LAND EVALUATION SYSTEMS OTHER THAN THE FAO SYSTEM

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Contents

Summary

This chapter gives an overview of the most important and most currently used methods in land evaluation, except the FAO approach which is dealt with in another chapter in the EOLSS. In total 14 systems are described and discussed, belonging to one of the three major types of approaches, e.g. the parametric, categoric or special purpose systems.

Parametric systems are based on numerical correlations between land attributes and yields. The best known method is the Storie index, initially developed for tax purposes in California, but later extended outside the USA. Other more complex methods which take into consideration more parameters, are the Riquier *et al*. method for general use, and the Sys and Verheye method for application in semi-arid areas.

Categoric systems group land into categories with a different land use potential. They are often associated with land capability assessments of which the USDA classification of Klingebiel and Montgomery is the best known. The Canadian and British systems of land classification are good examples of a derived system, but with adaptations to the local conditions and objectives. There are numerous special purpose systems, but only

two of them are discussed in this chapter: the USBR method for irrigated agriculture and the Fertility Capability Classification of Sanchez *et al*. Both methods constitute a good complement to the assessments obtained from the general land capability approaches.

1. Introduction

The primary objective of soil investigations is to optimize land use and obtain a high and beneficial production. Users of soil maps are generally not interested in the soil map itself but rather in its application. They require information about soil performance under different forms of land use and about the measures required to obtain the best output of the land. They want to know the function of the soil properties in the processes and the site conditions affecting a specific land use. Moreover, map users often require a more comprehensive description of soil performance in terms of soil suitability.

There exist a wide range of land evaluation systems, from the most simple single-factor correlation to the very complicated and complex formulas or models. Though it is generally agreed that the beneficial use, and in particular the production potential of land depends on both physical and socio-economic factors, almost all systems put a major emphasis on the physical factors. The reason for this is simple as the former are rather stable and allow us to come to an assessment once for all, while socio-economic factors are constantly changing and thus require a permanent updating and/or re-evaluation. In most cases the main focus is hereby on the soil properties.

Land evaluation systems currently in use belong generally to 4 main groups: parametric systems, categoric (or capability) systems, special purpose systems, and crop-specific assessments. In this chapter an overview is given on the first three systems only. The fourth one - commonly associated with the FAO approach - is discussed *in extenso* in *The FAO Guidelines for Land Evaluation.*

The land evaluation systems discussed in this chapter have been described at large in McRae and Burnham (1981), Landon (1984), van Diepen *et al.* (1991) and Davidson (1992). Much of the material used in this chapter is derived from the original documents or has been borrowed from these publications. For more details interested readers are invited to consult these studies.

2. Parametric Systems

Parametric systems find their origin in field trials and fertility tests, especially where a good correlation could be found between crop yield and one or more key land factors. Parametric systems like all numerical correlations are a simple quantified expression of soil productivity. Their reliability depends, however, heavily on the choice of the factor determinants, their weighting, and the validity of the assumed interactions between the factors.

In a parametric approach all factors with a relevant impact on the land use potential are allocated a numerical value ranging usually between 1.0 (for the highest potential) and almost 0.0 (for the lowest potential). For example, in the case the parameter soil depth has “no constraint” (corresponding to a depth of more than 120 cm) it may be given a 1.0 value, while a “slight constraint” (for example depth between 80 and 120 cm) is rated 0.8, and a “moderate constraint” (for example soil depth between 50 and 80 cm) receives a value of 0.5, etc. The final index is obtained by either multiplying or adding the individual rating values. This index is finally converted into a yield level.

Systems may differ in the factors they include (both in terms of nature and amount of parameters) and in their mathematical manipulation. Three main kinds of manipulation can be recognized: additive, multiplicative and complex functions. The best-known parametric system for rating the quality of the land is the Storie index. The Riquier *et al.* (1970) and Sys and Verheye (1975) systems are derived and somewhat more complex systems which are still relatively frequently used as well.

2.1. The Storie-index

The Storie index was originally devised for the agricultural rating of citrus soils in California, in particular for taxation purposes. The first edition of the index appeared in the 1930s, but it has frequently been revised, even up till 1978. Adaptations of the system have also been used in many other parts of the world.

In its original version the Storie index was written as: $I = A \times B \times C$ relying on three factors, e.g. soil profile (A), texture of surface soil (B), and a miscellaneous land factor including drainage, slope and alkalinity (C). In the 1944 and subsequent versions a new factor C was introduced to evaluate slope and the former factor C became factor X (miscellaneous factor that can be modified by management).

Each factor is scored as a percentage but multiplied as a decimal. The final index is expressed as a percentage. Where more than one property is considered, as in factor X, each is also scored as a percentage, then all are multiplied together as decimals and expressed as the combined percentage of that factor. All derivates of the Storie index use this convention. The most recent revision, published in 1978, gives the following ratings for each factor.

