

Support system based on GIS and weighted sum method for drawing up of land suitability map for agriculture. Application to durum wheat cultivation in the area of Mleta (Algeria)

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Abstract

Due to constant decrease in farmlands, it is important to identify the best lands 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 a range of factors. Spatial analysis approaches, based on the concepts of the weighted sum, combined with Geographical Information Systems (GIS) offer the opportunity to efficiently produce these land suitability maps. The functions of the weighted sum make it possible to assign numerical weights, to distinguish between positive and negative criteria and to rank alternatives. A spatial decision support system has been developed for establishing the land suitability map for agriculture. It incorporates a version of the weighted sum method SAW (Simple Additive Weighting), applicable to the vector data model, in ArcGIS within the GIS program package environment. This approach has been tested on the area of Mleta (Algeria) to assess the land suitability for durum wheat agriculture. The parameters and the classification system used in this work are inspired from the FAO. The coherence of results confirms the system effectiveness.

Additional key words: FAO classification; geographical information system; land evaluation; spatial analysis; sustainable agriculture.

Resumen

Sistema de apoyo basado en SIG y método de la suma ponderada para elaborar mapas de aptitud de tierras para la agricultura. Aplicación al cultivo de trigo duro en la región de Mleta (Argelia)

Debido a la constante disminución de las tierras dedicadas al cultivo, es importante identificar cuales son las mejores tierras para una agricultura sostenible (agricultura productiva y rentable que protege el medio ambiente y es socialmente equitativa). Este requisito se ha traducido en el desarrollo de mapas de aptitud de tierras para la agricultura mediante la combinación de una serie de factores. Los métodos de análisis espaciales, basados en el concepto de la suma ponderada, en combinación con los SIG, ofrecen la oportunidad de producir de manera eficiente estos mapas de aptitud. Las funciones de la suma ponderada hacen que sea posible asignar ponderaciones numéricas para distinguir entre criterios positivos y negativos y clasificar las alternativas. Para establecer un mapa de aptitud de tierras para la agricultura se ha desarrollado un sistema espacial de apoyo a la toma de decisiones, que incorpora una versión del método de sumas ponderado SAW (simple additive weighting o método de la suma ponderada simple), aplicable al modelo de datos vectoriales, en el entorno del programa ArcGIS. Se ha aplicado esta metodología para evaluar la aptitud de las tierras para el cultivo de trigo duro en la región de Mleta (Argelia). Los parámetros y el sistema de clasificación utilizado en este trabajo se inspiran en la FAO. La coherencia de los resultados confirma la eficacia del sistema.

Palabras clave adicionales: análisis espacial; agricultura sostenible; clasificación de la FAO; evaluación de tierras; sistema de información geográfica.

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Abbreviations used: CEC (cation exchange capacity); GDEM (global digital elevation map); GIS (geographical information system); PNDA (National Plan of Agricultural Development); SAW (simple additive weighting).

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, salinisation, floods, etc.).

The water supply is generally irregular and insufficient. Consequently, the soil becomes unproductive. Climate change may further disrupt agricultural production. Algeria decided in 2000 to establish a plan to revive the agricultural sector. This is the national plan of agricultural development (PNDA) that became in 2002 the national plan of agricultural and rural development (PNDAR). The plan aims to adapt production systems to the physical and climatic conditions of various production areas. However, the classification of agricultural lands is one of the priority actions initiated by the plan. The investment operation for this project aims to develop some tools, including the agricultural lands potentialities map, indispensable to the decision making in the field of affectation, use, exploitation, management, protection and preservation of agricultural lands (INSID, 2005). The sustainable agriculture concept involves a quality production in a supportive environment, socially acceptable and economically efficient, *i.e.* an optimum use of available natural resources for an efficient agricultural production. To satisfy these principles, we should grow crops where they are best suited and for which the first and most important condition is to conduct land suitability studies. Therefore it is necessary to move toward an agriculture system that preserves nature and guarantee the desired sustainability for future generations. 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 become increasingly cumbersome to implement or even inappropriate. Current approaches, based on geographical information systems (GIS), spatial analysis and criteria weighting 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 a weighted sum method, adapted to vector data, 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. It incorporates a multicriteria method characterized by an additive aggregation of criteria by weighted summation, based on spatial analysis, namely the Simple Additive Weighting (SAW) method, in ArcGIS 9.2 of ESRI. The system consists of a section for data preparation and another for data processing. This approach is a new and original application because it has not been used to assess land suitability for agriculture. The system consists of a section for data preparation and another for data processing. The exploitation of graphical display potentialities of this system provides the decision maker with information increasingly richer and easier to grasp. It was tested on the area of Mleta in Algeria.

