangement, depth, salinity and alkalinity of S, micro-relief and macro-relief of T, and surface and subsurface drainage of D, are selected on the basis of relevance to prediction of E at the given time or place. For land classification purposes, the quality of land for irrigation use can then be indicated by land classes that represent specified meaningful ranges in the value of E.

In general, as climate favours higher farm incomes, greater expenditures can be made for land forming, farm distribution systems, leaching salt and exchangeable sodium, profile modification practices, and farm surface and subsurface drainage. When considered in terms of land class determining factors such as uneven micro-relief; soil texture, structure, and depth; exchangeable sodium and soluble salt levels; permeability of substrata; and depth to groundwater barriers, then more severe deficiencies involving such factors can be tolerated in climates favouring high incomes than in those resulting in lower incomes.

General definitions of land classes used by the Bureau of Reclamation are as follows:

Class 1

Arable lands of class 1 are lands that are highly suitable for irrigation farming, being capable of producing sustained and relatively high yields of a wide range of climatically adapted crops at reasonable cost. They are smooth lying with gentle slopes. The soils are deep and of medium to fairly fine texture with mellow open structure allowing easy penetration of roots, air, and water and having free drainage yet good available moisture capacity. These soils are free from harmful accumulations of soluble salts or can be readily reclaimed. Both soil and topographic conditions are such that no specific farm drainage requirements are anticipated, minimum erosion will result from irrigation, and land development can be accomplished at relatively low cost. These lands potentially have a relatively high payment capacity.

Class 2

Arable lands of class 2 comprise lands of moderate suitability for irrigation farming, being measurably lower than class 1 lands in productive capacity, adapted to a somewhat narrower range of crops, more expensive to prepare for irrigation, or more costly to farm. They are not so desirable nor of such high value as lands of class 1 because of certain correctible or noncorrectible limitations. They may have a lower available moisture capacity, as indicated by coarse texture or limited soil depth; they may be only slowly permeable to water because of clay layers or compaction in the subsoil; or they also may be moderately saline which may limit productivity or involve moderate costs for leaching. Topographic limitations include uneven surface requiring moderate costs for leveling, short slopes requiring shorter length of runs, or steeper slopes necessitating special care and greater costs to irrigate and prevent erosion. Farm drainage may be required at a moderate cost, or loose rock or woody vegetation may have to be removed from the surface. Any one of the limitations may be sufficient to reduce the lands from class 1 to class 2 but frequently a combination of two or more of them is operating. The class 2 lands have intermediate payment capacity.

Class 3

Arable lands of class 3 are suitable for irrigation development but are approaching marginality for irrigation and are of distinctly restricted suitability because of more extreme deficiencies in the soil, topographic, or drainage characteristics than those described for class 2 lands. They may have good topography, but because of inferior soils have restricted crop adaptability, require larger amounts of irrigation water or special irrigation practices, and demand greater fertilization or more intensive soil improvement practices. They may have uneven topography, moderate to high concentration of salines, or restricted drainage, susceptible of correction but only at relatively high costs. Generally greater risk may be involved in farming class 3 lands than the better classes of land, but under proper management they are expected to have adequate payment capacity.

Class 4

Limited arable or special use lands of class 4 are included in this class only after special economic and engineering studies have shown them to be arable. They may have an excessive specific deficiency or deficiencies susceptible of correction at high cost, but are suitable for irrigation because of existing or contemplated intensive cropping such as for vegetables and fruits; or they may have one or more excessive non-correctible deficiencies thereby limiting their utility to meadow, pasture, orchard, or other relatively permanent crops, but are capable of supporting a farm family and meeting water charges if operated in units of adequate size or in association with better lands. The deficiency may be inadequate drainage, excessive salt content requiring extensive leaching, unfavourable position allowing periodic flooding or making water distribution and removal very difficult, rough topography, excessive quantities of loose rock on the surface or in the plough zone, or cover such as timber. The magnitude of the correctible deficiency is sufficient to require outlays of capital for land development in excess of those permissible for class 3 but in amounts shown to be feasible because of the specific utility anticipated. Subclasses other than those devoted to special crop use may be included in this class such as those for sub-irrigation and sprinkler irrigation which meet general arability requirements. Also recognized in class 4 are suburban lands which do not meet general arability requirements. Such lands can pay water charges or a result of income derived either from the suburban lands and other sources or from other sources alone. The class 4 lands may have a range in payment capacity greater than that for the associated arable lands.

Classes 5 and 6 - Non-arable

Class 5

Lands of class 5 are non-arable under existing conditions, but have potential value sufficient to warrant tentative segregation for special study prior to completion of the classification, or they are lands in existing projects whose arability is dependent upon additional scheduled project construction or land improvements. They may have a specific soil deficiency such as excessive salinity, very uneven topography, inadequate drainage, or excessive rocks or tree cover. In the first instance, the deficiency or deficiencies of the land are of such nature and magnitude that special agronomic, economic, or engineering studies are required to provide adequate information, such as extent and location of farm and project drains, or probable payment capacity under the anticipated land use, in order to complete the classification of the lands. The designation of class 5 is tentative and must be changed to the proper arable class or to class 6 prior to completion of the land classification. In the second instance, the effect of the deficiency or the outlay necessary for improvement is known, but the lands are suspended from an arable class until the scheduled date of completion of project facilities and land development such as project and farm drains. In all instances, class 5 lands are segregated only when the conditions existing in the area require consideration of such lands for competent appraisal of the project possibilities, such as when an abundant supply of water or shortage of better lands exists, or when problems related to land development, rehabilitation, and resettlement are involved.

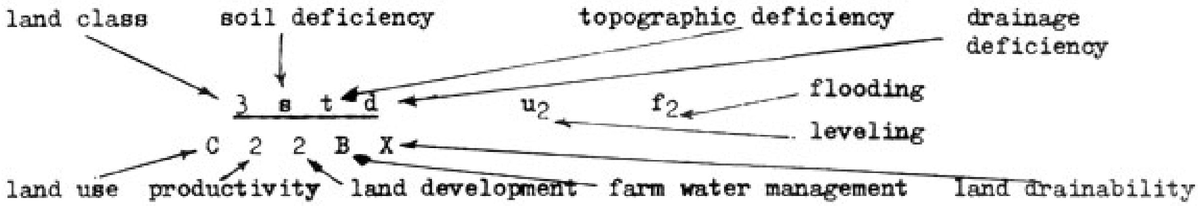
Class 6

Lands of class 6 include those considered non-arable under the existing project or the project plan because of failure to meet the minimum requirements for the other classes of land, arable areas definitely not susceptible to delivery of irrigation water or to provision of project drainage, and class 4 and 5 land when the extent of such lands or the detail of the particular investigation does not warrant their segregation. Generally class 6 lands comprise steep, rough, broken, or badly eroded lands; lands with soils of very coarse or fine texture; lands with shallow soils over gravel, shale, sandstone, or hardpan; or lands that have inadequate drainage and high concentrations of soluble salts or sodium. With some exceptions, class 6 lands do not have sufficient payment capacity to warrant consideration for irrigation.

In a given project area, specific limits of soil properties and other parameters are set up to segregate the different classes. Flexibility in the limits relating to each class is required, of course, from project area to project area.

Detailed land classification is usually done at a map scale of 1:4 800 (400 feet to the inch) to provide adequate information as to the extent and character of the various lands in each 40-acre tract. A smaller scale, not less than 1:12 000, may be used on fully developed areas or on highly uniform new land areas where no specific problems are associated with soils, topography, or drainage and non are anticipated. Base maps at scales of 1:24 000 are considered only for reconnaissance studies by the Bureau, and are used for preliminary evaluations and for drainage basin studies (e.g: runoff, conservation) of areas not to be irrigated, but within the general project area.

At the large scales employed a great deal of information can be put on the map by use of letters, numbers, and symbols. The following example of some standard mapping symbols is used in USBR land classification surveys:



Although the Bureau of Reclamation's irrigation suitability classification sets up specific limits for classes and subclasses, the specifications are not absolutely rigid, and can be modified from one project area to another. In Thailand, for example, a Class 1R was set up for arable lands for wetland rice (Bureau of Reclamation, 1967), and included:

> Lands that are highly suitable for paddy rice production under irrigation, being capable of producing sustained and relatively high yields of rice at reasonable cost. The surface horizon soil should be of medium to fine texture associated with subsoil characteristics and drainage conditions that provide for optimum soil submergence, but the build-up of reduction products or salinity should not be toxic to plant growth. These lands should occupy a position with project facilities to assure adequate runoff of surface water. These lands shall have relatively high net farm income potential.

The feasibility report for the Pa Mong area in the Mekong River drainage basin is a good example of adaptability of the Bureau irrigation suitability classification. The Stage 1 study (Bureau of Reclamation, 1970) determined (1) lands in Laos and Thailand that would be of the most suitable quality for a first-stage irrigation development along the Mekong River a short distance downstream from the Pa Mong damsite, (2) the area that could be served by an economically located and sized gravity conveyance system originating at Pa Mong Dam, and (3) the scale of development that could be utilized under the economic and social conditions that are expected to prevail in the region with project development.

Improvements and changes in irrigation agriculture also necessitate that the irrigation suitability classification be constantly examined and revised when necessary. In the Phoenix, Arizona area (Olson, 1970), for example, urban and industrial developments are taking over former agricultural lands within irrigation project boundaries at a fairly rapid rate; urban encroachment of farmland is encouraged because the water charges for urban industries and residences are the same as for agricultural irrigation customers. Concrete pipe, weather modification, radio-controlled water gates, computer-controlled dispatch centres for water distribution, and improved watershed conservation practices (McMullin, 1967) are constantly changing the payment capacity and cost benefit ratioes of irrigated agricultural lands.

MODIFIED STORIE INDEX

Land classification by quantitative productivity indexes has been used in many places. The Storie index, developed at the University of California, illustrates principles of application of productivity indexes in land classification that have been relatively widely applied (Edwards et al., 1970). The Storie index method has undergone a number of revisions over the years, as more data have been gathered and more experience has been obtained in using it.

Master ratings developed for Oahu lands (Nelson et al., 1963) were based on general character of the soil profile, texture of the surface soil, slope of the land, climate, and other physical conditions affecting use of the land; ranges in percentage values were selected for the various factors which were appropriate for the local conditions. The land productivity index can be stated as follows:

Land productivity index = A x B x C x X x Y

where A = Percentage rating for the general character of the soil profile

B = Percentage rating for the texture of the surface horizon

C = Percentage rating for the slope of the land

X = Percentage rating for site conditions other than those covered in factors A, B, and C (e.g: salinity, soil reaction, freedom from damaging winds)

Y = Percentage rating for rainfall

The land productivity index is a product obtained by multiplying a series of percentage ratings. Percentage ratings are converted to decimal equivalents for use in the formula and the resulting product is reconverted to a percentage basis. The percentage rating for each factor (A, B, C, X, Y) increases as the favourableness of that factor increases. As the land productivity index approaches 100 percent, the agricultural quality of the land increases. Less productive land types have indexes with lower values. If even one factor alone has a low percentage rating, that factor can substantially reduce the level of the land productivity index.

The following then were the criteria used in Oahu and their assignment to the factors A, B, C, X, and Y. They are not necessarily applicable to other parts of Hawaii:

Table 1

A - Soil Types			
a)	7 immature soils; subclassified on drainage and depth		100 - 20%
b)	12 well developed soils, subclassified on drainage and depth at latter index bedrock is exposed		100 - 10%
c)	Lithosols and regosols at latter index there is virtually no soil		85 - 0%
d)	Man made soils	Deep	95 - 80%
		Shallow, well drained	70 - 60%
B - Textures			
a)	Normal latter index for sands		100 - 65%
b)	Rocky latter index is for Pahoehoe		85 - 20%
C - Slope			
	0 - 10%	Index 100% down to	
	> 80%	Index 15%	
X - Miscellaneous			
a)	pH		100 - 80%
b)	Salinity		100 - 55%
c)	Fertility based on P_2O_5, K_2O, CaO by Truog		100 - 65%
d)	Erosion		100 - 85%
e)	Wind		100 - 85%
Y - Rainfall	latter index for under 20"		98 - 55%

To illustrate the use of the revised Storie index the process for deriving it for Oahu land type 10 was:

Land productivity index = A x B x C x X x Y

A = 97 percent because the soil is deep, well drained, and has developed in uplands or old alluvium on upland terraces

B = 90 percent because the texture of the soils is silty clay loam

C = 100 percent because the slope of the land is in the 0 to 10 percent range

X = 74 percent (Table 1) because the surface soil reaction is medium acid to slightly acid (98), the fertility level is poor (82), a moderate level of erosion has occurred (92), and wind damage and salinity pose no problems (100). The product of the percentage ratings for these factors is .98 x .82 x .92 x 1.00 x 1.00 = 74 percent

Y = 92 percent because the annual rainfall ranges from 30 to 80 inches.

Decimal equivalents of percentage ratings for individual factors were multiplied in sequence (A x B x C x X x Y). The resulting product upon conversion to a percentage basis constitutes the land productivity index:

A x B x C x X x Y = Land productivity index for type 10
.97 x .90 x 1.00 x .74 x .92 = .59 = 59 percent

The land productivity indexes for the various factors are given in table 2 for some of the land types on Oahu. Master productivity ratings (table 3) are assigned when productivity of all of the land types of Oahu have been evaluated. Yields have been specified, for example, for lands used for growing pinapples, sugarcane, vegetables, alfalfa, pasture, oranges, papayas, bananas, and trees. This type of land classification has not only been of great value to help in managing the best lands for the highest yields, but it has also been used for zoning the best agricultural lands for preservation from urban encroachment - an agricultural problem of considerable magnitude at the present time in Hawaii.

Table 2. Percentage ratings of individual formula factors and land productivity indexes for several land types

Land type No.	A %	B %	C %	X %	Y %	Land productivity index %
1	96	95	100	95	90	78
10	95	95	100	77	80	56
20	95	96	90	68	80	45
30	95	75	90	81	92	48
40	92	75	90	91	80	45
50	90	90	50	81	85	28
60	25	85	75	55	75	7

Table 3. Master productivity ratings for land productivity indexes of Oahu

Ranges in land productivity index (%)	Master productivity rating
85 - 100	A
70 - 84	B
55 - 69	C
30 - 54	D
< 30	E

LAND SYSTEMS

In Australia, parts of Africa, and in some other places, the land systems approach has been widely used in land inventory. This technique generally identifies areas with reasonably similar and recurring characteristics of climate, vegetation, geology, soils, land use, and topography. Generally the mapping is done at relatively small scale (e.g: 8 miles = 1 inch; Rowan and Downes, 1963), but individual soils or other land characteristics (Coaldrake, 1961) may be mapped at larger scales in smaller selected areas, particularly for the specific purposes of working out the history of the landscape (e.g: Litchfield, 1969) or for project developments (Churchwood and Flint, 1956). Generally, considerable chemical, morphological, and physical analyses (Stace, 1961) accompany the small scale maps, and a considerable amount of research goes into the identification, description, and delineation of each land system. As scale of mapping increases, delineations can be made with fewer soils and other variables, and more precise statements can be made about use and management of the areas (Beckmann and Thompson, 1960; van der Eyk et al., 1969). In some places interdisciplinary teams consisting of several experts (e.g: geomophologist, soil scientist, botanist) work together as the survey team in doing the field work and compiling the report.

The study of the land in north-western Victoria is a good example of the land systems approach. The basic aim of this survey of 14 000 square miles was to describe the various natural environments and their relationships to land use. The integrated approach, considering the total environment, is emphasized. In this region, for example, a classification of land based primarily on soils would fail to emphasize the differences in the productivity of the light-textured clays for cropping as affected by different climates; the light-textured clays are productive cropping soils in the Culgoa land system where the average annual rainfall is 14 inches, but the same soils cannot be economically cropped in the Millewa land system where the rainfall is only 10 inches.

Thirteen land systems were delineated in north-western Victoria. The soils were classified into morphological groups and subgroups, the topography into landforms, and the native vegetation into structural units. In each land system there is a limited range of landforms and soils in a characteristic pattern. A difference of one inch in average annual rainfall can be significant; in these places subdivisions are made of climatic zones on the basis of isohyets which are superimposed on the land systems map. Land use in the various land systems is discussed primarily from the point of view of the erosion hazard, erosion incidence, and the pattern of conservation farming which has developed. General recommendations for use of the areas for the common practices are made for the different land systems. They can also be made for parts of each land system, within the influences of the identified and mapped variables of climate, vegetation, geology, soils, land use, and topography. Specific recommendations for fields or parts of fields, however, must be made by consulting agricultural officers or from large-scale maps made especially for farm planning. Specific recommendations cannot be made for small areas from small-scale maps.

MODERN AIDS TO LAND EVALUATION

Recent trends and developments in this field are discussed in the book Land Evaluation which is a collection of papers of a CSIRO symposium, organized in co-operation with UNESCO, to review the "State of the art" (Stewart, 1968). Techniques and principles outlined in the book have many applications to land classification for agriculture, although many of the applications illustrated are in the field of engineering. The parametric approach, to establish impartial quantitative measurements for which parameters can be established for land classes, offers considerable opportunities to advance land classification from the present more qualitative stage. Generally, however, use of land is dependent on the interaction of a number of parameters of various attributes, and not upon a single variable which can be easily measured by a machine.

Use of computers, mathematical simulation models, remote sensing, and new engineering devices (e.g: for soil strength measurement, for aerial photographic interpretation) suggests that substantial improvements in land classification, or at least in measurement and analysis of some of the important parameters, will be implemented within the next few years. Computer data banks, computer map printout systems, and computer retrieval programmes are already being used in several places to put together, collate, and correlate large amounts of data on soils, land use, slope, elevation, vegetation, climate, geology, drainage, and other natural resource and social attributes. At the present time most of the programmes are in the research and testing stages, and have not been developed into really efficient workable systems. The first indications appear very promising, however.

LAND USE INVENTORY

Land use mapping is one of the most preliminary and one of the most important of all land classification considerations. Generally the present land use has been affected by the past land use as well as by environmental attributes. Future land use also is likely to be influenced by past and present land use. In several places, extensive programmes are underway to map land use along with other natural and cultural resources (e.g: Swanson, 1969; Tomlinson, 1968; Wiebe, 1971).

In Canada, data collected under the computer information system is restricted to five types: (1) the present use of the land, (2) the capability of the land for agriculture, (3) the capability of the land for forestry, (4) the capability for recreation, and (5) the capability for supporting wildlife.

In the United States, the land use and natural resource inventory of New York State has mapped land use and collected the data in a computer system; soil, geological, and agricultural characteristics have been added to the computer system, and other physical, economic, and social data will be added later. The inventory was made from recent aerial photographs, with ground control, at a scale of 1:24 000, and transferred to topographic base maps. After mapping and production of overlays, cells of one square kilometer were identified on the maps as a geographic referencing system for data storage and retrieval. The Universal Transverse Mercator grid system was used, with 140 000 cells covering the state. Data were then summarized by cell: percentages of a cell in a certain area land use; numbers of items; numerical types (presence or absence); or mileages of various point count items. These data were then keypunched on special coding forms, stored on direct access discs (IBM 2316), and became available for quantitative analysis and display.

The Center for Aerial Photographic Studies at Cornell University, which did the work under contract to the Office of Planning Co-ordination of New York State, with assistance from the Laboratory of Computer Graphics at the Graduate School of Design at Harvard University, has developed two computer programmes that anyone can use, even without experience with computers or computer programming. These programmes are: DATALIST, which produces inexpensive direct listings and summaries capable of arithmetic and logical manipulation; and PLANMAP, which produces simple or weighted computer graphic displays of area or point data or combinations of the two. PLANMAP, a computer graphic programme, may also be used to identify and display grid cells with certain very specific qualities or combinations of qualities involving any of the presently coded 130 land use characteristics.

Agricultural land use in New York State is classified first as active (in commercial use) or inactive (fairly recently removed from agriculture). Active areas are delineated according to use by major enterprizes - orchards; vineyards; horticulture; cropland intensively used for cash crops; and land used more extensively for crops related to dairy and poultry, pasture, and speciality farms. Inactive agriculture classifications include land fairly recently removed from active agriculture but not yet committed to forest regeneration, and also land waiting to be developed or under construction for urban uses.

CORNELL FARM AREA CLASSIFICATION

The system of farm classification developed in the Department of Agricultural Economics at Cornell University for use in New York State has been discussed by several reviewing authors (e.g: Jacks, 1946; Hilton, 1962). Recently the system has undergone a number of revisions that have made it particularly useful for inventory, resource planning, and legislative programmes. The Cornell classification is an economic land classification (or farm classification) made to forecast the general degree of farming success likely in various areas. By evaluating the present condition of farms, predictions can be made about the economic viability of geographic areas for farming in the future. Although the best farms tend to be located on the better soils, provision is made in the classification to also include areas with good farms on poor soils, or poor farms on good soils. In Lewis County (Conklin and Lucas, 1954), for example, land classes were set up to include the following class definitions:

1. A pattern of small ownerships or inadequate adjustment of farm enterprises persists on a land resource which is basically strong. This situation holds farm incomes at a level much below the potentialities of the area;
2. An extreme degree of skill, thrift, and attention to good farming practices by a group of farmers may raise the agriculture of an area considerably above the income level which is normally supported by its land resource. As long as the tradition of good farming persists among the farm operators, this unusually high level of income may persist. The risk, however, is high. Any unfavourable circumstances or a change in the character of the population may upset the fine operational balance, resulting in a decline in incomes and in probable deterioration of the capital structures.

Evaluation of the farm areas is done in a fairly systematic and quantitative fashion, mainly from the economic point-of-view to evaluate capital investment and potentialities, but considering all other relevant information as well. Maps are made at a scale of 1:24 000 of the farms in the following fashion (Nobe et al, 1960):

"A crew of four men travelling in a carryall-type vehicle made the field examinations. The vehicle was equipped with a work table, filing cabinets, and a recording machine. One man followed the route on the aerial photographs as the group travelled, and made continuous verbal notes on the recording machine. These notes described the buildings, fields, crops, livestock, and other visible characteristics of the farms. Points were numbered on the air photos and the notes were made with reference to these numbers to permit an interwoven record. Another man, following the route on topographic and soil maps, made a written record of observations about relationships between the maps and the kind and level of farming observed. The third man supplied the others with photographs and maps from the files, and consulted reports of soil studies, farm management surveys, climatic data, and other specialized materials as these became relevant at various points along the route. The fourth man was the driver. The crew made north-south traverses across the entire area at 5 to 10 mile intervals, travelling in as nearly straight lines as possible. In this way they travelled on all types of roads and saw as wide a range as possible of the use conditions that exist in the area.

The air photos, for both the areas seen in the field and those not seen, were later examined in detail in the office. All notes made in the field were used at this time. Studies of the photographs for areas that had been seen, together with the notes, made it possible to classify by photographic interpretation the areas that had not been seen. Further studies of soil maps, climate data, farm management surveys, and other materials were made. This work produced a classification of farms; a classification arranged according to the intensities with which farms are being used. Farms were classified individually, then the areas were mapped to show differences among farms and between regions."

In inventory evaluations, the Cornell farm classification has proved to be very valuable, particularly for predictive implications (Olson and Hardy, 1967) and for programme planning (Conklin, 1969). The system enables integration of the following considerations of agricultural land use: (1) soil resources, topography, conditions of climate, and water resources; (2) location, markets for farm products, and access roads; (3) the level and condition of farm investments in real estate and non-real estate items; (4) the present and most probable levels of farming skills; (5) the feasibility and rates of adoption of new technologies; (6) competition from substitute products and other farming regions, and local income alternatives; (7) patterns of farm ownership and operation; and (8) levels of farm community morale, urban influences, and governmental policies affecting farming.

The Cornell system has been effective in presentations to the public and to legislative groups, because it has several levels of generalizations or simplifications. Maps have been constructed, for example, at scales of 1:24 000, 1:250 000 and 1: 500 000; these maps in three colours show the classes (Conklin and Linton, 1969):

Green identifies farms that appear capable of supporting viable farm business for the foreseeable future. Their land is well adapted to modern farming methods, current capital investments are usually adequate and in good repair, new improvements usually keep pace with technical developments, and most operators are skillful and dedicated to continuing their units in agriculture.

Yellow identifies farms near enough to the economic margin to make their future somewhat uncertain. Income prospects now provide these farm families the option of continuing in farming, but not all will prefer this option to non-farm employment, and further developments in farm technology will tend to put these operators gradually at a disadvantage. Only two-thirds of these farms are expected to pass to the next generation as full-time units, but individual circumstances will determine which businesses discontinue.

Red identifies farms judged obsolete for full-time use under modern farming conditions. This includes full-time and part-time farms, but units converted primarily to residences or other non-farm purposes were excluded from classification altogether.

Use of the maps and reports has convinced the general public and lawmakers in New York State that agriculture is an important industry, and deserves to be protected. Recent legislation has provided for establishment of agricultural districts, where farming is likely to remain viable and continue into the future. These agricultural districts are given preferential tax treatment to encourage farmers to continue production on their farms, and are also protected in other ways from urban construction encroachments and urban economic pressures.

SOIL SURVEY INTERPRETATION

Soil survey interpretation deals with use of specific soil areas (Bortelli et al., 1966; Steele, 1967); it is similar to land classification except that it is not so broad or comprehensive, being confined generally to interpretation of soil map delineations and interpretation of descriptions of soil profiles. Increasingly, however, soil survey interpretation is broadening its scope to include also many environmental attributes that can be directly or indirectly related to soil profiles and to soil areas.

Soil moisture regimes, as affected by climate, are also receiving prominent place in soil classification system (Soil Survey Staff, 1970); in the United States temperature measurements in soil profiles are being made routinely and climatic effects on specific soils are being increasingly measured and quantified (Fritton and Olson, 1972).

Soil survey procedures, and soil survey interpretations, are becoming more quantitative so that they can be better fitted into parametric land classification schemes. Engineering analyses are being adapted to better described soils for the various uses that must be made of them. Emphasis is being increasingly placed on the comprehensive uses of soils; suitability of soils for roads, foundations, sewage disposal, and irrigation affects development of agriculture and rural areas as well as urban areas; interpretations affecting woodland, rangeland, wildlife, and environmental quality are being considered to be more important from the point of view of the total environment. New kinds of engineering analyses, like measurement of co-efficient of linear extensibility (Soil Survey Staff, 1967), are of importance to determine trafficability of soils for heavy agricultural machinery as well as to determine probable performance of roadbeds of superhighways. As more data becomes available to relate to specific soil properties, soil profiles, and soil map units, better predictions can be made about performances of specific soils under certain management conditions.

As an increasing amount of data is collected and related to specific soil series and soil map units, ratings are being made of capability, suitability, or limitations of the soils for the various uses to which they must be put. As soil series and soil map units are precisely defined, then predictions of performance or statement of limitations about a specific soil under a specific use can be made with equal precision. Interpretations such as these are currently being standardized and computerized for soils in the United States. Soil survey reports currently being published in the United States contain interpretations of soil map units for many uses as well as yield estimates for different levels of management (Edwards et al, 1970; Giddings et al., 1971). Additional information, like location of frost pockets and marketing conditions, are necessary supplements to the soil information, more related to land classification and economic considerations.

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INTERPRETATIVE LAND CLASSIFICATION IN FRENCH-SPEAKING COUNTRIES[1/]

DIFFERENT TYPES OF LAND CLASSIFICATION MAPS

Throughout the world the usual purpose of pedological studies is to obtain a better understanding of the environment in order to promote further development of agriculture, forestry and similar activities. Maps (including explanatory texts) produced for this end may have one or more purposes, e.g:

1. Actual soil use - an inventory of the existing state of vegetation and management;
2. Agricultural productivity - a map intended to provide data for improved production through the informed selection of soil/crop combination and the possibility of improvement of techniques not amounting to a drastic change in current methods;
3. Agricultural potential - a map intended for the intensification of agriculture through maximum investment and the accompanying radical changes in current techniques. Irrigation, drainage, new crops, market gardening, are amongst the possibilities;
4. Non-agricultural "secondary" maps used for civil engineering purposes and arising as a direct consequence of the high level of information available from the best type of pedological maps. Of considerable importance in developed countries.

