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Evaluation of the Main Variables that Influence the Sediment Connectivity Based on Applied Models

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Evaluation of the Main Variables that Influence the Sediment Connectivity Based on Applied Models

Abstract

The hydro-sedimentological connectivity index determines the degree of possibility that sediments from a given area reach a control point. To understand the dynamics that occur with sediments, the use of variables that represent the morphology and environmental conditions involved in space and time is necessary. This research proposed the analysis of models, identifying the main variables that explain the connectivity of sediments and observing their influences and frequency of use. Based on 35 specific articles that addressed sediment connectivity models, an important representativeness of the use of digital elevation models was found in 85% of the studies, emphasizing slope variables, drainage area, and land use and cover. Roughness was used only with tabulated data, despite being extremely important, thus being able to be an element to be detailed in new models.

Keywords: Hydro-sedimentology. Connectivity Index. Hydro-sedimentological parameters. Hydro-sedimentological methods

Avaliação das principais variáveis que influenciam na conectividade de sedimentos com base em modelos aplicados

Resumo

O índice de conectividade hidrossedimentológica determina o grau de possibilidade que os sedimentos de uma determinada área chegue a um ponto de controle. Compreender a dinâmica que ocorre com os sedimentos requer o uso de variáveis que representam a morfologia e as condições ambientais envolvidas no espaço e no tempo. Essa pesquisa propôs a análise de modelos, identificando as principais variáveis que explique a conectividade de sedimentos e observar as influências e frequências de uso das mesmas. Com base em 35 artigos específicos que trataram de modelos de conectividade de sedimentos, foi constatado uma representatividade importante do uso de modelos digitais de elevação em 85% dos trabalhos com destaque para variáveis declividade, área de drenagem, além do uso da terra. A rugosidade, apesar de extrema importância, foi usada apenas com dados tabelados, podendo assim ser um elemento a ser detalhado em novos modelos.

Palavras-chave: hidrossedimentologia; índice de conectividade; parâmetros hidrossedimentológico; métodos hidrossedimentológicos.

Evaluación de las principales variables que influyen en la conectividad de sedimentos basados en modelos aplicados

Resumen

El índice de conectividad hidrosedimentológica determina el grado de posibilidad de que los sedimentos de una zona determinada lleguen a un punto de control. Comprender la dinámica que ocurre con los sedimentos requiere el uso de variables que representen la morfología y las condiciones ambientales involucradas en el espacio y el tiempo. Esta investigación propuso el análisis de modelos, identificando las principales variables que explican la conectividad de los sedimentos y observando sus influencias y frecuencia de uso. A partir de 35 artículos específicos que abordaron modelos de conectividad de sedimentos, se encontró una representatividad importante del uso de modelos digitales de elevación en el 85% de los trabajos, con énfasis en variables de pendiente, área de drenaje, además del uso del suelo. La rugosidad, a pesar de ser sumamente importante, se utilizó únicamente con datos tabulados, pudiendo así ser un elemento a detallar en nuevos modelos.

Palabras Clave: hidrosedimentología; índice de conectividad; parámetros hidrosedimentológicos; métodos hidrosedimentológicos.

Introduction

Sedimentology addresses all the processes of production, transport, and deposition of sediments from their origin to the outlet of a basin or at a given reference point for analysis. This dynamic can occur through water, wind, the dragging movement of animals, or anthropic actions (Perry; Taylor, 2007; Oliveira, 2023; Mahoney; Fox, 2024). To understand sedimentological processes (also studied by Rodrigues, 2015), recent studies have employed computational models and/or developed indices that can represent the dynamics of sediments along the watershed.

These examples are presented in this article. These models were built with available data input depending on the objective and the study area. These are addressed as variables in this article and considered input parameters for some authors.