Methodology

An assessment of suitability for agriculture may be done through overlay operations on numerous multidisciplinary data mainly related to soil, climate and crops. These data can be represented as layers and tables. The spatial aspect of our problem led us to use GIS and spatial analysis. Indeed, GIS is seen as a decision support tool for solving a range of territorial problems (Chrisman, 2002). Spatial analysis is a vital part of GIS and can be used in several applications such as analysis of land suitability for agriculture (Raju, 2003).

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).

Spatial analysis and suitability for agriculture

Spatial analysis existed long before the development of GIS. In the past suitability maps for agriculture were usually produced by manual overlay of various criteria maps. As a result of developments in computer science, this analysis has been incorporated in GIS. Thus, current GIS are equipped with modules and tools for modeling to improving decision support. Some techniques are already implemented and can be used for determining land suitability for agriculture. These in-

clude computer-aided combination of maps (with multicriteria evaluation) (Malczewski, 2004). It is a method based on mapping algebra techniques including overlay analysis (Tomlin, 1990). These techniques are often referred to as multicriteria evaluation (Hopkins, 1977). They are the most used approaches for assessing land suitability for agriculture. The user provides criteria maps and constraints maps.

Traditionally, SAW is widely used in GIS using raster-based analysis. In order to meet our own needs, we implemented a version of this method applicable to vector data. Each land unit is classified on the basis of its suitability for a particular crop type.

The process to determine land suitability begins by understanding the problem (De la Rosa & Van Diepen, 2003). The capacities of GIS are used to define the potential land units and to identify the full set of criteria. GIS capabilities in display and representation (Goodchild, 1987) of data are used to present the results. The proposed solution is an automation of the main steps to determine the land suitability for agriculture according to Figure 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 have been collected (85 criteria). It will make it possible to choose the required criteria for a particular crop. The

user has the opportunity to specify land units for which the suitability for agriculture will be estimated. Here the constraints will be specified. In order to do this, some overlay operations are used. To achieve the spatial join it is necessary to specify the aggregation rule to be applied on criteria maps. Then the user has to define automatically the number of classes and legends. The limits of classes of suitability are defined according to the values of the aggregation result according the following equation:

$$\text{Suitability assessment} = \sum_{i=1}^{\text{Number of criteria}} \text{Criterion weight} * \text{Criterion evaluation}$$

Each criterion evaluation takes a value from: 1, 2..., number of classes, 1 being the worst value and Class 1 the worst class. But before the user defines the class boundaries, theoretical limits are proposed using the following rule: the maximum value of suitability that a land unit may take against a given class corresponds to the maximum values that a unit can take for each criterion with respect to the same class. For example, if we had four classes and 10 criteria where three criteria are of high importance (3), four criteria are of medium importance (2) and the remaining three criteria are of low importance (1), the theoretical limits will be defined according to Figure 2.

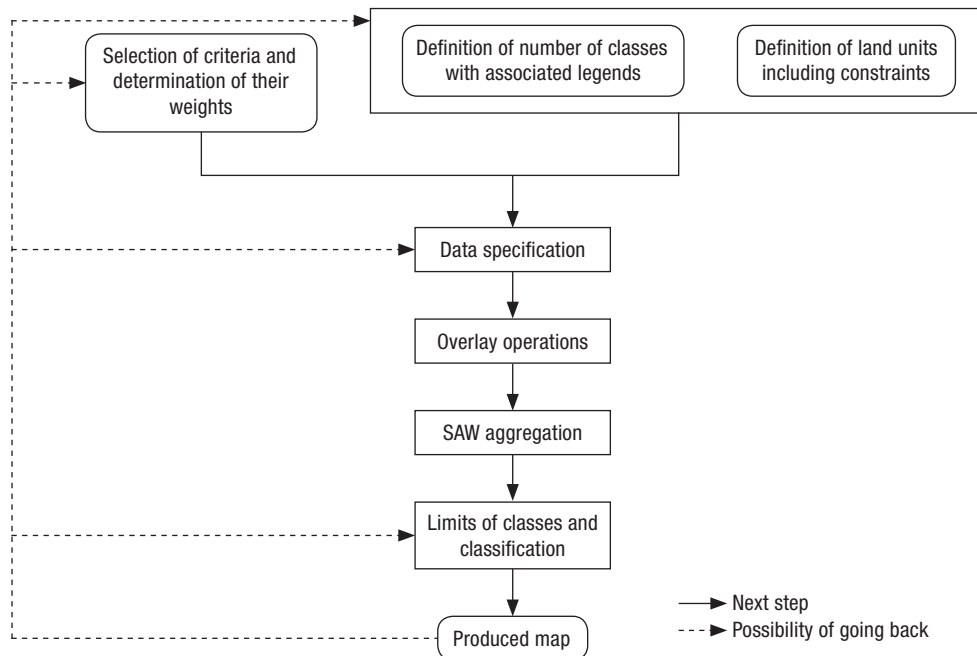


Figure 1. Main steps of the drawing up of land suitability map for agriculture.