Techniques used to provide map data

1. Pedological studies which lead to pure soils maps and from which a great many interpretative maps can be derived.

   Interpretative maps can very often be used to reconstitute the original soil map. Such pedological maps are costly because of the time consuming nature of the data collection.

2. Phyto-sociological studies in which are determined the association of soil with natural and imposed vegetation. These cost less but are time consuming for the botanist who has to learn the local flora and there are difficulties with the correct assignment of soil factors to vegetation association. The method has its highest value in areas where an environmental factor is really dominant, such as aridity in the south of Tunisia or excess of moisture in Sologne (France).

3. Combined geomorphological/pedological studies in conjunction with vegetation as derived from aerial photos with careful ground checking permit, a soil inventory to be started. Made at 1:50 000 - 1:200 000 these studies indicate the zones for more intensive survey. The cost is low in relation to full pedological survey but the method is not very appropriate in areas with ironstone cuirasse or calcareous crusts, nor in the flat Sudan-Guinean savannas or the equatorial forest. Basic references for these approaches in scientific literature are:

   Aubert and Fournier 1955 "Les cartes d'utilisation des Terres" Sols Africains III.1. 89-109, and the U.S. Bureau of Reclamation Land Classification Handbook 1951

1/ Summary in English of the document "Conception et Réalisation des Cartes d'Utilisation des Sols par les Pédologues d'Expression Francaise" which was prepared by M.J. Boyer, Directeur de Recherches, O.R.S.T.O.M., Paris.

but French speaking pedologists have rarely conformed to these systems and almost always substantial modifications, to accomodate local conditions, have been made. As a result there is a great diversity of soil map types, ranging from IRAT[1] and OMVA's transpositions of the USBR system to SCA's map of the Aisne region, the latter a most complete example.

CLASSIFICATION OF LAND UTILIZATION MAPS

1. Actual usage maps document agricultural and forestry use of land at a given moment. Their interest is more social and historical than agricultural. Rarely requested as a prime object but sometimes arising from current studies, such maps provide a mine of information whose value increases with the passage of time. The SES map for Brive is cited.

2. Soil characteristic maps on which are displayed physical, chemical and hydraulic properties of soils (sometimes of each soil horizon) of the parent material. Typically these do not offer comment on crop potentialities but they may indicate major favourable or adverse factors which can be interpreted by the agricultural scientist. Existing crop or vegetation conditions may be shown. The map, however, shows principally the permanent factors and so it should not become obsolete for perhaps 50 years if the survey is really exhaustive (and hence costly). The cost is the main inconvenience, for the survey should be made of all permament factors regardless of their present relevance. SOGETHA, SCET, IRAT and ORSTOM provide such maps and even mention possible crops in the legend.

3. Thematic maps which are prepared in response to a specific purpose or question such as:

   a) areas suitable for irrigation;

   b) erosion potential;

   c) suitability for a new crop;

   d) specific civil engineering needs.

   Such maps may be prepared mainly or wholly in the office if a soil characteristic map is available. They can be prepared in isolation but such maps are generally made obsolete by the improvement in technique and changes in economic factors and may have a life of only a few years. Again, the actual implementation of the recommendations based on the map may raise problems for which the map is inadequate.

   With this in mind pedologists try to foresee problems by indicating not only the limiting factors but also the most commonly occurring favourable factors most likely to influence future trends. These maps of an intermediate nature are still much less expensive than a full survey map.

4. Agro-pedological inventory maps usually made at scales between 1:50 000 and 1:500 000 and most frequently at 1:100 000, are either:

   a) An inventory in the strictest sense and intended to delimit the zones most likely to repay intensive study. These are broad reconnaissance studies carried out with a low density of ground observations;

   b) Small scale maps synthesised from larger scale studies. Both of these types of maps, because of their small scale, are of more interest to planners and economists than to agriculturalists.

1/ For explanation of abbrieviated titles of organizations see 'Sources' at end of this text.

PREPARATION OF SOIL CAPABILITY MAPS

General

Soil capability maps show a juxtaposition of areas each of which represents a soil unit in terms of use/suitability. Words such as "class" and "subclass" are sometimes used by French authors to describe the units but not in the same sense as these terms are used in the United States; they must always be understood as units of soil. These maps present those factors believed to have substantial influence positive or negative on crop growth generally and on specified crops.

Some of the factors are:

Physical: slope, soil depth, texture, salinity, stones, toxicity, calcium, water status.

Chemical: contents of N, P, K, absorption status, pH.

However, mapping of chemical data is less common. The French consider that these factors are far from permanent and very susceptible to modification by man.

French practice is not usually restricted to displaying limiting factors. Those likely to be favourable and of appreciable extent will probably be shown but solely in regard to presence and intensity. Conclusions are not commonly stated.

Three systems are used:

a) characteristics

b) thematics

c) intermediate (a combination of a) and b).

The following examples give some idea of the methods of mapping for each system:

Characteristics depend on what is considered the most prominent or most important of the factors. These will then receive the principal indicator namely flat colouring. Secondary factors in order of importance are generally indicated by:

Barring of the colour vertically, obliquely, horizontally;

Striping of two or more colours to show conglomerates of units of one factor or two factors of equal importance;

Delimitation of areas accurately by overprinted lines, dashes or dots, generally black, white or blue;

Overprinting of circles, triangles, squares, grids, providing a general guide to an area and its boundaries;

Overprinting of letters and numbers.

Examples of this usage with the factors in order of importance are: Aisne (SCA). Texture 14 classes from pure sand to pure clay in basic colours and hatching giving top soil and lower horizon. Calcareous material yellow; peat, water, and substrata-striping. Hydromorphism by overprints. Lime, stones, and certain profiles by overprints. Drainage and water capacity in the legend.

SCET-Inter uses much the same system. For both systems, scales used are 1:2 000 - 1:25 000. At smaller scales maps are illegible or must be oversimplified.

Soil depth and texture

Similarly CNABRL use colours for three soil depths, and for texture, by shading based on the GEPA triangle. Slope is by black striping. Hydromorphism, lime, stones, and salinity are all overprints. Deep horizons and parent materials are indicated by symbols in "windows". Again the same scales to cover all factors, while at 1:50 000 deep horizon is omitted and stones, lime and hydromorphism are simplified. At 1:100 000 upwards only depth, salinity, hydromorphy and slope are depicted.

Phyto-sociological

CEPE de Montpellier choose vegetation and water reserve for their main factors in colour. They distinguish "Helophillic", "Hydrophillic", "Mesohygrophillic", "Mesoxerophillic" and "Xerophillic" associations in the Sologne.

None of the "characteristic" systems listed above provide more than a detailed or very detailed summary of the soil characteristics. Capability is not included in the work but may be used to derive thematic "capability" maps.

Thematic System

Used by IRAT, ORSTOM, SCET-Inter, CNABRL, SES, OMVA to provide maps indicating the degree of suitability for a crop or small range of crops throughout a particular area.

Such a map provides an integration of factors, not individually displayed, considered as influential for the specified crop(s). Occasionally individual factors are displayed if they are "limiting" or totally inhibitory. In addition to crop capability, such maps may give irrigation potential, erosion likelihood, water availability etc. The make-up of the map is generally simple with a minimum of overprinting.

Such maps reflect the current interplay of economic trends with agricultural techniques and materials. All of which can alter fundamentally within a year. The map is, therefore, of short life only unless there exists also a pure soil map by means of which the thematic map can be upgraded in the light of improved techniques etc.

Intermediate mapping

as done by SSEPH, IRAT, SCET-Inter, SOGETHA, SES, OMVA, INRA consists of a combination of the two systems characteristic and thematic: It is the type most frequently used and allows a reconciliation between the pedologist wanting to inventory all the soil properties and the user immediately interested only in a very few, and unaware perhaps that the proposed action will generate a new set of problems not answerable from a map of too limited a scope.

Such a map is a compromise. Its content is dependent principally on the finance allotted to it (to the collection of data for it). It will vary from at best a pure characteristic map provided additionally with a full interpretation appropriate to the questions set and at worst an entirely thematic map restricted to display of a few "limiting" factors and their disposition. Examples are:

Irrigation suitability by OMVA which are virtually characteristic maps provided with an interpretation for irrigation and drainage with six classes similar to the USBR and "downgrading" factors slope, relief, texture, depth, porosity, permeability, structure, salinity, limes. The maps are in black and white.

Irrigation reclamation by AGG with limiting factors; two major of: slope over 15%, and a soil less than 40 cm depth; and two minor of: unfavourable texture and mediocre fertility. Permitting six suitability classes based on the integration of the limiting factors in each sector. The maps prepared for agricultural use will also display texture lime, reclamation need, subsoil, substrata.

Integrated textural maps by IRAT made in Madagascar on heterogeneous deep alluvial soils of which the principal control is the capillary rise of water. Definitions are of soil to 120 cm and from 120-220 with integrated textures for each. The resulting combinations lead to eleven classes of crop suitability from high to non-cultivable. Definitions for specified crops are given. Additionally, since levelling and irrigation is possible as an alternative to groundwater use the author proposed to add the textural classes and horizons for the top (120 cm) layer where such techniques could be employed.

Suitability for dry-farming/irrigation in Algeria is mapped using three maps: one pure soils, one suitability for dry crops and one for irrigated crops. On these, suitability is displayed by a colour and a letter for crop type and a number for suitability. A mixture of crops have their letters entered in a cartouche with subscript numbers (of suitability) against each letter. Certain desirable/essential works are also indicated such as drainage. These maps though thematic in character, are not of a temporary nature because of the wide range of options displayed and the resulting capacity for usage over a wide spectrum of economic/technical combinations.

Suitability maps by SCET for Cahors define 11 units of soil combining slope, texture, soil depth, substrata, stones. Each unit is precisely related to an approximate crop. Irrigation needs are displayed. 11 colours are used for the eleven units.

Thus there are a range of systems of intermediate mapping of which the common factor is the provision of information as far beyond the immediate needs specified as finances will permit. And with the maximum of adaptation to local conditions and phenomena.

Characteristic maps are normally specified in France as although costly, they can then serve a very wide spectrum of uses. Thematic and intermediate maps are mostly specified overseas though they are also occasionally used in the metropolitan territory.

EVOLUTION OF THE CONCEPT OF A UTILIZATION MAP

Studies in soil mapping started 25-30 years ago in North Africa, 15-20 years ago in France. In the beginning thematic maps were most frequently requested either for new crop promotions or for a specified restricted number of factors considered vital by the client. The latter approach being unwelcome to pedologists led to the soil survey being considered an expensive and unwarranted luxury.

However, the limitations of pure thematic maps and their evanescence soon became apparent leading to a reassessment of the pedological position. And so to compromises between the two positions. As examples 12 years ago maize cultivation in the cool cloudy Aisne valley would have been thought laughable. Now, thanks to adapted varieties and the opening of a new demand through the Common Market, this area is an important maize producer. Again, in the south of France peach suitability studies were based on lime contents. Now there is a lime resistant rootstock and the criteria for peach production have been significantly revised.

This type of technological revolution is slower in the developing countries so the purely thematic map may be expected to have a longer life. But still the pedologist in the light of these trends, prefers to show contributary factors which can, if necessary, be reassessed, rather than an arbitrary integration not capable of resolution into its significant physical components. And so to an increasing extent maps of pure characteristics are prepared together with interpretative legends or ancillary maps. Which latter can be oriented towards the non-agricultural client when requested.

Nevertheless, characteristic maps have their drawbacks. The first of which is cost. Secondly that the pedologist conscious of the actual needs of the survey and of the need for economy may restrict or slant his choice of items for recording and thus fail to collect data whose importance lies in the future rather than in the present. And it must be remembered that there is a practical limit to the data which can be displayed on a map of working scale. And that the pedologist will have to supply a base for interpretation of the data displayed or to prepare a thematic map therefrom.

This is now the general trend in French circles and it does illustrate the confidence built up between pedologists and their employers.

Development and appreciation of suitability

Having defined or recorded the soil properties the pedologist has to produce a method of interpreting these in terms of the crop suitability in question, if he is to produce a thematic or intermediate map or an interpretative annexe to a characteristic map. Local conditions will determine the procedure to be followed. Generally a survey of farmers and research studies will produce some correlation between cultivated plants and the soil data being recorded. There will be a subjective element in such a correlation but nevertheless it will be based on quantifiable observations.

The pedologist will probably try to rank his factors in order of apparent significance for crop growth (general and specified). Lack of water or flooding is inhibitory for all crops whereas texture or pH affects different crops in different directions. The AGG method has already been mentioned, major factors slope and soil depth; minor factors texture and fertility; giving rise to 6 capability classes.

OMVA has a similar system based on salinity and texture together with stones, structure and permeability.

SCAP define four series of factors - absolutely limiting: slope, shallow soil, water logging, salinity. Limiting: rock, excess water, high lime, salinity in clay. Unfavourable: steep slopes, shallow soils, active lime, stones, salt in sandy soil, deficient in water. Unfavourable minor: friable horizons, limited water, temporary waterlogging, stones, lime, less favourable texture, low fertility.

From these factors in combination seven suitability classes are defined. However, it must be remembered with all these methods and those following that the pedologist's judgement is involved.

Numerical indices

STORIE, SCET, OMVA, RIQUIER, DURAND, CNABRL have used systems in which each factor was given an index commonly 1-5, sometimes 1-20 or as a percentage of 100 percent. Major factors cover the entire range of indices (which may even include negative values) and minor factors only a part, e.g: level of organic matter 80-100%. These indices may be multipled together, added or expressed separately as a series in ranking order. Certain indices or index levels have been included or indexed in this manner with the priorities dictated by the local conditions.

Computerization

The use of the computer to provide suitability assessments has been considered but the initial investment in programming and research is heavy having regard to the complexity of the inter-relationships. SOGETHA is one organization which has made a start and has produced a programmed scheme. This, however, has not yet passed the test of time.

Evolution of norms expressing fertility

The process has taken place via the use and adaption of the American system and is now tending towards original norms conceived as functions of current conditions. In the Mediterranean region over 60% or coarse fragments in soils impedes root development, so 60% has become the benchmark. Lime contents at 0-1, 1-5, 10-12, and 40-50% are similar values.

Texture is expressed through the GEPPA triangle. These are some current examples in a process still very much under way. Again, the French attitude is towards localized norms rather than an attempt to fit local phenomena into a global system.

Evolution of colour and other representation

In this instance there is a distinct trend towards standardization of view point. Green is used for the best soils, most favourable factors, highest capability classes. Yellow is used for the intermediate classes and red for the lowest levels of fertility. Blue is used for hydromorphic representation. And where symbols are concerned, there is a desire to standardize usage in a similar manner. The only exception to this trend is in Tunisia, where the display is designed to give the maximum visual impact.

To sum up the trend is towards the collection and mapping of complete data covering the maximum of soil information and from which more specialized maps can be produced. And that in the sphere of thematic representation, harmonization of colouring and printing is accepted in principle and in the process of adoption.

GENERAL CONCLUSION

The soil use maps developed by French pedologists are diverse in form and concept. In spite of a certain originality in every map, introduced by the concern of each author to adapt as exactly as possible to local conditions, one can classify them in the following way:

- maps of actual land-use making a special point of human enterprise on the land whilst indicating the main natural formations of vegetation. Unfortunately, these are not often made;
- thematic use maps showing cultural suitability for one or a small number of cultivated plants or else the study of several simple factors (for example, the reserve of available water);
- maps of soil characteristics which describe a certain number of soil characteristics in the most exhaustive possible manner, without predjudging the cultural capability of the soil and its future use; in summary, a map of the properties of a superficial formation which is the soil (pedon);
- intermediate maps combining in various degrees the principles of the maps of soil characteristics and those of the thematic maps. These intermediate maps are often the result of a compromise between the needs of the client and the wish of the pedologist to provide a document which is as general as possible.

The present evolution in the mapping of applied pedology tends more and more towards elaboration of the characteristics maps (or of intermediate maps which approach the characteristics map); the thematic map will then become a thing of the past.

Thus the map of soil characteristics becomes a kind of communal store from which one can extract thematic maps relating to agriculture or to other activities (public works, urbanization).

One can also note a tendency towards standardization of cartographic representation, already far advanced for colours but much less so for symbols and overprints.

The causes of this evolution are:

- recognition of the rapidity of development of agriculture especially in the developing countries which leads to accelerated 'ageing' of the thematic maps in contrast to the maps of soil characteristics which, being very general documents, appear to have a longevity which is clearly more satisfactory,

- the demand for use maps by users who are not farmers or agronomists but public works engineers, town planners, etc.

In conclusion, the map of characteristics is the product of two considerations:

- to produce a general, long-lasting document;
- to reach the widest range of users, agriculture remaining, nevertheless, the privileged client.

(NOTE: This summary does not include extensive appendices which formed part of the original document prepared by M. Boyer. These appendices provide details of methods used by various French-speaking organizations for rating and presenting data on texture, salinity, lime content, content of stones, soil depth and slope.)

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3. LAND EVALUATION AND CLASSIFICATION IN EAST-EUROPEAN COUNTRIES[1/]

INTRODUCTION

Specialists of all East-European countries are deeply concerned in the elaboration of methods for land evaluation and in the practical implementation of the evaluation and classification of farm and forest lands. Research Institutes of these countries have co-operated for more than 12 years in this sector.

The examination of the main pre-occupations and achievements in the development and in laying the foundation of work for the estimation and classification of the production potential of farm lands should take into consideration the following aspects:

1. theoretical principles and work assumptions;
2. the object of land evaluation;
3. natural and man-created conditions considered;
4. the manner of expressing taxonomical and classification categories, used for land evaluation;
5. theoretical land evaluation bases and schemes of the general systems;
6. correlation between land evaluation and economic elements of production;
7. practical application of land evaluation works;
8. period of validity of evaluation systems; the differential effect of additional investments in agriculture and forestry. In this paper the author seeks to synthesize the achievements of the last ten years. He is fully conscious that the subject is far from being finalized, so much the more that researches are intensely continuing and new and valuable facts may appear at any time.

THEORETICAL PRINCIPLES AND WORK ASSUMPTIONS

All principles for the approach of land evaluation problems approximately originate from the same assumption, i.e: that the determination of the farm land's production potential should be made by considering the characteristics of those production factors which control plant growth on a certain part of a given area.

With a few exceptions, stressed by some URSS (1) and Bulgarian (2) Scientists - who propose as a methodological principle the classification of farm lands according to their economic results, ignoring the factors which determine these results - all the other research and practical procedures are based on the knowledge and use of analytical methods for the determination - in a larger or lesser measure - of the natural and man created conditions controlling yields per hectare.

The specialists supporting the "economic" stand point of land evaluation, consider that the total return from plant production and the net return are the only criteria which should be used as a base for farmland evaluation and classification. This principle was used by the former Land Survey Service of the Austro-Hungarian Empire, and was based on the so-called "cadastral net return" which also included livestock. However, ecologists and pedologists from other countries do not consider this principle as satisfactory from the theoretical

1/ by Dr. D. Teaci, and Mr. M. Burt, Institute d'Etudes et de Recherches Pédologiques, Bucharest, Romania.

stand point, as it does not study those factors which control crop production. The said scientists believe that when evaluating and classifying farm lands, one should start by knowing the characteristics of environmental factors and the way in which each of these factors and conditions affect crop production.

Two basic principles may be simultaneously defined, as far as the manner in which land evaluation is expressed i.e: 1) a formulation by relative values or comparison with a given standard - usually the best lands; 2) a formulation by absolute values, i.e: in the cost of the land as a monetary expression of the value of its use.

This synthesis of work-assumptions shows that in the case of the so-called "economic principle", we start from the idea that yield is the only base for determing the production potential of lands, while the "ecological principle" - which may be considered as determining the causes affecting production - may be used to determine the causes which produce crops. This principle is based on the assumption that actual possibilities are available for determining the way in which each of the production factors affects crop production and determines a certain percentage of it.

OBJECT OF LAND EVALUATION

The following units are generally considered as land evaluation objects:

- ecologically homogeneous parts of the area (EHA);
- plots considered from a soil survey stand point;
- lands belonging to private individuals or to state and Co-operative farms.

If the principle of land evaluation according to production is used then the object of evaluation can only be a portion of land, having a predeterminated area. On the other hand if the ecological and pedological principle is to be applied then it is essential to first draw up a detailed pedo-ecological study of the area and to determine the characteristics of each of its homogeneous portions. It is obvious that the final characterization of farms or other units is obtained by a computation of the marks or average classes of the weighted means (EHA) of all the areas covered by each of the ecologically homogeneous units.

Until about 10-15 years ago, land evaluation and classification were drawn up for three main categories of land use: farm lands, pasture lands, and forests. At present, and chiefly in Romania, an evaluation of all agricultural uses and for various crop plants has been adopted, as the land is not used "in general" but for well defined purposes and as it also behaves differently, according to specific uses and to the crops planted.

NATURAL AND MAN-CREATED CONDITIONS CONSIDERED

In the course of the evolution of land evaluation methods and concepts, a large number of suggestions were made with respect to the number and nature of the environmental and economic factors to be considered.

The number of these elements ranges from several hundreds - in which case only approximations can be made on the manner they affect production - and five or ten, in which case we may attempt to determine their quantitative influence on production.

Table 1 presents the main factors considered in East-European countries when elaborating land evaluation methods.

Table 1

Natural and economic factors considered for land evaluation and classification

	Natural factors											Economic factors			
Country	Climate		Topo-graphy	Hydro-logy	Gl	Soil						Distance to markets	State of roads	Plot shape	Plot area
	T°	Pmm				Texture	Depth	Humus	pH	Gleyfica-tion	Salinity				
Bulgaria	x	x			x							x		x	
Czechoslo-vakia	x	x	x			x	x	x							
G.D.R.					x	x									
Poland					x										
Romania	x	x	x	x		x	x	x	x	x	x	x	x	x	x
Hungary	x	x			x										
U.S.S.R.						x	x	x	x	x					

The minimal list of environmental factors and of their characteristics should include:

I. <u>Cosmic and atmospheric factors</u>

Light: duration, intensity

Temperature: averages, maximum, minimum totals

Rainfall: averages, evapotranspiration etc.

Wind: frequency, strength, direction

II. <u>Edafic factors and conditions</u>

Topography: forms, energy, slope

Lithology: texture, geochemics, mineralogy

Hydrology: water: its existence, nature and dynamics

Soil: depth, texture, humus content, reactions, gleyification, salinity etc.

III. <u>Biological factors</u>

Vegetal cover

Soil microfauna and microflora

Obviously, the number, nature, and characteristics of the above mentioned factors is far from being exhaustive. However, in certain cases some factors and conditions, mainly some of their characteristics, are correlated and may be eliminated from the above list, as they are reciprocally conditioned and therefore determine certain relationships between them.

One of the most difficult tasks when studying problems related to land evaluation and classification is the identification and isolation of the effect of each factor. That is why the multiple statistical method is required and a large number of situations must be considered in order to be able to examine a variable, all the other factors being constant.

According to several scientists from Eastern-Europe the following economic factors should be considered:

- the distance to markets;
- the state of the roads;
- the area and shape of plots.

As a rule the following economic indexes are considered, as they express the final production results:

- yield per hectare;
- costs per hectare and tonne of products;
- value of the total crop production per hectare;
- net returns per hectare;
- production costs per hectare.

Economic indexes may vary very much as they actually represent the factors for comparing the modifications of the various features of environmental factors and conditions.

EXPRESSION OF CLASSIFICATION CATEGORIES FOR LAND EVALUATION AND CLASSIFICATION

Generally, the various categories of land quality are expressed as classes. However, the relationship between these classes is only relative and it is often necessary to explain the way in which the absolute values of these classes decrease or increase.

The number of classes varies with countries and authors, the highest number met in the specialist literature being 11, and the lowest 3.

As early as the past century and simultaneously with the definition of the notion of land evaluation, scientists suggested that soil quality should be expressed in points by drawing up schemes including a series of marks for the various features of environmental factors.

Expressing soil quality by means of closed schemes, with points ranging from 0 to 100 is actually the relative expression of soil quality as compared with a standard. As a rule this standard is expressed as the optimum ecological condition. Schemes with 100 points are in turn divided in classes by introducing a series of intervals either from ten to ten, with ten classes, or from 20 to 20 with five classes. Sometimes eight classes are established.

Leaving aside the difficulty of theoretical basis of the closed land evaluation schemes with 100 points in use in Europe, we must recognize that the latter offers several operational advantages, being easy to use and expressing more accurately the relativity of the "value" of land evaluation classes or points.

Recent researches mostly carried out in Romania show that a mathematical basis for land evaluation schemes with 100 points may be obtained by using the determinants (   ) calculation method.

Another way of representing land evaluation categories is by using crop plants which may be grown on a certain category of land, as for instance: land or soils; for wheat and beets, rye and potatoes; lupin and seradela. Naturally even in this case, significant differences of value exist from one land category - thus expressed - to another, which are even in some cases subdivided (Poland, D.R.G., Hungary - a former suggestion, 1961). In other cases, lands are classified according to the number of plants that can be grown and in which those lands allowing the largest number of plants to be grown are considered the best.

THEORETICAL AND ECONOMICAL BASIS OF THE GENERAL LAND EVALUATION SCHEMES AND SYSTEMS

Soil fertility, or more accurately, the productivity of farm and forest lands, is a particularly complex economic and social category so that it is very difficult to express properly and is the cause of endless controversy.

In all areas of human development, the notion of "good" and "bad" lands has existed since the furthest antiquity. However, never has a unit of measure, this "goodness" been defined in universally accepted terms.

A multitude of factors and natural or man-created conditions control the production of spontaneous vegetation and crop plants, and interact for reciprocally stimulating or impeding growth. However, each of them acts in its own specific way.

In the course of time and chiefly after nutrition mechanisms of plants had been explained, several attempts were made to define the chemical and physical factors of plant nutrition, and factors capable of affecting plant growth and fructification were identified.

It is largely known that all environmental factors, excepting topography and edaphic volume - differentially affect production, with a curvilinear representation of their favourability rising from a minimum to an optimum and then going down again towards the minimum when the respective factor is in excess or becomes harmful. This action may be principally expressed by the following curve:

a) $y = a + bx - cx^2$

Most of the land evaluation schemes have been based on the principle according to which production increases simultaneously with the increase of the characterization values of the features of factors.

This procedure is erroneous, and therefore the schemes were often criticized.

Sometimes, along with the physically measurable elements, several so-called quality indexes were also considered which affected both the production and land management levels.

Frequently evaluation schemes concern only the soil, as the latter is considered as being the depository of all the influences of the other environmental factors and consequently as faithfully representing the global ecological conditions. Sometimes certain corrections are included according to climatic indexes (Bulgaria, Hungary).

During the last ten years (1962-1972), researches were undertaken in Romania for a methodology for the drawing up of land evaluation schemes. Results are summarized hereafter.

Considering that it is not possible to determine an absolute value for land on a monetary or gold base, the old conception of drawing up schemes based on "evaluation points" was conserved. The best ecological condition being accordingly marked with 100, and considered as being in a relative relationship with the others.

Consequently the manner in which each production factor with a measurable property (chemical, physical, hydrological, heat, etc.), affects the production level of a certain soil, or rather of an ecologically homogeneous area should be determined.

A large number of data were gathered, concerning effective chemical and physical soil characteristics and ecological conditions were accurately determined as well. Simultaneously production data were obtained for the main field-crops, both from experimental stations and production units and in certain cases also information on cost prices.

Calculation of the simple correlation of production with a series of environmental characteristics (soils, climate, topography, hydrology) shows in the first place the way these characteristics are correlated with production. In order to avoid erroneous data, a preliminary selection of cases was made, so that only the studied factor would be variable, the others remaining as far as possible constant.

