EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology, 2025, 26(7), 255–268
https://doi.org/10.12912/27197050/205300
ISSN 2719–7050, License CC-BY 4.0

Received: 2025.04.27
Accepted: 2025.05.30
Published: 2025.06.15

Soil erosion assessment in river basin of Chanthaburi province, eastern coastal area of Thailand, using universal soil loss equation and geographic information system techniques

Jakkapan Potipat[1], Phummipat Oonban[2*], Kumpee Teeravech[2]

[1] Department of Environmental Science, Faculty of Science and Technology, Rambhai Barni Rajabhat University, Chanthaburi 22000, Thailand
[2] Geoinformatics Program, Faculty of Computer Science and Information Technology, Rambhai Barni Rajabhat University, Chanthaburi 22000, Thailand
* Corresponding author's e-mail: phummipat.o@rbru.ac.th

ABSTRACT

Accurate information on soil erosion is crucial for sustaining agricultural productivity and managing natural resources. This study aimed to apply empirical models and geo-informatics technology to calculating, classifying and spatial processing erosion severity within the river basin of Chanthaburi province, Thailand. The methodology is examined soil loss factors and sediment yield using the universal soil loss equation (USLE) with the sediment delivery ratio (SDR). Rainfall variability and changes in land use and land cover (LULC) were found as the primary factors influencing the terrestrial model. The layer of erodibility (K-factor) was reclassified from soil series data. Additional USLE factors derived from the digital elevation model (DEM) provided by Thailand's Land Development Department (LDD), were integrated. There is a need for more innovative techniques for spatial evaluation to protect the surface runoff. Remote sensing (RS) and geographic information system (GIS) were applied to collect rainfall data and assess the degree of erosion. Statistical analysis revealed a significant difference in annual rainfall between the rain gauge observation and the dataset ($p < 0.05$). Annual soil erosion in most parts of the study area ranged from very low to moderate severity levels, whereas predictive rainfall data did not indicate any risk intensity. The potential of sediment accumulation increased over the decades, with rates of 128.28, 149.20, 162.58, and 190.92 tons/year for the years 1992, 2002, 2012, and 2022, respectively. Our results compared various rainfall measurements using linear regression and approached some research gaps that provide the development of precipitation data collection for hydrological study. The outcome of these results can serve as scientific data for lithologists to support disaster prevention and guiding decision-making in the anti-erosion planning.

Keywords: soil erosion, universal soil loss equation, sediment delivery ratio, geographic information system.

INTRODUCTION

Soil is considered to be a major natural resource that functions as an ecosystem's foundation. According to Eekhout and de Venta (2022), the functioning of ecosystems and their ability involving the provision of productivity are currently being negatively impacted by global catastrophes. One phenomenon is soil erosion affecting the environment, economic and social disturbances, public utility service, and regional pollution (Pradhan et al., 2012). Soil erosion is a geomorphological process of detaching and transporting soil components from their origin by the agents of erosion, such as storm and precipitation (Achu and Thomas, 2023). Due to the current rainfall and extreme weather conditions, land degradation and deforestation have contributed to landslides and soil erosion, which are among the most pressing environmental concerns, particularly in river basin areas (Mairaing et al., 2024). Although soil erosion is a natural process, its severity is exacerbated by various anthropogenic activities. The erosion of soil acts as the primary element in the initial process of the delivery of sediment to waterways, in which the effects of erosive forces transform the soil particles into sediments during transportation (Chuenchum et al., 2020). Approximately 80% of agricultural areas worldwide experience significant to severe erosion, which contributes to higher sediment levels, leading to increased river turbidity and elevated pesticide concentrations (Li et al., 2013; Tang et al., 2014). The impacts of soil loss erosion are extensive and include a decline in conservative areas, ecological damage, and an increase in sedimentation in downstream bodies (Pakoksung, 2024).

The categorization of approaches for the assessment of soil erosion include three major processes: (i) the method involving field plot experiments or fallout radionuclides that employ measurements of average soil loss, (ii) the method using field surveys of the visible indicators of soil erosion and identification of the factors that influence soil erosion, and (iii) the modeling of soil erosion (Senanayake et al., 2020). Soil erosion has been assessed through field experiments in worldwide over several decades, estimating both filed plot-scale and watershed-based approaches. Many field studies of soil erosion are constrained by the size of the study area and the observation period, most conventional methods for assessing soil erosion are both costly and time-consuming (Poesen, 2015; Ganasri and Ramesh, 2016). However, the approach of soil erosion modeling provides an estimation for investigation of erosion and sediment yield that is both quantitative and reliable across a diverse range of environments.

The common approaches to soil erosion modeling often involve the use of empirical models for estimating soil loss, such as the universal soil loss equation (USLE) (Wischmeier and Smith, 1978), revised universal soil loss equation (RUSLE) (Renard et al., 1997), modified universal soil loss equation (MUSLE) (Williams, 1975), water erosion prediction project (WEPP) (Nearing et al., 1989) and European soil erosion model (EUROSEM) (Morgan et al., 1998). Among them, the USLE remains a widely used empirical models for watershed scale applications worldwide, due to its efficiency in managing limited input data and compatibility with GIS software (Parveen and Kumar, 2012). However, there is no difference between USLE and other models in estimating soil erosion and the ease of accessing input data, the USLE model has been widely modified to assess soil erosion at various spatial scales (Pham et al., 2018). Moreover, the gross erosion in the study area is used in conjunction with the concept of SDR to calculate the sediment yield. The sediment delivery ratio (SDR), originally proposed by Brown in 1950, is a technique for estimating sediment yield by quantifying the proportion of sediment delivered from the upstream area relative to the total gross erosion within the study area (Sirikaew et al., 2020). Geomorphological, hydrological, and ecological diversity has impacts on the transport of generated sediments from land surface to sink, in terms of the overall facilitation of the delivery of the sediments (Dawoud et al., 2023). Sediment in a creek led to flooding due to reduced depth, can also induce chemical reactions that accumulate to the biological species. Evaluating sediment yield by SDR is essential for effective watershed management and ecosystem protection.

As an aspect of digital transformation, geo-information technology has increasingly played a crucial role in environmental monitoring, resource mapping, urban planning, risk assessment, and the promotion of sustainable spatial development. In recent decades, GIS and RS have been recognized as essential technologies for the management of natural resources, disaster analysis, and epidemiological studies (Mara and Jat, 2019; Wei et al., 2024). The USLE model was included in a GIS framework, incorporating a wide range of environmental variable, including hydrological, geological, ecological and LULC factor. Moreover, the parallel integration of GIS and RS has significantly provided the effectiveness and accuracy of the USLE and RUSLE models in assessing soil erosion across large spatial scales (Efthimiou et al., 2020; Maliqi et al., 2023). The RS technology is increasingly used to gather data on environmental conditions, Earth's surface features, natural disaster, and regional characteristics over extensive areas. As stated by Wang et al. (2025), due to its global coverage, extensive time-series availability, and relatively simple data processing, the most commonly used data in the monitoring of soil erosion is currently obtained through satellite remote sensing. This is because remote sensing data provides multi-spatial and temporal resolution and is effective in extracting the important factors that are related to erosion, for example land cover, intensity of rainfall, and topography, and thus, it has become an vital element in the investigation of soil erosion. Furthermore, GIS technology facilitates cost-effective and accurate prediction of soil loss and its spatial distribution over large geographic areas. This is achieved through various techniques, including the derivation of the topographic factor (LS) from DEM data, interpolation of risk area data, the computation of quantifying soil loss and mapping of soil erosion (Ostovari et al., 2017). GIS offers advanced capabilities for analyzing soil loss by generating geostatistical data to support erosion assessment and prediction, incorporating both spatial and temporal dependencies derived from observational monitoring (Arumugam et al., 2022).

