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LAND CAPABILITY CLASSIFICATION FOR LAND EVALUATION : A REVIEW

Klasifikasi Kemampuan Lahan untuk Evaluasi Lahan : Suatu Tinjauan

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ABSTRACT

Land capability classification has been used for land evaluation for various purposes in many countries in the world. Since developed by the United States Department of Agriculture as a part of the programme to control soil erosion, the land capability classification has been further developed by a number of authors in many countries to suit their requirements. Of the numerous land capability classification have been published, fourteen are selected to be reviewed. The results shows that the aims of the various land capability classification schemes are generally similar: to evolve methodology whereby land may be evaluated for a particular land use purposes. Most of the methodologies were designed mainly for evaluating the capability of land for agriculture, either in narrow (specific) or in broad terms (including forestry, pasture, etc). Three methods of evaluation of data can be identified: Firstly, descriptive methods whereby capability classes or other categories are descriptive solely in words. Secondly, rating, grading or indexing system whereby each attribute is assigned a rate, grade or index and the capability class or other category is defined in terms of the sum of the weighted scores. Thirdly, quantitative methods whereby the relationships between variables are defined in terms of an equation used to obtain a score or index which defines the capability class or other categories. The capability methods also vary both as hierarchical systems and in terms of the number of categories used. They are also vary in terms of scale, and some do not even specify the scales used. Although substantial differences are found among the methodologies in terms of their purposes and detailed procedures, these are all broadly similar in terms of the general approach and activities involved.

Keywords : Land classification, land capability assessment, land capability methodology, land evaluation

ABSTRAK

Klasifikasi kemampuan lahan telah digunakan untuk evaluasi lahan untuk berbagai keperluan di berbagai negara di dunia. Sejak dikembangkan oleh Departemen Pertanian Amerika Serikat sebagai bagian dari program untuk mengendalikan erosi tanah, sistem klasifikasi kemampuan lahan telah dikembangkan lebih lanjut oleh banyak ahli di berbagai negara sesuai dengan keperluannya. Dari sekian banyak klasifikasi kemampuan lahan yang sudah dipublikasikan, 14 klasifikasi dipilih untuk ditinjau. Hasil menunjukkan bahwa tujuan dari berbagai sistem klasifikasi kemampuan lahan yang ada pada umumnya sama yaitu melibatkan metodologi dimana lahan dievaluasi untuk keperluan penggunaan lahan tertentu. Sebagian besar metodologi dirancang utamanya untuk mengevaluasi kemampuan lahan untuk pertanian, baik dalam arti sempit maupun dalam arti luas (termasuk kehutanan, padang penggembalaan, dan sebagainya). Tiga metode evaluasi data dapat diidentifikasikan. Pertama, metode deskriptif dimana kelas kemampuan atau kategori lainnya dideskripsikan hanya dalam bentuk kalimat saja. Kedua, sistem nilai, angka, indeks dimana masing-masing atribut diberi nilai, angka atau indeks dan kelas kemampuan atau kategori lainnya ditentukan berdasarkan jumlah skornya. Ketiga, metode kuantitatif dimana hubungan antara variabel ditentukan dalam bentuk persamaan yang digunakan untuk memperoleh skor atau indeks yang menentukan kelas kemampuan atau kategori lainnya. Metode kemampuan juga beragam, baik dalam sistem hirarki maupun dalam jumlah kategori yang digunakan. Klasifikasi kemampuan juga beragam dalam skala, dan beberapa bahkan tidak mencantumkan skala yang digunakan. Meskipun beberapa perbedaan dijumpai dalam metodologi dalam kaitan dengan kegunaan dan prosedur terincinya, tetapi semuanya secara umum sama dalam pendekatan umum dan jenis kegiatannya.