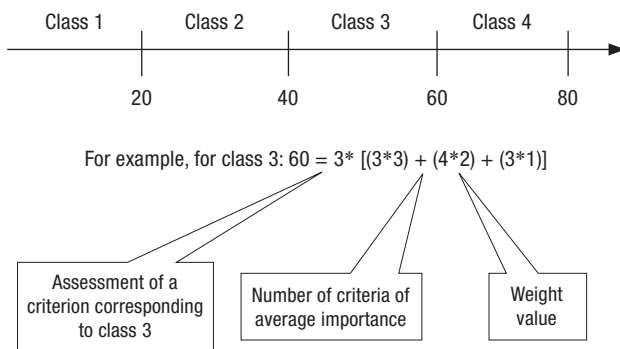


Figure 2. Example of classification (theoretical limits).

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 agriculture. In the developed system, the FAO classification method has been implemented for the following main reasons:

- Simplicity, objectivity and opportunity to develop automated procedures (Delli *et al.*, 1996).
- The method has been revised to adapt to new technologies: GIS, remote sensing, etc. (FAO, 2007).
- It takes into account the criteria useful to develop sustainable agriculture.
- It is general and independent of the study area and of the land use type.

The SAW method (Malczewski, 1999) was chosen in this work. It is among the most often used techniques for resolving spatial decision making problems. The decision maker directly assigns weights of relative importance to each attribute. A total score is then obtained for each alternative (land unit) by multiplying the importance weight assigned for each attribute by the scaled value given to the alternative for that attribute, and summing the products over all attributes.

The alternative with the highest overall score is chosen (Malczewski, 1999).

In this work the application of the SAW method follows the steps below:

- Choose a numeric evaluation scale (number of classes: 5).

- Reclassify each land unit to values from the evaluation scale (values 1, 2, 3, 4 and 5 for classes: very suitable, moderately suitable, marginally suitable, not suitable and outside assessment respectively).

- Weight each input criterion map. Land units of each criterion map are multiplied by the required weights (3, 2 and 1 for: very important, moderately important and unimportant respectively).

- Aggregate together the resulting land unit values, for each criterion, to produce the output map of suitability. New minimum and maximum limiting values of previous classes will be defined.

The SAW method can be supported by any GIS system having overlay capabilities. The overlay techniques allow the aggregation of criteria maps to determine the final map. This method can be implemented in raster or vector GIS environments (Malczewski, 1999).

In this study all these approaches (SAW and FAO classification) have been integrated into ArcGIS 9.2 of ESRI (2005) to develop a spatial decision system. This system is independent of the study area and of the type of crop.

Description of the system

Our system consists of two parts. The first is devoted to data preparation and the second is intended to land suitability assessment as illustrated on Figure 3.

The user can access the ArcMap menu via a button that enables the user to hide or activate it. In this way, the user can take advantage of all available tools in ArcMap, without cluttering the interface or misleading uninitiated users. The interface is designed so that the user realizes that he/she is using a tool conceived for the assessment of land suitability for agriculture and not a simple ArcMap tool.

This part is important insofar as it includes a set of tools to facilitate analysis on the one hand, and to use some existing data and to adapt them to the project on the other. Three tools have been developed. These are the tools of proximity, zoning and standardization. The *proximity* tool makes it possible to carry out a map which will be used when the specified criterion is expressed in prox-

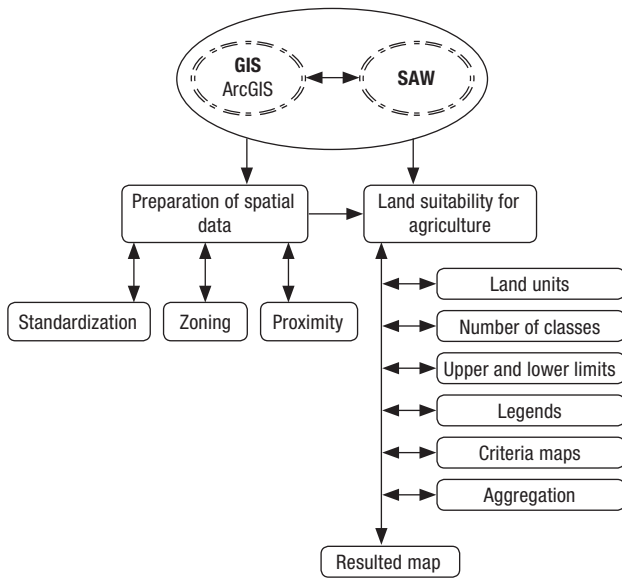


Figure 3. Main components of the system.