As part of Sedimentology studies, connectivity has been gaining ground, as reported in a literature review addressing sediment dynamics (Najafi *et al*., 2021). According to the authors, most studies focused on static characteristics and not on dynamic aspects of connectivity, developing methods and indices based especially on structures and placing functional connectivity—basically related to sediment transport processes—at the margin of the studies. With the evolution of these, the concepts to define sediment connectivity emerged, such as water transfer mediated by matter, energy, and/or organisms within or between the elements of the hydrological cycle (Pringle, 2001); passage of water between compartments of the landscape from runoff in the basin, affecting biological processes and sediment movement (Bracken *et al*., 2013); estimation of the potential connection between the eroded sediment on the slopes and the stream system (Borselli; Cassi; Torri, 2008); integrated transfer of sediment throughout the basin, from any possible source to a given control point in a system, where the transport vector is solely and exclusively water, with links along the sediment cascade (Zanandrea; Kobiyama; Michel, 2017).

Sediment connectivity works with both structural and functional components. Structural connectivity is related to physical characteristics, such as slope, land use and cover, drainage area, surface roughness, and sediment characteristics. Functional components, in turn, are related to characteristics such as soil erosion, transport, sediment deposition, surface runoff, and precipitation (NAJAFI *et al*., 2021). One of the first models to calculate sediment connectivity by an index was proposed by Borselli, Cassi, and Torri (2008), using topographic characteristics and land use and cover and with the support of Geographic Information Systems (GIS). The LAPSUS model (Research, 2018), which applies kinematic wave theory to simulate erosion and deposition by surface flow, was used with six digital elevation models with different characteristics to evaluate the relationship of different landforms with sediment connectivity. The results confirmed that the relationship is not linear and that rainfalls may have different importance depending on the complexity of the landscape (Baartman *et al*., 2013).

Sediment production, connectivity, and delivery ratio are strongly related, but some significant differences can be identified. Sediment production quantifies mass in space and time by mathematical models using equations consolidated in the literature (Carvalho, 2008). The sediment delivery ratio (SDR) determines the fraction of all eroded sediment in the watershed outlet (Minella; Merten; Clarke, 2009). Sediment connectivity only depends on morphology for its determination. However, other variables can be used to calculate connectivity (Zanandrea *et al*., 2020).

By several articles reviewed within the topic of sediment connectivity, Najafi *et al*. (2021) organized the studies into five different categories: (1) development of conceptual structures; (2) representation of spatial and temporal distribution of sediment source and sink areas; (3) development of sediment connectivity indices; (4) use and development of models; or (5) investigation of the probability of sediment delivery by a network analysis approach.

Studies have been developed using geomorphological and morphometric data, such as the length of the sediment transport path, terrain slope, drainage area, and surface roughness, derived from digital terrain model (DTM). This high number of research using these DTM data can be explained by the evolution of Geographic Information System (GIS) applications, which facilitate and streamline the processes of using these data. These applications can be observed in older articles such as Fryirs *et al*. (2007) and Borselli, Cassi, and Torri (2008).

Among the diverse variables applied in the models, some had greater frequency, and others were specific to the sediments, which were the targets of analysis and observations in this study. Based on the search for studies that applied models related to sediment connectivity, the proposal of this article is a literature review aiming at analyzing and discussing the main variables applied, based on a grouping of hydrological, geomorphological, and sedimentological variables, to identify possible gaps for future research.

Materials and methods

This study reviews the analytical scientific literature regarding the models applied for sediment connectivity analysis. The search and selection of reference information for this study was done using the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*(CAPES) database, Google Scholar, and Science Direct. We selected only articles published from 2000 to 2023 as a search criterion. Among the articles found on Sedimentology, those that used sediment connectivity models to analyze the parameters applied in the methodology were identified, which served as the basis for the discussion of this study. After identifying the articles, the main variables used in the models were selected to observe the frequency of application by the studies.

At first, we grouped the variables of interest into hydrological (precipitation, erosivity, antecedent precipitation, infiltration rate, surface runoff), geomorphological (drainage length, slope, drainage area, topographic factor, terrain roughness), sedimentological (sediment density, soil erodibility, sediment granulometry, sediment cohesion, suspended solids, and soil loss), and land use and cover. We created a spreadsheet to organize and identify the variables applied in the articles and thus calculate the appropriate proportions.