Thailand has been propelled by flagship policies aimed at enhancing its economic structure, comprising the Eastern Economic Corridor (EEC) initiative and the Eastern Special Development Zone Act B.E. 2561 (2018), located in the eastern part of Thailand, with the goal of transforming Thailand into a modernized nation in the next decade (Niyomsilp and Bunchapattanasakda, 2020). Previous studies on developmental and infrastructural violence have demonstrated that such projects result in environmental impacts (Rodgers and O'neill, 2012). Additionally, Chanthaburi coastal area has already been affected by development planning and climate change-related phenomena, including heavy rainfall, soil erosion, rising sea-level and tidal flooding as well as gusty winds (Panpeng and Ahmad, 2018). The central government of Thailand has invested in many irrigation projects in Chanthaburi Province, claiming to solve drought problems and eliminate poverty, but excessive irrigation can lead to topsoil erosion (Benjanavee, 2024). As mentioned in Homyamyen et al. (2007), the land development department (LDD) is the primary department of the Thai government that is responsible for the conservation and improvement of soil resources that are necessary for sustainable land use, agricultural productivity, and conserving soil and water. The LDD also conducts soil classification and analysis, planning of land use, and carrying out experiments and various aspects of changes in land use.

The severity of soil erosion constitutes an environmental impact with limited controllability related to inaccurate rainfall forecasting, accelerates to the degradation of soil texture and increases land sensitivity to landslide, flood and desertification. Given the need for comprehensive soil erosion information at the river basin scale, the main approach of this study was to assess and map the risk of soil erosion through the integration of RS and GIS techniques.

MATERIALS AND METHODS

Study area

The coastal region of Chanthaburi province receives substantial runoff, erosion and sewage

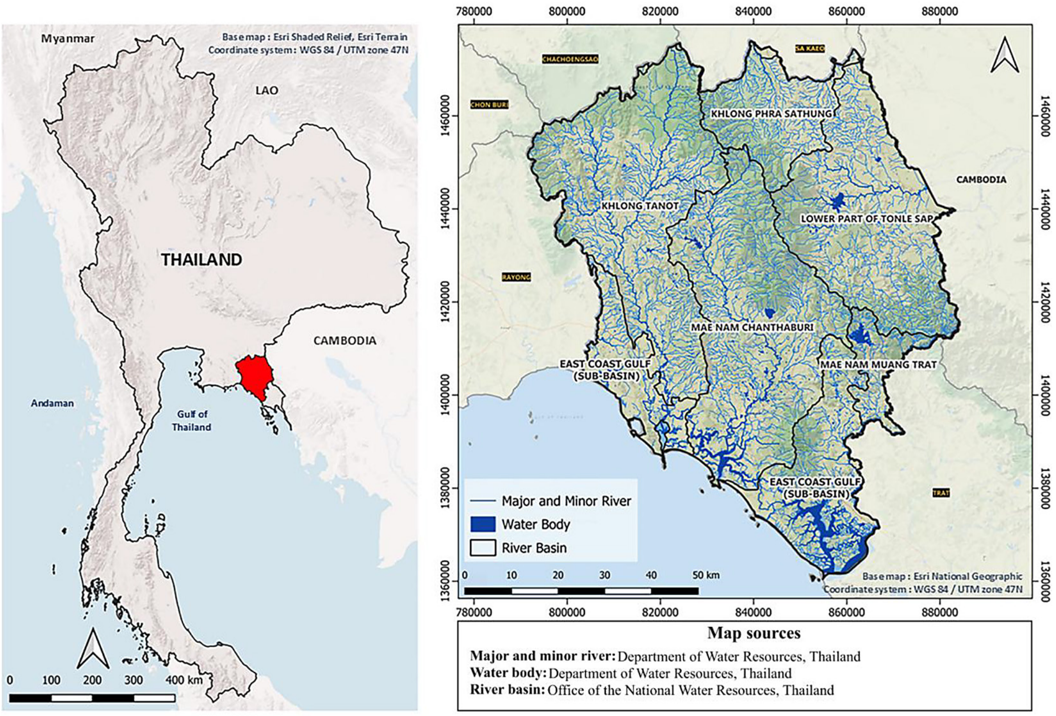


Figure 1. Topographical map of the river basin of Chanthaburi province

from six river basins namely: Chanthaburi river, Muang Trat river, Wang-Ta-Nord, Phra Sathung, Lower Tonle Sap and the Eastern Coast which have a catchment area of 6.346 km^2 (Figure 1). The Chanthaburi river, as an important domestic river in the eastern coastal area, is the major river responsible for flood protection of Chanthaburi province since 1948. Agricultural investment, driven by rising local income, contributes to Chanthaburi's GDP, with Chanthaburi durian emerging as a globally traded commodity following the 2003 China-Thailand FTA (Datepumee at al., 2019). Most of areas in the upstream river basin has been deforested to cultivate orchard and adventure tourism. After the area has been utilized, the soil is reconstructed and becomes sensitive to surface erosion. Agricultural land use, particularly orchards, is a dominant type, covering more than 30% of the watershed areas. Besides, the forest land nearby the upstream area has been transformed by agricultural succession and structural irrigation (Chatewutthiprapa, 2017).

Chanthaburi province is located within a tropical monsoon climate zone, characterized by two distinct rainfall periods: the wet season influenced by the southwest monsoon (May to October), and the dry season linked to the northeast monsoon (December to February), which together contribute for approximately 85% of the annual rainfall. The Chanthaburi region receives an average annual rainfall of 455.2 mm, as recorded by two meteorological stations in the area, with a mean annual temperature of approximately 29 °C (Source: Thai Meteorological Department). Most of the population engages in agricultural activities such as orchard cultivation, aquaculture and agritourism, with their livelihoods being largely dependent on natural resources.

Rainfall data collection

10 rain gauge stations, recorded from 1992 to 2022 by the Thai Meteorological Department (TMD), were input into the USLE model to analyze soil loss pattern (Table 1).

USLE analysis

One of the most commonly used empirical soil erosion models employed to predict average annual loss of soil in a range of environmental settings that includes both forested and agricultural landscapes is the USLE model (Alewell et al., 2019). In this present study, only the overland areas were analyzed, whereas the stream channels and waterbodies were not considered, and the USLE, developed by Wischmeier and Smith (1978), was used for conducting the soil erosion assessment in the study area. In the processing of the USLE, the annual loss of soil resulting from water erosion per unit area is calculated using the formula as seen in Equation 1:

$$A = R \times K \times LS \times C \times P \quad (1)$$

where: A represents soil erosion (Tons per square kilometre per year); R is the index of rain erosion (rainfall factor) in normal year's rain; K is the soil erodibility factor; L is slope length of the slope; S is slope-gradient factor; C is crop management factor; P is conservation practice factor.

The variability of these factors depends on location and the specific values of the factor or variable. Each data characterising is counted as a thematic layer within the GIS database for use in the modeling process including:

a) R-factor layer – for each location as defined

Table 1. Rain gauge stations of Chanthaburi study peroids during 1992–2022

Rain gauge stations	Cover areas (km^2)	Latitude; Longitude
Muang Chathaburi	253.093	12.6105 102.1041
Khlung	756.038	12.4457 102.2132
Thamai	612.800	12.6220 101.9713
Pong Nam Ron	926.970	12.9059 102.2630
Makham	480.123	12.6856 102.1970
Laem Sing	198.751	12.4816 102.0737
Soi Dao	733.821	13.1372 102.2192
Kaeng Hang Maeo	1,254.125	13.0085 101.9057
Na Yai Am	300.017	12.7705 101.8550
Khao Khitchakut	830.220	12.8043 102.1149

by LDD was used for this study, as shown in equation

$$R = 0.4669X - 12.1415 \quad (2)$$

where: R is represents soil erosion; X is the average annual rainfall (mm).

