Bulletin of the Geological Society of Greece

Vol. 43, 2010

ASSESSMENT OF THE QUANTITY OF THE MATERIAL TRANSPORTED DOWNSTREAM OF SPERCHIOS RIVER, CENTRAL GREECE

Sigalos G. — ArcEnviro
Loukaidi V. — ArcEnviro
Dasaklis S. — ArcEnviro
Alexouli-Livaditi A. — National Technical University of Athens (NTUA), Department of Minerals Engineering

https://doi.org/10.12681/bgsg.11239

Δελτίο της Ελληνικής Γεωλογικής Εταιρίας, 2010
Πρακτικά 12ου Διεθνούς Συνεδρίου
Πάτρα, Μάιος 2010

Bulletin of the Geological Society of Greece, 2010
Proceedings of the 12th International Congress
Patras, May, 2010

ASSESSMENT OF THE QUANTITY OF THE MATERIAL TRANSPORTED DOWNSTREAM OF SPERCHIOS RIVER, CENTRAL GREECE

Sigalos G.[1, 2], Loukaidi V.[1], Dasaklis S.[1] and Alexouli-Livaditi A.[2]

[1] *ArcEnviro – Makrygianni 1 str, 157 72, Zografos, Athens. e-mail: sigalos@arcenviro.gr*

[2] *National Technical University of Athens (NTUA), Department of Minerals Engineering Heroon Polytechniou 9 str., 157 80 Zografos, Athens*

Abstract

It is well known that streams are an integral part of a natural ecosystem. The Sperchios valley is crossed by a large number of seasonal or permanent flow streams and rivers, out of which the Sperchios river can be distinguished, not only for its length but also for the area surrounded by the boundaries of its drainage system. The present study is aimed to estimate the quantity of the transported material at the mouth of Sperchios River. For this purpose we applied the Revised Universal Soil Loss Equation (RUSLE) model to the Sperchios drainage network in a Geographical Information Systems (GIS) environment. We estimated that approximately 2,308,000 tons per year are flooded mainly down the Sperchios drainage system, supporting the Malian delta.

Key Words: *Sperchios River, soil loss, RUSLE, GIS.*

1. Introduction

It is well known that soil erosion, usually due to rainwater runoff, is a process by which the soil epidermis of the soil surface is washed away from the land. Soil erosion is a worldwide environmental problem that affects not only the natural environment, leading to sediment deposition, soil degradation, water quality degradation etc, but human activities as well, such as agriculture productivity regression. Soil loss can be one of the most important and still unknown natural processes leading to serious natural hazards, such as floods.

Research on soil loss has started quit early (in the 1930s), mainly emphasizing on its impact on agricultural productivity. During 1940 and 1956, USA research scientists began to develop a quantitative method for estimating soil loss. Several factors were introduced to an early soil loss equation, in which slope and agricultural practice were primarily considered. Based on the data collected for almost a decade at the National Runoff and Soil Loss Data Center at Purdue University, as well as previous studies, Wischmeier & Smith (Wischmeier and Smith, 1978) developed the Universal Soil Loss Equation (USLE), a widely accepted mathematical model that estimates the average annual soil loss of a study area. Additional research, experiments and data collection in the years after (Renard K.G et al., 1997) led to the development of the Revised Universal Soil Loss Equation (RUSLE), an improved mathematical model, that takes into consideration not only morphological factors but conservation practices as well. It has been used since in developing conservation planning and land-use decision making.

2. Study Area

The study area of this paper (Fig. 1) is located in the prefecture of Fthiotis, Central Greece, covering a region of approximately 1,875 km^2, out of which almost 88%, that is 1,645 km^2, correspond to the watershed of Sperchios River basin, while the rest of the area belongs to the nearby watersheds of several other minor rivers.

The Sperchios River basin can be outlined by the Tymfistos, Vardoussia, Iti and Kallidromo mountains. It has an elongated shape along the E-W direction and is open to the sea on the east side. It is covered both by alpine and post-alpine formations, the former outcropping of the basin and usually forming the nearby mountains while the latter covering the flattened areas at the centre of the basin. Alpine formations consist primarily of limestones and dolomites of Lower Triassic – Upper Jurassic, Cretaceous or even Eocene age, schists of Jurassic age, ophiolites, flysch of Upper Cretaceous or Eocene age, sandstones and conglomerates of Cretaceous age etc. Post-alpine sediments consist of sandstones, conglomerates, clay and mudstones of Eocene age, marls of Pleiocene age, breccia and alluvial deposits. The presence of bedrock lithology is quit extensive, affecting not only the morphology of the area or the size of individual watersheds, but also the amount of sediment that can be transported throughout the years.

