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How Could Geomatics Promote Our Knowledge for Environmental Management in Eastern Algeria?

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ABSTRACT

Geomatics are referring to the combination of Earth measures with the computer science. Nowadays it is a crucial tool for decision-making in many areas such as environmental information systems and natural hazards. The use of classical statistics led to forget the first time in objects location, supplemented by the cartography, then found in an analysis in terms of residues, the spatial effects. GIS based software applications have been used widely for environment management and analysis studies. The usage of GIS in environmental risk management ranges from simple development of databases/inventory systems, to advanced GIS layers overlay, then to complex spatial decision-making systems for study of the impact of air, water and soil pollutions, ecological imbalance and natural disasters on the environmental and human receptors. Moreover, as tools of geomatics, the methods of geostatistics and mathematical morphology, when grouped in spatial statistics, they analyze the information directly in a geocoded structure. In this study, the use of Geomatics tools (GIS and Remote Sensing) for the execution and spatial analysis of land cover in the region of Aures (eastern Algeria) was discussed as well as desertification and water erosion risks were assessed. This study aims to highlight the advantages and disadvantages of these tools and to know its potential for assessing and management of natural environments within arid and semi arid contexts.

Key words: East Algeria, desertification risk, Geomatics, GIS, land cover, remote sensing, spatial analysis, water erosion hazard, environmental hazards

INTRODUCTION

The growing recognition of the relevance of protection and environment management for natural resources sustainability, combined with computer technologies has led to the development of computer based Environmental Information Systems (Ball, 1994). Such systems offer spatially referenced information “geo-information” for support environmental decision-making.

Geomatics can be defined as the modern scientific term referring to the integrated approach to measurement, analysis, management and display of spatial data (Sandewall and Nilsson, 2001). Geomatics activities include but are not limited to, cartography, control surveying, digital mapping, geodesy, geographic information systems (GIS), hydrographical surveying, land information management, land and mining surveying, engineering surveying and industrial measurement, photogrammetry and remote sensing (Ruther, 2001).

Land-cover/Land-use is a key variable for regional planning as well as for the survey of environment dynamics (Foody, 2002). It affects the biogeochemical cycles and global warming (Penner, 1994) and helps understanding soil erosion and sustainable development (Douglas, 1999) and biodiversity monitoring (Chapin *et al.*, 2000). This importance makes it of an essential theme in most cartographic inventory and monitoring of environmental phenomena. This topic can be obtained through several techniques and methods, including remote sensing. Whether space or airborne multi or hyper spectral, it makes use of passive or active sensors, for automatic classification or directed, remote sensing covers at present many types of vector data and techniques of analysis and interpretation that can characterize the surface morphometry (Lillesand *et al.*, 2004; Bonyad, 2005; Salim *et al.*, 2008).

Ecologically and environmentally, Algeria is highly precarious-more than 85% of its area (2.4 million km^2) is arid and semi-arid, which experiences irregular rainfall and frequent droughts (Chenchouni *et al.*, 2010). In Algeria, inventory of natural resources is not yet completed despite many studies carried out during the last two decades. These resources are not distributed equitably, whether in terms of their geographical distribution, quantity or nature. To predict, monitor and mitigate such disturbance in natural resources, we need rapid and continuous data and information gathering. However, conventional methods are not effective for the large areas affected and struggle to adapt to global change. Consequently, this recent context makes environmental management in Algeria a serious challenge. That is why the appeal to Geomatics is a primordial and crucial step, because GIS technologies help in organizing data about natural issues and understand their spatial relationship associations and provide a relevant mean for analyzing and synthesizing information about them.

This study aims firstly to analyse a database on multi-temporal land-cover in order to assess different states and dynamics of land use in the Aures region (East Algeria). It focuses on the integration of GIS by creating a Digital Elevation Model “DEM” in carrying out a spatial analysis that allows measurement of the real surface for each class of land-cover, because without correction, DEM gives only surface of flat areas. Moreover, this approach permits also to evaluate changes in land-cover and/or land-use. Several practical studies were reviewed to highlight the importance of Geomatics in considering environmental management or conservation studies. Our research aims at finding tools and techniques that allow a best methodological approach for the study of landscape by using both remote sensing and applications of spatial analysis with GIS. In the present study, we evaluate two case one with remote sensing and the other with GIS with perspective to know advantages and disadvantages of both tools. We aim to know which are the potentials and the limits of each of these tools.

On another hand, in order to manage effectively environmental hazards and land degradations we tested the contribution of Geomatics in understanding and assessing desertification risk and water erosion hazards. To guarantee soil loss problem control within sustainability context, policymakers need reliable spatial information that could be offered by powerful and appropriate tools (Pimentel *et al.*, 1995). Geographical Information System (GIS) allows cross maps with different themes, merge several variables to obtain a final and interactive database of soil erosion factors. It includes structured and coded data of the main factors involved in the erosive process and allows the application of mathematical equations on the numerical values of these 3 factors

(Rahman *et al.*, 2009). Furthermore, remote sensing appears as the data source of land cover. It is essential within desertification/erosion risk analysis since it constitutes a component that provides data to the geographical database (Bonn, 1998; Vrieling, 2006; Benabderrahmane and Chenchouni, 2010).

Geomatic data gathered for the Aures region (East Algeria) have allowed us to carry out several other studies, such as studying water erosion desertification risk assessment (Chenchouni *et al.*, 2010; Benabderrahmane and Chenchouni, 2010) which will be reviewed and discussed briefly in this study to highlight the contribution of GIS tool in analyzing geospatial data. We try also to give an overview through our personal knowledge (published studies and others in press) on the importance of using GIS and remote sensing as a significant tool to help decision-makers in environmental management and natural hazard mitigation.

MATERIAL AND METHODS

Study area: The study area is located in Aures region in eastern Algeria; belonging to the eastern edge of the Saharan Atlas mountain chain and separating the High Plains "Hauts Plateaux" from the Sahara Desert. It covers about 12,000 km² (Fig. 1). Furthermore, this region is located across a broad ecotone located between the sub-humid climate on Mediterranean Sea side at the north and Desertic climate from the south. This geographical position makes habitats vulnerable to climate variability.