In this study, the equation was applied to calculate the soil erosion index for assessing soil erosion in the river basins of Chanthaburi. Hence, the annual rainfall from the studied periods was used to determine the rainfall factor.

b) K-factor layer – depends on the available soil texture, with values assigned according to the identification by LDD. For Thailand, soil erodibility factors were divided in to 2 categories: highland (slope > 35%) and flat area (slope < 35%).
c) LS-factor layer – influence soil erosion assessment, with slope being a critical determination of runoff damage. LS-factor layer was defined geographically by integrating 2 aspects: the slope length and slope gradient. Therefore, LS factors in this study were applied based on the LDD definitions for erosion analysis.
d) C-factor layer – the crop management concerns various land cover classes, involving dry evergreen forest, dry deciduous forest, mixed deciduous forest, orchard, grass land, paddy field, field crop, urban area, aquaculture, wet land, and water body. To establish the C-factor layer, values for each land cover class were assigned based on the classifications provided by Committee on Soil Erosion Maps (2020).
e) P-factor layer – the soil conservative practice, it is more complexity, as it involves not only land use but also the specific soil conservation practices applied within each land use type. In this study, the P factor is defined to 1 when no soil conservative implementation. Conversely, the P factor is less than 1, resulting to reduced soil erosion in areas where soil conservative guidelines are activated.

Sediment delivery ratio (SDR)

The definition of SDR is the sediment yield derived from an area divided by the gross erosion of that same area, which is used to describe the degree to which the eroded sediment or soil has been stored in the reservoir or watershed. The sediment yield, which is defined as the sediment that is transported to the estuary within the boundary of the study area, is calculated as follows:

$$Sediment\ yield = SDR \cdot Am \quad (3)$$

where: Am is derived from USLE equation. The topography of Chanthaburi province comprises eastern coastal plains along the Gulf of Thailand, with alluvial plains and bordered by mountainous terrain: the Renfro equation (Renfro, 1975) is used to calculate SDR:

$$log\,(SDR) = 1.7935 - 0.14191\ log\,(A) \quad (4)$$

where: A represents the river basin area (km^2).

The SDR is impacted by the drainage area and other characteristics of the river basin, which are determined by the length of the stream, the sediment source's proximity to the stream, and the eroded contact surface. Due to the estimated sediment delivery most closely matching that of the field survey for the watershed of Thailand, Renfro's method was applied (Sirikaew et al., 2020).

Statistical analysis

A statistical analysis was calculated to assess various aspects of model performance. The root mean square error (RMSE) is a key metric used to evaluate the overall magnitude of model error. RMSE is commonly applied to quantify the difference between values predicted by the model and the actual observed values from the located area. The RMSE ranges from 0 to infinity, with a value of 0 indicating perfect agreement as follow:

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(y_i - x_i)^2}{n}} \quad (5)$$

In this equation, x_i and y_i represent to the observed and predicted values, respectively, and n signifies the sample number.

GIS analysis

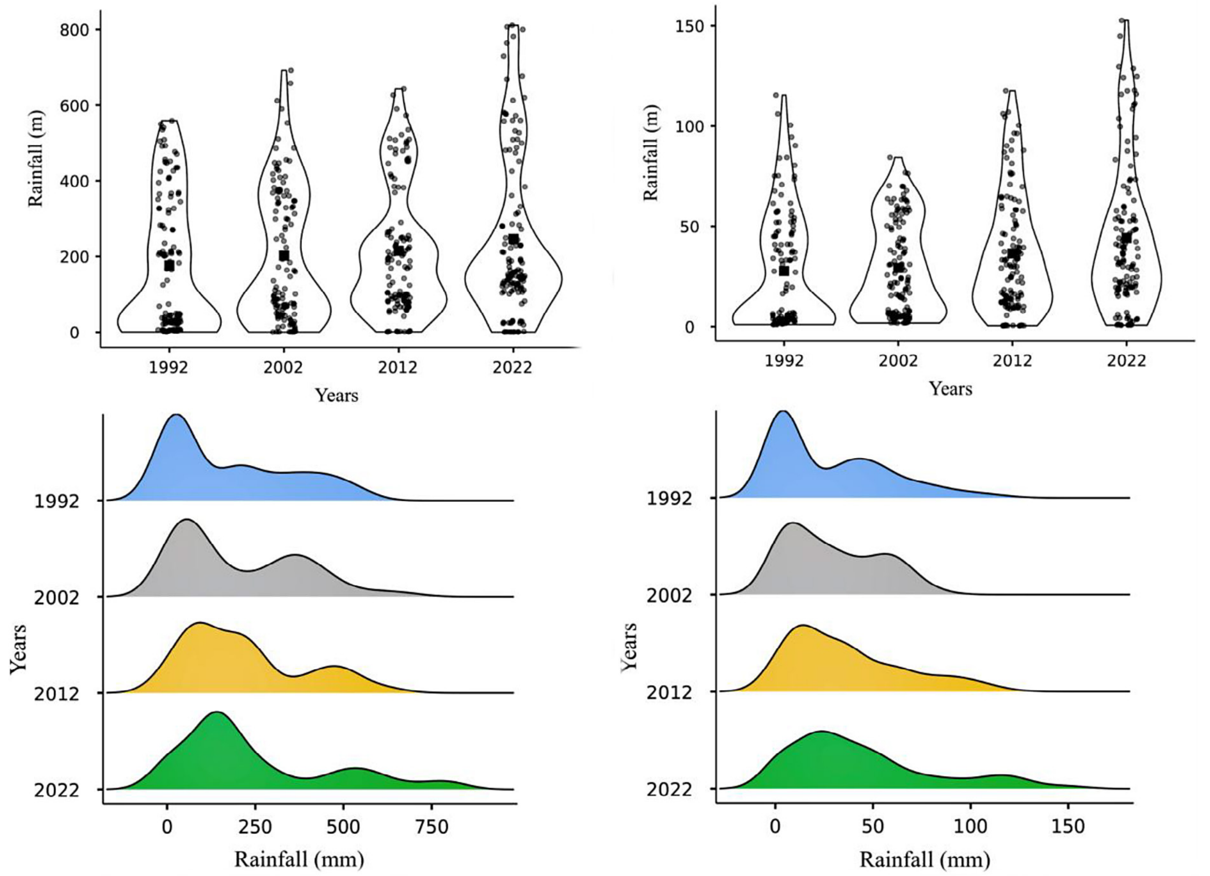
Analysis of five factors was performed in accordance with the spatial resolution and coordinate system of the original data. The data, including rainfall, soil erodibility, slope, land use types, and land cover, that were input into the USLE model were imported and calculated by employing the functions found in quantum GIS (QGIS) (http://www.qgis.org/), which provides a variety of tools for the visualization, processing and analysis of data, thereby making it a spatial software that can be used for the investigation of environmental dynamics across multiple disciplines (Scala et al, 2024).

