RESEARCH PAPER

COMPARISON OF EPM WITH RUSLE FOR SOIL EROSION MODELING IN THE STRUMICA RIVER BASIN

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ABSTRACT. The most recent climate change scenarios indicate an increase in extreme climate events (rainfall) and therefore an increase in soil loss. Strumica River is a tributary of river Struma/Strimon – a transboundary basin in North Macedonia (Strumica), Bulgaria and Greece that flows to the Aegean Sea. Most of the models incorporated in several software packages, use the USLE (Universal Soil Loss Equation). USLE-based models (RUSLE, MUSLE) are designed to model soil loss on gentler slopes and in agricultural areas. Furthermore, the model considers soil removal, but not the mass movement processes. On the other hand, the EPM (Erosion Potential Method by Gavrilovic), considers all soil particles (including rocks and mass movement) as well as all slope topography. The EPM considers the whole basin area. The aim of this research is to assess the differences between the two methods in the case study of the Strumica river basin. The results show differences in the quantities of the produced sediment. On the basin level, according to EPM, the quantity of annual produced sediment is 3.38 m^3 ha $year^{-1}$ while RUSLE depicted an annual soil loss at 1.59 t $ha^{-1}year^{-1}$. When observing just the agricultural land, according to EPM, the annual produced sediment is 4.22 m^3 ha $year^{-1}$ while according to RUSLE, the annual produced sediment is 2.84 t $ha^{-1}year^{-1}$. The EPM yields higher quantities because it takes into account the gully erosion and mass movement processes.

KEYWORDS: EPM, RUSLE, soil loss, soil erosion, produced sediment, Strumica river, Struma/Strimon

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INTRODUCTION

A Hazard is something that has the potential to harm you. Risk is the likelihood of a hazard causing harm (EFSA, online). A hazard is a situation or potential condition to harm or threat to life, health or damage to property or environment, social and economic disruption. The mass movement of soil is an indicator of a soil erosion hazard. This includes gully erosion, riverbank erosion, rock falls, debris-falls and landslides that can create damage to the environment and livelihoods (Senanayake *et al*., 2020).

Erosion hazard refers to the threat of channel migration and/or down cutting, due to erosion during times of flooding, or erosion of the ground around a structure in such a manner as to threaten the stability of the structure. It depicts the susceptibility of a site to erosion, based on soils, conditions and steepness of a slope, rock type, vegetation, and other site factors.

Soil erosion is one of the major environmental threats (Amundson *et al*., 2015) that is forecasted to diffusely increase under the impact of climate change (Borrelli *et al*., 2022; Panagos *et al*., 2022, Bezak *et al*., 2024).

Erosion risk assessment is a much more complex task since it considers various adverse effects that occur both on-site and off-site. The main on-site impact of soil erosion is the reduction in soil quality which results from the loss of the nutrient-rich upper layers of the soil, and the reduced water-holding capacity of many eroded soils. In an affluent area of the world, accelerated water erosion's on-site effects upon agricultural soils can be mitigated by increased use of artificial fertilizers; however, this is not an option for much of the earth's population (Favis-Mortlock, 2017).

Off-site effects, caused by erosion, transport the sediment through the watershed drainage pattern, are less visible and less studied. In the process of runoff on eroded slopes, along with soil particles (erosion sediment), all the other substances contained in the eroded soil layer are also removed. These substances can be natural, organic, inorganic, or artificial. Natural substances vary depending on the slope's or eroded region's geologic and pedologic properties. Most often, various fertilizers and pesticides are applied in agricultural production, and they reach the lower hydrographic network along with the eroded sediment. After reaching the streams and reservoirs, erosion sediment has the following ecological (and other) adverse effects: a) mechanical pollution of the stream and reservoir water, b) chemical pollution of water by manures and fertilizers, and c) chemical pollution by pesticides (Kostadinov, 2002).

Various methods for erosion vulnerability assessment are used by various countries in the world. Development of erosion vulnerability assessment methods, soil loss estimation and erosion intensity estimation, have a long–term tradition and a large number of methods and models have been developed in the past 100 years.

Generally, three types of approaches exist to identify areas at risk: qualitative approach, quantitative approach, and model approach. All these methods vary in their characteristics and applicability (Eckelmann et al., 2006). On the territory of the Republic of North Macedonia, the most practiced method is EPM by Gavrilovic. Considering the worldwide use of the USLE/RUSLE methods globally, it has also been applied in the country (Blinkov *et al*., 2020).

