SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 4, (2026), pp. 2541-2548
Open Access. Online & Print

DOI: 10.5281/zenodo.12426329

EVALUATION OF WATER EROSION USING THE RUSLE METHOD IN THE VINCES RIVER BASIN

Carlos Alberto Nieto-Cañarte[1]*, Evelyn Elizabeth Flores-Bazurto[2], Angelita Leonor Bosquez-Mestanza[1], Dolores Mariela Carrera-Maridueña[3], Manuel Gregorio Jiménez-Icaza[3], Víctor Manuel Guamán-Sarango[1], Kevin Miguel Veliz-Ibarra[4]

1Universidad Técnica Estatal de Quevedo
2Universidad de Guayaquil
3Universidad Agraria de Ecuador
4Universidad Politécnica Salesiana

Received: **07/11/2025**
Accepted: **02/03/2026**

Corresponding Author: Carlos Alberto Nieto-Cañarte (cnieto@uteq.edu.ec)

ABSTRACT

The research evaluated water erosion in the Vinces River basin (Ecuador) by applying the RUS LE method (Revised Universal Soil Loss Equation), this approach allowed estimating the potential loss of soil based on variables such as rainfall erosivity, soil erosivity, topography, vegetation cover and conservation practices. Using QGIS software and geospatial data, the areas most vulnerable to erosion were identified, determining that 34% of the basin presents an extreme level of erosion, while 66% shows low or moderate erosion. The main causes of erosion are linked to the geomorphological characteristics of the terrain and the lack of sustainable agricultural practices. The results of this study provide a solid basis for implementing watershed management and soil conservation strategies, in order to mitigate erosion and promote sustainable agricultural development in the region.

KEYWORDS: Water erosion, Vinces river basin, soil loss, RUSLE, GIS.

1 INTRODUCTION

Water erosion is one of the most important problems on earth, with high repercussions on the ecosystem, crop production, increased flooding, sedimentation of reservoirs, which generates economic losses (Felix et al., 2023). The severity of erosion is due to steep topography, overgrazing, poor crop technology and mechanisms, gully formation, and nutrient loss related to runoff and sedimentation (Abebe & Ayele, 2024).

Weathering is the natural disintegration of rocks (with or without minerals) when they come into direct contact with the environment (atmosphere, hydrosphere, biosphere, cryosphere), occurs on or near the earth's surface, being a static process (Xu et al., 2022). And giving way to a dynamic process such as erosion, transport and sedimentation: this soil erosivity is the wear (physical and/or chemical) that occurs on the surface of an unconsolidated body (soil), by the action of external agents (wind and/or water) or by the continuous friction of other bodies (glaciers and/or hail); transport (mass movement) is the transfer of eroded materials in a certain place (alluvium, eluvigium or colluvion); Sedimentation is the last process of morphogenesis and consists of the accumulation of materials after they have been eroded and transported. It is worth mentioning that this dynamic process is natural, but anthropogenic activities can cause disturbances and accelerate it (Fernández & Veja, 2018). This form of degradation has gained global interest and has been documented by various studies focused on assessment, risk analysis, mapping and monitoring at different scales; the modeling and construction of scenarios (Gürtekin & Gökçe, 2021).

The Universal Soil Loss Equation (USLE), initially proposed by Wieschemeier and Smith (1978), and its revised form (RUSLE), developed by Renard & Freimund (1994), are the most widely used empirical models for estimating soil loss. The RUSLE model is characterized by its flexibility, time- and cost-effectiveness, and practicality in contexts where limited measured data is available for watershed conservation (Hui et al., 2010). The Geographic Information Systems (GIS) have been identified as a useful tool for making estimates (Shekar & Mathew, 2024). The functionality of GIS includes the storage, processing, manipulation, and visualization of spatial databases, which makes them a good alternative for supporting the planning and management of natural resources.

