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Dynamic of Sediment Transport Capacity by Overland Flow: A Review

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ABSTRACT

This paper systematically reviews the relationship between sediment transport capacity and factors such as flow velocity, slope gradient, hydraulic parameters, soil properties, and root parameters in overland flow. The aim of this paper is to investigate the relationship between the sediment transport capacity on flow velocity, slope gradient, hydraulic parameters, soil properties, and root parameters on sediment transport capacity by overland flow and to evaluate the research findings for improving the accuracy of sediment transport predictions. A total of 36 journal articles from 2019 to 2024 were eligible through conducted Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) method protocol. The review identifies that each factor significantly influences sediment transport capacity. Increased flow velocities and steeper slopes generally enhance sediment transport by providing more energy and higher runoff velocity. Hydraulic parameters, including flow depth and discharge rate, are critical, with greater depths and faster flows increasing transport potential. Soil properties, like texture and cohesion, affect sediment detachment and transport, with sandy soils typically showing lower transport rates than clayey soils under similar hydraulic conditions. Root parameters, such as root density, diameter, depth, and biomass, contribute to soil stabilization and reduce sediment transport by improving soil structure and increasing resistance to erosion. The review underscores the importance of considering the combined effects of these factors, which often result in complex interactions impacting sediment transport. Identified research gaps suggest the need for models integrating these interactions to improve predictive accuracy. Addressing these gaps can enhance sediment transport models, informing better soil conservation strategies and erosion control measures.

Keywords: Soil erosion; sediment transport capacity; overland flow; systematic literature review

INTRODUCTION

Soil erosion is the most common source of sediment in ecosystems that are naturally occurring and a serious threat to the environment that is expected to gradually worsen because of climate change. Global evaluations may give scientific information regarding the extent of the issue, as soil erosion poses significant risks to food security and the sustainable supply of ecosystem services (Liu et al. 2023). The most recent publications from the Intergovernmental Panel on Climate Change (IPCC) on the effects of climate change on land degradation also contain evaluations of soil erosion (Bezak et al. 2024). It is also results in issues including diminished soil fertility, deteriorated water quality, and decreased storage capacity in reservoirs and expected to continue worsen in the future due to climate change (Bezak et al. 2024). As highlighted by Borrelli et al. (2021), soil erosion monitoring has not been carried out on a regular basis in many regions of the world, thus the magnitude of soil erosion and its environmental effect can help to be comprehend with global modelling applications.

Erosion immediately contributes to the sediment load that can be transported. Therefore, sediment transport capacity (Tc) serves as a crucial mechanism in understanding soil erosion dynamics. Sediment transport by overland flow is a fundamental process in hydrology and geomorphology, shaping landscapes and influencing ecosystem dynamics. It represents the maximum amount of sediment that can be transported by flowing water across the land surface under specific hydraulic and environmental conditions. Soil erosion refers to the three subprocesses interconnected when modelling soil erosion (Wang et al. 2019). The three processes are the detaching of soil particles from the parent material, sediment deposition, and sediment transport, where the sediment transport capacity and sediment load directly restrict these three processes (Liu et al. 2023; Jiang et al. 2023). According to Mu and Fu, (2023), the sediment transport capacity of overland flow is influenced by a myriad of factors such as surface roughness (microtopography, rock fragments, vegetation litter and stems), and hydraulic characteristics. In experiments involving beds susceptible to erosion, a portion of the flow's force or energy is allocated to transporting and dislodging sediment, as well as altering the bed's configuration. Furthermore, higher flow velocities, deeper flows, and increased sediment concentrations augment sediment transport capacity, while factors such as sediment size, shape, and cohesion can either facilitate or impede transport. Bedload transport, suspension transport, and saltation transport are the primary mechanisms through which sediment is conveyed by overland flow, with sediment particles moving along the bed, lifted within the water column, or transported in short hops, respectively. As highlighted by Liu et al. (2023), accurately calculating the sediment transport capacity is key to the construction of soil erosion process models. Understanding sediment transport capacity by overland flow is pivotal for predicting soil erosion, sediment deposition, and water quality degradation, and for informing erosion control measures and land management strategies aimed at mitigating the adverse impacts of sediment transport on ecosystems and human communities.

Meanwhile, overland flow epitomizes the movement of water across the Earth's surface, spurred by rainfall intensity surpassing the soil's capacity for infiltration or when the ground is already saturated. Overland flow primarily transported detached soil particles and aggregates due to the water-stable aggregate's density or specific gravity being significantly smaller than that of the original soil particles, and the aggregates quantity is affected by many factors, making Tc research on standard soil somewhat complicated (Liu et al. 2023). The interaction between overland flow and sediment transport is closely tied to various environmental phenomena, including soil erosion, sediment deposition, and nutrient cycling, all of which are essential for sustaining terrestrial and aquatic ecosystems. Overland flow typically arises when the intensity of rainfall surpasses the soil's ability to absorb it, resulting in the formation of surface runoff. As this runoff travels downhill, it gathers and transports soil particles downstream, contributing to erosion and sediment deposition in river channels, lakes, and reservoirs. Water flows over the surface, carrying sediment particles with it excluding water that has naturally permeated the soil during typical agricultural activities, irrigation tailwater if its reuse adheres to best practice standards, and rainwater gathered from roofs for storage in rainwater tanks. As water moves across the land surface, it interacts with sediments, carrying them along in its flow and guiding their movement downstream. Researching overland flow presents challenges due to the complexity of defining the variables involved, and while open channel flow equations are available to predict overland flow, there are uncertainties associated with their application, as noted by Ferro and Guida (2022). The magnitude and rate of soil erosion determine the quantity of sediment generated within a given area over a specific period.

As a result, understanding sediment transport capacity is critical for monitoring and managing soil erosion, a major environmental issue globally. Decision-makers and other interested parties can address issues with soil erosion or the application of soil protection measures by using soil erosion models, which are helpful tools (Bezak et al. 2024). By quantifying sediment transport capacity, researchers and land managers can predict erosion rates, identify vulnerable areas, and implement erosion control measures to mitigate the impacts of soil erosion on soil productivity, water resources, and ecosystem health. For example, in process-based soil erosion models, using the sediment transport capacity by overland flow (Tc) where the greatest amount of sediment that an overland flow can move, is a crucial component (Yao et al. 2023). Moreover, global modelling applications are also needed to identify areas that are most vulnerable to soil erosion and design conservation and mitigation measures against soil erosion (Borrelli et al. 2021). Our knowledge of sediment transport by overland flow is based on early studies of erosion and landscape development. Farmers, engineers, and naturalists have long observed the impacts of rainfall and runoff on soil erosion, with overland flow playing an important role in carrying materials downslope. Therefore, the estimation of sediment transport capacities in rills is discussed in this study which is under overland flow conditions.