Like most regions of Algeria except coastal areas in the North, Aures region is significantly affected by the phenomenon of natural resources degradation that led to land, water and

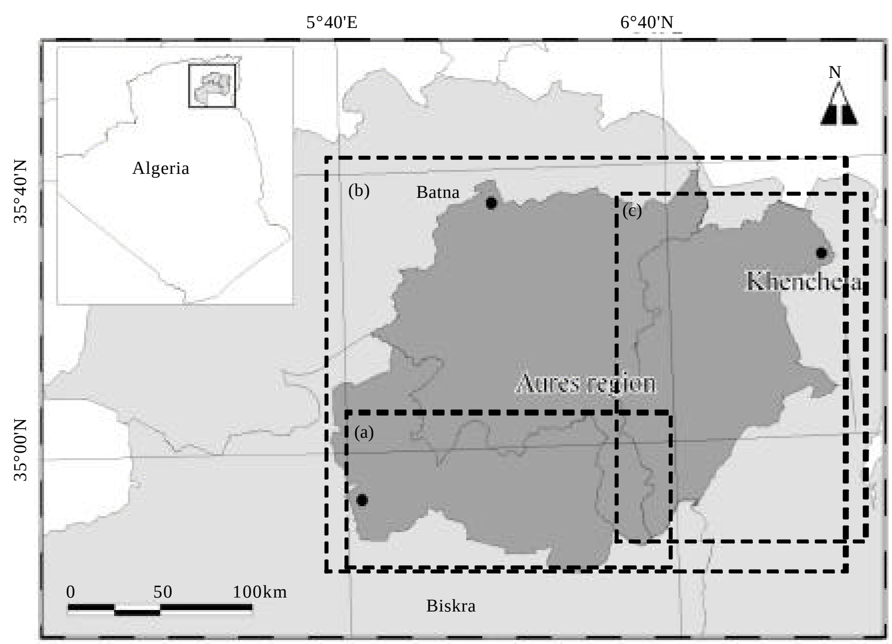

Fig. 1: Location of the study area: Aures Region corresponds to mountainous lands with its surrounding areas. Discontinuous lines define plots where partial studies were tested: (a) Diachronic analysis of land-cover evolution (b) Desertification risk assessment and (c) Water erosion hazard mapping

vegetation-cover deterioration. Indeed, huge woodland patches in this area were dramatically suffering recently of effects of drought and desertification (Allen *et al*., 2010; Benabderrahmane and Chenchouni, 2010).

Creation of land-cover maps from remote sensing data: We used a method that relies on analysis of Landsat satellite images of two different dates; one took on 1990 and the second on 2006. In order to map land-cover/land-use, satellites imageries were treated according to the following steps (see details: Lillesand *et al*., 2004): (i) Visual interpretation; (ii) Unsupervised Classification; (iii) Supervised (Thresholding uni-band and multiband); (iv) Post-classification; and finally (v) Combination of images: The multi-temporal analysis. We used the software ENVI 4.2 that characterized spatiotemporal evolution of eight classes of land-cover, including forest cover in particular since we interested in knowing its evolutionary trend (Bonyad, 2005; Salim *et al*., 2008). The software helped us to make a thematic analysis of the study area and gave us a fast and global overview on changes that occurred in the area.

Creation of digital elevation model "DEM" by GIS: A DEM was derived from measurements of altitude on the earth's surface, taken into space by digitizing contours or spot elevations on existing maps, input field (surveying) or remotely using photogrammetric aerial techniques or satellite radar measurements or, more recently airborne laser surveying (Lillesand *et al*., 2004). Most Geographic Information Systems (GIS) underestimate the areas of patches in a mosaic land and the distance between them due to planimetric projection of land elements. As most of commonly used landscape metrics utilize information about patch geometries as input parameters, this circumstance can lead to systematic errors in resulting index values (Walz *et al*., 2007). To improve this we tested a method developed by (Jennes, 2004) to approximate the realistic surface area from digital elevation model created from a topographic map of the study area by conducting a digitalization of contour lines in MapInfo 9.0 software.

The method used in this study is the triangulation with smoothing in Vertical Mapper 3.0 (a module within MapInfo 9.0). This method is based on the idea which consists in using only the points neighbouring of the related knot. When over 3 points were used, continuity problems of the resulted surface can appear. They were corrected with using of smoothing method. When only 3 points were used, the method consists to define a triangular stitch in study surface and the measuring points are the summits of triangles. Linear interpolations can else be calculated inside of each triangular facet. The DEM obtained was quite near the reality if the number of measuring points in enough. If necessary, the effects of facets can be reduced by a smoothing. Modelling methods create grid of derived values, for example by measuring attractive characteristics in percentage. In this case, the resulted grid has not the same unit as the original points table. Then lastly, we obtained a DEM in Grid format, which permit to conduct our calculations correctly.

Spatial analysis and geo-statistics: In this step, GIS was used for carrying out different operations. Products issued from satellite images represent a key-reference in geographic studies (Bonyad, 2005), even for digitized product issued from classification. Already satellite data give: (i) A good representation and compaction structure of data; (ii) Quality of representation at different scales; (iii) Updating and generalization of data is possible.

Firstly, the two land-cover maps digitalized from DEM were superposed to compute surfaces in each polygon. The method described here derives surface areas for a cell using elevation

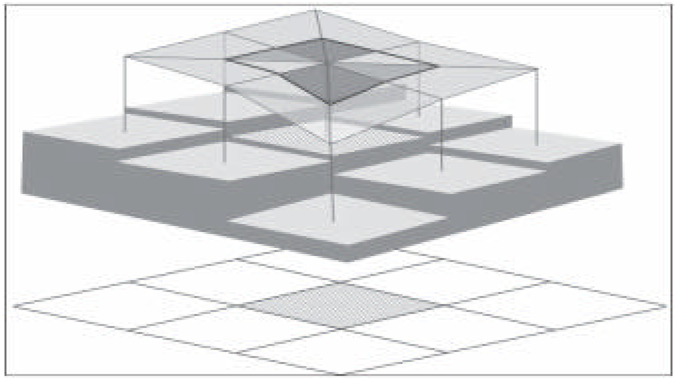

Fig. 2: Method to determine true surface area and true surface perimeter of patches. True surface area of the focal raster cell is obtained by adding the eight shaded triangles, true surface perimeter by summation of the eight bold line segments (figure redrawn according to Jennes (2004)

information from that cell plus the 8 adjacent cells. According to Jennes (2004), this method would calculate the surface area for the cell with elevation value "Z" based on the elevation values of that cell plus the 8 surrounding cells. That central cell and its surrounding cells were pictured in 3-dimensional space as a set of adjacent columns, each rising as high as its specified elevation value. Next, calculate the surface lengths of the lines that connect each of the 8 surrounding cells with the ones adjacent to it to get the lengths of the sides of the 8 triangles projected in 3-dimensional space that all meet at the center point of the central cell. These surface lengths were calculated using the Pythagorean Theorem (Fig. 2).