Significant linear and curvilinear correlations were thus obtained, assessing correlative relationships between the various features of natural factors and crop production.

On the basis of the results obtained, several empirical curves were plotted, showing the way in which the various environmental features affect crop plant production.

Simultaneously, information was obtained concerning the rate of production increase when the value of independent variables,respectively of characteristics of ecological conditions taken individually, changes.

Further multiple correlations were computed.

Knowing that R^2 represents the global determination of the respective correlation, partial determinants were calculated in the case of multiple linear correlation.

One of the main conclusions to be drawn from these studies is that in order to obtain multiple correct correlations and respectively a correct determination of the part each environmental factor and condition play in production, the following principles should be respected:

1. To accurately determine the actual and possible area of growth and fructification for crop plant for which land evaluation is made, and to eliminate from the very beginning all impossible or absurd cases;
2. Data concerning the characterization of environmental features used in the computer for obtaining multiple correlations in order to determine the part of the various features play in crop production, should have a correct ecological significance as they are obtained from simple correlations according to their actual effect
3. The studied community should: a) be representative, b) exceed 50-100 cases having a rational and uniform agrotechnical level; the cause factors (X_1) should be properly selected so that the global determination (R^2) be in excess of 0,80.

The number of factors studied ranged from 3 to 7. As a rule it is wise to first establish partial correlations between all the factors which can be considered and to eliminate all the interrelated ones, so as to reduce calculations and to obtain higher levels of determination.

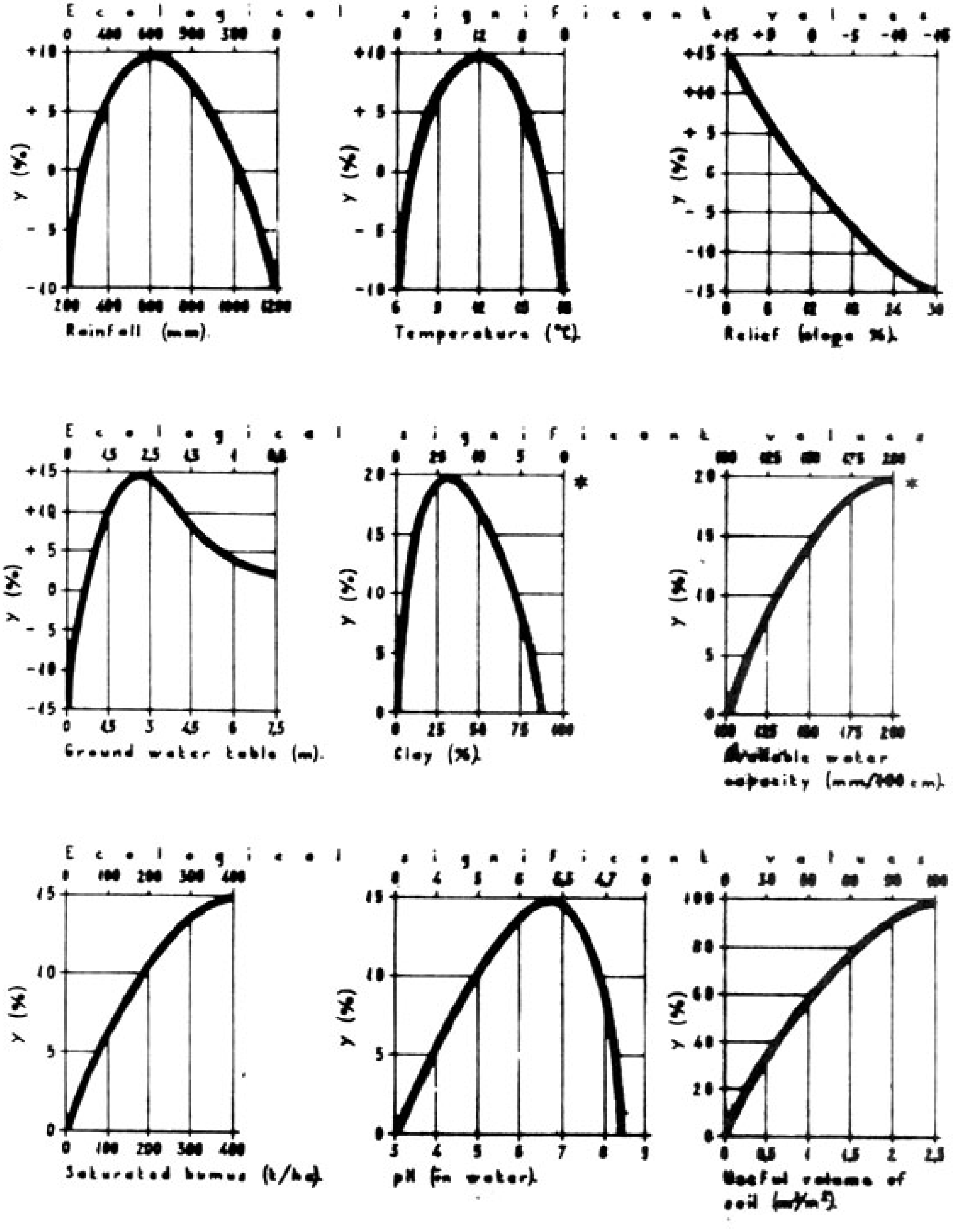
Land evaluation schemes for conditions prevailing in Romania have been drawn up considering the following characteristics of environmental factors and conditions:

1. Climate	1.1. Mean annual temperatures 1.2. Mean annual rain fall
2. Topography	2.1. Slope 2.2. Exposure
3. Hydrogeology	3.1. Depth of the water table 3.2. Nature of water (salt content) 3.3. Flooding hazards
4. Soil	4.1. Total depth (edaphic volume) 4.2. Humus content (t/ha) 4.3. Available water capacity mm/150 cm 4.4. pH 4.5. Total P_2O_5 content 4.6. Salinity level 4.7. Gleyification

Based on the above mentioned principles, Fig.1 illustrates several empirical curves showing the way in which the yield of a certain crop plant - say corn - may be affected by each of the considered features. Some of the curves are based on calculations, the others being more assumptions developed for the use of further research in this field.

Similar research and studies are at present carried out in all the countries of Eastern Europe. They will help to shortly establish a series of land evaluation systems specific to each of these countries. Although based on an unitary principle, i.e: the mathematical determination of the basis of evaluation schemes, these systems will be adapted to the specific conditions of each country. Besides a unitary methodology does not imply an identity going as far as the superposing of all indexes, but rather the respect of objective proceedings based on biological and economic laws and on the social relationships existing at a certain stage of development of our society.

Fig. 1. – Some examples of empirical curves for the establishment of parameters on the base of natural data concerning the features of environmental factors, in view of their use for the calculation of factors' relative weight, for corn growing.



*). – One of these features may be used for calculation; clay content or available water capacity.

RELATIONSHIPS BETWEEN FARMLAND EVALUATION AND CLASSIFICATION WORK AND THE ECONOMIC ELEMENTS OF THE PRODUCTION UNITS

The actual purpose of farmland evaluation and classification work concerns the rational and efficient use of these lands and just returns for all workers in this branch of economy (farmers, hired labour). In all cases, this kind of activity is carried out with a well defined pragmatic purpose and only the theoretical premises require effective scientific research.

The economic elements with which farmland evaluation and classification studies are concerned and related are finally synthetized by the returns obtained per unit/area of the agricultural activity, and in particular crop production.

Land evaluation and classification allow us to determine the rational economic and social limits of land use by analysing economic relations of each time period, with respect to the actual needs and capacity of man to use land in a given form.

In all the countries considered, the land categories determined by evaluation and classification are given an economic interpretation expressed by synthetic indexes (marks, points, classes) with an actual signification for the production potential. Thus for instance in Romania, it is possible to obtain in the present phase and with an above average technology for each evaluation mark (points) of a given crop, 60-70 kg corn, 50-60 kg wheat, 30-55 kg sunflower, and 400-600 kg potatoes.

This method of expression is very useful and adequate for agro-economists as it enables them to use the data in the computer. Thus presentation of ecology in a quantitative instead of a qualitative form, becomes the only one to be processed in mathematical models.

PRACTICAL APPLICATION OF LAND EVALUATION AND CLASSIFICATION WORKS

The use of land evaluation data in economic studies is as old as this activity itself; in some cases application, if required by stringent necessity, even preceded drawing up of theoretical premises.

The range of application of land evaluation in the above-mentioned countries, is as shown in table 2. However, owing to their close relationship with some aspects of the economic and fiscal activities, it is not possible to present the whole range of their possible uses.

As a whole, however, classification based on land evaluation may be used for the outlining and redistribution of the differential ground rent which appears whatever the form of land tenure may be as a consequence of productivity differences and of the differential efficiency of the steps taken for agricultural crop production increase (additional investments in farming activities).

In some countries (Poland, G.D.R.), the cost of land is computed on basis of land evaluation data and of general economic relationships, both for buying and selling in the range of farm and forestry production, and for estimation purposes when land is reallocated as to usage (industrial and social objectives, roads etc.).

Considered as an essential part of the cadaster, land evaluation has the main task to allow drawing up the qualitative inventary of land resources, which is the base of all current and prospective economic plans.

Table 2

Main sectors of use of land evaluation and classification data in some socialist countries

Countries	Technical		Technical and economic			Economic and tax policies		
	Investments	Annually differentiated	Production zonation	Selection of uses	Crop location	Land	Taxes	Subventions differential prices
Bulgaria		x	x	x	x			
Czechoslovakie		x	x	x	x		x	
G.D.R.	x		x	x	x		x	x
Poland				x	x	x	x	
Romania	x	x	x	x	x		x	
Hungary		x	x	x	x		x	
U.S.S.R.			x	x	x			x

PERIOD OF VALIDITY OF LAND EVALUATION AND CLASSIFICATION WORKS. ASPECTS OF THE DIFFERENTIAL EFFECT OF ADDITIONAL INVESTMENTS IN AGRICULTURE AND SYLVICULTURE

Having as a main feature the close relationship with the economic and social conditions of the time when they are undertaken, land evaluation and classification have a periodical character and therefore must be periodically brought to date, when so required by social and economic conditions.

We may distinguish on the one hand several ecological factors which remain unchanged for quite a long time, and on the other rapidly changing elements. Changes accelerate as farming and sylviculture become more intensive, following an increase of investments and technical equipment.

It is, therefore, of the utmost importance to understand accurately and in time,the way in which the various ecological factors may produce more in the given new conditions.

The normal interval of time after which any land evaluation should be revised is about 10 years. In some instances, however, classification systems such as the German or Austro-Hungarian remained unmodified for more than 40 and 50 years respectively.

However, those systems too are subject at present to adaptations and corrections in order to bring them up-to-date.

The period of validity also depends on the rate of application of the new technical findings, so that it is believed that in some instances these periods should be reduced to 5-7 years.

Concerning the effect of capital and current investments in agriculture, it should be kept in mind that these investments highly complicate land evaluation and classification. The influence of fertilizers and plant breeding associated with the unlimited range of natural conditions requires careful arrangement of the factors forming wide ranges of correlations. This arrangement should be such as to enable us to determine for each particular ecological condition the action of each new fertilizing or plant breeding method and the economic results obtained in these new conditions.

Researches carried out both in Romania and some other countries of Eastern-Europe, have helped to determine some aspects of the increase of land potential, as a consequence of irrigation, drainage, and erosion control. On the base of these data it will be possible to determine the required modifications of classes and land evaluation marks respectively and to select new areas to be reclaimed with respect to the possible economic effect.

The effects of the various reclamation works vary, depending on ecological conditions. Thus for instance in Romania, irrigation applied on sandy soils increases yields by 5 to 7, while if applied on groundwater wetted chernozem, yield increases will be as low as 1,1 or 1,2.

Similar examples may be given for a number of cases. However, as research in this field is only in its infancy, no conclusion may yet be drawn.

SUMMARY

Highly important studies, research, and operations are being achieved in the East-European countries concerning evaluation of farm and forest lands. Methods used are specific to each of these countries. Most of the land evaluation methodologies are based on a common principle, i.e: the determination of the production potential of lands on the basis

of features of the controlling environmental factors. On the other hand it is considered that land evaluation is valid only for a certain period of time and therefore should be periodically adapted in accordance with the development of new technologies and the biological amelioration of plants.

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A SUMMARY OF PARAMETRIC METHODS OF SOIL AND LAND EVALUATION[1/]

INTRODUCTION

The parametric method consists of (1) evaluating separately the different properties of soils and giving them separate numerical valuations according to their importance within and between each other, (2) combining these factors (numerical values) according to a mathematical law taking into consideration the relationships and the interactions between the factors to produce a final index of performance, (3) which in turn is used to rank soils in order of (agricultural) value.

This method has most varied possibilities such as the classification of soils according to fertilizer need, suitability for irrigation, transport of heavy loads, forestry, or simply to display the agricultural potential in the widest sense.

PRINCIPLES OF THE METHOD

Each factor has an influence on the final result according to its own equation other factors being considered constant. For example, production is a positive function of depth of soil. The index of this factor is a mathematical function based on $Cx_{0-100} = 100\ (1-e^{-ax})$ which expresses that when the depth of soil increases, the production also increases, at first rapidly then tending to an asymptote, constant for any given crop but varying according to the rooting depths of different crops. Thus a = 0.10 for market gardening with little root growth and 0.02 for forest trees.

This equation arises from experimentation and is empirical and can only be confirmed by the actual yields.

The combination of factors to include their interactions may follow any of three methods. (1) additive, (2) additive and subtractive, (3) multiplicative, (4) a more complex equation:

$$P = f(C'x C''y C'''z \text{ etc})$$

$$P = Cx' + C''y + C'''z \ \ldots\ldots (1)$$

$$P = C'x + C''y - C'''z \ \ldots\ldots (2)$$

$$P = (C'x')\ (C''y)\ (C'''z) \ \ldots\ldots\ (3)$$

$$P = A\ (1-(x-b)\ (y-c)\ (z-d)\ \ldots\ldots)$$

P the production (kg/ha); x y and z being factors: depth of soil, texture, saturation etc.,; A b c d are constants. C' C'' C''' are the mathematical functions appropriate to the individual factors.

The most simple, the additive method, postulates that each factor operates without mutual interference which does not seem to be the case in nature. The additive and subtractive method assume that all the favourable factors add together while all the harmful ones subtract from each other. The multiplicative method is certainly an improvement and allows using the law of the minimum. Yield is limited by the lowest factor. Particularly if it is a factor inhibiting production it will be indexed "O". So this method of calculation appears realistic and conforms to the experimental data.

Example: increase in production as a function of nitrogen applied with/without irrigation. (see Fig.2.)

1/ Prepared by J. Riquier, FAO, Rome, and incorporating material from Riquier and Schwaar (1972).

The Baule function (Baule 1937) is a multiplicative use:

$$P = A\,(1 - e^{-ax})\ (1-e^{-by})\ 1-e^{-cz})\ \ldots\ \ldots$$

other and more complex functions can be utilized and are characterized by a family of curves e.g: (x-P) (y-P) (100-P) = A. (see Fig.2.)

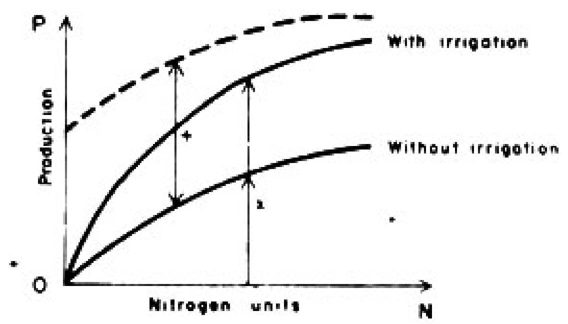

Fig. 1

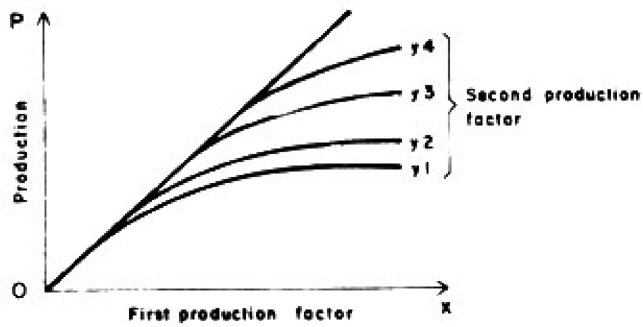

Fig. 2

——— Experimental curves coinciding with curves calculated by multiplicative method

- - - Curve calculated by additive method

Generally, production is expressed as a percentage of the maximum obtainable with all conditions optimal.

If one uses the crop as parameter one can determine the suitability of a (specified) soil for that crop. Vary the parameter (alter the crop), calculate the resulting indices and the highest index specifies the crop most suited to that soil.

Conversely specify the crop and take the soil(s) as parameter(s). The highest index now shows the soil most suited to that crop.

If in addition external factors such as slope, climate etc., are used then a soil classification is produced.

THE MAJOR PARAMETRIC METHODS

A great many parametric methods already exist; unfortunately, none of them are pre-eminent. It must be noted, however, that considerable improvements have been brought to these methods with respect to the number of productivity factors considered, the adoption of the multiplication procedure, the inclusion of several crops etc. It is believed that the most difficult point to overcome is to develop further and to adopt internationally a satisfactory method of worldwide range application.

Historically, the first application of a parametric method seems to have been made by FACKLER (1928) in Bavaria. This extremely simple method, later adopted as a reference for land taxation, is based on the addition of a few factors only - humus content, depth of soil, etc. It is prone to the above mentioned short-comings of the arithmetical procedures.

A popular method is the Storie Index (1937) revised in 1944, 1948 and 1955. It is a multiplication method based on factors such as the soil series, the slope and several others. Its drawback is the introduction of the soil series because some of the characteristics included in this synthetic factor are introduced again in the formula through other specific factors. The Storie Index was developed in California with reference to the soil series of that region; consequently, other indices must be proposed elsewhere whenever new soils occur.

Clarke (1950) developed a productivity index based on a very simple multiplication formula substantiated by field trials; this formula considers the three following factors only: texture, depth, and drainage of soils.

Riquier, Bramao, and Cornet (1970) proposed a multiplication method using seven physical and chemical characteristics (or their substitutes) of the soil with a view to obtaining a sufficiently general productivity index covering the three following major agricultural areas: crops, pasture, and forestry. The limiting factors can be improved or even suppressed through adequate improvements. For example, the salt content will decrease with soil leaching practices producing lower salinity values; this new value is then introduced in the general formula, thus yielding the potential productivity after improvement. There is great flexibility in the method since it is also possible to introduce in the formula the kind or level of upgrading which is economically or technically feasible. However, the system oversimplifies the influences of both climate and improved management practices on productivity.

In the USSR, Blagovidov (1960), Taychinov (1971) and others apply some simple factors, e.g: humus content, texture, etc., and add them together. Their ambition does not go beyond the formulation of indices of regional value.

More elaborate methods have been developed by Bulgaria and Romania.

The Poushkarov Institute in Sofia, in particular, set up a comprehensive land evaluation method using the addition procedure for some factors and multiplication for the others.

It is believed to be the first time that different evaluations were made for different crops - wheat, maize, sugarbeet, lucerne, cotton, apples, grapes, etc. Naturally this leads to the production of a large number of tables. An attempt to appraise the economical value of the land in terms of income per hectare is thus made with relationship to the productivity of the various crops considered in one rotation, their respective area, the present marketing price, etc. Although some factors external to the soil are considered too, for example irrigation and slope, others such as the application of fertilizers are overlooked, probably because they are too difficult to evaluate. Apart from the inherent faults of the addition procedure already mentioned, the indexing is inconsistent. In the case of grapes for example, a water table level lying between 0 and 300 cm is considered prohibitive and indexed 0 accordingly, although it is obvious that a water table level of 299 cm does not imply zero productivity.

In Romania, Teaci (1964 and 1970) is currently applying an addition and substraction method using compounded factors (-15 to + 15 for the slope, 0 to 6 for the total phosphorus content (etc,). As in the Bulgarian method, correction factors are used to multiply the figure of the addition and evaluation is also made for a number of crops. The climate, the relief and the hydrological conditions contribute 26, 20 and 20 percent respectively of the final score. The soil component covers the remaining 34 percent of the productivity evaluation. This distribution of influence on the final rating may be appropriate for Romania, but is clearly not equally applicable elsewhere.

Searl in Trinidad and Tobago (1968) and Millette and Searl (1969), in Canada, multiply non-easily modifiable factors such as texture, depth of soil, topography, and climate, by easily modifiable factors like nutrient elements, moisture regime, pH and stoniness. They compute two indices, one for the present productivity and the second for the potential productivity. For this, they give a maximum value to all the easily modifiable factors. The improvement coefficient is given by the ratio between the present and the potential productivities. This sytem is very similar to the one proposed by Riquier, Bramao and Cornet (loc.cit).

In France, Durand (1965) and recently Duclos (1971) have proposed a multiplicative and an additive—subtractive method respectively. The latter aims at the determination of the suitability for management rather than the productivity and provides for cartographic representation.

Sys and Frankart (1971) have developed a multiplication method for the soils of the humid tropics. It considers the following criteria: profile development, parent material, depth, colour, drainage, pH, base saturation and development of the A1 horizon of the soil. Like the Storie Index, the profile development factor actually refers to the type of soil considered and thus suffers from the same drawbacks. In this method, improvement measures are taken into consideration but without computing their influence on productivity. The climatic factor does not appear in the formula and it is supposed to be very warm and very humid.

For the soils of the arid and semi-arid zones, Sys has worked out, together with Verheye (1972) another multiplication method yielding two indices: one capability index for irrigation and one land productivity index for a number of crops. The former involves the following factors: texture and depth of soil, $CaCO_3$ and $CaSO_4$ contents, Na saturation, salinity, drainage and slope. In addition to these factors (other than the slope) the productivity index considers the following factors: development of the A1 horizon and weathering stage of parent material. The correlation between capacity for irrigation and productivity is not established.

An addition and subtraction method comprising a large number of indexed factors was proposed for use in Indonesia. Unfortunately it shows all the major short-comings of all the addition procedures: a limiting factor has little bearing on the final evaluation result whenever the other factors are good. At present Driessen[1/] is developing in Indonesia a much more satisfactory method based on the multiplication procedure. It considers 15 significant factors related to soil conditions and environment, 5 land-use categories and 3 management levels. The management levels are introduced after improvement; this latter value has to be obtained by field trials. This point is indeed the most delicate part of the problem and it has not been solved yet satisfactorily by any system.

A complex mathematical model w s applied in Algeria by the SOGETHA (multivar experimental programme) with a view to predicting the production of date palms in the Oued Rhir Oasis. This model can be easily computerized. Moreover, by application of the multiple variable method, the computer itself can help in determining the correlation between production factors and productivity, thus leading to their eventual objective translation in terms of mathematical functions.

Another complex mathematical model of wider scope and compass than the proceeding one but based on the same principles, is currently being tested by Riquier at FAO.

PROSPECTS OF PARAMETRIC METHODS

All the non-parametric methods are by definition of a subjective nature. The parametric ones have a definite advantage over these because they imply the non-subjective treatment of standard mathematical models. It must be accepted, however, that in parametric methods, only the mathematical treatment of factors is purely objective; the selection and compounding of these factors is still prone to variable intensities of subjectivity according to the kind of mathematical procedure followed. Realizing the complexity of the problem, it is clear that men will always have the responsibility of selecting and assigning significant factors, but should then aim at limiting to an acceptable minimum the role played by subjectivity in these operations. This can only be done if the consideration of the significant factors retained reflects results of field trials and if these results have a statistical value. The existing parametric methods are still in need of varying degrees of improvement with respect to the introduction of a climatic factor, the introduction of plant coefficients, the definition of characteristic functions translating into continuous curves the correlation which exists between each individual production factor and productivity

1/ Personal communication Dutch bilateral assistance, Bogor.

(thus suppressing the undesirable application of discontinuous steps). In particular, there is a need for the creation of an optimum complex mathematical model able to show as objectively as possible the interactions between all the significant production factors considered and productivity.

It is very probable that the use of parametric methods will undergo two distinct but complementary types of evolution. Firstly, rather simple mathematical models will continue to be applied for use at a national or at a regional level in those countries where the amount of information on soil conditions and environment does not yet allow the systematic application of more complex formule. Such simple parametric methods will have to be amended when and if necessary following the improvements above; or they will have to be selected from already improved methods estimated to match best prevailing local conditions. Secondly, complex mathematical models will be further developed and refined with a view to establishing a universally acceptable index.

ADVANTAGES OF PARAMETRIC METHODS

1. Each factor and its interactions must be considered;
2. Subjectivity, a drawback to other methods is eliminated. The indices and the equations can be standardized;
3. If the factors are well chosen the method is of universal application. An equation expressing the relation of a crop to its environment can be applied to other areas of the world. The soil classification is thus comparable between regions;
4. One can introduce plant parameters into the equations and determine suitability for each separate crop;
5. Or conversely if one ignores the individual plant parameters a soil potentiality classification is obtained;
6. Upgrading and development are affected by limiting factors (such as low fertility status requiring use of fertilizer) but improvements will in their turn modify the production factors which, when introduced into the equation, will give a new potential. The method is very simple and one can repeat for successive improvements of varied intensity;
7. The system is quantitative. It expresses production in kg/ha for a predetermined level of cultivation. Economists can predict outputs and inputs. A balance sheet can be predicted given the choice of crop and cultivation;
8. The method is particularly adapted for computers and data banks. The general mathematical relationship is programmed. And the introduction of the appropriate parameters soil/climate/crop as given in the data bank immediately allows a quantitative evaluation of the potential of the crop in the area.

DRAWBACKS OF PARAMETRIC METHODS

1. Action of certain factors, such as light and photo periodism, the incidence of disease etc., are difficult to evaluate and are badly documented. Slope is a complex factor further complicated by soil degradation;
2. Interactions are not well known. Multiplication rather than addition is empirical and no more than an approximation;
3. The elaboration of the standard values is experimental and based on comparisons themselves subjective;

4. It is difficult to choose independent factors. One must avoid a reintroduction of a factor in a common characteristic;
5. Certain data is missing. It has to be replaced by approximations;
6. The mathematical model may hide or hinder a comprehension of the true process. Alternatively it may prove helpful;
7. The comparison between regions is difficult. It is necessary to return to a comparison of limiting factors.

CONCLUSION

The parametric method provides an attempt to express land evaluation in quantitative terms compatible with modern facilities for calculation. It introduces quantitatively the use of yield and productivity in a manner which provides communication between the pedologist and the economist. It can easily be integrated with other global methods of land classification to provide an evaluation of the agricultural value of the soil.

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LAND EVALUATION FOR AGRICULTURAL LAND USE PLANNING - AN ECOLOGICAL METHOD[1/]

SUMMARY

In agricultural land use planning there exists a great need for the identification of various development alternatives. Such alternatives should deal with the various combinations of farming practices taking into consideration the development needs and the existing socio-economic conditions.

For the systematic identification and comparison of such alternative roads to development a land evaluation method is proposed which relates the physical qualities of the land with both the ecological and farming requirements of the plants.

The basic idea underlying the proposed method is that land should be rated on its value (suitability) for a specific purpose, since there is no absolute and generally applicable value of land.

INTRODUCTION

Definition of land

In the context of this study the term "land" comprises all but the purely socio-economic and human attributes of the environment, important for agricultural production (see also Christian and Stewart, 1964).

Ecological land evaluation

The ecological approach to land evaluation presented here systematically relates the physical qualities (attributes) of the land with the ecological and agricultural requirements of the plants and with the requirements peculiar to the pertinent types of land utilization.

This results in a technical suitability classification of the land for certain defined types of land utilization. This is a pragmatic classification.

Economic land classification

The proposed land suitability classification represents the first stage of the overall land evaluation procedure. The subsequent stage is the economic land classification which is a synthesis of the suitability classification and the relevant social and economic factors (Kellogg 1961, Vink 1960).