The Erosion Potential Method (EPM) is a complex methodology designed for use in the field of Integrated Water Resources Management and was originally developed for Yugoslavia by Slobodan Gavrilovic in 1972. EPM is factor-based, which means that a series of factors, each quantifying one or more processes and their interactions, are combined to yield an overall estimation of soil loss. The EPM method gives a quantitative estimation of erosion intensity as well as the estimation of sediment production and transportation (Gavrilovic *et al*., 2006).

The Universal Soil Loss Equation (USLE) predicts the long-term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices. USLE only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, wind or tillage erosion. This erosion model was created for use in selected cropping and management systems but is also applicable to non-agricultural conditions such as construction sites. The USLE can be used to compare soil losses from a particular field with a specific crop and management system to "tolerable soil loss" rates. Alternative management and crop systems may also be evaluated to determine the adequacy of conservation measures in farm planning. The Revised Universal Soil Loss Equation (RUSLE) is an upgrade of USLE that is independent of land use. It can be used on cropland, disturbed forestland, rangeland, construction sites, mined land, reclaimed land, military training grounds, landfills, waste disposal sites, and other lands where rainfall and its associated overland flow cause soil erosion. RUSLE maintains the same empirically based equation as USLE to compute sheet and rill erosion (FAO, online).

The first erosion map of the Republic of Macedonia was finished in 1993 by the Institute for water economy (orig: Zavod za vodostopanstvo) in a process that lasted eleven years with extensive field validation and traditional mapping techniques. Thirty years later, in 2020, it was updated with contemporary mapping techniques (GIS and Remote sensing, including field mapping using an expert judgment approach as control of the modelling results). The erosion map EPM and RUSLE were developed in a project funded by UNEP (UN Environmental program) for the Ministry of Environment and physical planning of Republic of North Macedonia. The latest erosion map (update of the first erosion map) was used in the analyses of this paper (Blinkov *et al*., 2020). There are several other erosion maps developed for research purposes (Milevski, 2015).

In the scope of this research, an erosion map using the two methods, EPM by Gavrilovic and RUSLE was produced. Conceptually, EPM was intended to be used for the whole country and RUSLE was intended mainly for the agriculture area.

The aim of this paper is to show the difference between two models for soil erosion estimation: EPM and RUSLE. The separate objectives are: (1) to estimate the produced sediment in the basin using EPM, (2) to estimate the soil loss in the basin using RUSLE, and (3) to compare the modeled values on different land uses.

MATERIALS AND METHODS

Study area

Struma/Strymon is a transboundary river with a basin of 18,078 km^2 (290 km and 10,797 km^2 in southwest Bulgaria; 110 km and 7,281 km^2 in northern Greece), its tributaries even extending into four countries (small parts are in Serbia and Republic of North Macedonia) (INWEB, online).

The river Strumica is a tributary of Struma River. Strumica river basin is 1,649 km^2 which is 6.4% of the territory of North Macedonia. A major part of the total watershed (75%) is in North Macedonia, while the remaining is in Bulgaria and Greece. River Strumica takes its source from the Plackovica Mountain at an altitude of 1,540 m asl running south in a deep valley and known as the Stara Reka (Popovska and Geshovska, 2014).