Factor A refers to the profile development which is an expression of the weathering stage of the soil and its inherent chemical composition. Nine soil types are hereby differentiated.

Development stage I groups soils on recent alluvial fans, flood plains or other secondary deposits having $A\text{-}C$ profiles; these are rated at a 100% level. This rating may be reduced because of (1) limited soil depth : 80% for soils of 90 cm thick, and 50-60% for soils less than 60 cm deep; (2) the presence of gravelly sub-soils: 80-90%; and (3) the presence of clay stratifications in the subsoils: 80-95%.

Development stage II groups soils on young alluvial fans, flood plains, or other secondary deposits having slightly developed $A\text{-}(B)\text{-}C$ profiles: 95-100%. Ratings are reduced on the basis of (1) shallowness: 70% on 90 cm deep soils, and 50-60% on 60 cm deep soils; (2) gravel content in the subsoil (80-90%) and (3) stratified sub-soils: 80-95%.

Development stage III refers to soils on older alluvial fans, alluvial plains or terraces having moderately developed A - Bt - C profiles: 80-95%. Rate reductions are applied for (1) shallowness: 60-75% for 90 cm deep soils, 40-65 for 60 cm deep soils, and (2) gravelly sub-soils: 60-90%.

Development stage IV is attributed to soils on older plains or terraces having strongly developed A - Bt - C or A - Box - C profiles with ratings of 40-80%.

Soils of the other development stages are mainly rated on the basis of profile depth as indicated in Table 1.

Soil development stage	**Depth class (cm)**					
	<30	**30-60**	**60-90**	**90-120**	**120-180**	**>180**
V. Soils on older plains or terraces having hardpan subsoil layers	5-20	20-30	30-40	40-50	50-80	-
VI. Soils on older terraces and upland areas with clayey sub-soils on consolidated material	40-80					
VII. Soils on upland areas underlain by hard igneous bedrock	10-30	30-50	50-70	70-80	80-100	100
VIII. Soils on upland areas underlain by sedimentary rocks	10-30	30-50	50-70	70-80	80-100	100
IX. Soils on upland areas underlain by softly consolidated material	20-40	40-60	60-80	80-90	90-100	100

Table 1: Factor A ratings in the Storie index for soils belonging to development stages V to IX.

Factor B rates surface texture. It makes a distinction between fine texture (less than 2 mm) and coarse fractions, either gravels with diameter up to 7.5 cm or stones with diameter above 7.5 cm. The respective ratings are summarized in Table 2.

Textural class*	**Non-gravelly and non-stony**	**Gravelly**	**Stony**
Coarse sand	30-60		
Sand	60	20-30	10-40
Fine sand	65		
Very fine sand	80		
Loamy sand	80		

Loamy fine sand	90		
Very fine sandy loam	100		
Fine sandy loam	100	70-80	70-80
Coarse sandy loam	70-90		50-70
Sandy loam	95	50-70	
Loam	100	60-80	60-80
Silt loam	100	60-80	60-80
Silty clay loam	90		
Clay loam	85	60-80	50-80
Silty clay	60-70		
Clay	50-60	40-70	40-70

* Classes as defined by Soil Taxonomy.

Table 2: Factor B ratings in the Storie index.

Factor C refers to the ratings on the basis of slope and overall topographic conditions. Ratings are defined as follows:

- Nearly level (slopes between 0 and 2 per cent): 100%
- Gently undulating (slopes between 2 and 3 per cent): 95-100%
- Gently sloping (slopes between 3 and 8 per cent): 95-100%
- Undulating (slopes between 3 and 8 percent): 85-100%
- Moderately sloping (slopes between 9 and 15 per cent) 85-95%
- Rolling (slopes between 9 and 15 per cent): 85-95%
- Strongly sloping (slopes between 16 and 30 per cent): 70-80%
- Hilly (slopes between 16 and 30 per cent): 70-80%
- Steep (slopes between 30 and 45 per cent): 30-50%
- Very steep (slopes of 45 per cent and over): 5-30%

Factor X refers to the rating of conditions other than those identified in factors A, B or C. Conditions which are taken into consideration may or may not be relevant for the specific location, and can therefore be omitted or considered as optimal in the calculations. The most obvious land factors in this respect are: drainage, nutrient or fertility level, acidity and alkali levels, erosion and micro-relief.

Drainage - Well drained soils are rated 100%; fairly well drained and moderately waterlogged soils get a 80-90% and 40-80% rating respectively; badly waterlogged land gets a 10-40% value; and areas subject to flooding get a variable rate depending on the length and importance of the overflow.

