MAPPING OF ENVIRONMENTAL VULNERABILITY OF DESERTIFICATION BY ADAPTATION OF THE MEDALUS METHOD IN THE ENDOREIC AREA OF GADAINE (EASTERN ALGERIA)

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ABSTRACT:
The development of endoreic areas of arid and semi arid climate character is strongly affected by the land conservation and combating desertification. Desertification is the result of a set of several processes. In this study, we apply the MEDALUS method (Mediterranean desertification and Land Use) on an endoreic area (Gadaine), which is located in the highlands of eastern Algeria, in order to map the desertification vulnerability due to soil salinity. This mapping was developed by crossing four thematic layers (vegetation, climate, soil, management system and human influence). Application of this method is based on the identification of vulnerable areas by different parameters (grouped into four indicators cited above) that can affect the process of desertification, using a powerful tool of spatial analysis that allows modeling of each layer. Cartographic and alphanumeric data are entered and organized in a managed and analyzed database by a Geographic Information System (GIS). The result provides a document on spatial priority areas of intervention and opens new opportunities for integrated management of this endoreic area.

Key-words: *MEDALUS method, Desertification, Gadaine, GIS, Vulnerability.*

1. INTRODUCTION

The phenomenon of desertification in arid, semi-arid and dry sub-humid zones under the (PNUE, 1991) and the (CNUED, 1992) mainly due to the interaction of environmental factors, human activity and climate variations. This phenomenon occurs through processes that lead to changes in land cover, soil surface elements (bare soil, icing film, sanding), soil depletion and disappearance. The final stage of this dynamic process makes practically no biological productivity. Nowadays, the desertification is considered as a major environmental issue for the 21st century (World Bank, 2002). According to UNCCD (2008) combating drought, land degradation and desertification is an international priority. In addition, desertification is one of the most serious problems in many countries. In Algeria, this phenomenon is the result of a series of processes in arid and semi-arid environments.

However, steppes are the most sensitive to desertification, with 20 million hectares in (UNCCD, 2002). Recently, the endoreic zone of Gadaine experienced rapid and worrying degradation of arable farmlands and another natural resources, under the combined effect of human pressure and climate change in recent decades. This area serves several criteria of desertification such as: the dynamics and progression of sebkhas and chotts (Bouhata, 2008), salinization and pollution (Temagoult, 2013) and the reduction of agro-pastoral production. So the realization a vulnerability map is an essential step for the development of this area.

This article aims to study and develop a map of vulnerability to desertification due to soil salinization of the endoreic area of Gadaine located in Eastern Algeria, using an adapted modal of MEDALUS (Kosmas, Kirkby & Geeson, 1999) and GIS tools.

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2. PRESENTATION OF THE STUDY AREA

The study area is part of the southern Constantine high plains of eastern Algeria, which constitute a vast corridor mostly dominated by two mountains ranges: Aures massif to the south and Constantine mountains range to the north, a few kilometers north of Batna city. It is defined between the ranges of coordinates; Longitude: 6°12'15" E and 6°29'50" E, Latitude: 35°55'51"N and 35°40'50" N. According to ANRH, it belongs to the watershed of Constantine high plains (07-03) (**Fig. 1**). Located at an altitude of (784 m to 1246 m), the study area is characterized by an impressive platitude whose slope rarely exceeds 5%. The area is spread on a surface of (348 km^2) representing 46% of the total surface. This favors the presence of endoreism resulted in a multitude of Sebkhas and chotts that occupying the center of the plain (Bouhata, 2008). In geologic term, the presence quaternary formations (sebkha soil, salted lemons...etc) and Triassic formations (colorful marls and gypsum breccias), significantly contribute to the salt character of these endoreic spaces. Generally, due to the semi-arid climate we can only find steppe and halophytic species that are resistant to soil salinity, mostly presented by a characteristic vegetation of large clumps Artiplex or Salsolaceae (Bouhata, 2008).