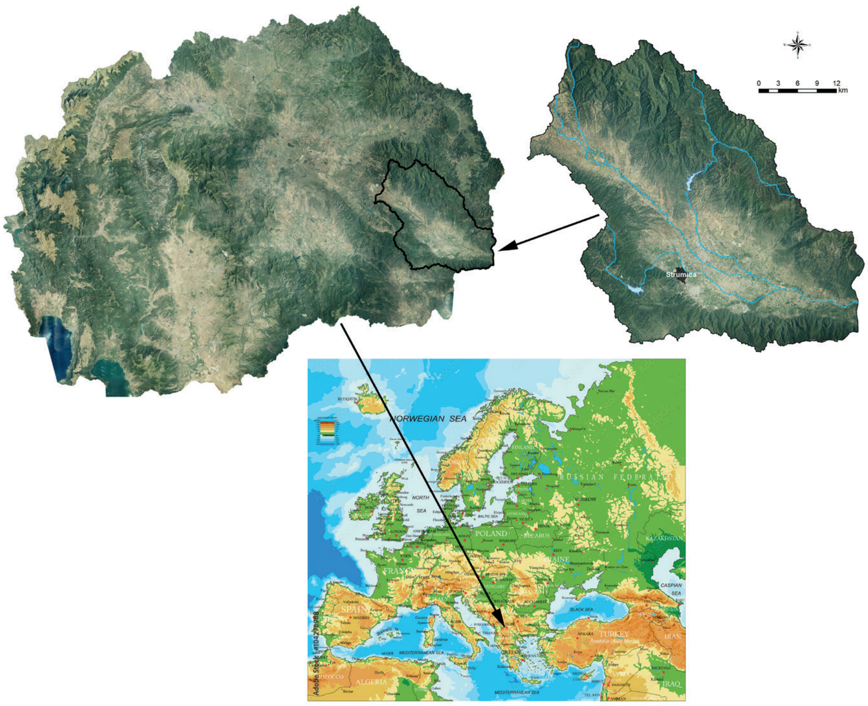

Fig. 1. Location of the basin of Strumica river in North Macedonia

The basin area of the Strumica River is situated in the south-eastern part of North Macedonia (Fig. 1). In this paper, only the part of the basin which is located in North Macedonia is considered. The basin has a total area of 1485 km^2. The land cover is dominated by broad-leaved forests in the higher parts of the basin with 38.9% and transitional woodland 19.7%. On the other hand, agricultural land is present at 35.2% of the total (Fig. 2).

The specific geographical and topographical position of the Strumica region is characterized by two zonal climates: sub-Mediterranean and continental. Sub-Mediterranean with long hot summers, with high average daily temperatures and reduced annual rainfall, decreased winter temperatures and winds from all directions (Lazarevski, 1993).

The climatic characteristics of the basin are strongly influenced by the location, orography, vegetation, and hydrological conditions of the region. The lowest parts of the basins are affected by the sub-Mediterranean climate, hilly and upland areas are affected by moderate continental and mountainous climate and highland areas are affected by typical mountain climate. Within the analysed period (1981-2010), the average annual air temperature for the basin is 11.2°C. The average annual rainfall sum is 626 mm, and in the higher parts of the basin, it can get up to 1014 mm (Aksoy *et al*., 2020).

The basin area of the Strumica River is part mountainous with 2/3 of the area and the flat valley with a dominant agriculture area. The average slope of the catchment is 27%, with maximal value of 230%; most of the mountainous area is with steep slopes in the range of 45-100%.

The dominant soil type in the mountainous part of the basin area is cambisol with 34.4%, on the other hand, in the valley the most dominant are the alluvial soils (12.7%) and colluvial fans (11.8%). Also, in the basin there are regosols (6.8%), complex of cambisol and regosol (6.5%), complex of humic eutric and umbric regosol (6.1%), complex of chromic luvisol on saprolite and regosol (5.6%) and leptosol (4.5%) (Markovski *et al*., 2018).

The geology of the investigated area is very diverse. In the northern and east-northern parts prevail Proterozoic gneisses and shales. In the central part, along the Strumica river, prevail Quaternary alluvial sediments and Neogene clastic sediments. In the central-eastern part and in the south-eastern part magmatic rock are present, while in the south-western part prevail Paleozoic shales with the inclusion of Paleozoic carbonates (Stafilov & Šajn, 2016, Čančalova et. al, 2017). The basin area is dominated by double mica gneiss (15.3%), alluvium (14.9%), biotite granite (10.6%), mica schist and leptynolite (10.3%), deluvium-proluvium 9.1% and marl clay, sandstone and gravel (8.8%).

Modeling produced sediment (soil loss) in the basin of Strumica river with the Erosion Potential Method (EPM)

There are many methodologies which are used for soil erosion estimation. Blinkov and Kostadinov (2010) provide a review of applicability for various usage scenarios of several models for estimation of erosion: EUROSEM, USLE, PESERA, KINEROS, WEP, WEPP and EPM.

The EPM was developed in the Balkan region, south Serbia, which is very similar in climatic conditions to North Macedonia, and therefore it is well adapted to the study area. Also, the model has the ability to predict sediment transport and deposition and it was developed by calibration with the measurement of the deposited sediments in the existing reservoirs. The EPM was validated using bathymetric measurements of several water reservoirs and it show similar results of the model and the measurements (Mincev, 2018).