Assessing desertification risk: Vulnerable areas to desertification were mapped by applying MEDALUS model methods "Mediterranean Desertification and Land Use" (Kosmas *et al.*, 1999). This approach was based on use of environment-state and indicator means. Desertification risk was assessed by defining level on the basis of some parameters or indicators of four variables: soil, climate, vegetation and Management-State. Each parameter was weighted in relation to its influence and contribution on desertification process. Methodology details followed to carry out this analysis are assembled (Fig. 3).

In modelling process, four quality layers representing Soil Quality Index (SQI), Climate Quality Index (CQI), Vegetation Quality Index (VQI) and Management "Anthropogenic Factors" Quality Index (MQI) were generated stating from cartographical and alphanumerical data. The quality layers, obtained in such a way, do not depend on the structure of the input layers (number of classes, etc.) and they were compared among them as equivalent ignoring the format of input data. The values of Quality Index for each elementary unit within a layer were obtained as geometric average of scores of single indicators according to the following formula:

$$\text{ESAI} = (\text{SQI} \times \text{CQI} \times \text{VQI} \times \text{MQI})^{\frac{1}{4}}$$

where, ESAI describes a synthetic environmental sensitive areas index

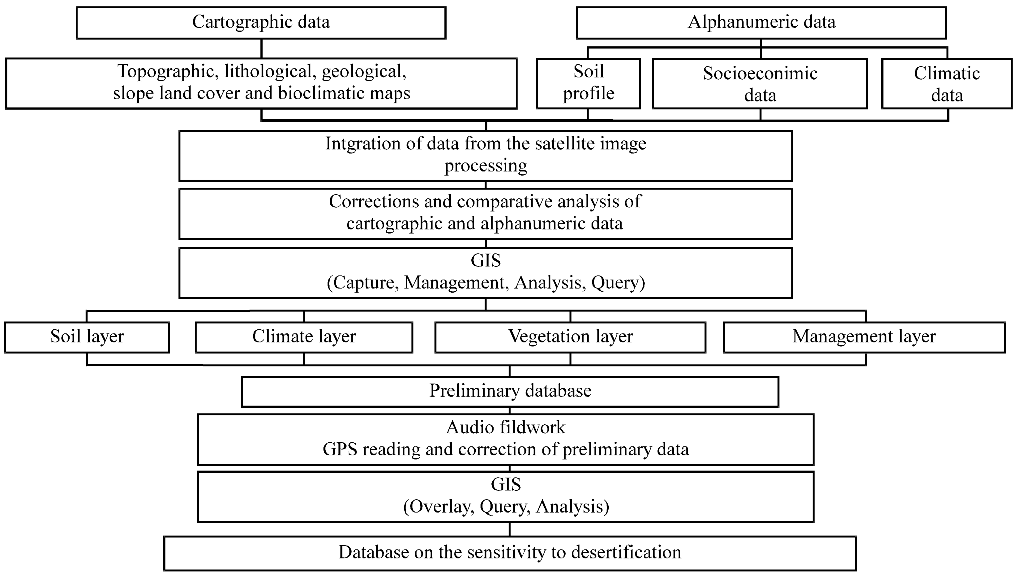

Fig. 3: Organizational chart explaining the approaches of the methodology and its components. (According to Benabderrahmane and Chenchouni, 2010)

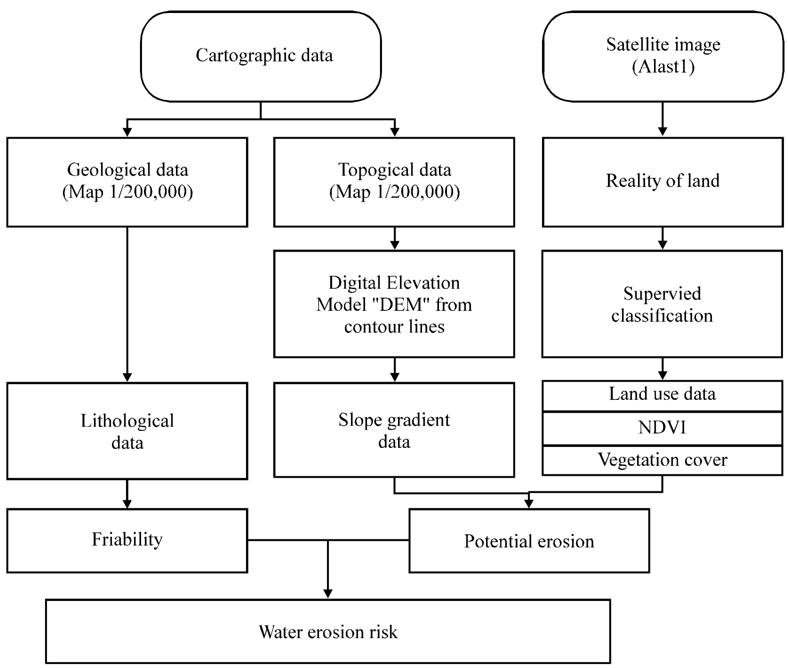

Fig. 4: General organization of the methodology for mapping water erosion risk

Assessing water erosion hazard: Several methods have been adopted for estimating the rates or the state of water erosion; the most used are the Universal Soil Loss Equation “USLE” (Wischmeier and Smith, 1978) and the Water Erosion Prediction Program "WEPP" (Laflen *et al*., 1991). Geomatics data can be used to assess the risk areas in relation to water erosion. Here we adopted a qualitative method that was used in several North African regions. This approach is based on the combination use of GIS and remote sensing and other data to model water erosion risk by analyzing three environmental factors: topography (slope gradient), geology (lithology classes) and land cover (vegetation cover) in order to obtain erosion risk map. Steps followed are listed in (Fig. 4).