As highlighted by Liu et al. (2023), accurately calculating the sediment transport capacity is key to the construction of soil erosion process models. During this time, various equations were constructed to measure sediment transport, which were classified as theoretical formulae, semi-theoretical, and semi-empirical formulas. Some assumed others based the equation on energy conservation, while sediment movement was random (Li et al. 2023). In the realm of studying sediment transport capacity through overland flow, several theoretical frameworks and models play crucial roles. One prominent example is the Universal Soil Loss Equation (USLE), a widely employed tool in soil erosion prediction (Bezak et al. 2024). This equation provides a systematic approach to understanding and quantifying erosion processes, offering practical applications in soil conservation and land management strategies. Additionally, hydrological model also used, based on spatial distribution and drainage patterns, is used for land surface characterization and prediction of geomorphic processes and runoff characteristics, providing accurate, detailed, and time-efficient results in various scientific, engineering, and planning applications (Chowdhury, 2023). Given the dearth of applications for soil erosion modelling in developing regions especially for most vulnerable locations, large-scale assessments of soil erosion modeling are now often the only tools available to assist policy decisions and the implementation of mitigation solutions (Bezak et al. 2024).

RECENT LITERATURE REVIEW AND IDENTIFIED GAPS

Recent reviews on sediment transport have provided significant insights but also highlighted several areas that require further investigation. For instance, Wang et al. (2019) stated that existing prediction models frequently fail to integrate these combined effects, resulting in less accurate predictions. A comparison of observed data revealed that none of the selected twelve functions provided satisfactory outcomes for transport capacity prediction across all overland flow datasets, and all of them offered very poor predictions for loess soil.

Additionally, Alewell et al. (2019) discovered that, whereas individual components like vegetation and slope gradient have been widely investigated, the combined impacts of flow velocity and surface roughness are not well understood. The author also highlighted that prior models that did not incorporate these characteristics had larger prediction errors. Moreover, current reviews have not sufficiently addressed the variability in sediment transport capacity due to different soil types and root systems. Liu et al. (2023) emphasized the need for more detailed studies on how soil properties and vegetation interact to influence sediment transport.

Given the focus of this research on presenting a systematic literature review of studies on the influence of various factors sediment transport capacity by overland flow, this paper aims to investigate the relationship between the sediment transport capacity on flow velocity, slope gradient, hydraulic parameters, soil properties, and root parameters on sediment transport capacity by overland flow and to evaluate the research findings for improving the accuracy of sediment transport predictions.

METHODOLOGY

This study adopts a systematic literature review (SLR) of previous studies on sediment transport capacity by overland flow which varies in methodologies and approaches SLR is a procedure that allows for the collection of relevant information on a specific issue that meets the predetermined criteria for eligibility, as well as an answer to the defined research questions (Mengist et al. 2020).

According to the objectives stated, the SLR seeks to answer the following research questions:

RQ1: What are the relationships between sediment transport capacity and factors such as flow velocity, slope gradient, hydraulic parameters, soil properties, and root parameters in the context of overland flow?

RQ2: What are the key findings from recent studies on sediment transport capacity that can enhance the accuracy of prediction models?

RQ3: What gaps or inconsistencies exist in the current literature regarding the factors influencing sediment transport capacity?

This SLR conducted according to the guidelines as illustrated in Figure 1. As shown in the figure, the section below describes the steps as follow: information collection, resources, identification, screening, eligibility and data extraction.

INFORMATION COLLECTION

Primary data is derived from a variety of scientific articles and the findings of previous studies in order to construct theories and identify the relationships between variables. Information collection conducted using Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) method. The PRISMA statement, as stated by Sultana and Paul (2024), is a list of 27 points that comprises a four-tiered flowchart that clarifies the flow of data through all phases of a systematic review and confirms the exact number of articles that were located, screened, found eligible, and eventually retained. This contributes to the advancement of information derived from several investigations in a qualitative and quantitative manner. After the search, the papers that are found are screened for inclusion in the review based on their titles, abstracts, and complete texts.

DATA RESOURCES AND EXTRACTION

Firstly, a clearly defined research question is formulated to guide the review process, with identifying the factors influencing sediment transport capacity such as slope gradient, flow discharge, soil properties, hydraulic parameters, and root parameters. A search word from research question as shown in Table 1 with filtered out based on the papers abstract-screening relevance. Scientific databases used to find the studies were ScienceDirect, Google Scholar and Scopus as it provides complementary access to a wide range of high-quality academic literature, specifically ScienceDirect provides access to high-quality journal articles and books published by a major academic publisher, Scopus as largest database of peer-reviewed literature and Google Scholar as comprehensive search engine for academic and scholarly publications. Furthermore, the study comprises publications timeframe within 2019 until 2024 that also include further research.

SCREENING

Quality assessment is performed to evaluate the methodological rigor and reliability of included studies, considering factors such as study design, sample size, and potential biases. Finally, data synthesis is carried out to analyse and interpret the findings, identifying common themes, trends, and gaps in the literature related to sediment transport capacity by overland flow. The results of the systematic literature review are then reported following established guidelines, providing valuable insights for researchers, practitioners, and policymakers involved in soil erosion and sediment management efforts.

The second stage of a systematic review is called screening, during which time pertinent articles are located and everything unrelated is eliminated (Sultana & Paul, 2024). Articles must fulfil the requirements for inclusion and exclusion listed in Table 2. Based on the eligibility and exclusion requirements of literature type, language, time frame, study emphasis, and analysis approaches, 1045 publications were assessed in this step of the process.

In the beginning, only journal papers published in the English language between 2019 and 2024 were considered in our analysis. Conference proceedings and unpublished publications were not included in this study. Second, after carefully reviewing the title and abstract on the ability of overland flow to transfer sediment, research on at least one of the following components were selected: flow velocity, slope gradient, hydraulic parameters, soil qualities, and root parameters. Since theoretical frameworks do not offer information on sediment transport capability, they were disregarded. Since this research aims to examine changes over a certain era exclusively, articles that describe sediment movement in a particular location are often overlooked during the screening process. One of the admission criteria was the article that included discussed equations. After evaluating 1045 abstracts, 704 were removed as irrelevant to the study objective. After eliminating duplicates, 148 articles were identified in this screening process for further eligibility tests. Duplicates does not include paper that combined two or three factors appearing several times and considers as 2 papers if there are two combined factors.