imity to specific items as, for example, roads, rivers, etc. This map is produced by a set of buffers associated with specified distances. The *zoning* tool gives the possibility to create shapefiles corresponding to areas that the user has defined either by specifying already existing areas or by defining himself these areas. Thus, the user will be able to have a clear vision of the area that will be taken into consideration during the assessment. Because of the difficulties encountered during the preparation of project data, we have given thought to a *standardization* tool. It facilitates the data manipulation on the one hand, and it can give the user an overall view on data and on the spatial distribution of attribute values contained therein on the other. This tool also allows the establishment of the constraints map. The user will have to choose criteria deemed useful to assess the suitability for a particular type of crop. In this way the application will be conducted for any type of crop. Here weights recommended by FAO (1977) (3 for very important; 2 for moderately important; 1 for unimportant) are taken into account. The 85 criteria are regrouped according to the 32 factors and the five categories defined by FAO (1989).

Determination of land suitability

That consists of specifying (i) the title of the suitability map and (ii) land units for which the assessment will be conducted. There should be a field containing the constraints value (0 or 1). The value 0 corresponds to

land units unused for agriculture. The value 1 corresponds to efficient land units that can be grown and (iii) the number of classes that must be greater than or equal to 2. In our case, according to the FAO guide (FAO, 1977) we have four classes (S1: very suitable, S2: moderately suitable, S3: marginally suitable and N: not suitable). A fifth class corresponds to units outside assessment. The user can choose between legends random or in line with those defined for the final map. The analysis by the SAW method incorporated into the ArcGIS software is coherent with the methodology set out in the FAO guide (FAO, 1977). Legends corresponding to predefined classes are associated for each criterion.

The user will subsequently indicate data of criteria maps and fields containing their assessment. In order to achieve this, some data overlay operations have been used. Their main purpose is to recover land units assessments for every chosen criterion. A spatial joint is carried out between layers according to the scheme illustrated in Figure 4.

Data will be aggregated by the algorithm most used in GIS namely the weighted sum. But this algorithm already incorporated in GIS is applicable only on raster data creating land units with no meaning in our case study. However, the objective of the research which requires land units well delineated and the nature of data available to develop our application have led us to propose a version of this algorithm applied to vector data, especially to polygons. This avoids the conversion of all data to raster format.

Before the classification of land units, the user must first specify the limits of his/her classes, notably their

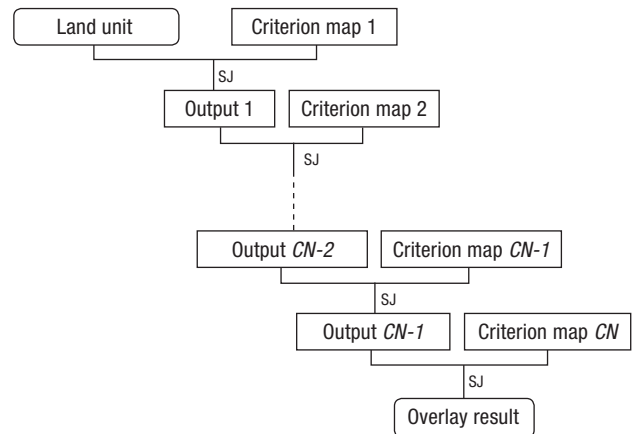


Figure 4. Overlay operations. SJ: spatial joint or intersection and spatial joint. CN: criteria number.

lower limits. The interface for determining classes is designed so that the user should have an idea about the extent of each class. It also informs him/her on the minimum and maximum values of the aggregation. A legend is defined.

By taking into account the constraints field (value 0 and 1) we will obtain the final map which initially involved all land units (Figure 3).