Kata kunci : Klasifikasi lahan, penilaian kemampuan lahan, metodologi kemampuan lahan, evaluasi lahan

Land capability assessment forms part of the board field of 'land evaluation' defined as: "the process of assessment of land performance when used for specified purposes, involving the execution and interpretation and surveys and studies of land-forms, soil, vegetation, climate and other aspects of land in order to identify and make a comparison of promising kinds of land use in terms of applicable to the objective of the evaluation" (FAO, 1976). Land evaluation requires consideration of not only soil characteristics but of all natural conditions such as relief, hydrologic conditions, etc., which influence the utilization of land, application of techniques and crop yields (Blagovidov, 1960).

Land evaluation is a relatively new concept whose methodologies are contentious due mainly to the complexity of the problem, the multitude of disciplines involved, and the lack of precise definitions and associated misuse of terminology. For instance, the same features of land are sometimes described by different terms, and the same terms may be applied with numerous meanings. For the purpose of this paper, therefore, it is important that terminology and definitions are examined explicitly, including such terms as 'land', 'capability', and 'classification' which can all be interpreted differently.

The word 'land' can have numerous meanings. One that corresponds to common usages, and is most appropriate to the context of this paper is 'the entire complex of surface and near-surface attributes of the solid portions of the surface of the earth which are significant to man; water bodies recurring within land masses are included in some land classification systems' (Soil Conservation Society of America, 1982). Land in its physical aspects may be subdivided into several principal components, notably soil, climate, topography and relief, vegetation and geographic location (Lacate, 1961). Through the principles of land evaluation, however, land as the complex of many interrelated and integrated parts must be viewed as a combined entity and not separately in terms of its components.

The present review has revealed that the concept of 'capability' has not been clearly distinguished from all other related terms. There is a lack of international standardization of terms which refer, or are related, to capability (see for instance, Smyth, 1974) particularly concerning the distinction between 'capability' and 'suitability'.

'Capability' is viewed by some as the inherent capacity of land to support a generally defined land use (Klingebiel and Montgomery, 1961; FAO, 1976), or refers to a range of uses, e.g. for agricultural, forestry, or recreational development (McRae and Burnham, 1981). 'Suitability', on the other hand, refers to the fitness of a given type of land for a particular use, for example, suitability for sugar cane or rice, etc. (Brinkman and Smyth, 1973; FAO, 1976; McRae and Burnham, 1981). However, some authors consider that the two terms are interchangeable, with no essential difference between them (e.g. Vink, 1975). For the purpose of this paper 'capability' is used to refer to "the potential of the land for use in specified ways, or with specified management practices" as defined by Dent and Young (1981). This means capability is more simply an assessment of the relative suitability of the land for a particular use.

'Classification' means ordering or arranging objects into groups or classes on the basis of their similarities or relationships. The product of this process is a classification system, and subsequent placement of objects into the system is called identification (Sokal, 1974). Such identification of objects and their subsequent delineation over an area of land becomes mapping or regionalization. The science of classification is called taxonomy (Bailey *et al*., 1978).

Classification has been applied somewhat loosely in most resource survey fields under all of these meanings. As the term is commonly used in a broad sense, the present author will include all of these related aspects of the classification process, identification and regionalization under 'classification'. It is important to emphasize that classifications are man-made rather than natural, and that a set of objects can be arranged in many different ways according to the classification procedure applied to the data. Although the classification procedure can be carried out in many ways, most writers agree on the fundamental purposes of classification: to provide a grouping which is valid for the scientific activity being undertaken and to allow generalizations to be made about the object classified (e.g. Grigg, 1965; Sokal, 1974; Johnston, 1976).

LAND CLASSIFICATION

The term 'land classification' has been used widely in many different fields of study and hence has some differences in meaning. In this paper, 'land classification' is defined as "the arrangement of land units into various categories based on the properties of land or its suitability for some particular purposes" (Soil Conservation Society of America, 1982).

