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Use of GIS to predict potential erosion areas in a typical Mediterranean watershed

H. BELAID
CNEA
30 RUE ALAIN SAVARY
1002 TUNIS
TUNISIA

M.A. KARTERIS
LABORATORY OF REMOTE SENSING
BOX 248
ARISTOTLE UNIVERSITY
THESSALONIKI
GREECE

SUMMARY - Erosion can be considered as a major environmental problem in the Mediterranean area, in particular in Tunisia, Greece, Italy and Spain. In this study, Geographic Information Systems (GIS) (GRASS) were used to establish an information data base to characterize a watershed in northern Greece, and locate potential erosion areas using proximity analysis and modelling involving six layers. GIS characterized the watershed easily and efficiently. The possibility of using GRASS to generate buffer zones around linear and area features helped to quantify sensitive areas close to streams. Better results were obtained using a complex model based on weight assignment and using geology, soil, rainfall, slope, first order stream buffer zones and land cover/use. The model located potential erosion areas which need control and preventive measures according to the degree of erosion. The problem of cell resolution was overcome by reference to the mapping scale and other factors.

Key words: Erosion, GIS, watershed.

RESUME - *"Utilisation du GIS pour la localisation de zones d'érosion dans un bassin versant typique méditerranéen". Le problème d'érosion est un problème environnemental majeur dans la région méditerranéenne, en particulier en Tunisie, Grèce, Italie et Espagne. Le Système d'Information Géographique (SIG) (GRASS) est utilisé dans cette étude pour établir une base de données, dans un but de caractériser un bassin versant au nord de la Grèce et de localiser les zones d'érosion potentielle en utilisant l'analyse de proximité et la modélisation avec six cartes. Le SIG a permis de caractériser le bassin versant d'une manière efficace. La possibilité de génération des zones buffeurs autour des objets linéaires et surfaciques a aidé a quantifier les zones sensibles a l'érosion autour des cours d'eau. Des meilleurs résultats ont été obtenues en utilisant un modèle complexe basé sur l'affectation de valeurs (poids) et utilisant la géologie, le sol, la répartition des pluies, la pente, les zones buffeurs autour des cours d'eau de premier ordre et l'occupation du sol. Le modèle a permis de localiser les zones d'érosion potentielle sujets a des mesures de contrôle préventif suivant leur degrés d'érosion. Le problème de résolution spatiale a été résolu en se referant a l'echelle de cartographie, ainsi qu'a d'autres facteurs.*

***Mots-clés** : Erosion, SIG, bassin versant.*

Introduction

A watershed is a land unit which drains water into a stream system and includes a major part of the natural resources. From these resources, water is of vital importance; the development of a nation is intimately connected with its water resources. In the Mediterranean area, all natural resources are in strong relationship to each others. However, their state is man-induced, not only because of the long history of this area but also because of the vital link between man and land in a sociodynamic context, which in turn has led to the degradation and erosion of soils and watersheds, as shown in studies in Tunisia, Greece, Italy and Spain (Hamza, 1978; Vouzaras, 1988; Chisci, 1991; Rubio and Sala, 1992; Stephanidis and Kotoulas, 1992). In particular, accelerated land or soil erosion, in contrast to physical erosion, especially in semiarid areas of the Mediterranean, is mainly due to to the action of man on his natural environment (Hamza, 1978).

Sound management of degraded watersheds requires not only the study of their characteristics, but also the investigation of their interrelationships. Like other kinds of management, watershed management needs the sophisticated tools which have been developed in recent decades, remote sensing and Geographic information Systems (GIS) have an important contribution to make. Both of these two techniques are the most suitable for natural resources management in general (Karteris *et al.*, 1988) and for watershed management specifically.

By definition, Colwell (1983) states that remote sensing is the gathering and processing of information about the earth's environment, particularly its natural and cultural resources, through the use of photographic and related data acquiered from an aircraft or satellite.

