DESIGN OF AN EROSIONABILITY MODEL OF THE TEYNA RIVER WATERSHED TO MONITOR EROSION RISK

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Abstract: *Soil erosion has been one of the main global issues. It is very importance and widely distributed in the Balkan and Mediterranean countries. Following the processes of abandonment and wildfires erosion's manifestation has knock-on effects for centuries. The main objective of this work is to design a model of the soil erosion risk of the Teyna River Watershed. The study area of the work is Teyna River Watershed. Several methods using spatial analysis capabilities of geographic information systems (GIS) exist and are in operation for soil erosion risk assessment. Such examples are Universal Soil Loss Equation (USLE), Revised Universal Soil Loss Equation (RUSLE) in operation worldwide and in USA and Modèle d'Evaluation Spatiale de l'ALéa Erosion des Sols - Regional Modelling of Soil Erosion Risk-MESALES in Europe. Despite their rigour, they all are based on the local conditions of natural features, or are encumbered with many parameters, which are usually missing or are not available for each location. The methods employed are weighted overlay of soil, vegetation and slope raster datasets, ranked accordingly to the expert knowledge of the erosion susceptibility of each factor. The model output represents a weighted combination map with four classes of erosion risk on the territory of the Teyna River Watershed. Suggestions and recommendation for improvement of the model's performance are given in the relevant sections.*

СЪЗДАВАНЕ НА МОДЕЛ НА ЕРОЗИОННАТА ОПАСНОСТ НА БАСЕЙНА НА Р. ТЕЙНА ЗА МОНИТОРИНГ НА ЕРОЗИОННИЯ РИСК

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Ключови думи: *GIS, ерозионна опастност, ерозионен риск, пространствен анализ,*

Резюме: *Почвената ерозия е един от основните глобални проблеми. Тя има особено голямо значение и проявление в балканските и средиземноморските страни. Последствията от ерозията се проявяват векове след процесите на изоставяне на земеделските земи и горските пожари. Целта на настоящето изследване е създавенето на модел на риска от ерозия, като предпоставка за планиране на земеползването на територията на водосборния басейн на р. Тейна. Района на изследване на водосборния басейн на р. Тейна е използван като пилотен за прилагане на модела на ерозионната опасност с цел бъдещи изследвания в областта. Съществуват няколко методики за оценка на риска от почвена ерозия. Тези методики използват възможностите за пространствен анализ на географските информационни системи (ГИС). Подобни модели са универсалното уравнение за почвени загуби-USLE, ревизираното универсално уравнение за почвени загуби-RUSLE използвани основно в САЩ и по света и Модела за пространствена оценка на опасността от почвена ерозия-MESALES в Европа. Въпреки тяхната сложност и комплексност те всички са основани на местните условия на природните компоненти, или пък включват множество параметри, които обикновено не са налични. Използваните методи при създаването на модела включват ранкиране и линеен модел с тегловни коефициенти на факторите на ерозията. Ранговете на факторите: почва, растителност, наклон на склона са ранжирани съобразно експертни оценки на степента на ерозионната опасност за всеки фактор. Модела на ерозионната опасност представлява резултантен слой с четири класа представящи степените на ерозионния риск за територията на водосборния басейн на р. Тейна. Предложения и препоръки за подобряване на резултатите от модела са дадени в съответните секции на настоящата работа.*

Introduction

During the past decennary, after the Green revolution and the abandonment in the Mediterranean, first manifestation of widely spread erosion phenomena has emerged worldwide. Global conservation community has launched many campaigns at local, regional and continental level for preservation of soil resources in order not only to stop or mitigate human impact on nature, but to improve life in rural and agricultural areas introducing new approaches for soil cultivation. Such example in Bulgaria, led to launching of many soil mapping campaigns in order to better understand the soil resources and their susceptibility to erosion. Based on years of field observation and scrutiny Soil Institute *N. Poushkarov* prepared maps of Soil regionalization and erosion regionalization (Boardman and Poesen, 2006). Despite that, with the advancement of computer aided cartography, GIS and remote sensing, most of the field observations become more or less supportive to the field and laboratory work. In the case of pedology, the issues with soil mapping are not still overcome, due to the fact that there is not a reliable field or remote sensing methodology to scan the soil horizons in deep and in detail. Based on the field test sites some of the well known models for soil erosion have been revised several times in order to improve their reliability and performance around the world. Two of these models are Universal Soil Loss Equation (USLE) and its revised version (RUSLE) (Wischmeier 1978). In former Soviet Union the research on soil erosion had been conveyed under the scope and the demands of national centralized economy, as well as within the joint initiatives of FAO. These investigations were being used for creation of soil erosion equations applicable as in USLE and RUSLE case with caution, due to the varying factors from place to place. At European scale, soil erosion risk investigation has been done within the framework of MESALES Project (Modèle d'Evaluation Spatiale de l'ALéa Erosion des Sols - Regional Modelling of Soil Erosion Risk) developed at Land Management and Natural Hazards Unit, Joint Research Centre (JRC). Not only the erosion risk was assessed but also the consequences from overgrazing, wildfires and abandonment have been taken into account in Mediterranean - Satellite Based Desertification Monitoring in the Mediterranean Basin (DeMon) Project. Present study uses a simplified erosionability or soil erosion risk assessment model for a study area of the Teyna River watershed in the north part of Sofia kettle. The study tries to evoke a series of field studies and large scale investigation for the territory of Bulgaria, in order to assess the risk of erosion at nation scale. This will help the governmental agencies, land-use owners and entrepreneurs to apply land-use planning on local and national level, and to devise and outline the new agenda for land-use/land-cover management for the next decade.

