The Soil and Terrain Information System SPICE for Estimating Yield Potentials at a Regional Scale in the States of Piauí and Ceará (Brazil)

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Abstract
Within the German-Brazilian research program WAVES, the soil and terrain information system SPICE (**S**oil and Terrain Information System for the States of **Pi**auí and **Ce**ará) is being developed using the SOTER approach. The data domain contains presently 160 terrain (landscape) units with about 300 terrain and 600 soil components. It is linked to other databases with climate and crop information. The information stored in the SPICE data domain is used for various applications, including methods to estimate the yield potential of several tropical crops in relation to soil and climate at a regional scale. One of these methods, the ITC/LSC method attributes ratings to each unit of land (defined as a combination of climate, terrain and soil characteristics) depending on the extent it meets the requirements of a specific crop. The ratings of the different requirements are used to calculate the "land index". For six crops at different sites the land index correlated well with the observed yield index (R^2=0.70). Completion of the database, testing and improvement of the existing application modules, implementation of additional modules, as well as the development of appropriate scaling methods are necessary, in order to render the information system a tool that could be used by regional planning authorities in the states of Piauí and Ceará.

Keywords: Northeast Brazil, soil information system, crop model, regionalization

Introduction
Within the WAVES (Water Availability and Vulnerability of Ecosystems and Society in the Northeast of Brazil) program, there is the challenge to assess and store soil and terrain information for a highly variable area of about 470.000 km^2 in such a way, that it can be made available in an adequate form (raw or processed data) to various applications at different scales. The applications (hydrological, agroecological and economic models) require detailed information about the spatial variability of soils, terrain and crop yield for simulating processes like run-off, crop growth or evapotranspiration. For this purpose, the soil and terrain information system SPICE (**S**oil and Terrain Information System for the States of **PI**auí and **CE**ará) is being developed.

Structure of the Information System

The information system SPICE holds two main domains: the data storage domain and the method domain (Figure 1). The user can choose the methods which he wants to use to process the data of his interest for a specific purpose. The data storage domain of SPICE is further subdivided into two sections. The first section stores the geometries of the spatial units (e.g. mapping units) and the second section stores the attributes of the respective units. The structure of the data storage domain follows the SOTER approach (FAO, 1993). The land surface is considered as being constituted of natural entities (terrain units) consisting of a combination of terrain and soil components, which are hierarchically structured (Figure 2). SOTER provides the methodology to represent the hierarchy in the landscape in a relational database. The database contains presently 160 terrain (landscape) units with about 300 terrain and 600 soil components. Each soil component is represented by at least one reference profile or, preferably, a set of profiles. Depending on the scale, the geometric data section holds maps of terrain units (1:250.000 to 1:1.000.000) or terrain components (1:50.000 to 1:250.000). Where detailed soil maps are available (>1:50.000), the database provides the framework to include such maps at the soil component level. The most critical issue at the terrain and soil component level is the estimation of the coverage of these components within the terrain units. When these data are not available through maps, estimation procedures as proposed by Graef et al. (1998) have to be applied. For complex applications, the soil and terrain information in the data domain is linked to other databases, containing climate and crop information.

Figure 1: Structure of the Soil and Terrain Information System for the States of Piaui and Ceara (SPICE)