RESULTS

Land cover maps for the years 1990 and 2006 were produced by independent supervised classifications using the maximum likelihood tool. Figure 5a shows land-cover of the southern Aures region in 1990 and Fig. 5b in 2006. Eight land-cover classes were intended to be mapped: forests, bush, cultivated lands, pastoral lands, steppes, watercourses, sandy soils and vacant lands (Fig. 5). The sample-areas were identified by photo interpretation according to a specific colour composition of both satellite images.

Geostatistical analyses were draw up for each land-cover class of the two satellite images (1990 and 2006) in order to highlight the evolution trends and changes of land use. These data allowed getting richer cartographical observations and obtaining area values of each land-cover in order to compare them to have real evolution rates in vegetation cover in particular. Results

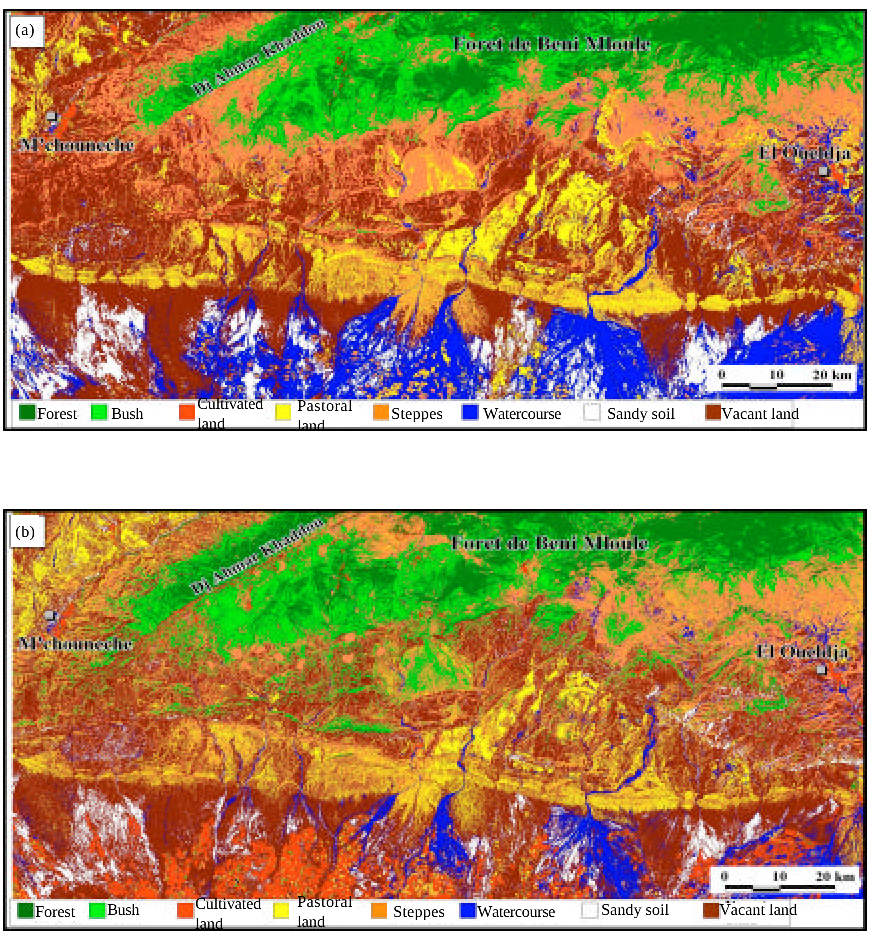

Fig. 5(a-b): Land-cover map of southern Aures region produced using supervised classification of maximum likelihood in (a) 1990 and in (b) 2006

Table 1: Changes in percentages calculated for the eight land-cover classes and their differences between 1990 and 2006

Class of land-use	Area in 1990 (%)	Area in 2006 (%)	Difference (%)
Forest	9.308	8.102	–1.206
Bush	8.076	11.979	+3.903
Cultivated lands	0.656	3.637	+2.981
Pastoral land	11.799	11.271	–0.528
Steppe	21.267	18.796	–2.471
Water	12.188	5.482	–6.918
Sandy soils	5.928	5.270	–0.658
Vacant soils	30.780	35.462	+4.682

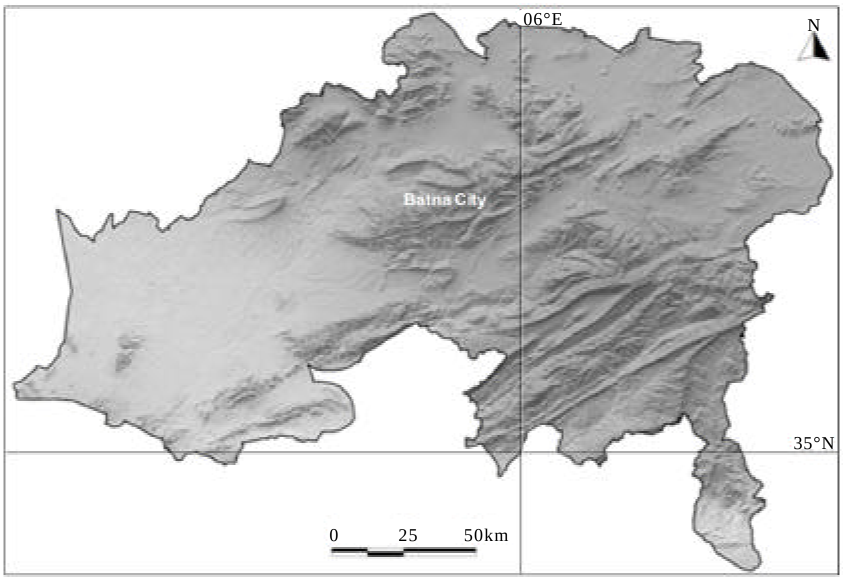

Fig. 6: The digital elevation model (DEM) displayed as relief map for Northern Aures (here Batna city ~ 12,192 km²)

showed significant regression in natural habitat areas (Forests, steppes and watercourses). An increase in surfaces was observed in bush vegetation, cultivated lands and vacant lands (Table 1).

The contour lines were digitized according to the scanned topographic map forms "basic model". The « matrix model » was interpolated from the basic model using a regular grid with a mesh of 10 m. This permitted to extract a high resolution DEM to conduct computations. DEM can be used as a background build-up for many maps, here is an example of a DEM involved in a relief map (Fig. 6).

