



ISSN:1984-2295

Revista Brasileira de Geografia Física

Homepage: <https://periodicos.ufpe.br/revistas/rbgfe>



Spatialized Model of Susceptibility to Erosion Risk in a Energy Transmission Line in the Cerrado Biome

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Artigo submetido em 02/01/2023 e aceito em 05/06/2023

ABSTRACT

The installation of Transmission Lines (TL) provokes disturbances in the environment, which reacts in different ways. The suppression of vegetation, even when limited to what is necessary for the execution of the project, may cause erosive processes. Spatialized inputs have made the monitoring of large portions of land viable. Data from the GPM (*Global Precipitation Measurement*) constellation allows access to rainfall data even in areas which do not have pluviometric stations. Also by satellite, the landscape can be represented with SRTM (*Shuttle Radar Topography Mission*) images. Similarly, maps of soil erodibility and land use, necessary together so that the diagnostics methodology on the risk of erosion can be obtained. Therefore, a logic is methodologically developed in which freely obtained input data follow a conceptual model, which defines the variables and their relationships in the potential issue's context, while having replication accessibility in mind. Of the 43 gaps present in the pilot tracing located in Minas Gerais, Brazil, four of them received the "likely" risk of erosion classification in a period without record of any meaningful rainfall. The methodology mirrors an evaluation which increases the risk as long as the rains occur.

Keywords: Geotechnology; Susceptibility, Erosion, Map Algebra, Hierarchic Analysis.

Modelo Espacializado de Suscetibilidade ao Risco à Erosão em uma Linha de Transmissão de Energia no Bioma Cerrado

RESUMO

A instalação de Linhas de transmissão (LT) provoca perturbações no ambiente, que reage de diferentes formas. A supressão de vegetação, ainda que limitada ao necessário para execução do projeto, pode desencadear processos erosivos. Insumos espacializados têm tornado viável o acompanhamento de grandes extensões de terra. Dados da constelação GPM (*Global Precipitation Measurement*) permitem acessar dados de chuva mesmo em áreas onde não se dispõe de estações pluviométricas. Também por satélite, o relevo pode ser representado a partir imagens SRTM (*Shuttle Radar Topography Mission*). Com a mesma premissa, obtém-se os mapas de erodibilidade do solo e de uso da terra, necessários para em conjunto, sugerir o diagnóstico de suscetibilidade ao risco de erosão. Com esta finalidade, desenvolveu-se metodologicamente uma lógica em que os dados de entrada são obtidos gratuitamente atendendo um modelo conceitual, que define as variáveis e suas relações frente ao potencial problema, com vistas a uma acessível replicação. Dos 43 vãos presentes no traçado piloto localizado em Minas Gerais, Brasil, quatro deles receberam a classificação "possível" de risco à erosão em período sem registro significativo de chuva. A metodologia espelha uma avaliação que potencializará o risco à medida que chuvas ocorram.

Palavras-chave: Geotecnologia, Suscetibilidade, Erosão, Álgebra de mapa, Análise hierárquica.

Introduction

Tracing a power Transmission Line (TL) constitutes physical structures composed by towers and cables that runs through different landscapes, in long distances.

Along the TL usually occurs an expressive variation of the natural conditions of the land (Li et al., 2021b), with different types of soil, relief forms and vegetation species that respond differently to this impact (Li et al., 2021b).

In spite of depending on natural factors, such as rainfall intensity and soil fragility (Kulimushi et al., 2021), human activities, through infrastructure works, can accelerate the erosion process (Serbaji et al., 2023).

In this context, the installation of a TL impacts the environment (Chunxia et al., 2021), being able to quote the triggering of erosive processes (Oliveira et al., 2021).

In Brazil, the Technical Norm NBR 5422 (ABNT, 1985) states that there must be a minimum vegetal suppression during the project and execution phases. Nevertheless, the vegetation cut-out can be total or partial, which predisposes the soil surface to erosion.

In order to preventively act on the erosive hotspots, the monitoring of traditional field starts being a waste of labor and material resources (Fan et al., 2021).

This way, applying techniques of remote sensing in order to obtain geographic data may contribute and ease the monitoring of erosion risk.

The acquisition of inputs in this way expands the possibilities and has become viable in smaller scale demands (Bagwan and Gavali, 2021), applicable in the long stretches of a TL.