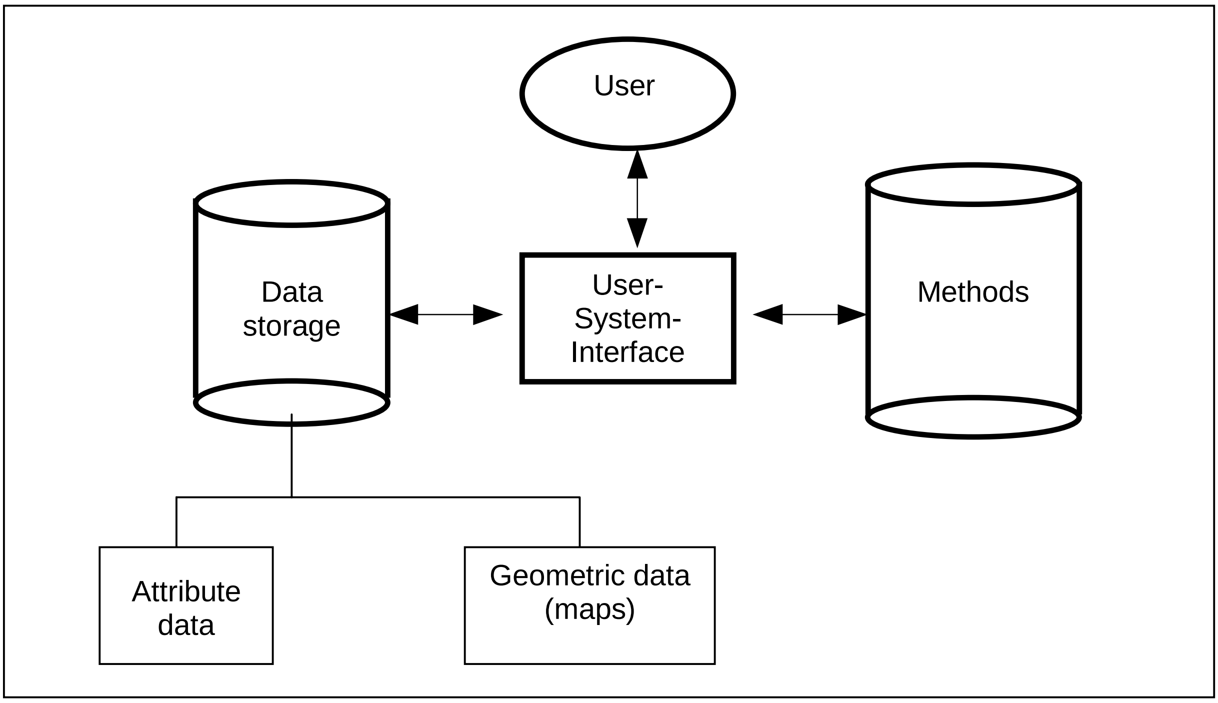
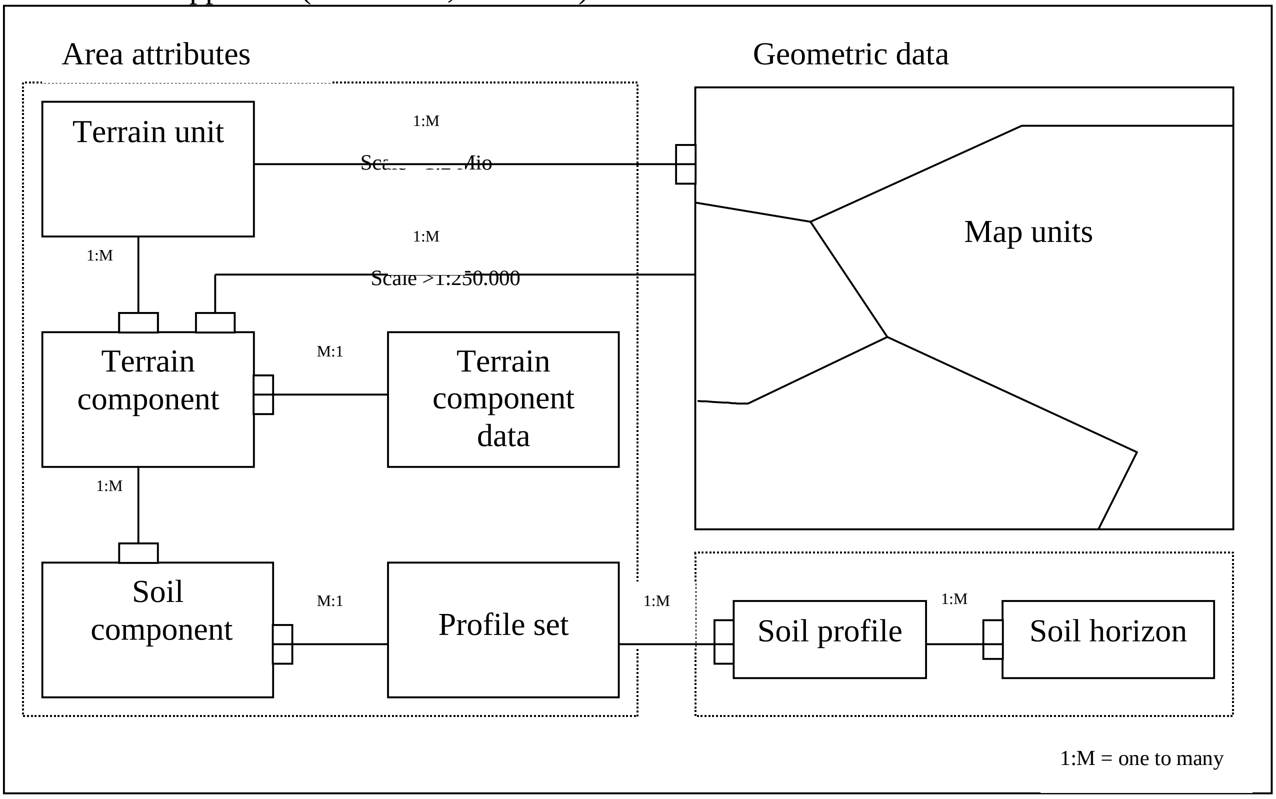


