GEOMATIC TOOLS AND MULTI-CRITERIA ANALYSIS FOR MANAGING AND CONSERVING THE BIODIVERSITY OF THE NATIONAL PARK OF AHAGGAR (ALGERIA).

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ABSTRACT:
This paper presents a geographic information system GIS-based multi-criteria decision making approach for biodiversity preservation at the national park of Ahaggar (Algeria). This tool named SDMA (Spatial Decision Making Aid) enables decision makers to evaluate the relative priorities of conserving the biodiversity in protected areas based on a set of preferences, criteria and indicators for the area. In this study, we have developed conceptual and methodological solutions to integrate outranking methods (such as Electre Tri and Promethee) of multi-criteria analysis in the GIS software to enhance the potential of these as tools of spatial decision support in land management problems. These method are more appropriate to spatial decision-making problems and their integration into a GIS vector (ArcView GIS 3.2 software of ESRI).

1. INTRODUCTION

The main objective is to develop a methodological approach that ensures the repetitive acquisition of multi thematic data (ecological, socio economic...) and their integration into a geographical information system (GIS), this last ensure the location of the natural and cultural heritage at the National Park of Ahaggar (NPA) (Algeria).

In front of the problems, the management of the natural and cultural heritage of Algerian Sahara (where is located the NPA) which is currently knowing very serious dysfunctions (Le Houérou H.N., 1968, 1997) and, in addition, the absence of an coherent approach able to mobilize all competences and the resources which present the different needs for the sustainable development.

Biodiversity is the natural diversity of living organisms. It appreciates by considering the "totality of genes, species, and ecosystems of a region” in space and time, as well as the organization and distribution of the ecosystems on biogeography scales Maintaining biodiversity is an essential component of sustainable development.

To conserve biodiversity, we need to understand what biodiversity is, determine where it occurs, identify strategies to conserve it, and track over time whether these strategies are working (Melina, F.L., et al, 2008). The national park of Ahaggar, occupies an important part of Algeria (447,000 km²), analysis of space at the moment t₀ then the follow-up spatio-temporal of the most relevant biological indicators are necessary stages in this case. However, conventional methods of diagnosis phyto-ecology and following-up biodiversity, which are numerous and diverse, do not allow the study of large spaces in a reasonable time and do not meet often, the expectations of the practitioner's field; In this context, the application of geomatic technologies (GIS, DTM, data of remote sensing, digital mapping...) is quite justified.

Indeed, the National Park of Ahaggar, by its large area, is characterized by:
- unknown natural and cultural patrimony, to locate and explore;
- rich but weakened and threatened biodiversity, to preserve;
- ecosystems undergoing unpredictable climatic variations in time and space, to manage;
- And, overall, an heritage, both cultural and natural, to preserve and transmit to future generations.

For this, the management of protected area (the case of Ahaggar), from its complexity and its multiple-sector character, called upon important masses of data which, for the majority, are geographically located, i.e. topographic data, cadastral data, satellite images, verification, completely, spatio-temporal monitoring, maps and various thematic data (geology, pedology, hydrology, natural vulnerability, land use, conservation, communication, transport, archeology), data and socio-economic, fauna and Flora (forest stands, hunting, fauna corridors, areas used by fauna, potential, sensitivity to desertification).

How to manage this important set of data? The whole purpose is to ensure:
- the perennity of data;
- easy and quick acces for the different data;
- spatial analysis and high accuracy location-based applications;
- cartographic editions of good quality for the authorities concerned;
- a decision support and management of various planning actions, protection of natural and cultural heritage.
2. METHODOLOGICAL APPROACH

Geomatics includes several tools and methods to represent, analyze and integrate spatial data, it is therefore at least three distinct activities: collecting, processing and dissemination of geographic data.