The economic land classification or recommended land use classification is beyond the scope of this report. However, the data provided by the land suitability classification (which is a technical feasibility classification for a defined purpose), serves the requirements of the economic land classification. As such,ecological land suitability classification provides a reliable base for rural land use planning development, and environmental control or readjustment.

1/ By K.J. Beek, FAO (Santiago) and J. Bennema, Agricultural State University, Wageningen (Netherlands) being a summary of a document which will be published under the same title by the International Institute for Land Reclamation and Improvement, Wageningen, the Netherlands. This paper was read at the first FAO/UNDP Latin American Seminar on Systematic Land and Water Resources Appraisal, Mexico, November 1971 and is an elaboration of the system of soil survey interpretation, developed in Brazil (Beek, Bennema, Camargo, 1964).

Land evaluation and land use planning

In land use planning there is a great need for alternative solutions comprising a variety of technical possibilities for development. These solutions should take into consideration the locally most feasible methods of management, in view of the needs and the socio-economic conditions. The proposed system is constructed in such a way that its application automatically leads towards these alternative solutions.

There is also a great need for flexibility. (De Vajda, 1969). Easy revision of the conclusion, and inclusion of solutions not previously envisaged, must be possible. The presented approach offers this possibility of easy revision, because it is built up by consecutive steps. In the case of newly arising situations it is usually not necessary to go back to the data of the original surveys, but a next step can be used, where the data of the survey are synthesized for the application.

While natural resources surveys as such can be carried out to a great extent independently from the work done by other specialists concerned with land use planning, close co-operation with agriculturists and crop specialists is however required during the suitability classification, while also contacts are needed with specialists of the socio-economic and organizational disciplines. The latter contacts will intensify during the stage of economic land classification, and the greater part of the responsibility will then devolve upon the latter specialists.

Fig. 1. shows the relationship between the tasks of the socio-economic disciplines and of the disciplines in the field of natural resources and agriculture in land evaluation. It also indicates the most important points of contact:

1. the definition of possible solutions as expressed in the defined land utilization types; and
2. the establishment of the land management specifications and the land suitability classification for the relevant utilization type.

THE ROLE OF NATURAL RESOURCES SURVEY AND LAND SUITABILITY CLASSIFICATION IN AGRICULTURAL LAND USE PLANNING

General

Fig. 2. indicates the role of resources survey, and of land suitability classification in a model of an overall land use planning project designed for this specific purpose.

The planning model (Fig. 2) consists of three phases:

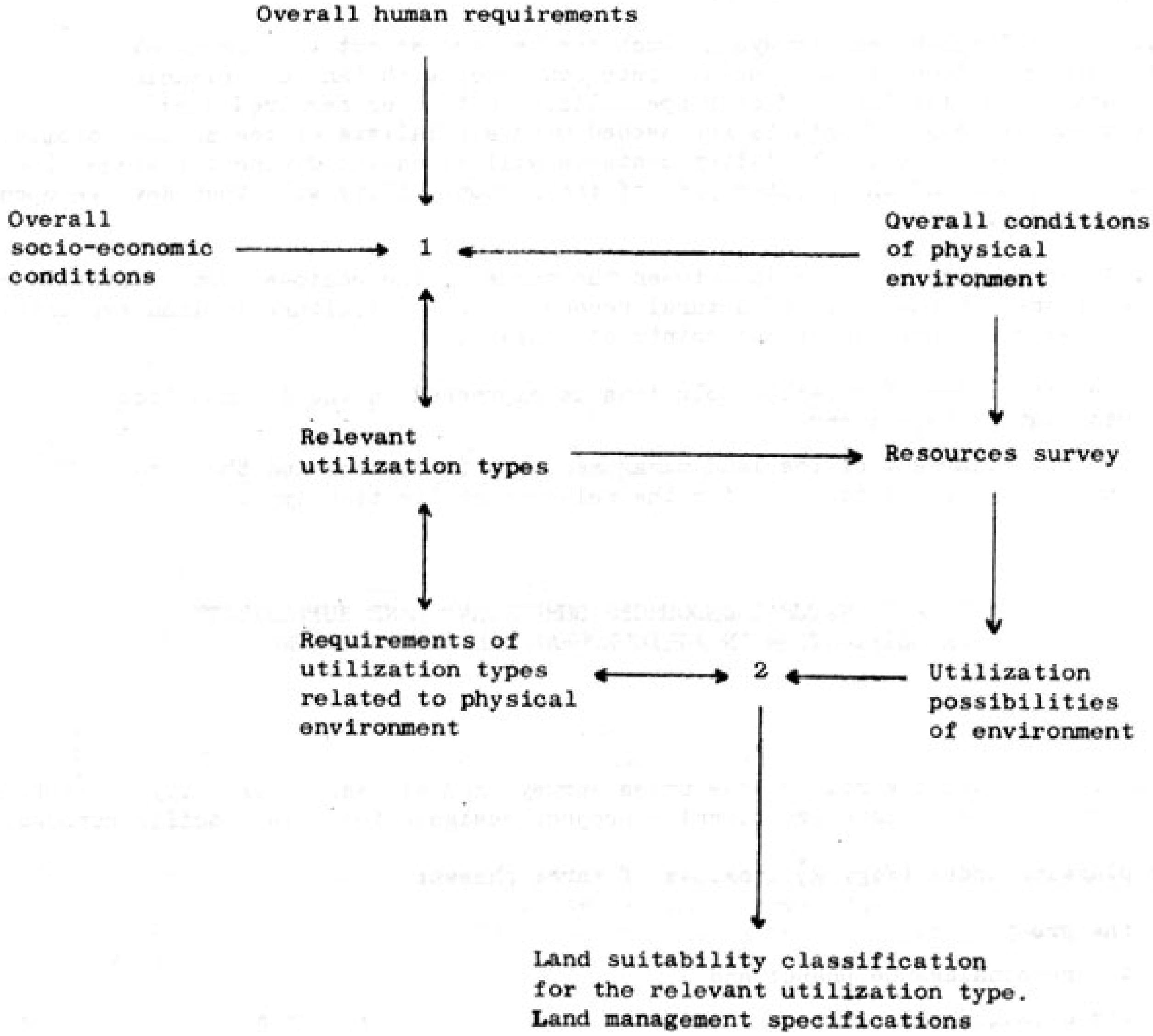
a) the pre-project;
b) the reconnaissance phase; and
c) the detailed phase.

Quantitative data related to the best use of the land and water resources under the given socio-economic conditions become available with greater precision and detail during each consecutive phase.

During the planning project three main questions have to be answered:

1. should the development project be effectuated or not?
2. what are the feasibilities? and
3. how should the development project be carried out?

Fig. 1.


Overall human requirements
Overall socio-economic conditions
1
Overall conditions of physical environment
Relevant utilization types
Resources survey
Requirements of utilization types related to physical environment
2
Utilization possibilities of environment
Land suitability classification for the relevant utilization type. Land management specifications

The emphasis is shifting during the planning from the first question to the last one.

The scheme is an outline for the planning of a relatively large area, in which many disciplines are involved. In the planning of smaller or less complicated areas, phases b) and c) are often combined.

Every phase proceeds along five steps. Although differing greatly in their elaboration, these steps are basically the same. These steps are: preparation, surveys and investigations, interpretation, economic land classification, and reporting.

The planning phases

Phase a), the pre-project. This phase consists of an exploratory "Broad stroke" orientative study of the composition of the natural resources, the agricultural possibilities and other aspects relevant to the agricultural development planning. Fact finding is an important aspect of phase a).

In this phase a broad suitability classification will be made which, integrated with the socio-economic conditions, will furnish a broad land classification.

Phase b), the reconnaissance phase. Strong emphasis is laid during this phase on the inventory of the area. The number of specialists directly involved will be greater than in phase a) and generally more time in the field will be needed in order to obtain the neccessary more detailed data.

Short term experiments can be carried out, such as measurements of soil properties, related to irrigation and drainage possibilities. If sufficient field experiments and fundamental research cannot be done in the region itself, a great deal of extrapolation from results in other areas with improvement practices under similar land conditions is required at this stage.

Phase b) is concluded with the formulation of an outline of the land development plan. The conclusions reached by the various disciplines are synthesized into an overall plan of recommended land use (economic land classification) and of farm production. A choice is hereby made from the alternative solutions.

Phase c), the detailed phase. The central question is: what should be done during the programme effectuation? Detailed surveys and studies are necessary to answer this question. These surveys and studies should be carried out in pilot areas, and/or in larger areas where a more intensive use will be made of the land.

One result is the overall land classification for recommended use, reconciling the technical possibilities with the needs for production and development, the social and economic needs and feasibilities and the organizational and institutional feasibilities for changing the production methods.

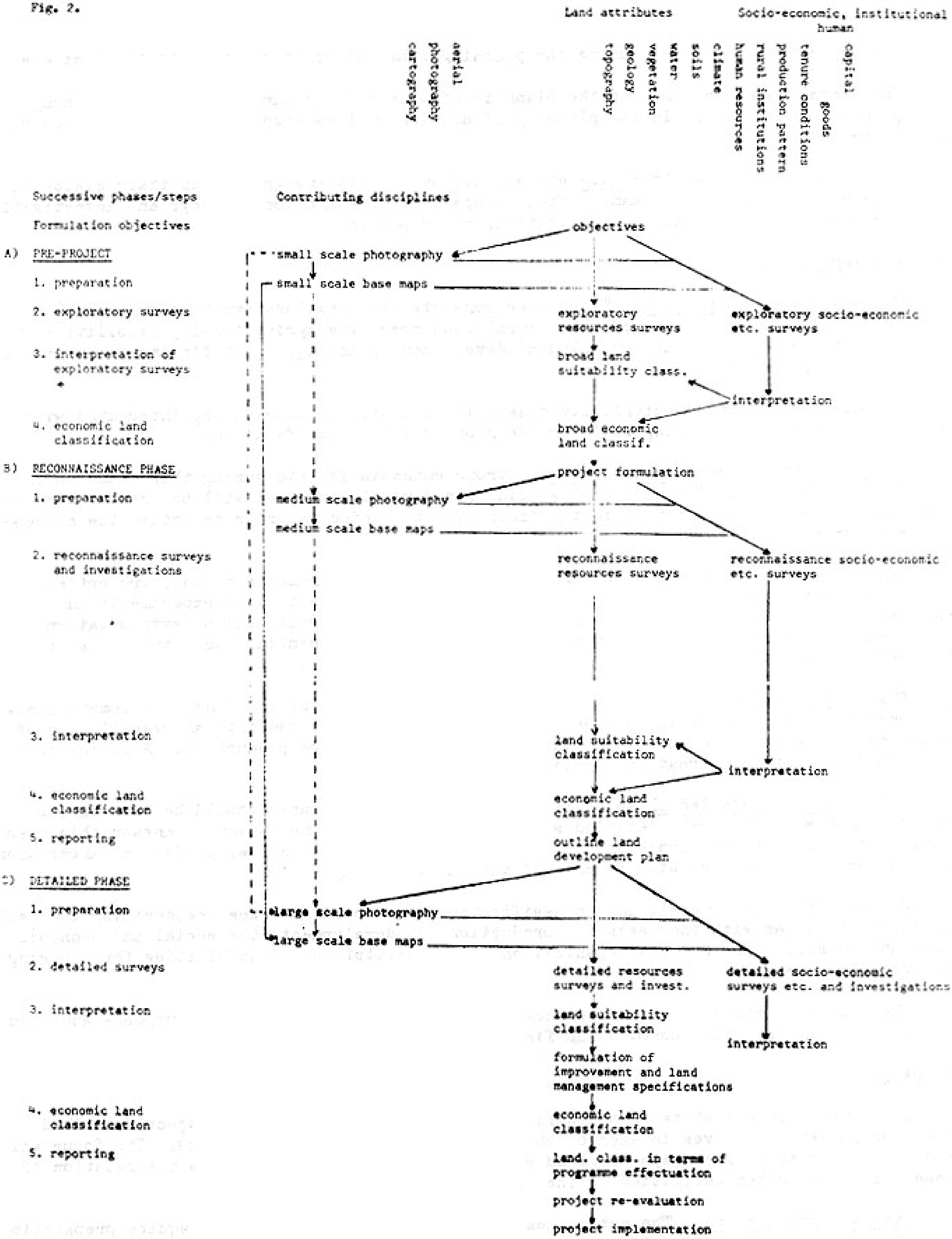
The report of phase c) should be acceptable to a bank for investment purposes and should, therefore, fully show the economic and financial implications of the project.

The steps

The five different steps of the agricultural development planning project described hereafter repeat themselves in each of the phases a), b) and c) (see Fig.2). The focus will be on natural resources surveys, on land suitability classification and on the relation of these aspects to other activities of the project.

Step 1 : preparation. The activities to be developed in each phase require preparations, e.g: the provision of staff, office space, transport and collection of all kinds of necessary materials. It is imperative for successful operations to have aerial photographs and topographic maps available before the next step starts.

Fig. 2.



Land attributes
Socio-economic, institutional
human
aerial
photography
cartography
topography
geology
vegetation
water
soils
climate
human resources
rural institutions
production pattern
tenure conditions
goods
capital
Successive phases/steps
Contributing disciplines
Formulation objectives
objectives
A) PRE-PROJECT
1. preparation
2. exploratory surveys
3. interpretation of exploratory surveys
4. economic land classification
small scale photography
small scale base maps
exploratory resources surveys
exploratory socio-economic etc. surveys
broad land suitability class.
interpretation
broad economic land classif.
project formulation
B) RECONNAISSANCE PHASE
1. preparation
2. reconnaissance surveys and investigations
3. interpretation
4. economic land classification
5. reporting
medium scale photography
medium scale base maps
reconnaissance resources surveys
reconnaissance socio-economic etc. surveys
land suitability classification
interpretation
economic land classification
outline land development plan
C) DETAILED PHASE
1. preparation
2. detailed surveys
3. interpretation
4. economic land classification
5. reporting
large scale photography
large scale base maps
detailed resources surveys and invest.
detailed socio-economic surveys etc. and investigations
land suitability classification
interpretation
formulation of improvement and land management specifications
economic land classification
land. class. in terms of programme effectuation
project re-evaluation
project implementation

Step 2 : the surveys and investigations. A wide range of disciplines is often involved in these surveys. The following aspects are important:

- natural resources;
- socio-economic conditions;
- agricultural services; and
- human resources.

In the land evaluation the surveys of socio-economic conditions, agricultural services and human resources have to be fully integrated with the natural resources surveys in orienting the land evaluation towards the recognition of suitable types of land utilization. An integration between the different natural resources surveys is also necessary.

This can be obtained in two ways. The land can be surveyed as an integrated unit (e.g: land systems) or as synthesis of separately surveyed land attributes. For small scale surveys integrated land units may be more practical, whereas the surveys of the separate attributes (e.g: soil surveys, vegetation surveys, etc.), become more indicated for detailed scales.

The surveys in the different phases will be carried out at different scales:

- the small scale surveys (1:100 000 - 1:500 00 or smaller) of phase a) will serve to get general information about the land conditions in the area;
- in phase b) (scales 1:25 000 - 1:100 000) more detailed information will be furnished regarding the area still included in the development plan;
- in phase c) (scales 1:5 000 - 1:25 000) surveys will also include the survey and study of pilot areas to collect data in relation to specific uses of the land e.g: for irrigation, drainage, and soil conservation.

Photo interpretation with some limited field check will in many cases furnish the data needed in phase a). If the same information has to be gathered by field work alone, much time is lost. During phase b) photo interpretation is also a usual technique. Generally more additional field work will be needed than in phase a), but if the surveyor has a good understanding of photo interpretation much time can be saved. In phase c) photo interpretation may be of less importance, although (depending on landscape and purpose) it can often be of great value and in many cases it is essential.

Step 3 : the land suitability classification. The data of the natural resources survey are interpreted in terms of technical feasibilities for defined uses. During the survey it is necessary to have clearly in mind what additional data besides those normally provided by the survey will be required for step 3. This step has been dealt with in more detail in part III, as it represents the essence of this paper.

Step 4 : economic land classification. The economic land classification is a quantitative classification of land units based on cost/benefit analyses for specific land utilization types. This might include an optimizing of the main production factors such as farm size, labour intensity and capital input level.

Quantitative economic land classes do not necessarily coincide fully with the qualitative technical land suitability classes. The latter classes do support, however, the determination of economic land classes by providing essential data on land management and improvement cost as well as estimates of benefits to be expected in terms of predictable yields. The main difference in the land suitability classification and the economic land classification is that land suitability classification aims in the first place at a systematic comparative study of the development prospects of a variety of land utilization types for given land conditions. Economic land classification deals only with one or a few promising utilization types which are then analysed in great detail on their economic value in socio-economic and financial terms.

Step 5 : reporting. By using the presented scheme of agricultural land use planning, two interim reports and a final report have to be made.

The interim report of phase a) (the pre-project) deals mainly with the formulation of the planning project. The interim report of phase b) (the reconnaissance phase) will give the first outlay of the master plan which will be finalized during phase c) (the phase of detailed studies). In these reports a full integration should be achieved of all the disciplines contributing to the planning project. Overall land classifications are, as was already stressed earlier by the descriptions of the phases, an essential part of these reports.

PROPOSAL FOR A LAND SUITABILITY CLASSIFICATION METHOD

The basic idea underlying the proposed method of land suitability classification is that land should be rated only on its value for a specific purpose, since there is no absolute and generally applicable value of land.

For a good understanding of the method several basic elements are explained first:

- the definition of land utilization types;
- the concept of land qualities; and
- the determination of land improvement capacities.

Land utilization types

Land evaluation should include at its earliest stages a broad selection of types of land utilization which are relevant under the given environmental socio-economic and overall national or regional political conditions.

Depending on the intensity of the study, separate alternatives could represent broad differences in agricultural use (e.g: irrigated arable farming; rainfed arable farming; range land; etc.); specific aspects of such use (e.g: gravity irrigation; sprinkler irrigation); or even specific crops. Refinement of the definition of land utilization types should never exceed limits set by the detail of the project and the availability of reliable data on ecological environment and management response. The following factors are important, most of which can be quantified per unit area and have a marked influence on the productive capacity of the land:

a) Produce is definitely the most diversified and important factor. In its widest sense not only primary biological production could be included (pastures, crops, forests) but also secondary production (livestock, wildlife) as well as other alternative types of land utilization as engineering and outdoor recreation.

b) Capital intensity determines possibilities for improvement maintenance and conservation of the land conditions. Technically it would be possible to condition virtually any given site to satisfy a particular need or requirement. However, the extent to which this occurs, in practice, depends on the inherent characteristics of the land conditions, the cost of modifying them in relation to the value of the desired product, and the availability of private and public capital. A distinction must be made between:

- non-recurring input requirements or development cost; and
- recurring inputs.

Within each biological production process several input levels can be distinguished. At least two levels are suggested: low (traditional, present land utilization type) and high (advanced, modern, potential land utilization type).

c) Labour intensity is a variable influenced by the level of applied capital and technology, and by the labour requirements of the produce concerned. Since employment opportunities are a major issue of most development policies, this factor should be taken into consideration when alternative land utilization types are formulated.

Variable ratios of capital/labour intensity also influence the recommended execution of initial special site conditioning works.

d) The source of farmpower to a great extent symbolizes the accompanying set of agricultural implements, and the level of capital inputs on the farm. The set of agricultural implements, in its turn, represents a combination of farm management practices significant for the land utilization type. The performance of each set of agricultural implements is affected differently by the agricultural land conditions. An important distinction is:

- engine-power operated machinery;
- animal power; and
- manpower.

e) The level of technical know-how of the farmer. It is often the relatively low level of technical know-how of the local farmers which limits the possibilities for ambitious land and water development schemes to solutions of only an intermediate level of technology and efficiency, a restricted range of crops, less sophisticated farm machinery and a restricted capital input level.

f) Farm size is closely related to most of the other factors. In certain cases it is determined beforehand entirely on the basis of socio-economic considerations rather than also considering physical conditions. It would be desirable to recognize the farm size as a major variable within a certain range and which is definitely established at an optimal level during the economic land classification.

Sometimes other factors are variables of dominant importance, such as land tenure systems and the status of infrastructure.

Criteria for defining separate land utilization types need to be agreed upon. The feasibility of identifying a range of possible systems on a global basis should be investigated, if possible through groupings which represent several levels of generalization. It should be noted that earlier conception of "level of management" is fully covered within the proposed concept of Land Utilization Types.

Land qualities

The data of the surveys are used to establish first the major qualities of the land (Kellog, 1953; 1961; Vink, 1960).

Major land qualities are main land characteristics as seen from the view-point of the user: the farmer, the forester, the hunter, as well as seen from "the view point" of the plants and animals. Major land qualities could also be called major ecological conditions, including phyto-ecological, bio-ecological, human-ecological and agro-ecological conditions. Phyto-, bio- and human ecological conditions are related with requirements of respectively plant growth/animal growth and health and well being of human beings. Agro-ecological conditions are related with management practices in agriculture (or in the widest sense rural-ecological conditions as related with management of rural uses).

Each major land quality has its own direct functional relationship with a specific use and has a distinct influence on a particular major requirement of that use. This makes it possible to treat the different major qualities as separate factors in that use.

Availability of water for plant growth in the growing season is an example of such a major quality. Soil texture is an example of a land characteristic which is not a major quality because it does not have a direct functional relationship with the use but only an indirect one. The major quality availability of water for plant growing depends on many single and compound land characteristics, one of which is texture. The weight of each characteristic depends on the total set of characteristics.

The definition of a major land quality reads as follows:

A major land quality is a complex attribute of the land which acts largely as a separate factor on the performance of a certain use. The expression of each land quality is determined by a set of interacting single or compound land characteristics having different weights in different environments depending on the values of all characteristics in the set.

Major land qualities in relation with agricultural use can be grouped according to the kind of requirement they serve, for instance:

Major land qualities related with requirements of plant growth

- availability of water
- availability of nutrients.

Major land qualities related with requirements of animal growth

- nutritive value of grazing land
- available drinking water
- absence of endemic diseases.

Major land qualities related with requirements of natural product extraction

- presence of valuable timber
- presence of medicinal plants
- accessibility of the terrain

Major land qualities related with requirements of management practices in plant production, animal production or in extractions

- possibilities of mechanization
- resistance of the soils against erosion.

Land qualities and productivity ratings. It is often possible to make a reasonable estimate of the productivity of a land unit for a utilization type in terms of yield per surface unit (crops, meat, milk, extraction products). The estimated productivity can be used as an element in the suitability classification. It replaces those major land qualities which affect productivity. The number of major qualities to be considered in the conversion table decreases considerably if production levels are introduced. For example: a suitability classification is made for coffee growing under modern management and if productivity levels under such management are known, then only this productivity as well as the major qualities resistance of the soil against erosion and possibilities for mechanization, have to be considered. If the productivity levels are not at all known such qualities as availability of water, availability of oxygen, nutrient status of the soils, together with climatic factors have to be taken into account. See also tables 1 and 2.

Land quality grading. Each major land quality or the production potential has to be classified in different grades. In the case of potential land use the expected grades of the major land qualities after improvement should be estimated. When the improvement has been implemented, we are dealing with the real grades of the major land qualities after improvement, which we hope will match the expected grades.

Most of the major land qualities cannot be measured directly but are determined by a set of measurable land characteristics. For instance: availability of water is determined by such properties as effective soil depth, soil texture, ground water level, precipitations and evaporation. Each of these properties has its importance as part of the whole set of properties. Effective soil depth will, e.g.: have much influence in soils without ground water level and under climatic conditions, where there is a dry period within the growing season. But if the ground water level is high or precipitation is abundant the whole year round, then soil depth is of less importance.

Often the surveyor or the land evaluation specialist will reach his first conclusions about the grade of major qualities by observing plant life and farm management. Lack of available water will e.g.: show clearly in the kind of natural plant vegetation, and in the crop choice. Quantitative data from laboratory, field experiments and meteorological stations provide additional information. If part of an agricultural planning project, then the major qualities will in phase a) often be based on qualitative and semi-qualitative field data alone, while in phases b) and c), quantitative data from field and laboratory will become more important. It is also possible to use a parametric approach to determine the grades, which will require careful quantitative measurements of the contributing land characteristics and an assessment of their weights in each situation. The resulting grades related to plant growth quantified by such a parametric approach could further be used in an biological growth equation.

Plant and land management practices may vary widely in their requirements and tolerance towards the grades of land qualities distinguished, therefore the land quality classification does not pretend a listing of grades from good to bad. It is better to use such terms as high and low, for instance: high availability of water/oxygen/nutrients; high resistance to erosion. In the case of risk of flooding and toxicity such terms as high or low absence of risk could be used.

In a further stage of the land evaluation the grades of the land qualities are compared - in conversion tables - with the requirements of the different utilization types. Only after this comparison can it be indicated on firm grounds to which extent a major quality of a certain land unit should be considered as a limitation for the utilization type under consideration.

For the grading of qualities, grades can be formed which have either only local importance or which tend to have a more regional application.

For grades of local importance the total amplitude of the quality as it occurs in the project area is subdivided in as many grades as are possible and useful.

In a regional classification the grades have to be defined beforehand. The definitions of the different grades will mostly refer directly or indirectly to a major utilization requirement corresponding with the land quality under consideration.

Land improvement capacity

An assessment of the improvement capacities of land qualities has to be made as far as they are of interest for the considered land utilization types.

The technical improvement potentialities of the land qualities comprise many aspects such as the improvement of the fertility status by using fertilizers, the improvement of the water availability by irrigation, the improvement of oxygen for roots by drainage, the improvement of possibilities for mechanization - for instance by removing stones, the control of erosion with soil conservation practices and the control of floods with embankments.

Table 1.

Conversion table
Suitability for irrigated agriculture as a function of the grades of land qualities and the level of improvement inputs.

Suitability classes	level improvement inputs	Availability nutrients	Availability water	Absence risk salinization	Availability oxygen	Adaptability mechanization	Resistance erosion	Freedom Lay-out of the scheme
(High) I	C	1	1	1	1	1	1	1
(Medium) II	D	1	1	1	2	1	1	1
	C	1	1	2	2	1	1	2
(Restricted) III	D	1	2	2	3	2	1	2
(Low) IV	Any grade of the qualities lower than for restricted or level of improvement inputs higher than for restricted.							

Table 2.

Conversion table
Suitability for irrigated agriculture as a function of expected yields and grades of land qualities not affecting productivity and of the level of improvement inputs.

Suitability Classes	Level improvement inputs	Expected yields of wheat	Adaptability mechanization	Resistance erosion	Freedom to select size and shape of fields
(High) I	C	1	1	1	1
(Medium) II	D	1	1	1	1
	C	2	1	1	2
(Restricted)III	D	2	2	1	2
(Low) IV	Any grade of the qualities lower than for restricted or level of improvement inputs higher than for restricted.				

The conclusion of this part will be an indication of improvement requirements for specific utilization types for each quality in terms of inputs requirements and improvement effectiveness. Five capital input levels for land improvement are proposed:

A = low;
B = medium;
C = high;
D = very high with normal recurring costs;
E = very high with high recurring costs.

In an improvement capacity, table 3, the grades of the qualities and the yield potential improvement are shown for each relevant input level (improvement effectiveness). This is done in a five-point scale:

1 = very high;
2 = high;
3 = medium;
4 = low;
5 = very low.

Table 3. Improvement capacity

GRADES OF RELEVANT LAND QUALITIES / LEVELS OF INPUT REQUIREMENTS	AVAILABILITY NUTRIENTS	AVAILABILITY WATER	ABSENCE RISK EROSION	ABSENCE RISK SALINIZATION	AVAILABILITY OXYGEN	AVAILABILITY CONDITIONS FOR MECHANIZATION	FREEDOM LAY-OUT OF SCHEME	YIELDS POTENTIAL
(Natural land conditions) O	3	4	2	2	3	2	1	5
A	2	4	1	2	2	1	1	4
B	2	4	1	2	2	1	1	4
C	1	2	2	4	3	2	1	3
D	1	1	1	3	2	1	1	2
E	1	1	1	1	1	1	1	1

Functioning of the proposed land suitability classification method

Fig. 3. shows the land suitability classification method in its most simplified form, giving only inputs and output. The inputs consist of data on the physical environment and of a description of the relevant utilization types, the land suitability classes being the output.