Figure 2: The structure of the data storage domain of SPICE according to the SOTER approach (FAO 1993, modified)

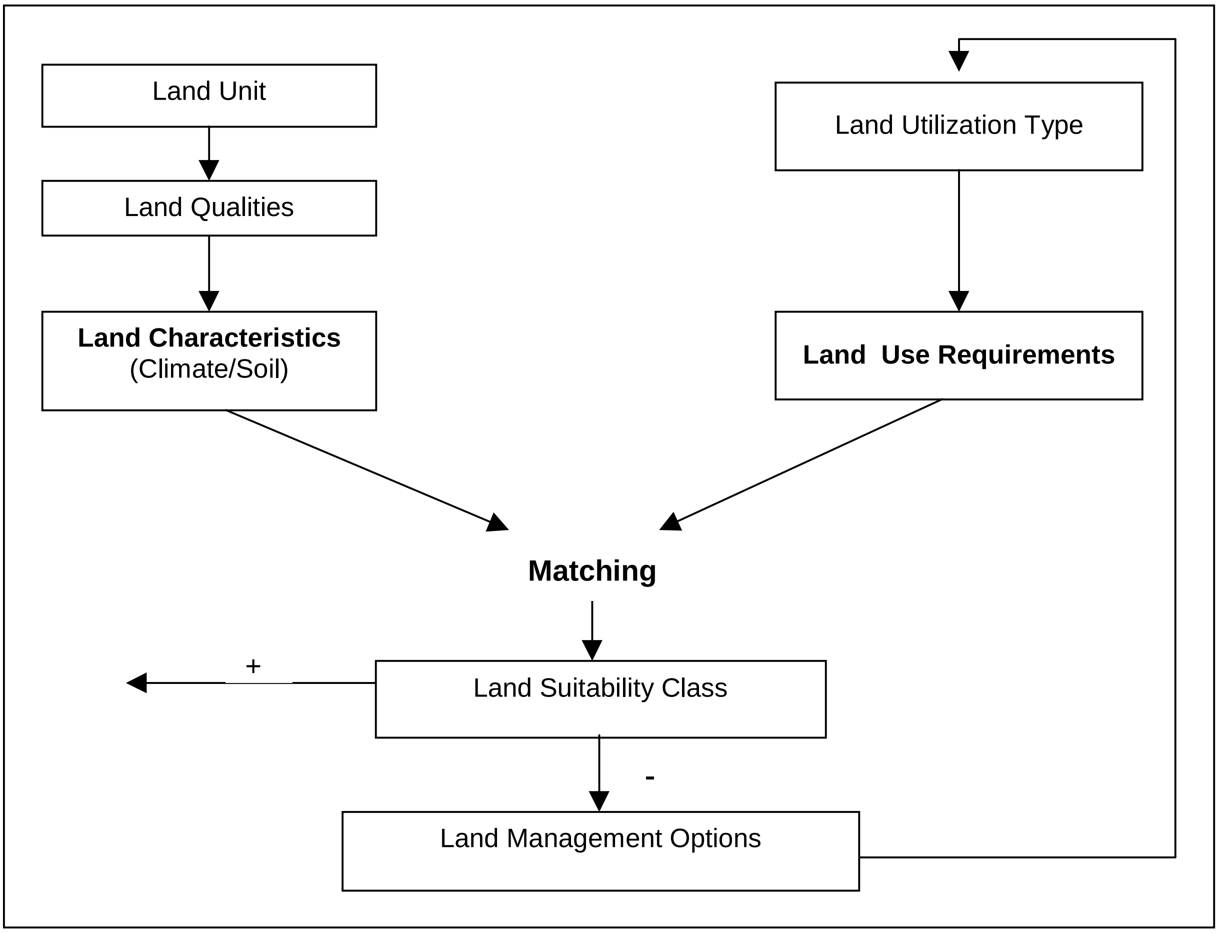


Application of SPICE for yield estimation
The method domain of the information system contains various methods (application modules) to process the information that is stored in the data storage domain. The methods currently available range from simple summary statistics for terrain units or terrain components to complex crop growth models.

One of the key issues for modeling the agricultural production in Piauí and Ceará is the estimation of the yield potential of the 14 (economically) most important crops in relation to climate, soil, crop and management at a regional scale. Within SPICE, this is performed either by the the crop growth model EPIC (USDA, 1990) or by the parametric approach of the ITC/LSC method (International Training Center/Land Suitability Classification) (Sys et al., 1991). The EPIC model is currently tested for maize and cowpea in relation to soil, cropping system (sole/mixed cropping) and management (fertilization, irrigation) at different locations in Piauí and Ceará (Hilger et al., 1999). Since EPIC provides the facilities to estimate the yield potential of only 9 out of 14 crops, that are considered being most important for both states, in addition the ITC/LSC method is used to estimate crop yield. Originally, the ITC/LSC method has been developed to classify a given unit of land according to its suitability for a certain crop (cropspecific land suitability classification). The classification scheme is primarily designed for qualitative evaluation purposes, but the parametric approach of the method allows quantitative assessment of the yield potential, when the results are calibrated against yield data from the region that is to be classified.

The ITC/LSC method compares the requirements of a specific land use (e.g. crop) with the characteristics of the land unit (defined as a combination of climate, terrain and soil characteristics) that is to be classified (Figure 3). The following land characteristics are considered in the classification procedure: rainfall (total amount of rainfall during the growing period, rainfall per month, number of dry months for tree crops), temperature (mean temperature during the growing period, monthly means (mean, minimum, maximum), minimum/maximum temperature in critical growing phases), air humidity (relative humidity in critical growing phases), radiation (sunshine hours during the growing period), topograpy (terrain inclination), moisture/oxygen dynamics (flooding risk ,drainage), physical properties (soil depth, texture/structure, gravel, carbonate and gypsum content), chemical properties (base saturation, sum of basic cations, pH, total organic carbon, CEC of clay fraction), salinity/alkalinity (electrical conductivity, exchangeable sodium percentage). Depending on the extent the land characteristics match the requirements of the crop, ratings are attributed to the individual characteristics. The ratings of the different characteristics are used to calculate the "land index", which ranges between 0 ("not suitable") and 100 ("very suitable").