ELIGIBILITY

After reviewing the content of each of the 182 remaining articles, 148 were eliminated from the review process as they did not focus on the inclusion criteria. Studies that explore combined effects of these factors and provide quantitative or qualitative data on sediment transport capacity were selected.

INCLUSION AND EXCLUSION

At the final stage of the review, 34 articles were identified and utilized for qualitative analysis because several articles did not present the modelling approaches. The last part of the review was inclusion and exclusion criteria are established to select relevant studies. 32 articles were identified and utilized for the analysis.

TABLE 1. Keywords search strings in the selected databases

Factor	Search Strings
Flow Velocity	(“sediment transport capacity” OR “sediment transport”) AND (“overland flow” OR “surface runoff”) AND (“flow velocity”)
Slope Gradient	(“sediment transport capacity” OR “sediment transport”) AND (“overland flow” OR “surface runoff”) AND (“slope gradient” OR “terrain slope”)
Hydraulic Parameter	(“sediment transport capacity” OR “sediment transport”) AND (“overland flow” OR “surface runoff”) AND (“hydraulic parameters” OR “flow depth” OR “discharge rate” OR “stream power”)
Soil Properties	(“sediment transport capacity” OR “sediment transport”) AND (“overland flow” OR “surface runoff”) AND (“soil properties” OR “soil texture”)
Root Parameter	(“sediment transport capacity” OR “sediment transport”) AND (“overland flow” OR “surface runoff”) AND (“root parameters” OR “root density” OR “vegetation”)

TABLE 2. Inclusion and exclusion criteria

Criteria	Exclusion	Inclusion
Literature type	Gray literature (unpublished literature, conference proceedings)	Published in peer-reviewed journals,
Language	All non-English literature	English literature
Time frame	Literature that was not published between 2019 and 2024	Published between 2019 and 2024
Research focus	Focused on sediment transport in aquatic environments (rivers, lakes, etc.) rather than overland flow.	Focused on sediment transport by overland flow.
Analysis technique	Theoretical	Investigate at least one of the following factors: flow velocity, slope gradient, hydraulic parameters, soil properties, root parameters. Explore the combined effects of these factors. Provide quantitative or qualitative data on sediment transport capacity.

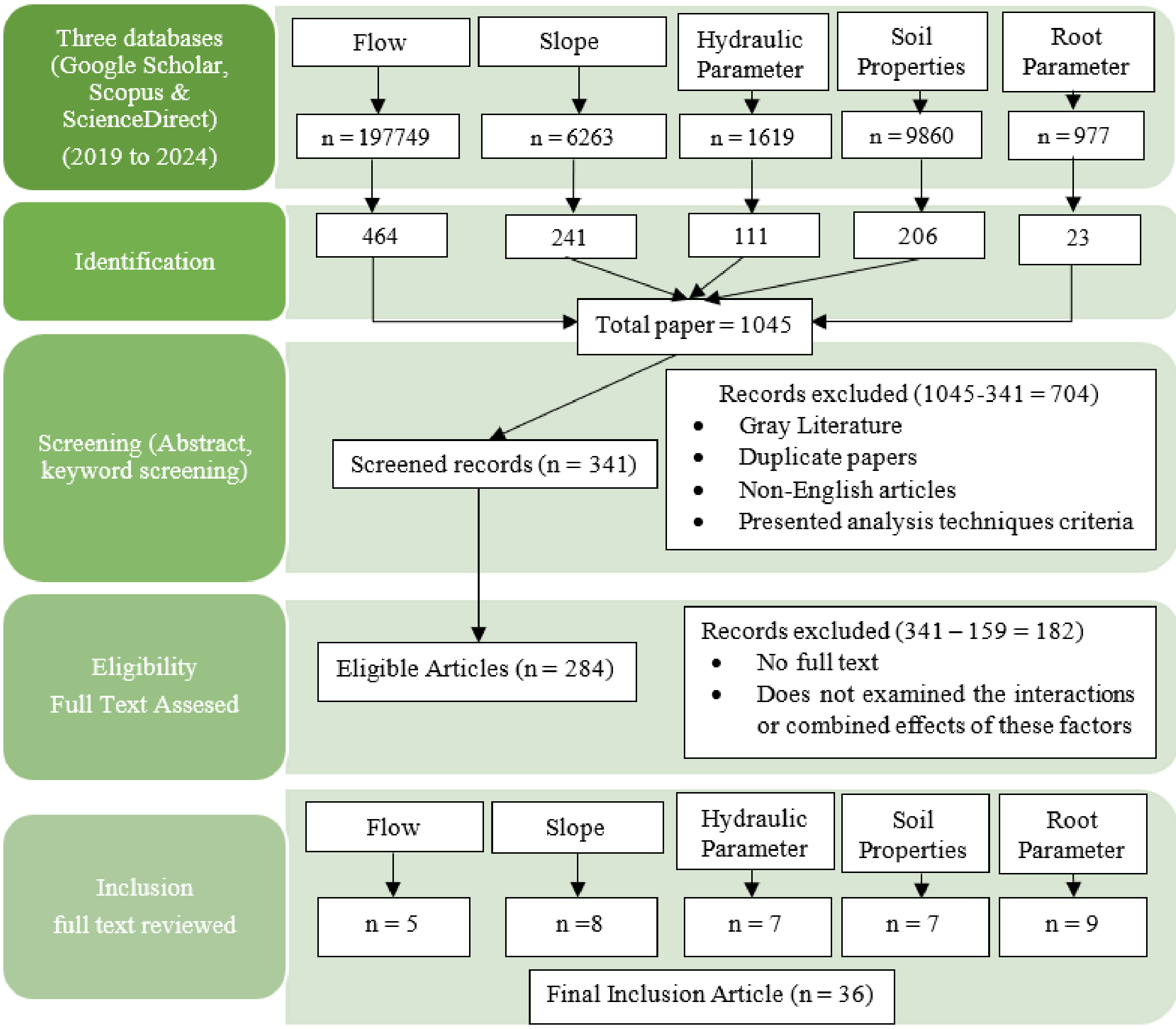

FIGURE 1. Flow chart of SLR

RESULTS AND DISCUSSIONS

The systematic literature review of the available literature on the dynamics of sediment transport capacity during overland flow has provided several valuable insights. This section presents the main results of the review, including the experimental approaches and methodologies employed in the studies and a summary of the key factors influencing sediment transport capacity. Sediment transport capacity is a critical parameter reflecting the maximum amount of sediment that can be carried by flowing water over the land surface. It is influenced by a complex interplay of factors, including flow velocity, slope gradient, surface roughness, hydraulic parameters, soil characteristics, and vegetation (root parameters).