Scenario simulation models have been used as an alternative to assess the risk of soil erosion in areas that require constant monitoring. By preserving little input data, the models can contribute to wide application in areas exposed to erosion (Lense et al., 2021).

There is a consensus that some conditions are considered essential for determining soil loss at an international level, namely: rainfall erosivity; soil erodibility; slope length; degree of slope; land use and management; and conservation practice.

These factors were organized in an empirical model developed by Wischmeier and Smith (1978) called *Universal Soil Loss Equation* (USLE).

Silva et al. (1997) point out that obtaining data for the application of the USLE is extremely time consuming, and depends on precipitation data determined in the field, recorded in pluviographs, which in many places do not exist.

For Serbaji et al. (2023), even when presented, the spatialized thematic data are often outdated or incomplete.

Based on this assumption, other ways are sought to obtain the factors that influence the triggering of erosion.

According to Sinshaw et al. (2021b), the Remote Sensing and the Geographic Information System (GIS) have great potential for mapping parameters that influence the soil erosion and degraded areas.

For Rodrigues and Peixoto (2022), maintaining the monitoring of erosions allows prevention of bigger problems that are caused by them.

Considering this, the following hypothesis is formulated: an empirical modeling with few input requirements, essentially obtained by spatialized processes and by means of remote sensors, can point out areas at risk of erosion along the TLs with a high update rate, facilitating the management of energy assets in this regard.

In this proposition, free acquisition options are presented as an input for the erosion risk model, combining greater frequency of registration and dynamic updating.

In this case, the base for the construction of the methodology of susceptibility to risk of erosion along the TLs depends on data from sensor satellites and imagers.

Having free data, even if acquired remotely, represents gains beyond erosion control along the TLs.

It establishes the expansion of the application of science by the global reach/supply of data – specifically those related to rainfall volumes – the main erosive agent.

The methodological principle of the research seeks to explore new forms of data acquisition – free and based on remote sensing organized in a simplified model, supported by multicriteria and hierarchical methods to subsidize a model of susceptibility to the risk of erosion of facilitated replication.

This study aims to: establish a model that identifies the risk of erosion due to static and dynamic factors, as recorded to data in analysis and allow concessionaires to promptly identify the areas that are exposed to any risk of erosion, enabling action planning.

Material and methods

The pilot Transmission Line for this research is about 16 km long, operates in 138 kV and is located in the northwest of the state of Minas

Gerais, near the border with the state of Goiás (Figure 1).

On the traced mark, which is entirely in the Cerrado biome, there are 43 towers distributed

between the Mata Velha Substation and the Unai Baixo Substation. The entire structure and power distribution is the responsibility of the Companhia Paulista de Força e Luz - CPFL.