It was observed that the use of this model increased from 2011 to 2019, and very few studies were conducted in the preceding decade (2000–2010). This method has been widely used in the European continent making it the third (6.7%) most used quantitative method
(Pandey *et al*., 2021).

$$Z = \gamma * Xa * \left(\varphi + \sqrt{I_{sr}}\right) \quad (1)$$

$$W_{year} = T * H_{year} * \pi * \sqrt{Z^3} * F \quad (2)$$

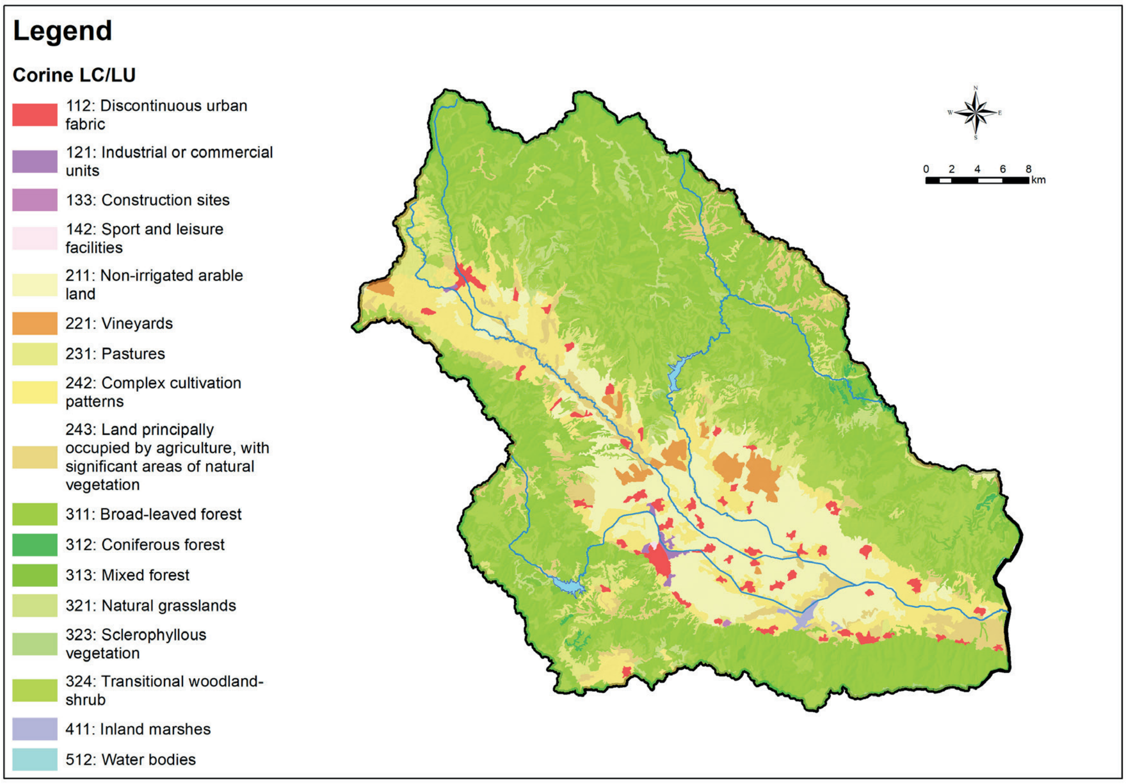

Fig. 2. Land cover/use map of the Strumica River basin

Where:
Z – coefficient of erosion by Gavrilovic (dimensionless)
γ - the reciprocal value of resistance of soils/rocks on erosion processes
Xa – protection of the basin in natural conditions and after erosion control
φ - coefficient of visible processes of erosion
Jsr - mean slope of the basin
W – quantity of produced sediments [m^3 $year^{-1}$]
T – temperature coefficient
H – total annual precipitations [mm]
π – Ludolph number
F – basin area [km^2]

The EPM (by Gavrilovic) was originally designed to be used with hardcopy maps, and the mapping process itself was carried out on a basin level. With the advent of GIS tools and the large variety of geographic data available (Corine LC/LU, soil maps, geology maps, elevation data – DEM, rainfall models, etc.), the mapping process evolved on much smaller mapping units. These datasets can be of good quality, but the production scale should be taken into account, and they could be reclassified according to the given classes in the methodology. The use of a global dataset is recommended due to the easy transferability and comparability of the results (Mincev, 2015).

The input parameters used for the EPM and RUSLE were as follows: National soil map (scale 1:50,000); Land cover: Corine LC/LU 2018 (developed by European Environmental Agency, scale 1:100,000), later improved using visual photo-interpretation of aerial imagery with spatial resolution of 0.3 m (2019) (Fig.2); DEM spatial resolution of 5 m; climatic parameters developed in spatial resolution of 20 m, analysed period (1981-2010) (Aksoy et al. 2020).