Land classification implies the development of a logical system for the arrangement of different kinds of land into defined categories, according to the characteristics of the land itself. These characteristics may include those that are directly observable, such as slope gradient, or those that may be ascertained only by inference, such as soil fertility. The systems are often designed to serve very restricted purposes and may stress only certain attributes of land. As land units with similar properties and environmental settings should respond similarly to the same management practices, or to a particular crop, a suitable classification system can increase our ability to generalize, to extrapolate research results, and to transfer management experience.

A comprehensive system of land classification that would serve all purposes can only be developed if our knowledge of all science were, complete and properly integrated. This stage of perfection has not been reached, and may never be. Therefore, several more-or-less pragmatic or 'technical' systems have been developed, based on the fundamental concepts.

Numerous approaches to land classification have been postulated, as reviewed, for example, by Lacate (1961), Mabbutt (1968), Wright (1972), Mitchell (1973), Olson (1974), Whyte (1976), Higgins (1977), Zonneveld (1979), McRae and Burnham (1981), Dent and Young (1981) and Sitorus (1983). This paper is not intended to consider the diversity of these schemes, but selected classification systems are reviewed.

The procedure of land classification varies from one system to another due to differences in principles, assumptions and purposes. Moreover, to achieve the same purposes, the same attributes of land may be integrated differently, being given different weights within unlike combinations (Kellogg, 1951). Most schemes, however, are intended as aids to planning whether to ensure the range of alternatives for selected uses is considered on its merits, or to minimize the harmful consequences of changing from existing uses and to maximize its usefulness.

Most systems achieve a land classification by dividing the land into smaller, more homogeneous units to achieve a simpler and more precise description (Beckett and Webster, 1965). In this 'divisive' procedure the problem is to find a consistent method of delimiting the units on the ground and ultimately on maps.

Two considerations are commonly used for delineating units: recognisability and reproducibility (Beckett and Webster, 1965). Recognisability refers to establishing the identify of the units and requires differentiating characteristics to be selected (Cline, 1949; Beckett and Webster, 1965). The differentiating characteristics should be intrinsic properties of the land to be classified (Wright, 1972). There is an infinite number of land properties which could be selected as differentiating characteristics to be selected (Cline, 1949; Beckett and Webster, 1965). The common approach is to select properties which are visible and measurable, to facilitate field delimitation of units.

Reproducibility appears to be subjectively recognized in many systems and when defined is usually considered in relative terms. According to Beckett and Webster (1965) and Sitorus (2001), reproducibility refers to how similar in their attributes are different occurrences of the same unit. Of special interest in Sitorus (2001) research is whether different occurrences of the same unit are similar and also relatively homogeneous in terms of properties which are related to plant growth, so that they can provide a solid basis for the evaluation of land use potential.

Many boundaries for land classification mapping can be identified from remote sensing imagery particularly the conventional panchromatic aerial photographs. These latter are widely uses in soil and other land surveys, to provide a stereoscopic model of the terrain from which boundaries can be drawn for subsequent checking in the field (Thomas, 1980). Moreover, aerial photography and remote sensing imagery constitute valuable field tools for the acquisition of observable land use data and other land attributes. Air-photos may be employed as base maps and, depending on the scale, the images contain an infinite number of control points allowing extremely accurate location of various field phenomena (Aldrich, 1981).

Conventional land classification has developed in the main in association with soil surveys, and land classification is often used to represent a second phase of mapping based on the interpretation of the soil survey results or soil mapping units. In Canada, this is called soil capability classification (Canada Land Inventory, 1965). Many such second-phase mappings deal with the potential for land uses. However, Zonneveld (1979) objects to the use of the term land classification for those activities which involve evaluation, instead he proposes the use of the term 'pragmatic land classification'.

