SOIL EROSION MODELLING BY USING GIS & REMOTE SENSING : A CASE STUDY, GANOS MOUNTAIN

Berk Ustun [a, *]

[a] ITU, Civil Engineering Faculty, 80626 Maslak Istanbul, Turkey-(e0727619@student.tuwien.ac.at)

KEY WORDS: Environment, GIS, Hazards, Land Cover, Prediction, Vegetation, Monitoring

ABSTRACT:

This paper focuses on the size of the amount of soil loss because of the erosion in the surrounding area of the Ganos Mountain over Thrace Peninsula region in Turkey. Ganos Mountain is the second highest point in this peninsula.

In this study satellite imagery is used to reach rapidly to the actual land use classification. Morgan method is applied to solve the modelling problem of the soil erosion. Geographic information system software named ILWIS and ERDAS Imagine are used to monitor the probable success of the determining method. The question why Morgan method is preferred can be answered by the following explanations made by geologists and agricultural engineers. According to them Morgan method has a more powerful physical fundamental than the USLE method and is easier and more flexible method than the CREAMS method.

1. INTRODUCTION

Nowadays one of the major problems on global scale is the rapidly increasing demand to the food. This demand is of course totally parallel to the population growth. Even more land is used for agricultural purposes day by day. Cultivation without using specific control techniques, unplanned land use, such as establishing industrial facilities or constructing summer houses on the agriculture land, uncontrolled urban development and also destroying forests are fundamental factors of soil erosion (Biard and Baret,1997).

Soil erosion over Earth is a quite-frequent and well-distributed problem. Mapping the level of risk of areas subjected to rain and wind erosion is therefore all important issue. Models of soil erosion highlight the importance of soil coverage by active green vegetation and residue. When soils are covered by senescing vegetation or crop residue, the cover fraction is often very low and may coincide with heavy rainfall events. It has been demonstrated that a 15% cover fraction by corn residue reduces soil run off by 75% (Melesse and Jordan,2002).

In this study, the size of the amount of soil loss because of the erosion in the surrounding area of the Ganos Mountain over Thrace Peninsula region in Turkey was investigated by using satellite data. Morgan method is applied to solve the modelling problem of the soil erosion. The question why Morgan method is preferred can be answered by the following explanations made by geologists and agricultural engineers. According to them Morgan method has a more powerful physical fundamental than the USLE method and is easier and more flexible method than the CREAMS method.

2. THE STUDY AREA AND MATERIALS

In this study, Ganos Mountain over Thrace Peninsula region in Turkey was selected as the study area. Ganos Mountain is the second highest point in this peninsula with its 945 metres peak. This region lies approximately between 27°00' and 27°30' East longitudes and 40°30' and 41°00' North latitudes covering an area of approximately 1000 km^2, has the most fertile territory for the agriculture especially for vineyards. Figure 1 illustrates the location of the study area.

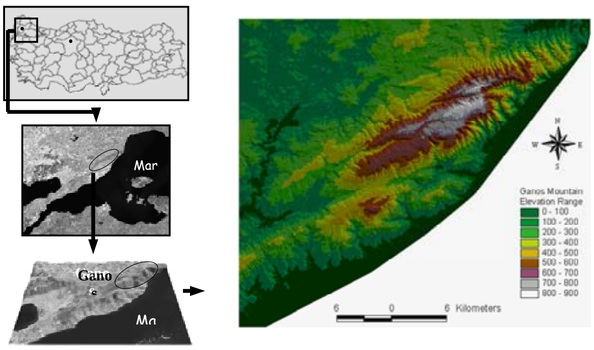

Figure 1: Location of the study area.

At the first stage of this study all the possible data for modelling soil erosion at Ganos Mountain region were obtained. These data are the sloppiness and the altitude of the study area, ph value, surface texture, stoniness and drainage class of the soil, annual precipitation, soil depth, land use classes and crop texture. If enough necessary data can be collected, a predictive model about the soil loss per year will be established. The results of this model will be presented in ton / hectare per year. These results make it easier to determine if the soil loss under the average tolerance limit is or not.

In this application, Landsat-5 TM image from July, 1992 was used as the satellite data. Image processing operations were carried out by using ERDAS Imagine and ILWIS software, located in the Remote Sensing Division of the Geodesy and Photogrammetry Department of the Istanbul Technical University. Also, Photoshop and Corel Draw software were used for several purposes.

* Corresponding author

3. METHODOLOGY

Generation of DEM

3.1.1 A DEM of the area was generated by spatial interpolation of digitised contour lines from a 1:50 000 scale map (in every 20 m), using the distance transform algorithm. The DEM was used to generate the slope map. The slope computed at each pixel is the plane formed by the vector connecting the left and right neighbours versus the vector connecting the upper and lower neighbours of the pixel (Riaño et al.,2003).