RESULTS AND DISCUSSION

Rainfall study

Rainfall data were systematically collected and recorded using rain gauge stations located in Chanthaburi Province. Additionally, the CHIRPS (Climate Hazards Center InfraRed Precipitation with Station Data) dataset website provides more accurate spatiotemporal mapping and rainfall estimation in Chanthaburi Province, with the output generated using JavaScript code. The reliability of the CHIRPS dataset has been comprehensively validated and demonstrated by Sa'adi et al. (2023). Figure 2 present violin plots for observation and prediction of annual rainfall in Chanthaburi Province across different gauge stations. Violin plots llustrate the probability variation of rainfall data across a range of values, with the shape generated by symmetrically reflecting a kernel density estimate along a central axis. The potential of JAMOVI is demonstrated through practical applications in proposing descriptive statistics and parametric hypothesis tests (de Souza Junior et al., 2024).

The rainfall series was segmented into four distinct periods: 1992, 2002, 2012, and 2022. The results of the *t*-test indicated that the temporal changes in rainfall amounts differed significantly ($p < 0.05$) between observations (R_O) and predictions (R_P) across the ten gauge stations. While weather satellites can provide global rainfall estimates, dataset rainfall retrievals remain highly inaccurate due to their uncertainty compared to rain gauges confirmed by Maggioni et al. (2016). In general, precipitation datasets can be obtained from three main platforms: terrestrial gauge measurements, satellite-originated observations, and reclassify datasets. Among these, rain gauge



(a) (b)

Figure 2. The violin plot of averaged month rainfall of study area for 1992, 2002, 2012 and 2022 between observation (a) and prediction (b). For each violin plot, the bold square within the violin shape denotes the mean

records, collected from local weather stations nationwide, are the most fundamental data sources for the creation of global precipitation datasets (Yin et al., 2025).

The rainfall data of Chanthaburi province on each year showed a higher level compared to the cumulative annual rainfall of Thailand. As shown in Figure 3, a correlation analysis of observations and predictions was performed, indicating the linear regression with a slope of 0.155 and the general equation $R_P = 1.839 + 0.155\ R_O$ (n=480). The comparative results are consistent with the characteristics of the rainfall in the study area.

USLE factor

Land use land cover analysis

Four LULC categories were identified and classified, encompassing construction, plant, water bodies and miscellaneous. The analysis results revealed distinct LULC pattern in Chanthaburi province, encompassing categories such as paddy fields, field crops, perennial plant, orchard, forest land, aquaculture, water bodies, urban and built-up areas and miscellaneous land types.

Soil erodibility factor

The resistance to soil erosion, represented by the soil erodibility factor (K factor), depends on the structural/textural of soil aggregates. The K factor for the study areas was derived using soil series values from the provincial soil series map of Thailand, at a scale of 1:25,000, as shown in Figure 4.

Slope

Establishing the LS-factor layer for a large area is particularly complex and time-consuming. The slope of the study area, estimated using the DEM technique, was classified into two distinct categories: slope less than 35% and slopes greater than 35% (Committee on Soil Erosion Maps, 2020). The 30×30 m grid size from DEM revealed that the terrain characteristics of the river basin of Chanthaburi Province comprise both mountainous and floodplain areas as show in Figure 5.

Factor of C and P

The C-factor and P-factor were determined based on land cover data, corresponding to conservative practices, respectively (Figure 5). The soil loss estimates in this study may reasonably either underestimate or overestimate the actual

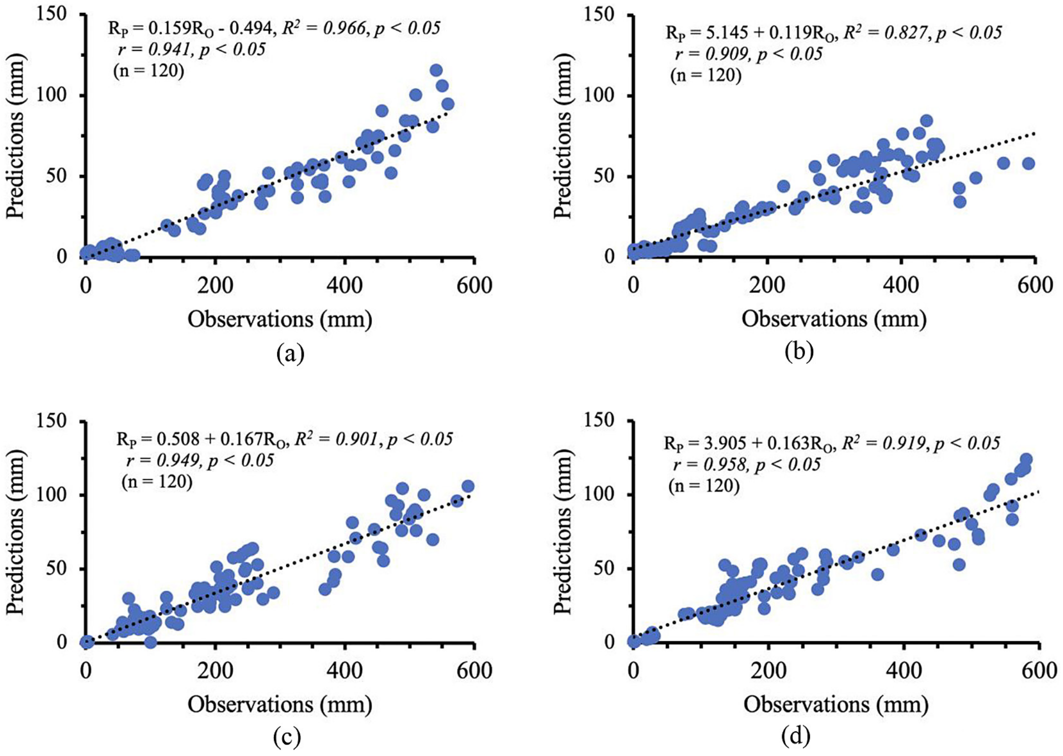


Figure 3. Relationship between rainfall data series of observations (R_O) and predictions (R_P) at Chanthaburi province for 1992 (a), 2002 (b), 2012 (c), and 2022 (d)

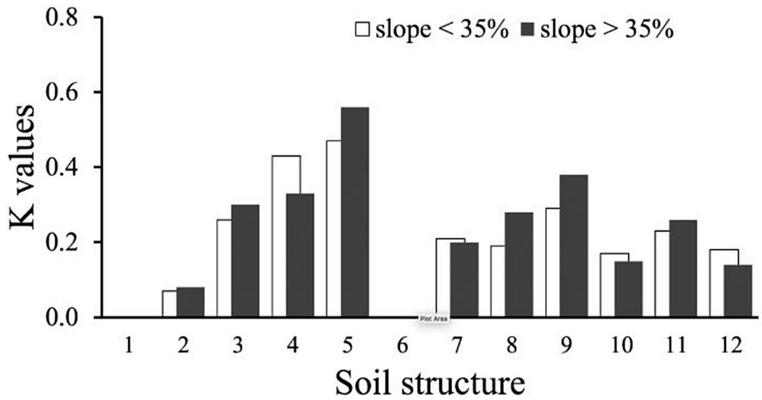


Figure 4. Factors of tolerance to soil erosion in eastern region of Thailand (1 - sand, 2 - lonmy sand, 3 - sandy loam, 4 - loam, 5 - silt loam, 6 - silt, 7 - sandy clay loam, 8 - clay loam, 9 - silty clay loam, 10 - sandy clay, 11 - silty clay and 12 - clay)