Ecuadorian agriculture has historically adopted an agronomic approach rather than an ecological one, a practice that has contributed to water erosion due to conventional crop management and has had a direct impact on the natural ecosystem of the soil (Nieto-Cañarte et al., 2024). The provinces of Santo Domingo de los Tsachilas, Cotopaxi, Los Ríos, and Guayas are distinguished by their predominantly agricultural nature, which has a detrimental effect on the erosion of the basin. This is potentially attributable to the utilization of inadequate and unconservationist methods by most farmers, coupled with a lack of awareness regarding the management of water resources. Consequently, the short-, medium-, and long-term causes and effects of activities contributing to soil loss remain unaddressed, as do the potential measures to be implemented to mitigate erosion (Pandey et al., 2024).

In the contemporary era, hydrographic delimitation holds significant importance as it serves as a foundational framework for the planning and sustainable management of natural resources. The research focused on the estimation of water erosion in the Vinces River basin using the RUSLE method. This approach enabled the description of the processes that cause erosion, dragging, and sedimentation. Additionally, it facilitated the identification of areas most susceptible to water erosion through the creation of maps.

2 MATERIALS AND METHODS

The research focused on the hydrographic basin of the Vinces River whose extension is approximately 4,600.00 km², located in the center west of Ecuador between the projected coordinates UTM "X/Y" (East/North): 630000m / 9980000m and 740000m / 9780000m; geographical coordinates (Longitude/Latitude): 79º49'54.475"W / 0º10'51.27"S and 78º50'32.645"W / 1º59'20.334"S (Figure 1).

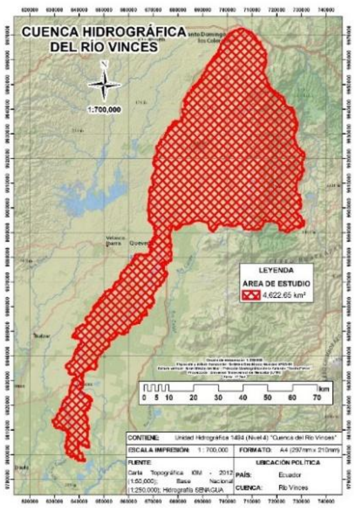

Figure 1. Vinces River Basin

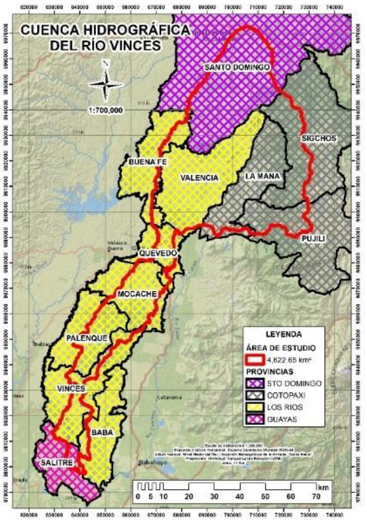

Figure 2. Cantons in the basin

It is worth mentioning that twelve cantons are directly influenced by the basin (Santo Domingo; Pujilí, Sigchos, La Maná; Buena Fe, Valencia, Quevedo, Mocache, Palenque, Vinces, Baba; Salitre), distributed in four provinces (Santo Domingo de los Tsachilas, Cotopaxi, Los Ríos and Guayas), with Los Ríos having the most territory in the basin (Figure 2).

Tian et al. (2021) mention the determination of the potential soil erosion process according to the RUSLE modelling framework with the QGIS software (with GRASS), the equation "A=RxKxLS" is applied, (Figure 3) in which rainfall erosivity "R", erodability "K" and topography "LS", which are natural factors (Zhang et al., 2023); and to establish the current soil deterioration, the complete equation "A=RxKxLSxCxP" will be used, where the aforementioned factors are involved, plus the coverage and management "C" and conservation practice "P" (Pinson & AuBuchon, 2023); procedures presented by Ed-daoudy et al. (2023). For the interpretation (Table 1), the classes or intensity of soil wear hazard due to water erosion were used:

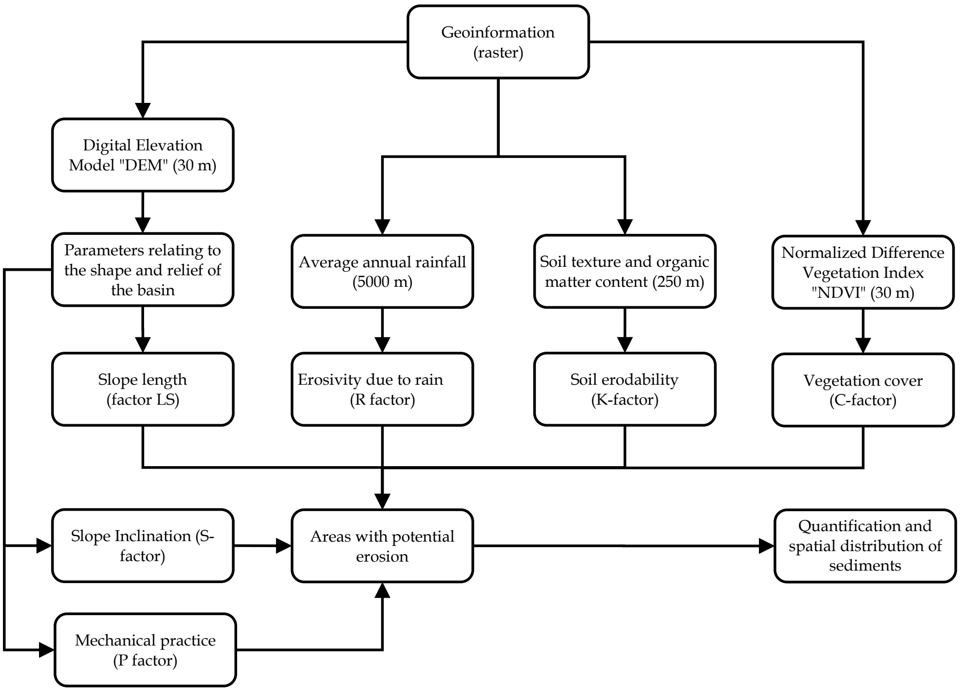

Figure 3. RUSLE Methodology Flowchart

Fuente: Arnold et al. (2012); Ochoa-Tocachi et al. (2018)

Table 1. Erosion levels established by FAO

Serial Number	Erosion Levels	Potential Soil Loss/Sediment Yield
1	Very low	< 5.00 t/ha/year
2	Low	5.00 - 25.00 t/ha/year
3	Moderate	25.01 - 50.00 t/ha/year
4	High	50.01 - 100.00 t/ha/year
5	Very High	100.01 - 200.00 t/ha/year
6	Extreme	> 200.00 t/ha/year
Fuente: Al-hasn et al. (2020)		

3 RESULT AND DISCUSSION

According to the result obtained from the geographical analysis, it was determined that the R Factor (erosivity index) of the Vinces River basin ranges between 664.32 and 2,373.56 MJ.mm/ha/h (Figure 4), where the maximum rainfall that is considered to be strong and constant is found in the Quevedo River sub-basin.