Study area

The present work has been applied on the study area of the Teyna River Watershed. The basin of the Teyna River is located in the North part of Sofia kettle in the footsteps of Sofiyska Mala Planina Mountain. The total area of the test site for modelling is – 4.775 km2. The altitude ranges from 500 m.a.s.l.; at the Iskar River entrance of the Iskar Gorge; to 964 m.a.s.l. on the topmost part of the the Teyna River catchment. Climatic conditions of the watershed are temperate to Transitional. Due to the fact that almost 28.74% of the slope exposition is oriented to the South and 35.44% to the East, the local climatic conditions are assumed to be drier than those of the Sofia kettle. Moreover, the fact that the Teyna River basin is opened towards South-East direction causes local mountainous valley winds to occur on a daily basis. The bedrock is a diverse mixture of Neogene-Quaternary argillite, alevrolite, Ordovician-Silurian argillite, schist, sandstone, breccias etc. All these rocks are more or less loose in their structure, so that they facilitate the manifestation of erosion. The vegetation is mainly planted. Some species found on the study area are: Scots pine (*Pinus sylvestris L.)* and European Black Pine (*Pinus nigra L.)*. Decommissioned mining in the study area has led to the destruction of the natural ecosystem. Today it is replaced by xerothermic plant communities. Much of the species are characteristic for highly polluted and eroded soil, because they are resistant to contamination. The majority of forest vegetation is artificially afforested with durable types of pollution. However, they are exotic to the area or for that altitude. *Robinia pseudoacacia* and *Populus deltoids* were transferred to the Bulgarian flora of North America. *Pinus silvestris* and species of the genus *Quercus* are not natural for this region and this low altitude. They form monocultures that do not support enough faunistic diversity. The mixed oak and hornbeam forests are presented mostly by *Quercus cerris*, *Q. pubescens*, *Q. frainetto*, *Q. delechampii*, *Carpinus betulus*. In the past these forests were presented mainly by *Crategus monogyna*, *Cornus mas*, *Corylus avellana*, *Ligustrum vulgare*, *Viburnum lanata, Syringa vulgaris*. Grasslands consist primarily of: *Festuca heterophylla, Poa nemoralis, Dactylis glomerata, Stellaria holostea, Heleborus odorus, Bzachipodium sylvaticum, Cruciata glabra, Ficaria verna, Trifolium pannonicum* etc. The so formed ecosystem is unstable.

The main soil types have following participation: Chromic Luvisols - 45.8 % located on the lower parts of the slopes. The next prevailing soil type is Cambisols with 36.37 %. This soil type is located on a higher altitude. The rest 17.4 % are covered with bare soil or Antroposols, which is connected to the human impact on soils. The diverse pattern and big proportion of human induced changes are observed on the embankments of the former coal mine *Kutina*. The former uranium ore extraction site *Brezi Vruh* covers almost the entire right slope of the main tributary of the Teyna River. This complicated environmental condition along with the complex geology features and climatic pattern in the valley, helps to speed up the erosion processes within the river basin.

Materials and methods

The dataset used in present study can be grouped in two categories. First category is raster dataset which consists of one QuickBird satellite image with four multispectral – 4m and one panchromatic - 0.7m bands acquired in May 2008, a mosaic of large-scale topography maps – 1:5 000 from the beginning of 1990s and Digital Elevation Model (DEM) with spatial resolution of 5m used as a reference one. The DEM was created from the scanned topography maps.