Geographic Information Systems are powerful sets of tools used to collect, store, retrieve, transform and display spatial data from the real world for a particular purpose (Burrough, 1986). The application of remote sensing in watershed management is well reported in bibliography, but the use of GIS in this field is a recent topic, mainly its application in erosion modelling. Even if available, most of the studies concentrated on the use of empirical formulae (Bocco and Valenzuela, 1988), such as the Universal Soil Loss Equation (USLE), which is not always the appropriate tool for erosion studies. Spanner *et al.* (1983) used a GIS to predict soil erosion. They used the universal loss equation (USLE) including LANDSAT data and collateral data to accurately map soil loss in a GIS environment. Welch *et al.* (1985), used photogrammetric methods and ground survey network to monitor gullies in the eroded soil surrounding the watershed. They expected that a GIS approach would be helpful in developing models for erosion processes. The International Institute for Aerial survey (Meijerink, 1985) carried out research on using information systems to support development planning within the context of watershed management, in other words on the optimal use of GIS in watershed management (Meijerink, 1990). Meinjerink *et al.* (1986) presented a procedure leading to an automated map of gross erosion and a map with estimated yields. The method was tested in three sloping areas (NW Argentina, the central highlands of Sri Lanka, and the kasserine area, Tunisia). The main input of the GIS data base were climatic, vegetation and land use, and physiographic and geomorphologic data. The map produced was reliable, as it was based on many systematic and detailed observations.

Bocco and Valenzuela (1988) used an integrated method based on GIS and image processing for soil erosion in ILWIS environment. They improved image classification and mapping eroded land, using the GIS technique. Johnston *et al.* (1988) used ERDAS-GIS for cumulative impact assessment in many watershed study sites. Using buffer zone generation around linear and polygonal features, they quantified land uses adjacent to streams and located areas contributing to potential cumulative impact.

In Tunisia, Derouiche and Mizouri (1991) using ILWIS, prepared a soil erosion map from a soil and slopemaps derived from digitised contours. The erosion map was merged with a thematic land use map obtained from SPOT data to obtain a soil management map. Ghedira (1991) studied erosion dynamic using a PC ARC/INFO GIS in a small watershed in Zaghouan area. He monitored the course of erosion over 15 years.

Study area

The study area is the Olynthos watershed, located in the Halkidhiki peninsula, near Polygyros south east of Thessaloniki in northern Macedonia, Greece. It lies approximately between 23°17' to 23°E and 40°15' to 40°30'N. The main river is called the Olynthos and the watershed area is approximately 244 km^2, with an altitude ranging from sea level to 1100 m. The area is of particular interest to many natural resource managers because of its typical Mediterranean bioclimate, characterised by hot and dry summers and cold humid winters. The area is also of interest for dam construction on the upper part of Olynthos river which carries large load of debris after heavy rain, the result of soil erosion, a serious problem in the area. Mean annual rainfall in Polygyros is 587 mm and mean annual temperature is 13,4°C. More to the south of the area, the rainfall decreases and temperature increases.

Materials and methods

GIS software

The system used in watershed analysis was the raster-based Geographic Resources Analysis Support System (GRASS) version, developed by the US Army Corps of Engineers Construction Engineering Research Laboratory (USA-CERL, 1988) and implemented in the Laboratory of Forest Management and Remote Sensing, Faculty of Forestry and Natural Environment at the Aristotelian University of Thessaloniki.

Data collection

Map, photographic and tabular data were used. The maps used were:

(i) topographic maps 1:50,000; (ii) geologic maps 1:50,000; (iii) soil maps 1:50,000; (iv) vegetation maps 1:500,000; (v) climatic maps 1:200,000; (vi) orthophotomaps at a nominal scale of 1:20,000; (vii) black and white aerial photographs, at a scale of 1:30,000.

Land cover/use mapping

The land cover/use map represents human activity in the area and land cover. The methodology followed was that of Karteris and Pyrovesti (1986) with some modifications. The principle interest was to establish a land cover/use classification system based on 12 land cover/use categories.