During desertification risk assessment, inputs (Soil, climate, vegetation and socio-economic data) (Fig. 7a-d) and output data (desertification risk) were mapped (Fig. 7e). Results showed 4% of the region fit into "unaffected class" which present no sign of desertification since it is located at mountain-forest areas. About 33% of the region was allocated in low class and 24% in the medium class which means that land degradation has some little effect on it. Areas affected by desertification process (39% of the region) are located on plains surrounding forested-montane lands (Fig. 7e).

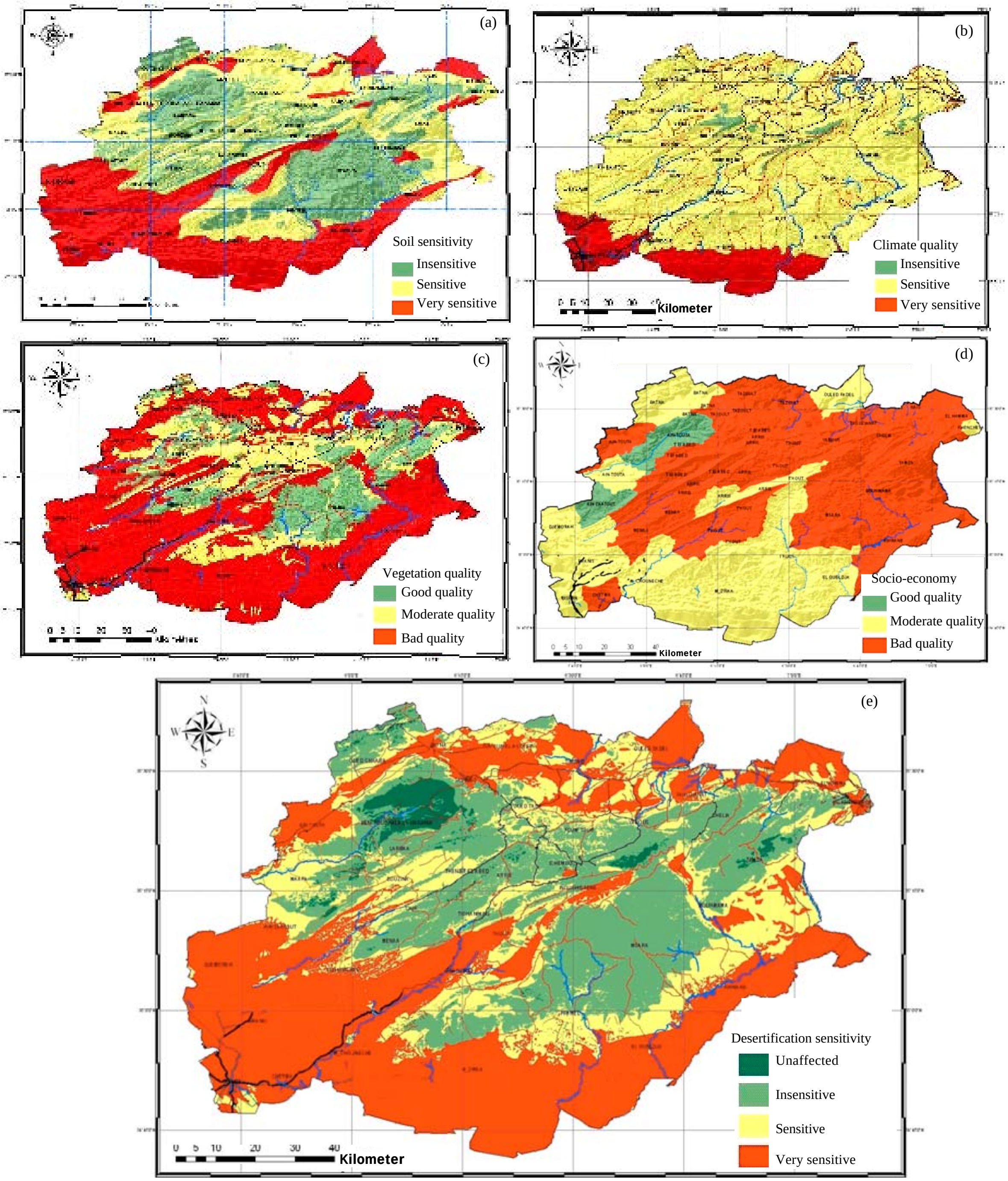

Fig. 7(a-e): Mapping inputs and outputs geomatic data involved in desertification sensitivity assessment in the Aures region. (a) Soil quality map, (b) Climate quality map, (c) Vegetation quality map,(d) Socio-economy quality map and (e)desertification sensitivity index

Water erosion mapping gave several useful sub-products. Geomatic inputs involved and mapped in erosion-risk assessment were: (i) Slope gradient map divided into seven classes with

