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Integration of MultiCriteria Decision Analysis in GIS to develop land suitability for agriculture: Application to durum wheat cultivation in the region of Mleta in Algeria

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ABSTRACT

Due to constant decrease in farmlands, it is important to identify the best lands useful for sustainable agriculture (productive and profitable agriculture that protects the environment and that is socially equitable). This requirement has resulted in the development of land suitability maps for agriculture by combining several factors of various natures and of differing importance. The integration of MultiCriteria Decision Analysis approaches (MCDA) in a Geographical Information System (GIS) provides a powerful spatial decision support system which offers the opportunity to efficiently produce these land suitability maps. Indeed, GIS is a powerful tool for analyzing spatial data and establishing a process for decision support. Because of their spatial aggregation functions, MCDA methods can facilitate decision making in situations where several solutions are available, various criteria have to be taken into account and decision-makers are in conflict (Dias et al., 2002). The parameters and the classification system used in this work are inspired from the FAO (Food and Agriculture Organization) approach dedicated to a sustainable agriculture. A spatial decision support system has been developed for establishing the land suitability map for agriculture. It incorporates the multicriteria analysis method ELECTRE Tri (ELimitation Et Choix Traduisant la REalité) in a GIS (ArcGIS) within the GIS program package environment. This approach has been tested on the area of Mleta in Algeria. A land suitability map for durum wheat has been produced. Through the obtained results, it appears that ELECTRE Tri method, integrated into ArcGIS 9.2 of ESRI, is better suited to the problem of land suitability for agriculture. The time saving during the development of the land suitability map for the agriculture of the durum wheat was considerable. The coherence of the obtained maps confirms the system effectiveness.

1. Introduction

The moderate growth in agricultural production and the rapidly increasing in the population rank Algeria among the main importing countries of food and agricultural products. Moreover, a large part of the soil is poor and is subject to a series of degradation processes or threats (erosion, decline in organic matter, compaction, salinization, floods, etc.). The water supply is generally irregular and insufficient. Consequently, the soil becomes unproductive. In addition climate change may further disrupt agricultural production. Therefore it is necessary to move toward an agriculture system that preserves nature and guarantee the desired sustainability for future generations. This is therefore referred to as sustainable agriculture. In order to change this deplorable situation for agriculture and to guard against future problems, a reallocation of land according to suitability for specific cultivation in terms of sustainable development is necessary (Shepande, 2002). Traditional methods based on manual overlay procedures become unwieldy to implement or even inappropriate. Indeed, the implementation of these procedures requires a lot of time because of the thesaurus of data and may be subjected to errors (human and/or graphical). Current approaches, based on GIS, spatial analysis and multicriteria analysis are available and are able to assist in management and decision-making (Mendas et al., 2007).

The main purpose of this research is to propose a conceptual and methodological framework for the combination of GIS and multicriteria methods in a single coherent system that takes into account the whole process from the acquisition of spatially referenced data to decision-making. In this context, a spatial decision support system for developing land suitability maps for agriculture has been developed. The algorithm of ELECTRE Tri is incorporated into ArcGIS environment and added to the other analysis functions of GIS. The system consists of a section for data preparation and another for data processing. It was tested on an area of Mleta in Algeria. This approach to assessing land suitability for agriculture is a new and original application in Algeria.

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2. Methodology

Despite its enormous potential, GIS contributes little to solving specific problems for decision-makers. In order to fill these gaps in terms of decision support, other analytic capabilities must be incorporated into GIS (Mendas et al., 2010). By focusing only on the spatial aspect of the problem, we can neglect an important fact namely that the assessment of land suitability for agriculture is based on a number of criteria (qualitative and/or quantitative with a contradictory effect and a differing importance) and takes into account data from various sources. Moreover, decisions must be taken at different levels: from the selection of types of land use through to their allocation to the areas most suitable for agriculture. In other words, the assessment of land suitability is a process of multicriteria decision support (Prakash, 2003). Rules and methods defined in spatial multicriteria decision support can be widely used to assess suitability. Indeed, these methods relate to the application of multicriteria analyses in spatial contexts in which alternatives, criteria and other elements of the decision problem have an explicit spatial dimension.