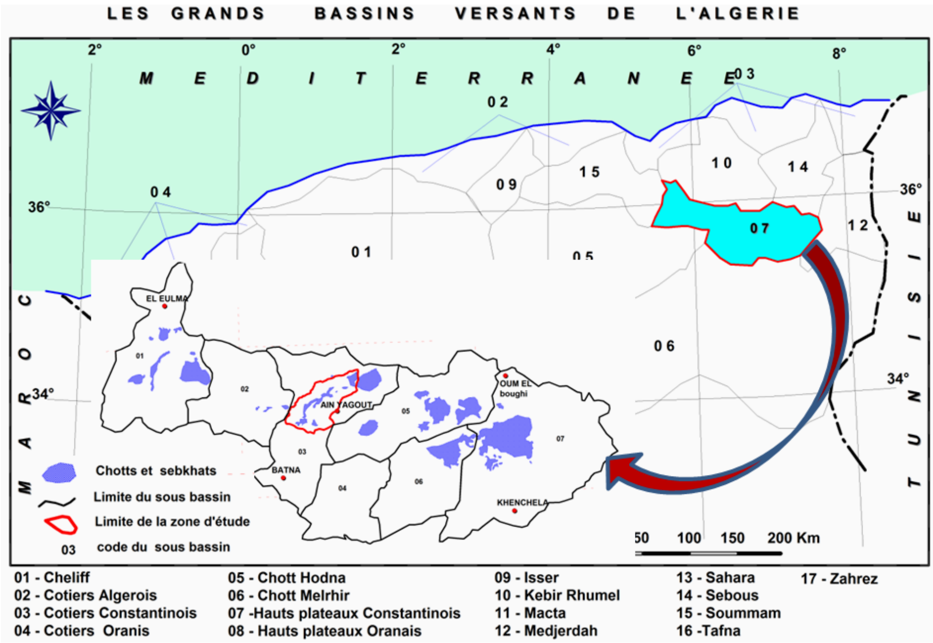

Fig. 1 Location of the study area according to ANRH (l'Agence Nationale des Ressources Hydriques) distribution.

3. MATERIALS AND METHODS

The methodology of this work is based on that one developed in the MEDALUS (Mediterranean Desertification and Land Use) project, (Kosmas, Kirkby & Geeson, 1999); identifying the vulnerability to desertification of Mediterranean ecosystems by an index of desertification sensitivity (ISD), obtained from the geometric average of another four index issued from the environment and man action. These indexes are related to the followings:

climate quality index (QCI), soil quality index (QSI), vegetation cover quality index (VQI), and the management system quality and human influence index (MSQI).

Each of these index is grouped into different uniforms classes with a weighting factor assigned for each class; then four layers are evaluated. All data defining the four main layers are introduced in a geographic area by a geographic information system (GIS), (Sepehr et al., 2007).

The Overlay control (overlay.mbx) allows the merging of layers; the superposition is made by combining databases of thematic layers and the result is the creation of a new database (Benabderrahmane & Chenchouni, 2010). All geographic data are integrated and processed in a GIS system using the software MapInfo 9.0.

The desertification sensitivity index (DSI) is given by the following equation:

$$(DSI) = (CQI * SQI * VQI * MSQI)^{1/4} \quad (1)$$

3.1. Climate quality index

The climate quality index will be determined based on two factors: index of average annual precipitation (PP) and field orientation index (OR). It is given by the following equation:

$$QCI = (PP * OR)^{1/2} \quad (2)$$

Table 1. Classes and assigned weights corresponding to calculate the climate quality index.

Factor	Class	Description	index
Average annual precipitation (PP)	1 2 3	> 350 mm 300-350 mm < 300 mm	1 1.5 2
Field orientation (OR)	1 2	NW - NE SW - SE	1 2

The determination of the PP factor is done according to the established isohyets map. While the Digital Terrain Model (DTM) allows to generate the field exposures as a basis for calculating the OR index.

3.2. Soil Quality index

This index expresses the susceptibility to the fine soil particles removal by the mechanical effect of wind, rain and runoff, considering the importance of consistency and relative distribution of soil (Basso et al., 1998). This index will be obtained depending on the factors related to the parent material (PM), the electrical conductivity of soils (EC), drainage (D) and to the field slope (S). The soil quality index is given by the following equation:

$$SQI = (PM * EC * D * S)^{1/4} \quad (3)$$

Geological maps of (Ain El Ksar 1/50000 and Ain M'lila 1/50000), the map of the electrical conductivity of soils and the Digital Terrain Model (DTM) of the study area are the basic documents for the determination of the various parameters.

Table 2. Classes and assigned weights corresponding to calculate the soil quality index.

Factor	Class	Description	Characteristic	Index
Parent material (MP)	1	Coherent	Limestones, dolomites, ophites	1
	2	Average	Colorful marl and gypsum breccia	1.5
	3	Tend to friable	Sebkha soils, anciant salt Soils, arable land	2
Electrical conductivity (CE) ds/m	1	Very low	< 4	1
	2	Low	4-8	1.2
	3	Average	8-16	1.5
	4	High	16-32	1.7
	5	Very high	> 32	2
Drainage (D)	1	Well drained		1
	2	Imperfect drainage		1.2
	3	Poorly drained		2
Field Slope (S)	1	Very gentle to flat	< 5%	1
	2	Gentle	5-10%	1.2
	3	Steep	10-20%	1.5
	4	Very steep	> 20%	2

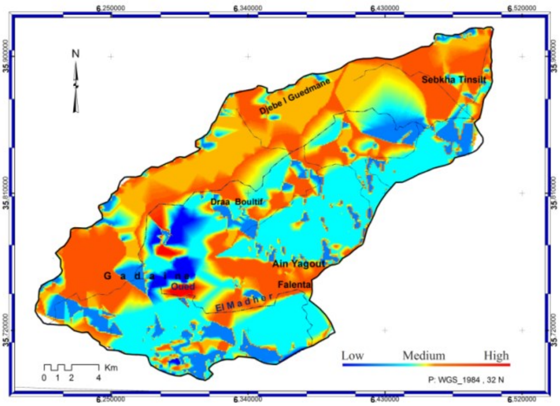

Fig. 2 Map of the climate quality index.