Nutrient status - The nutrient or fertility level holds four classes identified as high, fair, poor and very poor fertility with a corresponding rating of 100%, 95-100%, 80-95% and 60-80%. It should be noted that the nutrient status is not severely penalized in the ratings because natural fertility can rather easily be corrected through the use of fertilizers.

Alkali status - Five classes are differentiated with the following corresponding ratings: alkali free (100% rating), slightly affected (60-95%), moderately affected (30-60%), moderately to strongly affected (15-30%) and strongly affected (5-15%).

Acidity status - Ratings range between 80 and 95% as a function of the pH level.

Erosion - The following ratings are applied : none to slight erosion (100% rating), detrimental deposition (75-95%), moderate sheet erosion (80-95%), occasional shallow gullies (70-90%), moderate sheet erosion with shallow gullies (60-80%), deep gullies (10-70%), moderate sheet erosion with deep gullies (10-60%), severe sheet erosion (50-80%), severe sheet erosion with shallow gullies (40-50%), severe sheet erosion with deep gullies (10-40%), very severe erosion (10-40%), moderate wind erosion (80-95%), severe wind erosion (30-80%).

Micro-relief - Six major classes are distinguished: smooth (100%), channels (60-95%), hogwallows (60-95%), low hummocks (80-95%), high hummocks (20-60%), dunes (10-40%).

A soil developed on recent alluvial deposits with a depth of more than 120 cm (Factor A = 100%), with a clay loam texture, non gravelly and non-stony (Factor B = 85%) occurring in a gently undulating relief of 2 % (Factor C = 95%), well drained, with a high fertility level and no erosion nor alkali/acidity constraints (Factor X = 100%) receives a final rating:

$$I = A \times B \times C \times X \text{ or } I = 100\% \times 85\% \times 95\% \times 100\% = 81\% \text{ or } 0.81$$

Parametric indices have little but academic meaning if they are not converted into effective production levels. For California, Storie regrouped the index values into six soil grades:

- Grade 1 or excellent quality land: The soil rating is between 80 and 100% and the land is suitable for a wide range of crops, including alfalfa, orchard, truck and field crops.
- Grade 2 or good quality land: Soils rate between 60 and 79%. They are suitable for most crops, and expected yields are generally good to excellent.
- Grade 3 or fairly good quality land: Soils are rating between 40 and 59%. They are generally of fair quality, though they have a less wide range of suitability than grades 1 or 2; they give good results with certain specialized crops.
- Grade 4 or poor-quality land: Soils are rated between 20 and 39%. They have a relatively narrow range in their agricultural possibilities, in the sense that they may give good results for some crops but be unsuitable for other crops.
- Grade 5 or very poor land: Soils rate between 10 and 19%. They are of very limited use except for pasture, mainly because of critical adverse conditions such as shallowness, roughness and alkali levels.
- Grade 6 or non-agricultural land: Soils rate below 10% and are unsuitable for any economic land use.

2.2. The Riquier, Bramao and Cornet System

In 1970 Riquier and collaborators developed a parametric system of soil appraisal in terms of actual and potential productivity. This approach involves the calculation of a productivity index on the basis of nine factors, each of which is given a numeric value from 1 to 100. The resultant index obtained by a multiplication of those factors is positioned in one of the 5 productivity classes.

The factors involved refer to moisture status (H), drainage (D), effective depth (P), texture and structure (T), base saturation (N), soluble salt concentration (S), organic matter content (O), mineral exchange capacity and type of clay (A) and mineral reserve (M). The Productivity index (P_i) is obtained from the formula:

$$P_i = H \times D \times P \times T \times (N \text{ or } S) \times O \times A \times M$$

The system allows us to calculate the *actual productivity*, referring to the present situation, and the *potential productivity* based on anticipated ratings which could be obtained after soil reclamation. The coefficient of improvement of a soil is expressed by the ratio between potential (or future) and actual productivity indices. Therefore, it is in first instance necessary to determine which management practices are necessary and which of those are technically, viz. economically feasible, and then to evaluate their repercussions on the productivity.

Two groups of management aspects are hereby differentiated, e.g. those imposed by soil limiting factors and those related to physiographic and environmental constraints. The management activities related to the first group refer to irrigation (in case of H: moisture constraints), drainage (as a remediation of D: poor drainage), soil deepening (to correct some of the texture/structure constraints), fertilizer application (to correct N: low nutrient content), leaching of salts (to correct S: salinity constraints) and application of organic matter (to correct factor O). Management activities imposed by physiographic constraints refer to the control of wind and water erosion, and to land clearance.

The application of the method is similar to the Storie method described above or to the Sys and Verheye method explained below.