The identification of the data used as input in the models to meet the objectives of each study is understood as variables. Notably, other variables are applied in the models and not previously reported because they are not common to all articles analyzed. Once the articles were selected, the following aspects were identified and tabulated: the model used, an objective definition of the study, the resolution of the digital elevation model (DEM) applied, the variables used, and the group that the variables belong to.

Regarding the database search, 831 articles containing the term "sediments" were identified at CAPES, 105 at Google Scholar, and 835 at Science Direct, all in the past 24 years. When we restricted the search to "sedimentological models," the number of articles was considerably reduced, totaling 70 articles at CAPES, 371 at Google Scholar, and 645 at Science Direct. Finally, with one more keyword, "hydro-sedimentology," the search found 40 articles at CAPES, 1,650 at Google Scholar, and none at Science Direct. In the end, 35 articles addressed the application of sedimentological connectivity models to analyze and discuss the parameters applied in the connectivity models.

Results and discussions

During the analyses, studies applied more than one model, and some adaptations were observed (Table 1).

The first sedimentology study recorded in Brazil was carried out by the *Companhia Estadual de Energia Elétrica* (CEEE) on the Camaquã River in the state of Rio Grande do Sul, aiming to predict siltation and calculate the useful life of the reservoir of the Paredão powerplant (Carvalho, 2008). However, regarding specificity with the sediment connectivity process, research is more recent (Zanandrea, 2017). The chronological evolution of scientific production related to sediment connectivity was reported by 142 studies and shown in Figure 1, highlighting 2017 as the apex (Najafi *et al*., 2021).

Among the articles evaluated, 43% applied the basis of the model proposed by Borselli, Cassi, and Torri (2008) or adapted by Cavalli *et al*. (2013), and 69% cited Borselli, Cassi, and Torri (2008). This shows the importance of the proposal initiated by Borselli, which has been evolving and bringing new indices and elements to sediment connectivity modeling.

By the groups in Table 2, 31% of the articles used hydrological data, 46% geomorphological data, 12% sedimentological data, and 11% land use and cover data. This reinforces the importance of geomorphological data. Also, 28% of the articles used at least one variable from each class, thus demonstrating a diversity in the use of variables.

Even with an extensive application of the variable drainage area (Table 2), this does not mean that the area value was used in the analyses as a possible influence on sediment dynamics. Although it is not considered a variable in the analyses, DEM is crucial information, and only one article did not use it as input data for the model. However, it is important to emphasize that some variables are derived from DEM, such as slope, ramp length, and drainage area, which justifies the wide use of this variable.

Table 1 – Relationship of sediment connectivity assessment models.

Authors	Model	Definition	Borselli as reference*	Resolution	Applied variables	Group
(Asadi; Dastorani; Sidle, 2023)	Application with Artificial Neural Networks	Application with Artificial Neural Networks with the use of CI (Borselli) for comparison	Applied	DEM 30m	Precipitation, Erosivity, Antecedent Precipitation, Surface Runoff, Course Length, Slope, Drainage Area, Topographic Factor, Terrain Roughness, Land Use and Cover, Soil Erodibility, Mean Elevation, Mean Slope Gradient, and Soil Surface Moisture	Geomorphological, hydrological, sedimentological, and land use and cover
(Liu *et al.*, 2022)	Adapted CI (Borselli) with inclusion of calculation of erosivity, erodibility, and land use and cover characteristics	Revised sediment connectivity index (RCI) incorporating the functional with the structural components of a sediment routing system	Applied	DEM 30m	Precipitation, Erosivity, Antecedent Precipitation, Surface Runoff, Course Length, Slope, Drainage Area, Topographic Factor, Terrain Roughness, Land Use and Cover, Soil Erodibility	Geomorphological, hydrological, sedimentological, and land use and cover
(Zingaro *et al.*, 2019)	Sediment Flow Connectivity Index (SCI)	Represents a sediment mobility gradient integrating functional aspects within the structural component	Cited	DEM 2m	Land use and cover, Soil, Precipitation, Slope, Roughness	Geomorphological, hydrological, and land use and cover
(López-Vicente; Ben-Salem, 2019)	Aggregate Flow and Sediment Connectivity Index (ACI)	Represents the potential connectivity of flow and sediment considering temporal and spatial variation	Applied	DEM 5m	Precipitation, Erosivity, Antecedent Precipitation, Surface Runoff, Drainage Length, Slope, Drainage Area, Topographic Factor, Terrain Roughness, Land Use and Cover, Soil Erodibility, Soil Loss	Geomorphological, hydrological, sedimentological, and land use and cover
(Turnbull; Wainwright, 2019)	Connectivity indicator	Quantifies the rate between functional and structural connectivity with surface runoff and sediment transport models	Cited	Not Informed	Precipitation, Erosivity, Surface Runoff, Slope, Drainage Area, Terrain Roughness, Land Use and Cover, Soil Loss.	Geomorphological and hydrological