Land classification poses various difficulties. Most systems of land classification imply that specific bodies of land in the different categories will be shown to scale on maps. Mapping is sometimes very costly and time-consuming, especially if boundaries are drawn with reasonable accuracy in respect of local detail. Thus, for the purpose of mapping, particularly at a small scale, unlike bodies of land sometimes must be grouped into geographic associations or 'complexes', defined in terms of the taxonomic units in the system of classification. In this sense, land classification is an integrative process (Nelson *et al.*, 1978). One of the function of any land classification system is to permit inferences about the objects being classified. In most applications, classification provides a framework for interdisciplinary inventory of the land controlling its capability (Nelson *et al*., 1978).

At least three fundamental problems in classifying land have been identified (Mabbutt, 1968; Zonneveld, 1979). Firstly, there is the problem of the complexity of land attributes, their spatial variations and the intricacy of these relationships which have to be simplified. Secondly, there is the problem of defining the 'extent', and hence location, of boundaries of land areas possessing a large number of attributes varying in different spatial expression, and for which the unit limits may be sharply defined or gradational, forming part of a continuum. Thirdly, there is the problem of association resulting from the interrelationships of adjoining areas, which means that each area is an open rather than a closed system.

THE METHODOLOGY OF CAPABILITY ASSESSMENT

The capability scheme for evaluating agricultural land has been developed by the United States Department of Agriculture (USDA) since half a century ago as part of the programme to control soil erosion (Hockensmith and Steele, 1943; 1949; Hockensmith, 1950; 1953). Capability as a methodology for land use planning, however, was first made explicit in the land capability classification system by the USDA (Klingebiel and Montgomery 1961). This classification system is one of a number of interpretative groupings made primarily for agricultural purposes. One of its aims is to group arable lands according to their potentialities and limitations for sustained production of the common cultivated land. The system involves the application to a land classification of accepted limiting factors and hazard potentials (Klingebiel and Montgomery, 1961; Canada Land Inventory, 1967; Bibby and Mackney, 1969).

The USDA System divides land into a small number of ranked categories according to the number and extent of its physical limitations to crop growth, from the highest category 'class' to 'sub class' and 'capability units'. The capability classes range from Class I, in which soils have no major limitations to crop growth, to class VIII in which soils have limitations which preclude their use for commercial crop production.

The grouping of soils into capability units, sub-classes, and classes is done primarily on the basis of their capability to produce common cultivated crops and pasture plants without deterioration over a long period of time. In short, agricultural capability is defined in terms of the relationship between land properties and known crop requirements, with the overall aim of maximizing sustained crop yield over a period of time, which is a readily measurable variable.

This system is, in fact, derived from an assessment of inherent land qualities based on conventional soil and physiographic data (Thomas, 1976). Although designed for detailed classification of land in a highly developed area, the system has several advantages that make it also suitable for use in a first, broad assessment of the resources of undeveloped areas, as follows. Firstly, as it is based on the evaluation of the nature and degree of limiting physical characteristics, it is conducive to objective, comparative assessment, avoiding personal or regional bias in classification. Secondly, it is based almost entirely on physical land characteristics, and economics are not considered except for an assumption for certain management practices applied. Thirdly, the system indicates the kind of land uses that are adapted in both developed and developing countries, sometimes with modifications to suit local conditions and the availability of data, as discussed by McRae and Burnham (1981). For reconnaissance survey purposes, the system has been used successfully for land capability classification as demonstrated, for example, by Haantjens (1963) in a survey of Papua and New Guinea.

Translated into general terms, the concept behind the USDA approach is that capability classes can be defined for a particular land-use based on the degree of correlation between the physical characteristics of the land and the land-requirement of the use in question.

Whilst the process of land classification is complex, Kellogg (1961) explained that it involved two main stages: firstly, analysis, requiring a study of individual land characteristics (for example, allocating land into slope groups as nearly level, sloping and hilly); secondly, synthesis, in which all the essential date are combined according to the classification desired. This second stage also entails interpretation, whereby predictions are made about each unit of land as an entity, and the assessment of qualities like productivity and fertility.