Figure 3: ITC/LSC classification procedure



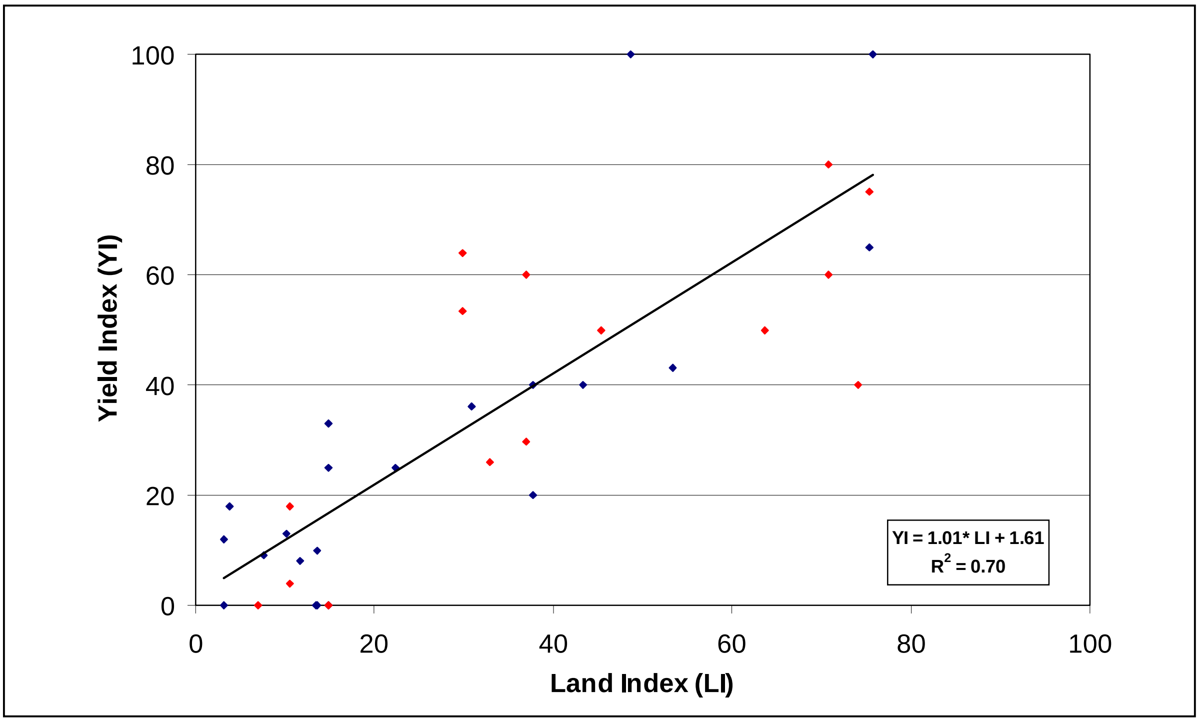
Land indices have been calculated for six strongly differing sites in Piaui and Ceara in relation to their suitability for maize, cowpea, cotton, tomato, cassava and rice. The results were compared to the yield indices defined as :

$$YI_i = \frac{Y_i}{Ypot_i} \times 100 \qquad \text{Eq.(1)}$$

where YI_I is the yield index, Y_i is the observed yield and $Ypot_i$ is the potential yield of crop i. The calculated land indices of the six crops studied were correlated with the yield index

(Figure 4). The goodness of fit ($R^2 = 0.70$) is satisfactory for regional studies. The variability not covered by the regression is caused by varying management conditions (e.g. crop residue restitution, grazing) and spatial microvariability of the soil. Further testing at other sites and evaluation of other crops is necessary to use the ITC/LSC method as a tool to assess the yield potential under the prevailing agroclimatic and socio-economic conditions in the Northeast of Brazil.

Figure 4: Land indices (LI) calculated according to the ITC/LSC method compared to the yield indices (YI) of six different crops in the states of Piauí and Ceará



Conclusions

The soil and terrain information system SPICE creates a framework for the storage, processing and retrieval of soil, terrain and climatic data at scales between 1:250.000 to 1:1.000.000. At these scales the information system is able to consider subscale variability of terrain and soil components and allows for down-scaling, when more detailed spatial information (soil survey maps greater than 1:250.000) is available. On the application side, SPICE holds presently data processing modules for the assessment of hydrological properties, land suitability classification and estimation of yield potentials in relation to terrain, soil and climatic conditions. Completion of the database, testing and improvement of the existing application modules, implementation of additional modules, as well as the development of appropriate scaling methods are necessary, in order to create a tool that could be used by regional planning authorities in the states of Piauí and Ceará.

Acknowledgement

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