Application to Algeria

Because of the critical situation of the agriculture, Algeria decided in 2000 to establish a plan to revive this sector. This is the national plan of agricultural development (PNDA) that became in 2002 the national plan of agricultural and rural development (PNDAR). The plan aims to adapt production systems to the physical and climatic conditions of various production areas. However, the classification of agricultural lands is one of the priority actions initiated by the plan. The investment operation for this project aims to develop some tools, including the agricultural lands potentialities map, indispensable to the decision making in the field of affectation, use, exploitation, management, protection and preservation of agricultural lands (INSID, 2005). The sustainable agriculture concept involves a quality production in a supportive environment, socially acceptable and economically efficient, *i.e.* an optimum use of available natural resources for an efficient agricultural production. To satisfy these principles, we should grow crops where they are best suited and for which the first and most important condition is to conduct land suitability studies. In order to implement the developed system, the area of Mleta in Algeria (Figure 5) was chosen. Most data needed for our application are available in the hydro-agricultural improvements and the pedological studies conducted by SCET-Tunisia/ENHYD–Algeria (2007) and ANRH-Algeria respectively. The findings of these studies will allow us to validate the results obtained by our system. This area covers some 10,033 ha and is located approximately 20 km from Oran. The study area is easily accessible by National Road 4 (RN4) and National Road 3 (RN3) which cross the area in the west-east and in the north-south directions respectively. Furthermore, several roads of Wilaya as CW35, CW18 and CW50 cross or surround the area.

The land units map (74 units) was obtained by digitizing existing maps. The constraints map was

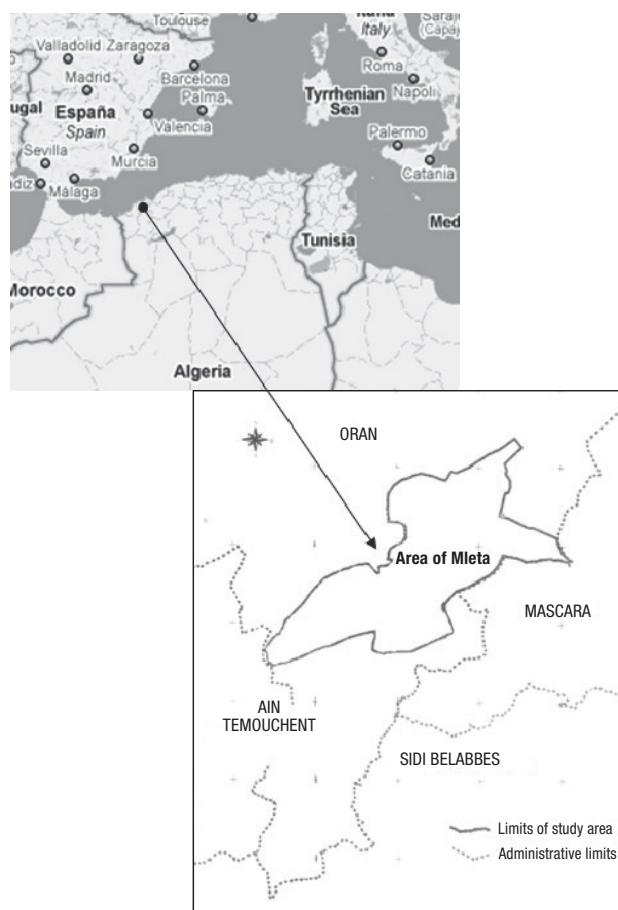


Figure 5. Situation of study area.

produced from the land use map available with agricultural services. It is obtained by adding a field to the associated attribute table that contains the value 1 for the selected land units and 0 for those restricted. It first speeds up the processing and, secondly, facilitates the interpretation of outcomes. Indeed, units of value 0 in the added field are directly eliminated and assigned to the outside assessment class.

The main criteria necessary to establish the suitability map for agriculture are deduced from (i) agronomic factors, (ii) planning, (iii) land enhancement and improvement, (iv) soil conservation and environment protection and (v) socio-economic conditions (FAO, 1989).

On the basis of these factors we identified eleven criteria, necessary for durum wheat (*Triticum durum* Desf.), to which we added the two criteria of proximity and availability of labour. These 13 criteria are regrouped in Table 1 according to the corresponding data source.

Table 1. Main used criteria

Criteria	Importance	Weight	Data source
CEC ¹	Medium	2	Hydro-agricultural improvements study (SCET-Tunisia/ENHYD-Algeria, 2007)
Soil water	Medium	2	
Soil useful depth	Low	2	
Active limestone	Medium	2	
Sodicity	Medium	2	
Drainage	High	3	
Organic matter	High	3	
Salinity	High	3	
Slope	Low	1	Aster GDEM ²
Availability of labour	Low	1	World population map (www.diva-gis.org). Topographical map in 1/25,000
Proximity (roads)	Low	1	
Rainfall	High	3	National Agency of Water Resources (ANRH, Algeria)
Temperature	High	3	

¹ CEC: cation exchange capacity. ² GDEM: global digital elevation map.

Each criterion is represented as a “criteria map” in a shapefile. For all criteria maps, we used the standardization and the proximity tools to identify the final data to be used for the application.