Input I – The data on the physical environment comprise the delineated and classified land units and the information about these units which is needed for the suitability classification. Which kind of information will be required depends partly on the land use foreseen. It is often not possible to define at the beginning of the resources surveys the relevant utilization types in precise terms. However, at this stage it will be possible to describe in broad terms which kinds of broad land uses are relevant for the suitability classification. This information can be very helpful to determine the scope of the surveys and to indicate which data about the land have to be collected.

Input II – The relevance of the utilization types should be decided from a study of human requirements and further from what is already known about the socio-economic and environmental conditions (Fig. 1). The relevant utilization types are thus already adapted to the conditions of the environment as far as these are known, while the suitability classification proceeds with a further adaptation in the light of new information.

Some of the land utilization types may have a complementary function. They are only relevant if the suitability for other more relevant utilization types is low. If for instance in the first place agricultural land for cropping is needed in view of employment, the less labour intensive grazing or forestry will be only taken into account for those land units which are not suited for cropping. The system as applied in this case resembles in this aspect the land capability system of the USDA Soil Conservation Service, which has the priority of relevance of cropping above grazing and grazing above forestry as its basic principle.

How the data about the land are processed in the land suitability classification is not shown in Fig. 3. The processing is merely indicated as "conversion table".

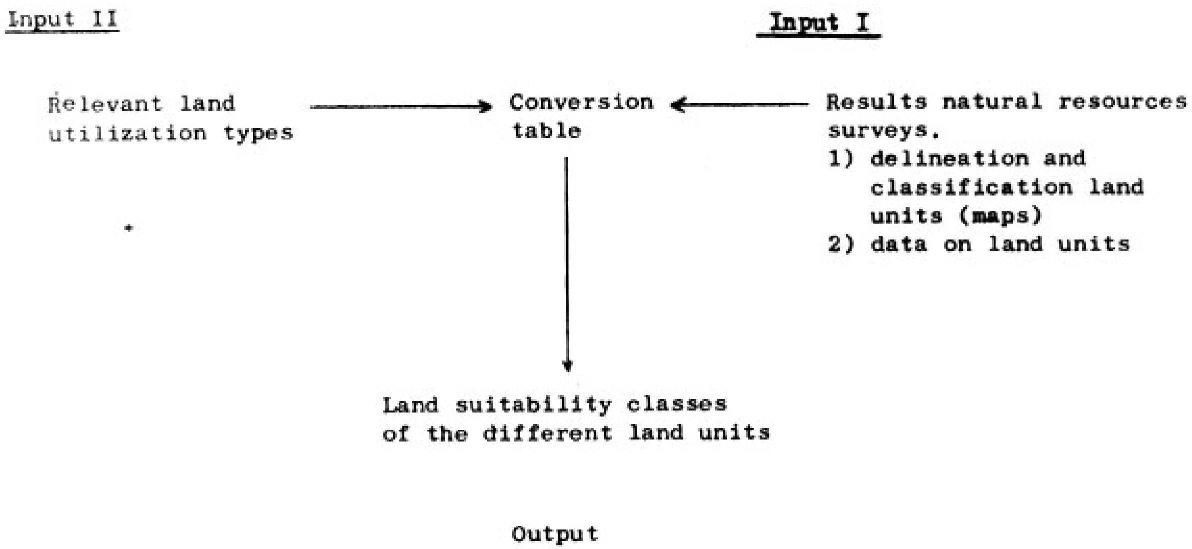
Fig. 4. presents the system in a more elaborated form. This figure indicates how the major requirements of the relevant utilization types and the corresponding land qualities of the different land units determine the land suitability classes. Examples of major requirements and of their corresponding land qualities are: water requirement for plant growth - availability of water for plant growth; mechanization requirements for the defined utilization systems - possibilities of mechanization. Instead of the ecological qualities also the yield potentials can be used.

It will be understood that a land unit is classified as being well suited if its qualities fully meet the requirements of the utilization type in question. The unit will be classified as not suited, if one or more major requirements are not met at all. If requirements are not fully met, an intermediate class will be indicated. The influence of the levels or grades of the land qualities in the determination of the quality class can be shown in conversion tables. The conversion table occupies a central position (see Fig. 3, 4 and 5) construction requires the interdisciplinary contact between the resource surveyors on one hand and agronomists, crop specialists, farm management specialists on the other. Examples of conversion tables are shown as tables 1 and 2.

The item, land suitability classes, in figures 4 and 5, has been expanded to include the item management specifications.

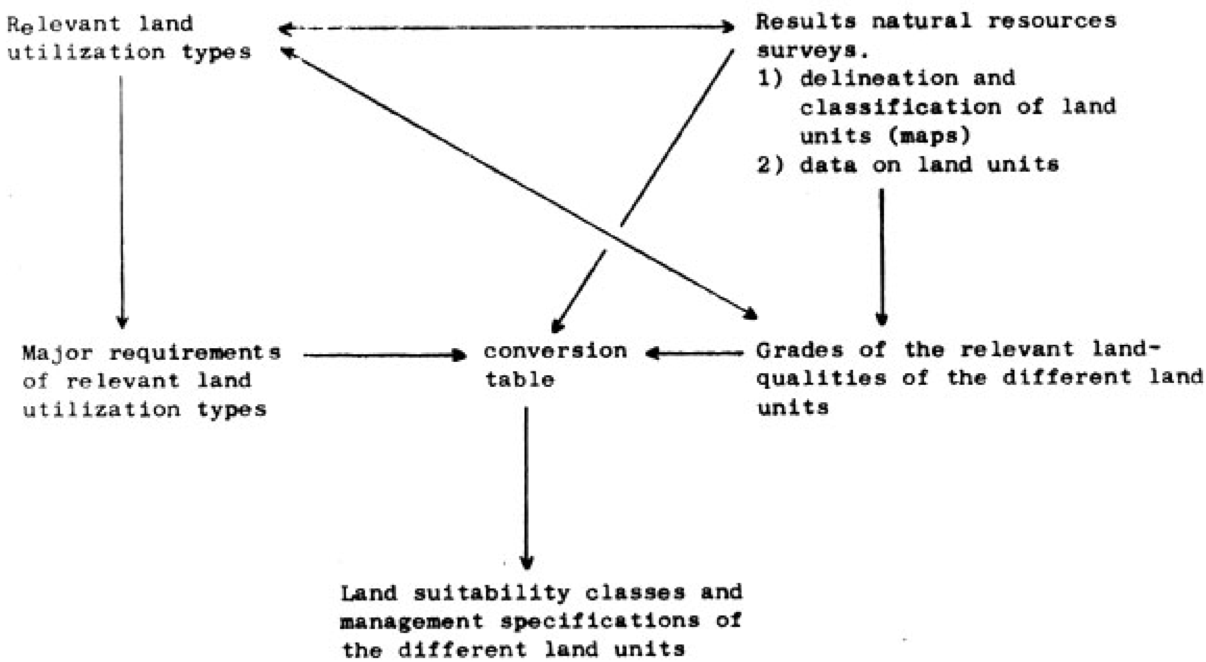
It is assumed in the suitability classification, that the farmers adopt management practices in accordance with the conditions of the land units. This leads to a number of specifications for the management of these land units.

Fig. 3.



Input II
Input I
Relevant land utilization types
Conversion table
Results natural resources surveys.
1) delineation and classification land units (maps)
2) data on land units
Land suitability classes of the different land units
Output

Fig. 4.



Relevant land utilization types
Results natural resources surveys.
1) delineation and classification of land units (maps)
2) data on land units
Major requirements of relevant land utilization types
conversion table
Grades of the relevant land-qualities of the different land units
Land suitability classes and management specifications of the different land units

If major improvements of the land conditions are foreseen, suitability classification should be concerned with the classification of the improvement capacities of the land and with the evaluation of land conditions after improvement (see Fig. 5). In effect this is a classification of potential suitability.

In this study major improvements are considered to be those which require large scale land and water engineering operations such as the installation of irrigation and drainage systems and the terracing of hillsides.

Such improvements which can cause a radical change in the land conditions have a determining influence on the possible types of land utilization, while the envisaged types of land utilization determine the relevancy of the improvements.

The item, land suitability classes, has been expanded with the items, management specifications and improvement specifications. The latter specifications indicate what operations have to be undertaken to make the potential suitability a reality.

Improvement specifications relate to operations which apply once only or which recur sporadically, while the management specifications relate to practices which are cyclic and recur mostly annually.

Land suitability classes

Suitability classes indicate the relative benefit which the utilization type is expected to derive from the land unit, assuming that land improvement and management practices are those pertinent to the land utilization type.

Three levels of detail are proposed: Land suitability class, distinguished by the degree to which the land meets the requirements of the specified land utilization and the required input level; Land suitability subclass, distinguished additionally by the nature of the diagnostic criteria that are not optimal (the limitations) and the nature of the dominant improvements where applicable; and Land suitability unit, used mainly in high or moderate intensity surveys to separate areas with different improvement and management requirements within one subclass.

The references in the following definitions to production levels and to acceptable or unacceptable cost are made under the assumption that the defined land utilization type is relevant: i.e: that the use is economic in at least part of the total area considered.

Class 1 - Good (well suited)

Land suited to the defined land utilization type after improvements where applicable, having no limitations to this use, or only minor limitations that will not seriously reduce production levels or that can be corrected at readily acceptable cost.

Major improvements where necessary are relatively simple, or apply to all land in the area considered.

Management practices required to ensure sustained use without hazard to the land resources are normal and can be implemented at readily acceptable cost.

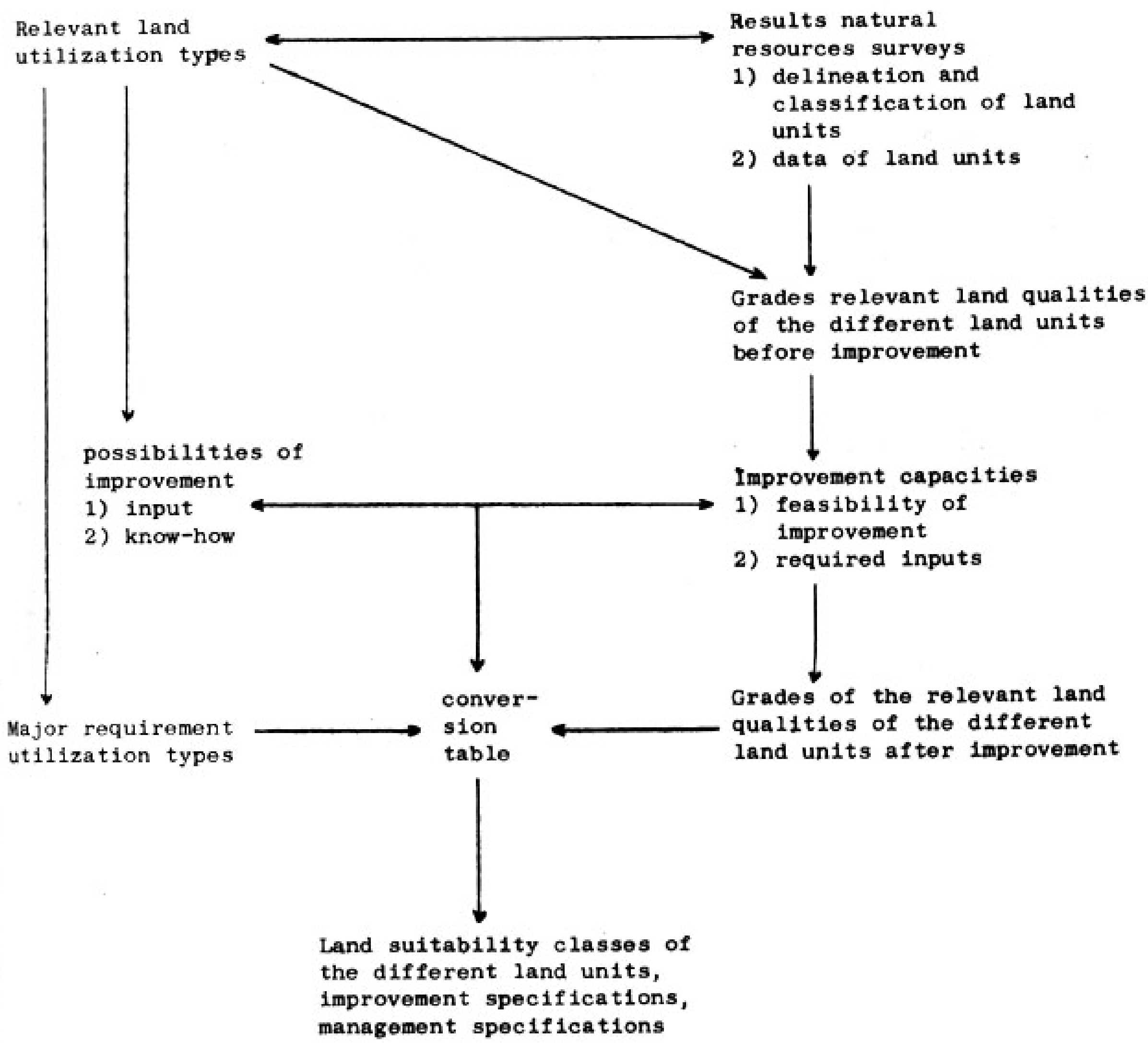
Class 2 - Moderate (moderately suited)

Land suited to the defined use after improvements where applicable, but having one or more moderate limitations that will significantly reduce production levels or that require correction at significant cost.

Major improvements where necessary are more difficult or expensive than in the case of Class 1 land but their cost is acceptable.

Measures required to ensure sustained use without hazard to the land resources may be more difficult or expensive to apply and maintain than in the case of Class 1 land but their cost is acceptable.

Fig. 5.


Relevant land utilization types
Results natural resources surveys
1) delineation and classification of land units
2) data of land units
Grades relevant land qualities of the different land units before improvement
possibilities of improvement
1) input
2) know-how
Improvement capacities
1) feasibility of improvement
2) required inputs
Major requirement utilization types
conver-sion table
Grades of the relevant land qualities of the different land units after improvement
Land suitability classes of the different land units, improvement specifications, management specifications

Class 3 - Restricted (marginally suited)

Land marginally suited to the defined land utilization system, after improvements where applicable, having one or more severe limitations. These seriously reduce average production levels or cause erratic variations in production, or require correction at high cost.

Major improvements where necessary are still feasible but difficult and expensive.

Measures required to ensure sustained use without an unacceptable degree of hazard to the land resources are still feasible but may be difficult and expensive to apply.

Class 4 - Unsuitable (not suited)

Land having limitations which are or appear so severe as to preclude successful application of the defined land utilization system, or which cannot be corrected except at an unacceptable cost.

Major improvements where needed may not be feasible or may be so expensive as to be impractical.

Measures required to prevent an unacceptable degree of degradation of the land resources may not be feasible or their cost may be unacceptable.

Classes are thus defined in terms of increasing limitations and decreasing profitability: a "value judgement" mainly based upon physical and technical consideration.

The most important application of these land suitability classes is in the selection of land which is expected to be relevant for further consideration for the development proposed.

The land suitability subclasses and units play an important part in the subsequent quantitative and economic studies which are limited to the classes expected to be relevant, as well as in the establishment of management and improvement specifications.

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MULTI-PURPOSE LAND EVALUATION IN IRAN[1/]

In developing a method of land evaluation applicable to Iran, the following points were taken into account:

- the background information available and experience gained in land evaluation in Iran;
- the conditions of the land resources and of land use in the country;
- the specific needs of land evaluation according to the present trend of development;
- the recent advances on the subject.

BACKGROUND

Considerable information had been gathered on the different aspects of the land resources of Iran: climate, soil, topography, geologic substratum, present land use, etc. The available data could be classified in two categories:

- General information on the whole country on each of the aspects of the land resources was available in the form of publications with a small scale map (Soil Map of Iran, Land Use Map of Iran, Geological Map, Climatic Atlas, Vegetation Map, etc). The maps are at scales varying from 1:1 000 000 up to 1:5 000 000. They are used for general reference and for general planning, but have not been integrated into a single map of land resources of the country;
- Detailed information was also available on selected areas, namely those where development projects were studied and/or implemented. Maps on soils, present land use, topography, etc., were produced for these areas at scales varying from 1:10 000 up to 1:100 000.

The land evaluation on these development project areas was made essentially on the basis of soil studies and only according to a system of land classification for irrigation based on present land limitations. Further interpretations were then made for each project with their own criteria.

Another type of land evaluation was also made by fertilizer trials on various crops in farmers' fields. These investigations gave, by area or region, an appraisal of fertilizer requirements and the average attainable yields with addition of fertilizers.

LINES OF ACTION

The study of this available information and of its present utilization led to recommending the following lines of action:

1. The different aspects of the land needed to be more closely integrated: climate, soil, topography, vegetation and/or present land use were shown by separate maps. Maps of land resources had to be prepared - grouping all this information together.

1/ Based upon a paper entitled "A method of Land Evaluation in Iran" by M. Vakilian and P.J. Mahler - proceedings Land Evaluation Seminar, 8-13 March 1969 - Publication No.249. Soil Institute of Iran, October 1970.

2. There was a need for maps showing the distribution of the lands of each province for regional planning at scales intermediate between those of the existing maps: 1:250 000 - 1:500 000.

3. Land evaluation also needed to be made for uses other than irrigation: dry farming, range, forests, etc., - both for planning and for specific project studies.

4. Land evaluation was not restricted to an assessment of present limitations, but also appraised the need for land improvement and land conservation work and the potentialities of the lands after improvement.

5. Data on soil, climate, and present use had to be linked with the results of experiments. For this purpose, it was recommended that experiments be conducted under controlled conditions on representative sites of defined types of land, so that the results could be safely extrapolated to other areas with the same type of land.

6. There was a need to evaluate the land of various regions with the same standards. For this purpose, norms of land evaluation had to be prepared for each type of land use.

GENERAL PRINCIPLES OF THE LAND EVALUATION METHODS IN IRAN1/

1. Since the different aspects of the land resources were studied by different government bodies, the methods of "a priori" integrated survey could not be applied. A method of integration "by stages" was necessary, leaving to each study its individuality and permitting a progressive integration of the data, essentially on the basis of a framework of physiography and soils. Preparation of maps of soils and physiography were therefore considered as a prerequisite for elaborating land resource maps. This integration led to defined "land units" described as a combination of conditions of climate, soils, physiography, vegetation or present land use, and drainage over a certain area. These could, in general, be recognized on aerial photographs.

2. The presence of mountains in most of the regions of Iran makes the pattern of land units rather intricate. It is therefore necessary in Iran to show on the map the actual distribution of these individual land units separately. Use of complex mapping units such as "land systems" would lead to grouping, within the same mapping unit, lands of quite different potentialities. This would not provide an adequate inventory of land resources for evaluation. However, in order to avoid the difficulty of defining and mapping all the existing different land units, major types of land units have been defined, such as alluvial plains, gravelly piedmont fans, flood plains, etc. By recognizing and mapping these major land resource types, the main land resources of each region could be shown on the map and individually evaluated. In some complex cases and where repetitive patterns of land units were observed, land systems could be defined. However, the maps show the composing land types within each land system.

3. The land evaluation should be a multi-purpose one. Potentialities have to be studied separately for each major land use: irrigated crops, dry farming, pasture, etc. This land evaluation should permit comparison of the various potentialities for different uses of the same land unit and also the potentialities of different land units for the same use. This comparison requires the definition of "classes" of different potentials. A system of 6 land classes being already used for irrigation in Iran, the classification adopted for the other uses was devised with 6

1/ An extract from the Manual of Multi-purpose land classification of the Soil Institute of Iran - Chapter 2 "Basic objectives, principles, and assumptions" annexed to this paper provides more details.

classes also, having the same general definitions, but based on a wider range of parameters and different criteria according to the land use contemplated.

As a result, the land evaluation had to be presented in the form of a table, giving the land classes of each land unit for each major land use. (See section 8.2.1. of main text.)

4. The trend of development in Iran required an evaluation of the investments needed for improving each potential land use. It was therefore necessary to make the land evaluation under two sets of assumptions: (a) in the first case, evaluate the present potential with improved management practices, but without investments for land improvement or land conservation work; (b) in the second case, one evaluates the "potential after initial input" i.e: with improved management practices and the removal, by capital investment, of some land limitations and degradation hazards by drainage, levelling, salt leaching, etc. For this purpose, 4 levels of initial capital investment were defined (low, moderate, high, very high). (See section 6.2.2. of main text.)

5. The last principle of the method of land resource evaluation in Iran was that the data should be presented in a simple way, easily understood by the non-specialists. It was therefore necessary to avoid, as much as possible, the use of technical or scientific vocabulary not in common use. It was also important that the maps should be easy to read, with a limited number of mapping units. The users cannot take into account all the local differences found in soils, topography, drainage, etc. Land resource maps should therefore summarize, synthetize and simplify the existing maps on each factor: soil, climate, topography, etc.

APPLICATION OF THE METHOD

Different types of land evaluation studies were developed.

1. Land evaluation for planning;

   Maps of land resources and potentialities of large regions at scales 1:250 000 to 1:500 000;

   Maps of land resources and potentialities of limited areas at scale 1:20 000 or 1:50 000.

2. Land evaluation for specific development projects at scales varying from 1:10 000 up to 1:100 000;

   Land evaluation for irrigation projects;

   Land evaluation for forestry development.

3. <u>Local and detailed land evaluations</u>

Besides these activities, rapid land evaluations called "site evaluations" were made on request for land use recommendations on the basis of field observations and laboratory data on soil and water samples.

FURTHER STUDIES

Further studies are being implemented in order to extrapolate results of trials and experiments to wider areas on the basis of soil surveys and land resource surveys, ("transfer" method of evaluation).

Standards for specifications of land classes were also developed,[1] so as to provide a more precise and objective basis for evaluation of land potentialities (parametric method of land evaluation). These standards are being further elaborated as more information and more experience becomes available.

These further studies should make possible the full implementation of a "by stages integration and evaluation method" which proceeds by successive approximations and appears to be the most suitable method for conditions encountered in Iran. (See Fig. 1.)

Storage of data on cards (filing and coding system), may also make possible in the future, more comprehensive processing, using computers.

ANNEX

Extract from the Manual of Multi-Purpose Land Classification of the Soil Institute of Iran

Chapter 2. BASIC OBJECTIVES, PRINCIPLES AND ASSUMPTIONS

Whereas the primary objectives of land classification for irrigation are the comparative assessment and selection of irrigable lands, the multipurpose land classification has a double objective:

- the selection of the most suitable lands for a given use;
- the determination of the most suitable use(s) of a given land.

The fulfilment of these objectives implies, firstly, the assessment of the land potentialities for each type of use considered, and, secondly, the comparison of these potentialities for the selection of the most suitable land use or land capability.

These assessments and comparisons should meet the basic requirements of objectivity, accuracy, consistency and practical usefulness which apply to any land classification.

For this purpose, it is necessary to specify under which conditions and assumptions the land classification is made and also set out the criteria, norms, definitions and standard procedures for it.

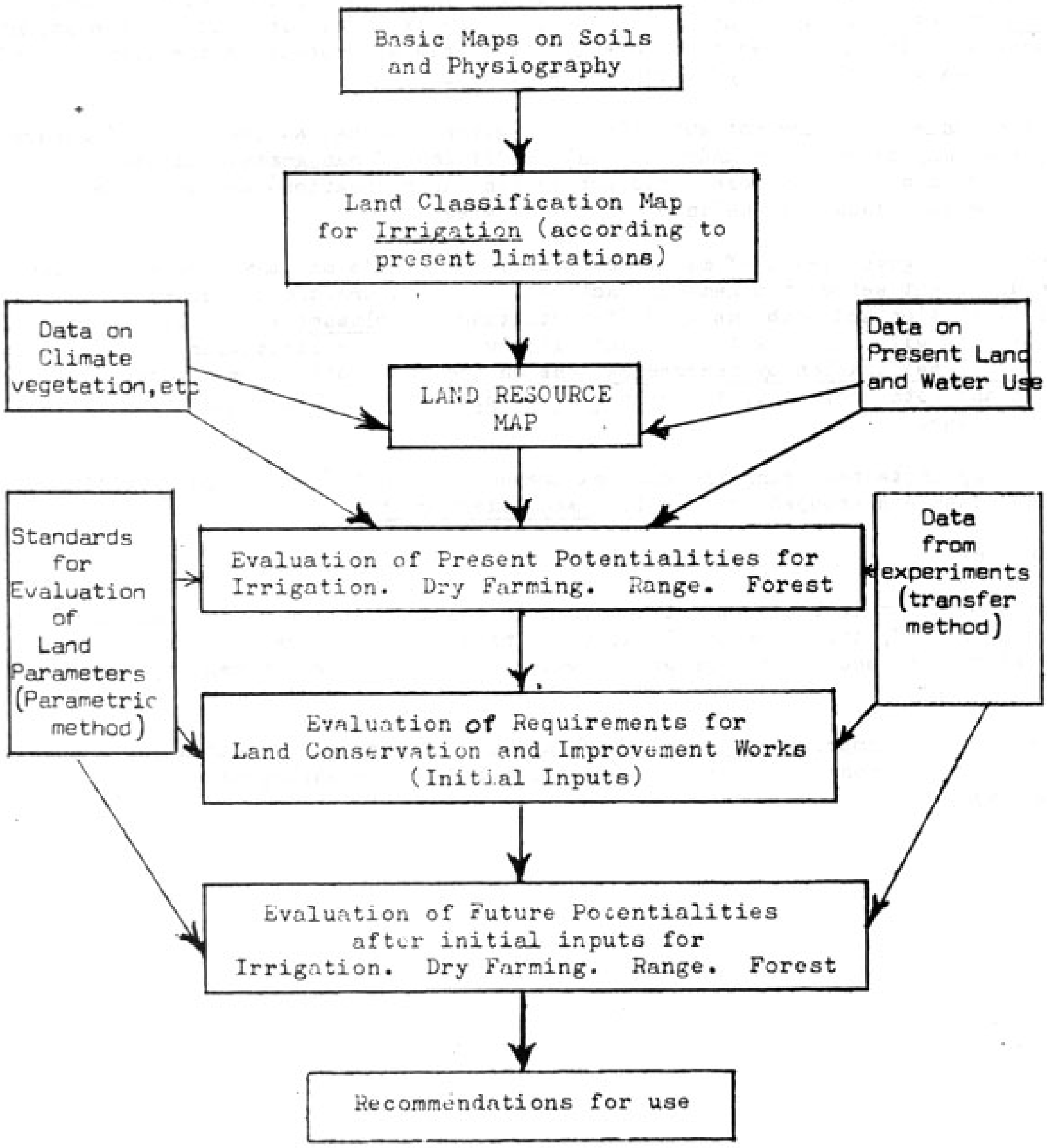
Since a given land unit may be equally suitable or suitable in varying degrees for several land uses, it is not desirable to define mutually exclusive land classes such as lands suitable for forestry only, lands suitable for dry farming only, etc. Consequently, it is necessary to first classify the lands for each land use separately without considering the desirability of other land uses and independently from geographical distribution, extent and location of these lands. This leads to make as many land classifications as there are land uses considered. For example, a land will be placed in class 3 for dry farming, in class 1 for range, in class 5 for forestry, etc. The whole set of land classifications expresses the potentialities of the lands for different uses.

1/ Manual of Land Classification for Irrigation (second approximation, 1970, subject to revision) Soil Institute of Iran, Publication No.205. Jan., 1970.
Manual of Multipurpose Land Classification (first draft. subject to revision) Soil Institute of Iran, Publication No.212. March 1970.

