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DUTCH AND VICTORIAN APPROACHES TO LAND APPRAISAL

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PREFACE

In 1971 Frank R. Gibbons, Principal Research Officer with the Soil Conservation Authority of the State of Victoria, Australia, spent 9 months as a visiting scientist in the Netherlands Soil Survey Institute in Wageningen.

His task was to combine the experience gained in land appraisal in Australia with existing knowledge in the Netherlands. This publication, compiled with the cooperation of Dr. J. C. F. M. Haans of the Netherlands Institute is the result of his stay. It has become a critical review of methods for the collection of land resources data and their interpretation and application for various kinds of landuse.

In the period as a visiting scientist Frank Gibbons demonstrated the important contribution an experienced research worker can make through intensive contact with a group of colleagues from another part of the world. His analytical mind, philosophically inclined, facilitated a review in depth of methods and experiences. This has significantly stimulated and contributed to the thoughts on soil survey and its applications in this Institute.

We would like to convey some of this to our colleagues elsewhere. Land resource inventories have become increasingly important, not the least in developing countries. We feel that it may be valuable to make the results of Frank Gibbons' visit available to a wider international audience.

The Director of the
Netherlands Soil Survey Institute,

R. P. H. P. van der Schans

SUMMARY

From the concepts of conservation, classification and the integrated approach to landuse, we conclude that five features are important in systems of land-appraisal:
— a number of environmental features and their relationships,
— a range of types of landuse,
— input-output relationships,
— conservation-aspects (processes and hazards),
— socio-economic data.

In the Dutch approach, soils and their water-table are emphasized. This results in a comprehensive and useful general-purpose system of soil-classification, which is the basis of a sophisticated system of mapping. Many types of intensive landuse are considered, from horticulture and arable farming, through grazing, forestry and building to recreation. A strong point is the attempt to link features with productivity in these forms of landuse, by both empirical and rational methods. In the latter, the chief soil-limitations in each mapping-unit are identified, for each type of landuse. For success in this method, qualitative and quantitative terms must be established for the factors, features, inputs, site-conditions and products involved, and those variables must then be related to each other, and their desired levels determined. Not all such requirements have yet been met for the mapping-units rated.

Except for the almost ubiquitous high water-table, hazards are not emphasized in the Dutch approach. Socio-economic factors predetermine the kind of production or benefit, and information about the soils is used to show what limitations must be removed, the management-practices to be followed, and the cost.

In the Victorian approach, a wider range of land-features is considered, and especially their relationships, so as to predict the land-features over large areas and to surmise the ecological processes. Success depends on the close local correlation of land-features. Many forms of landuse are considered, but in assessing the capability of the land for them, the method is largely empirical.

However, the hazards in each type of landuse — hazards for both that and any other type of landuse — receive much attention, with an attempt to work out the processes involved. This information is used in determining the safe management-practices for various kinds of production, and, together with socio-economic data, in coming to an opinion about the most worthwhile kind of production.

These differences can be linked to the circumstances of the two States. The Netherlands are small and densely populated, soil is the most variable land-feature, the land itself is at a premium and the resources are there to appraise it. Victoria is bigger and sparsely populated, with a wide range of land-features; some of the land has been damaged, and much is still unallocated.

In the Dutch approach, it would be useful to set up schemes for meeting and applying the requirements in the rational method of assessing capabilities. In the Victorian approach, the basic assumptions about correlations between land-features should be tested properly.

1. INTRODUCTION

It is often useful to look at things as a whole in order to understand the significance of individual parts and to see where a fresh emphasis may be needed. So it is with land-appraisal, and here the aim is to see the overall picture and to suggest a worthwhile approach.

We try to do this by, first, considering basic principles which have a bearing on land-appraisal, in order to identify some of the features which are important in a system of land-appraisal. Then, by finding out, from an examination of Dutch and Victorian approaches, how these features are handled in two different systems, we assess what is involved in each feature and so we identify any weaknesses in the techniques in the two approaches.

Finally, we determine, from a comparison of the two countries, the reasons for the differences in approach.

2. IMPORTANT FEATURES IN A SYSTEM OF LAND-APPRAISAL

These are determined by the purpose of the appraisal and by the concepts which bear on the nature and use of land.

2.1 Purpose

To appraise land is to estimate its worth or value. Worth and value have meaning only in relation to the use and user. The purpose of land-appraisal is to know the way in which to use the land so that its worth and value are the greatest. Put in another way, it is to find the most worthwhile system of landuse: the kind of production, the modifications needed to attain it and the management practices required to maintain it.

Worth depends on feasibility (available resources) and on desirability (need for the product and alternative ways of obtaining it). Therefore, data of an economical, social and policy nature will be required for interweaving with the physical data about the land.

Because the former sooner become outdated than the latter, the interweaving should be deferred as late as possible, so that as much as possible of the processed data remain valid. But the significance of the physical data (e.g. the size, shape, proportion and location of different types of land) often depends partly on socio-economic data. Also, a knowledge of feasible inputs (monetary, technical and managerial) may be required before the likely hazards can be assessed.

Therefore, land-appraisal should include the use of socio-economic data, both in a preliminary form and then as a full interweaving at a later stage.

2.2 Concepts

The concepts of conservation, classification and the integrated approach to landuse have a bearing on the nature and use of land, and so on land-appraisal. These concepts and their bearing are now considered in turn.

2.2.1 Concept of conservation

Conservation is the husbanding of resources so that they may continue to provide for our present and yet undefined future needs. Under some circumstances, this allows the resource (here, the land) to be used at a high level of the required kind of production, provided that the management practices keep it sound for that purpose, although perhaps not for other kinds of production. Under other circumstances, the resource may need to be preserved in its natural or present condition, so that its capability for any form of use is not impaired.

In either case, the appraisal of land should not encourage an *unwitting* impairment in its capability for any foreseeable use. The land should be kept as versatile as possible.

One result of this is that the scope of land-appraisal should embrace a range of types of landuse. Another is that, in order to prevent deterioration, a knowledge is required of the probability and nature of potential hazards for all types of landuse. This knowledge is best obtained from an understanding of processes operating in the ecosystem. Land appraisal must provide information about those processes.

2.2.2 Concepts of classification

The aims in classification (DE BAKKER, 1970) are to elucidate or to demonstrate relationships between objects and by this to aid the prediction of information required for their use. A requirement of a classificatory system is that it be attuned to the process in which it is to play a part. For the first aim, the usefulness of the system depends on its predictive ability for the value of an attribute, and also on the relevance of the predicted information in the proposed use of the objects (GOODALL, 1968).

The features which make for high predictive ability and relevance depend on the classificatory approach adopted (GIBBONS, 1961).

The general-purpose or intrinsic approach is where many uses (or any use) of the objects are envisaged. In such a system, high predictive ability depends on a high degree of covariance between the values of the attribute of the object. Values of many attributes must be known, in order to test that covariance. With high covariance, the classes based on any one attribute will satisfactorily parallel the classes for any other attribute. A wide range of attributes will not achieve the aim in the classification when the covariance is low, because then the predictive ability, also, would be low for an attribute *at random*.

In short, it is the degree of covariance which is the measure of the degree of predictive ability of a general-purpose system. To test this, a range of attributes must be examined.

The special-purpose or extrinsic approach is where only few uses of the objects are envisaged at any one time. Here, there are two requirements to ensure high relevance. One is that the attributes which form the basis for the classification should be known beforehand as the relevant ones and chosen accordingly, and their significance for the proposed use should be known. Such attributes are identified from a knowledge of the relationships between various attributes and a measure of the proposed use. Consequently, a knowledge of the relations between attributes, performance and any inputs affecting them is needed at the outset.

The other requirement is an understanding of the interaction between the chosen attributes and other environmental features, because interaction may alter the relations between the attributes and the proposed use, and thus the relevance of the attributes. A knowledge of the input-output relations will allow an understanding of these interactions and enhance our understanding of the processes operating.

It is, therefore, not possible to construct a special-purpose system until the appropriate attributes be known. Once constructed, the system will have a high predictive ability for the chosen attribute, although not necessarily for any other attribute.

For both systems a quantitative knowledge of the relations between attributes, inputs and performance is needed in order to make accurate and precise predictions about the actual performance of the land and the measures required to obtain the desired result. If the drainage-status of the soil should be important for the growth of summer grain-crops, then it should be included in a special-purpose classification. With either system of classification, the effect of the various degrees of drainage upon the crop must be known, if predictions are to be made about productivity or required treatment of the soil.