Thirteen criteria needed to the durum wheat agriculture have been selected from the eighty five criteria already collected and recorded in the developed system in tabular form. All criteria used in this study have been weighted with help from experts from agricultural services directorate. Thus, drainage, organic matter, salinity, rainfall and temperature were estimated of high importance. Cation exchange capacity (CEC), soil water, soil useful depth, active limestone and sodicity were considered of medium importance. Availability of labour, slope and proximity (roads) were estimated of low importance (Table 1).

Results and discussion

The development of land suitability map for durum wheat agriculture requires the analysis of criteria illustrated in Table 1. These criteria exist in different vector maps with different value scales (meter, degree ...). We cannot overlay, for example, a map of slope to a map of drainage and obtain a meaningful result. Additionally, in our study, criteria are not all of equal importance. In a single criteria map we must prioritize values. The SAW method makes it possible to take all these issues into consideration. Values have been reclassified in the input criteria maps onto a common

evaluation scale of suitability. Criteria maps have been weighted and aggregated together to produce land suitability map for the durum wheat cultivation. Restricted land units are excluded from the analysis because they were implicitly assigned to the “outside assessment” class.

Once data are prepared, the necessary parameters to operate the system have been defined as land units, criteria and criteria maps. The implementation of the achieved system has led to the map shown in Figure 6.

Thirty land units were assigned to class S1, twenty six land units to class S2, five land units to class S3 and only two land units were assigned to class N. Eleven land units were considered outside assessment. In terms of surface area, 4,925.68 ha were very suitable, 4,015.52 ha moderately suitable, 226.58 ha marginally suitable and 206.69 ha not suitable to durum wheat cultivation. Some 659 ha were outside assessment.

The results of this study can be considered satisfactory since they tend to the findings of the study conducted by SCET-Tunisia/ENHYD–Algeria. It would suffice to have all reliable and necessary data relating to the case study if better outcomes were to be expected. These data are easily introduced in the system and can be updated in any time if necessary.

Therefore, using the developed system, results should be closer to reality since all criteria and their relative importance are taken into account at the same time. With classic methods land assessment is based on past experience of specialists in the field of agriculture and on the most important criteria.

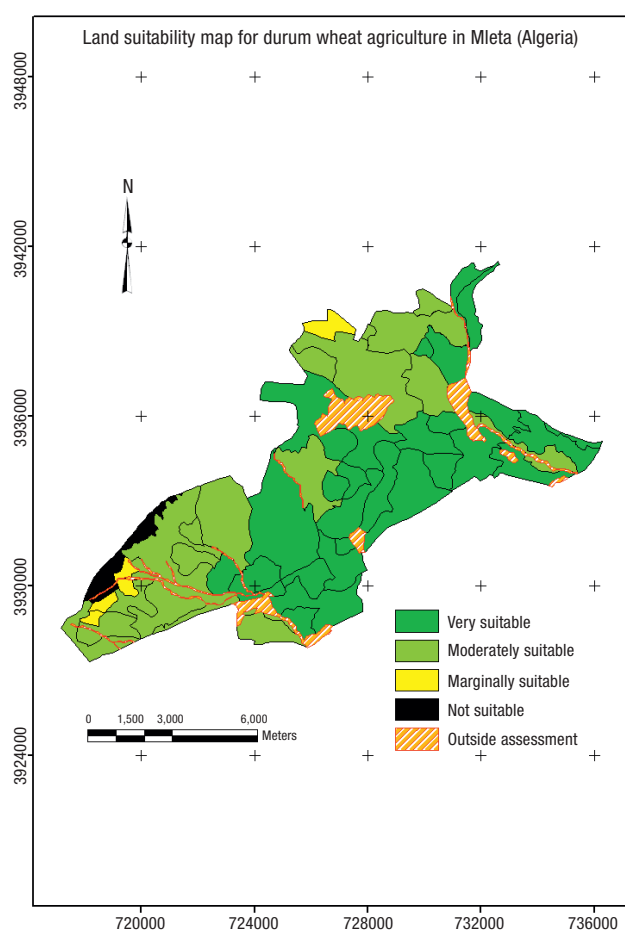


Figure 6. Land suitability map for durum wheat agriculture in the region of Mleta.

It is clear that this map does not represent a definitive result of the suitability. By the way, it is the very principle of the spatial decision support. We do not take a decision instead of the decision-maker but he/she is provided with the necessary elements in order to make his/her own choices. However, it must be recognized that the SAW method provides more accurate and better outcomes than those obtained by the classic method if all necessary data are available.

Several authors used the concept of spatial analysis and GIS to develop a conceptual approach of decision support for land suitability. This concept has been applied in a wide variety of situations including suitability of land for agricultural activities.