Fig. 1.

"By Stages" Integration and Evaluation

Method Applicable to Iran



Moreover, a land that has a restricted suitability for a given use at present, may become suitable for this use after removal of some limitations by land improvement works. It is therefore necessary to appraise the potentialities under two sets of assumptions:

a) without land improvement: present potentialities

b) after land improvement: potentialities after initial input (specifying the type and degree of land improvement required).

Other inputs may remove or overcome temporarily some limitations: these are the management practices which have to be repeated annually or for each crop rotation. The land potentialities will, in general, increase as more inputs are made in terms of management practices, fertilizers, varieties, etc. It is therefore necessary to specify at which level of management the evaluation of the land potentialities is made. In general, the assumed level of management is the one which is easily attainable at present by the average good farmer in the area with the help of extension services.

Among the lands which are not suitable for a given land use at the level of management considered, some may be suitable under special conditions of management (either more or less intensive) or for a special purpose (land protection and recreation) and bring indirect benefits. A special class 4 is defined for these cases.

Moreover, at a given level of management, different lands may have the same potentiality but require different set of management practices. It is therefore necessary to indicate the type of limitation and problems by differentiating sub-classes within land potentiality classes (sub-class with soil limitation, sub-class with climate limitation, etc.), and also supplement the classification by recommendations on the most suitable management practices, adapted crops and rotation, etc., for each soil mapping unit within a given land potentiality class and sub-class.

Soil mapping units requiring the same management within the same land potentiality class and sub-class are grouped into a "land management unit".

Other assumptions

The classification is based upon the intrinsic characteristics of the land itself. The extent of the land, its shape and location in relation with those of other lands, its distance to market, to sources of irrigation water, to roads, its ownerships, present field pattern, are disregarded.

The costs of land improvement works which are not exclusively required for a specific land unit are also not considered in the classification (for example, main irrigation and drainage canals).

IRRIGATION SUITABILITY CLASSIFICATION [1/]

BASIC STRUCTURES

The land classification system of the Bureau of Reclamation of the U.S. Department of the Interior has been developed to guide formulation and plans for irrigation projects and subsequent use to assist in constructing, developing, and operating such projects. A rigid or fixed methodology is not used. Instead, general principles are applied to fit land classification to the economic, social, physical, and legal patterns existing in the project area.

To permit transfer and exchange of experience, comparability is generally maintained among such features as symbolization, terminology, and mapping procedures for defined levels related to the intensity of the investigation.

The physical, soil, topographic, drainage, climatic, and water quality factors are interrelated. These factors influence the needed crop production inputs and yield outputs, which in turn are controlled by technological levels, economic conditions, social organization, resourcefulness of people, and the goals of the development. Planning of irrigation projects can be accomplished by using the land classification survey as a systematic, integrating process for many of these plan determining elements.

The irrigation suitability classification meets to the extent practicable the traditional classification principles. These are (1) the classification must be based upon a single principle - some one aspect of the facts to be classified must be selected and adhered to for the entire classification, (2) the classification should be exhaustive - it should include everything to be classified, (3) the subdivisions should be mutually exclusive - the facts are arranged in discrete and determinate groups.

The first principle is met by selecting an economic factor that is matched to the development goals. For this purpose, single factors such as gross crop income, net farm income, or payment capacity are generally used. Selection of such factors to define ranges in the basic land classes is thought to permit more efficient planning than using qualitative expressions of expected soil productivity under irrigation.

In selecting irrigable lands, mutual exclusiveness is achieved by specifying nonoverlapping ranges in the value of relevant physical characteristics of the land and relating these to selected ranges and economic output expected under irrigation. In field practice, it is frequently difficult to maintain this exclusiveness because soils and landscape transitions occur everywhere and continuity rather than discreteness characterize this universe. It is inevitable, therefore, that difficulties will arise at the margin of irrigable or nonirrigable land.

In addition to the foregoing, four basic principles are followed in structuring the classification to fit the project's setting. These may be identified as the principles of prediction, economic correlation, arability-irrigability analysis, and permanent-changeable factors.

1/ A contribution prepared by staff of the Bureau of Reclamation of the United States Department of the Interior.

Under the prediction principle, the classes in the system express the soil-water-crop interactions expected to prevail under the new moisture regimen resulting from irrigation. The classification, therefore, identifies and evaluates the changes anticipated to be caused by irrigation and plans are formulated to assure that a successful, permanent agriculture will result.

Examples of changes that may be induced by irrigation are development of shallow water tables causing drainage problems and related salinity, sodic, and aeration conditions which unfavorably influence crop growth; modification of slope and microrelief by land forming; and alteration of soil profile characteristics by deep ploughing, chiseling, or addition of amendments. The irrigation water may cause favorable changes in the salinity of soils through leaching, or an unfavorable increase in salinity through high water tables or insufficient application of irrigation water. Depending upon water quality, the exchangeable sodium level of the soil may equilibrate at levels favoring water movement through the soil or it may increase the level causing the soil to become impermeable. Calcium carbonate and gypsum may be precipitated or dissolved. Texture may be changed by sediment-laden water. Organic matter levels will change and new biological populations will develop in the soil. Flooding of soil, as practiced under rice cultivation, instantly sets into motion a series of physical, microbiological, and chemical processes which influence crop growth. These include retardation of gaseous exchange between soil and air, reduction of the soil, and the electrochemical and chemical changes accompanying the reduction. Carbon dioxide and other gases (nitrogen, methane, hydrogen) are produced in the soil and tend to accumulate, build up pressure, and escape as bubbles. There is a decrease in redox potential, increase in pH, and an increase in specific conductance. Also, the flooding causes dentrification; accumulation of ammonia; reduction of manganese, iron, and sulfates; accumulation of the products of anaerobic organisms; and other secondary effects of reduction.

The future drainage conditions in the proposed project area are recognized prime determinants of the permanency of irrigated agriculture. The dynamic equilibrium level of ground water and the relation of water input to output are major factors influencing the success of irrigated agriculture. The changes which will occur in salinity, exchangeable sodium percentage, and aeration conditions in the root zone are largely controlled by these factors. It is an essential consequence of the prediction principle that the land classification survey must, therefore, deal not only with the soil but the substrata conditions as well.

To meet requirements of the prediction principle, land classification survey organizes and synthesizes facts concerning such parameters as (a) drainage requirements, (b) equilibrium salinity levels, (c) equilibrium exchangeable sodium levels, (d) water requirements, (e) soil productivity following land forming and expected soil profile modification practices, (f) crop production inputs and outputs, (g) anticipated land use and management practices, (h) chemical suitability of the water supply, (i) quality of return flow, (j) flood hazard, and (k) soil erosion.

The economic correlation principle involves relating, within a given project setting, the physical factors of soil, topography, and drainage with an economic value. In the Bureau of Reclamation system, the economic value is defined as payment capacity - the residual available to defray the cost of water after all other costs have been met by the farm operator. Depending upon the purposes to be served by the land classification, other economic values may be chosen to define land class. On the Canadian prairie provinces, net farm income is used as a measure of the producing ability of various classes of land. In planning water development projects, the economic basis for the land classification is usually chosen to contribute toward determining whether irrigation is feasible for increasing net farm income, how irrigation might be planned to achieve the most benefits, and to evaluate the interrelationships of investment feasibility and optimum water use.

With land classes defined as economic entities, a set of relevant and mappable land characteristics is chosen for the time and place to provide a physical definition of the land classes. The set is referred to collectively as the land class specifications. These land class determining factors generally consist of observable morphologic characteristics such as texture, structure, depth, presence of hardpans, sand, gravel, caliche, or other root-limiting influences, consistence, color, mottling, kind and amount of coarse fragments, kind and thickness and sequence of horizons, laboratory measurements including particle size distribution, clay minaralogy, cation exchange capacity, soil reaction, gypsum lime, and organic matter. They also include the topographic features of microrelief and general gradient, and the surface and subsurface drainage conditions. The land class determining range of such physical characteristics will vary with the economic, ecologic, technological, and institutional factors prevailing or expected to prevail in the area. As a consequence, land classes express the local ranking of land for irrigation use, e.g., best suited, moderately suited, poorly suited, and unsuited for irrigation development.

The permanent-changeable factors principle recognizes that changes in land arising from irrigation development impose a need to identify characteristics that will remain without major change and those which will be significantly altered. This identification permits construction of a consistent set of land class determining factors assuring uniform appraisal of land conditions by the various soil scientists engaged in making the land classification survey. Usually, the permanent factors include such characteristics as soil texture, depth of soil to gravel, cobble or bedrock, depth to lime zone, claypans, hardpans, and macrorelief. Typical changeable factors include salinity levels, exchangeable sodium percentage levels, pH, microrelief, water table levels, flood hazard, brush and tree cover, and rock cover. Whether given characteristics will be changed will usually depend upon economic considerations. The land classification survey thus deals with two aspects of this principle. Can the change be physically accomplished, and what degree of change is economically feasible? This will be largely dependent on the economic setting of the project. For example, a large investment may be made to reclaim a saline and sodic soil which after improvement will yield a net farm income of $ 200 per acre. In another climatic and economic setting, where net income after improvement would only be $ 30 per acre, the soil having similar saline-sodic conditions would be regarded as nonirrigable. In the latter case, it would be infeasible to make the change. It is evident that the goal of the development will determine how far it would be feasible to carry out such remedial measures. If attainment on a self-sustaining dietary balance and economic growth is the goal, then a substantial investment can be made in improving unfavorable land factors. This would be particularly true under those conditions where the land resources available for development are limited and, therefore, maximum utilization is deemed essential. If the goal is maximum economic efficiency, then the amount of change that could be made would be controlled by the relationship of benefits and costs for including such increments in a project plan. Investment decisions are thus involved in most cases, and these should be guided by the correlation established between the physical and economic factors in the land classification system.

The arability-irrigability principle states that the selection of lands for irrigation proceeds through an initial step in which land areas of sufficient productivity to warrant consideration for irrigation are identified and that there is superimposed upon this determination the selection of the lands to be specifically included in the plan of development. The former may be termed "arable" lands, and the latter "irrigable" lands. The selection of arable lands is guided by an economic value such as gross crop income, payment capacity, or net farm income, as chosen to define the land classes. On the other hand, the irrigable lands are chosen through the plan formulation process. Here, water is allocated to irrigation, hydroelectric power, municipal and industrial water supply, and other project purposes. The irrigable area is thus selected in relation to the water allocated to irrigation and to the size and location of the distribution and drainage system. Fundamentally then, the selection of lands for irrigation is a 2-step process: (1) selection of an arable area as guided by farm production economics, and (2) selection of an irrigable area is guided by the economics of plan formulation. The steps are interrelated and often complex, requiring close interdisciplinary cooperation.

The application of plan formulation criteria to the classification generally leads to successive elimination of identifiable increments of arable lands from the plan of development. Typical adjustments include (1) elimination of noneconomic increments such as those that are too costly to serve, drain, or provide distribution works, (2) conformance of land area to the available water supply, (3) elimination of tracts located above water service delivery elevations, (4) exclusion of isolated segments, odd-shaped tracts, and severed areas that cannot be efficiently fitted into the farm unit pattern, (5) deletion of proposed public rights-of-way, and (6) elimination of areas unable to meet minimal criteria for economic returns under the plan. Of these factors, it is evident that Items (1) and (6) will again be goal-dependent.

APPLICATION OF METHODOLOGY

The system of selecting lands for irrigation is guided by a series of somewhat interrelated stages. These may be identified as the presurvey, survey, and postsurvey stages.

Before the land classification is started the matter of handling land development costs is determined. Methodology between countries may vary according to whether the Government expects the landowner to pay for all development costs or if the Government does all of the on-farm development with no direct cost to the landowner. The land classification would be varied to show a reduced payment capacity and lower land class where land development costs are borne by the farmer. When development costs are handled as a Government expense, they do not influence the land class.

The presurvey stage involves study of the land resources, associated productivity, and drainage capability experiences in a fully developed irrigated area having physical and climatic conditions similar to the area of investigation. Field experiments may also be used to provide the initial data for developing classification specifications. In some instances, demonstration and experimental farms are established to provide answers to questions pertaining to management systems, fertility, liming, irrigation practices, and other factors.

During the presurvey stage, the project soils are studied and available soil survey data evaluated for applicability to the selection process. Soil survey work is examined in the field to appraise reliability for irrigation suitability evaluations. Additional field work requirements, if any, are established.

During the presurvey stage, available data on crop production, land development requirements, methods of irrigation, level of skill to be applied by the farmer, and related economic considerations are evaluated. These provide a basis for study of the agricultural economy under future conditions with the irrigation scheme in operation. Such data provide a basis for developing the definition of land classes and the physical nature of the soil, topography, and drainage conditions which will constitute each land class.

Data on the water quality are also studied and their potential effect on the soils appraised. Only the soils which will respond favorably to the type of water available for irrigation are selected for development.

A significant undertaking during the presurvey stage involves the analysis of the probable influence of specific physical, chemical, land, and water factors in the economics of production and the cost of land development. Preliminary farm budget studies are usually done at this time to define the selected range in economic values, such as net farm income, which will be used to define each land class.

The characteristics and qualities of lands that determine suitability for irrigation use varies with each project. The land class determining factors represent selected and correlated ranges for such characteristics as texture, depth to bedrock, hardpan, sand, gravel, caliche or other root-limiting influences; structure, consistence, color and mottling, kinds and amounts of coarse fragments, and kind, thickness, and sequence of horizon. In addition, the prediction aspect of selecting irrigable lands require many laboratory measurements. Performance qualities are also either measured or inferred. These would include factors such as fertility, productivity, erodibility, and drainability, as well as such measurable factors as infiltration rate, hydraulic conductivity, moisture characteristics, and moisture-holding capacity.

Topographic characteristics considered consist of the degree of slope, relief, and position. These factors are evaluated as they influence land development needs and costs, method of irrigation, design of on-farm water conveyance systems, erosion hazards, crop adaptability, drainage requirements, water use practices, and selection of management systems. In classifying lands for irrigation, it is necessary to make decisions regarding the extent to which slope and relief will be modified by landforming, and to make estimates regarding the amount, type and cost of land development.

Surface and subsurface drainage requirements are considered in the selection process. This is usually done by a coordinated effort between land classification and drainage specialists. The objective of drainage requirement studies is to assure that the areas included in the plan of development will have favorable surface and subsurface drainage conditions, or such remedial measures as may be needed can be economically provided to support a sustained irrigated agriculture.

In the survey stage, appropriate land classification specifications are applied in the performance of the arable classification. This involves field traverse; soil and substrata observation and sampling; laboratory analysis of soil samples; delineation of the land classes, subclasses, informative appraisals, and the related procedures necessary to accomplish the field survey work. Performance of the field work is guided by the type of investigation being performed. These may be of reconnaissance, semidetailed, or detailed grade. If the reconnaissance studies show promise of achieving the development goals, then more detailed studies are subsequently performed.

The requirement for investigative detail is set not only by the type of investigation being formed but also by the complexity of the landscape being investigated. In accomplishing the field survey, the Bureau of Reclamation generally uses not more than six land classes defined on the basis of their range in payment capacity. In short growing season areas, fewer land classes are sufficient. Class 1 lands have the highest level of irrigation suitability.

Class 2 lands have intermediate suitability. Class 3 lands have the lowest suitability for general farming. Class 4 designates special use classes such as 4F, fruit, or may be used to designate land with excessive deficiencies which special engineering or economic studies have shown to be irrigable. Class 5 is used as a temporary designation for lands requiring special studies before a final land class designation can be made, and Class 6 is land not suitable for irrigation development.

Subclasses are used to indicate the reasons land is placed in classes lower than Class 1. This is shown by appending the letter <u>s</u> for soil deficiency, <u>t</u> for topographic deficiency, and <u>d</u> for drainage deficiency to the land class designation. Subclasses of the land classes 2, 3, 4, and 6 are <u>s</u>, <u>t</u>, <u>d</u>, <u>st</u>, <u>sd</u>, <u>td</u>, and <u>std</u>. The mapping unit symbol also provides for showing the present land use, productivity level, development cost, water requirement, drainage requirement, and as needed, special appraisals to indicate specific deficiencies.

For drainage evaluation purposes, the field work involves numerous observations and measurements of conditions of the substrata as well as the true solum and surficial parent materials. Some observations to depths of at least 10 feet are used in all investigations, and to greater depth as needed depending upon the particular type of landform encountered.

In the post survey stage, the arable land classification may be modified as additional pertinent physical engineering, hydrologic and economic information is obtained. Arable classification adjustments are needed if the final project plan and costs for water and drainage are significantly different than original estimates. During the postsurvey stage, application is made of tests for the engineering feasibility and project formulation criteria of benefits and costs, repayment, and the operation, maintenance and replacement costs as needed to select the plan and related irrigable land under the development goals.

Rerults of the land classification are applied to (1) selection of irrigable lands, (2) determination of water requirements, (3) selection of land use and size of farm, (4) selection of the land development methods, (5) determination of payment capacity, (6) determination of irrigation benefits, and (7) development of layouts for irrigation and drainage system.

LAND PRODUCTIVITY EVALUATION IN BULGARIA 1/

Introduction

Agriculture in Bulgaria is rapidly developing in the recent 25 years. The yields from the main crops are the best testimony for that. Twenty five years ago the average yield of wheat was approximately 1.0 - 1.2 tons per hectare, now it is 3.5 - 4.0 tons per hectare, for corn it was 1.5 - 2.0 tons per ha, now it is 5.0 - 6.0 tons per hectare. The capital investments in agriculture now are several times higher than those in 1948. The quantity of the introduced fertilizers has reached about 180 kg of nutrient elements per ha. The areas under irrigation have increased from 30,000 ha to 1,200,000 ha, that is to say 25 percent of the arable land is under irrigation. The average size of one farm in Bulgaria until 1948 was 0.6 ha. After the creation of co-operative farms and establishment of Agro-Industrial Complexes the average size ranges from 30,000 ha to 50,000. It is quite obvious that under this dynamic development of agriculture new problems will arise in the field of agricultural science. One of these problems is land productivity. It comprises some natural problems, as well as economic ones.

Previous Attempts at Soil Grouping and Land Productivity Evaluation

The soils surveys in Bulgaria have been carried out on the scale 1:25 000. Recommendations for rational use of the individual land units were made as integral part of the soil reports. These recommendations can be considered as interpretations of soil maps. Soil Taxonomic units were grouped according to the criteria shown in table 1. It is clear that these criteria comprise mainly some indices reflecting the ecological conditions (soil indices : stoniness; depth of parent material, if hard; salinity; and geographical indices: slope, water table, altitude, length of plot). The altitude reflects the temperature characteristics of the climate.

Later on principles for land classification were worked out on the basis or more detailed soil and climatic factors. It is in conformity with the different requirements of the crops grown in Bulgaria. The criteria of this more detailed classification are shown in table 2. Additional soil indices have been taken into consideration, such as pH , texture coefficient-Q (the ratio between clay in B horizon and clay in A horizon), texture of top soil and sub-soil.

1/ Prepared by: the Bulgarian working group: Prof. I. Garbouchev, Dr. H. Trashliev, Dr. S. Krastanov, in collaboration with: Prof. M. Elgabaly (UAR), Dr. M.L. Dewan (India), and Dr. T. Okuno (Japan) of FAO.

Table 1

Criterion for grouping of soils (orders)

	Arable lands	Pastures	Forests	Unsuitable for agriculture
Slope in 0^{o}(%)	15^{o} 27%	25^{o} 46%	-	-
Underground waters /depth in m/	50	30	-	up to 30
Depth of hard rock (cm)	50	15	15	on the surface
Stoniness	weak	-	-	strong
Erosion	slight or medium	-	-	-
Salinity:				
a) water soluble salts %	less than 1	under 1	under 0,8	above 1
b) exchangeable Na meq/100g	under 20	under 20	under 15	above 20
Length of plot in meters	>50	-	-	-
Altitude above sea level (M)	below 1 300	-	above 1 800	-

Table 2

Criterion for detailed grouping of soils (suborders)

Indexes	Crops on dry land	Orchards on dry land	Vegetables on dry land	Vineyards on dry land	Tobacco on dry land	Pastures on dry land	Meadows on dry land	Forests	Unsuitable for Agriculture
1	2	3	4	5	6	7	8	9	10
Climatic									
for the growing period V–VIII	> 150 (pption/year)	> 200	–	> 100	> 120	> 150	> 200	> 200	–
$\sum t^{o}$ for the period with $t^{o} > 8^{o}$	> 2 100	> 2 500	> 2 500	> 3 000	> 3 000	–	–	–	–
Soil:									
Texture – phys. clay %*	> 20	20–75	10–75	10–60	10–60	–	> 20	–	up to 10
Depth of soil: to hard rock	> 50	> 100	> 50	> 100	> 30	> 15	100	15	up to 5
on soft rock	no import.	–	–	–	–	–	–	–	–
pH	> 4	4–7,5	> 5	> 5	5–7,5	–	> 4	–	–
Texture coefficient	< 3	< 2	< 2	< 2	–				
Underground waters in cm	< 50	< 150	< 50	< 300	< 50	< 30	< 30	< 50	up to 30
Steepness of slope	< 15° 27%	up to 25° 46%	< 3° 5%	up to 25° 46%	< 15° 27%	–	up to 7° 12 %	–	> 40–50° 100%
Erosion	< medium	< medium	< medium	–	–	–	up to medium	–	–
Salinity:									
a) water soluble salts	< 1%	< 0,8%	< 0,8%	< 0,8%	< 0,8%	< 1%	< 1%	< 0.8%	< 1%
b) exchangeable Na mg/equ	< 20	< 15	< 15	< 15	< 15	< 20	< 20	< 15	> 20
Stoniness:	to weak	to weak	–	–	–	–	no	–	very strong
Altitude above sea level	< 1 000	< 800	< 600	< 600	< 1 000	–	< 1 800	< 1 800	–

* Physical clay particles less than 0,01 mm.

The main principles in creating the methods of land classification was to take into consideration the unfavourable values of different indices which show that certain production is impossible. In this way a land can be divided into two categories: suitable and non suitable. The suitable lands were divided into classes according to the conditions for this respective crop. This division was made on the basis of evaluation of the ecological conditions for the main crops grown in Bulgaria. In extensive farming it is relied exclusively upon the natural soil fertility and is evaluated chiefly by the storage of nutrients. With the intensive farming considerable amounts of fertilizers are used. Under these conditions the most important soil and climatic indices are those which favour the efficient fertilizer utilization. The Bulgarian method for land evaluation was created on the basis of this principle. The integrated indices, comprising a number of single soil properties, have great importance in the conditions of intensive farming. These indices are: thickness of humus horizon; thickness of soil (for soils developed on hard rocks): texture coefficient; pH; humus content; water table; texture of top or sub-soil (depending on the crop). Evaluation of those factors was very subjective. It was based on experience and scientific knowledge with regard to their importance in crop formation. The soil value was calculated from the values of each single factor. If one of the above mentioned factors was zero, the total soil evaluation should be equal to zero (table 3). This points out the equivalence and unchangeability of the fertility factors.

The climatic conditions for the basic crops were evaluated individually, and a map with coefficients for the whole country was compiled. The final evaluation of the ecological conditions (land evaluation) was calculated by multiplying the soil marks by the climatic coefficients. The principle of estimation of the climatic indices taken into consideration for the different crops is shown in table 4. The soil and climatic conditions were considered as equivalent fertility factors. The climatic coefficients range from 0 to 1. Certain soil can develop completely its productive possibilities for individual crop if the climatic coefficient is 1, while the same soil at a zero coefficient has no productivity because of the climatic limitations. The criterion for the reliability of land evaluation of the obtained yield from the respective crop.

Another peculiarity of the land evaluation method in Bulgaria was the establishment of correction coefficients for the management practices and more dynamic processes, which change the productivity. Such coefficients were established for irrigation, salinity and erosion (table 5, 6 and 7). Steepness of slope and length of field were considered as economic indices and their correction coefficients were established according to the influence upon the production cost. This country was divided into 165 regions with similar ecological and economic conditions. The above method was applied to the land evaluation of each region. The obtained results are used for planning of agriculture, financing of the farms and redistribution of the differential rent. This evaluation was the first approximation in this respect. The problem should not be considered complete. It was only a beginning that should be continued with the aid of some new statistical methods.

Mathematico-Statistical Approach to Land Productivity Evaluation

In the last 3-4 years there have been applied the following mathematico-statistical methods: analysis of the main components and regression factorial analysis. Due to the fact that the relationship between yield and the tested factors was not very well expressed at $Y = a_o, X_1 + b$ we tried to establish the relationship according to the equation:

$$Y = Y_2(Z_1 Z_2 \ldots . Z_n, X_1 X_2 \ldots \ldots X_n) = Y_2(ZX),$$

where Y = yield, Z = climatic and X = soil factors.

Table 3

Evaluation of soil indexes for corn

Soil indexes		Values	Notes
Texture			
Gravelly	0% clay	0	When the water table is from 100 to 300 cm, all soils except the gravelly and sandy soils acquire an index value of 100.
Sandy	0 -20% clay	0	
Light sandy clay	20 -30% clay	50	
Medium sandy clay	30 -45% clay	70	
Heavy sandy clay	45 -60% clay	100	
Light clay	60 -70% clay	70	
Clay	above 75% clay	50	
Depth of humus horizon in cm	under 20	20	
	20 -30	80	
	30 -50	90	
	50 -80	100	
	above 80	100	
Depth of soil in cm	under 30	0	Only for soils on hard rock. The index values are trebled.
	30 -50	5	
Texture coefficient	under 1	70	When the water table is from 100 to 200 cm, the index value is 100.
	1 - 1,3	100	
	1,3 - 2	90	
	above 2	20	
pH	above 7,5	80	
	6,5-7,5	100	
	5 -6,5	90	
	under 5	40	
Humus contents in %	under 1	40	
	1-2	70	
	2-3	95	
	3-4	100	
	above 4	100	
Water table in cm	0-50	0	Only for soils with a water table from 0 to 300 cm.
	50-100	80	
	100-300	100	

Table 4

Average values of agroclimatic conditions and coefficients for the different crops

Crops	Indices	Average value	Coef-ficient	Average value	Coef-ficient	Average value	Coef-ficient	Average value	Coef-ficient	Average value	Coef-ficient	Average value	Coef-ficient	Average value	Coef-ficient
		I		II		III		IV		V		VI		VII	
Cotton	t° for the growing period *	up to 3 400	0,2	3 400--3 600	0,5	3 600--3 800	0,7	3 800--3 900	0,8	3 900--4 000	0,9	above 4 000	1,0	regions above 500 - 600 m	0
Wheat	Balance of moisture for the period IV + VI	-150m	0,8	-150 up to -100	0,9	-100 up to 0,0 mm	1,0	0 mm	0,8						

*) Cumulative total of daily t°

Table 5

Correction coefficients for erosion and accumulation

Soils / Rate of erosion or accumulation	Calcareous and typical chernozems, chernozem-smolnitsas	Leached and podzolized chernozems and dark grey, chernozem-smolnitsas	Grey and cinnamonic forest soils	Light-grey cinnamonic, podzolized and brown forest soils
1	2	3	4	5
I. For wheat, maize, sunflower vegetables, sugar beet, lucerne.				
Slightly eroded	0,85	0,88	0,75	0,50
Moderately eroded	0,65	0,70	0,60	0,30
Strongly eroded	0,32	0,40	0,25	0,15
Slightly accumulated (up to 20 cm)	1,10	1,05	1,05	1,00
Moderately accumulated (up to 50 cm)	1,30	1,10	1,10	1,05
Strongly accumulated (above 50 cm)	1,50	1,30	1,30	1,10
II. For cotton				
Slightly eroded	0,95	0,95	0,95	0,95
Moderately eroded	0,70	0,75	0,70	0,30
Strongly eroded	0,40	0,40	0,40	0,10
Slightly accumulated	1,05	1,05	1,05	1,00
Moderately accumulated	1,10	1,10	1,10	1,00
Strongly accumulated	1,10	1,10	1,10	1,00
III. For orchards				
Slightly eroded	1	1	1	1
Moderately eroded	1	1	1	1
Strongly eroded	0,80	0,80	0,80	0,80
Slightly accumulated	1	1	1	1
Moderately accumulated	0,90	0,90	0,90	0,90
Strongly eroded	0,90	0,90	0,90	0,90

Table 6

Correction coefficients for irrigation

Soils	Crops						
	wheat	maize, sunflower sugar beet	cotton	orchards	tobacco	vine-yards	lucerne
1. Chernozems	1,2	1,6					
(calcareous, typical)	1,2	1,6	1,3	1,4	1,3	1,2	2,1
2. Chernozems (leached and podzolized) and dark-grey forest soils	1,1	1,4	1,2	1,9	1,2	1,1	2,0
3. Grey forest	1,1	1,3	1,0	1,8	1,1	1,1	1,8
4. Light-grey forest soils	1,0	1,1	1,0	1,0	1,0	1,0	1,2
5. Chernozem-smolnitsas	1,2	1,6	1,6	1,4	1,1	1,1	2,0
6. Cinnamonic forest (leached and typical)	1,2	1,6	1,6	1,9	2,0	1,2	2,0
7. Cinnamonic forest (podzolized)	1,1	1,5	1,4	1,5	1,8	1,1	1,4
8. Brown forest	1,0	1,0	1,0	1,0	1,0	1,0	1,0
9. Meadow (chernozemlike, alluvial-meadow, meadow-cinnamonic, meadow chernozem-smolnitsas)	1,2	1,6	1,2	2,0	1,3	0,9	1,8
10. Rendzina	1,2	1,5	1,5	1,0	1,3	1,2	1,5
11. Delluvial	1,1	1,4	1,4	2,0	2,0	1,0	1,0

Correction for cotton irrigation is done only in the cases when the climatic coefficient for a definite region is higher than 0,5.