These concepts touch on other aspects of land-appraisal. In general-purpose appraisals, the land may be characterized before any of the use-relationships need be considered, because (with high covariance) the classes will be assumed a proper basis for considering any system of landuse. On the other hand, in special-purpose appraisals, the relationships between attributes and performance must first be known.

For a successful general-purpose appraisal, the useful survey-techniques include those leading to a recognition of areas where the covariance is the highest locally (e.g. the landscape-approach). Those techniques also play a useful part in special-purpose appraisals. Interactions are then consistent throughout the recognized areas, so that the relevance of attributes is not altered, or, if altered, the alterations follow the classes, which continue to be discriminatory groupings.

2.2.3 Concept of the integrated approach to land-studies

Definition and applications. The integrated approach is the inter-relating of a number of environmental factors, land-features and site-conditions, and considering the significance of these for performance and management in various types of land-use. Figure 1 illustrates the approach diagrammatically. Five variables are involved: factors, features, inputs, site-conditions, and products or outputs (payoffs).

The two basic reasons for the approach, each with its corresponding application, are:
- the hazard to and productivity of the land may be influenced by many factors and features; consequently as many as possible must be considered;
- factors, features and site-conditions interact and differ in importance according to the circumstances; consequently, the interactions, processes and input-output relationships must be known so that each feature can be properly emphasized.

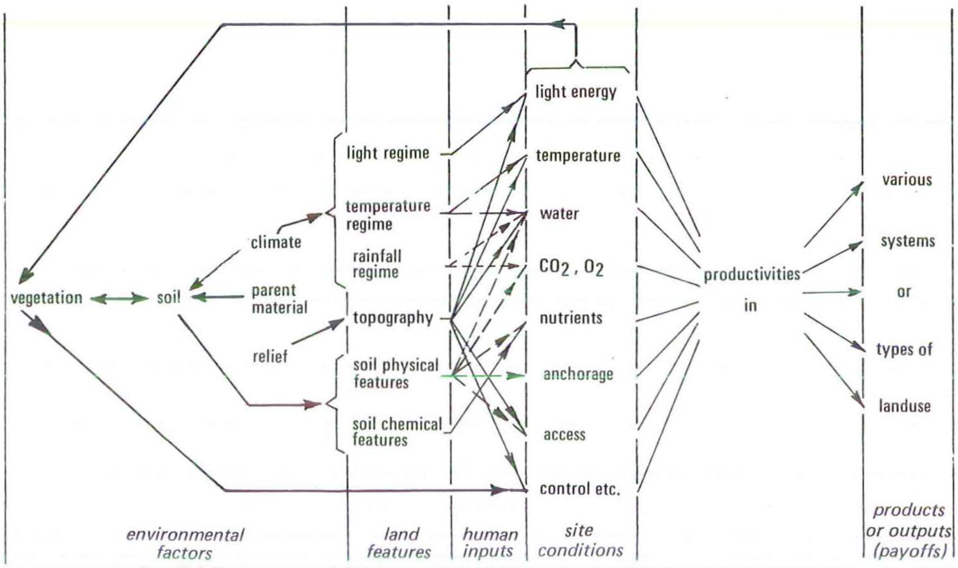

Fig. 1. Integrated approach to land studies.

Origin and variants. The approach has been developed from a number of sources. STARING (1856) mapped the Netherlands into areas each characterized in terms of geological material, relief, climate and soil-features, but his work was forgotten for about eighty years. HERBERTSON (1905) showed that a range of environmental variables may be used to identify natural regions, and both Dokuchaiev and Hilgard's work supported Herbertson's genetical approach. They had pointed out the particular variables which were responsible for the formation of soil. These ideas were put into practice by the Michigan Land-Survey in 1922. Then BOURNE (1931) and UNSTEAD (1933) showed that to characterize the land by combinations of a number of features can result in useful units for identifying it, classifying it and for considering its nature and use. MILNE (1935) then pointed out that a limited number of small such units could form a repetitive sequence with topography, and so could produce consistent patterns of those units over broader areas. Because of the consistent associations of particular values of the several features, it was possible to predict, within the area characterized by the pattern, the nature and location of land types, from some single feature which is easily identifiable. This was a mapping-tool of great strength, and is the basis of the landscape approach. JENNY (1941), continuing the functional approach of Dokuchaiev, and attempting to define the soil system, distinguished dependent and independent properties or variables of the soil system and the independent variables of its environment. He listed the chief environmental variables, so establishing the range of features in terms of which the land could be defined, and the scheme of their causative relations.

Meanwhile, the ecosystem concept had been introduced by TANSLEY in 1935 and by SUKACHEV in 1944. This is the concept of "the whole complex of environmental features, both biological and physical, operating as an inter-related unit" (OVINGTON, 1962). Such units may exist at different levels, so forming an hierarchy of increasingly inclusive ecosystems.

From different combinations of these various sources, three main streams of integrated approach have been developed.

The first was Edelman's school, begun about 1942 in the Netherlands, in which "accent was placed on the connection between the landscape and the soil-conditions" (PIJLS, 1970). From this landscape approach have stemmed the programme of the Netherlands Soil Survey Institute, with increasing emphasis on soil, the work of VAN DIJK (1959) and of BUTLER (1959), with emphasis on pedogenetic history and the approach of the INTERNATIONAL TRAINING CENTRE (1968) which produces co-ordinated resource-reports for each area studied.

Another stream is the school of CHRISTIAN and STEWART, who, in 1953, produced the first of their land-reports. These contain representations of patterns of the environment in which, on the basis of physiography, is hung the associated information about the other features of the land. An offshoot is the school of AITCHISON and GRANT (1967) who publish coded terrain classifications based on photo-interpretation, with emphasis on features of engineering significance. The work of the BECKETT and WEBSTER school (1965), also of this stream, emphasizes the storage, retrieval and interpretation of data by automated means, and the reliability of the interpretations.

The third stream issues from the monograph of COSTIN (1954) plus the work of his colleagues DOWNES (1949) and HALLSWORTH and GIBBONS (1951). They brought together, from JENNY, a list of the significant features of the land, and from the ecosystem-concept an emphasis on ecological processes and the consequences of interfering with them. The result was the use of ecosystems, mapped according to vegetation, as the basis for considering the other features, the processes operating and the consequences of interfering with them. From Costin and Downes came the contribution of mapping units suitable for conveying information relevant to process and hazard as well as to feature and performance. This engrafting of conservation concepts has been continued in the land-studies of the Soil Conservation Authority of Victoria.

The basic difference between these streams is in what is sought, and from this come the other differences — importance placed on the ecosystem concept, choice of features in mapping and kind of integration.

Thus, in Edelman's stream and Christian and Stewart's stream, the aim is the prediction of many features from a few, whereas, in Costin and Downes' stream, it is an understanding of processes and hazards. Consequently, in the first two streams, parent material and relief are the features chosen as the basis of mapping, because, being the most independent, they form the best basis for predicting other features. By contrast, Costin chose vegetation, for the converse reason, that, being the most dependent feature, it most reflects the way in which the others are integrated, and so the processes and hazards. This difference is widening. The present exponents of the first two approaches, in their search for predictive ability, are moving further away from the ecosystem approach by their increasing reliance on a single feature, physiography; whereas, Costin's school, in its emphasis on redeeming the hazards, keeps to the ecosystem concept by giving due weight to each feature. Combination — for example, of discipline, work and organization — is an aim in the first stream (VINK, 1966), whereas in the third stream, an integration is preferred.