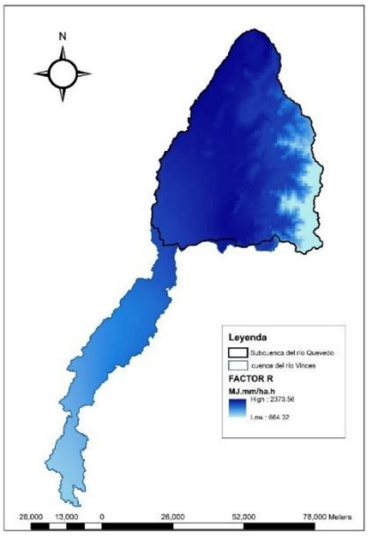

Figura 4. Factor R

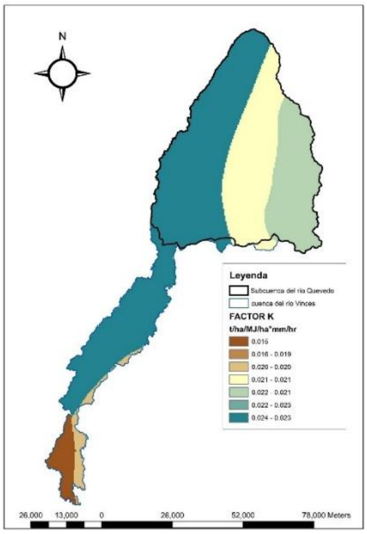

Figura 5. Factor K

Also from the geographical analysis, it was determined that the K Factor (soil erosivity) of the Vinces river basin is mostly made up of category 7 (TH7) humic andosol soils with 0.022 t/ha - MJ/mm/ha/h, lithosols (I) with 0.019 t/ha - MJ/mm/ha/h and category 4 (TH4) humic andosols 0.021 t/ha - MJ/mm/ha/h, which indicates a high probability of water erosion due to the composition of its "lithosol" soils (Figure 5). In addition, all the data obtained from the different soil layers that make up the Vinces River basin are shown (Table 2), observing seven types:

Table 2. K-Factor values according to FAO/UNESCO

Symbol	Soil Types	Fsand (Arena)	Fclay	Forg (MO)	Fsilt (Limo)	Factor K
TV	Viticose Andosols	0.200002	0.912897	0.982633	0.975942	0.022
TH7	Humic Andosols	0.200633	0.898523	0.974400	0.999765	0.022
TH4	Humic Andosols	0.200000	0.901194	0.974400	0.898638	0.021
GH	Humic Gleysols	0.200218	0.816728	0.974400	0.999787	0.020
I	Lithosols	0.200001	0.756314	0.992542	0.991686	0.019
I	Eutric Fluvisols	0.200000	0.780015	0.988398	0.926641	0.019
VP	Pelic Vertisols	0.201064	0.580181	0.997206	0.999991	0.016

Viticose Andosols (TV) are volcanic soils; Humic andosol soils (HT) of category 7 and 4, these types of soils have a difference that makes them unique in agricultural management, since they are rich in organic matter, and it is due to high biological activity; humic Gleysols (GH) have a dark coloration due to the presence of decomposing organic matter, with seasonal humidity; Lithosols (I) are characterized by the effective depth of ±10 cm, with a lot of rocks and are very susceptible to erosion due to environmental factors; Eutric Fluvisols (JE) are formed by fluvial sediments and have a sandy texture; and Pelic vertisols (VPs) are formed by sediments containing smectic clays.

Likewise, from geographical analysis it was determined that the LS Factor (slope length and slope magnitude) of the Vinces river basin, which ranges between 0.030 and 82.309 (Figure 6), interpreting that the slopes are short and steep, which intensifies soil erosion by precipitation.

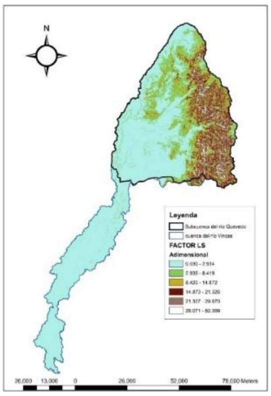

Figure 6. Factor LS

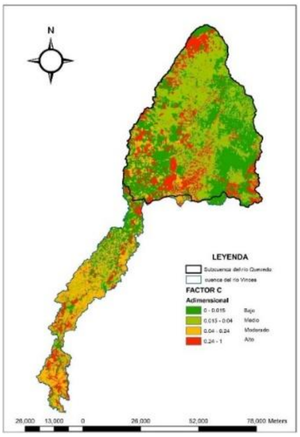

Figure 7. Factor C

In addition, Table 3 shows all the percentages of slopes obtained in the study area.