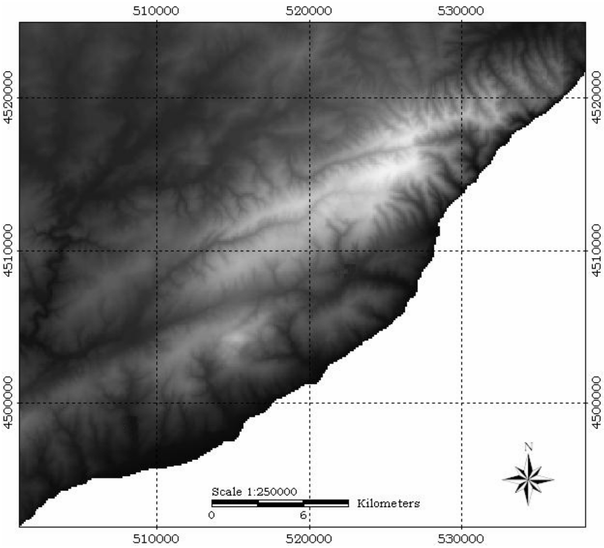

Figure 2: DEM of the area derived from digitised contours.

Geometric correction

The quarter of Landsat-TM scene was orthorectified using a set of 40 ground control points (GCPs) extracted from 1:50.000 scale maps and the DEM.

At first step ground control point coordinates were digitized from the topographic maps with standard scale 1:50.000. Geometric correction was carried out by using first order polynomial equation as a second step. Than at the last step of the geometric correction process, the nearest neighbour resample method was used with root mean square (RMS) error of <0.5 pixels. In order to preserve radiometric integrity, a nearest neighbour interpolation method was used (Almeida-Filho and Shimabukuro,2002).

Classification

A digital classification using LANDSAT TM data covering the visible, infrared and microwave regions of the spectrum was carried out to detect the overall soil erosion potential of the Ganos Mountain area in Thrace Peninsula, Turkey. Remote sensing data to assess land degradation and soil erosion are derived mainly from the visible and infrared bands (Metternicht and Zinck,1998).

In this step of the study, the Iterative Self-Organizing Data Analysis (ISODATA) technique method of unsupervised classification was used. This technique uses a maximum-likelihood decision rule to calculate class means that are evenly distributed in the data space and then iteratively clusters the remaining pixels, using minimum distance techniques (Jensen, 1996). Each iteration recalculate means and reclassifies pixels with respect to the new means. This process continues until the number of pixels in each class changes by less than a selected pixel change threshold or until a specified maximum number of iteration is reached (Melesse and Jordan, 2002).

ISODATA classification of the image based on the TM visible, infrared and microwave bands were set to yield a maximum of spectral classes. (Lillesand and Kiefer, 1987) The resulting 40-class image was then recoded into eight classes.(Ekercin et al. ,2003)

Soil erosion modelling

Soil loss determination method consists of two different base phases. First one is the water phase; second one is the sedimentation phase. At the water phase kinetic energy of rainfall, overland flow and annual precipitation values and at the sedimentation phase rate of soil detachment by raindrop impact and transport capacity of overland flow values are calculated for every pixel by generating maps for each input data (Faust,1989). This predictive model for the assessment of soil erosion risk is called Morgan model. The input parameters and operating functions about this model are given below.

Water phase:

$$E = R\,(11.9 + 8.7 \log_{10}(I)) \quad (1)$$

$$Q = R \exp(-R_c / R_o) \quad (2)$$

$$[R_c = 1000\ MS\ BD\ RD\ (E_t / E_o)^{0.5} \quad (3)$$

$$R_o = R / R_n\ ] \quad (4)$$

Sediment phase:

$$F = K\,(E \exp^{(-0,05A)})\,10^{-3} \quad (5)$$

$$G = C\,Q^2\,(\sin S)\,10^{-3} \quad (6)$$

Operating functions:

E : Kinetic energy of rainfall (J /m ^{2})
Q : volume of overland flow (mm)
F : Rate of splash detachment (kg / m ^{2})
G : Transport capacity of overland flow (kg / m ^{2})

Input Parameters:

MS : Soil moisture content at field capacity
BD : Bulk density of the top soil layer (g / cm^3)
RD : Topsoil rooting depth (m)
E_t / E_o : Ratio of actual (E_t) to potential (E_o) evapotranspiration
R : Annual rainfall (mm)
R_n : Number of rain days in the year
I : Typical value for intensity of erosive rain (mm / h)
K : Soil detachability index (g / J)
S : Steepness of the ground slope expressed as the slope angle
A : Percentage rainfall contributing to permanent interception and stem flow
C : Crop cover management factor
W : Rate of increase in soil depth by weathering at the rock soil interface (mm / year)
V : Rate of increase of the topsoil rooting layer (mm / year)

D : Total soil depth (m)

4. RESULTS

4.1.1 Overall soil erosion potential

The main result is that generally at the study area modelled soil erosion values are in the expectable range approximately 10 ton per hectare. But these values jump over the 10 ton per hectare limit if the slope angle is more than 16°. As you can also see from the image below, in our study area annual soil erosion values reach up to 20 ton per hectare in some barren land usually near the top of the Ganos Mountain. (Ustun, 2001)