2.3 The important features

From these concepts the features which are important in systems of land appraisal include the five following (see Fig. 2):

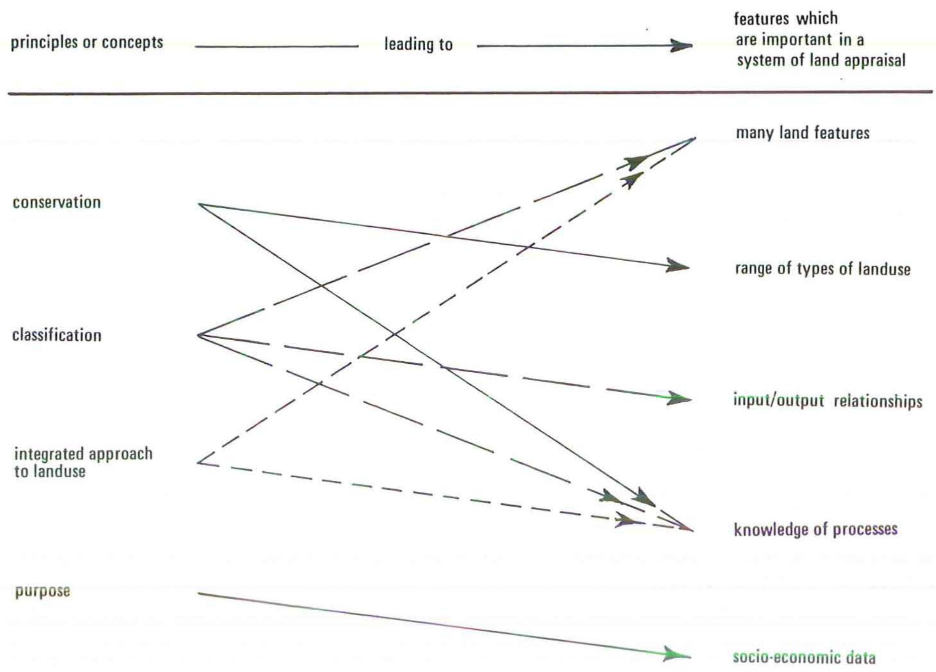

Fig. 2. Concepts determine what features are important in a system of land appraisal.

— the use of data on a number of environmental features and their relationships;
— the consideration of a range of types of landuse;
— a knowledge of input-output relations (relations between features and performance) for each kind of production, so that the various capabilities can be estimated;
— conservation-aspects — a knowledge of processes, so that the hazards, suitabilities and compatibilities can be assessed;
— the use of socio-economic data, so that the relative worth of different systems of landuse may become known.

Dutch and Victorian approaches are now examined on the basis of these five features.

3. THE DUTCH APPROACH

The approach used by the Netherlands Soil Survey Institute is the 1 : 50,000 general purpose soil survey plus the suitability ratings of the soils. The surveys are published in a standard series, each publication covering an area of 20 x 25 kilometres.

The essential features of the more detailed surveys (1 : 2,000 to 1 : 25,000), commissioned for various purposes, are similar.

3.1 Land-features considered

3.1.1 Soil

Attributes. Most can be estimated semi-quantitatively in the field by competent surveyors (with periodic laboratory control on samples in order to check the field estimations), and information about them is, when applicable, obtained at most sites examined (augerholes mainly). These attributes (with respect to the sequence, depth and thickness of horizons and layers) are:

field texture, content and type of organic matter, calcium carbonate content, colour and mottling, content and type of peat, consistency, nature and distribution of roots, level of groundwater, and evidence of human influence or other types of disturbance.

Their values are estimated in terms of predetermined ranges.

Other attributes are determined quantitatively in the laboratory on samples obtained from various horizons at a few selected places. They are:

pH value, calcium carbonate content, organic matter content, nitrogen content, carbon/nitrogen ratio, particle-size distribution, exchangeable Na, K, Mg, Ca & H, sodium, potassium, calcium, magnesium and hydrogen, cation exchange capacity, ferric oxide content, Fe-dithionite content, alumina content, magnesia content, potassium-fixation capacity, phosphorus content, phosphorus-fixation capacity, pore volume, moisture content at different pF levels, Atterberg values, specific surface and specific weight.

Classificatory system. The general-purpose classificatory system of DE BAKKER and SCHELLING (1966) is used.

Its broad subdivisions or parts are each based on a genetic modal concept (e.g. podsols, earths); in each such part many attributes are involved, but the boundaries between classes at any level are defined in respect of only a few chosen attributes, which may differ from part to part of the system.

The system allows any soil in the Netherlands to be allocated to a single class, and the modal concepts are likely to result in soil groupings wherein the attributes covary more than in the range as a whole, permitting a higher predictive ability with a minimum of interactions.

There are four higher categorical levels: order, suborder, group and subgroup, plus lower categorical levels equivalent to the lower levels of mapping units. A locally derived nomenclature for the higher levels, and a logical and comprehensive system of coding with letters and ciphers for the lower levels, indicate some salient features of the class.

Both higher and lower categorical levels are based upon the same range of attributes; the information provided in the lower levels is greater because it is more precise as a result of the narrower range of values for classes and because of the larger number of combination possibilities.

Mapping units. The mapping units both of 1 : 50,000 sheets and of the larger scale surveys are of areas of soil classes at lower levels (the soil group level and lower, or associations thereof) with bulking appropriate to the scale. As for the classificatory system, the information provided by mapping units of larger scale surveys (1 : 5,000, 1 : 10,000 and 1 : 25,000) differs from that of mapping units of the 1 : 50,000 surveys by having narrower classes and more precise values for the various attributes at lower classificatory levels.

In the map legend, mapping-units are grouped into higher categories; this grouping, however, is not necessarily the same as in the soil classificatory system, and may be on a landscape basis. The soils included in a particular higher level of the classificatory system may occur in a number of groups at the higher levels of the map legend; conversely, a particular higher level of the map legend may include representatives of a number of higher levels of the classificatory system. Also, the colours of the main mapping-units are chosen to conform with conventional cartographic representations of the landscape. As a result, the coloured maps and their legends tend to bring out the landscape relationships of mapping units, rather than the classificatory relationships of soils.

Uncoloured maps are also produced, to show particular aspects of interest, such as the distribution of single features (e.g. depth to sand or ground water classes), ratings for various kinds of use, or some other relations. This is often done for the commissioned surveys. Such maps are derived or interpreted from the original soil survey, and their usefulness depends upon the interrelationships of the aspects of interest and the mapping-units.

A common problem in mapping the soils occurs in the zone where the soils narrowly straddle the limits between two classes at a higher categorical level. To map both classes results in boundaries too complex for the scale. One procedure has been to alter the boundaries of the classes, but this distorts the classificatory system as a whole; another is to map the area as a complex but this may reduce the usefulness of the map.

Some distinguishing classification criteria are not easily estimated in the field, e.g. the humus content of the topsoil in order to distinguish adjacent soils of the "earth" and "vague" groups on the transect from a river levee to the back swamps.

3.1.2 The ground-water table

This is the level at which the surface energy of soil-water is that of a free water surface. The table may vary regularly throughout the year and irregularly from year to year. It is regarded as a feature of the soil, but is considered separately here because of its particular importance to landuse in the Netherlands.

The level is usually highest in winter and lowest in summer. On a graph, the trend indicating the relation between time of the year and elevation of the water-table is a single cycle measured between such highest and lowest levels. The cyclical average over a number of years is a regular curve, the highest point being termed "mean highest water table", and the lowest "mean lowest water table". A classification of average seasonal fluctuations of the water table is based on these two levels, according to the scheme of Table 1.

Table 1. Classes of ground-water.

Ground-water class	I	II	III	IV	V	VI	VII
Mean highest water-table in cms beneath the surface	—	—	< 40	> 40	< 40	40-80	> 80
Mean lowest water-table in cms beneath the surface	< 50	50-80	80-120	80-120	> 120	> 120	> 120

The ground-water gives rise to particular soil features which help to identify the ground-water class. Consequently, there is some association between ground-water classes and soil classes, but on the soil map they are shown separately.

A full account of the identification, classification and mapping of the ground-water table in the Netherlands is given by VAN HEESEN (1970).

3.1.3 Climate

Usually, there is no mention of climate in the various reports; climatic variations are small in the Netherlands.

3.1.4 Geology and topography

Information on geology, topography and landscape is always presented, and on the history of the development of those features. The individual geological formations (mainly quaternary) are named and characterized in detail so that the chief features of the parent material of each profile can be known.

Examples are in the reports accompanying sheets 32 East (Amersfoort) and 31 West (Utrecht). In the former, which covers ice-pushed ridges and the Guelders Valley with its gravels, sand and peat, the fourteen different deposits of Riss times and later are named and described, and their relationships with the landscape are shown. In the latter sheet, covering peaty riverine and marine clayey areas in South Holland, the seven major deposits of the last 5,500 years are similarly described.

The commissioned surveys at larger scale — for example, that for Lopikerwaard — are similar in these regards.