Table 3. Slope ranges for the LS Factor

Factor LS	Study Area	Categories
<5	1%	Weak slope
5-12	1%	Gentle slope
12-25	3%	Moderate slope
25-40	3%	Steep slope
40-70	65%	Very steep slope
>70	27%	Steep slope

Likewise, from the geographical analysis it was determined that Factor C (vegetation cover and soil management) of the Vinces river basin (Figure 7), depending on the reclassification there are four categories (low, medium, moderate and high) where the low category "0.00 - 0.015" are native forest, permanent crops, natural (bodies of water) and forest plantation; the medium category "0.015 - 0.040" are populated areas and infrastructure; the moderate category "0.04 - 0.24" is agricultural land, annual crops, and pasture; and the high category "0.24 - 1.00" are semi-permanent crops, agricultural mosaic, páramo, shrub vegetation, herbaceous vegetation and area without vegetation cover (Table 4).

Table 4. Soil Classification for Factor C

C-Factor	Study Area	Percentage of Area
Low	99,055.74 ha	21%
Middle	4,716.94 ha	1%
Moderate	240,563.94 ha	51%
High	127,357.38 ha	27%

And finally, from the geographical analysis it was determined that the P Factor (soil conservation practices) of the Vinces River basin, whose soil conservation practice was considered to be equal to 1, because it is not possible to specify the knowledge of the different erosion control practices in the different agro-productive activities (Talebi & Karimi, 2024).

Potential erosion: According to the result obtained from the final geographical analysis, it was found that the potential erosion of the Vinces River basin according to the revised universal soil loss equation (RUSLE), showed that 34% of the area presents extreme erosion levels, which correspond to 160,375.96 hectares of the basin; while only 9% of the area showed very low erosion levels, which corresponds to 42,452.46 hectares of the basin (Table 5):

Table 5. Levels of potential erosion in the Vinces River basin

Series	Erosion	Potential soil loss	Area
1	Very low	<5 t/ha/year	12%
2	Low	5-25 t/ha/year	23%
3	Moderate	25-50 t/ha/year	12%
4	High	50-100 t/ha/year	10%
5	Very High	100-200 t/ha/year	9%
6	Extreme	>200 t/ha/year	34%

Figure 8 shows the potential erosion in the Vinces River basin, but at the cantonal level: with the highest level of risk of potential water erosion are La Maná, Pujilí, Sigchos, Santo Domingo and Valencia; and with a lower risk of erosion is the Quevedo canton.

Current Erosion: According to the result obtained from the final geographical analysis, it was found that the current erosion of the Vinces River basin according to the revised universal soil loss equation (RUSLE), showed that 66% of the area has a very low level of erosion, which corresponds to 311,318.04 hectares of the basin, while only 1% of the area has a very high to extreme level. which correspond to 4,716.94 hectares of the basin (Table 6):

Table 6. Current erosion levels in the Vinces River basin

Series	Erosion	Current soil loss	Area
1	Very low	<5 t/ha/year	66%
2	Low	5-25 t/ha/year	25%
3	Moderate	25-50 t/ha/year	5%
4	High	50-100 t/ha/year	2%
5	Very High	100-200 t/ha/year	1%
6	Extreme	>200 t/ha/year	1%

Figure 9 shows the current erosion in the Vinces River basin, but at the cantonal level: the cantons of Pujilí and La Maná have a high level of erosion. Although most of them have low levels of erosion, possibly due to the influence of the vegetation cover (according to the estimate of Factor C).