2.1. Process for determining land suitability

The use of a GIS tool is essential when using an approach of MCDA (Mendas et al., 2007). This need is due to GIS capabilities for acquirement, storage, extraction and analysis of spatial referenced data, hence the importance of spatial multicriteria analysis. The conceptual idea of combining GIS–MCDA is based on the use of GIS capacities to prepare a suitable platform for the use of multicriteria methods (Fig. 1). The limitation of classical Boolean operations of data overlay can be removed by integrating GIS and multicriteria decision making methods (Malczewski, 2004). The process to determine land suitability begins by understanding the problem (De la Rosa and Diepen, 2003). The capacities of GIS are used to define the potential alternatives (land units) and to identify the full set of criteria. Data overlay procedures are used to reduce the initial set of alternatives and thus to facilitate their evaluation by multicriteria methods (Chakhar and Mousseau, 2008). Capabilities of GIS concerning the display and representation (Goodchild, 1987) are used to present the outcomes. The proposed solution is an automation of the main steps to determine the land suitability map for agriculture according to Fig. 1.

The users should select the required criteria and determine their weights. In order to assess the land suitability for any crop type all possible criteria and their characteristics have been collected (85 criteria) and recorded in the developed system in tabular form. Selections are possible on the criteria during the choice of a particular type of crop. The determination of land units allows the user to specify land units from which will be estimated the suitability for agriculture. Here the constraints are specified. In order to do this, some overlay operations are used.

2.2. Concept of the solution

In this study it proved unnecessary to incorporate analysis methods in GIS independently of a special theme. In other words, it would be preferable to implement modules easily integrated in a GIS and dedicated to specific applications. These modules will present interfaces that use terms related to the field under consideration. Moreover, they will integrate only the most appropriate analysis methods. The issue addressed is land suitability for agriculture. The ideal solution would be to incorporate a module including important classification methods in a GIS as well as appropriate analysis methods independently of data, of the study area or of the crop type. It will represent a spatial decision support system dedicated to developing land suitability maps for agricul-

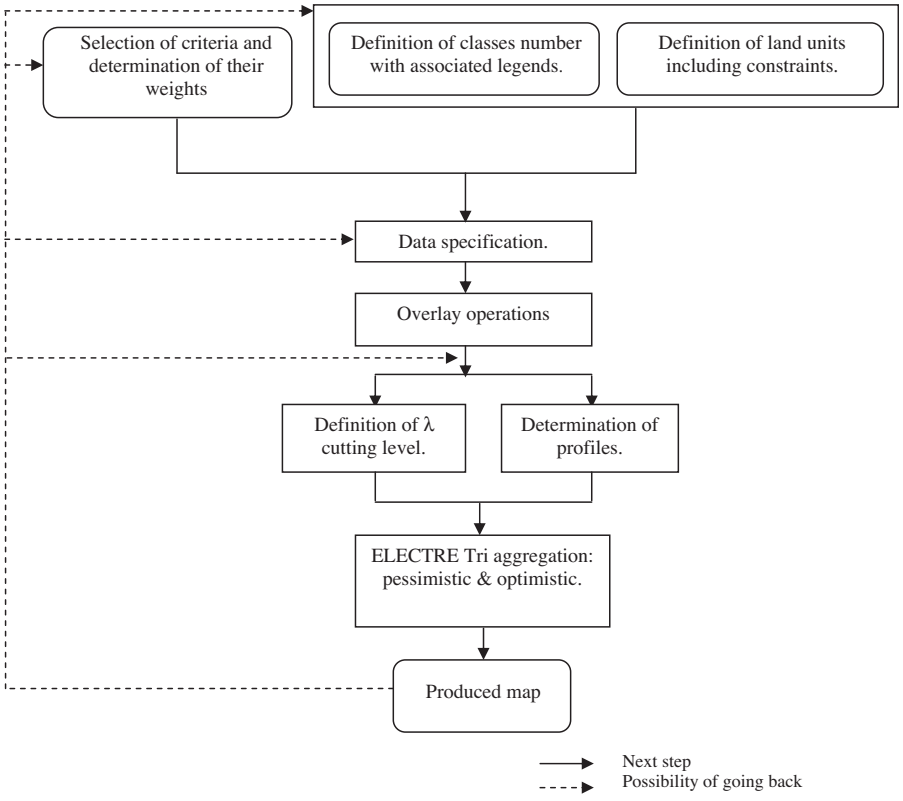

Fig. 1. Main steps of the drawing up of land suitability map for agriculture.