The Sperchios River is considered to be one of the longest rivers in Greece, having a length of approximately 85 km, of which 80 km alone correspond to the central axis of the stream. The river springs from the Panaitoliko Mountain (Evritania prefecture), flows northeast of the Vardousia and Tymfistos mountains, crosses the large plain south of Lamia and flows into the Malian Gulf. It is also considered to have one of the most extensive delta formations, not only in Greece, but in the Eastern Mediterranean as well. Indeed, its delta comprises a region of approximately 196 km^2, which can give an idea of the amount of sediment that has been transported up to the river mouth.

Hundreds of major or minor rivers contribute to each other creating the large drainage network of Sperchios. Detailed drainage network studies have revealed that drainage is highly organised in the basin and primarily controlled by neo-tectonic movements. These recent movements seem to have also affected the morphology of the region. The area is characterised by steep morphological slopes, usually varying from 20% to 40% and sometimes reaching almost up to 70% especially at the borders of the Sperchios watershed, while the regions near the Sperchios River centerline remain almost flat. The average slope of the area is estimated to be 33%.

Agriculture plays an important role in the economic development of the study area. Almost 35% of the study area is dedicated to cultivations, another 35% to state, municipal or private pasture, while only 23% is covered by forestry. A small portion (5%) corresponds to wetlands and swamps. The remaining 2% is occupied by human infrastructure, that is settlement, road network etc.

3. Data Used

In order to carry out this work a primary database was created via digitising the cartographic background (topography, hydrographic network, geology) of the topographic maps "Amfikleia", "Amfissa", "Domokos", "Efxinoupolis", "Fourna", "Karpenision", "Lamia", "Leontarion", "Lidorikion", "Spercheias" and "Stylis"of the H.M.G.S. at a scale of 1:50.000, as well as of the homonymous geological maps of I.G.M.E., also at a scale of 1:50.000. Data concerning land cover information were extracted from the Corine Land Cover project (CLC2000) carried out by the European Environmental Agency (European Topic Centre on Land and Spatial Information, 2000). Data regarding