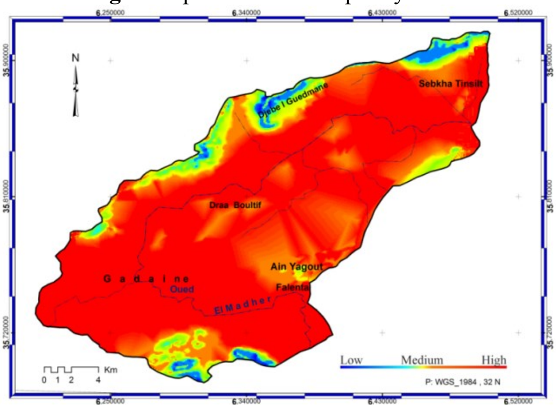

Fig. 3 Map of soil quality index.

3.3. Vegetation quality index

This index is determined by the superposition of mapping data about factors related to the type of vegetation (TV), resistance to salinity (RS), protection against salinity (PS) and vegetation cover rate (VC). The vegetation index is given by the following equation:

$$VQI = (TV * RS * PS * VC)^{1/4} \quad (4)$$

The satellite image (TM 2009) and the land use map will both serve as a basic element for the determination and the indexing of these factors.

Table 3. Classes and assigned weights corresponding to calculate the vegetation quality index.

Factor	Class	Description	Characteristic	Index
Vegetation type (TV)	1 2 3	Irrigated crops Cereals Halophytes		1.2 1.5 2
Resistance to salinity (RS)	1 2 3	High Average Low	Halophytes Commercial crops (Tobacco) Cereals and Irrigated crops	1 1.7 2
Protection against salinity (PS)	1 2 3	High Average Low		1.2 1.8 2
Vegetation cover rate (VC)	1 2 3 4	High Average Low Very low	Irrigated crops Forest Chotts Bare soils and sebkha	1 1.2 1.5 2

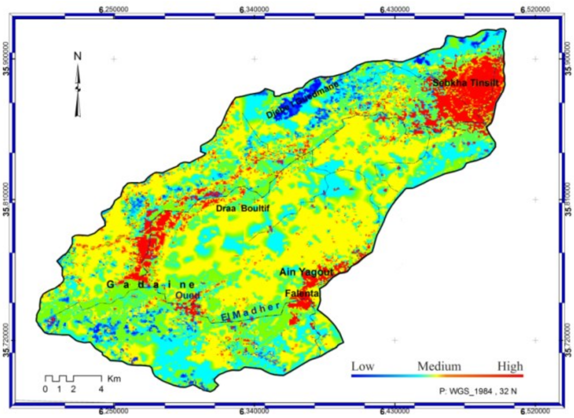

Fig. 4 Map of the vegetation cover quality index.

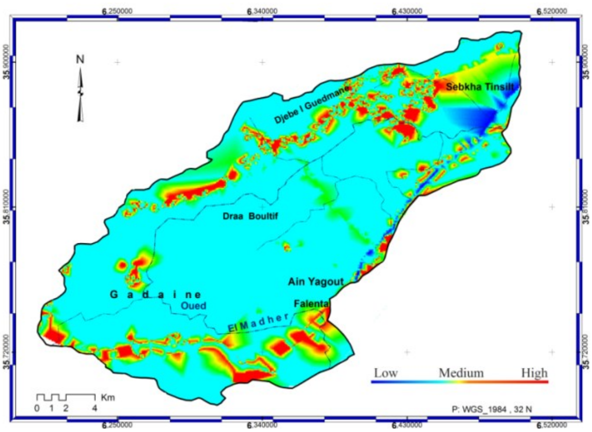

Fig. 5 Map of management system quality and human influence index.

3.4. Management system quality and human influence index

Given the endoreic character of the study area, we considered in the calculation of this index the following parameters: the intensity of agricultural land use (IALU), the spatial distribution of wells and drillings their areas of influence (SDWD), the type and impact of road networks (TRN), finally the development works and soil protection (DW). The management system quality and human influence index will be calculated by the following equation:

$$(MSQI) = (IALU * SDWD * TRN * DW)^{1/4} \quad (5)$$

The intensity of agricultural land use will be classified according to the types of used crops, based on the land use map.