KEY FACTORS AFFECTING SEDIMENT TRANSPORT CAPACITY

The review of the literature has identified several key factors that play a significant role in governing the dynamics of sediment transport capacity by overland flow. These factors can be broadly categorized into the following groups: flow velocity, slope gradient, hydraulic parameters, soil properties, and root parameters.

FLOW VELOCITY

One of the primary factors influencing sediment transport capacity is the velocity of the overland flow. As stated by Liu et al. (2020), flow velocity plays a crucial role in sediment transport capacity, with a linear increase in transport capacity observed with increasing mean flow velocity. Studies by Liu et al. (2020) and Ferro and Guida (2022) depicts that sediment transport capacity increases linearly with mean flow velocity, and a threshold velocity exists beyond which sediment can be transported. Therefore, there was a significant correlation between sediment transport capacity and mean flow velocity. The kinetic energy of flow is a fundamental factor in sediment transport determined by flow velocity, affects sediment transport capacity where higher flow velocities result in increased kinetic energy, enhancing the sediment transport capacity (Liu et al. 2023). Furthermore, sediment transport capacity increases as a power function of these parameters, demonstrating that higher flow velocities contribute to greater sediment transport capacity (Ma et al. 2022).

Table 3 shows flow velocity as a factor of sediment transport capacity by overland flow. As summarized in Table 3, the reviewed studies have consistently demonstrated that as the flow velocity increases, the sediment transport capacity also rises significantly with limiting the amount of sediment deposited. Moreover, several empirical equations, such as the modified Yalin equation, have incorporated flow velocity as a key variable in predicting sediment transport capacity under different flow conditions. It was proven by Yao et al. (2023) that modified Yalin's equation to develop a new Tc equation based on general flow parameters improving prediction accuracy to 83% for different soil types.

TABLE 3. Flow velocity as a factor of sediment transport capacity by overland flow

Author	Method	Key Findings
Li et al. 2023	Experimental	The sediment transport capacity is influenced by the velocity of the sediment-laden flow, which decreases as sediment is deposited. Sediment management strategies influenced sediment transport capacity by altering flow velocity, potentially exacerbating reservoir sedimentation.
Yao et al. 2023	Empirical	Settling velocity of soil particles, influenced by particle shape, flow viscosity, and temperature, is crucial for accurately predicting Tc, especially for soils with small particles. Therefore, a new Tc equation based on general flow parameters was developed, improving prediction accuracy to 83% for different soil types.
Wu et al. 2023	Empirical	The study found that Tc increased with mean flow velocity, emphasizing the influence of flow velocity on sediment transport in agricultural regions of the Loess Plateau. Tc showed a positive correlation with mean flow velocity, as observed in the study on different test soils.
Li et al. 2022	Experimental	Flow velocity plays a significant role in determining how much sediment can be carried away in rill erosion. Higher flow velocities mean more force acting on the soil, increasing the amount of sediment that can be transported since it can detach more soil particles and carry them along, impacting the overall erosion process.
Mu & Fu, 2023	Experimental	Flow velocity, along with other hydraulic variables, is essential for estimating sediment transport capacity. In the presence of vegetation stem cover, unit stream power (u) becomes a more reliable indicator for predicting sediment transport capacity compared to shear stress and stream power. This highlights the significance of considering flow velocity in understanding sediment transport processes under vegetation cover.

SLOPE GRADIENT

Another important factor that affects sediment transport capacity is the slope gradient of the land surface. Ren et al. (2021) described slope gradient refers to the angle of inclination of the land surface and is commonly measured in degrees or as a ratio of vertical rise to horizontal distance. Liu et al. (2020) proven that the relationship sediment transport capacity across various soil types increases as the slope gradient increases, is significant with nonlinear regression analysis showing a strong correlation (> 0.93) between sediment transport capacity and slope gradient. The relationship between slope gradient and sediment transport capacity has been validated through various studies, including those on non-erodible and erodible beds (Wang et al. 2020b; Liu et al. 2020).

Table 4 depicts slope gradient as a factor of sediment transport capacity by overland flow. From Table 4, slope gradient is a critical factor influencing natural processes like erosion and sediment movement, with steeper slopes often leading to higher flow velocities and increased sediment transport rates (Liu et al. 2020). This is because the slope gradient directly influences the acceleration of the overland flow, which in turn affects the shear stress exerted on the soil surface and the detachment of sediment particles. The reviewed studies have shown that the impact of slope gradient on sediment transport capacity is significant, as different slope gradients can result in varying sediment transport parameters.

TABLE 4. Slope gradient as a factor of sediment transport capacity by overland flow

Author	Method	Key Findings
Ren et al. 2021	Empirical	The sediment transport capacity by overland flow increases with sediment content and slope gradient, aligning with the characteristics of high sediment content and steep slopes in the Loess Plateau.
Li et al. 2023	Empirical/ experimental	The study highlighted a significant positive relationship between slope gradient and Tc in different test soils. This suggests Tc increases with steeper slope gradients, emphasizing the importance of slope gradient in determining sediment transport rates in the agricultural regions studied.
Yao et al. 2023	Experimental	The slope gradient plays a crucial role in determining the Tc of a river channel. Understanding the relationship between slope gradient and sediment transport capacity is essential for managing erosion and deposition in silt-laden rivers.
Zhu et al. 2023	Experimental	The middle-slope position likely had the largest soil detachment and sediment transport capacities due to its steeper slope gradient. Material at the middle-slope position was coarser, with higher sand and gravel contents, leading to higher soil porosity and SIPs compared to other positions.
Wang et al. 2023	Experimental	The relationship between slope gradient and Tc is significant. Steeper slopes result in higher sediment transport capacity, highlighting the importance of slope gradient in erosion processes.
Ma et al. 2021	Experimental	The study observed that as the slope gradient increased, the soil detachment rate also increased, indicating a direct relationship between slope steepness and sediment transport capacity.
Zhang et al. 2023	Experimental	Slope gradient directly influences Tc, with steeper slopes generally leading to higher sediment transport rates. The relationship between slope gradient and sediment transport capacity is complex, with some studies showing that flow discharge has a more significant impact on sediment transport than slope gradient.
Mu & Fu, 2023	Experimental	By testing different combinations of stem diameters on various slopes, researchers were able to understand how slope gradient influences Tc emphasizes the importance of considering slope characteristics when studying sediment transport processes under different vegetation conditions.