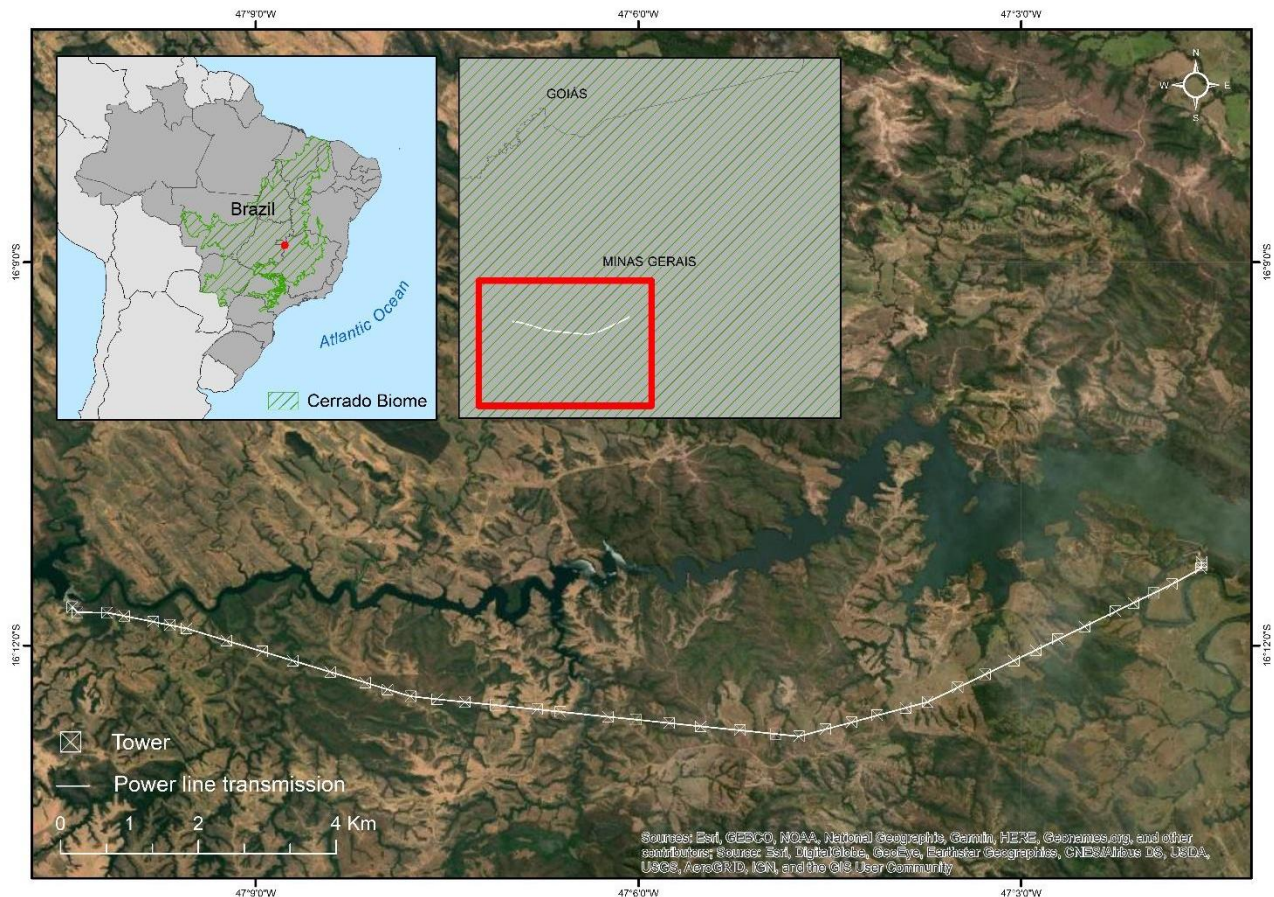


Figure 1. Map of location of Mata Velha TL
Source: Authors, 2022.

The Cerrado biome has a great rainfall diversity and the accentuated seasonality, characterized by a dry season, affects the water availability in this region (Algarve et al., 2022).

The drought lasts for five months, between May and September. The rainy season lasts for seven months, from October to April, concentrating just over 90% of the accumulated annual precipitation (Rocha and Nascimento, 2021).

According to Silva et al. (1997), the frontal rains occur from December to February. In the other months of the rainy season (October, November, March and April) convective rains mainly occur, with isolated rains predominating (Dedecek, 1988).

Even though they may occur during winter – the full dry period, the rains are so insignificant that they can be disregarded in the context of erosion risk. It so happens that the dry period that

precedes the rains also contributes to the development of erosion.

As the lack of moisture causes the soil to dry out, it favors the detachment of particles with the impact of raindrops, facilitating the carry-over in the rainy season (Guerra, 2012).

It becomes evident that the particularities of the biome require even more attention when elaborating a proposition involving large works in large areas.

For Sinshaw et al. (2021a), decision making from multicriteria analysis that are supported by spatialized data has been a differential concerning the management of natural resources.

Thus, as inputs to the model, matrix-type files were used, in the form of information plans worked in a GIS environment.

In the erosion risk prediction methodology, the following factors were considered: rainfall in

the last 2 hours; accumulated rainfall; soil erodibility; land use; and land topography.

Precipitation data were obtained by sensors from the GPM (*Global Precipitation Measurement*) satellite, which are administered by NASA (*National Aeronautics and Space Administration*), to monitor and record rainfall volumes in millimeters (mm).

The rainfall pattern was considered as a dynamic factor in the research, being divided into two factors: recent rainfall (2 h) fundamental to build the erosion potential in near-real time, and

accumulated rainfall (24 h, 96 h, 360 h), to express soil water saturation.