Modeling soil loss in the basin of Strumica river with RUSLE

The main factors affecting the rates of soil erosion by water are precipitation, soil type, topography, land use and land management. In a recent inventory, Karydas et al. (2014) identified 82 water-erosion models classified on different spatial/temporal scales with various levels of complexity. The most used erosion model is the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) and its revised version (RUSLE) (Renard *et al.*, 1997) which estimates long-term average annual soil loss by sheet and rill erosion. It should be noted that soil loss caused by (ephemeral) gully erosion is not predicted by RUSLE (Poesen *et al.*, 2003). Despite its shortcomings, RUSLE is still the most frequently used model at large scales (Renschler and Harbor, 2002; Kinnell, 2010) as it can process data input for large regions and provides a basis for carrying out scenario analysis and taking mitigating measures against erosion (Lu *et al.*, 2003; Panagos *et al.*, 2015e). The equation of USLE (RUSLE) is:

$$E = R * K * C * LS * P \tag{3}$$

Where:
E - annual average soil loss (t ha^{-1} yr^{-1}),
R - rainfall erosivity factor (MJ mm ha^{-1} h^{-1} yr^{-1}),
K - soil erodibility factor (t ha h ha^{-1} MJ^{-1} mm^{-1}),
C - cover-management factor (dimensionless),
LS - slope length and slope steepness factor (dimensionless) and
P - support practices factor (dimensionless).

Each parameter is estimated and defined in detail, in separate papers by Panagos et al., published in 2015 (Panagos et al., 2015a, 2015b, 2015c, 2015d, 2015e). Also, a modification and development of the R factor for North Macedonia was published by Blinkov et al. (2022). More detailed description of the both methods used it can be found in Tavares et al., 2019.

RESULTS AND DISCUSSION

The main difference between RUSLE (and similar to USLE methods) and EPM is different terminology that represents different processes and conditions. Soil loss is in fact loss of consolidated material. Sediment production refers to unconsolidated material. The difference is in bulk density because in situ soil bulk density is higher then bulk density of unconsolidated or partially consolidated erosive material (Blinkov, 2014). Apart from that, the main difference between EPM is that USLE (RUSLE) are limited on sheet and inter-rill erosion. On the other hand, EPM recognizes deep erosion –

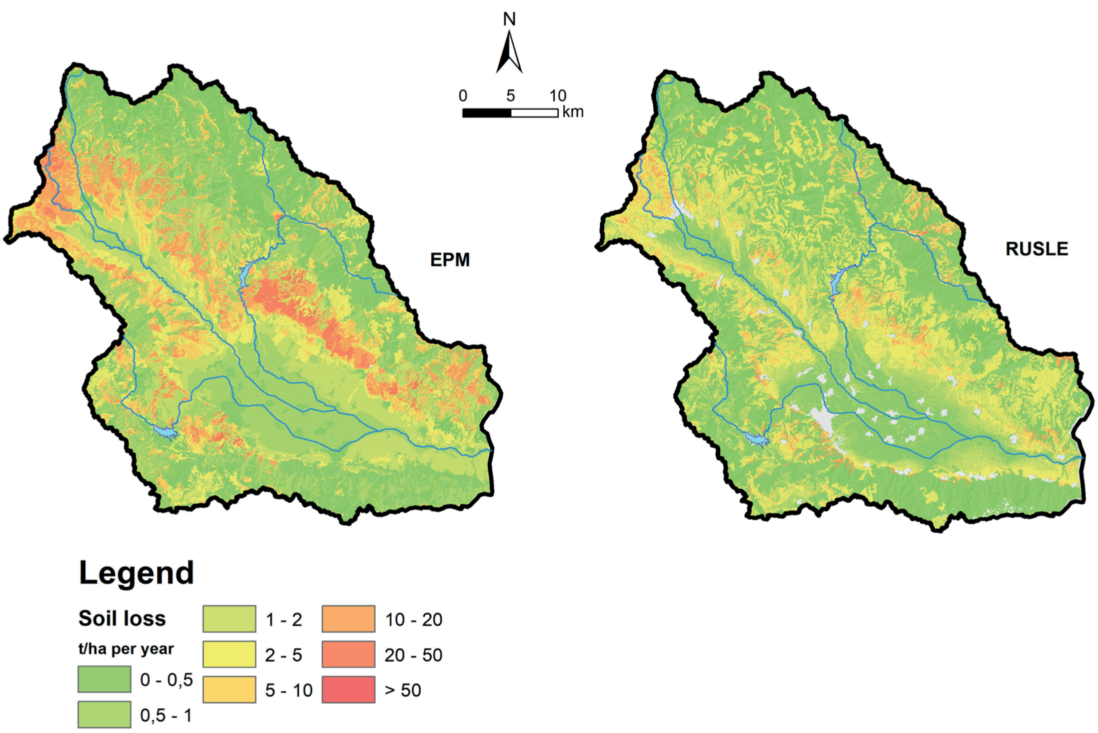

Fig. 3. Comparison of soil loss/produced sediment of EPM vs. RUSLE in the basin of Strumica river