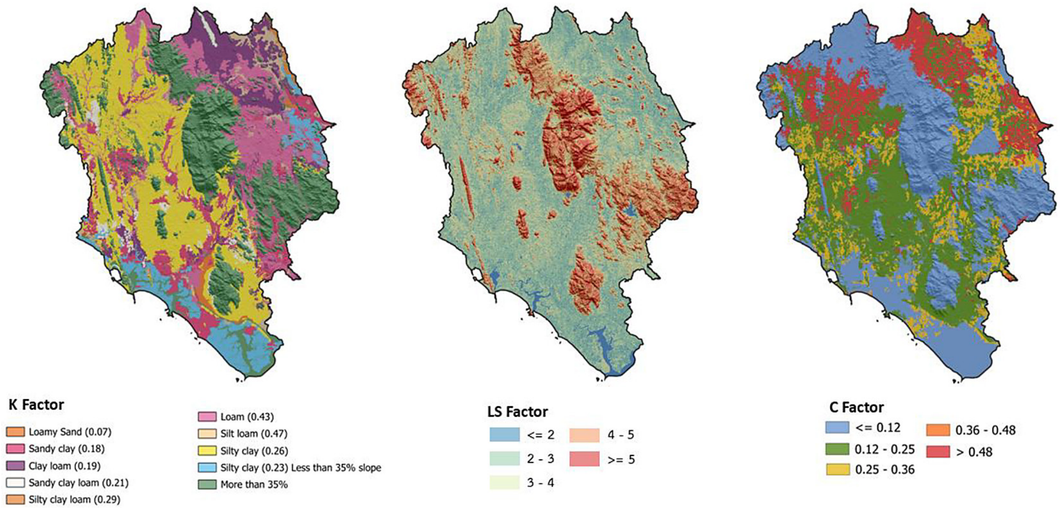


Figure 5. The factors of K, LS and C in river basin of Chanthaburi province

losses. However, this study incorporated estimated soil loss rates to illustrate the impact of land cover change.

Soil erosion

Soil erosion in the river basin of Chanthaburi province was analysed using data from two types of rainfalls (i.e., actual rainfall and approximate rainfall). The comparison of soil erosion rates from rainfall data between observations and predictions for 2022 indicates an increasing rates of anthropogenic-induced soil erosion, as illustrated in Figure 6. The results revealed that most of the study area was classified as ranging from very low to moderate severity based on actual rainfall data. Conversely, the estimated rainfall from the CHIRPS database indicated a very low risk intensity, accounting for 99.99% of the study area, as show in Figure 7.

The quantitative soil erosion was estimated by spatially overlaying factor layers within the USLE model, applied to the river basin of Chanthaburi province in 2022 as shown in Table 2. The levels of soil erosion were categorized into five severity classes, based on the classification system established by LDD (Committee on Soil Erosion Maps, 2020). Figure 8 demonstrates the variation in soil erosion severity correlated with the data for each decade of rainy years. The results indicated that most of the area was classified as very low severity throughout the study period. Notable, the area classified as very low degree continuously decreased from 1992 to 2022, whereas other severity categories increased. The extent of soil erosion increased as a results on varied factors, including

Table 2. Soil erosion areas in the river basin of Chanthaburi province, eastern coastal region of Thailand, in 2022

Class	Rate (t/km²/y)	Area (km²)	%	Degrees of severity
1	0.0000–0.1250	4,347	68.93	Very low
2	0.1250–0.3125	1,431	22.68	Low
3	0.3125–0.9375	520	8.25	Moderate
4	0.9375–1.2500	8	0.12	Severe
5	> 1.2500	2	0.02	Very severe

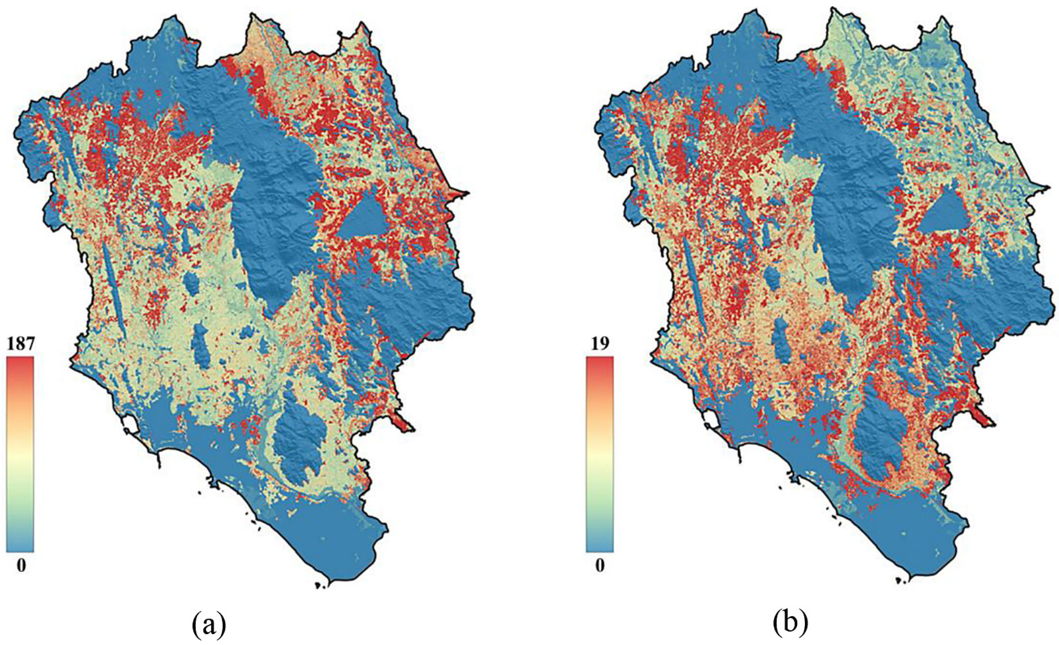


Figure 6. The comparison of erosion rates between observations (a) and predictions (b) in the river basin of Chanthaburi province in 2022

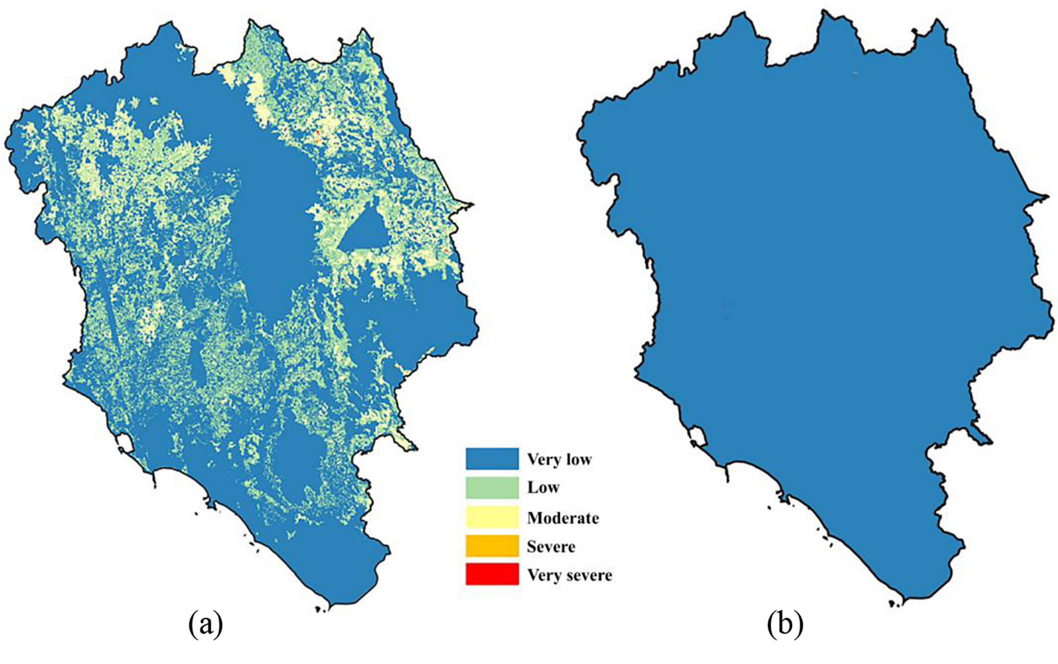


Figure 7. The classification of soil erosion intensity between observations (a) and predictions (b) in the river basin of Chanthaburi province in 2022