3.1.5 Vegetation

Most of the reports do not refer to vegetation except for the chief crops grown on each mapping-unit. In some, e.g. 43 West (Willemstad), the chief species of the original vegetation on particular mapping-units are mentioned.

3.2 Types of landuse considered

The various systems of landuse, with the different kinds of production involved and the species grown, are shown in Table 2. The management practices associated with them are not shown.

Table 2. Types of landuse considered in Dutch approach.

System of use	Kind of production involved	Species grown
Horticulture	fruit-growing	— apples, pears
	vegetable production	— tomatoes, cucumbers, asparagus
	flower-growing	— carnations, roses
	bulb production	— tulips, various
Arable farming	cereal-cropping	— wheat, rye, oats, barley
	root-cropping	— potatoes, sugar beet
	pulse-cropping	— peas, beans
	forage production	— vetches, maize
Pasture production	hay-making	various grasses and other herbs
	silage production	
	grazing	
Forestry	softwood production	— pine, larch
	hardwood production	— oak, beech, birch
Building	housing	
	roading	
	industrial use	
Recreation	sportsfields	
	passive recreation	
	National Parks	

3.3 Assessing the capability of the land

The significance of the soil for the various kinds of production is assessed in two different ways.

3.3.1 Empirical method

This has two stages. In the first, inductive, stage, yield-data are obtained and are deemed to apply to a classificatory group of soils, or mapping-unit, as a whole. In the second stage, this data is used to deduce the productivity (at various inputs) of a particular member of the group or at a particular place in the mapping-unit.

In the first stage the yield-data are obtained by various procedures, both qualitative and quantitative. An example of qualitative procedures is the use of farmers' opinions about the relative merits of different soil types for various crops, as in the soil suitability classification for the island of North Beveland (STEUR, et al., 1963). Another is the use of the opinions of sports clubs about the suitability of particular soils for sports fields (NEDERLANDSE SPORT FEDERATIE et al., 1969). So also is the development of the surveyor's preliminary hypotheses about the ratings of the soils in his area, on the basis of observation and experience.

In the quantitative procedures the records of farmers, commercial institutions and research organizations can be used. An example is the ranking method of DE SMET (1961), first applied in the Dollard area of Groningen and in Drenthe. Various mapping-units are ranked according to yield of any particular crop, with known management practices over a number of years. Earlier examples are the "best-farm method" of VAN LIERE (1948) and the "poor-site method" of DE BAKKER (1950).

Alternatively, trials are established or observations made on the soil types concerned. Three examples are the investigations into the growth of asparagus by VAN DAM (1967) on six different soils, the good correlation of tree growth with some soil groups as found by VAN LYNDEN (1967) and the determination of the suitability of a wide range of soils for tomatoes by VAN DAM and VAN DER KNAAP (1968). The results of such trials and observations, however, are more commonly used in the second, or rational, method to be described later.

This empirical method is realistic, and applicable locally, indicating the "net effect" of all physical factors there. However, the information obtained is limited to the economical and technical circumstances of the time and place, and if those should be changed, the conclusions may no longer be valid. A more fundamental drawback is the possibility of faulty inductive reasoning in the first stage. Thus, because the method is based on previously determined classificatory-units or mapping-units of soil, we must rely on the relevant attributes varying less within the class (or mapping-unit) than between different classes (or mapping-units). The relevant attributes may not vary in this way because the attributes upon which the classes or mapping-units were based are not necessarily those relevant to the forms of use concerned.

The method is primarily a test of the usefulness of the classificatory or mapping units, and only secondarily an assessment of the capability of the soil. Its real value is that it can help to provide the information required in the rational method now to be described.

3.3.2 Rational method

Here (HAANS and HOUBEN, 1967, VINK and VAN ZUILEN, 1974) the relevant site-conditions and limitations are identified. In order to do so, a knowledge of processes is sought and used.

Stages. The five stages are:
— identifying any site-conditions which affect the productivity;
— determining the levels of the site-conditions which, together, will result in the required level of productivity;
— assessing, from the features of the soil, the actual level of site-conditions;
— determining the general disparity between the actual and the ideal, in terms of the extent of disparity for each kind of site-condition: Such disparities are the limitations to be removed, in order to achieve the required productivity;
— identifying the most relevant site-conditions (i.e. those, which, for a particular form of use, in the range of soils and environmental features concerned, usually show the greatest degree of disparity between actual and ideal). This fifth stage is feedback to

the first stage and further attention can be focussed on those relevant site-conditions when considering other soils in the range concerned.

Requirements of the method. In this rational method the five variables of the integrated approach (see p. 10 and Fig. 1) are involved, namely, *factors, features, inputs, site-conditions and payoffs.*

It is clear that, in any scheme involving the transformation of data between these variables, in addition to knowing the purpose in the transformations, we must also know the relationships of the variables. For this, we must be able to express each of them in comparable entities. Put more formally, there are certain requirements which must be fulfilled for the method to be successful, viz.:

— the qualitative term for each different expression or kind of each of the above five variables (e.g. the payoffs related to a certain use of land, and the site-conditions involved);
— a scheme of quantification for each such term;
— a knowledge of the relations between the five variables, in those quantitative terms;
— a knowledge of the desired levels of productivity in each kind of production and of the corresponding levels of the other variables.

Procedures used. In the first two stages (identifying the relevant site-conditions and determining their required level for some purpose) a knowledge of the processes of production is required.

We can determine the effect of the environmental factors, or of the soil features, on the productivity in a variety of local circumstances. By considering these effects, we induce the types of site-conditions involved and the optimum levels of those conditions. The aim, in the words of VINK (1966), is, "by ascertaining the nature of the differences in suitability", to surmise both the processes involved and the conditions most closely affecting them. The data is obtained in the same way as in the empirical methods, but it is used to elucidate the processes and to identify the site-conditions rather than to estimate the capabilities of a particular site directly.

For this, a wide enough variety of situations must be examined to ensure a range of values of the various factors or features, so that the effect of each factor may be assessed. The selections may be at random — e.g. the testing for possible correlations between chemical features and tree-growth (VAN LYNDEN, 1967). Usually, they are deliberately chosen to provide a range of values for each of as few features as possible; examples are the investigation in North Beveland into the effect of the depth of sandy topsoil on the yield of summer wheat (STEUR et al., 1963) and the study of the effect of soil compaction on the development of roots (HAANS et al., 1973). Further examples are the comparison of three soils of different texture on potato production (HOEKSTRA and VAN WALLENBURG, 1967) and the comparison of the effects of different water-status on grassland vegetation (DE BOER and PONS, 1960).

A drawback of these procedures is that, although an estimate may be made of the effect of a particular factor or feature, such a factor is still operating within the context of many others. Their interactions must be recognized and known if the effect of the factor is to be assessed properly and a knowledge of the processes is to be obtained. The importance of the interactions is brought out in many of the field studies; examples are the study by STEUR et al. (1963), that by HOEKSTRA and VAN WALLENBURG (1967) and in the fact that VAN LYNDEN (1967) obtained better correlations between single factors and tree growth for soils within groups than for soils over the whole range. Moreover, when the information gained from the first two stages is applied, it is difficult to predict the effect of many different site-conditions acting together. Their interactions are complex. Such complexity, as pointed out by HAANS and WESTERVELD (1970) is well illustrated by the study of VAN DAM and VAN DER KNAAP (1968) on earliness in tomatoes, wherein the texture and moisture status of the soil and the temperature, humidity and darkness of winter were all interwoven.

From the information so obtained on the effects of various individual factors, the possible processes to account for them are formulated, and any site-conditions involved are identified.

Further progression through the five stages requires a knowledge of the desired levels of productivity and a knowledge of the relationships between soil-features and site-conditions, and between site-conditions and productivity. No formal procedures are used for any of these, as discussed later.

The site-conditions. As a result of the procedures described above, certain site-conditions (or "quality" as it is termed in the American literature) have been identified as sufficiently important in the Netherlands to be the basis of rating schemes for various forms of land-use. They are presented in Table 3 together with further information about them, which it is useful to consider here, viz.:

— whether or not there is a scheme of quantification i.e. whether or not various levels, degrees or magnitudes of the site-conditions are recognized;

— whether or not the desired level, degree or class of site-condition has been determined;

— whether they refer to the basic biological (or mechanical) productive processes or to the system of management;

— whether they refer to soil-chemical conditions or to soil-physical conditions.