Table 1. Comparison of soil loss/produced sediment of EPM vs. RUSLE on different land cover and slope

Corine Land cover/Land use (Level 3)	EPM-W (t/ha)	RUSLE-E (t/ha)	Slope (%)
Non-irrigated arable land	2.1	1.5	3.3
Complex cultivation patterns	4.2	2.5	7.5
Land principally occupied by agriculture, with significant areas of natural vegetation	3.4	4.2	13.7
Pastures	11.2	6.3	24.6
Vineyards	3.4	3.4	4.4
Broad-leaved forest	1.3	0.2	41.9
Mixed forest	1.4	0.1	37.4
Coniferous forest	1.1	0.1	36.2
Transitional woodland-shrub	6.2	2.1	33.7
Natural grasslands	6.2	3.0	29.2
Sclerophyllous vegetation	3.7	3.8	42.1

gullies, landslides, rockfalls, fluvial, deep erosion etc. (Blinkov and Kostadinov, 2010).

The EPM produces an output expressed in volume units $m^3ha^{-1}year^{-1}$. On the other hand, RUSLE expresses the output in weight measure $t\ ha^{-1}year^{-1}$. In order to make a comparison of the results of the soil loss or produced sediment the EPM values were converted from m^3 to tons using the bulk density of the soil/erosive material of 1.2 ($1\ m^3 = 1.2\ t$).

The map above (Fig. 3) depicts the difference in quantities of soil loss of the two methods. From the visual inspection, it can be seen that the quantities in the valley are similar (mostly green color). On the other hand, larger discrepancies can be observed in the central part of the basin, north of the confluence of the rivers. Focusing on the red/orange color on the EPM map (classes 5-10, 10-20 and 20-50 $t\ ha^{-1}$) and the RUSLE map, the same areas have maximum values of 5-10 $t\ ha^{-1}$. This can be attributed to the fact that the RUSLE model does not account for the mass movement erosion processes and only quantifies the topsoil removal.

Table 1 depicts how the two models perform on different land cover classes. The values are expressed as average values, which were calculated on a polygon level of the Corine land cover map from 2018. The agriculture areas yield 1.3 times higher values with the EPM than with RUSLE. This was also confirmed before by Bezak *et al.*, 2024, and this was expected. The lower part of the table shows the natural land cover classes. Here the difference is much higher. On average, EPM yielded values that were seven times higher than those of the RUSLE model. This difference can also be accounted for by the slope of the terrain since the RUSLE model was mostly developed for agricultural areas and for slopes up to 15%. Similar comparison can be found in Tavares *et al.*, 2019.

CONCLUSIONS

The results show differences in the quantities of the produced sediment. On the basin level, according to EPM, the quantity of annually produced sediment is 3.38 $m^3\ km^{-2}\ year^{-1}$ and according to RUSLE the annual soil losses is 1.59 $t\ ha^{-1}year^{-1}$. When observing just the agricultural land according to EPM the annually produced sediment is 4.22 $m^3\ km^{-2}\ year^{-1}$ while according to RUSLE the annual produced sediment is 2.84 $t\ ha^{-1}\ year^{-1}$. EPM yields higher quantities because it considers gully erosion and mass movement processes. On the other hand, the RUSLE model is much more adapted for agricultural land and in terms of soil loss estimation, it should yield more accurate results.

REFERENCES

Aksoy, E., Arsov, S., Mincev, I., Fang C. (2020) Agro-ecological atlas of the Republic of North Macedonia. Rome, FAO

Amundson, R., Berhe, A.A., Hopmans, J.W., Olson, C., Sztein, A.E., Sparks, D.L., (2015) Soil and human security in the 21st century. Science (80-.) 348, 1261071. https://doi.org/10.1126/science.1261071

Bezak, N., Borrelli, P., Mikos, M., Auflic, M.J. and Panagos, P., (2024) Towards a multi-model soil erosion modelling: An evaluation of the Erosion Potential Method (EPM) for global soil erosion assessments, CATENA, ISSN 0341-8162, 234, 2024, p. 107596, JRC134173

Blinkov I. and Kostadinov S. (2010). Applicability of various erosion risk assessment methods for engineering purposes, BALWOIS conference 2010, Ohrid, Macedonia