Table 1 – Cont.

Authors	Model	Definition	Borselli as reference*	Resolution	Applied variables	Group
(Fressard; Cossart, 2019)	Connectivity indicator	Assesses structural sedimentological connectivity by residual flow index		DEM 20m	Precipitation, Surface Runoff, Drainage Length, Slope, Drainage Area, Land Use and Cover	Geomorphological
(Mishra *et al.*, 2019)	Sediment Connectivity Index (CI) and SWAT (*Soil and Water Assessment Tool*) model	Evaluated the connectivity of sediments with a combination of models, comparing with observed data and highlighting the spatial variability with the structural dynamics of sediments	Applied	DEM 90m	Precipitation, Infiltration Rate, Surface Runoff, Slope, Drainage Area, Land Use and Cover, Suspended Solids, Soil Loss	Geomorphological, land use and cover, hydrological, and sedimentological
(Di Stefano; Ferro, 2019)	Sediment Delivery Distributed (SEDD) model	Use of morphometric variables to evaluate sediment connectivity	Cited	DEM 2m	Precipitation, Surface Runoff, Drainage Length, Slope, Drainage Area	Geomorphological
(Cislaghi; Bischetti, 2019)	Method: PRIMULA PRobabilistIc MUltidimensional Landslide Analysis	Determined the probability of connectivity of sediment on slopes to the water body	Cited	DEM 5m	Precipitation, Surface Runoff, Drainage Length, Slope, Drainage Area, Land Use and Cover, Sediment Cohesion	Geomorphological, hydrological, land use and cover, and sedimentological
(Llena *et al.*, 2019)	Sediment Connectivity Index (CI) and SfM-MVS algorithm	Understand the evolution of sediment connectivity associated with different land uses and topographic changes	Applied	DEM 5m	Precipitation, Surface Runoff, Land Use and Cover, Drainage Length, Slope, Drainage Area	Geomorphological and land use and cover

Table 1 – Cont.

Authors	Model	Definition	Borselli as reference*	Resolution	Applied variables	Group
(Mahoney; Fox; Al Aamery, 2018)	Probability of sediment connectivity	The sediment connectivity model is based on the probabilities of source intersection, sediment detachment, and transport integrated into a hydro-sedimentological modeling framework of watersheds.	Cited	DEM 9m	Precipitation, Surface Runoff, Slope, Drainage Area, Land Use and Cover, Suspended Solids	Geomorphological, hydrological, and sedimentological
(Grauso; Pasanisi; Tebano, 2018)	Simplified Connectivity Index (SCI)	Expresses the potential sediment transfer capacity available in a section of the river.	Cited	DEM 20m	Surface Runoff, Drainage Length, Slope, Drainage Area, Soil Loss	Geomorphological and sedimentological
(Persichillo *et al.*, 2018)	Sediment Connectivity Index (CI)	Analyzed the anthropic effects on landscape modifications from the influence resulting from sediment delivery	Applied	DEM 5m	Precipitation, Surface Runoff, Drainage Length, Slope, Drainage Area, Terrain Roughness, Land Use and Cover	Geomorphological, hydrological, land use and cover, and sedimentological
(Rathburn; Shahverdian; Ryan, 2018)	Resilience Index	Evaluate post-disturbance sediment recovery through resilience		Not Applied	Drainage length, Slope, Drainage Area, Sediment Density, Sediment Cohesion, Soil Loss	Sedimentological
(Zanandrea; Kobiyama; Michel, 2017)	Hydro-sedimentological Connectivity Index (HSCI)	Calculates the degree of connectivity of a slip with the channel	Applied	Not Informed	Precipitation, Antecedent Precipitation, Surface Runoff, Drainage Length, Slope, Drainage Area, Terrain Roughness, Land Use and Cover	Geomorphological and sedimentological
(Coulthard; van de Wiel, 2017)	Landscape evolution model	Use of landscape evolution model to evaluate sediment connectivity		DEM 50m	Precipitation, Surface Runoff, Slope, Drainage Area, Suspended Solids	CAESAR and CAESAR-Lisflood
(Calsamiglia *et al.*, 2017)	Sediment Connectivity Index (CI)	Analyzed soil quality using spatial patterns of hydrological and sedimentary connectivity	Applied	DEM 1m	Precipitation, Surface Runoff, Drainage Length, Slope, Drainage Area, Terrain Roughness, Land Use	Geomorphological, hydrological, land use and cover, and sedimentological