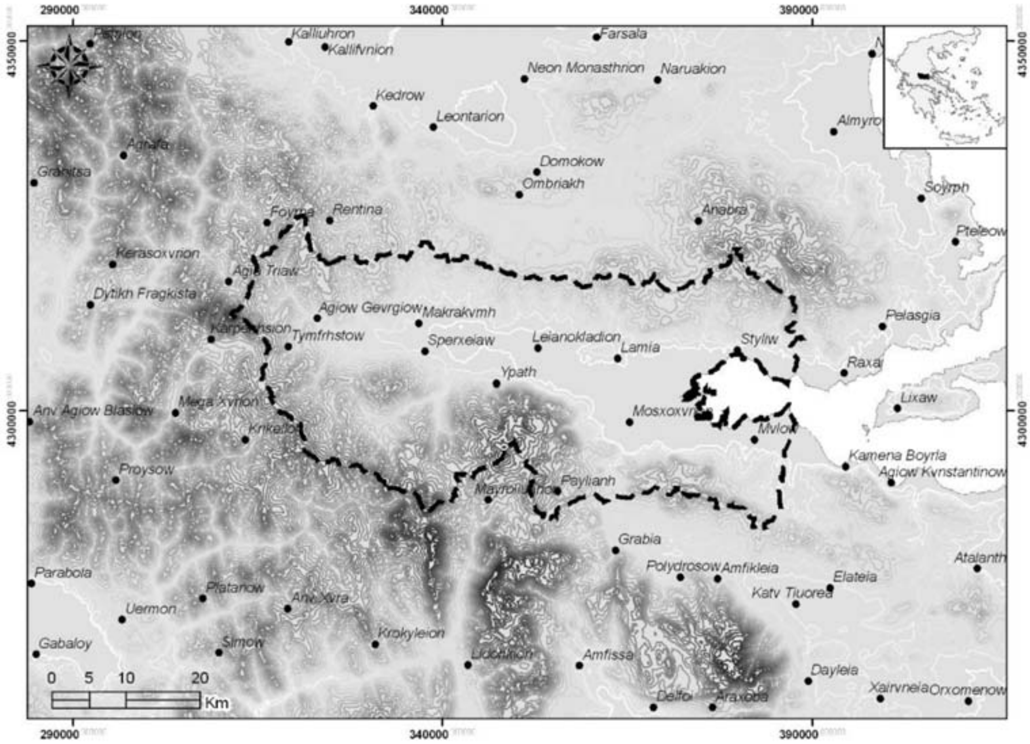

Fig. 1: Study area.

rainfall amounts were collected from the Hellenic National Meteorological Service. All data were transformed, edited and inserted in a spatial database. Enriched by field investigations as well as literature, this primitive database allowed us to analyse the factors that control soil loss.

The use of Geographic Information Systems (GIS), applied in this work, provides us with an important geographic database that can be used either directly for estimations regarding the present state or under assessment models used for predictions of the future state and estimations of possible conditions.

4. Methodology – Data Analysis

In order to estimate the soil loss in the basin, the Revised Universal Soil Loss Equation (RUSLE) model was used in a Geographic Information System environment. The RUSLE equation computes the average annual erosion by using a functional relationship of several other factors as:

$$A = R * K * LS * C * P \tag{1}$$

where: (A) is the computed average soil loss per unit of area. Usually, A is expressed in tons/acre/year.

(R) is the rainfall - runoff erosivity factor, expresswed in MJ*mm / ha*h,

(K) is the soil erodibility factor (in t*h / MJ*mm),

(L) is the slope length factor,

(S) is the slope steepness factor,

(C) is the cover and management factor and

(P) is the support practice factor.

Factor R: It is the average annual summation values in a normal year's rainfall. In literature, the only equation relating the R factor with the mean annual precipitation, adapted to the greek climate characteristics, is provided by Flambouris (Flambouris, 2008) and has the following form:

$$R = \alpha * Pi \qquad (2),$$

where: (a) is precipitation coefficient and
(Pi) is the mean annual precipitation, measured in mm.

In his work, Flambouris also provides the value of the coefficient a, corresponding to the study area, which, according to him, should be equal to 0.7 (a = 0.7), depending not only on the meteorologic, but on the morphologic characteristics of the Lamia weather station. We disagree, since the Lamia weather station does not reflect the meteorological characteristics of the whole of the study area, especially the highlands, whose mean annual precipitation is expected to be much higher. Therefore we apply the value of 1.3 (a = 1.3) to our estimations, which we consider the most suitable for the study area, based on research conducted in Greece (Zarris et al., 2001), as well as in Italy (Van der Knijff et al., 2000). The equation (2) has the following form now:

$$R = 1.3 * Pi \qquad (2),$$

Factor K: Is soil erodibility factor which represents susceptibility of soil to erosion and the rate of runoff, taking into account the % portion of silt, sand or organic matter, soil texture, soil structure and permeability (Wischmeier et al., 1971). Since the K factor can easily be related to geological formations' susceptibility to erosion (Koutsoyiannis and Tarla, 1987; Lykoudi and Zarris, 2004), each rock formation of the study area was given a K factor value, based not only on the rock type, but on the age, the geotectonic unit etc. The following figure represents the classification of rock formations based on the proposed by the bibliography K values.

Factors L and S: Slope length is the distance from the origin of overland flow along its flow path to the location of either concentrated flow or deposition. Fortunately, computed soil loss values are not especially sensitive to slope length and differences of ±10% in slope length are not important, especially on flat landscapes. On the other hand, slope steepness is the ratio of soil loss from the field gradient to that from a 9 percent slope under otherwise identical conditions. Soil loss increases more rapidly due to slope steepness than due to slope length.

Table 1. K factor values.