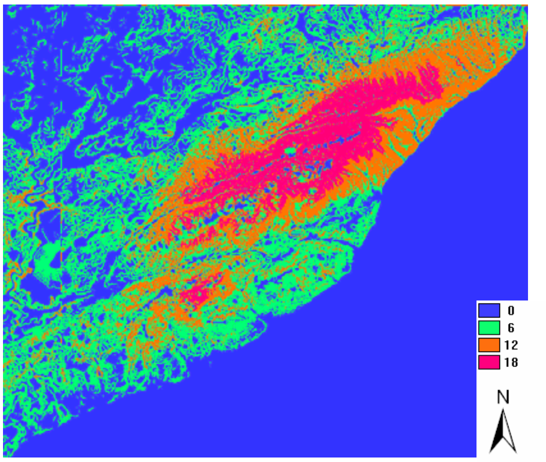

Figure 3: Soil erosion potential in the region. (ton/ha)(VII)

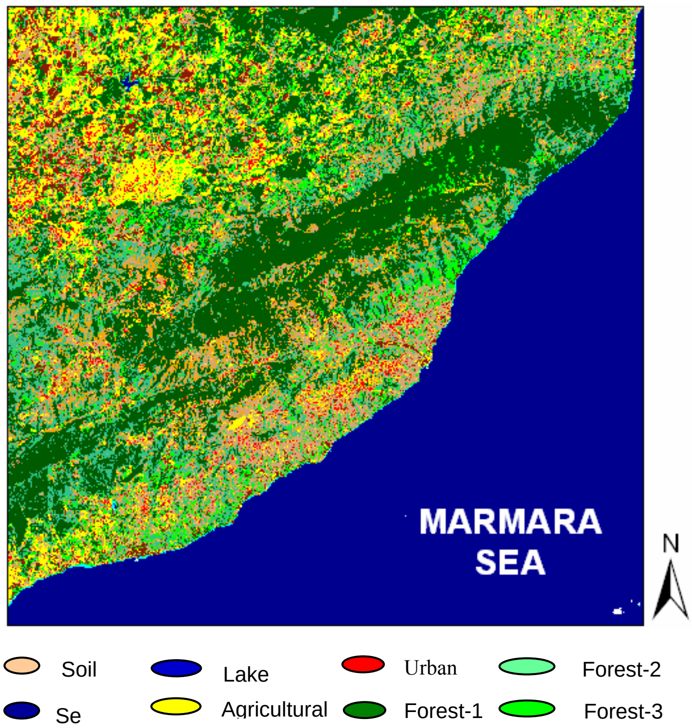

Figure 4: Land use map of the Ganos Mountain and its surrounding area. (Ustun,2001)

If it is combined with the land use or land cover patterns it can be easily seen that surprisingly high soil erosion values are obtained for the forestry areas.

Land use/cover data is obtained from classified LANDSAT 5 TM image data. By the classification process ISODATA

(Iterative Self Organizing Data Analysis) unsupervised classification is chosen

REFERENCES

Biard, F. & F. Baret, 1997. Crop Residue Estimation Multiband Reflectance Using. Remote Sensing of Environment, 59: 530-536.

Riaño D., E. Chuvieco, J. Salas, I. Aguado, 2003. Monitoring changing position of coastlines using Thematic Mapper imagery, an example from the Nile Delta. IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, 41: 1056–1061.

Almeida-Filho, R. & Y. E. Shimabukuro, 2002. Digital processing of a Landsat-TM time series for mapping and monitoring degraded areas caused by independent gold miners, Roraima State, Brazilian. Remote Sensing of Environment, 79: 42-50.

Metternicht, G.I. & J.A. Zinck, 1998. Evaluating the information content of JERS-1 SAR and Landsat TM data for discrimination of soil erosion features. ISPRS Journal of Photogrammetry & Remote Sensing, 53: 143-153.

Melesse, A. M. & J. D. Jordan, 2002. A comparison of fuzzy vs. Augmented-ISODATA classification algorithms for cloud-shadow discrimination from Landsat images. Photogrammetry Engineering and Remote Sensing, 68: 905-911.

Ekercin S, C Ormeci & C Goksel, 2003. Coastline change analysis of the Meric River by using multitemporal remotely sensed data. In: EARSeL SIG Remote Sensing of the Coastal Zone, (EARSeL, Ghent, Belgium)

Jensen, J. R.,1996. Introductory Digital Image Processing: A Remote Sensing Perspective. (Englewood Cliffs, New Jersey: Prentice-Hall).

Faust, N. L., 1989. Image Enhancement. (Marcel Dekker, Inc. Press).

Ustun B, 2001. Modelling of Soil Erosion by Using GIS Sorroundings of Işıklar Mountain. Msc Thesis, Istanbul Technical University, Institute of Science and Technology, Turkey.

Lillesand, T. M. and Kiefer R. W., 1987. Remote Sensing and Image Interpretation. (Chichester: John Wiley), pp, 696-697.