Table 1 – Cont.

Authors	Model	Definition	Borselli as reference*	Resolution	Applied variables	Group
(De Walque *et al.*, 2017)	Logistic regression with Sediment Connectivity Index (CI)	Assessed the risk of muddy flooding with logistic regression and CI as one of the explanatory variables	Applied	DEM 10m	Precipitation, Surface Runoff, Drainage Length, Slope, Drainage Area, Terrain Roughness, Land Use, Suspended Solids, Soil Loss	Geomorphological, hydrological, land use and cover, and sedimentological
(Kalantari *et al.*, 2017)	Sediment Connectivity Index (CI)	Assessed the likelihood of flooding in transport infrastructure from sediment accumulation	Applied	DEM 2m	Precipitation, Antecedent Precipitation, Surface Runoff, Drainage Length, Slope, Drainage Area, Terrain Roughness, Land Use	Geomorphological, hydrological, land use and cover, and sedimentological
(Masselink *et al.*, 2017)	Random Forest Classifier and earth oxide tracer	Assessed sediment connectivity with Random Forest machine learning method		DEM 0.1m	Precipitation, Sediment Granulometry, Soil Loss	Geomorphological, hydrological, land use and cover, and sedimentological
(Bywater-Reyes; Segura; Bladon, 2017)	Least squares regression and Principal Component Analysis	Relevance in natural controls in sediment production		DEM 0.9m	Precipitation, Surface Runoff, Slope, Drainage Area, Soil Loss	Geomorphological, land use and cover, and sedimentological
(Ortíz-Rodríguez; Borselli; Sarocchi, 2017)	Joint Connectivity Index (JCI) and Lateral Hydrological Efficiency Index (LHEI)	Mobilization analysis of pyroclastic sediments Identification of watersheds that provide large amounts of sediment with new index	Applied	DEM 5m	Precipitation, Erosivity, Infiltration Rate, Surface Runoff, Drainage Length, Slope, Drainage Area, Terrain Roughness, Land Use and Cover, Suspended Solids, Soil Loss	Geomorphological, hydrological, land use and cover, and sedimentological

Table 1 – Cont.