Other thematic mapping

The drainage network, the watershed boundary and the contour lines were transferred to mylars from the topographic maps. Geological, soil and bioclimatic informations were also transferred to mylars from the original maps.

Data entry

The documents were converted into digital form readable by manual digitisation. Reference points were marked with their respective Northings and Eastings (x,y) on each map, entered in the computer through the keyboard, and then registered using the digitizer cursor buttoms. GRASS allows digitisation either in point or stream mode. In this study, the former was chosen for more accuracy, although the second is faster.

GIS management

Once the features on a map were digitised, they were stored as a vector file. Labels of the features were created from a prepared table, for the categories (with their corresponding numbers). Labelling differed according to whether the feature was a line or an area. For a line, the label must be on it and not close to a node. For an area, it must be inside the polygon and close to the centre. Labels are attached to categories by the support programs of GRASS. Once the labels are attached to features, the vector file can be converted to the cell file (raster format). Based on the digitised vector and the new cell files, the GIS analysis was made.

Results and discussions

Erosion potential model

Erosion is a complex phenomenon because numerous factors can cause it. Consequently, six layers were the components of the model: these were the geological map, the soil map, a derived slope map, the bioclimatic map, a derived first order buffer zones map, and the land cover/use map. All categories of these layers were assigned weights according to their importance in erosion. A specific algorithm in GRASS summed these weights and helped to create an erosion potential map.

Final map

The model was developed mathematically by summing the coincidences of values between layers, resulting in a final map with low to high values. These were classified into ten categories according to the degree of erosion, to clarify potential erosion. The following Table 1 shows the percentage cover of each erosion potential category, the area and the number of cells in a 50x50 m resolution. The most dominant erosion potential categories are around moderate degree. Severe categories are larger than slight and low categories, which makes the situation in the watershed of much more interest for protection and prevention.

Table 1. Erosion potential categories in the watershed: percentage, km^2 and number of 50x50 m cells

Erosion category	Percentage	km^2	Number of 50x50 m cells
1. Nil	3.79	9.25	3,700
2. Slight	4.14	10.10	4,042
3. Medium low	7.92	19.31	7,723
4. Low	11.15	27.19	10,877
5. Medium moderate	12.75	31.07	12,429
6. Moderate	15.09	36.79	14,716
7. Medium high	13.41	32.70	13,801
8. High	12.91	31.48	12,592
9. Medium severe	9.53	23.23	9,292
10. Severe	9.30	22.67	9,067
Total	100.0	243.80	97,519

It was evident from the model that nil to slight erosion under forested areas. High severe erosion potential areas correspond mainly to agricultural land and mixed maquis, because of the sensitivity of this category to erosion. Other problems such as fire escaping after burning wheat residuals can cause soil erosion, when the protecting agent disappears. Overgrazing is also destructive, not only by reducing vegetative cover, but also compacting soil. In many areas only some undesirable species remain on the soil as a result of overgrazing.

The model also showed that it was possible to locate potential erosion areas, which were in general the same as actual areas of erosion, indicating the usefulness of GIS modelling for erosion protection and conservation planning in such watersheds.

Conclusion

Watershed degradation, which lead to reduced productivity, even on marginal lands, needs information which should be supplied in an accurate and timely effective manner. GIS and Remote Sensing are an answer to this problem (Belaid, 1991). The application of GIS using GRASS for watershed characterisation is a simple and efficient way (Belaid, 1993).

The erosion model using the different layers (geology, soil, slope, rainfall, first order buffer zones and land cover/use) located potential erosion areas, most of which were located on agricultural land and maquis, indicating their sensitivity and the need for erosion protection.

The drainage network was also well analysed in a GIS environment and delineated from LANDSAT TM data.

Both GIS and Remote Sensing techniques can be used separated or in combination in watershed analysis in such typical Mediterranean environmental conditions.