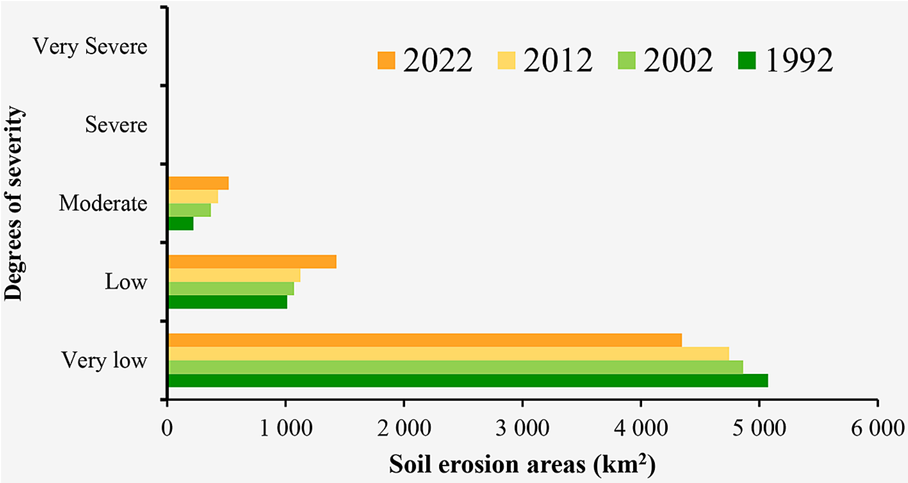


Figure 8. Comparative estimation of soil erosion areas based on rainfall data from 10 rain gauge stations in Chanthaburi province across the years 1992, 2002, 2012 and 2022

rainfall (R factor), changes in LULC, plant factor and terrestrial conservation management.

Rainfall erosivity is defined as the inherent potential of rainfall to accelerate and rotate soil erosion processes. It has been reported that the amount, intensity, and spatiotemporal distribution of rainfall is influenced by local climate conditions (Senanayake et al., 2020). Additionally, the percentage growth in agriculture areas corresponds to a significant increase in soil erosion rates and alterations to local hydrological cycles (Tunda et al, 2025), underscoring the necessity for implementing sustainable land use projects. The Chanthaburi river basin, initially dominated by tropical rainforest, experienced a decline following the 1999 and 2006 floods due to its transportation to agricultural land, support by Thai government policy for plantation and export activities, which altered LULC and crop types (Chatewutthiprapa, 2017). Notably, durian (*Durio zibethinus*), a local fruit product of Chanthaburi, has become a prominent export to China, a trend accelerated by the Thailand-China Early Harvest Programme (EHP) agreement implemented in October 2003 (Rattana-amornpirom, 2020). Moreover, traditional LULC patterns in Chanthaburi province were disrupted by the expansion of urban and built-up areas, particularly in Muang Chanthaburi district where urbanization rates significantly increased.

The relationship between forest areas and annual rainfall gained scientific attention during the second half of the nineteenth century and has resurged over the past three decades (Bennett and Barton, 2018). Abundant ecological areas function as “biotic pumps” or “recyclers” maintaining hydrological balance through the autonomous adaptation of the water cycle. Ecological services are closely tied to land use categories and practical managements, with changes in land use and land cover potentially altering service provision and affecting both human well-being and the environmental quality (Kamyo et al., 2025). The Millennium Ecosystem Assessment (MEA) classified terrestrial ecosystem services into four categories: (1) regulating services, such as flood control, water purification, and climate action through carbon sequestration; (2) provisioning services, including products like forest and food; (3) supporting services, which enable the production of other services, such as soil formation and nutrient cycling; and (4) cultural services, which contribute to intellectual development, spiritual enrichment, aesthetic experiences, recreation, and reflection (Ongsomwang et al., 2019).

However, the estimations have not been updates, particularly regarding the current values of each USLE factor. Some limitations of this analysis include the model’s reliance on historically validated LULC data from LDD, potentially limiting its ability to reflect land use change patterns in years 1992 and 2002, and its exclusion of socio-economic drivers such as land ownership and agricultural product prices. While calibration data were historically obtained through field surveys and photointerpretation of high-spatial-resolution imagery, these techniques are not cost-effective for meeting the extensive calibration data requirements at the national scale. Fieldwork studies and

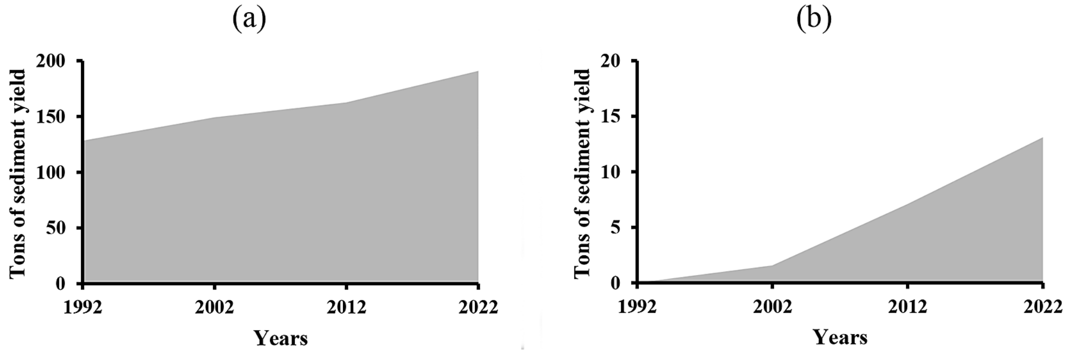


Figure 9. Sediment yield in the river basin of Chanthaburi province derived from observed rain fall (a) and predicted rain fall (b)

expert-based LULC interpretations are both high expenditures, intensive resource and long-term operations (Hermosilla et al., 2022). Currently, Thailand is experiencing rapid urbanization along rural boundaries, with the most intense transformations occurring in areas where land use plans are several years outdated. Furthermore, the practice of land use planning and updating reveals underlying tensions between entrepreneurialism and managerialism approaches within most areas of Thai local government organizations (Thinphanga and Friend, 2024).

Sediment accumulation

The sediment accumulation in the river basin of Chanthaburi province was investigated using the SDR model, estimated on soil erosion rates. The results revealed that the slope sediment yield increased proportionally with the concentration of rainfall. As a result, sediment deposition increased annually, with rates of 128.28, 149.20, 162.58, and 190.92 tons/year for the years 1992, 2002, 2012, and 2022, respectively, based on observed rainfall input. Conversely, the predicted rainfall data reveled the low sediment yield rates as show in Figure 9. The total sediment load is not entirely deposited in the river basin, but it becomes trapped within drainage channels and accumulates on the surface soil (El Amarty et al., 2024). Agricultural areas exhibited considerable susceptibility to erosion, resulting in increased SDR levels. According to Sthiannopkao et al. (2007), the transformation of forestlands to agricultural areas in northeast region, Thailand has caused severe soil erosion, increased riverine suspended solids and consequent siltation at river mouths.

Model performance in estimating soil erosion and sediment yield were evaluated by comparing observed and predicted rainfall data. The USLE efficiency demonstrated high predictive performance (R^2 = 0.95, RMSE = 8.54), whereas SDR model revealed higher error (R^2 = 0.94, RMSE = 15.33). However, the statistical analysis provided a strong correlation between observed and predicted for soil erosion data and sediment yield, with high R^2 values, indicating a very good model fit for these processes, as proposed by Me et al. (2015).