Correction for tobacco irrigation is done only in the cases when the climatic coefficient for a definite region is higher than 10,7.

Soil values are corrected by climatic coefficients and the numbers obtained are corrected for irrigation for all crops except for cotton and tobacco.

Table 7

Correction coefficients for salinity of soils

Crops	Degree of salinity				
	weak: a) water-soluble salts 0,3 – 0,5 % b) exch. Na 5-10mg/equ.	weak: a) water-soluble salts 0,8 – 1 % b) exch. Na 10-15 mg/equ.	weak: a) water-soluble salts 0,8 – 1 % b) exch. Na 15-20 mg/equ.	Solonchack water-soluble salts above 1 %	Solonetz exch. Na 20mg/equ.
Wheat	0,90	0,80	0,70	0,10	0,10
Maize	'.90	0,80	0,70	0,10	0,10
Sunflower	0,90	0,80	0,70	0,10	0,10
Cotton	1,0	0,90	0,80	0,20	0,20
Tobacco	0,80	0,70	0,50	0,10	0,10
Lucerne and Sugar beet	1,0	0,95	0,95	0,50	0,20
Orchards and Vegetables	0,85	0,70	0,50	0	0

Table 8

Correction coefficients for steepness of slope and length of plot

(Percent of decrease of the basic evaluation)

Crops	Steepness of slope in degrees					Length of plot			
	up to 3	3–6	6–9	9–12	above 12	above 600	350–600	200–350	up to 200
1. Wheat (barley)	–	2	10	13	16	–	3	9	12
2. Maize	–	3	12	15	18	–	3	10	13
3. Sunflower	–	3	12	15	–	–	4	10	13
4. Sugar beet	–	3	10	13	–	–	3	8	11
5. Tobacco	–	1	3	6	10	–	1	2	4
6. Cotton	–	3	10	13	–	–	3	8	11
7. Tomatoes and peppers	–	–	–	–	–	–	1	2	4
8. Potatoes	–	3	12	15	18	–	3	8	11
9. Lucerne	–	2	8	15	18	–	2	6	8
10. Vineyards	–	2	9	13	16	–	2	6	8
11. Orchards	–	2	9	13	16	–	2	6	8
12. Natural meadows	–	2	12	18	22	–	2	6	8

Table 9

Mean, standard deviation and coefficient of variation

	Variables	Mean	S.D.	C.V.
$y=x_1$	yield (wheat)	353 kg/dka	93,1	6,4 %
x_2	Tex/P top soil	5 ,3%	10,0	19,6
x_3	Tex/P subsoil	547%	10,3	18,9
x_4	Tex. coef.	1,08	0,30	29,8
x_5	Humus top	2,3%	0,69	28,8
x_6	Humus sub	2,00%	0,83	41,3
x_7	T.N. top	0,133%	0,038	28,8
x_8	T.N. subsoil	0,109%	0,039	35,6
x_9	pH top	5,89	0,83	14,0
x_{10}	pH subsoil	5,84	0,90	15,4
x_{11}	Hy. Mois. top	5,03	1,98	35,3
x_{12}	Hy. subsoil	5,62	1,81	32,2
x_{13}	$CaCO_3$ top	0,43	1,37	311,8
x_{14}	$CaCO_3$ subsoil	0,55	1,14	318,1
x_{15}	Depth Humus	$55,6^{cm}$	15,3	27,6
x_{16}	Precipitation Sept. - Oct.	$55,6^{mm}$	15,6	28,1
x_{17}	Sum. Temp. 5°C	79,3°	18,0	22,7
x_{18}	Supply moisture	$182,6^{mm}$	23,6	12,9
x_{19}	Precip. - May	106,2	34,5	32,4
x_{20}	Temp. - - May	19,2	1,14	5,9
x_{21}	Balance W.S.	9,22	68,5	949,0

$$Y = 1366 - 38,0x_{13} - 3,05(x_{14} - 0,63)^2 - 198.7(x_4 - 1,16)^2 -$$
$$- 14,87(x_6 - 1,76)^2 - 48,8\ x_{20}$$

From the above equation we estimated for x_4 an optimum value 1.16 and for x_6 - 1,76. The latter is improbable. It is well known that the observed optimum for x_6 was due to hail. From the equation it is apparent that there is negative correlation between yield and mean May temperature.

On the basis of the above equation and some agronomic consideration we suggest that the following indices should be included in the recommended model:

1. $CaCO_3$% in top soil
2. Humus % in sub-soil
3. $(\text{Tex Coef.} -1.2)^2$
4. $(\text{temp. in May} - 18,0)^2$
5. Temp. May
6. Texture of top soil
7. Balance of water supply
8. $(\text{Balance W.S.})^2$

At present research work is carried out in 43 experimental stations and 140 fields in co-operative farms are under examination for the purpose of land evaluation. Later, the data collected will be processed. It is forseen that the research studies will continue up till 1975.

We think the application of the parametric approach to the land productivity evaluation, using the mathematico-statistic method will enable the establishment of objective methods for yield prediction. On the basis of such comprehending experiments are carried out for parametrizing the elements of the eco-systems. Data for 20 climatic, over 40 soil and more than 10 geographical indices are collected from different locations in this country. The yield and soil management data are collected from the same location. The individual factors of fertility will be studied in model experiments apart from the above field experiments. After processing of the data it should be possible to find out a detailed method of yield prediction. In our opinion the final purpose of land productivity evaluation should be the elaboration of methods for reliable control and management of fertility. The modern computer technique and communications favour the fulfilment of this task. The socialist organization of agriculture in Bulgaria enables the successful performance of such problems.

Conclusion

1. Land productivity should be studied mainly by parametric method, using stable soil factors. The climatic factors should be studied separately. Their influence on yield formation can be expressed by coefficients. The influence of other changeable factors like irrigation, salinity, erosion, soil management, fertilizer application, etc. can also be expressed by coefficients. This is the only way to simplify the mathematical equation (reducing the number of indices to the admissible minimum).

2. The number of indices can be decreased by using integrated ones, which express quantitative influence of several factors or the dynamics of certain factor along the depth of the profile. The indices can bereduced by some simple processings as well.

3. On the basis of the knowledge about ecological factors and their functions in yield formation for a definite crop it is possible to establish mathematical models and examine them by simulation of the variations in different ecosystems.

4. It is absolutely necessary to establish a bank for collection of reliable soil and climatic data, data for management, fertilizer application, irrigation, etc. and the yields from the respective crop. The number of indices to be collected should be determined after profound investigations.

5. The experiments carried out under controlled conditions can be of extraordinary importance for land productivity evaluation and yield prediction.

LAND EVALUATION STUDIES IN IRELAND 1/

INTRODUCTION

A widespread land-evaluation programme was carried out in Ireland back in the early part of the 19th century under the direction of Sir Richard John Griffith. This evaluation which was based on the capacity of the land to produce certain crops was used mainly for taxation purposes, and has not been superseded up to the present time. Because of changed technology, however, certain anomalies in this evaluation are now apparent (1). Subsequent to Griffiths evaluation an attempt was made to prepare "agrologic maps" (2) which were based on a comparison of the soil as determined by chemical analysis with Griffiths evaluation. These agrologic maps were subsequently lost.

SOIL SURVEY

Systematic soil survey work based on modern principles commenced in Ireland in 1959 when the Agricultural Institute was established. It was decided to prepare soil maps for each of the twenty-six counties. For this purpose field mapping was carried out at a scale of 6 inches to 1 mile (1:10,560) but these maps were reduced to ½ inch to 1 mile (1:126,720) for publication purposes.

QUALITATIVE LAND EVALUATION

In addition to the systematic soil survey itself the suitability of the soils for agricultural, horticultural, forestry and amenity uses is determined. Based on their suitability for production the soils are grouped into suitability classes and a suitability map produced to accompany each soil map.

The suitability classes range from those with soils suitable for a wide range of farm enterprises and which have few limitations other than possibly their low pH and nutrient status to those with very severe limitations and which have an extremely limited potential in agriculture. Such soils may be more suitable for recreational or amenity purposes.

Six suitability classes ranging from A to F are usually established.

Class A

The soils placed in Class A are well adapted to modern techniques. Their main limiting factors of low pH and nutrient status are easily overcome by liming and fertilization. They can withstand the impact of heavy machinery, cultivate easily, allow early growth in spring and are capable of carrying large stocks of grazing animals over a prolonged period of the year without suffering physical damage.

1/ by M.J. Gardiner, Head, National Soil Survey of Ireland.

Class B

Class B soils have a more limited potential use-range than those in Class A and are generally only of moderate suitability for cultivated crops, pasture and forestry. Limitations include coarse texture, somewhat weak structure or the necessity for constant attention to drainage maintainance.

Class C

The soils included in Class C have a more limited potential use-range than those in Classes A or B and they are generally only of moderate suitability for cultivated cropping. Compared to Class A soils the effort required to develop a suitable tilth by cultural operations is greater and they are slow to warm up in spring due to their high moisture status. Growth is slow early in the season and harvesting by modern mechanical means is often difficult due to soft ground conditions. Economically, therefore, arable crop production is at a disadvantage compared to production from Class A soils.

They are well suited to pasture production and output can be very high. However, to attain this, they require constant attention with particular reference to grazing management. Allowance must be made for resting the pastures during wetter periods to avoid pouching by grazing stock. For this reason the high mid-season production must be exploited to the full by conserving surplus summer growth as silage or hay for winter feed.

Class D

Class D soils have a limited potential use-range due mainly to poor natural drainage conditions and in some also to weak structure and heavy texture resulting in slow permeability. They are poorly suited to cropping and provide poor growth conditions in spring.

They are more suited to pasture production but the restrictions to output and utilization and the procedures required to attain maximum returns, are similar or even more pronounced than those necessary on Class C soils.

Class E

Class E soils have a very limited potential use range. Main limitations are shallow depth and rock outcrop. Steep slopes prevail in some and pan formations in the profile can be a serious problem, restricting water movement and root penetration.

Class F

The potential use-range of these soils is extremely limited. They may be very poorly drained, very shallow or have very frequent steep slopes. Only limited improvement for extensive grazing or for forestry may be possible and for these reasons, therefore, they are often more suited to wild life or amenity development.

RESOURCES INVENTORY

After each soil map is completed, the extent of occurrence of each soil is measured. When this information is combined with the soil suitability or soil drainage classification as outlined above, the results constitute an inventory of the soil resources and potential within each county.

Some of the survey results indicate great differences in the agricultural potential between different counties and regions. A comparison of counties Wexford, Limerick, Carlow and West Donegal shows this clearly (Table 1).

Table 1 - Soil suitability classes as a percentage of the total area for counties Wexford, Limerick, Carlow and West Donegal.

	Area Statute Acres	Soil Suitability Classes (%)			
		I	II	III	IV
County Wexford	584,521	60	13	22	5
County Limerick	661,738	38	8	43	13
County Carlow	221,540	67	4	23	6
West Donegal Region	263,050	1	6	90	3

N.B. 1 acre = 0.405 ha

One of the most striking features of these findings is that West Donegal with only 1% of Class I land has more holdings per square mile than County Carlow which has 67% of Class I land. The question of whether areas like West Donegal can maintain as many holdings as exist at present is immediately raised. The extent of occurrence of 38% Class I soils in County Limerick by comparison with 60% in County Wexford and 67 % in County Carlow is also noteworthy especially in view of the popular reputation which County Limerick enjoys for good quality land. Provisional figures for percentages of different soil suitability classes in a number of other counties indicate the considerable differences between them in soil resources (Table 2).

Table 2 - A soil suitability classification for some Irish counties.

County	Soil Suitability Class (%)			
	I	II	III	IV
Roscommon	35	38	18	11
Monaghan	28	41	18	9
Mayo	23	20	12	45
Cavan	23	53	13	11
Sligo	21	41	16	22
Clare	14	14	46	26
Donegal	13	25	2	60
Kerry	10	14	23	53
Leitrim	1	2	64	53

QUANTITATIVE LAND EVALUATION

Measurements of crop yields have shown considerable performance variation between the different soil series already mapped even where management and fertilizer use are of a uniformly high order. Such yield measurements for sugar beet (3) and for wheat (Table 3) show a range of yields from 35.0 to 48.0 tons/ha and from 55 to 71 cwts/ha respectively (2,800 to 3,600 kg/ha) on different soil series.

Table 3 - Sugar beet and wheat yields on different soil series.

Sugar Beet		Wheat	
Soil Series	Tonne/ha	Soil Series	cwts/ha
Broadway	47.7	Clonroche	71.0
Clonroche	43.9	Screen	55.5
Screen	38.4	Rathangan	55.8
Rathangan	35.1	Macamore	57.5

N.B. 1 cwt = 50.8 kg

As a result of these and other measured performance variations of different soils a large-scale productivity experiment has been laid down on a number of representative soils throughout the country. It is hoped, through this experiment, to establish not only the absolute performance variations between the different soils but also any seasonal differences existing. In this way, farm management practices can be matched to the most suitable crops and to total and seasonal grass production patterns which are characteristic of different soils. It will help to make possible also the application of the particular fertilizer treatment most suited to individual soil types.

NATIONAL FIGURES

From the new soil map of Ireland (4) the extent of occurrence of each great soil group association was calculated and the results, together with the land-use interpretation findings were compiled to accompany the soil map (5). These results showed that the different soils have permanent limiting factors ranging from very strong limitations in some to only slight limitations in others. The extent of occurrence of soils in these different categories as well as the kind and degree of limitation involved is shown (Table 4).

Table 4 - Soils with varying degrees of limitations to agricultural use as a percentage of the whole country.

Degree of Limitation	Type of Limitation	% of Country
A Slight	No serious limitations	35.8
B Moderate	Somewhat shallow depth Coarse texture	10.4
C Moderate to strong	Somewhat shallow depth Somewhat high altitude Poor permeability, poor structure Somewhat heavy texture	13.4
D Strong	Very poor permeability Poor structure Heavy texture	11.2
E Very strong	Rock outcrop, shallow depth Steep slopes, high altitude	20.6

RANGE OF USES TO WHICH THE DIFFERENT SOILS ARE SUITED

The soils were then grouped on the basis of the range of uses to which they are suited under normal management and fertilizer practices. The results (Table 5) showed that approximately 32% of the total land area has a wide use-range with limitations that are overcome by normal manuring and management practices. Another 9% has a somewhat limited use-range.

Table 5 - Range of potential uses of Irish soils

Use-range category	% of total area
1 Wide	32.2
2 Somewhat limited	9.0
3 Limited	29.6
4 Very limited	9.5
5 Extremely limited	18.1

This constitutes a total area of 41% of soils with a wide or only somewhat limited range of potential uses.

Soils in the limited use-range category are those mainly unsuited to tillage but suited to a permanent grassland system (and mostly suited to forestry also); these occupy 29.6% of the country. The remaining 27.6% have an extremely limited use-range; the potential for agricultural development in areas occupied by such soils is greatly restricted.

The usefulness of such figures is based not only on the fact that the amount of land in various use-suitability and limitation categories is calculated but also that the map itself shows the regional distribution of these categories.

POORLY DRAINED LAND

It was possible also from the survey findings to make an assessment of the total amount of wet land in the country. It was found that (exclusive of the major peat areas) 29% of the country is occupied by poorly-drained mineral soils. When the soil characteristics of the wet land were taken into account, it was found that the 29% total could be broken down into 18% of soils which are wet because of heavy texture or poor structure, or both and 11% which are wet mainly because they are situated in low-lying positions. These latter soils would be classified as ground-water gleys whereas the former would be classified as pseudogleys. The techniques necessary for the successful artificial drainage of these two soil types may be quite different and since there is a considerable annual investment in land drainage in Ireland, the breakdown of the drainage problem on the basis of causative effect is regarded as most important.

GRAZING CAPACITY MAP

Land-use in Ireland is dominated by pasture production and with some 85% of the land devoted to pasture, the livestock industry plays a most important role in the national economy.

The present livestock population has been estimated at 5.2 million livestock units (L.U.). The extrapolation of animal production experimental findings from the various research stations to the country at large was made possible by the publication of the Soil Map of Ireland (1969). This extrapolation (6) showed that approximately 10 million livestock units could be carried on the lowland mineral soils by the application of existing knowledge and techniques. Since the present livestock population is estimated to be 5.2 million livestock units, it can be seen that almost 100% increase in livestock density is possible on the basis of our known soil resources.

Considerable differences were found to exist between the different soils in the country in this regard. In a comparison of four counties, it was found (6) that present stock densities in County Roscommon and in County Leitrim are approximately 75% and 50% respectively of those in counties Limerick and Wexford. This is a reflection of the type of soils occurring in each county as is shown by comparing the actual number of livestock carried with what is possible according to the extrapolation of research findings (6). It was found that possible improvements in livestock units per 100 acres were 103%, 81%, 70% and 65% for counties Roscommon, Wexford, Limerick and Leitrim respectively.

FUTURE PROGRAMME

The future programme is based mainly on the preparation of county soil maps at a scale of 1 : 126,720. A number of these have already been published e.g. (7), (8), (9), (10), (11). However, continuing emphasis will be placed on both the qualitative and quantitative interpretive work so that the basic soil survey programme will be as useful as possible in the planning of optimum land use. Where possible the basic soil and land-evaluation information will be correlated with the other physical, economic and sociological factors which are also highly important if we are to have a comprehensive understanding of the problems involved. Two such resource surveys have already been completed (12), (13). The ultimate aim of the programme would be to recommend the zoning of crop and livestock production on the basis of the most suitable soils and climate and the establishment of farm management systems based fundamentally on the seasonal pattern of production particularly in relation to pastures.

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THE CONCEPT OF LAND UTILIZATION TYPES 1/

SUMMARY

For the purpose of land appraisal, the concept "land utilization type" represents a broadly generalized equivalent of the management factor in rural land use. It is a technical organizational unit in a specific socio-institutional setting.

For the definition of a utilization type several key attributes are proposed which have been singled out for their marked influence on the production capacity of the land: 1) nature of produce 2) land tenure system 3) size of farms 4) labour intensity 5) capital intensity 6) level of technical know-how and 7) farm power (source and accompanying implements).

Only a broadly generalized concept is presented and key attributes eventually will need to be sub-divided precisely as is practical for the overall purpose of the land appraisal study.

Key attributes can be related to specific land management/engineering practices, which indicates their significance for the evaluation of input requirements and the socio-economic analysis of use alternatives.

Finally, the importance of present land use classification is stressed when defining relevant land utilization types. Reference is made to existing systems of land use typing. Coordination in approach and terminology with agricultural statistics and agricultural geography is suggested.

INTRODUCTION

The objective of this Expert Consultation 2/ is to discuss multi-disciplinary land evaluation methods and to make specific proposals for standardization of methodology and terminology.

Our discussion should result in the development of a standard framework for land evaluation that will indicate present and potential suitability of identified land units for alternative uses.

Furthermore, our terms of reference mention that such alternative uses should be judged relevant, in rather broad social and economic terms.

The main purpose of this paper is to introduce some diagnostic criteria which may be considered key attributes for the characterization of land utilization types at a high categorical level of generalization (Chapter 4.2.2. Background document) 2/ It is hoped that this panel can arrive at some agreement if such attributes should indeed be singled out and if a more detailed classification applicable to the more detailed phases of land appraisal will be needed.

1/ by Klaas Jan Beek, Coordinator FAO/UNDP Regional Project LAT 70/457 "Systematic Land and Water Resources Evaluation", Santiago, Chile.

2/ References to 'Expert Consultation' and 'Background document' throughout this paper relate to an FAO Consultation on Land Evaluation for Rural Purposes convened in Wageningen, 6-12 October 1972. A report on this meeting including the Background Document is published as Publication No. 17. International Inst. of Land Reclamation and Improvement, Wageningen, Netherlands.

MULTIDISCIPLINARY CONCEPT

Land utilization types, as conceived here, require multidisciplinary cooperation for their formulation.

Fig. 1 (from BEEK-BENNEMA 1971) indicates the position of the utilization type in the overall land evaluation procedure.

Apparently the subject occupies a boundary position correlative with sciences other than soils. Although this may represent a special attraction it can also be a source of confusion when approached unmethodically.

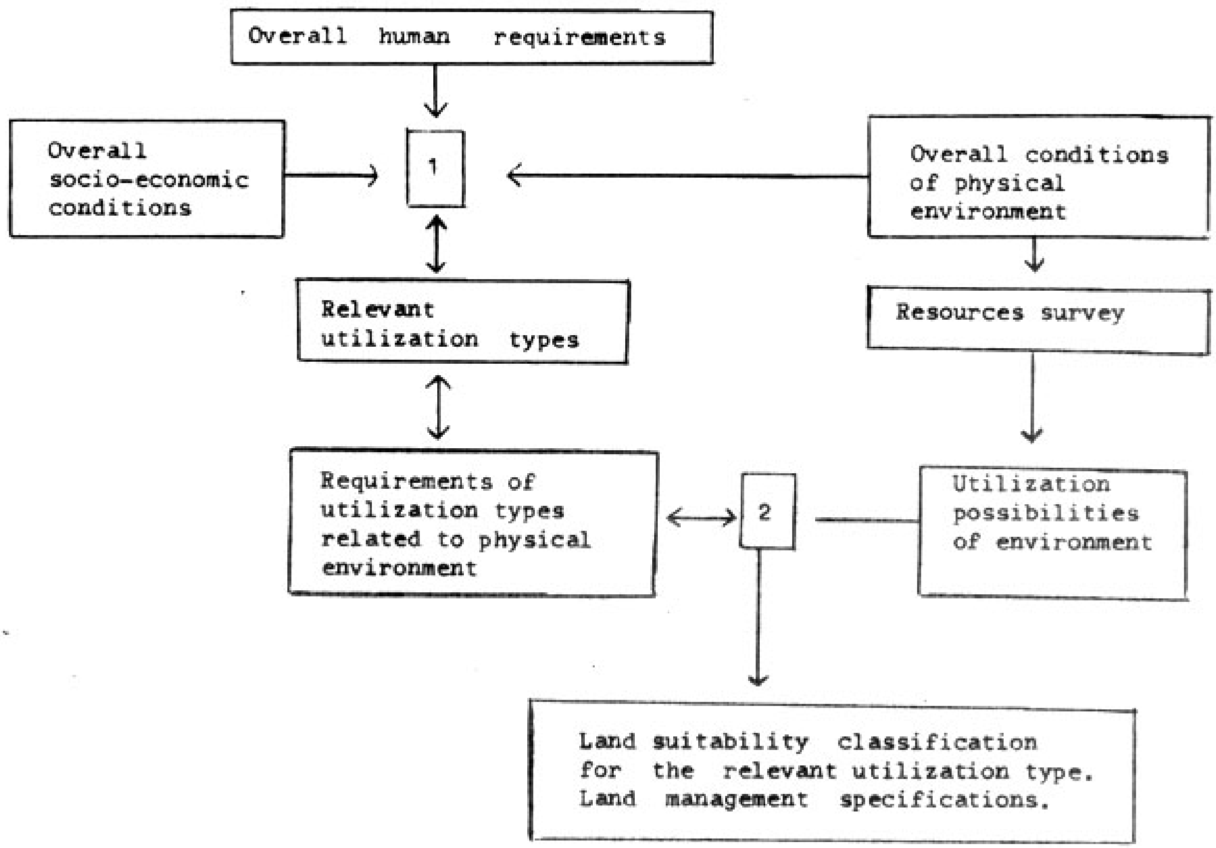
Leading questions when defining land utilization types are:

a. are the characteristics relevant and sufficiently mutually exclusive in their influence on land productivity?

b. can each characteristic be graded/classified in a practical way, distinguishing relevant groups/levels/threshold values which are meaningful for the purpose of land evaluation?

c. can subsequent socio-economic analysis quantify their influence? (production functions).

FIG. 1



In broad reconnaissance studies it is not necessary that the pure influence of each diagnostic characteristic on land productivity is known. It is often the combination of characteristics which is relevant. In detailed quantitative studies however, multifactorial regression analysis and multiple correlation would permit the assessment of the function of each variable in the production process (VASIL 'YEV, 1967).

KEY ATTRIBUTES OF LAND UTILIZATION TYPES

As key attributes only those factors have been selected which have a marked influence on the productive capacity of the land.

The following seven factors have been selected:

A. <u>Biological</u>

1. Produce

B. <u>Socio-Economic</u>

2. Land tenure system (legal status)
3. Size of farms
4. Labour intensity
5. Capital intensity
6. Level of technical know-how

C. <u>Technical</u>

7. Farm power (source and accompanying implements)

Sometimes other factors such as the status of infrastructure, location, degree of commercialization, availability of credit and markets are variables of dominant importance.

Each factor has been broadly commented on in the Background document pp. 42-44, reproduced as Annex 1 of this document.

DETERMINING UTILIZATION TYPES AND LAND SUITABILITY: AN ITERATIVE PROCESS

The selection of relevant land utilization types mostly takes into consideration the quality of the land. In almost every project requiring land evaluation albeit crop diversification, settlement, or merely the introduction of specific management improvements (fertilizer promotion, drainage, introduction of new machinery) increased productivity is one of the objectives. Even if social benefits have a much higher priority (land reform) land should be able to meet minimum requirements of management response and productivity.

In the overall land appraisal, selection of relevant utilization types and the determination of land suitability follow an iterative procedure: two mutually inter-dependent problems are solved simultaneously by getting a tentative solution to one (first outline of land utilization type) that is used in getting a tentative solution to the other (is the land unit suitable for the chosen utilization type)? That, in its turn is used in improving the solution to the first one (adaptation of first outline land utilization type to additional knowledge on suitability of the land unit) etc.

BIOLOGICAL AND AGRICULTURAL PRODUCTION SYSTEMS

NIX (1968) describes primary biological production as the result of dynamic interactions between genotype and physical environment in an attempt to model biological production systems.

$$Yg\ (T) = \int_{o}^{T} yg\ (Re,\ Rw,\ Rn,\ Rg,\ Rb)\ dt$$

Yg = biological yield of genotype g at time T
yg = rate of change of Yg which is a function of:

Re = energy Regime
Rw = water Regime
Rn = nutrient Regime
Rg = gas Regime
Rb = biotic Regime

(All functions of time t)

Theoretical production ecology is making considerable effort to evaluate the basic biological production processes and to predict potential yield by the use of simulation (building of models).