The vector dataset is stored and managed in file geodatabase feature classes within ArcGIS 9.2/ArcInfo academic license. It consists of contours, point elevation, hydrography, water bodies etc. for creation of a hydrological correct DEM of the watershed. Soil, vegetation and other ancillary data used as factors in the erosionability model, were also stored within the feature classes of the geodatabase to maintain its integrity in terms of spatial homogeneity.

All the data is in UTM coordinate system, WGS 84 datum, 35 North zone.

The methods applied in the study are geoprocessing and a simplified erosionability model. The model has fewer inputs than such models as USLE, RUSLE. The aforementioned MESALES model include land-use/land-cover, relief, soil and climate layers, which produce soil erosion sensitivity map as an input for the soil erosion risk map model, whereas the employed erosionability model does not take the climate into account. The main working environment for modelling was ModelBuilder embed within ArcGIS 9.2/ArcInfo academic license.

The main inputs to the model are feature datasets: *vegetation* and *soil* and *slope* derivative from the DEM. Feature datasets were subsequently converted to raster datasets with codes instead of names of vegetation types and soil types. The coded values of those two layers were subsequently recoded and ranked accordingly to their susceptibility to erosion. The first derivative of DEM, i.e. slope, was produced in degrees with 5m spatial resolution. After preparation of the parameters or factors in the erosionability model, the weighted overlay tool was used to overlay the three layers with following ranks or weights: soil–50%, vegetation–25% and slope–25%. The assigned weights are set accordingly to the model specifications. Climate features such as precipitation, temperature, soil moisture etc., which are very important for the process of erosion in terms of its mechanism, i.e. particle detachment and transport etc., were not included in the model due to the fact that the climatic conditions do not vary significantly throughout the study area. The spatial extent used was the Teyna River Watershed delineated using ArcHydro procedures for watershed delineation.

Results and discussions

After running the entire model the results show that most of the area under consideration, i.e. 28.46% is in the *first class* (0–4) of less or no erosionability. These territories are mainly occupied by deciduous forests or monoculture of oak *Quercus sp.* and *Robinia pseudoacacia L.* They are on slopes with moderate steepness and *Cambisols,* see **Figure 1**.

The *second class (4–5)* or the class with weak erosionability is found mainly in the river bed or in immediate adjacent territories and it is present on 31.61% of the territory. It is more widely spread on the embankments of the former coal mine Katina, due to the fact that the slopes are less than 3º and the prevailing vegetation cover is mainly meadows, pastures and grasslands mixed with orchards.

The *third class* (*5–6)* is found mainly on the river banks and slopes and it is present with 25.33%. It is also observed on the steeper slopes of the former coal mine and in the catchment area of Teyna River watershed. The interpretation of the factor participation to that class is that it is generally influenced by slope, but it is more widely spread in the upper part of the river catchment. That is due to the fact that there are mainly semi-natural deciduous and coniferous forests, which has shallow rooting; thus they are more prone to erosion.

The last, *forth class (6-9)* represents the most susceptible to erosion territories from the river basin of Teyna. The percent of their representation is 14.59. These territories occupy mainly the steepest slopes on the both sides of the mid river flow of the basin. Their steepness reaches 65°, which in turn prevent sustaining of any soil type. This fact probably was the main reason for vast afforestation in that area mainly with white bark pine and in the rest of the territory with oak. It is easily observed that exactly those areas have the most apparent manifestations of shield and gully erosion on the entire territory of the Teyna River Watershed, see **Fig. 1**.