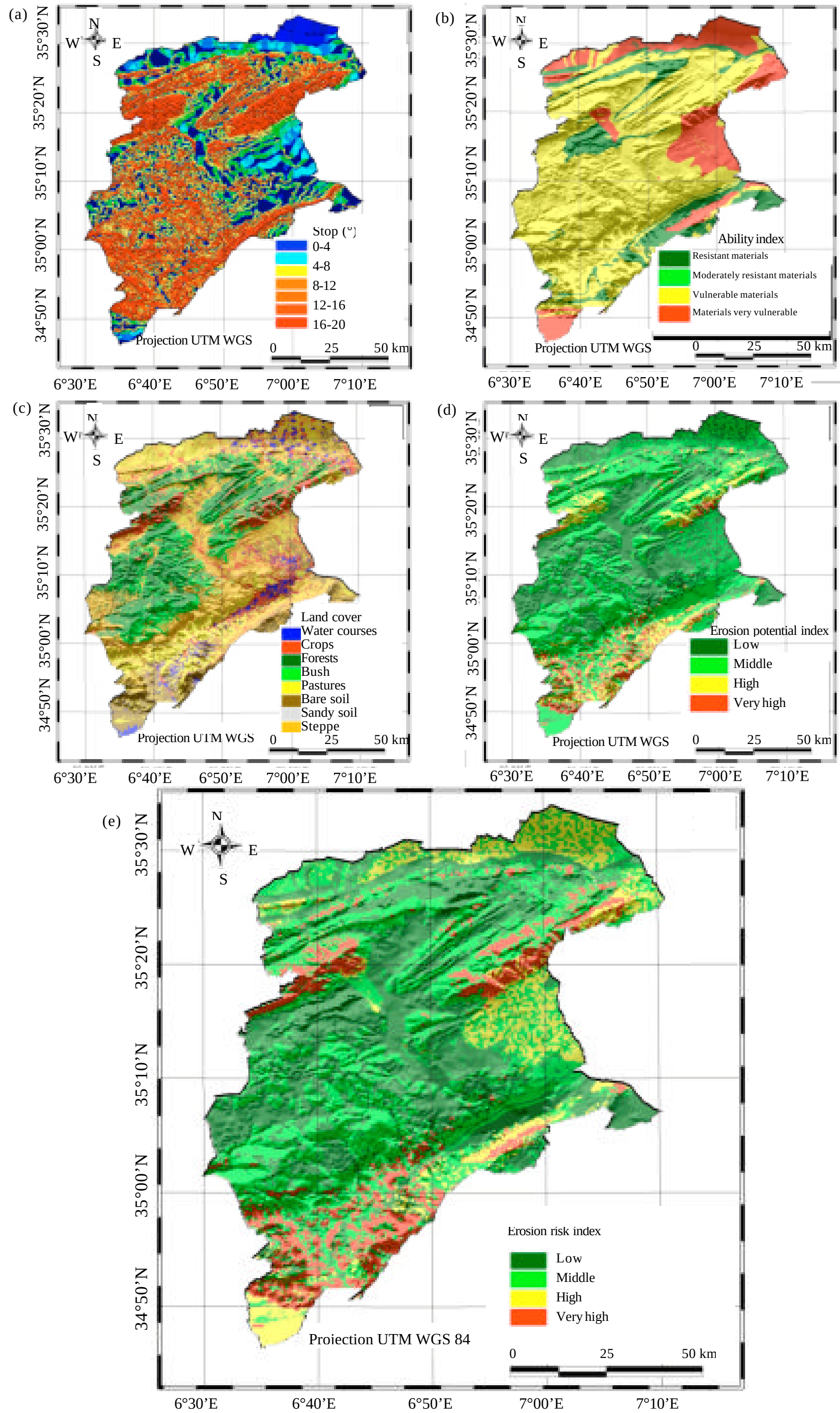

Fig. 8(a-e): Mapping input and output of geomatic data involved in erosion-risk assessment at eastern Aures, (a) Slope gradient map, (b) Map of substratum friability, (c) Land cover classes, (d) Erosion potential index and (e) Map of erosion risk limits of 4, 8, 12, 16, 20 and 24 (Fig. 8a), map of substratum friability (Fig. 8b), bedrock material were classed into three classes of friability (iii) land-use map showing eight type-classes defined after carrying out a supervised classification on Alsat-1 satellite image (Fig. 8c) (iv) map of potential erosion (Fig. 8d) and (v) map of erosion risk where the risk was classed into four variant: Low (32.9%), Medium (44.1%), High (13.5%) and Very high (9.5%) (Fig. 8e).

DISCUSSION

GIS have board uses in different disciplines (Al-Dakheel *et al.*, 2009). GIS include digital terrain data (Aravindan *et al.*, 2011), vegetation associations from satellite data (Salim *et al.*, 2008; Reddy *et al.*, 2008a), land-cover/land-use (Bonyad, 2005; Reddy *et al.*, 2008b), land types, water resources (Ahmed *et al.*, 2007), land ownership, administrative districts... Remote sensing can significantly help too (Al-Mashreki *et al.*, 2010; Mahi and Izabatene, 2011). Satellites can collect data at regional scales rapidly, repetitively and in digital form. In other hand, space and GIS technologies are widely used in planning and management of natural resources. Yet they have to be widely adopted across most of Algeria. Politicians and decision-makers remain unaware of their advantages, so environment management lacks institutional capacity or relevant policies and legislation.

Basically, most of Algerian natural resources occur across a broad ecotone located between the Mediterranean Sea and the Sahara Desert. Ecosystems in Aures area of North Algeria are distributed in scattered populations or groups of species. In addition, woodlands are seriously threatened due to the effects of desertification growing to the North and climate change in the image of the critical state of deterioration that know their biological resources as well the gradual decline of the forested area (Benmessaoud *et al.*, 2011). Recently, since the onset of severe drought since 1990, forests have undergone several kinds of disturbance such as mass mortality, affecting all age classes in many tree species (Allen *et al.*, 2010). In Algeria, GIS technologies are used generally as the primary management tool in natural resources inventory. In itself, the use of GIS to study spatiotemporal evolution of land-cover is not much more than automated cartography but it is the analytical power of GIS that sets it apart from cartography. In that case, GIS can store and analyze the land-cover information in ways that could not be previously done (Ball, 1994; Bonyad, 2005; Reddy *et al.*, 2008a).

There are various contributing factors in land cover change, including natural factors that affect particularly watercourses and forested areas in semiarid lands. These changes may have socioeconomic imbalance by reducing crop yield, infrastructure damage and leave a footprint in livelihoods of poor people in societies. Moreover, an inadequate environment management may lead to an ecological degradation and enhance climate change (Reddy *et al.*, 2008a). In Aures region, changes in land-cover indicate that bushes are in a very advanced ageing state and they are degraded due to drought and heat occurring since a long period (Touchan *et al.*, 2008; Allen *et al.*, 2010), water erosion, low and irregular precipitation. In addition, this vegetation-cover is used as grazing resource in livestock, especially for goat farming. Moreover, pastoral lands class has won about 15.4% of the total area that consists mainly of typical vegetation of Saharan pastures. This unit is widespread in the region with a grass cover.

Indicators used to assess desertification sensitivity provide also an overview on the evolution of ecosystems and environments. This approach can be used like an essential tool for decision support and planning since it mitigates the degradation of environment and protects rather than full rehabilitation for few years later, which are logistical and financial advantages (Basso *et al.*, 2000). The use of GIS, in such condition, provides a huge time saving, precision and reliability in studies linked with ecological conservation and environmental management (Santini *et al.*, 2010). Remote sensing may provide valuable information concerning climate, soil, vegetation quality at the regional scale (Salim *et al.*, 2008; Reddy *et al.*, 2008b). The GIS, by its side, is a valuable tool to store, retrieve and manipulate the huge amount of data needed to compute and map different factors and complex phenomenon in arid and semiarid lands (Basso *et al.*, 2000; Rahman *et al.*, 2009; Chenchouni *et al.*, 2010; Kumar, 2011).