Blinkov I., (2014) An approach for conversion of erosion data produced by EPM method in weight measure, Monograph: Advances in GEOECOLOGY 43 – Challenges: Sustainable Land Management – Climate Change, Edition: Advances in GEOECOLOGY, Editors: Miodrag Zlatic & Stanimir Kostadinov, Publisher: CATENA VERLAG GMBH Armelgasse 11, D-35447 Reiskirchen, Germany

Blinkov I., Trendafilov A., Mukaetov D., Monevska Alcinova S., Stevkova S., Stevkov A., Minchev I. and Trendafilov B. (2020) Erosion, Drought and Desertification Atlas of the Republic of North Macedonia; https://balkansfoundation.org/publications/

Blinkov I., Minchev I. and Trendafilov B. (2022) Calculation of the R-factor (the rainfall erosivity factor) for the needs of modeling soil losses using the RUSLE method, based on annual precipitation (in Serbian); Erozija - Scientific Journal of erosion and torrent control, No.:48, UDK 626 ISSN 0350-9648, https://phaidrabg.bg.ac.rs/view/o:28096

Borrelli, P., Ballabio, C., Yang, J.E., Robinson, D.A., Panagos, P., (2022) GloSEM: High resolution global estimates of present and future soil displacement in croplands by water erosion. Sci. Data 9, 406. https://doi.org/10.1038/s41597-022-01489-x

Čančalova, S., Stafilov, T., Šajn, R., & Alijagić, J. (2017). Spatial distribution of chemical elements in soil from the Strumica region, Republic of Macedonia. Geologica Macedonica, 31(2), 117-130. Retrieved from https://js.ugd.edu.mk/index.php/GEOLMAC/article/view/1954

EFSA, official website, [online] Available at: https://www.efsa.europa.eu/en/campaigns/hazard-vs-risk#:~:text=A%20Hazard%20is%20something%20that,of%20a%20hazard%20causing%20harm [Accessed 3 Apr. 2024].

Eckelmann, W., Baritz, R., Bialousz, S., Bielek, P., Carré, F., Hrušková, B., & Tóth, G. (2006). Common criteria for risk area identification according to soil threats. Office for Official Publications of the European Communities

FAO, [online] Available at: https://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/ru/c/1236444/ ; [Accessed 18 Apr. 2024].

Favis-Mortlock D., (2017) [online] Available at: https://soilerosion.net/on-site_impacts.html#:~:text=The%20main%20on%2Dsite%20impact,capacity%20of%20many%20eroded%20soils [Accessed 15 Feb. 2024].

Gavrilovic S. (1972) Inzenjering o bujicnim tokovima i eroziji (Engineering of torrents erosion) (in Serbian). Izgradnja, Belgrade special edition, pp. 272.

Gavrilovic Z., Stefanovic M., Milojevic M., Cotric J., (2006): "Erosion Potential Method» An Important Support For Integrated Water Resource Management. BALWOIS 2006 conference, Orhid, Republic of Macedonia http://balwois.com/balwois/administration/full_paper/ffp-700.pdf

INWEB, official website, [online] Available at: https://www.inweb.gr/workshops2/sub_basins/11_Strymon.html [Accessed 7 Apr. 2024].

Karydas, C.G., Panagos, P., Gitas, I.Z., (2014) A classification of water erosion models according to their geospatial characteristics. International Journal of Digital Earth 7 (3), 229–250.

Kinnell, P.I.A., (2010) Event soil loss, runoff and the Universal Soil Loss Equation family of models: a review. Journal of Hydrology 385, 384–397.

Kostadinov S., (2002) Erosion and Torrent Control in Mountainous Regions of Serbia; Proceedings,Keynote paper; International Year of Mountainous Conference:" Natural and Socio-Economic Effects of Erosion Control in Mountainous Regions; Edited by: M.Zlatić, S.Kostadinov, N.Dragović; Belgrade/ Vrujci Spa; Dec.10-13,2002; p.p.33-56.

Law Insider official website, [online] Available at: https://www.lawinsider.com/dictionary/erosion-hazard [Accessed 5 Apr. 2024].

Lazarevski A.: Climate in Macedonia, Kultura, Skopje, (1993), (in Macedonian)

Lu, H., Prosser, I.P., Moran, C.J., Gallant, J.C., Priestley, G., Stevenson, J.G., (2003) Predicting sheetwash and rill erosion over the Australian continent. Australian Journal of Soil Research 41 (6), 1037–1062.

