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Exploring suitability for tropical crop cultivation in Hainan Island by SOTAL methodology

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Abstract: A SOTER-based automatic procedure for qualitative land evaluation is developed. This procedure was created in the automated land evaluation system (ALES). The objective was to design a procedure that allows for a quick separation of potentially suitable from non-suitable SOTER units for the intended land use, indicating constraints to different kinds of land use. Different kinds of land are unequal1y suited to various uses, land eva1uation is the assessment of the suitability of a tract of land for a specified kind of land use. In practice this implicates the comparison (matching) between the requirements of a specified land use and the properties of the land. Land evaluation concepts and definitions are treated in the paper. The ALES is a computer program that allows land evaluators to build their own knowledge-based system with which they can compute the physical and economical suitability of map units in accordance with FAO framework for land evaluation. The ALES program works with so-called decision trees, being hierarchical multiway keys in which the leaves are results (e.g., severity levels of land qualities), and the interior nodes of the tree are decision criteria (e.g., land characteristic values). These trees are traversed by the program to compute an evaluation using actual land data for each map unit. SOTAL is a SOTER-based qualitative model developed in ALES for physical land evaluation in which presently three land utilization types (LUTs) are distinguished, i.e., cultivated banana, coffee and rubber under different input and technological conditions. These LUTs are characterized by 11 landuse requirements and evaluated by matching the land use requirements with the corresponding land qualities. The paper elaborates on the criteria used in SOTAL for land quality assessment and how a final suitability rating is achieved on the basis of the rated land qualities. Results are visualized through G1S-generated maps as products in response to the specific information and data needs of decision and policy makers.