The topographic maps of the study area: (Batna East 1/50000, Batna West 1/50000, Souk Naamane East 1/50000 and souk Naamane West 1/50000) serve as a background document for the determination and indexing of cartographic and alphanumeric data about the factors related to the mentioned parameters (IALU, SDWD, TRN and DW).

Table 4. Classes and assigned weights corresponding to calculate the management system quality and human influence index.

Factor	Class	Description	Characteristic	Index
Intensity of agricultural land use (IALU)	1 2 3	Irrigated crops Cereals Barelands		1 1.5 2
Spatial distribution of wells and drillings their areas of influence (SDWD)	1 2 3	Low Average High	> 300m 150 m < 75m	1 1.7 2
Type and impact of road networks (TRN)	1 2 3	Low Average High	Tracks Municipal roads and wilaya National roads	1.2 1.8 2
development works (DW)	1 2 3	Good Average Bad	Developed areas or in good conditions Developed areas requiring maintenance Areas in need of development works	1 1.5 2

4. RESULTS AND DISCUSSIONS

4.1. Map of the vulnerability to the desertification

Depending on their values, each of the four quality index is classified as high, average or low. Finally, all four are combined together to calculate a single index of desertification by using the equation (1).

The resulting map; map of the vulnerability to the desertification due to soil salinization, will be represented by three levels (**Table 5**) that reflect not only the degree of desertification, but also the risk and the severity of the natural resources degradation.

Table 5. Classes of vulnerability to desertification.

Description	Low	Average	High
Class	1 - 1.33	1.33 - 1.54	1.54 – 2

The overall review of the vulnerability to desertification map **(Fig. 6),** shows that much of the soil in the area of Gadaine are quite vulnerable to desertification due to soils salinization.

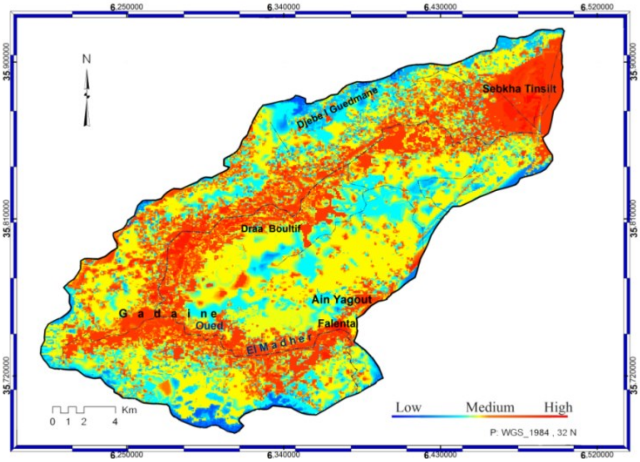

Fig. 6 Map of vulnerability to desertification.

According to the map of vulnerability to desertification:

- The seriously threatened areas by desertification and which consist of very vulnerable lands (critical) are generally located in the middle of the study area. They coincide with lands whose slope is between (0 to 8%) and occupy the areas of sebkhas and chotts and their ring surfaces, where salinity (EC) is greater than 16 ds/m.

- Areas relatively threatened by desertification and constituted by moderately sensitive land, occupy areas where drainage waters and irrigation result in the beginning of salinization due to the human pressure. The abilities of this class seem to respond more to commercial crops such as tobacco.

-Areas less vulnerable to desertification are located on the edges of Gadaine plain. They are characterized by a certain slope generating a natural drainage to Oued El Madher (main pipe).

- More than two-third (2/3) of soils in the study area are moderately to highly threatened by desertification, thus requires the implementation of a short to long term protection program and planning, in order to fight against this environmental phenomenon. The results also showed that the slope, lithology, soil type, water system, drainage and vegetation cover are the most important indicators affecting the process of desertification. This undesirable state and fact was accelerated by the rapid human impact in this area.

5. CONCLUSION

Desertification through soil salinization as a process of agricultural land degradation in arid and semi- arid zones, is widespread the endoreic Algerian areas. For the Gadaine region in Eastern Algeria, more than two-thirds of the total area, (348 Km^2), are moderately to highly threatened by the problem of the desertification. In this study, we tried to map vulnerability to desertification by adapting the method of MEDALUS and the GIS tools use. Four composites index, each of them had several sub-indicators were analyzed by using GIS that provided a huge time server, precision and reliability. Therefore, GIS is a valuable tool to store, retrieve and manipulate huge amount of data needed to map the vulnerability to desertification in arid and semi-arid areas.

The results presented the intensity and severity of desertification in this area and give us an overview on the evolution of ecosystems that can be used as an essential tool to help decision-making and planning (identifying priority areas for intervention in the fight against the desertification development).

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