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INTEGRATION OF GIS AND MULTICRITORIAL HIERARCHICAL ANALYSIS FOR AID IN URBAN PLANNING: CASE STUDY OF KHEMISSET PROVINCE, MOROCCO

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1. INTRODUCTION

The emergence of a desire for integrated urban planning in the Moroccan territory has led to new demands for the rationalization of land resources and the economic overvaluation of urban and rural positions in the agglomeration, in order to respond to the stakes economic and social and environmental challenges. At the present time, it is a strategic issue of local and national governance, and it remains a priority that also leads to a real investment and wealth creation opportunity. However, taking into account the concept of sustainable development requires a multidimensional analysis of the land mobilization and management project for the purposes of urbanization.

The extensive bibliographic study in the field of town planning reveals that few approaches based on methods of land use analysis in relation with the property protection regime, land tenure and the physical characteristics of the property and using the AHP method to structure the components and evaluate all the criteria of the problem according to their weight. It is this observation that led us to consider examining the contribution of multicriteria modeling to the planning of urban space, by exploring possible approaches to address the specific problems and challenges of territorial planning and urban management.

The objective of this study is to develop an approach for the classification of zones conducive to urbanization based on multicriteria analysis and a geographical information system (GIS) in order to orient the decisions makers to use and valorize of land for better management of urban planning programs and policies and sustainable development in the province. For the evaluation of the factors, we chose the single synthesis criterion approach using the Analytic Hierarchy Process (AHP) and Weighted Sum Model (WSM). The selection of this AHP method is mainly due to its simplicity, ease of understanding to solve a wide range of unstructured problems, its flexibility as well as its ability to integrate quantitative and qualitative criteria into the same decision framework. It will be supplemented by the WSM method for the definition of formulas for calculating the concepts of aggregate impact and weighted criticality.

2. DATA AND METHODS

The methodology adopted to examine the use of land resources for urbanization is a privileged and unavoidable path towards genuine decision support systems. It exploits the functionalities offered by GIS for the structuring of data, the crossing of layers of information and the spatial analysis of the different themes. It also uses the multi-criteria hierarchical analysis approach AHP which allows assembling a multitude of decision criteria in a single model, to make the comparative evaluation of each pair of criteria and to calculate their weight for the comparative evaluation of each pair of options for each subcriteria.

The process followed to meet the requirements of land mobilization for urban planning is implemented in the following major steps: Development of a digital GIS database that includes all spatial information, determination of the evaluation criteria/subcriteria and formation of the

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hierarchical structure of the multiple criteria problem, application of the analytic hierarchy process (AHP) method to calculate the criteria/subcriteria relative importance weights, aggregation procedure by the simple additive weighting (SAW) method to estimate suitability indexes.

2.1. STUDY AREA

The province of Khémisset is located in the northwest of Morocco between the parallels 33,12° to 34,17° north and meridian 5,67° to 6,84° west. The province has an area of 8,305 km^2. It is bounded on the north by the province of Kénitra, on the south by the provinces of Khouribga and Khénifra, on the east by the Wilaya of Meknes and on the west by the Wilaya of Rabat-Salé. It is subdivided into four circles (Khémisset, Oulmès, Rommani and Tiflet), four municipalities and 31 rural communes.

2.2. REPRESENTATION AND MODELING OF SPATIAL DATA

The approach applied in this research requires the use of data relating to several areas in relation to land-use planning such as land, topography, urban planning, infrastructure and demography. The collection, analysis and integration of data relating to the work area has allowed the creation of a spatially referenced database of the area was chosen as a pilot site. Software such as QGIS, Gobal Mapper and Google Earth were used to process the data and set up a geographic information system for the study area:

- The land layer includes data on land tenure, land protection, plot size and market value of areas. This information is essential to evaluate the land mobilization process.
- Relief is the second spatial layer needed to understand the land use event. Then, the slope and exposure maps were generated from a Digital Terrain Model (DTM) acquired from ASTER DEM data with a resolution of 30m.
- Planning and Urban Planning: The town planning allocation map is likely to inform all planning decisions and to draw up guidelines for regional development. The different layers of land use were developed by digitizing the different urban planning documents, city maps, topographic maps, Google Earth images and integrating data from the existing databases of the Ministry of Agriculture and the High Commission for Planning.
- Population density: The spatial distribution map of the population density was developed, taking into account the area and population of the various communes based on the demographic data published by the High Commission for Planning.

2.3. STRUCTURING A DECISION PROBLEM AND SELECTION OF CRITERIA

The evaluation criteria used are classified into three main categories, namely the Land property, Topography, and Land use criteria. The hierarchical structure of the decision problem consists of four levels. The first level represents the ultimate goal of the decision hierarchy (The suitability of land resources for urban planning), the second level represents the criteria, the third level represents subcriteria utilized in this work and the fourth level represents the spatial attributes of each subcriterion. The result is a classification of the set of attributes or parameters according to a hierarchical structure, which then allows applying the AHP method. The decomposition diagram of the problem in a hierarchical structure of the important decision criteria is explained in Figure 1.