Geological formations	*K factor value*
ophiolites	0.0005
limestones/dolomites	0.00055 to 0.00085
conglomerates	0.003
alluvia	0.0035
sandstone	0.015
flysh	0.02 to 0.03
schist	0.025
breccia	0.045

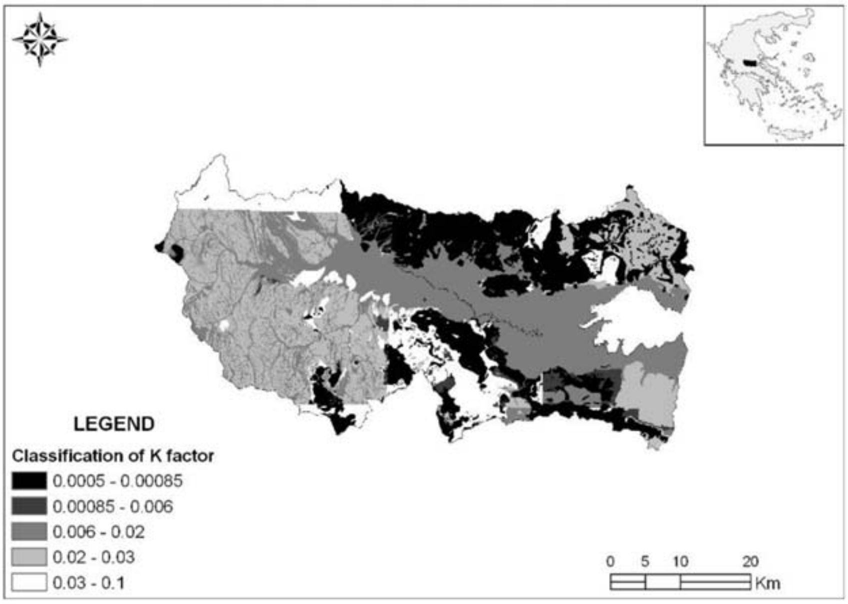

Fig. 2: Classification of K factor values.

Among these factors, the slope length factor (L) is the most difficult to compute. This is why it is widely estimated together with the slope steepness factor (S) through the Digital Elevation Model (DEM) of the study area. The combined result of L*S reflects the morphology of the study area. For this purpose several methods have been developed (Moore et al., 1986; Moore et al., 1993; McCool et al., 1997). For the aim of this paper the method developed by Mitasova and Mitas (2001) is adopted. The combined LS factor can then be calculated via the following equation:

$$LS = (m+1) * [(As / 22.13) m] * [(\sin\beta / 0.09) n] \quad (3)$$

where: LS is the computed L*S product,

As is the upslope contributing area per unit width of contour,

β is the slope angle in degrees,

m is an exponent varying from 0.4 to 0.6 and

n is an exponent varying from 1.2 to 1.3.

The upslope contributing area can be calculated in an ArcInfo environment using the "Flow Accumulation" routine multiplied by the squared cell size and divided by the cell size, while the slope angle can be calculated using the "Slope" algorithm and the "Atan" function in ArcInfo (that is, β = Atan (Tan β) = Atan [(Slope grid in %) / 100]). Computing the equation (3) led to the estimation of LS values for the entire study area, as follows:

Factor C: It reflects the effect of cropping and management practices on soil erosion rates. Since the C factor represents the effect of plants, soil cover, soil biomass and soil disturbing activities to erosion, soil loss ratios vary with time as canopy, ground cover, roughness, soil biomass and consolidation change. On the other hand, each land cover type can correspond to an estimated C value, thus the following figure pictures the C-factor values for the different land use categories.