For all eight site-conditions, gradations in the limitations (away from the ideal) are recognized. However, only two of the site-conditions are expressed quantitatively. There

Table 3. Site-conditions adopted in Dutch approach.

	Regarded as relevant for				Levels or gradations		Desired level determined	Refers to		Nature of condition	
Site-conditions	arable farming and hortic.	pasture production	forestry	recreation	recognized	quantitatively expressed		basic processes	management system	chemical	physical
Drainage status	×	×	×	×	×		×	×			×
Moisture supply	×	×	×	×	×		×	×			×
Workability	×				×		×		×		×
Structural stability	×				×		×		×		×
HCl-reaction/ lime content	×				×	×	×	×		×	×
Bearing capacity		×			×	×	×		×		×
Spring earliness	×	×			×		×		×		×
Nutrient status			×		×		×	×		×	

is no inherent reason why the others cannot be expressed quantitatively; for example moisture supply could be expressed as a function of the moisture holding capacity of the root-zone and the hydraulic conductivity between the root-zone and the water table (the practical problem of measuring it is another matter).

Nevertheless, for the other six site-conditions such schemes of quantification have not yet been devised or systematically elaborated for all soils. Clearly, the desired level, degree or magnitude have been decided here in qualitative terms. It remains questionable however, if it is possible to express level or degree in qualitative terms for all single conditions.

Four of the eight site-conditions identified can refer to the basic biological or mechanical process of production and four refer primarily to management-practices. The latter are more likely to change with time than site-conditions concerned with basic processes. Who, twenty years ago, would have given to bearing-capacity its present importance?

It is significant that of the eight kinds of site-conditions used as the basis of the rating-system, only two are to do with chemical features, whereas six can refer to physical features. One reason is that the relatively permanent features of the soil are more suitable than those which can be easily and frequently changed. Another is the high fertility status of Dutch soils.

Are the requirements fulfilled? The four proposed requirements, given in detail on p. 19, are in brief:

— qualitative terms for various kinds of each of five variables involved;
— quantification of those terms;
— knowledge of quantitative relations between variables;
— knowledge of desired levels of variables.

These may be considered in turn.

Many of the terms for the different expressions of each of the five variables are available, but not all — for example, the terms of pay-offs in recreation are not yet established.

There are schemes of quantification for most of the various kinds of factors, features, inputs and products. With site-conditions, however, (the important link between these variables) only two out of eight are expressed quantitatively. Yet the gradations in limitation are recognized for all eight. Consequently (because such gradations require a scheme of quantification) it follows that an *informal* quantification, or at least, classification, has been made for the other six site-conditions.

There are, of course, *formal* procedures for determining the relations between factors or features at one extreme and productivity at the other, as in all the experimental work, but no formal procedures are used for determining the relations between features and site-conditions and between site-conditions and productivity.

No formal statement of the desired levels of productivity has been noted. Nevertheless, the desired gradation in limitation (i.e. desired level) for each of the various site-conditions has been decided. Because this decision could have been made only with a knowledge of the desired level of productivity, it is concluded that such a level has been decided informally.

Three important steps in the process of assessing the capability of the land (quantifying some of the site-conditions, interpreting both features and productivity in terms of the site-conditions and determining the required levels of productivity, site-conditions and features) are done informally, subjectively and with unknown reliability.

3.4 Processes and hazards

Amongst the processes operating in the land, we must distinguish two overlapping sets. One comprises those former and present processes which have resulted in the various soil-features and their distribution in the landscape, and the other is the present processes which determine the productivity and stability of the system.

The Dutch have always been aware of processes of the first set, originating a hundred years ago with Staring and developed more recently by Edelman. Examples of the studies inspired by this outlook are those on sedimentation, peat-formation, the chronology of late Quarternary land-features, and the influence of ground-water movement on soil features (KNIBBE, 1969). These studies have allowed the distribution of the various features to be predicted.

However, less attention has been paid to the processes of the second set, and there have been few studies on the stability of the ecosystem. The obvious exception, of course, is the possibility and control of high water-table and flooding, and to this, a great deal of attention and money is continually being given on a national scale. Also, people are aware that, with changing systems of management, some soil-features may be more liable to deteriorate and that a higher standard of site-conditions is required, e.g. bearing-capacity.

3.5 Socio-economic aspects

These are excluded from direct consideration in the Dutch approach. Nevertheless, they have great influence on it because they constrain its purpose, scope and application.

In the intensively-used Netherlands, changes in, or decisions about, the kind of production in any area are greatly influenced by socio-economic factors as distinct from physical factors there. The influence of the soil is exerted largely on the choice of the management practices to attain and to maintain the already-chosen kind of production. Consequently, the main purpose and scope in the Dutch approach is to identify the soil-limitations which must be removed, how to do so, and the cost.

Socio-economic factors are strongly involved, sometimes over-riding.

4. THE VICTORIAN APPROACH

The approach of the Victorian Ministry for Conservation is presented in the standard series of the Soil Conservation Authority published as Studies of the Land, with basic information, general recommendations and a map at the scale of four miles to the inch (approximately 1 : 250,000).

4.1 Land-features considered

The following features are recorded, their relationships noted and their integrated effect on landuse considered:

4.1.1 Soil

Attributes. The following attributes (with respect to the sequence, depth and thickness of horizons) are observed semi-quantitatively at all sites examined:

colour, field texture, structure, organic matter, stratification, consistency, porosity, roots and hyphae, moisture, sesquioxides, carbonate, gypsum, salt and fauna.

Quantitative laboratory estimates are made of the following attributes on samples taken at a few selected places:

particle-size distribution, pH value, chloride content, organic carbon content, carbon/nitrogen ratio, total phosphorus, available phosphorus, total potassium, exchangeable calcium, magnesium, potassium, sodium and hydrogen, pF moisture curve.

Classificatory systems. Four have been used. One is based on the system of HALLSWORTH et al. (1953). It is similar to the Netherlands system, being general-purpose, modal, based on overall similarity, polythetic, and with selected criteria at particular categorical levels. However, the class-boundaries are not defined, so that it is less reproducible than the Netherlands system.

Another (ROWAN and DOWNES, 1963) is special-purpose, non-modal and monothetic with defined classes. Because the attributes were chosen for relevance it is useful in the wheat-growing area for which it was devised.

A third (ROWE, 1972) is a simplified form of the first system, although the nomenclature is based on that of NORTHCOTE's system (1960). The latter itself is the fourth, general-purpose, non-modal, monothetic and with strictly defined classes. It is comprehensive for Australian soils, objective and has high predictive ability for some features, but it may not be relevant for all circumstances.

4.1.2 Climate

In each Study, this is considered in terms of all or most of the following features:

Rainfall	— average annual — average monthly	for all stations
Temperature	— average annual mean — average monthly mean — incidence of frost	for all stations, or estimated from regression lines of temperature with altitude
Light energy	— estimated average monthly values for daily incident solar radiation	for selected stations
Relative humidity	— average annual 09.00 am values — average monthly 09.00 am values	for all stations
Wind	— annual roses	
Estimated potential evapotranspiration	— average monthly values estimated by Thornthwaite's modified formula	for all stations with temperature data

From this data, average annual isohyets and isotherms are constructed for the area. For selected stations, graphs are prepared which show the monthly distribution of rainfall, temperature and estimated potential evapotranspiration.

4.1.3 Geological and physiographic aspects

In all reports, the regional geology of the area as a whole is described in terms of history and distribution, and the physiography in terms of drainage systems and depositional systems. In most reports, the major physiographical divisions of the area are listed; for each, the geology is described in more detail and the history of the development of the landscape is recounted. If certain features are thought to be important for landuse — for example, the salinity of water in aquifers — then such data is presented.

Officers try to present sufficient information for a landscape approach (the recognition and delineation of areas with a consistent pattern of land surface) and to allow the parent material of the soils to be identified in broad terms.

4.1.4 Vegetation

This is recorded and characterized in terms of the structure of the plant community (form and arrangement of the individual plants) and of the floristics (species present). It is classified at two levels of structure, the formation and subformation, and at three levels of floristics, the alliance, association and subassociation (BEADLE and COSTIN, 1952).

The association is the basic unit of classification and is a plant community of which the dominant stratum is uniform with regard to the presence and proportion (within defined limits) of the chief species and which exhibits a uniform structure as a whole. Subassociations are characterized on the basis of the subordinate stratum. Floristically related associations of similar structure may be grouped together into an alliance, on the basis of one or more plant species.