In the context of land evaluation a land utilization type could be considered a broadly generalized equivalent of the management factor, which distinguishes agricultural production from potential biological production. It manipulates one or more terms in the biological yield equation. Produce in its most detailed definition would compare to the genotype in the formula of NIX. Thus the utilization type has a determining influence on the real yield/potential yield ratio.

PRODUCTION FUNCTIONS

Land evaluation should meet the requirements of subsequent socio-economic analysis. Therefore, it is not sufficient that agricultural production processes are traced through only in biological, chemical or physical terms, though be it very important for the identification of potential yield levels.

The scope of this expert panel rightly places great emphasis on the identification and preliminary evaluation of input requirements associated with alternative uses (chapter 1.2. background document).

Land utilization types somehow will need to indicate the input side of the agricultural production process: kinds and grades (levels) of inputs, how and in which proportion inputs can be combined, and at what times.

The land utilization type has been conceived to serve this purpose: each type, depending on the required detail, represents a certain range of inputs/management practices which can be applied if the specific land qualities would require these: a technical organizational unit in a specific socioinstitutional setting.

There are many different combinations of input factors, that will produce a certain yield. However, different yields on a specific land unit result from different input combinations (production-functions in economic analysis).

It should not be impossible to prepare a fairly complete list of "land" management practices 1/ and to examine the feasibility of their application in relation to the several grades of the proposed diagnostic attributes of the land utilization types. (Annex 2).

In typology of existing land use "land" management practices are mostly included in the characterization of the land use pattern.

LAND UTILIZATION TYPE AND FARM MANAGEMENT TYPE

The previously described iterative process indicates how land evaluation proceeds stepwise in matching the relevant qualities of the land unit to the requirements of relevant land utilization types. For our purpose the land unit is normally a mapping unit, restricted in its application by the scale of the map. Only very large scales will be able to produce land units which permit listing of management specifications for individual farm land units. But even then the land utilization type does not become the equivalent of farm management type, first of all because only "land" management practices are considered and second because farm management is an economic discipline, concerned with decision making on the combination of all kinds of inputs, not only those related to the manipulation of land qualities.

For successful land utilization, correct decision making concerning input combinations is essential. Land evaluation, by formulating land management specifications for relevant land utilization types, can contribute significantly to this success also on smaller mapping scales.

Land use planning in large territories with limited information on land resources in particular, would benefit from a multicisciplinary approach to the evaluation of land resources and the preparation of country-side or regional land suitability maps for a range of alternative land utilization types (land use zoning).

LAND UTILIZATION TYPES AND PRESENT LAND USE

Perhaps the focus of this expert panel does not place sufficient emphasis on the importance of present land use in land appraisal.

In a majority of cases land appraisal will need to be carried out in areas with an established land-use pattern. Here the solution of relevant land utilization types will very much depend on the interpretation of the present situation and of passed trends in land use. Good understanding of present land use is also important for easy reference to the various types of land use occuring elsewhere. In particular land tenure and farm size can be of dominant influence on eventual land use changes. Other important factors when projecting yield increases are: the really felt need for higher income, additional labour requirements, added value/added cost ratio of new inputs, available credit, marketing prospects and the available rural extension service.

1/ "Land" management = manipulation of land qualities

EDELMAN (1949) proposed a range of five types of land classification for development planning:

Land classification according to:

1. natural conditions (soil-climate etc. classification)
2. present land use
3. land suitability for alternative uses (use capability)
4. recommended land use (socio-economic analysis)
5. classification for programme effectuation.

The first type has been purposely excluded from this panel, which is only concerned with interpretation. The second type does not receive specific attention in the Background document, therefore the only type excluded is the present land use classification.

The third type (land suitability has been sub-divided in three kinds (Background document Chapter 5.2.1.):

i) actual suitability classification
ii) potential suitability classification (without amortization of major capital inputs)
iii) potential suitability classification (with amortization of major capital inputs).

The fourth and the fifth type have been listed in Chapter 2 of the Background document, representing after land evaluation the second and third stage in planning land development and readjustment.

This panel aims at a certain standardization in approach and presentation. Therefore, when discussing the concept of land utilization types, it will be justified to analyze the progress made by other specialized fields, scientifically concerned with the typology of land utilization. Mention is made here of agricultural statistics and agricultural geography.

It is desirable for purposes of cross reference that their terminologies are compared and to a certain extent coordinated.

AGRICULTURAL STATISTICS AND LAND USE TYPING

Reference is made to the FAO World Census 1970 which is based on a long check-list of items including 0) holding, holder, tenure and type of holding. 1) land utilization 2) crops 3) livestock and poultry 4) employment in agriculture 5) farm 6) agricultural power and machinery and general transport facilities 7) irrigation and drainage 8) fertilizers and soil dressings 9) wood and fishery products 10) association of agricultural holdings with other industries.

This check-list is expected to provide sufficient flexibility to meet the requirements of individual countries to formulate census questionnaires in accordance with local conditions. At the time it should allow for the preparation of internationally comparable statistics.

Coordination in the classification of those items on the check-list which concern both the Census and land evaluation is recommended. It must be kept in mind that the essential subject of agricultural census is the holding (farm unit) whereas the focus of land evaluation is the land unit. It will depend on the intensity (Scale) of the land evaluation how close relevant possibilities (land utilization types) approximate the concept of a holding model.

AGRICULTURAL GEOGRAPHY AND LAND USE TYPING

Agricultural geography studies the areal variation of agriculture and prepares land use maps. Mention is made of the world land use map, (scale 1:1.000.000) which is under preparation by the International Geographical Union. The legend of this map should comprise valuable elements for the construction of land utilization types within the framework of land evaluation.

A similar anxiety often expressed by land evaluation specialists concerning the context in which land should be compared and the importance of its areal variation and value can be found amongst agricultural geographers: " Should the accent be on relationships between rural activities and the physical environment? Should the purpose be to discover economic differences? Can generalizations ("laws") be derived from the study of variation or should one dwell largely on the unique combination of factors in each circumstance? (GREGOR 1970).

Land evaluation when orienting itself towards the most beneficial methods of rural land use in an ever changing process of inter-action between man, culture and nature may often find itself facing a unique situation to which no established laws apply when it comes to the determination of recommended development alternatives. The uniqueness again will be partly determined by the scale at which the land evaluation is executed.

Land use typing is probably the most inter-disciplinary step in the land evaluation procedure, correlative between the physical sciences and the social economic sciences. Conceivably in being a correlative science, research on land utilization types has not yet received the attention it deserves. However, the diminishing force of physical barriers to agricultural development as compared to socio-economic constraints stresses the need for strengthening such research by geographers, soil scientists and agronomists alike.

IGU PRELIMINARY SCHEME FOR TYPOLOGY OF WORLD AGRICULTURE

The Commision on Agricultural Typology of the International Geographical Union has conferred on various occasions. As a result a preliminary scheme for the typology of World Agriculture has been prepared by J. KOSTROWICKI (1971). The proposal is based on 20 selective diagnostic variables (features) each of which is divided into 5 classes by distinguishing 4 critical threshold values for each feature (Annex I).

The selected 20 variables are supposed to be of a synthetic significance and of universal character and to cover most aspects of agriculture. The 20 variables are arranged into typograms/star diagrams to express graphically the agricultural type under consideration. It was decided that a typogram which does not differ from the model type by more than 4 of the variables, is considered being of the same type. A world-wide examination resulted in 24 world types of agriculture (Annex II). It is interesting to review the 20 diagnostic features and the threshold values distinguished for each of these. As a rating system, it resembles the rating of land qualities into several grades (BEEK-BENNEMA 1971).

However, for the rating of land qualities natural (ecological) threshold values have been selected sifnificant for the purpose of land evaluation, whereas all 20 features of the agricultural typing have been sub-divided (perhaps too systematically and arbitrarily) into 5 levels each. Such strictly mathematical sub-divisions may not always be significant for the purpose of typology. However, they may be useful for the systematic grouping after data collection when large amounts of data are involved, as in the case of agricultural census.

A certain correlation exists between the threshold values established by KOSTROWICKI and by the FAO World Census. Good correlation can be found in Kostrowicki's features 1 and 2 for which the FAO Census proposes greater detail. A fair correlation exists for the Kostrowicki features 3.3-6.1-6.4-6.5. For the other features combination and recalculation of data of the FAO Census would allow for some correlation with Kostrowicki proposals.

Features and diagnostic levels proposed to this panel for the identification of land utilization types and features and ratings proposed by Kostriwicki have several aspects in common but serve different purposes. Land utilization types for land evaluation are selected use possibilities, development alternatives, whereas the agricultural types proposed by Kostrowicki are a taxonomic classification of existing land use. Both proposals have in common that they are meant to be flexible, and can be expanded into more detailed subgroupings in accordance with required detail.

The level of detail presented in the Kostrowicki proposal gives valuable ideas for reference when defining land utilization types for low intensity studies. As a system it is too restrictive and in relevant aspects too schematic for land evaluation purposes, (including such items as mechanical power, organic manuring, chemical fertilizing, irrigation, farming systems).

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ANNEX I 1/

IDENTIFICATION OF LAND UTILIZATION TYPES

Since land suitability to a large extent depends on the purpose which the land is required to serve, it is proposed that relevant use possibilities (land utilization types or development alternatives) should be identified at a very early stage in the land evaluation procedure and should, therefore, serve as the subject matter of separate interpretative classifications. Each evaluation as such would be considered independently and without reference to the desirability of other relevant uses of the same land. A given use possibility may be relevant only in parts of the area studied and would only be investigated there.

Only the most promising development alternatives would be selected for interpretation. The surveyor would require guidance in this choice before basic survey starts; he would perhaps identify further possibilities during the survey. An excessive range of interpretations must be avoided since it would confuse the user. The degree of refinement of the definition of land utilization types should be compatible with the objectives and intensity of the study and the availability of reliable data on ecological environment and management response. Extrapolation and transfer of analogy may help in assessing suitability of relatively unknown areas, but such data cannot replace the need for local research.

Depending on the phase of the development planning process and the corresponding intensity of the study, separate alternatives could represent broad differences in agricultural use (e.g. irrigated arable farming; rainfed arable farming; rangeland; etc.) specific aspects of such use (e.g. gravity irrigation; sprinkler irrigation); or even specific crops. Here only the essential distinguishing factors are dealt with, which have a marked influence on the productive capacity of the land. The following factors are important, most of which can be quantified per unit area:

(a) Produce
(b) Capital intensity
(c) Labour intensity (man months/ha)
(d) Farmpower (source of power and HP/ha)
(e) Level of technical know-how
(f) Farm size
(g) Land tenure

Sometimes other factors, such as the status of infrastructure, are variables of dominant importance.

Produce is definitely the most diversified and important factor. In its widest sense not only primary biological production is included (pastures, crops, forests), but also secondary production (livestock, wildlife), as well as other alternative types of land utilization such as outdoor recreation. The produce to a great extent determines the importance of the other factors pertinent for a land utilization type.

Sometimes different types of produce represent a single land utilization type (mixed farming models, crop rotations). Evaluation should then be undertaken for the land utilization type as a whole, which gives a better picture than a separate evaluation for each produce component. However, for reasons of comparison it will be advisable to compile the

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1/ Extract from Background Document to an Expert Consultation on Land Evaluation for Rural Purposes, Wageningen, 6-12 October; this section being based largely on an unpublished report by K.J. Beek (1971).

However, for reasons of comparison it will be advisable to compile the suitability for the land utilization type on the basis of the suitabilities for the individual component.

Capital intensity determines possibilities for improvements, maintenance and conservation of the land conditions.

Technically, it would be possible to condition virtually any given site to satisfy a particular need or requirement. However, the extent to which this occurs, in practice, depends on the inherent characteristics of the land conditions, the cost of modifying them in relation to the value of the desired product, and the availability of private and public capital.

A distinction must be made between:

- Non-recurring (capital) input requirements or development cost.
- recurring production inputs (including operation and maintenance where relevant).

Within each (biological) production process, several input levels can be distinguished. Only a few levels are suggested. Several land evaluation studies distinguish at least two levels: low (traditional, present land utilization type) and high (advanced, modern, potential land utilization type).

For crop production, four or five input levels may be of interest. Of course, very low/low/medium/high capital inputs would relate to specific types of crop production. Inputs per surface unit for grazing and forestry are generally of a different order of magnitude from those for crop production.

Labour intensity is a variable influenced by the level of applied capital and technology, and by the labour requirements of the produce concerned. Since employment opportunities are a major issue of most development policies, this factor would need to be taken into consideration when alternative land utilization types are formulated both in terms of permanent and seasonal employment.

Variable degrees of capital/labour intensity also influence the recommended execution of initial special siteconditioning works.

The source of farmpower to a great extent determines the accompanying set of agricultural implements, and the level of capital inputs on the farm. The set of agricultural implements, in turn, determine a combination of possible farm management practices significant for the land utilization type. The performance of each set of agricultural implements is affected differently by the agricultural land conditions. Important distinctions are:

- engine-power operated machinery
- animal power
- manpower.

The level of technical know-how of the farmer is an important data for the definition of the land utilization type. A major task of the multi-disciplinary land use planning team would be to visualize harmonious land utilization types embracing farming, land management and land improvement practices within the ability of a majority of the farmers and ranchers concerned.

It is often the relatively low level of technical know-how of the local farmer which limits the practical possibilities of potentially ambitious land and water development schemes to solutions at only an intermediate level of technology and efficiency with a restricted range of crops, less sophisticated farm machinery and a restricted input level.

Farm size is an important factor in the definition of land utilization types. It is closely related to most of the other factors. In certain cases it is determined in advance entirely on the basis of socio-economic considerations without reference to physical conditions. In the planning process, it would be desirable to recognize the farm size as a major variable within a certain range to be determined with increasing precision during each phase of landuse planning and finally established at an optimal level, in harmony with the other elements defining the land utilization type during the economic land classification.

The land tenure system may be an important factor in determining and defining appropriate land utilization types. The existence of some legal, customary or otherwise institutionalized relationship between government, society, groups and individuals may limit development alternatives, through rigidity of ownership rights and associated duties having important social, as well as production, relationships.

Criteria for defining separate land utilization types need to be agreed upon. The feasibility of identifying a range of possible systems on a global basis should be investigated. It is recommended that the Expert Consultation recognizes the essential elements which characterize the land utilization types, expresses an opinion on the classification of these elements, if possible through groupings which represent several levels of generalization. It whould be noted that the concept of 'level of management' is included within the proposed concept of Land Utilization Types.

KEY ATTRIBUTES OF LAND UTILIZATION TYPES

MANAGEMENT PRACTICES	AFFECTED LAND QUALITIES	PRODUCE: ANNUAL CROPS	PRODUCE: SEMI-ANNUAL CROPS	PRODUCE: PEREN-NIAL CROPS	PRODUCE: NATURAL GRASS LANDS	PRODUCE: CULT. GRASS LANDS	PRODUCE: FORESTRY	PRODUCE: MIXED FARMING	CAPITAL INPUTS DEVELOPMENT: LOW	CAPITAL INPUTS DEVELOPMENT: MEDIUM	CAPITAL INPUTS DEVELOPMENT: HIGH	CAPITAL INPUTS ANNUAL: LOW	CAPITAL INPUTS ANNUAL: MEDIUM	CAPITAL INPUTS ANNUAL: HIGH	FARMPOWER: HAND	FARMPOWER: ANIMAL	FARMPOWER: TWO WHEEL	FARMPOWER: FOUR WHEEL	EMPLOYMENT: LOW	EMPLOYMENT: MEDIUM	EMPLOYMENT: HIGH
CROP MANAGEMENT																					
Rotations		X						X	X			X			X	X	X	X	X	X	X+
Rotation grading					X	X		X	X			X							X	X	
Fallows		X	X					X	X			X			X	X	X	X	X	X	X
Special Planting Procedures		X	X	X		X		X	X			X			X	X	X		X	X	X
Strip Cropping		X	X	X		X		X	X			X			X	X	X	X	X	X	X
Salt tolerant crops		X			X	X		X	X			X			X	X	X	X	X	X	X
Deep rooting crops		X	X			X		X	X			X			X	X	X	X	X	X	X
Cover crops		X	X	X		X		X	X			X			X	X	X	X	X	X	X
Sod crops																					
Close, non cultivated cropping																					
Grass crops						X		X	X			X			X	X	X	X	X	X	X
Shelter belts				X					X			X			X	X	X	X	X	X	X
Growth regulators		X						X		X			X		X	X	X	X	X	X	X
Selective cutting																					
Controlled grazing					X	X	X	X	X			X	X		X	X	X	X	X	X	
Fertilizer spraying		X	X	X																	

KEY ATTRIBUTES OF LAND UTILIZATION TYPES

MANAGEMENT PRACTICES:		PRODUCE							CAPITAL INPUTS						FARMPOWER				EMPLOYMENT		
									DEVELOPMENT			ANNUAL									
SOIL MANAGEMENT	AFFECTED LAND QUALITIES	ANNUAL CROPS	SEMI-ANNUAL CROPS	PEREN-NIAL CROPS	NATURAL GRASS LANDS	CULT. GRASS LANDS	FORESTRY	MIXED FARMING	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	HAND	ANIMAL	TWO WHEEL	FOUR WHEEL	LOW	MEDIUM	HI
CHEMICAL FERTILIZERS		X	X	X	X	X	X	X	X			X			X	X	X	X	X	X	X
ORGANIC MANURING		X	X	X				X	X	X		X	X		X	X	X	X	X	X	X
LIMING		X	X	X	X	X	X	X	X	X		X			X	X	X	X	X	X	X
SOIL AMENDMENTS (GYPSUM, SULPHUR)		X	X	X				X	X	X		X			X	X	X	X	X	X	X
LEACHING		X	X	X		X		X		X		X	X		X	X	X	X	X	X	X
SOIL CONDITIONERS		X						X			X		X		X	X	X	X	X	X	X
WEEDING		X	X	X	X	X		X	X	X		X			X	X	X	X	X	X	X
WEED FREE NON TILLAGE		X	X	X						X		X			X	X	X	X	X	X	
MULCHING		X	X	X				X	X			X			X	X	X	X	X	X	X
MINIMUM TILLAGE		X	X	X				X	X			X			X	X	X	X	X	X	
SOIL COVER WITH DEAD MATERIAL		X	X					X	X			X			X	X	X	X	X	X	X
CROP RESIDUE MANAGEMENT		X	X					X	X			X			X	X	X	X	X	X	X
DUNE STABILIZATION		X	X	X		X		X		X		X			X	X	X	X	X	X	X
CONTOUR CULTIVATION		X	X	X		X	X	X	X			X			X	X	X	X	X	X	X
TIERIDGING		X							X	X		X			X	X	X	X		X	X
SOIL FUMIGATION		X	X	X				X					X					X	X		
CHISELING		X	X	X		X		X		X		X						X	X		
SOD SEEDING		X	X					X	X			X			X	X	X	X	X	X	

KEY ATTRIBUTES OF LAND UTILIZATION TYPES

MANAGEMENT PRACTICES: SOIL WATER ENGINEERING	AFFECTED LAND QUALITIES	PRODUCE							CAPITAL INPUTS: DEVELOPMENT			CAPITAL INPUTS: ANNUAL			FARMPOWER				EMPLOYMENT		
		ANNUAL CROPS	SEMI-ANNUAL CROPS	PEREN-NIAL CROPS	NATURAL GRASS LANDS	CULT. GRASS LANDS	FORESTRY	MIXED FARMING	MEDIUM	HIGH	VERY HIGH	LOW	MEDIUM	HIGH	HAND	ANIMAL	TWO WHEEL	FOUR WHEEL	LOW	MEDIUM	HIGH
LAND SMOOTHING		X						X	X				X			X	X	X	X	X	
LAND GRADING		X	X	X		X		X		X		X						X	X		
LAND LEVELLING		X	X	X				X		X	X	X						X	X		
DEEP PLOWING		X	X	X				X			X	X						X	X		
DEEP PLOWING "SANDING"		X									X	X						X	X		
SUBSOILING		X	X	X		X		X	X				X					X	X		
RIDGE TERRACES		X						X	X				X		X	X	X		X	X	X
BROAD BASE TERRACES		X	X			X		X	X			X	X			X	X	X	X	X	X
BENCH TERRACES			X	X				X	X	X			X			X	X	X		X	X
BROAD CHANNEL TERRACES		X	X	X		X		X	X				X		X	X	X	X	X	X	X
LEVEL TERRACES		X								X			X					X	X		
RIDGE CONSTRUCTION		X	X	X		X		X	X				X		X	X	X		X	X	X
CONTOUR BANKS		X	X	X				X	X				X					X	X		
DAM CONSTRUCTION		X	X	X	X	X		X		X	X	X				X	X	X	X	X	X
DIKE CONSTRUCTION		X	X	X	X	X		X			X	X						X		X	
BEDDING		X	X						X				X			X	X		X	X	
SURFACE DRAIN CONSTRUCTION		X	X	X	X	X		X	X	X			X		X	X	X	X	X	X	X
DIVERSION CHANNEL CONSTRUCTION		X	X	X		X		X	X	X			X		X			X	X	X	X
CANAL CONSTRUCTION		X	X	X	X	X		X			X	X	X		X			X	X		X
DITCH LINING		X	X	X		X		X		X	X	X			X		X	X	X	X	
MOLE DRAIN INSTALLATION		X	X	X		X		X	X				X					X	X		
TILE DRAIN INSTALLATION		X	X	X		X		X		X	X	X			X			X	X		X
BRUSH CLEARING		X	X	X	X	X	X	X	X				X					X	X		
JUNGLE CLEARING		X	X	X		X	X	X	X	X		X						X	X	X	
PIONEERING (STUMP REMOVAL AND CONTROLLED BURNING)		X	X	X	X	X	X	X	X	X		X			X			X	X		X
STONE REMOVAL		X	X	X				X	X	X		X	X		X			X	X	X	X
ROCK BLASTING		X	X	X				X			X	X			X			X	X		
GULLY CONTROL		X	X	X	X	X		X		X		X			X		X	X	X	X	X
MECHANICAL WINDBREAKS		X	X						X	X		X	X		X	X	X			X	

39 EXAMPLES OF LAND UTILIZATION TYPES	PRODUCE CROPS ANNUAL FRUITS & VEGETABLES	INDUSTRIAL	FIELD	SEMI-ANNUAL FRUITS	INDUSTRIAL	PERENNIAL FRUITS	INDUSTRIAL	GRAZING NATURAL	CULTIVATED	FORESTRY	MIXED ANNUAL CROPS & CULTIVATED GRAZING INDUSTRIAL CROPS & C.G.	FIELD CROPS & C.G.
No Irrigation												
Dry Farming												
small holding, handlabour		(X)	X									
animal labour		(X)	X									
modern		(X)	X									
Horticulture												
annual fruits and vegetables, handlabour	X											
annual fruits and vegetables, modern	X											
perennial fruits, hand labour						X						
perennial fruits, modern						X						
Mixed Farming												
field crops, cultivated pasture, animals												X
field crops, cultivated pasture, modern												X
Agriculture												
annual industrial crops, handlabour		X										
annual industrial crops, animal power		X										
annual industrial crops, moder, small plots		X										
annual industrial crops, modern, large plots		X										
annual field crops, handlabour			X									
annual field crops, animal power			X									
annual field crops, improved, animal power			X									
annual field crops, modern, large plots			X									
semi-annual industrial crops, handlabour					X							
semi-annual industrial crops, improved, labour intensive					X							
semi-annual industrial crops, modern, labour extensive					X							
perennial industrial crops, labour intensive							X					
perennial industrial crops, labour extensive							X					
annual field crops, improved terraced cultivation		X	(X)									
Grazing natural grassland								X				
natural grassland, improved								X				
cultivated grassland (meat)									X			
cultivated grassland (milk)									X			
Forestry commercial timber traditional										X		
commercial timber, intensive										X		
Irrigated annual fruits and vegetables	X											
annual industrial crops, labour extensive		X										
annual industrial crops, labour intensive		X										
annual field crops, labour extensive			X									

	PRODUCE											
	CROPS							GRAZING			MIXED	
	ANNUAL			SEMI-ANNUAL		PERENNIAL					ANNUAL CROPS & CULTIVATED GRAZING	
	FRUITS & VEGETABLES	INDUS-TRIAL	FIELD	FRUITS	INDUS-TRIAL	FRUITS	INDUS-TRIAL	NATURAL	CULTIVATED	FORESTRY	INDUSTRIAL CROPS & C.G.	FIELD CROPS & C.G.
<u>Supplementary irrigation</u>												
semi-annual crops				X	(X)							
perennial crops						(X)	X					
annual fruits and vegetables	X											
irrigated rice, fully mechanized			X									
irrigated rice, labour intensive			X									
<u>Permanent Drainage</u>												
"polder" modern, fieldcrops			X									

39 EXAMPLES OF LAND UTILIZATION TYPES	CAPITAL: DEVELOPMENT INPUTS			CAPITAL: RECURRING INPUTS			FARM POWER				EMPLOYMENT INTENSITY		
	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	HAND	ANIMAL	TRACTOR 2 WHEEL	TRACTOR 4 WHEEL & CRAWLER	LOW	MEDIUM	HIGH
No Irrigation													
Dry Farming													
small holding, handlabour	X			X			X					X	
animal labour	X			X				X				X	
modern		X				X				X	X		
Horticulture													
annual fruits and vegetables, handlabour	X				X		X						X
annual fruits and vegetables, modern		X				X			X				X
perennial fruits, hand labour	X				X		X					X	
perennial fruits, modern		X				X			X			X	
Mixed Farming													
field crops, cultivated pasture, animals	X				X			X				X	
field crops, cultivated pasture, modern		X			X					X	X		
Agriculture													
annual industrial crops, handlabour	X			X			X						X
annual industrial crops, animal power	X			X				X				X	
annual industrial crops, modern, small plots		X				X			X				X
annual industrial crops, modern, large plots		X				X				X		X	
annual field crops, handlabour	X			X			X						X
annual field crops, animal power	X			X				X				X	
annual field crops, improved, animal power	X				X			X				X	
annual field crops, modern large plots		X				X				X	X		
semi-annual industrial crops, handlabour	X			X			X						X
semi-annual industrial crops, improved, labour intensive	X				X				X				X
semi-annual industrial crops, modern, labour extensive		X				X				X	X		
perennial industrial crops, labour intensive		X			X	X							X
perennial industrial crops, labour extensive		X			X				X			X	
annual field crops, improved terraced cultivation		X			X				X				X
Grazing													
natural grassland	X			X				X				X	
natural grassland, improved		X			X					X	X		
cultivated grassland, (meat)		X		X						X	X		
cultivated grassland (milk)		X		X						X		X	

ANNEX II-4

	CAPITAL						FARM POWER				EMPLOYMENT INTENSITY		
	DEVELOPMENT INPUTS			RECURRING INPUTS									
	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH	HAND	ANIMAL	TRACTOR 2 WHEEL	TRACTOR 4 WHEEL & CRAWLER	LOW	MEDIUM	HIGH
Forestry													
commercial timber traditional	X			X				X				X	
commercial timber, intensive		X		X						X	X		
Irrigated													
annual fruits and vegetables			X			X				X			X
annual industrial crops, labour extensive			X			X				X		X	
annual industrial crops, labour intensive			X			X			X				X
annual field crops, labour extensive			X			X				X	X		
Supplementary irrigation													
semi-annual crops			X			X				X	X		
perennial crops			X		X					X	X		
annual fruits and vegetables			X			X			X				X
irrigated rice, fully mechanized			X			X				X		X	
irrigated rice, labour intensive			X			X			X				X
Permanent drainage													
"polder" modern, field crops			X			X				X	X		