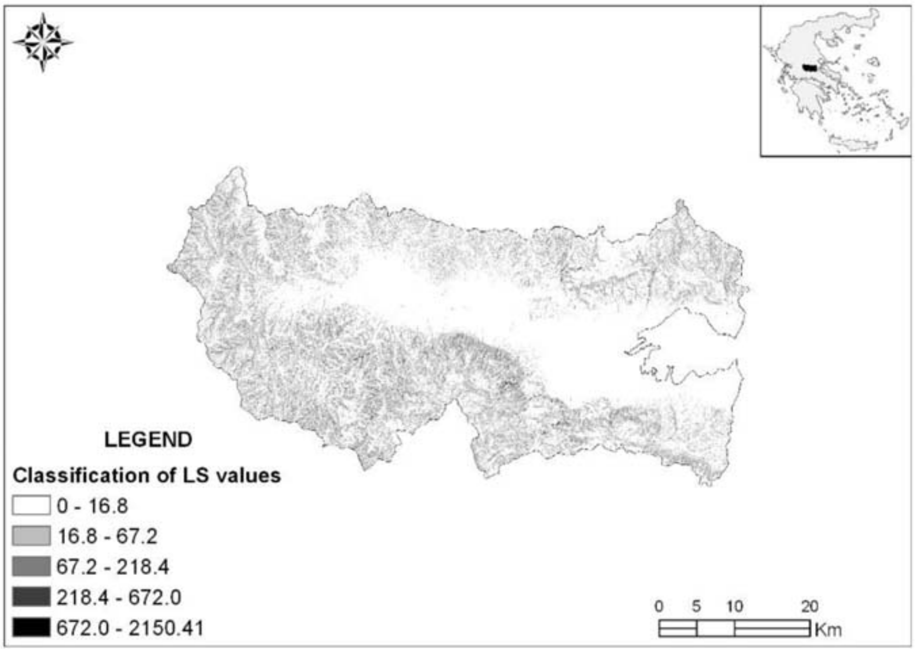

Fig. 3: Classification of LS factor values.

Table 2. C factor values.

Corine Type	*C factor value*	*Corine Type*	*C factor value*	*Corine Type*	*C factor value*
111	0.001	**221**	0.2	**322**	0.2
112	0.001	**223**	0.1	**323**	0.03
121	0.01	**231**	0.1	**324**	0.02
124	0.003	**242**	0.18	**331**	0.06
131	0.36	**243**	0.1	**332**	0.0001
133	0.36	**311**	0.001	**333**	0.001
211	0.3	**312**	0.001	**421**	0.18
212	0.15	**313**	0.001	**511**	0.00001
213	0.001	**321**	0.3		

Factor P: It reflects the impact of support practices on the average annual erosion rate. As with the other factors, the P-factor differentiates between cropland and rangeland or permanent pasture.

5. Results

By processing the gathered data according to the previously described model the following map was derived. It corresponds to the estimation of the annual soil loss, based on the rainfall, soil, to-

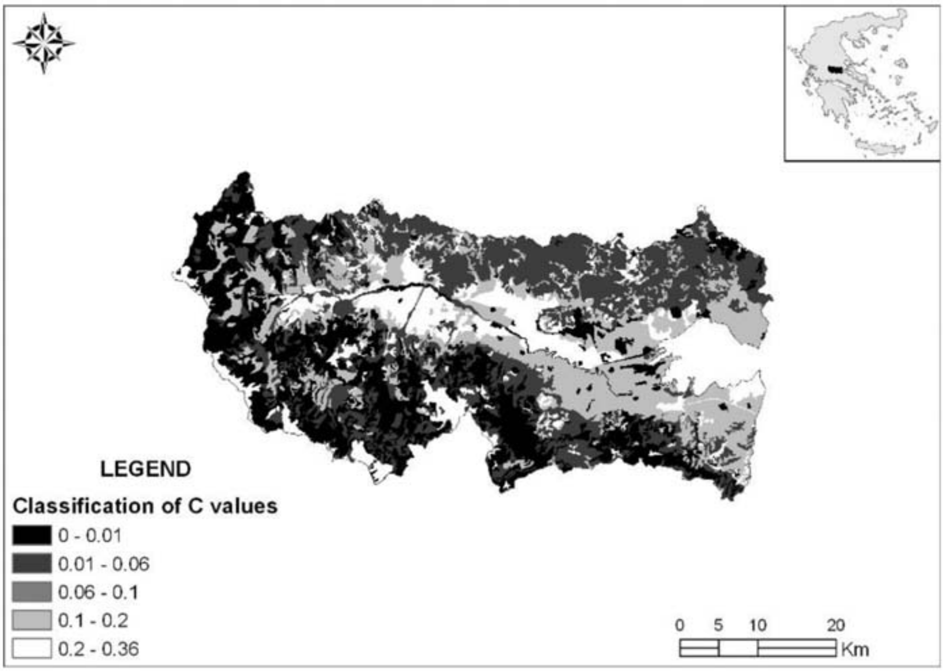

Fig. 4: Classification of C factor values.

pography, cover and management erodibility, as well as the support practice factor for the study area. According to the RUSLE model, the annual soil loss of the study area is estimated at approximately 2,308,000 tones per year, the vast majority of which corresponds to bedrock formations of the mountainous regions of the Sperchios watershed.