Alliances are further grouped according to structure into subformations and formations which are already-established classes based on the life-form of the dominant species. Examples of the latter are bog, heath, tussock, grassland, savannah woodland, and monsoon forest.

The classification is, therefore, compound. At the higher structural levels, it is intrinsic and monothetic and the classes are already established on criteria selected for an assumed general relevance. At the lower floristic levels it is extrinsic, and the classes (alliances) are based on species selected for their relevance for some particular purpose, after the basic units (the associations) have been identified. Such a selection depends on understanding the relations of the various species to the environmental features and site-conditions.

The predictive ability of the system for the chosen features of the vegetation will always be high. It is hoped to have some general relevance because of the broad relationships between structural classes and site-conditions and it is expected to have a high relevance for a few particular uses because of the floristic classes.

In short, the vegetation is used as an indicator, but for this, clearly, one must know its environmental relation.

For the approach to be successful, there must be at least sufficient remnants of the vegetation to allow surveyors to build up an overall picture of relations and to surmise what the original vegetation used to be.

4.1.5 Inter-relations of the land-features, and their integration

The various features at particular sites are noted and close relations over a limited area are induced. These form the basis of the more detailed mapping-patterns which are recorded in the diagrams of the mapping-units and are used as an aid to mapping. Also, the general relations over broader areas are induced; they are recorded in diagrams, for example vegetational structure as related to wetness of site.

The general and detailed relations are used together in order to allow an understanding of the processes operating. Furthermore, the features are interwoven, that is, the data on them are integrated. Two examples follow from south-western Victoria.

There, plant-growth is restricted by cold winters and dry summers. The combined effects may be assessed by considering, in turn, the limitations imposed by each, from an arbitrary maximum, on the growth rate of a particular plant species. The curve for incoming radiation through the year is taken as the first approximation of the curve of growth-rate. This is modified according to temperature on the basis of known relations of temperature and growth-rate for that species. It is further modified according to moisture-stress, which is estimated from a comparison of potential evapotranspiration and rainfall. The result is a graph of estimated potential growth-rate through the year for a particular species at a particular place.

The other example is the interaction of soil features with climate and with depth of root-system. Thus, in the 600 mm average annual rainfall zone, the low summer rainfall restricts plant growth, so that an impermeable clayey layer in an otherwise sandy soil is beneficial for shallowly-rooted plants by holding the water near to the root zone during early summer. In the 900 mm rainfall zone, however, that feature is not benificial because of water logging during winter.

Such interactions are described in the reports, to encourage the readers to make their own assessment of the significance of the various features.

4.1.6 Mapping

Mapping-units used. These are areas each with a characteristic pattern of the various land-features; the patterns are in the form of a repetitive sequence of certain values of the features — for example, a topographic sequence from crest to hollow and carrying a particular sequence of soil and vegetation.

There are different categorical levels of pattern according to the degree to which the various features can be correlated in the sequence, and hence to the detail in which the sequence can be described. Each level of pattern is associated with a particular scale of mapping. The mapping unit with pattern at the lowest level, highest covariance, capable of most detailed description and with most detailed scale of mapping, is the "land-unit". Others, with pattern at progressively higher level and with decreasing covariance, detail and scale of mapping are "land-system" and "land-zone" respectively.

A land-unit is an area where, for all the features which vary at all, the various values have a particular range and are consistently related to each other. An example is an area with a sequence of soil and vegetation with topography on a certain parent material in the same climatic zone (Appendix 1A). A land-system is an area where more than one, but not necessarily all, of the features which do vary, each have a particular range of values, and those values are consistently related to each other. An example is the same landforms extending over a range of climate (Appendix 1B). A land-zone is an area where only one of those features which vary, must have a particular range of values, but these values are not necessarily consistently related to the values of other features. Thus, the boundary of a land-zone coincides with the boundary of a major change in one environmental factor — for example, the boundary between upper montane and sub alpine zones.

Arbitrarily defined segments of these patterns may be recognized, and areas of them are termed "components". The most precise are the land-unit components (Appendix 1A). They are areas each embracing that recognizable part of the local sequence which does not warrant further subdivision for management and production in foreseeable types of use. Land-system components (Appendix 1B) have a limited range of values appropriate for some features, but an indefinite range for the other features which are not related to the sequence.

Because the usefulness of the mapping-units depends partly on the predictive ability, the more restricted the range of values for the various features in the sequence, the more useful is a mapping-unit. Nevertheless the covariance of the features in the sequence is more important than the range of values, for three reasons. Firstly, the correlation allows one to predict the nature and location of the land-features from a single feature which is easily determined — a valuable mapping-tool. Secondly the correlation allows a general-purpose system of appraisal to be successful; thirdly, the consistency of patterns within a mapping-unit allows one to understand the processes, and therefore the hazards, more easily.

Technique of surveying and investigation. With each of the mapping-units there is linked a stage of the survey.

The first stage is to recognize the land-zones by rapid traverses and by aerial-photo-interpretation and to delineate them at the scale of about 1 : 500,000. The parent materials, topography, soil and vegetation are briefly identified at a high categorical level in the field. Available information on climate, parent-materials and topography is then assembled and transferred to plans at the scale of about 1 : 100,000. This reveals the distribution of these features and any relations between them, and helps in identifying the factors most influencing any patterns.

The further course of the survey depends on the simplicity and clarity of patterns within the land-zones.

With relatively simple or clearly separated patterns, as in areas with contrasting land-forms, we may proceed to the land-system stage by identifying, in each land-zone in turn, sequences of a feature (such as a land-form or vegetation) indicating or determining the more detailed patterns. Traverses at about 15 kilometres apart, with aerial-photo-interpretation, may be used. The land-systems can then be defined in concept and subsequently are delineated from aerial-photographs at 1 : 100,000 or from any maps which show the required boundaries (for example, plans of geology or of old land-subdivisions or of peat). The land-unit stage follows. This is photo-interpretation with field traverses at about 8 kilometres apart, in order to observe the local sequences of land-features, to recognize the chief detailed land-types at about the level of the vegetation association and to observe changes in them with those factors which gradually change over the area as a whole. After deciding on suitable land-units in this way, each may be examined in turn, so as to define their components and observe the relationships. The hypothesis that there is a consistent pattern is tested by repeating an examination along the line of variation of the most variable feature, for example from ridges to valleys. The land-units may be delineated from the aerial photographs at 1 : 100,000 with check visits to the field.

If the patterns within a land-zone be diffuse, however, we must start straight away making a detailed examination of local sequences, in order to find out the way in which they change from one to another and which factor causes the change. In this way, appropriate sequences for defining land-units, and an appropriate generalization of sequences for defining land-systems, can be found.

If required, the land-unit-components can be delineated, by the use of diagnostic information gathered during the previous stages of survey.

Importance of relations and processes to a mapping programme. Because the usefulness of the mapping-units depends on the correlation of land-features, the aim in mapping is to recognize and to delineate areas in which the values of the several features are consistently related.

This will be made easier by understanding the reason for a high covariance of those features which do vary. The reason is that the covariance is more likely where fewer of the independent factors vary. Thus, where only one independent factor varies, the variations in each dependent feature will reflect only the variations in that factor, and so all the dependent features will covary. The surveyor can recognize such areas more easily, first by assessing the degree of relative dependence and independence in the features there, then by determining the circumstances under which fewest of the relatively independent factors will vary, and, thirdly, by selecting some diagnostic feature for recognizing the area concerned.

The first of these operations requires an understanding of the causative relations between the features of the land. The second will be easiest in areas with sharp discontinuities in an independent factor — e.g. with sudden changes in rock and topography. Where the changes are gradual, however, the surveyor must investigate the relations between the various land-features, as described above, in order to find out the reason for their variation. When an area has been recognized as likely to show high covariance, this hypothesis must be tested as described above, and, if necessary, modified or discarded. The third operation — selecting diagnostic features — can then follow and be applied.

Now, the common denominator for success in each of these stages is that the surveyor must understand both factual and causative relations between the various features of the land. The latter requires a knowledge of the processes involved, and these may be induced from a knowledge of factual relations.

A characteristic feature of the Victorian approach, therefore, is a knowledge of the relations between the features of the land, with an attempt to surmise the processes.

4.1.7 Is the mapping valid?

The essence of the mapping technique, indeed, the basis of the whole approach, is the high local covariance of those features which do vary; success depends on this and cannot be assumed until it has been verified.