Risk assessment of soil erosion at watershed scale requires mapping and analysis of many factors involved in the erosive process including mainly: climate (precipitation), topographic factor (slope), geological factor (lithology), human impact and land use including vegetation cover factor (Wischmeier and Smith, 1978; Poesen *et al.*, 1996; Vrieling, 2006). For managing effectively soil-loss problems within a sustainability context, policymakers need reliable spatial information that could be offered by powerful and appropriate tools. Assuming this task is a job of GIS (Pimentel *et al.*, 1995).

Agricultural practices make surface areas of cultivated lands increased by 4.6% in Aures. This gives a clear idea on human impact on land-use. Recent crops implementation in forestlands near urban areas justifies forests degradation due to socio-economic pressures. This anthropization has a direct incidence on functional ecology and biodiversity in these habitats (Mondal and Tewari, 2007; Chapin *et al.*, 2000). Without denying the main role of both drought and warmth, taken place since 1970, in fast and rapid decline of forests in the region (Touchan *et al.*, 2008; Allen *et al.*, 2010). The need for accurate and dependable tools for forest and/or natural habitats management has led to the demand for GIS in environment degradation assessment (Tagil, 2007). Because using a land cover map to assess future changes (for example) is critically important for decision-making (Kumar, 2011).

Geomatics offer accurate and timely information for safety and resource protection (Worboys *et al.*, 1990; Kohl *et al.*, 2006). Modeling natural disturbances is deeply needed because such techniques analyze and display spatial information in a timely and cost-effective manner. Indeed, to predict the behavior of natural hazards, we need for modeling high-resolution remote-sensing satellite imagery (Franklin, 2001) with other data according to the selected model in order to detect areas with high risk. This gives early warning to prevent degradation especially in inaccessible mountain terrain (Kohl *et al.*, 2006). Yet without reliable early warning systems for our environment management in Algeria neither for desertification nor for water erosion (Chenchouni *et al.*, 2010) nor for climate change and with lacking national capability to manage globally disturbances in natural resources especially in forest ecosystems (Fire, dieback, diseases, insect outbreaks ...), socioeconomic and environmental costs remain increasing.

CONCLUSION

This thematic study focusing on the use of satellite data and GIS tools for mapping changes in land-cover with perspectives of its application for environment management (especially for forestry in arid and semi-arid lands) has demonstrated over the chosen study area that Geomatics can contribute to update the state of land-cover in particular natural areas covered by vegetation. Thematic mapping of land use as well as multi temporal analysis are fundamental tools for assessing current state of biological resources in woodlands in order to take accurate policies for sustainable management.

Products of this study give a mapped overview on diverse phenomenon and risk assessments (Desertification, climate change, water erosion...). Over this approach, decision-making will be guided to develop the best strategies in rehabilitation operations and land degradation management programs at sensitive lands. However, it is not very precise and lacks for some details since main data were based on qualitative parameters. In that way, it is necessary to conduct further studies to make more detailed maps for the most concerned areas.

The integration of satellite imagery is a relevant tool for the evaluation, protection and management of our natural heritage through the tools of remote sensing and GIS, which provides a new perspective on the landscape and teaches us to examine the particularities of our environment and to monitor its spatial and temporal changes. However, natural resources management through drought context needs consistent data such as high definition multispectral satellite images combined with long-term climate and human activities data to predict climate change effects and/or desertification risk. In conclusion, data from satellite remote sensing has identified disturbance sites with critical and significant change in land-cover from likelihood diachronic studies, which may help to assess degradations and risks, monitor situations and offer locally early warnings.

REFERENCES

Ahmed, O.C.A., R. Nagasawa, K. Hattori, D. Chongo and M.F. Perveen, 2007. Analytical hierarchic process in conjunction with GIS for identification of suitable sites for water harvesting in the oasis areas: Case study of the oasis zone of Adrar, Northern Mauritania. J. Applied Sci., 7: 2911-2917.

Al-Dakheel, Y.Y., A.H.A. Hussein, A.S. El-Mahmoudi and M.A. Massoud, 2009. Soil, water chemistry and sedimentological studies of Al Asfar evaporation Lake and its Inland Sabkha, Al Hassa Area, Saudi Arabia. Asian J. Earth Sci., 2: 1-21.

Al-Mashreki, M.H., J.B.M. Akhir, S. Abd Rahim, K.M. Desa and Z.A. Rahman, 2010. Remote sensing and GIS application for assessment of land suitability potential for agriculture in the IBB governorate, the Republic of Yemen. Pak. J. Biol. Sci., 132: 1116-1128.

Allen, C.D., A.K. Macalady, H. Chenchouni, D. Bachelet and N. Mcdowell *et al*., 2010. A global overview of drought and heat-induced forest mortality reveals emerging climate change risks. For. Ecol. Manage., 259: 660-684.

Aravindan, S., K. Shankar and S.S. Mini, 2011. Integrated geohydrological studies in the sedimentary part of Gadilam River Basin, Cuddalore District, Tamil Nadu. Asian J. Earth Sci., 43: 183-192.

Ball, G.L., 1994. Ecosystem modeling with GIS. Environ. Manage., 18: 345-349.

Basso, F., E. Bove, S. Dumontet, A. Ferrara, M. Pisante, G. Quaranta and M. Taberner, 2000. Evaluating environmental sensitivity at the basin scale through the use of geographic information systems and remotely sensed data: An example covering the Agri basin (Southern Italy). Catena, 40: 19-35.

Benabderrahmane, M.C. and H. Chenchouni, 2010. Assessing environmental sensitivity areas to desertification in Eastern Algeria using Mediterranean desertification and land use MEDALUS model. Int. J. Sustain. Water Environ. Syst., 1: 5-10.

Bonyad, A., 2005. Multitemporal satellite image database classification for land cover inventory and mapping. J. Applied Sci., 5: 834-837.