In the case study and as mentioned earlier, there are no specific criteria for selection of potential sites for planning and urban development. The subcriteria used in this study were based on criteria derived from the literature review with some adjustments to locally desired priorities and requirements. The subcriteria used are classified into nine main categories, as shown in Figure 1: the land status, regime property, land prices, land slope, land exposure, surface property, urban land uses, density population and infrastructure. Among many aspects which have to be considered in the selection of potential sites, it is important to take into account most of these criteria and to weigh them objectively. In this study, subcriteria were standardized in a common interval of 0 to 10.

FIGURE 1

Graphical representation of the levels of the hierarchy of criteria

Goal	Programming of land resources for urbanization		
Level 1	Identification of potential sites for planning and urban development		
Level 2 Criteria	Land property	Topography	Land use
Level 3 Subcriteria	Land status	Land slope	Urban land use
	Regime property	Land exposure	Density population
	Land prices	Surface property	Infrastructure
Level 4	Spatial attributes		

Source: Our results.

2.4. CALCULATING CRITERIA WEIGHTS AND CHECK THE CONSISTENCY OF THE JUDGMENTS

The AHP method proposed by Saaty (1980) is an effective approach to extract the relative importance weights of the criteria. The AHP is based on pairwise comparisons, which are used to determine the relative importance of each criterion. By comparing pairs of criteria at a time and using a Saaty's scale, decision makers can quantify their opinions about the criteria's degree. For each pair of criteria, the decision maker is required to respond to a question such as "How important is criterion A relative to criterion B?" Rating the relative "priority" of the criteria is done by assigning a weight between 1 (equal importance) and 9 (extreme importance) to the more important criterion, whereas the reciprocal of this value is assigned to the other criterion in the pair. The weighing's are then normalized and averaged in order to obtain an average weight for each criterion. The calculated geometric means are then normalized and the relative importance weights are extracted (Table 1).

TABLE 1

Pairwise comparison matrix and relative importance weights of the evaluation criteria

Criteria	1	2	3	4	5	6	7	8	9	weights%
1	1	2,0	3,0	2,0	3,0	7,0	2,0	3,0	5,0	22,6
2	0,5	1	3,0	2,0	2,0	5,0	2,0	2,0	3,0	15,8
3	0,3	0,3	1	2,0	3,0	3,0	0,3	0,5	3,0	10,5
4	0,5	0,5	0,5	1	2,0	5,0	0,3	2,0	2,0	10,8
5	0,3	0,5	0,3	0,5	1	3,0	0,5	0,5	3,0	7,3
6	0,1	0,2	0,3	0,2	0,3	1	0,2	0,2	0,3	2,4
7	0,5	0,5	3,0	3,0	2,0	5,0	1	2,0	3,0	15,5
8	0,3	0,5	2,0	0,5	2,0	5,0	0,5	1	5,0	11,4
9	0,2	0,3	0,3	0,5	0,3	3,0	0,3	0,2	1	3,7

Source : Our results. (1) Regime property, (2) Land status, (3) Surface property, (4) land prices, (5) land slope, (6) land exposure, (7) Urban land use, (8) Infrastructure, (9) Density population.

The notion of coherence in the Saaty pair comparison (1980) is based on respecting the transitivity of our judgment. Thus, the coherence index measures the reliability of the comparison expressed incoherent judgments. However, perfect consistency rarely occurs in practice. In the AHP the pairwise comparisons in a judgment matrix are considered to be adequately consistent if the corresponding consistency ratio (CR) is less than 10%.

The comparison in pairs of the criteria applied for our study case and when these approximations are applied to the previous judgment matrix it can be verified that the following are derived: λmax = 9,640; CI = 0,08; RI =1,45 and CR = 0,05 < 0,1. The CR has a value less than 10%, indicating the consistency of the matrix and makes it possible to assert that the judgments of appreciation of the criteria have been coherent.

2.5. AGGREGATION PROCEDURE

To obtain a weight of importance by criterion, it is necessary to aggregate all the criteria defined for our theme and as confirmed in the hierarchical structure below. According to the literature, Our problematic corresponds to the complete aggregation or approach of the single criterion of synthesis since they consider that this method is the only one applicable when there are several criteria which vary continuously in the space. It consists in integrating all the data in the mathematical expression relative to the AHP method in order to obtain a single value after integrating the weight attributed to each criterion and combining these criteria into an indicator. In the case study of Khémisset province, the suitability index is estimated using the method of simple additive weighting. This is a widely utilized method for the calculation of final grading values in multiple criteria problems.

3. RESULTS AND DISCUSSION

The use of the method AHP combined with geographic information systems provided decision-making support for the assessment of potential land for urbanization. The multicriteria analysis of the factors and the spatial analysis made it possible to produce thematic maps by criterion, as well as a final synthesis map combining the nine criteria according to their corresponding weights.