Each class of each factor received a value called “weight”. Lower weights represent classes with less susceptibility to erosion, while higher weights represent classes with greater susceptibility to erosion for each of the considered factors.

The empirical attribution of weights was suggested by those involved in the research, based on theoretical and technical knowledge. For recent rainfall, the assigned weights are as described in Table 1.

Table 1. Weight attributed to the factor of Recent Rainfall

Volume of Rainfall in 2 hours	Weight
< 10 mm	0
Between 10 and 20 mm	21
Between 20 and 40 mm	34
Between 40 and 70 mm	55
Between 70 and 110 mm	89
> 110 mm	144

Source: Authors, 2022.

For the recent rainfall factor, it was necessary to correlate the weights with the volumes observed in 2 hours.

In this case, rainfall less than 10 mm in this interval was considered null, since Silva et al. (1997), in studies carried out in the Cerrado,

concluded that it was a volume without erosion potential.

The same non-erosive condition was projected for the other volumes in the other variables involving precipitation.

For accumulated rainfall, the assigned weights are as described in Table 2.

Table 2. Weight attributed to the factor of Accumulated Rainfall

Accumulated 24 hours	Weight	Accumulated 96 hours	Weight	Accumulated 360 hours	Weight
< 10mm	0	< 40 mm	0	< 70 mm	0
Between 10 and 25 mm	5	Between 40 and 60 mm	3	Between 70 and 140 mm	2
Between 25 and 40 mm	8	Between 60 and 90 mm	5	Between 140 and 210 mm	3
Between 40 and 55 mm	13	Between 90 and 140 mm	8	Between 210 and 280 mm	5
Between 55 and 85 mm	21	Between 140 and 200 mm	13	Between 280 and 350 mm	8
Between 85 and 115 mm	34	> 200 mm	21	> 350 mm	13
Between 115 and 150 mm	55				
> 150 mm	89				

Source: Authors, 2022.

The Map of Soil Erodibility to Hydric Erosion of Brazil, elaborated by Embrapa, was used to include the static data in the methodology. The file is available in the scale 1:250.000 in

vetorial format and was converted to matrix format, respecting the product's original classes and Figure 2 presents the product with the classes mapped to the area of interest.