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References

Belaid, H. (1991). *Remote sensing and watershed management.* A report to the Mediterranean Agronomic Institute of Chania (MAI Ch), Chania, Greece.

Belaid, H. (1993). *The use of remote sensing and GIS to study a typical Mediterranean watershed in northern Greece.* A thesis submitted in partial fulfilment of the requirements for the degree of Msc. Mediterranean Agronomic Institute of Chania (MAICh), Chania, Greece.

Bocco, G. et Valenzuela, C.R. (1988). Integration of GIS and Image Processing in soil erosion studies using ILWIS. *ITC J.*, 4: 309-319.

Burrough, P.A. (1986). *Principles of Geographical Information Systems for Land Resources Aseessment.* Oxford University Press, London.

Chisci, G. (1991). *Physical soil degradation due to hydrological phenomena in relation to change in agricultural systems in Italy.* Paper presented at a meeting on Research on indigenous soil and water conservation (SWC) and water harvesting in developing countries. Mediterranean Agronomic Institute of Chania, Greece, 13 p.

Colwell, R.N. (1983). *Manual of Remote Sensing* (2nd ed). American Society of Photogrammetry, Falls Church, Virginia.

Derouiche, M.C. et Mizouri, M. (1991). Use of GIS for establishing soil management maps. National Seminar on GIS, Tunis, Tunisia, 6 p.

Ghedira, A. (1991). Study of erosion dynamic using GIS. National Seminar on GIS, Tunis, Tunisia, 10 p.

Hamza, A. (1978). Remote sensing and the geography of erosion in central Tunisia. *Proc. Int. Symp. on Remote Sensing for observation and inventory of earth resources and the endangered environment.* Freiburg, Germany, pp. 2231-2237.

Johnston, C.A., Detenbeck, N.E., Bonde J.P. et Niemiand, G.J. (1988). Geographic Information Systems for cumulative impact assessment. *Photo. Eng. & Remote Sensing,* 54: 1609-1615.

Karteris, M.A. et Pyrovesti, M. (1986). Land cover/use analysis of Prespa National Park, Greece. *Env. Cons.,* 13: 319-330.

Karteris, M.A., Gatzoyannis, S. et Galanos, F. (1988). *Use of second generation earth observation satellites in the implementation of forestry management models in Greece.* Final Report to National Forest and Nature Agency, Danish Ministry of Environment, 93 p.

Meijerink, A.M.J. (1985). Geo information systems for land use zoning and watershed management. *ITC J.,* 4: 283-287.

Meijerink, A.M.J., Sayago, V.M., Emaruchi B. et Ziadi, B.K. (1986). A spatial assemblage model for the estimation of gross erosion and sediment yield using remote sensing and geo-data-base operations. *ITC J.,* 1: 174-195.

Meijerink, A.M.J. (1990). Summary report on ILWIS development. *ITC J.,* 3: 205-214.

Rubio, J.L. et Sala, M. (1992). Erosion and degradation of soil as a consequence of forest fire. *European Society for Soil Conservation,* 1: 5-8.

Spanner, A.M., Strahler, A.H. et Estes, E. (1983). Soil loss prediction in a geographic information system format. Proc. 17th Int. Symp. Remote Sensing of Env., Ann Arbor: 89-102.

Stephanidis, P. et Kotoulas, D. (1992). Accelerated erosion after the forest fires in Greece. *Internationales Symposion Interpravent Bern Tagungspublikation* 1: 365-376.

USA-CERL (1988). *GRASS User Manual, Space Remote Sensing Center.* Champain, Illinois.

Vouzaras, G. (1988). *Soil eroion and watershed restoration in Greece.* National Report to the Ministry of Agriculture, Athens, 8 p.

Welch, R., Jordan, T.R. et Thomas, A.W. (1985). Photogrammetric input to a geographic information system for modelling soil erosion. *Proc. Pecora,* 10: 272-275.