In order to calculate the suitability indexes, the evaluation criteria shown in Figure 2 were used with their corresponding relative weights shown in the last column of Table 1. The method of simple additive weighting was selected as the proper way to dissolve the multiple criteria problem of the land use suitable for urbanization. Factor weights are given in Table 1 after standardizing all factors. The sum of all factors is 1. Corresponding maps with all factors were reclassified by GIS. The score was assigned based on the grade of each area. Then, the final suitability map is produced by aggregation procedure based on weight.

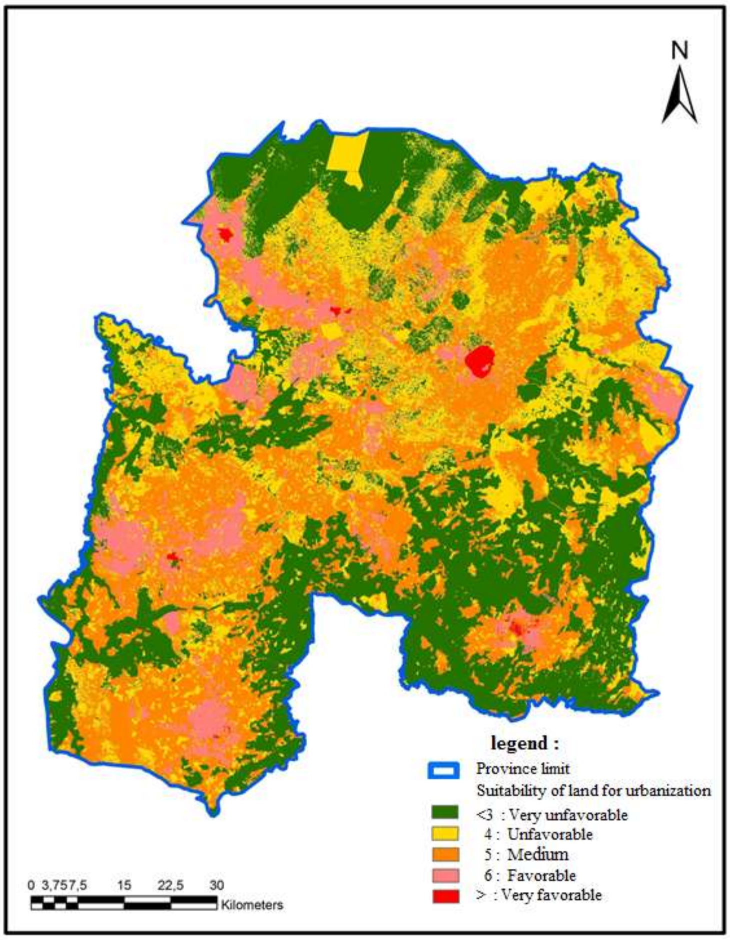
The synthesis map obtained shows, through its legend, the values of the aggregation of the various parameters organized into five classes ranging from the first rank favorable to urbanization to the fifth place to be reserved to be protected or excluded from the priority of urbanization. This classification is performed according to the experts' opinion after similarity with the basic data collected previously, reconciliation with the reality ground and juxtaposition with the images Google Earth and Bing Maps: the cells with a score greater than 7 were assigned to the first Ranks, cells with a score equal to 6 were assigned the second rank, cells with a score equal to 5 were assigned the third rank, cells with a score equal to 4 were assigned the fourth rank and the fifth rank collected the cells With a rating of less than 3.

As shown in Figure 2, land suitability increases as the suitability index increases. Areas with suitability indexes from 0 to 3 can be generally considered as unsuitable for urbanization. Sites with grades ranging from 6 to 10 are expected to be the best sites for urban development.

The final suitability results were divided into five discrete categories: the best potential sites for planning and urban development, good land resources for urbanization, medium land suitability, bad land suitability for urbanization and unsuitable areas, as shown in Figure 2.

FIGURE 2

Land use suitability mapping for urban area



Source : Our results

4. CONCLUSIONS

The methodology described in the present paper is an efficient approach in identification of land resources for planning and urban development. The methodology combines the evaluation abilities of hierarchical multi-criteria evaluation methods and the analytical tools of GIS. The AHP was utilized to form the siting problem into a decision structure of four hierarchical levels, namely, the goal (suitability of land resources for urbanization), evaluation criteria, assessment criteria subcriteria and spatial attributes. The AHP method was utilized to extract the relative importance weights of the evaluation criteria and the SAW method was utilized to calculate the suitability indexes, in order to solve the land resources use problem. GIS was utilized to create the spatial determination of the evaluation criteria and create the land suitability map. In addition, GIS was utilized to perform spatial statistics and spatial clustering processes in order to reveal the most suitable areas to urbanization.

The GIS federated to the multicriteria analysis offers territorial management possibilities integrating all parameters related to its development. These techniques have been applied to the province of Khémisset for the definition of a model for the understanding of the process of programming of the land resources for the needs of urbanization. It also provides a means of mapping the use of land suitable for urban development and of enlightening professionals on the destination and allocation of potential areas: to open for urbanization, to reserve for agriculture or to protect.