This is attempted by repeating the field examinations of particular sequences. Data for testing is thus obtained, but so far, for two reasons there has been no statistical treatment of it to determine the degree of covariance.

First, we have assumed that the required number of formal observations for a statistical approach has been precluded by time and cost, and, instead, surveyors rely on the large number of informal observations of a few features when traversing an area. Secondly, the statistical treatment is more easily done with quantitative terms, but these have not been available for some of the features.

Nevertheless, whatever the reasons, without such treatment the covariance remains in doubt; therefore, the various examples of the Victorian approach continue to rest on unproven assumptions.

4.2 Types of landuse considered

They are shown in Table 4, together with the kinds of production involved plus the management practices to avoid deterioration of the land.

4.3 Assessing the capability of the land

This is shown in two examples.

In the report on a large wind-erodible semi-arid area producing wheat and sheep (Rowan and Downes, 1963) the yields in wheat-trials were examined, and the chief kinds of requirements which appeared to be generally limiting there were induced as certain nutrient elements and the moisture in the soil during the month of October. No levels of requirements were reported, and attention was focussed on the *comparative* ability of the various land-types to reduce these general limitations. The authors based their estimate of this ability on a particular feature (texture of the top soil) which was thought to affect those conditions. For sheep-pastures the technique again pointed to

Table 4. Types of landuse considered in Victorian approach.

System of use	Kind of production	Desirable management practices
Agriculture	market-gardening fruit-growing mixed farming dairying beef-cattle raising sheep-raising (meat) (wool) wheat-growing	(I) arable permitted, no conservation measures needed (II) arable permitted, conservation measures needed a. agronomic means sufficient b. structural works also needed (III) arable not feasible because of physical impediment (IV) arable not permitted grazing only, conservation measures needed a. agronomic means b. structural works also needed
Forestry	softwood production hardwood production	
Water-supply	surface water-supply underground water-supply	
Mineral production	various	those not impairing the capability of the land for the chosen kind of production
Parkland	wildlife conservation outdoor recreation reference areas educational areas	
Multiple use	more than one primary kind of production	
Land-bank	no present primary kind of production, but any eventual primary kind of production	those not impairing the capability of the land for any kind of production

the importance of texture. Texture of the surface soil was taken to indicate the supposed requirements in that erodible wheat-and-sheep area.

In south-western Victoria, where the chief form of landuse is sheep-raising with some forestry, the most limiting of the site-conditions required for pastures were identified as certain nutrients and moisture in the topsoil in late spring. This conclusion was drawn by ranking certain land-types according to the yields obtained from them in trials, formulating processes which could provide an explanation for such an order, in the environment of the area, and identifying various site-conditions involved. Then, by interpolation or extrapolation of those land-types on the basis of the site-conditions the relative ability of a range of land-types to reduce the limitations was predicted. For pines, too, in that area, a similar technique was used.

No formal statement of a comprehensive range of required site-conditions has been noted, in kind or degree, nor a comparison with the features of the land in comparable terms. At best, there is only an identification of the most common kind of gap between the ideal and the actual in the area, and an estimate of the relative ability of various land-types to fill the gap. True, in doing so, thought may be given to processes and functional relationships. Nevertheless, one is left with the impression of fitting various land-types into an hypothetical framework of observed relationships between groups of features and their performance, with a guess as to which individual features should be used for making the framework. It is basically an empirical assessment.

4.4 Conservation aspects

Emphasis is placed on the processes and hazards of land-deterioration. The hazards are those involved in each type of use, and accruing to the capability of the land for that and any other type of use. From this, the compatibilities for various forms of use may be estimated, safeness of management practices assessed and the means of restoration may be determined.

Two examples are given.

The first is the use, for farmed areas, of a version of the land-capability-classification of the United States Department of Agriculture (see top of right column of Table 4). In it, land is distinguished according to the management practices and mechanical measures which are permitted or required for the prevention and control of soil erosion.

In determining to which class an area belongs, surveyors have relied on the obvious connection between erosion in the landscape as a whole, and the length and degree of slopes there, plus the density of surface vegetation. So, the classes have been identified on certain slope-categories, assuming an average standard of ground-cover. Now, however, MILTON (1973) has shown the importance of seepage in the mechanism of gully-formation in Victoria, as well as scouring. In the affected areas, seepage is controlled not only by slope and by density of ground-cover, but primarily by the life-cycle and root-system of the vegetation. This knowledge has given a better basis for identifying the land-classes.

The second example is a land-appraisal in a catchment in the Grampians area of Western Victoria (LAND UTILITY ADVISORY COUNCIL, 1969; see also SIBLEY, 1967).

There, the chief forms of landuse are pastoral, forestry, recreational and, particularly, water supply to Rocklands Reservoir. This is the major storage in a system supplying water to 70,000 people in a few townships and on some 10,000 farms, for stock, domestic and irrigation purposes. A proposal to develop about 15,000 hectares of forested land near the reservoir into farms would have involved clearing the trees (deeply-rooted perennial plants) and replacing them with pasture plants which, because of the soils and climate would be restricted to shallowly-rooted annual species.

In appraising the land the effect of such development on the salinity of the water-supply was considered. Standards were established for acceptable limits of salinity. Near the edges of the reservoir are geological formations of high salt content. An analysis of the ecosystem indicated that to maintain a satisfactory low level of salinity in the reservoir, the deep roots of trees were required to extract as much water as

Table 5. Determination of priorities of landuse in Tooloy.

Aspects of the use of the land		Agriculture				Mineral production	Forestry		Water supply		Parkland: conserving		Parkland: recreation + scenery	Land bank
		sheep	cattle	mixed farming	honey		hard wood	pines	surface	under ground	wild life	natural environment		
Capability of the land	high										×			
	medium	×			×		×	×		×		×	×	×
	low	×	×	×		×	×	×	×					
Costs to productive stage		← $ 110 per acre →												
Hazards involved		← low except for drought →					← fire →							
Need for increased production		← low →					← high →							
Alternative means of production		← high →					low	med.	low		← low →			
Compatibility (items with same letter are compatible)		a	a	a	ab	d	b	c	ab	ab	b	b	b	b
Priority for that kind of landuse		4	4	4	3	4	2	4	4	4	1	1	3	3

possible by evapotranspiration during the dry summer to allow for winter recharge. The proposed alternative, shallow rooting annual pasture, would not remove sufficient soil water to prevent significant movement of salts during the wet winter period.

The land, although *capable* of pastoral development (as it happened), was *not suitable* for the proposed development, because of the effect on its capability to supply water of good quality.

Two principles are brought forth. One is that to achieve a purpose of land-appraisal (to know the most worthwhile use of the land) we must determine the hazards involved in each type of use and accruing to the capability of land both in that type of use *and in any other type of use*. The other is that, in order to do so, the processes must be known.

4.5 Socio-economic aspects

Nearly one third of Victoria still remains as Crown Land uncommitted to any particular system of use. Some of this land is capable of more than one kind of production with normal inputs. On it, an appraisal should proceed to the point of estimating the relative worth of different systems of use, to allow the consequences to be known, and a choice to be made.

This requires, as well as a knowledge of the capabilities of the land for various kinds of production, and of the hazards involved, a knowledge of the need for the product (or benefit) now and in the future, and of the costs of producing it, both from the land appraised and by alternative means.

Although some information is often lacking, it has been found useful to apply a full formal procedure for considering it, because this has allowed a better decision with whatever information is available. A suitable procedure is an optimizing technique based on a matrix about:
— capabilities of a particular area for various kinds of production,
— hazards involved,
— compatibilities of the various systems of use and the management required for safeness,
— present and future benefits and requirements,
— costs of production in both the proposed means and alternative means.

An example is in Table 5 for a particular type of land in Western Victoria.

It is interesting that any difficulties are similar in principle to those in the Dutch approach — for example, establishing terms for expressing productivity and comparable terms for different kinds of production.

5. COMPARISON AND CONCLUSIONS

5.1 Comparison of approaches

5.1.1 Land-features, their relationships and distribution

In both approaches, a number of land-features and their relations are considered. In the Victorian approach, the range is more comprehensive and the relations are more important. The Dutch are more thorough in their treatment of one particular feature — the soil.