This result approaches soil loss older estimations for the same study area, such as the results announced by the Aristotle University of Thessaloniki (approximately 2,500,000 tones per year), while it differentiates from others, such as those announced by Poulos and Chronis (1997), who estimated the soil loss at approximately 1,500,000 tones per year. The differences between results, obtained from the application of empirical models like the present one, are due to different assumptions, estimations of the research variables and approach methods.

The annual soil loss rate of the study area is estimated at 11.5 tones per year. This rate is quite low, compared with soil loss rates for other regions, such as Acheloos basin, where the mean A was estimates at 47.26 t/ha, or Cephalonia island (Zarris et al., 2001), where the mean A was estimated at 47.26 t/ha (Lykoudi and Zarris, 2004). This is due to the fact that the majority of the study region corresponds to flat areas, having a LS factor of approximately zero.

It should be noted that the accuracy of the results, derived from the application of empirical models, such as in this work, depends on the quantification of the parameters involved and will never be absolute (Brazier et al., 2000). But, even though the quantitative estimatations are questionable, the qualitative results regarding the spatial distribution of erosion risk between different areas of interest value the most (Zarris et al., 2001; Saavedra, 2005). Therefore, the application of this model cannot replace other methods of collecting data or conducting experiments, though it can increase their effectiveness.

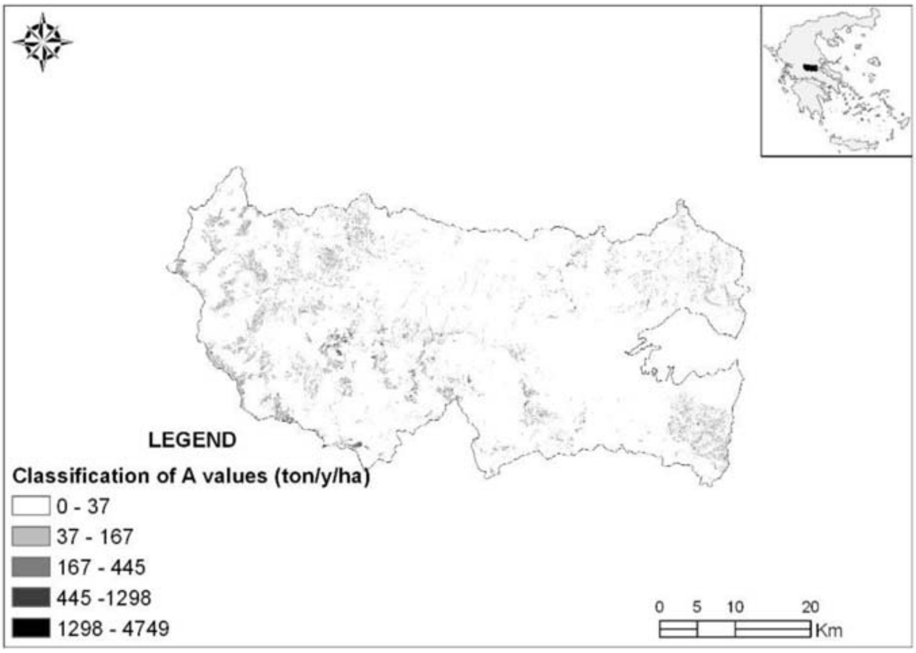

Fig. 5: Classification of A factor values.

6. Conclusions

The processes of weathering, erosion and deposition of sediment in river basins can vary, depending on a variety of biophysical and human factors. The intensity of these processes differentiates also not only in space, but in time as well, which makes the study conducted difficult and the results even more uncertain.

The importance of soil erosion assessment is great and associated with:

- a range of environmental impacts, including loss of organic matter and soil nutrients, reducing crop productivity etc,
- the management of natural resources and the approach to sustainable agriculture,
- a better understanding and assessment of erosion processes, compared with the current situation, as well as any changes in the present conditions, in a watershed or in a broader regional scale.