Exploring suitability for tropical crop cultivation in Hainan Island by SOTAL methodology ZHANG Xue-lei1, S. Mantel 2, ZHANG Gan-lin, VWP. van Engelen2 (1. Institute of Soil Science, CAS, Nanjing 210008, China; 2. International Soil Reference and Information Centre, AJ Wageningen, 353-6700, Netherlands) 1 Introduction Land degradation is a major threat to environmental and agricultural quality of land[1] and is directly related to food security issues. An instrument for decision-makers to plan or stimulate allocation of land to users that can be sustained and are economically viable and socially acceptable. Different kinds of land are unequally suited to various uses. Land evaluation is the assessment of the suitability of a tract of land for a specified kind of use and it provides objective sets of data on potentials and constraints, which can contribute to decision-making on a sustainable land use. In practice this involves the comparison (´matching´) of the requirements of a specified land use with the properties of the land. Land The evaluated spatial entities are land units (LU), or land mapping units (LMU). A LMU comprises an area on a map which is relatively homogenous in terms of soil, climate, topography and hydrology. A land (mapping) unit needs not to be uniform in all aspects. Relevant is whether the variation that occurs affects the functioning of the land under the intended use, therefore the concept of ´land unit´ is used for areas that can be considered uniform in view of the requirements of the defined (actual) or intended land use. Soil is but one aspect of land alongside of terrain, climate, vegetation, hydrology, infrastructure, etc. and the socioeconomic context within which a land unit is used. Land characteristics A land unit is described by its major land characteristics (LC). They can either be single or compound. Single land characteristics are properties of the land that can be measured or estimated, e.g., annual rainfall, dominant slope, soil drainage class and soil depth. Compound land characteristics are composed of associated single ch aracteristics. ´Available water capacity´ (AWC) is an example of a compound land characteristic, as it is a function of soil depth and matrix geometry. Land qualities A land quality (LQ) is a set of interacting land characteristics which acts in a distinct manner in its influence on the suitability of land for a specified use. Examples of land qualities are the ´water availability to a crop´ (a.o. influenced by AWC, rainfall, soil depth, hydraulic conductivity), ´availability of nutrients´ and ´resistance to erosion´. Land use The framework for land evaluation[2] uses the concept of major kinds of land use (e.g., ´deciduous forest´, ´annual crops´) and the more specific land utilization type (LUT), which is characterized by its ´key attributes´, the biological, social-economic and technical aspects of land use that are relevant to the productive capacity of a LU. Crop selection, labour intensity and management level are examples of key attributes. Land use requirements Land utilization types are characterized by a set of land use requirements (LURs), which are the conditions of land necessary for the successful and sustained practice of a given LUT. Where a land utilization type concerns the growth of a crop/variety, land use requirements are expressed mainly as crop requirements. Land use requirements express the demand of a land use, whereas land qualities express the supply, i.e., properties of a particular tract of land. Matching Matching is the comparison of land use requirements with land qualities of specified land units. The sufficiency of a land quality, which is the degree to which a requirement of land use is satisfied by a corresponding land quality, is expressed in a rating. In a broader sense, matching refers to the process of mutual adaption and adjustment of (descriptions of) land utilization types and land units, in order to find the best combination of (improved) land use and (improved) land qualities. Final suitability rating In order to arrive at a final suitability rating, the individual ratings of the various land qualities are translated into a qualitative suitability class of a land unit for the land use under study, using a conversion table. Often a simple limitation method is used in which the suitability class is determined by the highest severity level of one or more land qualities (Law of Liebig). No distinction is made between situations where a suitability class is determined by the severity level of one land quality (e.g., oxygen availability is limiting) or by several land qualities in the same severity level class (oxygen availability, availability of nutrients and conditions for germination are limiting). The detailedness of conclusions which can be derived from a land evaluation study is strongly determined by the level of spatial aggregation of the climate, terrain and soil maps/data, as well as the possible level of integration of the bio-physical and socio-economic information. The level of detail used for defining land qualities often depends on the amount, accuracy and availability of input data. Furthermore, the technical level of details when defining land qualities is determined according to the types of questions being asked. In SOTER database like HaiSOTER, each soil component is characterized by a representative profile, which is described in detail. This representative profile is selected from a number of reference profiles. These reference profiles have also contributed to the determination of the maximum and minimum values for a number of chemical and physical parameters of the soil. When interpreting soil component data for land evaluation, the scale should be considered in the level of detail. Some attributes may be representative or indicative, if however the variability of this attribute in the soil component is high (of which an indication is given by the maximum and minimum value), care should be taken to use this attribute (without probability statement) as diagnostic criterion in qualitative interpretations as well as in qualitative studies. 2 Materials and methods 2.1 Land utilization type definition Banana, coffee and rubber are the dominant tropical crops in Hainan Island. The LUTs as broadly defined for this study were banana/low input & low technology that includes a low application of organic fertilizer and simple implements for weeding and soil tillage, no terracing or artificial drainage is practiced; banana/medium input & low technology is practiced which includes modest application of organic fertilizer with no use of mechanised tools for weeding and soil tillage, no terracing or artificial drainage; banana/medium input & medium technology that means modest application of organic fertilizer and mechanised tools for weeding and soil tillage, artificial drainage is applied where required; and banana/high input/irrigated & technology which includes high application of organic fertilizer, mechanised tools for weeding and soil tillage and also good irrigation. Coffee/low input & low technology that includes modest application of lime and fertilizer and mechanised tools for weeding and soil tillage, no terracing is practiced; coffee/medium input & low technology which includes modest application of lime and fertilizer with only very simple mechanised tools for weeding and soil tillage, no terracing or artificial drainage is practiced; and coffee/medium input & medium technology that means modest application of lime and fertilizer and mechanised tools for weeding and soil tillage, no terracing is practiced, artificial drainage is applied where it is required. Rubber/medium input & low technology that includes modest inputs available such as occasional P fertilizer, covercrop, availability of mechanized tools for weeding and soil tillage, terracing is not practiced; and rubber/medium input & medium technology that means modest inputs available such as occasional P fertilizer, covercrop, availability of mechanized tools for weeding and soil tillage, terracing is not practiced. Artificial drainage is applied where it is required. 2.2 Data Land unit data were taken from the Hainan provincial 1:250,000 scale Soils and Terrain (SOTER) database HaiSOTER. Natural resource surveys often do not put high priority on collection of hydraulic parameters and key soil fertility characteristics. Consequently, data gaps are reality for any database. These gaps were filled with ´pedo-transfer-functions´ with which data can be estimated from correlated standard[3,4], measured soil survey data, such as soil texture. 2.3 Evaluation procedure (Figure 1) A mixed qualitative/quantitative approach was followed, where a qualitative land evaluation is used to exclude the area not suitable for the projected use and to indicate the limitations for use within the suitable area. The quantified procedure is used to calculate the land use potential within the suitable units[5,6]. First, the evaluation units should be defined by an overlay of agro-climatic zones (ACZ) with the land unit map providing the basic evaluation units. These agro-ecological units (AEU) formed the basis for further evaluation[7-9]. Only the spatially dominant soil component within each AEU was analysed. Second, suitability assessment can be made as the potentially suitable AEUs for the LUTs were identified using an expert model for physical land evaluation defined in the automated land evaluation system, (ALES)[10,11]. Erosion risk was not included in the suitability assessment at the moment. Figure 1 Flow chart of modelling process (modified after S Mantel et al., 2000[8]) 3 Results 3.1 Suitability assessment for banana Table 1 Extent (km2, numbers) of agroecological units grouped for banana suitability class (Figure 2) Respectively, 61.45%, 38.45%, 83.47% and 61.46% of Hainan Island were considered suitable for banana cultivation under different management of A, B, C and D. Severe restrictions of the land qualities ´availability of moisture´, ´availability of nutrients´ and ´available foothold for roots´ were the main causes for classifying land suitability. 3.2 Suitability assessment for coffee Table 2 Extent (km2, numbers) of agroecological units grouped for coffee suitability class (Figure 3) Figure 2 Suitability map for banana in Hainan So, 30.52%, 82.13% and 60.49% of Hainan Island were considered suitable for coffee cultivation under different management of A, B and C respectively. Severe restrictions of the land qualities ´availability of moisture´, ´availability of nutrients´ and ´available foothold for roots´ were the main causes for classifying land suitability. 3.3 Suitability assessment for rubber Table 3 Extent (km2, numbers) of agroecological units grouped for rubber suitability class (Figure 4) Therefore, 57.55% and 55.92% of Hainan Island were considered suitable for rubber cultivation under different management of A and B respectively. Severe restrictions of the land qualities ´availability of moisture´, ´availability of nutrients´ and ´available foothold for roots´ were the main causes for classifying land suitability. Figure 3 Suitability map for coffee in Hainan Figure 4 Suitability map for rubber in Hainan 4 Discussion and conclusions A methodology is presented for exploring the suitability of crops under specified management. Comparison of crop growth simulations for actual conditions provides estimates of changes in land quality status. They may serve as indicators of agroecological sustainability of land use systems. This exploratory study aimed to highlight trends in productive capacity under different conditions, whereby the emphasis should be placed on the relative difference between scenarios and between land units rather than on absolute values presented. The approach may be used to support strategic decision-making seeking to optimize land use, prioritize research, and guide conservation planning. It is shown that assuming appropriate conservation measures, the more management to be taken the more extent suitable for all the three tropical crops in Hainan Island are. The methodology can be repeated for relevant LUTs and can provide, especially when economic parameters are included, information on options for land use, resulting in a ´land zonation´. This procedure when combined with crop monitoring during the growing season may be the basis for an ´early-warning system´ for crop security. References

关键词： evaluation; tropical crops; HaiSOTER; Hainan Island