Authors	Model	Definition	Borselli as reference*	Resolution	Applied variables	Group
(Lisenby; Fryirs, 2017)	Sediment analysis by field collection	The distribution of the main types of sediment buffers (floodplains, terraces, etc.), barriers (weirs), and effective catchment area was evaluated to characterize the potential of (dis)connectivity of coarse sediments		DEM 1m	Precipitation, Surface Runoff, Drainage Length, Slope, Drainage Area, Terrain Roughness, Land Use and Cover	Geomorphological, land use and cover, and sedimentological
(Gran; Czuba, 2015)	Czuba and Foufoula-Georgiou model	Assessed the behavior of sediment pulses, observing the role of the network structure		DEM 3m	Precipitation, Erosivity, Surface Runoff, Drainage Length, Slope, Drainage Area, Terrain Roughness, Land Use and Cover, Soil Erodibility, Soil Loss	Geomorphological, hydrological, and sedimentological
(Liu; Fu, 2016)	Connectivity indicators	Quantifies the hydro-sedimentological connectivity of a basin using soil erosion and sedimentation model	Cited	DEM 10m	Precipitation, Surface Runoff, Drainage Length, Slope, Drainage Area, Terrain Roughness, Land Use and Cover	Geomorphological and hydrological
(Pechenick *et al.*, 2014)	Multi-scale statistics	Assesses sediment connectivity between rural roads and channels in the basin		Not Informed	Precipitation, Antecedent Precipitation, Slope, Land Use and Cover, Soil Loss	Geomorphological and sedimentological
(Messenzehl; Hoffmann; Dikau, 2014)	Sediment Connectivity Index + Morphometric Index	Morphometric index by geoprocessing, to characterize the connectivity of sediments to the channel	Applied	DEM 2m	Precipitation, Surface Runoff, Drainage Length, Slope, Drainage Area, Terrain Roughness, Land Use and Cover	Geomorphological and land use and cover
(Cavalli *et al.*, 2013)	Sediment Connectivity Index (CI)	Geomorphological approach of sediment connectivity concerning debris flows	Applied	DEM 2.5m	Drainage Length, Slope, Drainage Area, Terrain Roughness, Land Use and Cpver, Soil Loss	Geomorphological

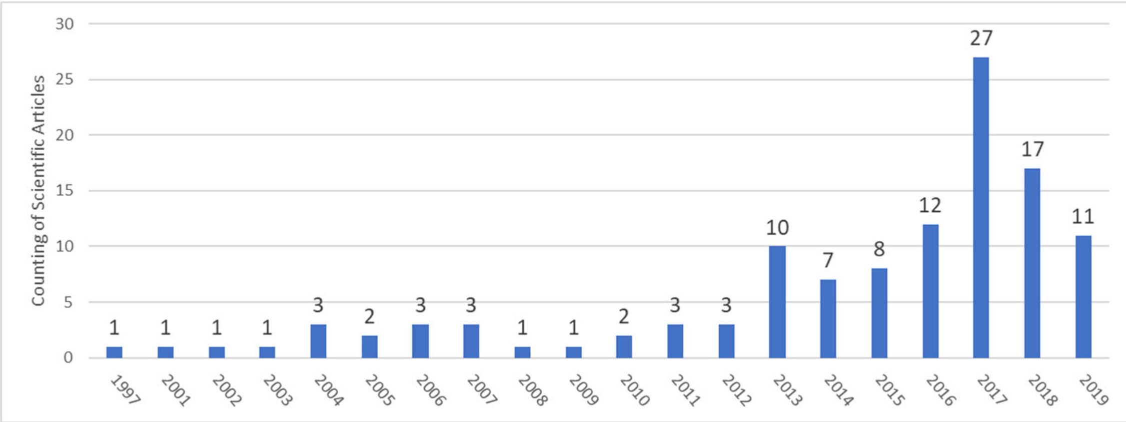
Table 1 – Cont.