Markoski, M., Mitkova, T., Tanaskovik, V., & Spalevic, V. (2018). Soil distribution in Strumica river basin and its importance for agricultural production. Agriculture & Forestry, Vol. 64 Issue 4: 121-128, 2018. DOI: 10.17707/AgricultForest.64.4.14

Milevski I. (2015). An approach of GIS based assessment of soil erosion rate on country level in the case of Macedonia. Proceedings of International scientificconference BALKANIKA 2015, pp. 97-104. http://dx.doi.org/10.18509/GBP.2015.13

Mincev I., (2015) Development of methodology for establishing protection zones in the proximity of water reservoirs from erosion and sediment transport aspect, Doctoral thesis, Ss. Cyril and Methodius University, Faculty of Forestry in Skopje

Mincev I., (2018) Measuring v.s modeling sediment, case study: Kalimanci reservoir, Soil and water resources protection in the changing environment, Ed.: Miodrag Zlatic; Stanimir Kostadinov; Schweizerbart and Borntraeger science publishers; Advances in Geoecology, Volume 45, ISBN 978-3-510-65418-5

Panagos, P., Borrelli, P., Matthews, F., Liakos, L., Bezak, N., Diodato, N., Ballabio, C., (2022) Global rainfall erosivity projections for 2050 and 2070. J. Hydrol. 610, 127865 https://doi.org/10.1016/j.jhydrol.2022.127865.

Panagos, P., Ballabio, C., Borrelli, P., Meusburger, K., Klik, A., et al., (2015a). Rainfall erosivity in Europe. Science of Total Environment 511, 801–814.

Panagos, P., Borrelli, P., Meusburger, C., Alewell, C., Lugato, E., Montanarella, L., (2015b). Estimating the soil erosion cover-management factor at European scale. Land Use Policy 48C, 38–50, http://dx.doi.org/10.1016/ j.landusepol.2015.05.021

Panagos, P., Borrelli, P., Meusburger, K., (2015c). A new European slope length and steepness factor (LS-Factor) for modeling soil erosion by water. Geosciences 5, 117–126.

Panagos, P., Borrelli, P., Meusburger, K., van der Zanden, E.H., Poesen, J., Alewell, C., (2015d). Modelling the effect of support practices (P-factor) on the reduction of soil erosion by water at European Scale. Environmental Science & Policy 51, 23–34.

Panagos, P., Borrelli, P., Poesen, J., Ballabio C., Lugato E., Meusburger K., Montanarella, L., Alewell, C. (2015e) The new assessment of soil loss by water erosion in Europe, Environmental Science & Policy 54, (2015) 438–447

Pandey Sh., Kumar P., Zlatic M., Nautiyal R., Panvar V.P., (2021) Recent advances in assessment of soil erosion vulnerability in a watershed, International Soil and Water Conservation Research, Volume 9, Issue 3, September 2021, Pages 305-318

Poesen, J., Nachtergaele, J., Verstraeten, G., Valentin, C., (2003) Gully erosion and environmental change: importance and research needs. Catena 50 (2–4), 91–133.

Popovska C., Geshovska V. (2014): Water Balance Model for Vulnerability Assessment of Water Resources in Strumica River Basin. Irrigation & Drainage Systems Engineering. Volume 3. Issue 3. pp.1-9.

Renard, K.G., et al., (1997) Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE) (Agricultural Handbook 703). US Department of Agriculture, Washington, DC, pp. 404.

Renschler, C.S., Harbor, J., 2002. Soil erosion assessment tools from point to regional scales – the role of geomorphologists in land management research and implementation. Geomorphology 47 (2–4), 189–209.

Senanayake S, Pradhan B, Huete A, Brennan J. (2020) A Review on Assessing and Mapping Soil Erosion Hazard Using Geo-Informatics Technology for Farming System Management. Remote Sensing. 2020; 12(24):4063. https://doi.org/10.3390/rs12244063

Stafilov T., Šajn R.: Geochemical Atlas of the Republic of Macedonia, Faculty of Natural Sciences and Mathematics, Skopje, 2016.

Tavares A., Spalevic V., Avanzi, J., Nogueira D., Silva M, Mincato R. (2019). Modeling of water erosion by the erosion potential method in a pilot subbasin in southern Minas Gerais. SEMINA: CIENCIAS AGRARIAS. 40. 555-572. DOI: 10.5433/1679-0359.2019v40n2p555.

Wischmeier, W., Smith, D., (1978) Predicting Rainfall Erosion Losses: A Guide to Conservation Planning. Agricultural Handbook No. 537 U.S. Department of Agriculture, Washington DC, USA.