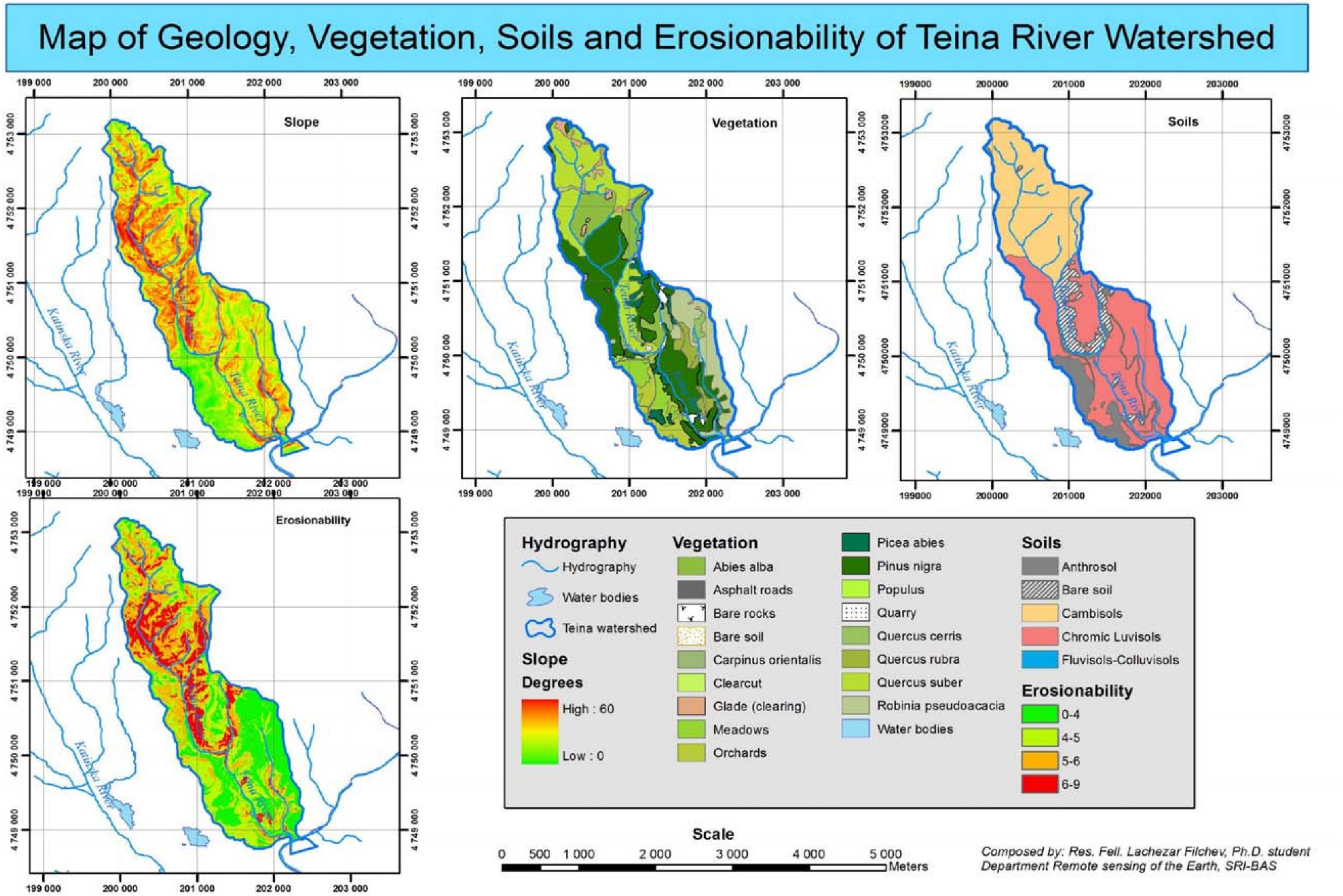

Fig. 1 Map of the geology, vegetation, soils and erosionability of the Teyna River watershed

The results and the interpretation bring some interesting insights and questions. Firstly, the erosionability model is sensitive only to those areas where ranking of the soil types, vegetation or slope is prevailing in the weighted overlay. This assumption is based on the facts drawn from the **Figure 1** in the results section above. The accuracy of the model could be greatly improved if climate and land-use practices are included as input parameters in it. Although, that the ranking of the parameters is biased due to the expert opinion, or because of less evidence, the model precision could be also improved by using the results from field observations. In case there are no sufficient observations or they are based in their nature the Analytical Hierarchical Process (AHP) can be also applied to improve ranking objectiveness.

Conclusions

In conclusion, presented study on the territory of the Teyna River Watershed comes to address the requirements and the agenda for sustainable development and rational land-use of present days. The applied methodology is well known in the GIS society for its simplicity and applicability for wider territories with less or missing field data. That makes it preferable for large-scale erosion risk studies. In order to include temporal dynamics in the model the more improved and elaborated MESALES model can be performed as well on a regular basis having the land-use as a dynamic parameter. The results from the analysis of the erosionability model shown that more than 28.46% of the territory is covered with class 0-4, 31.61% with class 4-5; 25.33% with class 5-6. The rest of the study area, i.e. 14.59% for the class 6-9, is occupied by prone to erosion territories, which is explained mainly with the openness, steepness and human induced changes of the relief during the period of active mining in the area. Despite the fact that afforestation has been applied using shallow rooting coniferous forests, the territory needs further erosion-combating mitigation measures in order to have its soils restored.

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