This paper shows that the combination of modern tools, such as Geographic Information Systems (GIS), methods and prediction models, gives us spatial and quantitative information of great importance and usefulness, if used properly. The spatial and quantitative assessment of soil loss gives us information which can stand as a guide, in order to take appropriate measures targeting to the control of the problems arising and to the rational environmental management of natural resources. The method may find practical use and application of local, regional or national level:

- the environmental impact assessment (e.g. desertification and climate change),
- the identification of new data involved in the effect of changes in the natural environment (e.g. destruction of plant cover due to fire),
- the risk assessment associated with economic and social impacts caused by soil erosion,
- the rational design of infrastructure and technical measures, which can be taken to avoid negative situations and to protect areas,
- and in general, spatial and environmental planning and management of land and natural resources.

7. References

Brazier, R. E., Beven, K. J., Freer, J. and Rowan, J. S., 2000, Equifinality and uncertainty in physically-based soil erosion models: application of the GLUE methodology to WEPP, the Water Erosion Prediction Project – for sites in the UK and USA, *Earth Surf. Process. Landf.*, 25, 825-845.

European Topic Centre on Land Use and Spatial Information. Corine Land Cover 2000.

Flambouris K. (2008). Study of rainfall factor R on the Rusle law. Phd Thesis, Aristotle University of Thessaloniki.

Koutsoyiannis D. and Tarla K. (1987). Sediment Yield Estimations in Greece, *Technica Chronica*, A-7, 3, 127–15.

Luca, A. (2004). Sviluppo di metodologie di analisi per la stima dell'erosione dei suoli con applicazione specifica ad un'area pilota. Technical Report, available via www lamma-cres.toscana.it

Lykoudi, E & Zarris, D. (2004). Identification of regions with high risk of soil erosion in the island of Cephalonia using the Universal Soil Loss Equation.

McCool D.K., Foster G.R., Weesies G.A. 1997. Slope-length and steepness factors (LS). In Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). USDA Agriculture Handbook No. 703, Chapter 4. Washington, DC: USDA.

Mitasova, H., Mitas, L., (2001). Multiscale soil erosion simulations for land use management, In: Landscape erosion and landscape evolution modeling, Harmon R. and Doe W. eds., Kluwer Academic/Plenum Publishers, pp. 321-347.

Moore, I. and Burch, G. (1986) Physical basis of the length-slope factor in the Universal Soil Loss Equation. *Soil Society of America Journal*, 50, 1294 – 1298.

Moore, I. D., A. K. Turner, J. P. Wilson, S. K. Jensen, and L. E. Band (1993). GIS and land surface-subsurface process modeling, in: Geographic Information Systems and Environmental Modeling. Oxford University Press, New York, 196-230.

Poulos S.& Chronis G. (1997). The Importance of the Greek River Systems in the Evolution of the Greek coastline - In: Transformations and evolution of the Mediterranean coastline, F. Briand and A. Maldolado (Eds), *CIESM Science Series no 3, Bulletin de l'Institut oceanographique*, Monaco, no 18: 75-96.

Renard K.G., Foster G.R., Weesies G.A., McCool D.K., and Yoder D.C. (1997). "Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)", Agriculture Handbook N°703. U.S. Department of Agriculture Research Service, Washington, District of Columbia, USA, 404.

Saavedra C. (2005). Estimating spatial patterns of soil erosion and deposition in the Andean region using geo-information techniques – A case study in Cochabamba, Bolivia. Thesis, ITC & Wageningen University, Netherlands.

Van der Knijff, J.M., Jones, R.J.A., Montanarella, L. (2000). Soil erosion risk assessment in Europe, EUR 19044 EN, 44pp. Office for Official Publications of the European Communities, Luxembourg.

Wischmeier, W.H. and D.D. Smith (1978). Predicting Rainfall Erosion Losses: A Guide to Conservation Planning. Agriculture Handbook No. 537. USDA/Science and Education Administration, US. Govt. Printing Office, Washington, DC. 58pp.

Wischmeier, W.H., Johnson, C.B. and Cross, B.W., 1971. A soil erodibility nomograph for farmland and construction sites. *Journal of Soil and Water Conservation*, 26, 5: 189-193.

Zarris, D., Lykoudi, E., and D. Koutsoyiannis (2001). Appraisal of river sediment deposits in reservoirs of hydropower dams. Contractor: Department of Water Resources, Hydraulic and Maritime Engineering – National Technical University of Athens, 243 pages, October 2001. In Greek.