Authors	Model	Definition	Borselli as reference*	Resolution	Applied variables	Group
(Baartman *et al.*, 2013)	Indices of morphological complexity and connectivity of sediments	Assessed relationships between landscape complexity and basin connectivity		DEM 30m	Precipitation, Erosivity, Infiltration Rate, Drainage Length, Slope, Drainage Area, Terrain Roughness, Land Use and Cover	Geomorphological and hydrological
(Croke; Fryirs; Thompson, 2013)	Connectivity channel/ floodplain system	Assessed water and sediment connectivity of the channel/ floodplain system	Cited	DEM 1m	Precipitation, Surface Runoff, Drainage Length, Slope, Drainage Area, Terrain Roughness, Land Use and Cover, Soil Loss	Geomorphological and hydrological
(Tobias; Wolfgang, 2013)	Spatial graph	Assessed the connectivity of sediment sources and their accumulation	Cited	DEM 1m	Precipitation, Surface Runoff, Drainage Length, Slope, Drainage Area, Terrain Roughness, Land Use and Cover	Geomorphological
(Duvert *et al.*, 2011)	Hydro-sedimentological monitoring	Evaluated the connectivity between sediment transfer rates and base flow		DEM 10m	Precipitation, Surface Runoff, Slope, Drainage Area, Land Use and Cover, Suspended Solids, Soil Loss	Geomorphological, hydrological, and sedimentological
(Borselli; Cassi; Torri, 2008)	Field Connectivity Index (FCI)	They depend on the intensities of events that occurred locally and that left visible signs	Applied	DEM 5m	Precipitation, Surface Runoff, Erosivity, Drainage Length, Slope, Drainage Area	Geomorphological and land use and cover
(Borselli; Cassi; Torri, 2008)	Sediment Connectivity Index (CI)	Identified potential connectivity representation based on landscape features	Applied	DEM 5m	Precipitation, Surface Runoff, Erosivity, Drainage Length, Slope, Drainage Area	Geomorphological and land use and cover
(Fryirs *et al.*, 2007)	Conceptual model	Assessed the connectivity of the sediment chain in the watershed		Not Informed	Precipitation, Course Length, Slope, Drainage Area, Sediment Density, Sediment Granulometry, Soil Loss	Geomorphological

Source – prepared by the authors.

*When the column "Borselli as reference" is blank, the model has not been applied or cited by the authors.

Figure 1 – Evolution of scientific production for sediment connectivity.



Source – prepared by the authors.

Table 2 – Proportion of applications of the variables in the evaluated studies

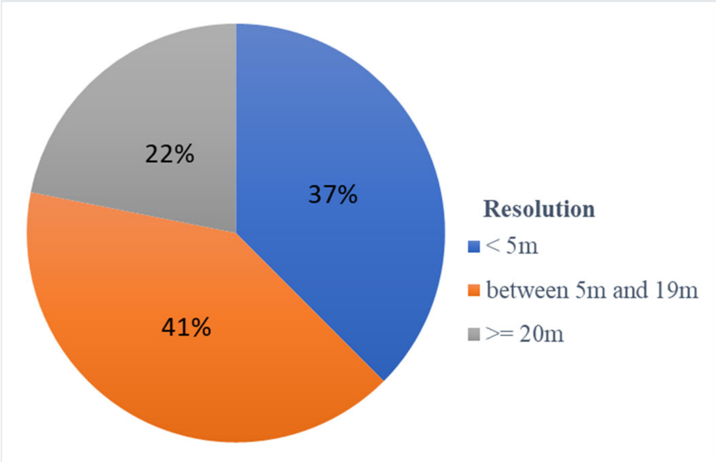
Group	Parameter	Proportion of applications
Hydrological	Land Use and Cover	77%
	Precipitation	91%
	Erosivity	20%
	Antecedent Precipitation	11%
	Surface Runoff	80%
Geomorpholo-gical	Ramp Length	74%
	Slope	97%
	Drainage Area	91%
	Terrain Roughness	51%
Sedimentological	Sediment Density	6%
	Erodibility	6%
	Sediment Granulometry	6%
	Sediment Cohesion	6%
	Suspended Solids	17%
	Soil Loss	40%

Source – prepared by the authors.

Due to the great use of DEM in the applications, we highlighted the resolutions of the images used in the modeling. The use of images with spatial resolution above 5m was observed in most articles, as shown in Figure 2.