Malczewski (2006) integrated the ordered weighted averaging (OWA) method and ArcView GIS 3.2 to develop watershed management strategies in the Cedar Creek watershed in Ontario.

Jayasinghe *et al.* (2010) used the available spatial information for the identification of suitable area for

tomato and cabbage crop. Layers and crop requirement factors were analyzed by spatial analysis tools of ArcView GIS 9.1. Abdelkawy *et al.* (2010) developed a model in order to assess the agricultural land capability and suitability, and to develop wheat and maize yield prediction. It based on ArcGIS 9.3 and multicriteria evaluation (MCE) concept. MCE is a methodology used to handle land suitability evaluation. It is primarily concerned with how to combine the information from several criteria to form a single index of evaluation. Basic concepts in land suitability assessment in MCE are expressed by four steps: factors, rating, weight and score. Reshmidevi *et al.* (2009) integrated GIS and MCE techniques to develop a model for the agricultural land suitability evaluation using the indigenous knowledge collected from the farmers and experts. Shahram (2010) used a MCE approach within GIS context for the physical land suitability evaluation based on FAO land evaluation framework for wheat irrigated area in the South of plains Damghan. This study was carried out by overlapping all individual maps (soil map units, soil depth map, slope map, texture soil map and soil fertility) with GIS techniques for physical land suitability classification.

In our study, because the required criteria are heterogeneous and measured on various scales, the SAW method was integrated into ArcGIS 9.2 of ESRI to identify land suitable for agriculture. Its concept is different than the concept of multicriteria evaluation used in most studies above mentioned. This approach is better suited to the problem of land suitability for agriculture based on the FAO classification mode. It aims to allocate land units to the predefined classes.

The SAW method is easier to use and requires few parameters for its execution. But it should be recognised that it is more sensitive to the data. As for the limits of classes, they depend solely on the user. It should be remembered that in this application, we have considered only the four classes: S1, S2, S3, N and a fifth class corresponding to units outside assessment. The subclasses were not taken into consideration. All criteria have been deducted from FAO guide (FAO, 1977). Each criterion is unique to eliminate the redundancies. Among the 85 criteria previously identified, only 13 criteria inherent to durum wheat were used. The importance of the criteria was taken into account. Through this application, we have not tried to identify the most appropriate type of land use, but rather to assess the suitability of land units for the cultivation of durum wheat. The classification result was presented as a suitability map.

The incorporation of SAW, for vector data, in ArcGIS was of great importance for the identification of suitable land for agriculture. Indeed, GIS functionalities have actively contributed to the preparation of geographical data, particularly to the definition of the criteria maps and the input of their main characteristics. Data required to the implementation of the SAW method are also recorded in attribute tables of GIS. Once the algorithm of SAW is incorporated into ArcGIS, the assignment of land units to predefined classes becomes easier.

The consistency of the outcomes reproduced here increases the degree of confidence of the decision-makers and affirms the efficiency of the method used. With a GIS, such information may be made available in a format that will be easily interpreted, can be interactively displayed, and is amenable to many types of data processing, which subsequently enables updating. The time saving during the development of the land suitability map for the agriculture of the durum wheat was considerable.

The interest and problems related to the determination of land suitability for agriculture are considered in this paper. Then, it was a matter of proposing the most appropriate solutions based on modern approaches. Spatial and multicriteria aspects of the studied problem led us to develop a spatial decision support system. This system incorporates a weighting method (SAW) in ArcGIS. It is a method based on the concept of the weighted sum intended to vector data and consists in classifying land units in accordance with the defined criteria and their importance as well as the limits predefined by users. This method is easily adapted to the classification mode used by FAO and retained in this research. But its use requires a good understanding of the problem on the one hand and data availability on the other hand. However, this approach uses the spatial analysis whether in the preparatory phase of data or during processing and aggregation procedures of evaluations and preferences of decision-makers. The developed system is of a special importance insofar as it integrates GIS functionalities and a weighted sum method in a single framework. It includes the 85 criteria of land assessment for agriculture established by FAO and all parameters needed to data aggregation. It is general and does not depend on the study area or crop type. The exploitation of graphical display potentialities of this system provides the decision maker with information increasingly richer and easier to grasp.