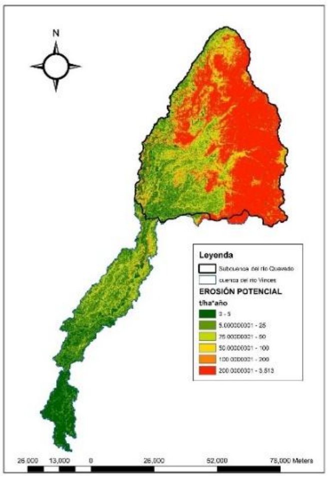

Figure 8. Potential water erosion

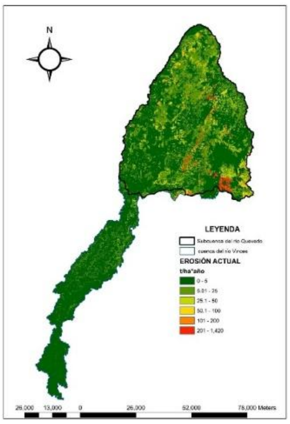

Figure 9. Current water erosion

In light of the findings and subsequent analysis, we concur with the assertions put forth by Fenjiro et al. (2020) that the physiography of a hydrographic basin facilitates preliminary inferences concerning its hydrological behavior and associated estimations. This assertion is corroborated by Hamouch et al. (1997), who contend that fluvial geomorphology facilitates the examination of geographical features, forms, and reliefs engendered by the activity of rivers on the surface or by alternative processes of erosion, transport, and sedimentation. This assertion is further corroborated by Amellah and El Morabiti (2021), who contend that morphometry facilitates the discernment of the physical characteristics of a basin, thereby enabling the specification of its current state through geometric characterization of surface forms. This process is achieved by means of hydrological estimations of surface, relief, and hydrography.

The findings obtained from this study align with those reported by Allafta and Opp (2022), who assert that land cover signifies the physical elements that occupy the earth's surface, including water bodies, forestry, and/or urban structures. This assertion is further substantiated by Ghavami et al. (2024), who contend that land use is intricately linked to human activities and economic functions associated with specific land segments.

The analysis obtained is consistent with the assertions made by Abdullah et al. (2002) and Patriche (2023), who indicate that the acquisition of terrestrial thematic maps is one of the primary and most advanced applications of remote sensing. Additionally, Thomas et al. (2018) reiterate this assertion, demonstrating that the utilization of satellite images is the most effective and efficient approach for developing land occupation cartography at various scales.

4 CONCLUSIONS AND RECOMMENDATIONS

The identification of areas with potential risk of erosion in the Vinces River basin was facilitated by the utilization of QGIS software, whose methodology was adapted to align with the research objectives. The resultant data from the analysis indicated the presence of potential and current erosion in the basin. The hypothesis is thus confirmed, as the identified areas are consistent with the expected levels of risk.

The findings are essential for proposing a comprehensive and sustainable water management plan. It is also imperative to engage in dialogue with governmental and non-governmental organizations to articulate the hydrological design and construction of hydraulic works that facilitate regulation and optimal use during the dry season, which is usually in the dry season (although it could occur in the rainy season with low rainfall).

REFERENCES

Abdullah Khan, Atta-ur Rahman, & Shakeel Mahmood. (2023). Spatial estimation of soil erosion risk using RUSLE model in District Swat, Eastern Hindu Kush, Pakistan. Journal of Water and Climate Change, 14(6), 1881-1899. https://doi.org/10.2166/wcc.2023.495

Abebe, T. G., & Ayele Woldemariam, A. (2024). Erosion spatial distribution mapping and sediment yield estimation using RUSLE and Arc GIS of Ayigebire watershed, North Shewa zone of Amhara region, Ethiopia. Water-Energy Nexus, 7, 124-134. https://doi.org/10.1016/j.wen.2023.12.002

Allafta, H., & Opp, C. (2022). Soil Erosion Assessment Using the RUSLE Model, Remote Sensing, and GIS in the Shatt Al-Arab Basin (Iraq-Iran). Applied Sciences 12(15), 7776. https://doi.org/10.3390/app12157776