HYDRAULIC PARAMETER

Hydraulic parameters are variables that describe the characteristics and behavior of water flow, particularly in open channels or overland flow. These parameters are essential for understanding and modeling the movement of water and sediment transport in various environments (Li et al. 2022; Yao et al. 2023). Hydraulic parameters such as average flow velocity, flow shear stress, Froude number, Reynolds number, stream power, and unit stream power significantly correlate with Tc. One important factor that affects both the mean flow velocity and the general hydraulic behavior of overland flow is flow depth. Because deeper flows may carry bigger sediment particles, they can also have an increased capacity for transporting sediment (Li et al. 2022). Also, the sediment transport capacity is closely correlated with mean flow velocity, where More and bigger silt particles can be carried by faster flow rates (Yao et al. 2023). Using the water flow continuity equation, the mean flow velocity is determined. Research indicates a power function correlation between shear stress and transport capacity, highlighting the significance of hydraulic parameters in sediment movement (Liu et al. 2020; Yao et al. 2023; Li et al. 2022). The hydraulic parameters of overland flow are mainly related to flow width, flow depth, and flow velocity (Zhang et al. 2023). Therefore, hydraulic parameter play a fundamental role in determining sediment transport capacity. Table 5 shows hydraulic parameter as a factor of sediment transport capacity by overland flow.

From Table 5, it can be summarized that higher flow velocities and depths result in increased shear stress on the bed and greater potential for sediment entrainment and transport. As hydraulic parameters consist of many variables, the main indicator depends on other external factors, as summarized by Mu and Fu (2023) that different hydraulic parameters affect sediment transport processes under the factor of root parameter in Table 5. Furthermore, Wang et al. (2019) using the emphasize stream power and shear stress to develop a new equation to estimate sediment transport capacity. This was supported by Liu et al. (2020) that emphasize stream power and shear stress as optimal predictor for sediment transport capacity. Unit stream power, flow depth and friction factor also influence sediment transport capacity as stated by (Mu & Fu, 2023; Wang et al. 2020). On the other hand, external variables like soil properties and vegetation characteristics are highlighted as key factors affecting sediment transport capacity, potentially overshadowing the direct influence of hydraulic parameters in the research (Yao et al. 2023). Additionally, variations in flow velocity profiles and turbulence intensity influence sediment particle movement and suspension within the flow.

TABLE 5. Hydraulic parameters as a factor of sediment transport capacity by overland flow

Author	Description	Key Findings
Liu et al. 2020	Experimental	The study emphasizes the importance of stream power as an optimal predictor for calculating sediment transport capacity, showcasing a linear relationship with mean flow velocity. Hydraulic variables such as shear stress and stream power are key factors in accurately predicting sediment transport capacity, with stream power showing better predictive capabilities.
Wang et al. 2020	Experimental	The hydraulic parameters such as flow depth, friction factor, and shear stress were found to significantly influence sediment transport capacity in overland flow experiments. These parameters showed a power function relationship with sediment concentration, indicating their impact on sediment transport.
Wang et al. 2019	Experimental/ Numerical	Shear stress and stream power were selected for predicting transport capacity due to their strong correlations with measured sediment transport capacity. A new equation was developed for overland flow sediment transport estimation based on the correlation analysis between measured sediment transport capacity and hydraulic parameters.
Wang et al. 2020	Experimental	The research observed that hydraulic parameters, such as water discharge and subsurface hydrologic conditions, significantly influence sediment transport capacity. Changes in soil strength and water discharge due to infiltration and exfiltration impact sediment transport capacity.
Zhang et al. 2023	Experimental	Variations in hydraulic parameters due to different slope gradients and flow discharges influence sediment transport rates, with higher velocities and shear stresses generally leading to increased sediment transport. Understanding the relationship between hydraulic parameters, slope characteristics, and flow dynamics is essential for predicting sediment transport accurately and improving soil erosion process models.

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Mu & Fu, 2023	Experimental	Hydraulic variables like flow velocity, shear stress, and stream power play a crucial role in determining sediment transport capacity. When considering vegetation stem cover, unit stream power (u) becomes a more reliable indicator for predicting sediment transport capacity compared to other hydraulic variables. This highlights the importance of understanding how different hydraulic parameters affect sediment transport processes under vegetation cover.

SOIL PARAMETER

In addition to the hydraulic parameters of the land surface, the intrinsic properties of the soil itself have also been identified as influential factors in the dynamics of sediment transport capacity by overland flow. Soil parameters play a crucial role in determining sediment transport capacity within a reservoir (Ren et al. 2021). For instance, soil texture refers to the relative proportion of sand, silt, and clay particles in a soil sample significantly influences water retention, drainage, and aeration properties of the soil and gravel content is the proportion of coarse fragments (diameter > 0.25 mm) in the soil, affecting soil porosity and water movement (Yao et al. 2023; Zhu et al. 2023). Soil characteristics like grain size and density play a significant role in sediment transport capacity by influencing the transportability and sorting of sediment grains during erosion and transport processes (Alewell et al. 2019). The inherent characteristics of the soil, including its physical, chemical, and mineralogical attributes, have been identified as influential factors in the dynamics of sediment transport capacity by overland flow. Table 6 shows key findings for soil parameter as a factor of sediment transport capacity by overland flow. Equations incorporating these characteristics perform better in predicting sediment transport capacity, highlighting the need to consider soil aggregate properties in such models (Wang et al. 2020b).