All land units were assigned to five categories (S1, S2, S3, N and outside assessment). Through the obtained results, it appears that the SAW method, integrated into ArcGIS 9.2 of ESRI, is well suited to the problem of land suitability for agriculture. The power of this method lies in the aggregation mode of decision-maker preferences and in the assignment of land units in accordance with predefined classes. It is true that the definitive decision is also the outcome of other processes, such as the political strategies which can not be formalized, but the scientific identification of land suitable for a particular cultivation is an important aid to the decision making. It should be pointed out that in practice a good assessment of the land suitability for agriculture requires the availability of multidisciplinary data. This approach is a new and original application in Algeria, because it has not been used to assess land suitability for agriculture. The work currently being carried out is aimed at integrating other multicriteria analysis methods for decision making to give more finesse to the expected outcomes. We are also proposing to give the user the possibility to manipulate, in the system, data in raster or vector format.

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References

- Abdelkawy OR, Ismail HA, Rod JK, Suliman AS, 2010. A developed GIS-based land evaluation model for agricultural land suitability assessments in arid and semi arid regions. *Res J Agric Biol Sci* 6(5): 589-599.
- Chrisman N, 2002. *Exploring geographic information systems*, 2nd ed. John Wiley & Sons, NY.
- De la Rosa D, Van Diepen C, 2002. Qualitative and quantitative land evaluation. In 1.5. Land use and land cover, *Encyclopedia of Life Support System (EOLSS-UNESCO)* (Verheye W, ed.), Eolss Publ, Oxford, UK.
- Delli G, Martucci A, Sarfatti P, 1996. Land suitability evaluation for winter wheat in Tiaret region (Algeria). In: *Surveillance des sols dans l'environnement par télédétection et systèmes d'information géographiques*, Monitoring soils in the environment with remote sensing and GIS

- (Escafadal R, Mulders MA, Thiombiano L, eds). Colloques et Séminaires ORSTOM, Paris, pp: 531-542.
- ESRI, 2005. ArcGIS 9. Prise en main d'ArcGIS. GIS by ESRI.
- FAO, 1977. Cadre pour l'évaluation des terres. Bulletin Pédologique n°32, 64 p. FAO, Rome.
- FAO, 1989. Evaluation des terres pour l'agriculture irriguée: directives. Bulletin Pédologique n° 55. FAO, Rome.
- FAO, 2007. Land evaluation. Towards a revised framework. Land and water discussion paper, n° 6. FAO, Rome.
- Goodchild MF, 1987. Towards an enumeration and classification of SIG functions. Proc Int Geograph Inform Syst (ISIG) Symp, The Research Agenda, pp: 67-77.
- Hopkins L, 1977. Methods for generating land suitability maps: a comparative evaluation. J Am Inst Planners 34(1): 19-29.
- INSID, 2005. Le classement des terres agricoles. Institut Supérieur de l'Irrigation et du Drainage). Available in: www.insid-algerie.com.
- Jayasinghe PKSC, Mashida T, 2010. Web based GIS online consulting system with crop-land suitability identification. Agr Inform Res 17(1): 13-19.
- Malczewski J, 1999. GIS and multicriteria decision analysis. John Wiley & Sons, NY. 392 pp.
- Malczewski J, 2004. GIS-based land-use suitability analysis: a critical overview. Progress in Planning 62: 3-65.
- Malczewski J, 2006. Integrating multicriteria analysis and geographic information systems: the ordered weighted averaging (OWA) approach. Int J Environ Technol Manage 6(1/2): 7-19.
- Mendas A, Hamadouche MA, Nechniche H, Djilali A, 2007. Elaboration d'un système d'aide à la décision spatiale- Application à la dangerosité de l'infrastructure routière. J Decis Syst 16(3): 369-391.
- Mendas A, Errih M, Benahmed Daho SA, Hamadouche MA, Saidi A, 2010. Water impoundment location -approach using GIS and multicriteria decision making. Rev Int Géomatique 20(1): 87-103.
- Raju PLN, 2003. Spatial data analysis. Proc Satellite Remote Sensing and GIS Applications in Agricultural Meteorology, Training Workshop, 7-11 July 2003, Dehra Dun, India. pp: 151-157.
- Reshmidevi TV, Eldho TI, Jana R, 2009. A GIS-integrated fuzzy rule-based inference system for land suitability evaluation in agricultural watersheds. Agr Syst 101(1-2): 101-109.
- SCET-Tunisia/ENHYD-Algérie, 2007. Hydro-agricultural improvements study of Mleta-Oran, Algeria.
- Shahram A, 2010. Land suitability analysis for wheat using multicriteria evaluation and GIS method. Res J Biol Sci 5(9): 601-605.
- Shepande C, 2002. Soils and land use with particular attention to land evaluation for selected land use types in the Lake Naivasha Basin, Kenya. MSc in Soil Information for Sustainable Land Management. ITC, Netherlands, 100 pp.
- Tomlin CD, 1990. Geographical information systems and cartographic modeling. Prentice-Hall, Englewood, Cliffs, NJ, USA.