2.1. GIS-based Evaluation and Biodiversity Conservation

The capability of geographic information systems (GIS) in handling spatial aspects of conservation has boosted its use in the criteria-based evaluation for prioritization and selection of potential conservation areas. This is because most of the criteria for conservation planning are spatial data. For example, GIS techniques have been used for predicting the distribution of the wild relatives of bean by analyzing climate conditions that favor bean’s growth (Jones et al., 1997), and for planning potential conservation areas by using relationships between environmental factors and the distribution of birds (Mariuki et al., 1997). GIS techniques were found invaluable as a rapid tool for wildlife species habitat modeling under situations of incomplete data (Rubino et al., 2003). Smallwood (Smallwood et al., 1998) employed an indicators assessment approach using GIS techniques for evaluating habitat of several species. The selection of conservation areas in most of these studies is based solely on scientific results where a rational decision making process is assumed.

GIS is a very powerful tool, and can be used for a variety of quantitative analysis. It is the "glue" that holds all the data together and allows the display, analysis and measurement of different information from different sources (Goodchild et al., 1996). GIS can be used for area’s measurement, testing different theoretical assumptions, and also develop useful models to try to find new resources based on statistical analysis of the relationship with environmental and cultural data.

The integration of remote sensing data within a GIS has a significant potential in regional applications for the management of cultural and environmental heritage. Various researchers worldwide use these tools today. Some of these applications include the location of new features such as archaeological sites, road network, automated extraction of hydrology network, land use and vegetation index (SPOT, Land Sat image).

2.2. GIS-based Evaluation and Multi-Criteria Analysis

The spatial decisions problems are generally refer to heterogeneous systems which interact on many different factors. Mastering the complexity of these problems requires the use of methods, techniques and powerful analysis tools, which must not only manage but also analyze a different spatial data. The geographic information systems (GIS) disposes powerful tools for manipulating, managing and analyzing spatial data, but they lack the mechanisms to integrate the decision maker's preferences and make a choice in a context of objectives assessment and conflicting criteria (Molines et al., 2002). These restrictions, in terms of preference modeling and selection procedures mean that the scope of GIS as a tool for decision support is currently limited (Joerin, 1995). Multi-criteria analysis (MCA) is suitable for evaluation of different impacts, quantitative or qualitative, relative to large-scale projects. It is also appropriate to the decision-making processes related to the collective choice where points of views are contradictory. Therefore the integration of GIS and Multi-criteria analysis is a preferred way to develop spatial decision support (Laaribi, 1995).

Indeed, the use of GIS contributes to the collection of information, production of derived information and handling a large volume of data which helps to consider the problem in all its complexity and describe the different alternatives (Cooodchild et al., 1996), through its functions of spatial analysis, it contributes to evaluate the different alternatives according to the criteria defined by the decision maker.

As for methods of decision support, they can synthesize this information to facilitate the interpretation for decision making (Roy, 1985).

2.3. Multi-Criteria Analysis Method

The use of these methods is primarily based on several reasons. They preserve the data in their initial format (Bouchard et al., 2005). The treatment, without reference of the ordinal data and the cardinal data, makes it possible to take account of the effect of each criterion (Maystre et al, 1994). Most of the territorial problems, whose nature is complex, use many criteria which often present a qualitative and incommensurable character. From where need for using methods which take account of this characteristic (Joerin, 1997). The examples of territorial management treated by the methods of outclassing are more numerous (Ben Mina, 2000; Ben Mina, 1999; Schärlig, 1996; Guinting, 2000). It thus seems more interest to expose the operation of these methods rather than the methods of local or complete aggregation. The smoothness of the results obtained (Thresholds of indifference, when the difference between two actions is not significant, and preference, to distinguish a strict preference, according to the variation of values recognized between two actions) makes it possible to take account of the possible inaccuracy of the evaluation and to bring closer to the real-world (Schärlig, 1985). These methods contribute to make the decision-making process more explicit. Lastly, the methods of partial aggregation are easy to include/understand, consequently easy to program (Maystre and al, 1994) relative with the methods being part of the approaches requiring from the adapted, often expensive software and length to be programmed.