The two approaches are generally similar in the range of soil attributes, both in the field and laboratory. In the Netherlands, particular attention is given to the groundwater, which is classified and mapped independently, although still regarded as a soil-feature. Only one soil classificatory system is used — general-purpose, workable and useful because of its comprehensive coverage with unambiguous classes wherein the attributes are likely to covary. In Victoria, a number of systems has been used — one similar to the Dutch system, but ambiguous, another precise but not always relevant, and some special-purpose of restricted applicability.

Of the other land-features, only geological aspects are considered in the Netherlands, and mainly as an aid to mapping the soils. In the Victorian approach, climate, geological features, topography and vegetation are included as well as soil, and the mutual relationships of all are examined. The latter are used as an aid to mapping and also to allow an understanding of the ecological processes, from which knowledge the various features are interwoven, so that their integrated effect on productivity and required management practices may be known.

The units and techniques of mapping differ greatly. In the Netherlands, the basic mapping-unit is an area of a soil-class at the lowest categorical level. As these classes have already been established comprehensively for the whole country, so also are the mapping-unit is an area of a soil-class at the lowest categorical level. As these classes soil profiles there, identifying various parts of the range in terms of the already-established classes, and then locating and tracing the boundaries by means of free survey (STEUR, 1961) based on the landscape approach.

By contrast, in Victoria, the mapping-unit is an area with a characteristic pattern of land — an area with a repetitive sequence of certain values of one or more land-features. Since the usefulness of these units depends on the degree to which the features are correlated, the immediate objective in mapping is to recognize areas where the covariance is the highest locally. This involves finding out the causative relationships of the land-features so as determine where fewest of the independent factors are likely to vary, testing the covariance there, and selecting suitable diagnostic features for mapping. These are different premises and procedures from those used in the Netherlands. Even the Dutch soil associations and the pattern of the Victorian approach are different, the one having a random distribution of its component units, but the other being a consistent sequence.

5.1.2 Types of landuse

In both approaches many types of landuse are considered, and the range is about the same. Also, the changes have been in a similar direction, from predominantly agriculture in the early days of each Institute to a diverse range including forestry, recreation, water supply and building, now. However, there has been a greater emphasis in the Dutch approach on the intensive types of use, e.g. horticulture.

A more deep-seated difference is the greater weight given in Victoria to certain aspects of landuse — i.e. to the kind of production (sheep, cattle, wheat, water or timber) and to the management practices to maintain the stability of the land. By contrast, more attention is given in the Netherlands to the other aspect — i.e. to the management practices or soil treatment required to attain the chosen kind and level of production.

5.1.3 Assessing the capability of the land

This relating of the input and the output, the central feature of any land-appraisal, is handled more thoroughly, logically and effectively by the Dutch than in the Victorian approach, where it is little more than a guess based on local observation. The different objectives must be remembered. In the Netherlands, it is to determine the main soil limitations to high productivity. In Victoria, it is to know the approximate plane of productivity with the inputs that are feasible. Nevertheless, similar methods are required.

Originally, the Dutch exploited to the full the empirical method by which yield-data obtained on a certain soil were deemed to apply to any other member of the group to which that soil belongs. However, the somewhat restricted applicability of the results have led to attention being concentrated on the rational method of identifying the chief limitations. The five stages of the method (p. 18) are, basically, certain manipulations within the framework of the scheme for the integrated approach (Fig. 1), the objectives being to identify the processes and the most relevant site-conditions. The four things required in the method (p. 19) involve, basically, establishing the qualitative and quantitative terms so that the five variables of the integrated approach can be related to each other, and the desired levels of each determined. However, a close inspection of the method as now applied reveals that not all of these requirements have yet been met for the mapping units rated, and that some of the manipulations are made informally. Nevertheless, much of the guesswork has been removed and the framework is there for a completely rational method.

In the Victorian approach, however, there is only a cursory application of the empirical method with a bit of the rational method informally brought in. Observed relationships between land-type and production are interpolated or extrapolated. In doing so, there may be an attempt to surmise the processes in order to identify the most relevant features for ranking the land-types, but there is no formal scheme for relating land-features, site-conditions and productivity in comparable terms.

5.1.4 Conservation aspects

By contrast, the Victorian approach is strong in processes and hazards. The hazards are those involved in each type of use and accruing to the capability of the land for any type of use. An example is the adoption of a modification of the land capability classification used by the United States Department of Agriculture, whereby land is classified according to the measures permitted or required for the prevention and control of soil erosion.

Furthermore, a knowledge of the erosion processes under Victorian conditions is used to determine how to allocate the land to the classes of this system.

Beyond this, however, the ecological processes operating in the land are studied so that the broad consequences of landuse may be foreseen. This is illustrated by an investigation of the suitability (as distinct from capability) of land for agricultural development in a water supply catchment.

In the Netherlands, apart from the great attention given to the ever-present danger of high water-table and of flooding, there is little emphasis on hazards. With changing systems of management, however, some aspects of deterioration are being reconsidered, for example, the bearing-capacity of the soil.

5.1.5 Socio-economic aspects

The need for particular kinds of products or benefits, and the different ways and costs of producing them, have a big influence on the Dutch approach, because they restrict its purpose, scope and application from the outset. That done, however, they are excluded from further consideration. In the Victorian approach, socio-economic aspects are important in achieving the objectives of the appraisal, and there is a framework for introducing them, but it has not been found easy to obtain the required data.

5.2 Comparison of circumstances, and reasons for differences in the two approaches

In the Netherlands, the soils vary widely because of the variable nature and combination of the materials which give rise to them, but there is no great range of climate and topography. Moreover, the climate is not severe and the topography is flat and low lying, so that there are no severe hazards of deterioration other than those associated with high water-table and with flooding, which, however, are widespread. The density of population is the second highest in the world, the land must be intensively used and the resources are there to appraise it in detail. By the same token, the kind of production from it is largely pre-determined on socio-economic grounds.

These circumstances have given rise to an intensive system of land-appraisal in which the emphasis are on the features and detailed distribution of the soils and groundwater, and on the chief soil-limitations to various types of landuse. From this, comes a knowledge of how the soils can be modified and managed best for the kind of production that has already been chosen.

In Victoria, the climate, parent material and topography vary widely, and with them, the soil and vegetation accordingly. In some places, the severity of the climate and other features, combined with management-practices inherited from another country, have resulted in deterioration of the land. The country is big, the population is sparse (outside the one metropolis) and much of the land still remains unallocated to any particular type of use.

In the system of land-appraisal to which these circumstances have given rise, the relationships of the environmental features are important. They allow the land to be mapped rapidly, and they help in its conservation by providing a means of identifying the processes and hazards, and so of determining the measures to avoid the hazards or to restore the damage. From this, plus socio-economic data, one may come to an opinion on the relative worth of the various forms of use to which, if any, the land should be put.

5.3 Recommendations

The objectives and methods of both approaches are broadly in tune with their circumstances. In both approaches, however, certain points need attention.

In the Dutch approach, the main one is the rational method of estimating the capability of the land. This method has five stages (p. 18), five variables are involved (p. 19) and there are four requirements for it to be successful (p. 19).

However, not all of these requirements have yet been met for the mapping-units rated. Two actions would be useful.

One is to ensure that the four-fold requirement is fully met, viz.:

1. to establish the qualitative term for each kind of each of the five variables concerned: factors, features, inputs, site-conditions and products or benefits,
2. to establish a scheme of quantification for each such term,
3. to seek the relationships between these variables in those quantitative terms,
4. to determine the desired level of productivity in each kind of production and the corresponding levels of the site-conditions and other variables.

The second is for the requirements to be applied, that is, to establish an arrangement for formally proceeding through the five stages, viz.:

1. identifying various site-conditions,
2. determining required levels of them,
3. estimating, from soil features, the actual level of site-conditions,
4. determining the disparity between actual and ideal,
5. identifying the most relevant site-conditions.

The objective would not be to impose a rigid scheme, but to allow the assessor to know where more data is required.

In the Victorian approach, three areas need attention.

The main one is the testing of the basis of the mapping technique and of the whole approach. At present, the covariance of values of the land-features is not properly tested. For this to be done (p. 28), quantitative terms must be established for each of the land-features considered, the number of formal observations must be increased, and statistical techniques applied to the data obtained.

Another area is the assessment of the capability of the land in various types of use. The third area is the development of an optimizing technique for determining the relative worth of various systems of use.

However, these should not preclude attention to process and hazard — the conservation aspects.

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