TABLE 6. Soil parameters as a factor of sediment transport capacity by overland flow

Author	Description	Key Findings
Ren et al. 2021	Experimental	Variations in soil characteristics influence sediment deposition patterns, affecting reservoir sedimentation rates. Understanding soil parameters is essential for implementing effective sediment management strategies to control sediment transport and deposition in reservoirs.
Yao et al. 2023	Empirical	The study revealed that soil properties like clay content and mean weight diameter have a notable impact on sediment transport capacity, with lower values of these parameters associated with increased sediment transport capacities in the studied agricultural areas.
Jiang et al. 2023	Experimental	The research emphasizes the importance of understanding the relationship between Tc and sediment characteristics, contributing to a better comprehension of the erosion process of soil-rock mixtures. Tc is significantly influenced by the gravel content and composition of soil-rock mixtures on steep slopes
Wu et al. 2023	Experimental	Soil parameters significantly influence the sediment transport capacity of rivers. Understanding the soil characteristics and their influence on sediment transport helps in implementing effective erosion control measures and stabilizing river channels.
Liu et al. 2020	Experimental	The study highlighted the importance of considering soil aggregate characteristics, especially aggregates greater than 0.25 mm WSA 0.25, in Tc equations for overland flow to improve estimating accuracy and prediction capabilities.
Wang et al. 2019	Experimental/ Numerical	Soil parameters significantly influence sediment transport capacity, with different soil types requiring specific equations for accurate predictions. This new function outperformed existing equations for modelling overland flow sediment transport capacity, providing a more reliable estimation method.
Liu et al. 2024	Empirical/ Experimental	Soil properties such as how well particles stick together (cohesion), the size of soil particles, density, organic matter content, porosity, and moisture levels play a crucial role in determining how resistant soil is to erosion, highlighting the importance of understanding and considering soil properties in erosion prediction and control strategies.

From Table 6, it can be summarized that soil parameters significantly influence sediment transport capacity by overland flow. Soil parameters impact processes like overland flow, sediment load, and hydraulic parameters, emphasizing the intricate relationship between soil characteristics and erosion dynamics (Wang et al. 2020). Soil parameters also has many variances as hydraulic parameters.

ROOT PARAMETERS

The fifth factor on sediment transport capacity by overland flow is root parameter that pertains to a specific attribute linked to the root system of vegetation, which can have implications on various hydraulic variables and sediment transport capacity (Reichenberger et al. 2023). As highlighted by Tian et al. (2023), the author found that vegetation cover had a direct effect on sediment transport and an indirect effect through runoff. Root parameter is a crucial factor in sediment transport capacity, influencing erosion rates and soil stability through its effects on slope steepness and surface roughness. Roots help in binding soil particles together, which increases soil cohesion and reduces the likelihood of soil particles being detached and transported by overland flow. This stabilization effect is particularly significant in heterogeneous soils with varying particle size (Li et al. 2023).

However, according (Reichenberger et al. 2023), the study does not explicitly address root parameters, instead focusing on other aspects of vegetation stem parameters and their effects on hydraulic variables and sediment transport capacity. This was proven from the key findings of reviewed articles where vegetation cover helps to increase soil stability (Reichenberger et al. 2023; Alewell et al. 2019), reduce erosion rate (Li et al. 2023), altering the flow dynamics and increase hydraulic resistance (Ma et al. 2022). It can be explain with the vegetation characteristics and its root system development that helps to hold the soil, preventing sedimentation easily occurred (He et al. 2024; Ma et al. 2021; Mu & Fu, 2023; Nouwakpo et al. 2016).

Table 7 shows the key finding of reviewed studies for root parameters as a factor of sediment transport capacity by overland flow. From Table 7, it can be summarized that roots help stabilize soil, reducing erosion by holding soil particles together and preventing them from being washed away by water (He et al. 2024).

Therefore, root parameters play a crucial role in understanding the dynamics between vegetation, hydraulic processes, and sediment transport in environmental studies. Monitoring and analysing soil parameters are vital for effective land management practices, erosion control strategies, and sustainable agricultural productivity (Li et al. 2023).

COMBINED FACTORS AND THEIR INTERACTION

In addition to examining individual factors, it is crucial to understand how combined factors influence sediment transport capacity. Studies indicate that the interplay between flow velocity, slope gradient, hydraulic parameters, soil properties, and root parameters can significantly modify sediment transport dynamics.

FLOW VELOCITY & HYDRAULIC PARAMETER

Flow velocity is significantly correlated with various hydraulic parameters such as Reynolds number and Froude number. The Reynolds number (Re) and Froude Number (Fr) are used to judge flow regime and profile. According to Ma et al. (2022), these parameters help in understanding the flow regime and its impact on sediment transport such as a higher Reynolds number ($Re > 500$) indicates higher turbulence and greater kinetic energy loss. Furthermore, (Jiang et al. 2023) stated that adding sediment settling velocity to the equations that include flow velocity improves the prediction accuracy of transport capacity (Tc). This indicates that combining flow velocity with sediment properties yields more accurate predictions

HYDRAULIC PARAMETER AND SLOPE GRADIENT

This relationship is significant, especially on non-erodible beds where mean flow velocity increases with flow discharge and slope gradient (Jiang et al. 2023).

SOIL PROPERTIES, FLOW DISCHARGE AND SLOPE GRADIENT

Sediment transport capacity increases as a power function of flow discharge and slope gradient. This relationship is consistent across different soil types, indicating that higher flow discharge and steeper slopes enhance sediment transport capacity (Liu et al. 2020; Wang et al. 2020b).

SOIL PROPERTIES AND HYDRAULIC PARAMETER

The influence of soil aggregate characteristics on sediment transport capacity is evident when considering shear stress and stream power. Equations incorporating these characteristics perform better in predicting sediment transport capacity, highlighting the need to consider soil aggregate properties in such models (Wang et al. 2020b).

ROOT PARAMETER AND HYDRAULIC PARAMETER

The influence of vegetation stem parameters on hydraulic variables and sediment transport capacity was also compared, highlighting the role of vegetation in modifying flow dynamics and sediment transport (Jiang et al. 2023). These parameters increased with larger stem diameters, affecting the overall hydraulic behavior of the flow (Mu & Fu, 2023).

SOIL PROPERTIES, SLOPE GRADIENT, ROOT PARAMETER & FLOW DISCHARGE

The relationship between hydraulic parameters and slope gradients, combined with different surface conditions (including vegetation cover), is crucial for understanding sediment transport mechanisms. Experiments show that varying slope gradients and flow discharges under different surface conditions, including vegetated surfaces, affect hydraulic parameters and sediment transport (Li et al. 2022; Shi et al. 2020).

SLOPE GRADIENT AND ROOT PARAMETER

Surface roughness, which can be affected by vegetation, plays a critical role in flow resistance. Different tillage methods and slope roughness impact the friction coefficient, which in turn affects soil erosion and sediment transport processes. Zhu et al. (2023) explored, showing that slope gradient inversely affects the parameter of flow resistance) on smooth surfaces. This relationship was confirmed across different surface conditions, including smooth, sandpaper, plastic grass cover, and various grass and shrub covers.