2.4. Weighting Method

Sometimes, it will be difficult to directly assign weights to the criteria. But it is possible to arrange the criteria in a direction growing preferably, where well, to compare between them. For this reason, there exist methods which consist in determining weights relating to the criteria, by introducing subjective information relative to these criteria. The method of the Scale of Saaty (Didier et al., 2002) consist to compare each criterion to the others and to preferably introduce a report/ratio according to the scale of Saaty (Figure 2) into a matrix which is characterized by:

\[
\forall i, j \in [1, nc]^2: a_{ij} = \frac{1}{a_{ji}} \quad \text{with} \quad i \neq j
\]

\[
\forall i \in [1, nc]: a_{ii} = 1
\]

where \( nc \) = number of criteria

\( a_{ij} \) = introduced from the scale of saaty.
2.5 Developed Prototype (Model)

The Spatial Decision Making Aid System (SDMA) is a GIS-based multi-criteria decision making approach (Figure 2) which integrates two different multi-criteria methods (Electre Tri and Promethee) in ArcView 3.2 GIS software (Copyright © 1992-1999 ESRI, Id product: 825661102074), we note that the 3rd level of integration has been used (Mendas et al., 2006; Molines, 2003; Laaribi, 1995). Also, the SDMA system contains other functionalities necessary to the problem described above. Also we have developed a decisional database to store all necessary data for the decision making process; figure 3 presents the conceptual modal for data (Hamadouche, 2005).

![Figure 2. SDMA system component.](image)

We've developed two new extensions:

### 2.5.1 "MCA" extension:

1. It gathers the algorithms of the multi-criteria analysis methods and ensures the introduction of the parameters necessary for the decision-making process such as: the choice of the MCA method, define and evaluate the potential actions and their evaluation, also, we can use SQL selection or by selecting from different layers, criteria and its parameters. Also, we have a weighted method based on scale of Saaty, the diagram in figure 4 presents the stage required to decisional problem in the SDMA (Hamadouche, 2005).

2.5.2 "Managing Biodiversity" extension: version 1.0

Recently, there has been a revolution in the availability of information and in the development and application of tools for managing information. Information needs for biodiversity are many and varied. Any database that deals with biodiversity information has to be geographically based, and able to predict where new populations of endangered species with a limited known range might be expected, indicating potential hot spots (Salem, 2003). A GIS plays an important role as a tool for environmental management, with the current greater concern for sustainable use of resources, and conservation and monitoring of biodiversity.

In the first version, it ensures the display of various data concerning the Ahaggar park such as morphological, hydrological data, manage the natural and cultural heritage, identifying the biological richness of the park, creation of maps (wildlife monitoring, health flora, spatial data on the flora and fauna, etc.), graphs (inventories, statistics), schemes.

![Figure 4. Stages of treatment in SDMA.](image)
3. APPLICATION

3.1. study area

National Park or Ahaggar is situated in the extreme south of Algeria (figure 5). It has 380,000 ha of area, it represent the largest protected area in Algeria. It is characterized by richness archaeological and historical priceless; it shelters archeological sites going back to 600,000 to 1 million years ago.

3.2. Environmental specificities and biodiversity

The forms of reliefs, combined with the presence of water, permanent or intermittent, support the development of particular vegetable éphémérophytes communities associated with the forests galleries, the steppes or maintain the formations of Mediterranean origin.

National Park of Ahaggar belongs to the central sahara which is according to the authors to the massif of Ahaggar, strongly mountainous (Tafedest, Taessa, Amguid) where the altitude varies between 1500 and 3000 m; These massif open on valleys, on ergs or on oases, “as soon as the reliefs, same weak emerge, the tree reappears, profiting can be, in addition to the natural shelter which they represent, of an infero- flow very major flow” (Barry et al., 1972-73). Thus for the massif of Ahaggar, the pluviometric and thermal parameters as their synthesis enable us to locate the climatic and bioclimatic originality. The annual average temperatures borders 24.5°C, for Tamanrasset (meteorological station of Ahaggar), the average temperature is of 30°C. January being the colder month 5.17°C at Tamanrasset and Juin the hottest month with the maximum ones which can reach 30.5°C at Tamanrasset. This attenuation seems to be a compensation of the high altitude which characterized the massif of Ahaggar (Barry et al., 1972-73).

3.3. Biodiversity preservation priority

As said above, the park of Ahaggar present an important natural and cultural heritage, by consequence, the services of the park office are often confronted by different situations of choices or determination, with contradictory point of view (called criterion), of the most favoured sites to an emergency preservation (to select the site in exposure to the various risks: fauna, flora, place of interest, …) (Galois, 2007).