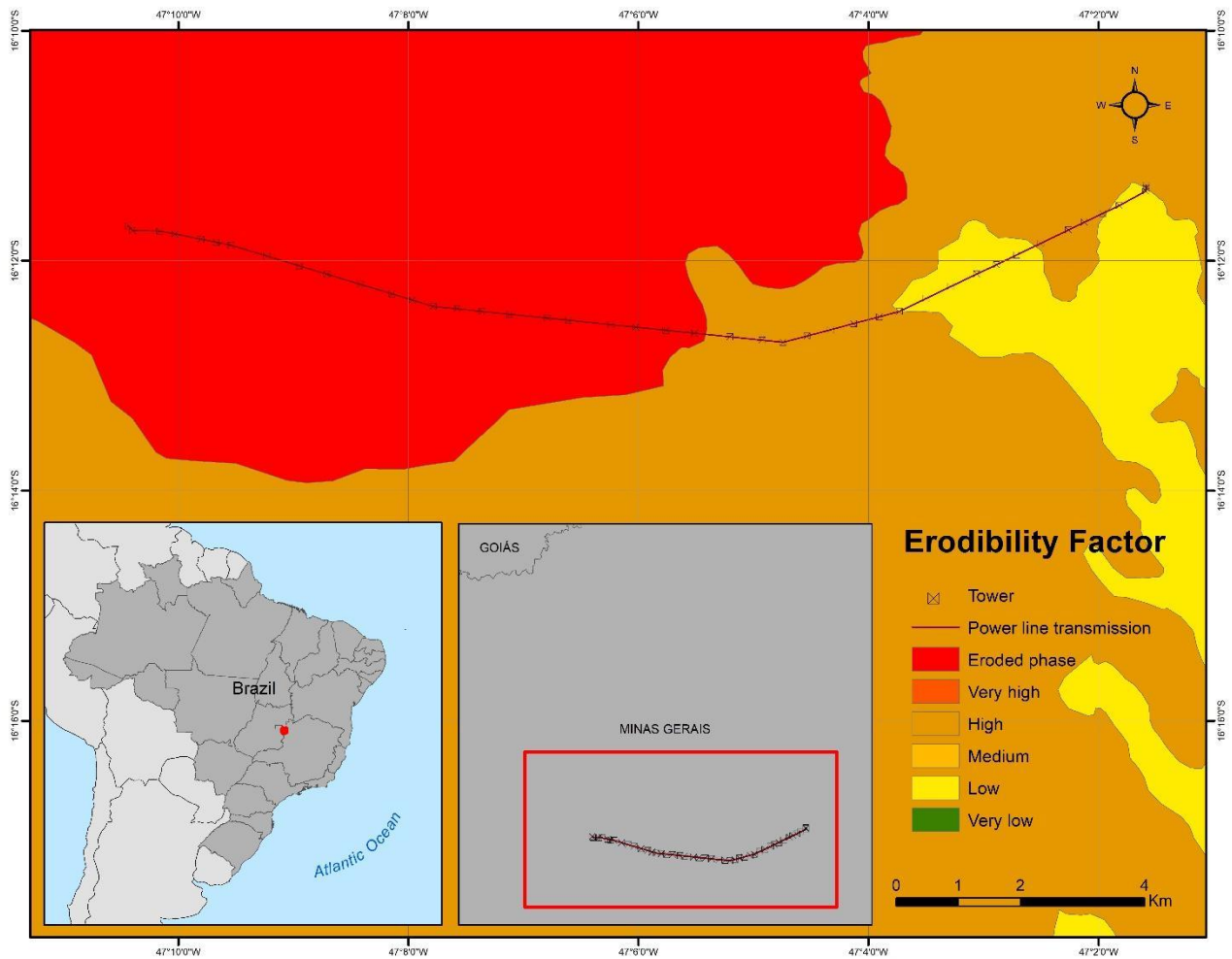


Figure 2. Map of Erodibility produced by Embrapa (2020) – clipping of area of interest
Source: Embrapa, 2020, elaborated and adapted by the Authors, 2022.

Considering the classes of the mapping, the weight attributed to this factor is detailed in Table 3.

Table 3. Weight attributed to the factor Erodibility proposed in the methodology.

Erodibility	Weight
Very low	5
Low	8
Medium	13
High	21
Very high	34
Eroded phase	55

Source: Authors, 2022 adapted from Embrapa, 2020

According to Embrapa (2020) this mapping is based on the interpretation of the soils

in the Soil Map units elaborated by the IBGE (Brazilian Institute of Geography and Statistics).

In the erodibility factor, the lowest weight was attributed to the class called “Very low erodibility” by Embrapa, that is, more resistant to the triggering of an erosion process. At the other extreme, the highest weight (55) was assigned to the “Eroded phase” class, where, according to Embrapa, there are already erosions.

Concerning the use and cover of the land, the mapping previous to the Initiative MapBiomass (Collection 6) was used, which classifies the national territory from Landsat images with spatial resolution of 30 meters.

The map establishes natural and anthropic classes that were mapped for application in scale of up to 1:100.000 already in matrix format. Figure 3 presents classes mapped to the area of interest.