TABLE 7. Root parameters as a factor of sediment transport capacity by overland flow

Author	Description	Key Findings
Alewell et al. 2019	Empirical	Incorporating root parameters into erosion models can improve the accuracy of predictions by considering the vegetation cover's impact on soil stability and erosion processes.
Li et al. 2023	Empirical	The root parameter plays a significant role in influencing sediment transport capacity, especially in areas with vegetation cover, impacting erosion rates and soil loss.
He et al. 2024	Empirical	The root parameter indirectly affects sediment transport capacity by influencing soil erosion processes. Vegetation with well-developed root systems can significantly decrease sediment transport by enhancing soil cohesion and reducing surface runoff.
Ma et al. 2022	Experimental	The root parameter plays a crucial role in sediment transport capacity on hillslopes. Roots can significantly impact the resistance to overland flow on slope surfaces covered with gravel and grass by altering the flow dynamics and increase hydraulic resistance.
Li et al. 2022	Experimental	This finding underscores the complex relationship between root parameters, such as grass cover density, and sediment transport capacity, highlighting the need to consider vegetation characteristics in erosion studies.
Ma et al. 2021	Experimental	The findings suggested that promoting vegetation cover with a focus on root system development is crucial for effective soil erosion control and sediment transport management. Encouraging vegetation growth, especially root system development, is essential for sustainable soil erosion and sediment transport mitigation.
Reichenberger et al. 2023	Empirical	The root parameter, representing grass and vegetation cover, is a crucial factor in influencing sediment transport capacity by overland flow. The presence of roots can stabilize soil, reducing erosion susceptibility and enhancing sediment trapping efficiency in vegetative filter strips.
Tian et al. 2023	Experimental	The study found that vegetation cover had a direct effect on sediment transport and an indirect effect through runoff, highlighting its importance in mitigating soil erosion and sediment transport. Vegetation cover increases land surface roughness, enhances soil particle resistance, intercepts surface runoff, and improves soil infiltration, all contributing to reduced sediment yield.
Mu & Fu, 2023	Experimental	Research indicates that differences in root characteristics can affect the vegetation's ability to reduce sediment transport, emphasizing the crucial role of root parameters in controlling erosion processes.

SLOPE GRADIENT AND VEGETATION COVER

The effects of slope gradient combined with vegetation cover (e.g., grass and shrub cover) were also examined. Zhu et al. (2023) shows results indicated a positive relationship between parameter and Reynolds number (Re) under different vegetation cover conditions, which affects flow dynamics and erosion.

Overall, the interaction between flow velocity, soil properties, and hydraulic parameters significantly influences sediment transport capacity. Studies have shown that considering multiple factors, such as flow discharge, slope gradient, and soil aggregate characteristics, provides a more accurate prediction of sediment transport capacity (Liu et al. 2020). For instance, by including sediment settling velocity to the equations that include flow velocity improves the prediction accuracy of transport capacity (Tc). This indicates that combining flow velocity with sediment properties yields more accurate predictions (Jiang et al. 2023). These models, that usually using factors of flow velocity, slope gradient and hydraulic parameter, consider the impact of vegetation on flow hydraulics and soil stability to provide more accurate predictions of sediment transport under different conditions (Wang et al. 2019).

However, he limitations of existing erosion prediction models, such as the USLE concept, highlight the necessity for more field-based assessments and monitoring of water erosion to enhance accuracy and understanding of erosion processes. By moving beyond the constraints of these established prediction models and instead focusing on expanding the empirical evidence obtained through field observations and measurements, researchers can work to develop more robust and context-specific approaches to estimating and managing water-driven erosion. This shift towards enhanced field-based research and monitoring could provide valuable insights to refine existing erosion prediction tools and, ultimately, improve the effectiveness of soil conservation strategies.

Furthermore, challenges exist in accurately measuring sediment transport capacity in the field due to the complexities of controlling hydrologic parameters, indicating a gap in field-based measurement techniques. The reviewed papers have highlighted the inherent difficulties in accurately quantifying sediment transport capacity through field-based observations and measurements. Researchers have acknowledged that the complexities involved in controlling and monitoring the various hydrologic parameters in a natural, real-world setting pose significant challenges in obtaining reliable and representative data on sediment transport dynamics.

EXPERIMENTAL APPROACHES AND METHODOLOGIES

The reviewed literature employed various experimental approaches and methodologies to investigate the underlying processes and influential factors. A significant portion of the studies were conducted using controlled laboratory experiments, which allowed for the systematic manipulation and measurement of variables such as flow velocity, slope gradient, surface roughness, and sediment characteristics. These studies often utilized flume or rainfall simulation setups to generate overland flow conditions and quantify the resulting sediment transport capacity. In addition to laboratory experiments, field-based studies provided insights into the dynamics under natural environmental conditions, involving the monitoring of sediment transport rates and associated hydrological and soil parameters in landscapes such as agricultural fields, rangelands, or forested areas.

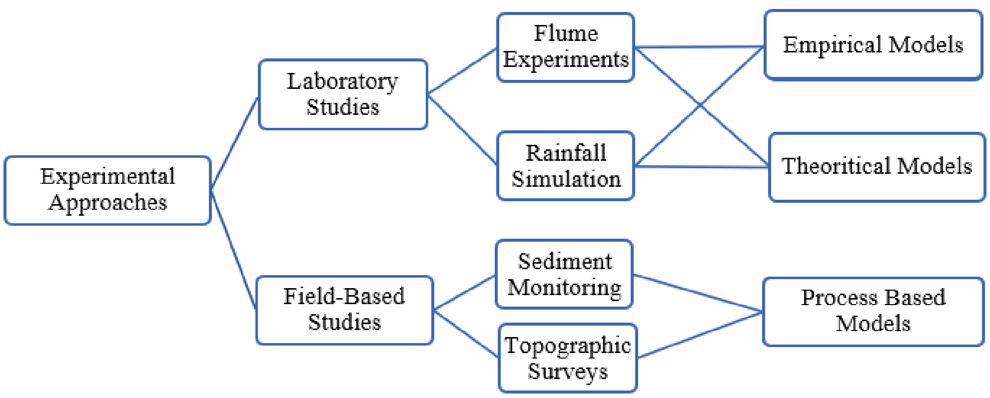

FIGURE 2. Experimental study on sediment dynamics capacity by overland flow

LABORATORY EXPERIMENTS

Many studies employed controlled laboratory experiments to quantify sediment transport capacity. These experiments typically used flume setups or rainfall simulators to create overland

flow conditions. The controlled environment allowed for precise manipulation of variables such as flow velocity and slope gradient. For example, Liu et al. (2020) used a flume setup to measure sediment transport rates under different flow velocities and slope gradients. The data obtained from these experiments provided empirical coefficients for predictive equations like the modified Yalin equation (Wang et al. 2019), which incorporates the effects of flow shear stress, particle size, and critical shear stress for sediment entrainment.