Benmessaoud, H., M. Kalla, S. Abdesselam and A. Bensaid, 2011. Utilisation d'un SIG pour l'etude de l'impact socio-economique sur le milieu Physique dans l'Est des Aures (Algerie). Eur. J. Scient. Res., 53: 637-652.

Bonn, F., 1998. Spamtialization of soil erosion models via remote sensing and GIS: Potential, errors and limits. Sci. Changements Planetaires/Secheresse, 9: 185-192.

Chapin, F.S., E.S. Zavelata, V.T. Eviner, R.L. Naylor and P.M. Vitousek *et al*., 2000. Consequences of changing biodiversity. Nature, 405: 234-242.

Chenchouni, H., M.C. Benabderrahmane and A. Arar, 2010. Modeling and mapping desertification risk in eastern Algeria with Geomatic data. Proceedings of the IECHAR Conference (IC`10), Al-Ahsa, KSA, Saudi Arabia, pp: 213-217.

Douglas, I., 1999. Hydrological investigations of forest disturbance and land cover impacts in South-East Asia: A review. Philos. Trans. R. Soc. Lond. B Biol. Sci., 354: 1725-1738.

Foody, G.M., 2002. Status of land cover classification accuracy assessment. Remote Sens. Environ., 80: 185-201.

Franklin, S.E., 2001. Remote Sensing for Sustainable forest Management. CRC Press, Florida.

Jennes, J.S., 2004. Calculating landscape surface area from digital elevation model. Wildlife Soc. Bull., 32: 829-839.

Kohl, M., S. Magnussen and M. Marchetti, 2006. Sampling Methods, Remote Sensing and GIS Multiresource Forest Inventory. Springer- Verlag, New York.

Kosmas, C., A. Ferrara, H. Briasouli and A. Imeson, 1999. Methodology for Mapping Environmentally Sensitive Areas (ESAs) to Desertification. In: The Medalus Project: Mediterranean Desertification and Land Use. Manual on Key Indicators of Desertification and Mapping Environmentally Sensitive Areas to Desertification, Kosmas, C., M. Kirkby and N. Geeson (Eds.). European Union, Brussels, pp: 31-47.

Kumar, D., 2011. Monitoring forest cover changes using remote sensing and GIS: A global prospective. Res. J. Environ. Sci., 5: 105-123.

Laflen, J.M., L.J. Lane and G.R. Foster, 1991. WEPP: A new generation of erosion predicting technology. J. Soil Water Conserv., 46: 34-38.

Lillesand, T., R. Kiefer and J. Chipman, 2004. Remote Sensing and Image Interpretation. 5th Edn., John Wiley and Sons, New York.

Mahi, H. and H.F. Izabatene, 2011. Segmentation of satellite imagery using RBF neural network and genetic algorithm. Asian J. Applied Sci., 4: 186-194.

Mondal, P. and V.K. Tewari, 2007. Present status of precision farming: A review. Int. J. Agric. Res., 2: 1-10.

Penner, J.E., 1994. Atmospheric Chemistry Air Quality. In: Changes in Land use and Land Cover: A Global Perspective, Meyer, W.B. and B.L. II Turner (Eds.). Cambridge University Press, Cambridge, pp: 175-209.

Pimentel, D., C. Harvey, P. Resosudarmo, K. Sinclair and D Kurz *et al*., 1995. Environmental and economic costs of soil erosion and conservation benefits. Science, 267: 1117-1123.

Poesen, J.W., J. Boardman, B. Wilcox and C. Valentin, 1996. Water erosion monitoring and experimentation for global change studies. J. Soil Water Conserv., 51: 386-390.

Rahman, M.R., Z.H. Shi and C. Chongf, 2009. Soil erosion hazard evaluation: An integrated use of remote sensing, GIS and statistical approaches with biophysical parameters towards management strategies. Ecol. Modell., 220: 1724-1734.

Reddy, C.S., M. Rangaswamy and C.S. Jha, 2008a. Monitoring of spatio-temporal changes in part of Kosi River Basin, Bihar, India using remote sensing and geographical information system. Res. J. Environ. Sci., 2: 58-62.

Reddy, C.S., S. Babar, K. Sudha and V.S. Raju, 2008b. Vegetation cover mapping and landscape level disturbance gradient analysis in warangal district Andhra Pradesh, India using satellite remote sensing and GIS. Space Res. J., 1: 29-38.

Ruther, H., 2001. EIS education in Africa the geomatics perspective. Proceedings of the International Conference on Spatial Information for Sustainable Development, Oct. 2-5, Nairobi, Kenya, pp: 1-13.

Salim, H.Z., X. Chen and J. Gong, 2008. Analysis of Sudan vegetation dynamics using NOAA-AVHRR NDVI data from 1982-1993. Asian J. Earth Sci., 1: 1-15.

Sandewall, M. and N.E. Nilsson, 2001. The area production model: A tool and concept for sustainable land-use and forest-resource management. J. Environ. Manage., 62: 415-427.

Santini, M., G. Caccamo, A. Laurenti, S. Noce and R. Valentini, 2010. A multi-component GIS framework for desertification risk assessment by an integrated index. Applied Geogr., 30: 394-415.

Tagil, S., 2007. Monitor land degradation phenomena through landscape metrics and NDVI: Gordes, Kavacik, Ilicak, Kumcay and Marmara lake basins (Turkey). J. Applied Sci., 7: 1827-1842.

Touchan, R., K.J. Anchukaitis, D.M. Meko, S. Attalah, C. Baisan and A. Aloui, 2008. Long term context for recent drought in northwestern Africa. Geophys. Res. Lett., Vol. 35, 10.1029/2008GL034264.

Vrieling, A., 2006. Satellite remote sensing for water erosion assessment: A review. Catena, 65: 2-18.

Walz, U., S. Hoechstetter and N.X. Thinh, 2007. How important is the third dimension for the analysis of spatial pattern of landscape structure?. Proceedings of the IALE World Congress, July 8-12, 2007, Wageningen, Netherlands.

Wischmeier, W.H. and D.D. Smith, 1978. Predicting Rainfall Erosion Losses: A Guide to Conservation Planning. Agriculture Handbook No. 537. US Department of Agriculture, USDA, Washington, DC. USA.

Worboys, M., H. Hearnshaw and D. Maguire, 1990. Object-oriented data modeling for spatial databases. Int. J. Geog. Info. Sys., 4: 369-383.