REVIEW OF LAND CAPABILITY METHODOLOGY

The physical factors affecting land use are generally grouped under three broad headings: climate, relief and soils. In reality, however, there is no clear-cut three-fold division, the interactions between the three phenomena being very important in determining land use possibilities (Bibby, 1973). Of the numerous capability methodologies which have been published, fourteen are selected and summarized in comparative form in Table 1, on which the following review is largely based. The aims of the various schemes are generally similar: to evolve a methodology whereby land may be evaluated for a particular land use purpose. It is notable, however, that in the description of capability classes, most of these classification systems also include the ability of the resource to sustain the productivity of the land use.

Table 1. Comparative summary of selected land capability methodologies for agricultural purposes

Author (s)	Study area	Study aims	Data sources	Method of data evaluation	Categories or land units (in order of decreasing generalisation)	Assumptions	Mapping scales
Klingebiel & Montgomery (1961)/Haatjens (1963)/Oyama (1965)	USA/Papua New Guinea/ Japan	To group (1) arable soils according to their potentialities and limitations for sustained production of the common cultivated crops; (2) non arable soils for the production of permanent vegetation	Soil-Survey maps	Descriptive interpretation based on known or inferred relationships between land factors and the growth and management of crops	8 capability classes (I to VIII); capability sub-class; capability units	14 assumptions, including moderately high level of management; ignores location and land-ownership patterns	Small to large
Hills (1961)	Canada	To rate the potential of land units for the purpose of agriculture, forestry, etc.	Physiographic/ landscape unit maps	Rating system applied to land factors based on known and inferred relationships with crop productivity	7 classes (A to G) defined by rating. Class A: the highest, Class G: the lowest potentially	---	Small to large 1:253, 433, landscape unit
Canada Land Inventory (1965)	Canada	To group mineral soils according to their potentialities and limitations for agricultural use	Soil maps	Descriptive interpretation based on known relationships between land factors and crop production	7 capability classes (1 to 7); capability sub-class	7 assumptions, included good soil management practices; ignores location, access, and land-owner-ship patterns	1:63, 360
Bibby and Mackney (1969)	Great Britain	To present the result of soil surveys in a form which may be of more use to agricultural advisers, farmers, planners and other land users	Soil maps	Descriptive interpretation based on known relationships between the growth and management of crops and physical factors of soil, site and climate	7 capability classes (1 to 7); capability sub-class; capability units	10 assumptions, including moderately high-level of management; ignores location and access	Small to large; 1:25,000 and larger for unit
United States Department of Interior (1953)	USA	To group soils according to physical and economic attributes which affect their suitability for irrigated agriculture	Survey data: field and laboratory	Descriptive classes defined according to known or inferred relationships between land factors, productive capacity, cost, and their payment capacity under irrigation system	6 classes (1 to 6); sub classes. Classes 1,2,3 arable; Class 4 limited arable; Class 5,6 non-arable	---	1:24,000 1:12,000 1:4,800