Among the articles that used surface roughness, 60% applied tabulated values, either by Manning's coefficient, *C* factor, or slope variation. The remainder (40%) used calculations based on residual topography with satellite imagery. Among the studies that applied a table of values for roughness, 73% used Manning's coefficient. Only 10% of the studies employed roughness based on land use and cover with tabulated data. Considering the high proportion of roughness

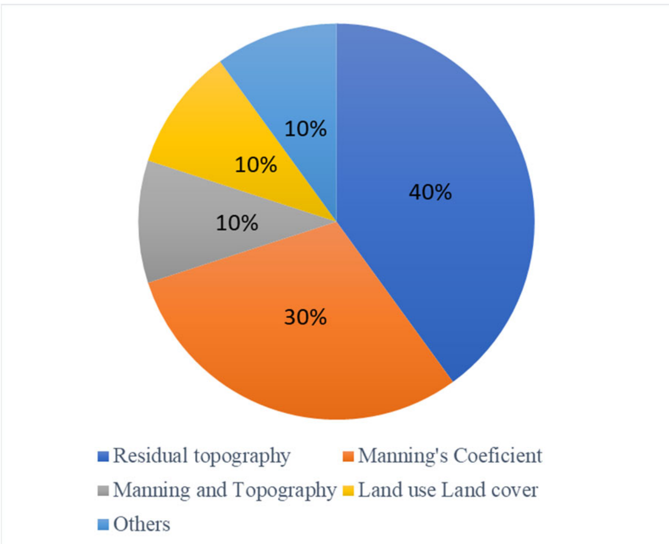
Figure 2 – Range of image resolutions applied in the articles.



Source – prepared by the authors (2023).

variables employed (91%), this variable draws attention to the value and different forms of use (tabulated or calculated). Although Manning's coefficient is well-consolidated data in the articles, it is noteworthy that tabulated values may not reflect the reality of the areas, which may suggest studies to compare the use of roughness in its two forms of application (tabulated or calculated). Only one article employed the SWAT model application's integration with land use and cover, slope, and soil type data; however, it was used with secondary data (Mishra *et al.*, 2019). Furthermore, the authors analyzed the influence of slope variation only related to watercourses and not the basin. Based on the articles evaluated, Figure 3 presents the distribution of the methods applied to use roughness.

Figure 3 – Methods applied for roughness.



Source – prepared by the authors.

Conclusions

Given the observations in the analyzed references, the authors converge to a consensus that sedimentological connectivity is a complex term where diversity, correlations between parameters, and the dynamics of sediments in a region can be the main obstacles in developing sedimentological connectivity models. Thus, the literature agrees that the evidence in the processes of sedimentological connectivity is limited and that there are still several gaps to be filled, such as using more parameters of functional elements or improving the representation of surface roughness. In addition to these limiting points, research tends to focus more on the structural component than on the functional component. Thus, it opens opportunities for future research to employ the variables of this component.

Despite the great potential of employing sedimentological connectivity associated with slope – which holds significant importance in connectivity processes – a more careful analysis of the relation between the variation of slopes and its influence over connectivity was not observed.

The use of geomorphological data, especially based on digital elevation models, is well consolidated in the literature, with the quality of the results standing out due to the spatial resolutions of the images. Therefore, these data can be better used and enhanced with drone imaging and more accurate photogrammetric processes, especially with those presenting smaller pixel sizes, reaching up to 0.05 m. Nevertheless, evaluating the current computational capacity limitations and feasibility in terms of processing time is important.

Only 12% of the articles studied applied these parameters when sedimentological parameters were observed. Notably, the parameters corresponding to density and cohesion were little used in the models, which does not eliminate their significance. Thus, searching for new models focusing on sedimentological parameters will open paths for future observations and a better understanding of sediment dynamics.

With a significant amount of parameters applied in the models, none of the studies discussed the relative importance of each one in the proper models. Important information that can direct future research better to understand the processes of the most sensitive variables.

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Warlen Librelon de Oliveira: Selection and analysis of the models found in the references and construction of Table 1; definition of the methodology; development of the results and discussions based on the selected models; review and contribution in the introduction; writing part of the conclusions.
Marcelo Antonio Nero: Search for references for analysis and reading, according to the necessary filters for the article's objective; write the introduction from the bibliographic survey; review the table with the analyzed models; review the discussion of the results; write part of the conclusions.
Diego Rodrigues Macedo: Search for references for analysis and reading according to the necessary filters for the article's objective; review the table with the analyzed models; review the discussion of the results; and write part of the conclusions.

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