FIELD STUDIES

Field-based studies provided valuable insights into sediment transport dynamics under natural conditions. These studies often involved monitoring sediment transport rates and associated hydrological and soil parameters in real-world landscapes. For instance, Zhang et al. (2023) conducted field measurements in agricultural fields to evaluate the impact of slope gradient and vegetation cover on sediment transport. While field studies offer realistic conditions, they also present challenges such as variability in environmental factors and measurement difficulties.

MODELING APPROACHES

Several studies utilized modeling approaches to predict sediment transport capacity. Models such as the Revised Universal Soil Loss Equation (RUSLE) incorporated various factors like flow velocity, slope gradient, and soil properties. The equation is expressed as:

$$A = R \times K \times LS \times C \times P$$

Equation 1: RUSLE equation to estimate transport capacity

where: A estimated average soil loss per unit area,
R is the rainfall-runoff erosivity factor,
K is the soil erodibility factor,
LS is the slope length and steepness factor,
C is the cover management factor,
P is the support practice factor.

These models relied on empirical data from laboratory and field studies to calibrate and validate their predictions. For example, Ren et al. (2021) used the WEPP model to simulate sediment transport under different hydraulic conditions and soil types.

INFLUENCE ON FINDINGS

The choice of quantification method significantly influenced the findings of the reviewed studies. Laboratory experiments provided controlled conditions that allowed for detailed analysis of specific factors. However, they might not capture the full complexity of natural environments. Field studies offered realistic insights but faced challenges related to variability and measurement accuracy. Modeling approaches integrated multiple factors and provided comprehensive predictions, but their accuracy depended on the quality of empirical data used for calibration.

For instance, the influence of flow velocity on sediment transport capacity was consistently observed across different quantification methods. Laboratory experiments showed a clear linear relationship, which was supported by field measurements and validated by models. The impact of slope gradient varied depending on soil type and vegetation cover, highlighting the importance of considering combined factors in predictive models. By understanding the quantification methods and their influence on the findings, this review provides a comprehensive evaluation of the factors affecting sediment transport capacity. This knowledge is essential for improving predictive models and developing effective sediment management strategies.

EVALUATION OF RESEARCH FINDINGS

INCORPORATING SETTLING VELOCITY WITH AGGREGATES

Existing models should be modified to include the settling velocity of undispersed sediment with aggregates. This adjustment can provide a more accurate representation of sediment transport in overland flow conditions (Liu et al. 2020).

IMPORTANCE OF SEDIMENT SETTLING VELOCITY

Sediment settling velocity, especially with aggregates, has been shown to significantly improve the accuracy of sediment transport capacity (Tc) predictions. This variable should be integrated into existing models to better reflect the migration processes of sediment (Wang et al. 2019).

IMPACT OF SOIL AGGREGATES

The presence and characteristics of soil aggregates, such as the mass percentage of aggregates greater than 0.25 mm, are crucial for accurate Tc predictions. Models should incorporate these characteristics to enhance prediction accuracy.

HYDRAULIC VARIABLES AND SOIL TYPES

Different soil types and hydraulic variables, such as slope gradient and unit flow discharge, significantly affect Tc. Models should be calibrated to account for these variables to improve their applicability across various soil types and conditions (Liu et al. 2020).

ADJUSTING FOR SOIL AGGREGATE CHARACTERISTICS

Models should integrate parameters that reflect soil aggregate characteristics, such as the geometric mean diameter and the mass percentage of aggregates greater than 0.25 mm. These parameters can help in better predicting Tc for different soil types.

CALIBRATION FOR DIFFERENT SOIL TYPES

Given the variability in sediment transport across different soil types, models should be calibrated specifically for the soil types they are intended to predict. This includes considering the cohesion between particles and the specific erodibility of soils like loess.

CONCLUSION

This systematic literature review has elucidated the complex interactions between sediment transport capacity and key factors such as flow velocity, slope gradient, hydraulic parameters, soil properties, and root parameters. The reviewed studies highlight the critical role these factors play in governing sediment transport dynamics, with each factor contributing uniquely to the overall process.

Flow velocity and slope gradient were consistently shown to have a direct impact on sediment transport capacity, often increasing Tc with higher values. Hydraulic parameters, including flow depth and discharge rate, were found to be pivotal in determining the transport potential, with deeper and faster flows generally enhancing Tc. Soil properties, such as texture and cohesion, significantly influenced sediment detachment and transport, while root parameters, including root density and diameter, were shown to modify hydraulic conditions and soil structure, thereby affecting sediment movement.

Recomendation for a place is that modify existing models to include the settling velocity of sediment aggregates rather than just mineral particles. This change can significantly enhance the accuracy of Tc predictions. Furthermore, introduce new variables such as the mass percentage of aggregates greater than 0.25 mm and the geometric mean diameter of soil aggregates. These variables have shown a strong correlation with Tc and can improve model predictions. Lastly, employ empirical models based on flow and sediment characteristics, including the settling velocity of aggregates. These models have demonstrated high accuracy in predicting Tc and should be further validated and refined

Despite these insights, the review also identified substantial gaps in the current literature. Notably, the combined effects of these factors are underexplored, and existing models often fail to integrate these interactions, resulting in less accurate predictions. Moreover, many studies lack a comprehensive approach to quantifying the influence of each factor, particularly in varied environmental conditions.

In order to improve the accuracy of sediment transport predictions, future research should focus on developing more robust models that incorporate the combined effects of multiple factors. Enhanced field-based assessments and long-term monitoring are essential to validate these models and refine their predictive capabilities. By addressing these gaps, we can better understand sediment transport processes and implement effective soil conservation strategies to mitigate the adverse impacts of soil erosion on ecosystems and human communities.

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DECLARATION OF COMPETING INTEREST

None.

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