Al-hasn, R., Alghamaz, F., Dikkeh, M., & Idriss, Y. (2024). Water soil erosion modeling with RUSLE, GIS & remote sensing: A case study of the AL-Sanaoubar River basin (Syria). Journal of the Saudi Society of Agricultural Sciences. https://doi.org/10.1016/j.jssas.2024.05.004

Amellah, O., & el Morabiti, K. (2021). Assessment of soil erosion risk severity using GIS, remote sensing and RUSLE model in Oued Laou Basin (north Morocco). Soil Science Annual, 72(3), 142530. https://doi.org/10.37501/soilsa/142530

Arnold, J. G., Moriasi, D. N., Gassman, P. W., Abbaspour, K. C., White, M. J., Srinivasan, R., Santhi, C., Harmel, R. D., van Griensven, A., Van Liew, M. W., Kannan, N., & Jha, M. K. (2012). SWAT: Model Use, Calibration, and Validation. Transactions of the American Society of Agricultural and Biological Engineers "ASABE", 55(4), 1491-1508. https://doi.org/10.13031/2013.42256

Ed-daoudy, L., Lahmam, N., Benmansour, M., Afilal, H., Ben-harra, A., & Damnati, B. (2023). Hydric erosion rates in Raouz watershed, Morocco: RUSLE, GIS, and remote sensing. Remote Sensing Applications: Society and Environment, 32, 101056. https://doi.org/10.1016/j.rsase.2023.101056

Fenjiro, I., Zouagui, A., & Manaouch, M. (2020). Assessment of Soil Erosion by RUSLE Model using Remote Sensing and GIS - A case study of Ziz Upper Basin Southeast Morocco. Forum geografic, XIX(2), 131-142. https://doi.org/10.5775/fg.2020.013.d

Felix, F. C., Cândido, B. M., & De-Moraes, J. F.L. (2023). Improving RUSLE predictions through UAV-based soil cover management factor (C) assessments: A novel approach for enhanced erosion analysis in sugarcane Fields. Journal of Hydrology, 626(A), 130229. https://doi.org/10.1016/j.jhydrol.2023.130229

Fernández, C., & Veja, J. A. (2018). Evaluation of the rusle and disturbed wepp erosion models for predicting soil loss in the first year after wildfire in NW Spain. Environmental Research, 165, 279-285. https://doi.org/10.1016/j.envres.2018.04.008

Ghavami, M. S., Ayoubi, S., Khaleghpanah, N., Mosaddeghi, M. R., & Gohari, A. (2024). Soil loss estimation using RUSLE model: Comparison of conventional and digital soil data at watershed scale in central Iran. Soil and Tillage Research, 244, 106238. https://doi.org/10.1016/j.still.2024.106238

Gürtekin, E., & Gökçe, O. (2021). Estimation of erosion risk of Harebakayiş sub-watershed, Elazig, Turkey, using GIS based RUSLE model, Environmental Challenges, 5, 100315. https://doi.org/10.1016/j.envc.2021.100315

Hamouch, C., Chaaouan, J., & Bouiss, C. E. (2024). Spatial-temporal assessment of soil erosion using the RUSLE model in the upstream Inaouène watershed, Northern Morocco. Natural Hazards Research. https://doi.org/10.1016/j.nhres.2024.08.002

Hui, L., Xiaoling, C., Lim, K.J., Xiaobin, C. & Sagong, M. (2010). Assessment of soil erosion and sediment yield in Liao watershed, Jiangxi Province, China, Using USLE, GIS, and RS. J. Earth Sci. 21, 941–953. https://doi.org/10.1007/s12583-010-0147-4

Nieto-Cañarte, C. A., Guaman-Sarango , V. M., Bosquez-Mestanza, A. L., Sinchi-Rivas, C. A., & Mecias-Herrera, N. L. (2024). Comparative evaluation of microbial activity in the decomposition of organic matter from solid household waste in Guayaquil. Sapienza: International Journal of Interdisciplinary Studies, 5(1), e24002. https://doi.org/10.51798/sijis.v5i1.713