CONCLUSIONS

The application of the USLE and SDR models lead to a better understanding of the spatial risk of soil erosion within river basin of the study area. The results also enable for a definitive classification of the most severely eroding areas in terms of soil erosion intensity and sediment yield. Indeed, the finding reveal moderate risk areas that should be designed as conservative zones for priority management to mitigate impacts on land use and land cover. In the absence of socioeconomic data, these models assess soil transport and estimate overabundance of marine sedimentation based on historical and current rainfall data. Thus, such studies appear to be inconsistent with the framework of an integrated sustainability concept due to limited data on population, economic values, and social susceptibility. But, these studies constitute an initial step towards a more accurate validation of various rainfall data collection process. What is involved, is the operation of pilot sites for the rainfall data collection both terrestrial and satellite-based field measurements, practiced at comparing the output of soil erosion models. The parallel analysis of the models clearly demonstrates that the results on this topic differ significantly. The findings will improve accepting of soil erosion vulnerability in Thailand's eastern region and reveal gaps in the integration of science-based data into anti-erosion management plans. With the same approach, it would also be possible to apply soil loss scenarios based on dynamical activity in land use (e.g., opening of new sites of river basin or impacts of deforestation etc.).

Acknowledgements

This study was conducted with the support and collaborative efforts of the Faculty of Computer Science and Information Technology and the Faculty of Science and Technology at Rambhai Barni Rajabhat University, Chanthaburi, Thailand.

REFERENCES

1. Achu, A.L., Thomas J. (2023). Soil erosion and sediment yield modeling in a tropical mountain watershed of the southern Western Ghats, India using RUSLE and Geospatial tools. *Total Environment Research Themes*, *8*, 100072. https://doi.org/10.1016/j.totert.2023.100072
2. Alewell, C., Borrelli, P., Meusburger, K., Panagos, P. (2019). Using the USLE: Chances, challenges and limitations of soil erosion modelling. *International Soil and Water Conservation Research*, *7*(3), 203–225. https://doi.org/10.1016/j.iswcr.2019.05.004
3. Arumugam, T., Kinattinkara, S., Nambron, D., Velusamy, S., Shanmugamoorthy, M., Pradeep, T., Mageshkumar, P. (2022). An integration of soil characteristics by using GIS based Geostatistics and multivariate statistics analysis Sultan Batheri block, Wayanad District, India. *Urban Climate*, *46*, 101339. https://doi.org/10.1016/j.uclim.2022.101339
4. Benjanavee, K. (2024). From the state's development promise to the uncertain lives of farmers in Eastern Thailand. *Humanities, Arts and Social Sciences Studies*, *24*(3), 540–557.
5. Bennett, B.M., Barton, G.A. (2018). The enduring link between forest cover and rainfall: a historical perspective on science and policy discussions. *Forest Ecosystems*, *5*(1), 1–9. https://doi.org/10.1186/s40663-017-0124-9
6. Chatewutthiprapa, C. (2017). *Land use and land cover change of Chanthaburi watershed following 1999, 2006 and 2013 floods*. Master Thesis, Faculty of Science, Chulalongkorn University, Thailand.
7. Chuenchum, P., Xu, M., Tang, W. (2020). Estimation of soil erosion and sediment yield in the Lancang–Mekong River using the modified revised universal soil loss equation and GIS techniques. *Water*, *12*(1), 135. https://doi.org/10.3390/w12010135
8. Committee on Soil Erosion Maps. (2020). *Status of Soil Erosion in Thailand*. Land Development Department, Thailand.
9. Datepumee, N., Sukprasert, P., Jatuporn, C., Thongkaew, S. (2019). Factors affecting the production of export quality durians by farmers in Chanthaburi province, Thailand. *Journal of Sustainability Science and Management*, *14*(4), 81–92.
10. Dawoud, O., Eljamassi, A., Abunada, Z. (2023). Mapping and quantification of soil erosion and sediment delivery in poorly developed urban areas: A case study. *Sustainability*, *15*, 13683. https://doi.org/10.3390/su151813683
11. de Souza Junior, R.S., Sequeira, C.A., Borges, E.M. (2024). Enhancing statistical education in chemistry and steam using jamovi. Part 1: descriptive statistics and comparing independent groups. *Journal of Chemical Education*, *101*(11), 5027–5039.
12. Eekhout, J.P.C., de Vente, J. (2022). Global impact of climate change on soil erosion and potential for adaptation through soil conservation. *Earth-Science Reviews*, *226*, 103921. https://doi.org/10.1016/j.earscirev.2022.103921
13. Efthimiou, N., Psoniadis, E., Panagos, P. (2020). Fire severity and soil erosion susceptibility mapping using multi-temporal earth observation data: The case of Mati fatal wildfire in Eastern Attica, Greece. *Catena*, *187*, 104320. https://doi.org/10.1016/j.catena.2019.104320
14. El Amarty, F., Lahrach, A., Benaabidate, L., Chakir, A. (2024). Estimating soil erosion and sediment yield using geographic information system in the Central Pre-Rif (Northern Morocco) - The case of the Oued Lebene Watershed. *Ecological Engineering & Environmental Technology*, *25*(8), 1-16. https://doi.org/10.12912/27197050/187977
15. Ganasri, B.P., Ramesh, H. (2016). Assessment of soil erosion by RUSLE model using remote sensing and GIS - A case study of Nethravathi Basin. *Geoscience Frontiers*, *7*(6), 953–961. https://doi.org/10.1016/j.gsf.2015.10.007
16. Hermosilla, Y., Wulder, M.A., White, J.C., Coops, N.C. (2022). Land cover classification in an era of big and open data: Optimizing localized implementation and training data selection to improve mapping outcomes. *Remote Sensing of Environment*, *268*, 112780.
17. Homyamyen, K., Sukchan, S., Hamada, H. (2007). Soil doctor system of Land Development Department in Thailand as one of participatory methods. *Journal of the Japanese Society of Soil Physics*, *105*, 79-82.