For this purpose, we proposed a multi-criteria step which makes it possible to answer the following question: which site should be preserved fist? or which is the most threatened site? or which site need urgent conservation action to be taken in the form of establishing protected areas?

3.3.1 Alternatives : We retained eleven (10) sites:
1. Wadi Idikel
2. Assekrem
3. Guelta of Afilal
4. Tarharnanet
5. Site of Agmaret
6. Agmaret
7. Wadi Tamakraste
8. Illamene
10. Wadi Tinamzi.

The actions are stored in a layer of the visited sites; all of the actions will be evaluated according to the nine (9) criteria chosen by the services of the park.

3.3.2 Criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence of agglomeration</td>
<td>14</td>
<td>Agglomeration layer</td>
</tr>
<tr>
<td>Distance to a road network</td>
<td>11</td>
<td>Road network layer</td>
</tr>
<tr>
<td>Nature of the ground</td>
<td>8</td>
<td>Land cover layer</td>
</tr>
<tr>
<td>Presence of source of water</td>
<td>10</td>
<td>Hydrology layer</td>
</tr>
<tr>
<td>Presence of vegetation</td>
<td>9</td>
<td>Vegetation layer</td>
</tr>
<tr>
<td>Quality of vegetation</td>
<td>12</td>
<td>Vegetation table</td>
</tr>
<tr>
<td>Altitude</td>
<td>9</td>
<td>Digital terrain model</td>
</tr>
<tr>
<td>Nature of slope</td>
<td>11</td>
<td>Slope layer</td>
</tr>
<tr>
<td>Presence of fauna</td>
<td>9</td>
<td>Fauna layer</td>
</tr>
</tbody>
</table>

Table 1. Criteria used.

In the table 1, evaluation column present the type of data used to evaluate each alternative, e.g. use the agglomeration layer to define the number of agglomeration presented in the region of the site (overlaying visited sites layer with the agglomeration layer). For both altitude and nature of slope, we have used DTM and slope grid.

3.4. Results and discussion

According to the results obtained two type of assignment for the Electre tri method: optimist and pessimist. According to the type of this method, the area assigned to the first category for the optimist represent area which required a preservation solution (e.g. site off Agmaret, wadi Tinamzi) whereas the last category of the pessimist represents also the threatened sites.
(e.g. site of Agmaret, wadi Tinamzi, Agmaret). For the Promethee method (classification), the first sites represent the sites which required a preservation solution (e.g. site of Agmaret, wadi Tinamzi, wadi Tamakraste).

By consequence, these results are coherent which increases the degree of confidence of the decision makers on the one hand, and affirms the effectiveness of the SDMA on the other hand. The authorities concerned will be able to think of appropriate solutions in order to decrease the degradation of these protected areas.

Figure 7. Optimistic affectation (Electre Tri method)

Figure 8. Pessimistic affectation (Electre Tri method)

4. CONCLUSION

Integrating MCA with GIS for spatial decision-making purposes is both a worthwhile aim and one which will be of widespread utility to those involved in what is a mainstay application of GIS technology. This will in turn create the opportunity for the increased use of GIS based technology as the basis of decision support systems. It is important to note, however, that GIS and MCA techniques are merely tools which provide a means to an end. Without the knowledge and expertise of the operator and decision-maker, and without appropriate data, such tools would be useless. Nevertheless, GIS-MCA applications appear to represent potentially fruitful areas for further research and development (Carver, 1991).

The present study has two main objectives: the first is to develop conceptual and methodological solutions to integrate the MCA methods of in a GIS software to fill its limits as tools of decision-making aid which take in account the spatial reference of problem, while the second is to use this system in order to help to preserve the biodiversity of protected area in Algeria.

The use of the geomatic tools for management and monitoring biological diversity is completely justified seen the important set of data which are located in a large area. Moreover, the geographical information system (GIS) is dedicated to the cartography, the management and the planning of the natural and cultural heritage of the national park of Ahaggar (Algeria).

Also, we will develop a web-mapping application in order to ensure a continuous partnership between the organization concerned as well as the public. The use of GIS is recommended as a more effective approach than either manual methods or non-spatial automated means, of making biodiversity assessments.

REFERENCES