Ochoa-Tocachi, B. F., Alemie, T. C., Guzman, C. D., Tilahun, S. A., Zimale, F. A., Buytaert, W., & Steenhuis, T. S. (2018). Sensitivity analysis of the parameter-efficient distributed (PED) model for discharge and sediment concentration estimation in degraded humid landscapes. Land Degradation & Development, 30(2), 151-165. https://doi.org/10.1002/ldr.3202

Pandey, R., Mehta, D., Kumar, V., & Pradhan, R. P. (2024). Quantifying soil erosion and soil organic carbon conservation services in indian forests: A RUSLE-SDR and GIS-based assessment. Ecological Indicators, 163, 112086. https://doi.org/10.1016/j.ecolind.2024.112086

Patriche, Cristian V. (2023). Applying RUSLE for soil erosion estimation in Romania under current and future climate scenarios. Geoderma Regional, 34, e00687. https://doi.org/10.1016/j.geodrs.2023.e00687

Pinson, A. O., & AuBuchon, J. S. (2023). A new method for calculating C factor when projecting future soil loss using the Revised Universal soil loss equation (RUSLE) in semi-arid environments. CATENA, 226, 107067. https://doi.org/10.1016/j.catena.2023.107067

Renard, K. G., & Freimund, J. R. (1994). Using monthly precipitation data to estimate the R-factor in the revised USLE. Journal of Hydrology, 157(1-4), 287-306. https://doi.org/10.1016/0022-1694(94)90110-4

Shekar, P. R., & Mathew, A. (2024). GIS-based assessment of soil erosion and sediment yield using the revised universal soil loss equation (RUSLE) model in the Murredu Watershed, Telangana, India. HydroResearch, 7, 315-325. https://doi.org/10.1016/j.hydres.2024.05.003

Talebi, A., & Karimi, Z. (2024). Incorporation of management responses in the direction of soil erosion changes from the past to the future based on the RUSLE and DPSIR model. Environmental and Sustainability Indicators, 23, 100412. https://doi.org/10.1016/j.indic.2024.100412

Thomas, J., Joseph, S., & Thrivikramji, K.P. (2018). Assessment of soil erosion in a tropical mountain river basin of the southern Western Ghats, India using RUSLE and GIS. Geoscience Frontiers, 9(3). 893-906. https://doi.org/10.1016/j.gsf.2017.05.011

Tian, P., Zhu, Z., Yue, Q., He, Y., Zhang, Z., Hao, F., Guo, W., Chen, L., & Liu, M. (2021). Soil erosion assessment by RUSLE with improved P factor and its validation: Case study on mountainous and hilly areas of Hubei Province, China. International Soil and Water Conservation Research, 9(3), 433-444. https://doi.org/10.1016/j.iswcr.2021.04.007

Wischmeier, W. H., & Smith, D. D. (1978). Predicting rainfall erosion losses. A gudie to conservation planning. Agriculture Handbook No. 537. USDA/Science and Education Administration. Washington, DC. 67p. http://naldc.nal.usda.gov/download/CAT79706928/PDF

Xu, Z., Zhang, S., Zhou, Y., Hou, X., & Yang, X. (2022). Characteristics of watershed dynamic sediment delivery based on improved RUSLE model. CATENA, 219, 106602. https://doi.org/10.1016/j.catena.2022.106602

Zhang, T., Lei, Q., Du, X., Luo, J., An, M., Fan, B., Zhao, Y., Wu, S., Ma, Y., & Liu, H. (2023). Adaptability analysis and model development of various LS-factor formulas in RUSLE model: A case study of Fengyu River Watershed, China. Geoderma, 439, 116664. https://doi.org/10.1016/j.geoderma.2023.116664