18. Kamyo, T., Marod, D., Pattanakiat, S., Asanok, L. (2025). Valuation of potential and realized ecosystem services based on land use data in Northern Thailand. *Land*, *14*(3), 529. https://doi.org/10.3390/land14030529
19. Li, J., Dong, S., Liu, S., Yang, Z., Peng, M., Zhao, C. (2013). Effects of cascading hydropower dams on the composition, biomass and biological integrity of phytoplankton assemblages in the middle Lancang-Mekong River. *Ecological Engineering*, *60*, 316–324. https://doi.org/10.1016/j.ecoleng.2013.07.029
20. Maggioni, V., Sapiano, M.R.P., Adler, R.F. (2016). Estimating uncertainties in high-resolution satellite precipitation products: Systematic or random error? *Journal of Hydrometeorology*, *17*(4), 1119–1129. https://doi.org/10.1175/JHM-D-15-0094.1
21. Mairaing, W., Jotisankasa, A., Leksungnoen, N., Hossain, M., Ngernsaengsaruay, C., Rangsiwanichpong, P., Pilumwong, J., Pramusandi, S., Semmad, S., Ahmmed, A.N.F. (2024). A biomechanical study of potential plants for erosion control and slope stabilization of highland in Thailand. *Sustainability*, *16*(15), 6374. https://doi.org/10.3390/su16156374
22. Maliqi, E., Kumar, N., Latifi, L., Singh, S.K. (2023). Soil erosion estimation using an empirical model, hypsometric integral and Geo-Information Science - A case study. *Ecological Engineering & Environmental Technology*, *24*(4), 62–72. https://doi.org/10.12912/27197050/161957
23. Mara, S., Jat, M.K. (2019). Geographic information system based spatio-temporal dengue fever cluster analysis and mapping. *The Egyptian Journal of Remote Sensing and Space Science*, *22*(3), 297–304. https://doi.org/10.1016/j.ejrs.2019.08.002
24. Me, W., Abell, J.M., Hamilton, D.P. (2015). Effects of hydrologic conditions on SWAT model performance and parameter sensitivity for a small, mixed land use catchment in New Zealand. *Hydrology and Earth System Sciences*, *19*, 4127–4147.
25. Morgan, R.P.C., Quinton, J.N., Smith, R.E., Govers, G., Poesen, J.W.A., Auerswald, K., Chisci, G., Torri, D., Styczen, M.E., Folly, A.J.V. (1998). The European Soil Erosion Model (EUROSEM): a dynamic approach for predicting sediment transport from fields and small catchments. *Earth Surface Processes and Landforms*, *23*(6), 527–544.
26. Nearing, M.A., Foster, G.R., Lane, L.J., Finkner, S.C. (1989). A process-based soil erosion model for USDA-water erosion prediction project technology. *Transactions of the ASAE*, *32*(5), 1587–1593.
27. Niyomsilp, E., Bunchapattanasakda, C. (2020). Impact of Eastern Economic Corridor (EEC) on Thailand 4.0 model. *Western University Research Journal of Humanities and Social Science*, *6*(3), 203–215.
28. Ongsomwang, S., Pattanakiat, S., Srisuwan, A. (2019). Impact of land use and land cover change on ecosystem service values: A case study of Khon Kaen city, Thailand. *Environment and Natural Resources Journal*, *17*(4), 43–58.
29. Ostovari, Y., Ghorbani-Dashtaki, S., Bahrami, H.A., Naderi, M., Dematte, J.A.M. (2017). Soil loss estimation using RUSLE model, GIS and remote sensing techniques: A case study from the Dembecha Watershed, Northwestern Ethiopia. *Geoderma Regional*, *11*, 28–36.
30. Pakoksung, K. (2024). Assessment of soil loss from land cover changes in the Nan River Basin, Thailand. *GeoHazards*, *5*, 1–21. https://doi.org/10.3390/geohazards5010001
31. Panpeng, J., Ahmad, M.M. (2018). Awareness of coastal fishing communities on climate change and its impacts: a case study of coastal erosion and seawater inundation in Chanthaburi Province, Thailand. *International Journal of Agricultural Resources, Governance and Ecology*, *14*(2), 138–164. https://doi.org/10.1504/IJARGE.2018.093992
32. Parveen, R., Kumar, U. (2012). Integrated approach of universal soil loss equation (USLE) and geographical information system (GIS) for soil soss risk assessment in Upper South Koel Basin, Jharkhand. *Journal of Geographic Information System*, *4*, 588–596.
33. Pham, T.G., Degener, J., Kappas, M. (2018). Integrated universal soil loss equation (USLE) and geographical information system (GIS) for soil erosion estimation in A Sap basin: Central Vietnam. *International Soil and Water Conservation Research*, *6*(2), 99–110.
34. Poesen, J. (2015). Soil erosion hazard and mitigation in the Euro-Mediterranean region: do we need more research?. *Hungarian Geographical Bulletin*, *64*(4), 293-299. https://doi.org/10.15201/hungeobull.64.4.3
35. Pradhan, B., Chaudhari, A., Adinarayana, J., Buchroithner, M.F. (2012). Soil erosion assessment and its correlation with landslide events using remote sensing data and GIS: a case study at Penang Island, Malaysia. *Environmental Monitoring and Assessment*, *184*, 715–727.
36. Rattana-amornpirom, O. (2020). The impacts of ACFTA on export of Thai agricultural products to China. *Journal of ASEAN PLUS+ Studies*, *1*(1), 44–54.
37. Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K., Yoder, D.C. (1997). *Predicting soil erosion by water: a guide to conservation planning with the revised universal soil loss equation (RUSLE) 703*. Washington, DC: United States Department of Agriculture.
38. Renfro, G.W. (1975). *Use of erosion equations and sediment-delivery ratios for predicting sediment yield.* Proceedings of the Sediment-Yield Workshop, USDA Sedimentation Laboratory, 33–45.

39. Rodgers, D., O'neill, B. (2012). Infrastructural violence: introduction to the special issue. *Ethnography*, *13*(4), 401–412.
40. Sa'adi, Z., Yusop, Z., Alias, N.E., Shiru, M.S., Muhammad, M.K.I., Ramli, M.W.I. (2023). Application of CHIRPS dataset in the selection of rain-based indices for drought assessments in Johor River Basin, Malaysia. *Science of The Total Environment*, *892*, 164471. https://doi.org/10.1016/j.scitotenv.2023.164471
41. Scala, P., Manno, G., Ciraolo, G. (2024). Coastal dynamics analyzer (CDA): A QGIS plugin for transect based analysis of coastal erosion. *SoftwareX*, *28*, 101894. https://doi.org/10.1016/j.softx.2024.101894
42. 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*, *12*, 4063. https://doi.org/10.3390/rs12244063
43. Sirikaew, U., Seeboonruang, U., Tanachaichoksirikun, P., Wattanasetpong, J., Chulkaivalsucharit, V., Chen, W. (2020). Impact of climate change on soil erosion in the Lam Phra Phloeng Watershed. *Water*, *12*, 3527. https://doi.org/10.3390/w12123527
44. Sthiannopkao, S., Takizawa, S., Homewong, J., Wirojanagud, W. (2007). Soil erosion and its impacts on water treatment in the northeastern provinces of Thailand. *Environment International*, *33*(5), 706–711.
45. Tang, W., Shan, B., Zhang, H., Zhang, W., Zhao, Y., Ding, Y., Rong, N., Zhu, X. (2014). Heavy metal contamination in the surface sediments of representative limnetic ecosystems in eastern China. *Scientific Reports*, *4*, 7152.
46. Thinphanga, p., Friend, R. (2024). Thailand's policy vacuum: Land use planning as sites of negotiation and contestation. *Land Use Policy*, *137*, 106994.
47. Tunda, A., Malamassam, D., Soma, A.S., Sudia, L.B. (2025). Dynamics of land cover change on hydrological conditions using the soil and water assessment tool model in the Tiworo watershed. *Ecological Engineering & Environmental Technology*, *26*(2), 14–26. https://doi.org/10.12912/27197050/196400
48. Wang, J., Yang, J., Li, Z., Ke, L., Li, Q., Fan, J., Wang, X. (2025). Research on soil erosion based on remote sensing technology: A review. *Agriculture*, *15*(1), 18. https://doi.org/10.3390/agriculture15010018
49. Wei, G., Han, G.S., Lang, X. (2024). Using RS and GIS for risk management of natural disasters consequences: The case of cultural heritage in Jinan city, China. *Heliyon*, *10*(19), e38217. https://doi.org/10.1016/j.heliyon.2024.e38217
50. Williams, J.R. (1975). Sediment routing for agricultural watersheds. *Journal of the American Water Resources Association*, *11*(5), 965–974.
51. Wischmeier, W.H., Smith, D.D. (1978). *Predicting rainfall erosion losses.* USDA: Agriculture Handbook No.537
52. Yin, X., Zhang, Z., Lin, Z., Yin, J. (2025). Assessment of rainfall frequencies from global precipitation datasets. *Atmosphere*, *16*(1), 66. https://doi.org/10.3390/atmos16010066