Author (s)	Study area	Study aims	Data sources	Method of data evaluation	Categories or land units (in order of decreasing generalisation)	Assumptions	Mapping scales
Vink (1960)	Netherlands	To evaluate suitability of soil types quantitatively	Soil maps, field and trial data	Quantitative interpretation based on 'rate of suitability' calculated from an equation	Suitability defined by a score obtained using an equation	---	---
Bennema, Beek & Camargo (1964)	Brazil	To group soils according to degree of limitation and degree of feasibility for improvement of the management systems	Soil maps	Descriptive interpretation based on known relationships between land factors and the growth and management of crops	4 classes (I to IV) Class I: good; Class IV: No.	---	Reconnaissance
Riquier, Bramao and Cornet (1970)	---	To evolve a quantitative approach to the assessment of soil and to use the concept of productivity to compare soils	Soil-survey reports and maps and published research data	Quantification of factors to determine productivity in the form of equation	Productivity index and potentiality index obtained using an equation	---	---
Beek and Bennema (1972)	---	To group soils according to the degree of suitability within the framework of a specific land utilization type for crop production	Field data and published research data	Grading system applied to land qualities ad land improvement capacities	4 classes (I to IV) Class I: high suitability; Class IV: low suitability	---	1:100,000 1:50,000 1:25,000 1:10,000
Sys and Frankart (1971)	Humid tropics; Congo	To group soils according to their suitability for various crops	Soil-survey maps and published research data	Indexing system applied to soil factors; capability index calculated using an equation	6 classes (I to VI) defined by capability index values; Class I: Exellent Class VI: Very poor	---	
Sys and Verheye (1972)	Arid and semi-arid regions; Iraq	To evaluate the capability of soils crop production, irrigation and land improvement requirements	Soil-survey reports and maps	Ditto	5 classes (1 to 5), defined by capability index values; Class 1: very suitable Class 5: Unsuitable	---	
Soepraptohardjo and Robinson (1975)	Indonesia	To define areas based upon their suitability for use at defined levels of generalizations and for specified types of utilization and management	Soil-survey reports and published research data	Descriptive interpretation based on relationships between production of crops and soil characteristics, site and climate	3 order (suitable, conditionally suitable, unsuitable); Classes; sub-classes; management group	12 assumptions; including moderately high level of management; ignores location, access and land-owner-ship patterns	Reconnaissance to detail; 1:100,000 1:20,000

Most of the methodologies were designed mainly for evaluating the capability of land for agriculture either in narrow (specific) or in broad terms (including forestry, pasture, etc.). The main exceptions are the approach of Hills (1961) which evaluates land capability for a variety of land uses, including forestry, wildlife, recreation and of freshwater fish resources; and the United States Department of the Interior (1953) approach designed for evaluating land for the very specific purposes of irrigated agriculture.

Data inputs for the capability methodologies are inevitably strongly influenced by available data sources such as soil maps and other published data. This is particularly true of the large-scale more comprehensive surveys which are actually being implemented as planning tools. Most of the methods reviewed combined fieldwork with a greater or lesser use of data from others sources, such as soil survey reports and maps and published research data. Some methods, in particular that of Haantjens (1963), utilize air-photo-interpretation supplemented by fieldwork as a rapid means of data collection for large-scale survey purposes.

Three methods of evaluation of data can be identified from those summarized in Table 1. Firstly, descriptive methods whereby capability classes or other categories are descriptive solely in words. Secondly, rating, grading or indexing systems whereby each attribute is assigned a rate, grade or index and the capability class or other category is defined in terms of the sum of the weighted scores. Thirdly, quantitative methods whereby the relationships between variables are defined in terms of an equation used to obtain a score or index which defines the capability class or other categories.

The methods also vary both as hierarchical systems and in terms of the number of categories used. The number of highest categories (i.e. order or classes), in the systems reviewed vary from 3 to 8. Six of the methodologies clearly stated the assumptions used, but in other studies the assumption are not made explicit. They also vary in terms of scale, and some do not even specify the scales used. Broader scale comprehensive studies tend to define land units on the basis of general physiographic criteria. Those which are more limited in aim and larger in scale have defined land units in more detail and more precisely.

CONCLUSION

1. The schemes reviewed are broadly similar in aim, however, widely the methodologies used to achieve this aim-combined with the assumption made-may differ. Also the methods operate at a variety of scales with differing degrees of general applicability. All of the methods described have some practical value but no seems to provide an adequate assessment of land resource potential for all purposes.
2. Although substantial differences are found among the methodologies in terms of their purposes and detailed procedures, these are all broadly similar in terms of the general approach and activities involved. For instance, all of them include activities such as a prolonged field survey and laboratory analysis of soils to collect information, followed by organization of the information into a classification; and the establishing of land capability classes on the basis of the classification results. These capability classes are commonly expressed in the form of maps, accompanied by descriptions and information about the characteristics of each class, as well as the kinds of management needed.

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