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Bibliography

Bibby, J.S., Douglas, H.A., Thomasson, A.J. and Robertson, J.S. (1982). *Land Capability Classification for Agriculture.* Monograph Soil Survey of Scotland, Macaulay Institute for Soil Research, Aberdeen. [Gives a good outline of the concept and utilization of the Land Capability Classification in Scotland].

Bibby, J.S., Heslop, R.E.F. and Hartnup, R. (1988). *Land Capability Classification for Forestry in Britain.* Soil Survey Monograph, Macaulay Land Use Research Institute, Aberdeen. [Explains the principles and application of the land capability classification for forestry in the UK].

Canada Land Inventory (1970). *The Canada Land Inventory: Objectives, Scope and Organization.* Dept. Region. Economic Expanses, Ottawa, Report n°1. [Describes the philosophy and the principles of the Canada Land Inventory System].

Davidson, D. (1992). *The Evaluation of Land Resources*. Longman Scientific and Technical, Longman, Harlow, UK, 198p. [Gives an excellent overview of the procedures to evaluate land and good background information on the pros and contras of each system; holds also an important reference list].

Klingebiel, A.A. and Montgomery, P.H. (1961). *Land Capability Classification*. USDA Agric. Handbook 210, 16p. [Constitutes the key publication of the LCC system, giving all details on how to apply the system].

Landon, J.R., ed. (1984). *Booker Tropical Soil Manual. A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics*. Longman Group Ltd, Harlow, UK, 450p. [An excellent practical handbook on how to evaluate land in the field; updates are under way]

McRae, S.G. and Burnham, C.P. (1981). *Land Evaluation*. Monographs on Soil Survey. Clarendon Press, Oxford, 239p. [A very good overview of the basic principles of land evaluation and of the methods used until the late 1970s; holds also an extensive reference list].

Ministry of Agriculture, Fisheries and Food (1988). *Agricultural Land Classification of England and Wales.* Ministry Agric, Food and Fisheries, London. [Outlines the revised system for land capability classification for application in England and Wales].

Riquier, J., Bramao,D.L. and Cornet, J.P. (1970*). A New System of Soil Appraisal In Terms of Actual and Potential Productivity.* AGL/TESR/70/6, FAO, Rome, 35p. [Explains the concept and the application of the parametric system developed by the authors].

Sanchez, P.A., Couto, W. and Buol, S.W. (1982). *The Fertility Capability Soil Classification System: Interpretation, Applicability and Modification.* Geoderma, 27: 283-309. [Describes the concept and practical application of this special purpose system of land evaluation].

Storie (1933). *An Index for Rating the Agricultural Value of Soils*. Bull. 556, Calif. Agric. Exp. Sta, USA, 25pp. [Outlines the principles and application of the first version of the Storie index].

Storie (1978). *Storie Index for Soil Rating (Revised).* Spec. Publ. 3203, Div. Agric. Sci. Univ. Calif., USA. [Describes the concept and explains the latest version of the Storie index].

Sys, C. and Verheye, W. (1975). *Principles of Land Classification in Arid and Semi-Arid Areas (Revised).* Publ. Intern. Training Centre Post-Graduate Soil Scientists, Gent, 42p. [Explains the philosophy behind the system and provides all numerical ratings for applying the Soil Capability Index in the field].

USBR (1953). *Bureau of Reclamation Manual. Vol. V: Irrigated Land Use. Part 2.: Land Classification.* US Dept. Interior, Washington DC. [Explains the application of the USDA system for land evaluation in the special case of irrigated agriculture].

van Diepen, C.A., van Keulen, H, Wolf, J. and Berkhout, J. (1991*). Land Evaluation: From Intuition to Quantification.* In B.A. Stewart, ed: Advances in Soil Science, Springer Verlag, New York, 139-204. [An excellent overview and critical evaluation of a number of methods used in land evaluation in different parts of the world; holds also an extended reference list].

Biographical Sketch

Willy Verheye is an Emeritus Research Director at the National Science Foundation, Flanders, and a former Professor in the Geography Department, University of Ghent, Belgium. He holds an M.Sc. in Physical Geography (1961), a Ph.D. in soil science (1970) and a Post-Doctoral Degree in soil science and land use planning (1980).

He has been active for more than thirty-five years both in the academic world, as a professor/ research director in soil science, land evaluation, and land use planning, and as a technical and scientific advisor for rural development projects, especially in developing countries. His research has mainly focused on the field characterization of soils and soil potentials, and on the integration of socio-economic and environmental aspects in rural land use planning. He was a technical and scientific advisor in more than 100 development projects for international (UNDP, FAO, World Bank, African and Asian Development Banks, etc.) and national agencies, as well as for development companies and NGOs active in inter-tropical regions.