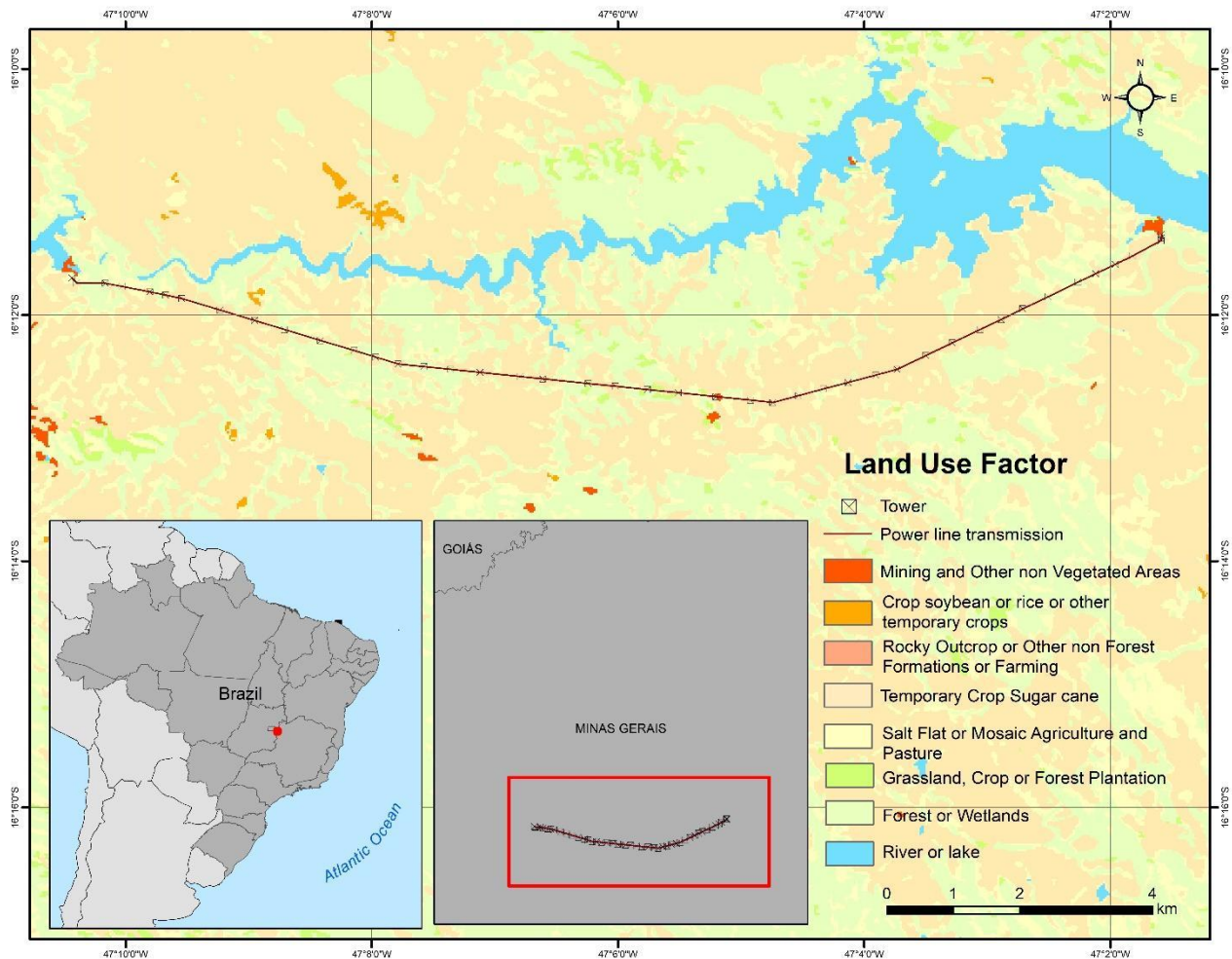


Figure 3. Map of land cover produced by MapBiomias – clipping of area of interest

Source: MapBiomias, 2021, elaborated and adapted by the Authors, 2022.

In the case of this factor, the classes determined by MapBiomias were grouped according to the susceptibility they represented.

The more protected the land, as is the case of areas already flooded or vegetated with forests, the lower the weight assigned. At the other end, the most unprotected classes received the greatest weight, as they are more susceptible to erosion.

The grouping of classes was carried out by similarity in the susceptibility assessment and so that the number of classes of other factors would not be extrapolated.

Table 4 presents the classes and their respective assigned weights. The lowest weight for this factor was 3, the highest being 55.

Table 4. Weight attributed to the factor Land use proposed in the methodology.

Land use	Weight
Forest or flooded field or swampy areas	3
Rural formation or perennial plantation or forestry	5
Apicum or mosaic of agriculture and pasture	8
Sugarcane plantation	13
Rocky flowering or other non-forest formations or farming	21
Soy plantation or rice plantation or other temporary plantations	34
Mining and other non-vegetated areas	55

Source: Authors, 2022, adapted from MapBiomias, 2021.

In order to obtain relief data DML (Digital Terrain Model) was used, generated through

SRTM (*Shuttle Radar Topography Mission*) imaging.

The DML was fit to elaborate the map of slope and to delimit the hydrographic basin and the drainage of the area of interest.

The results obtained by the equations performed on the matrix products, according to the methodology of Bertoni and Lombardi Neto (2008) are shown in Figure 4.

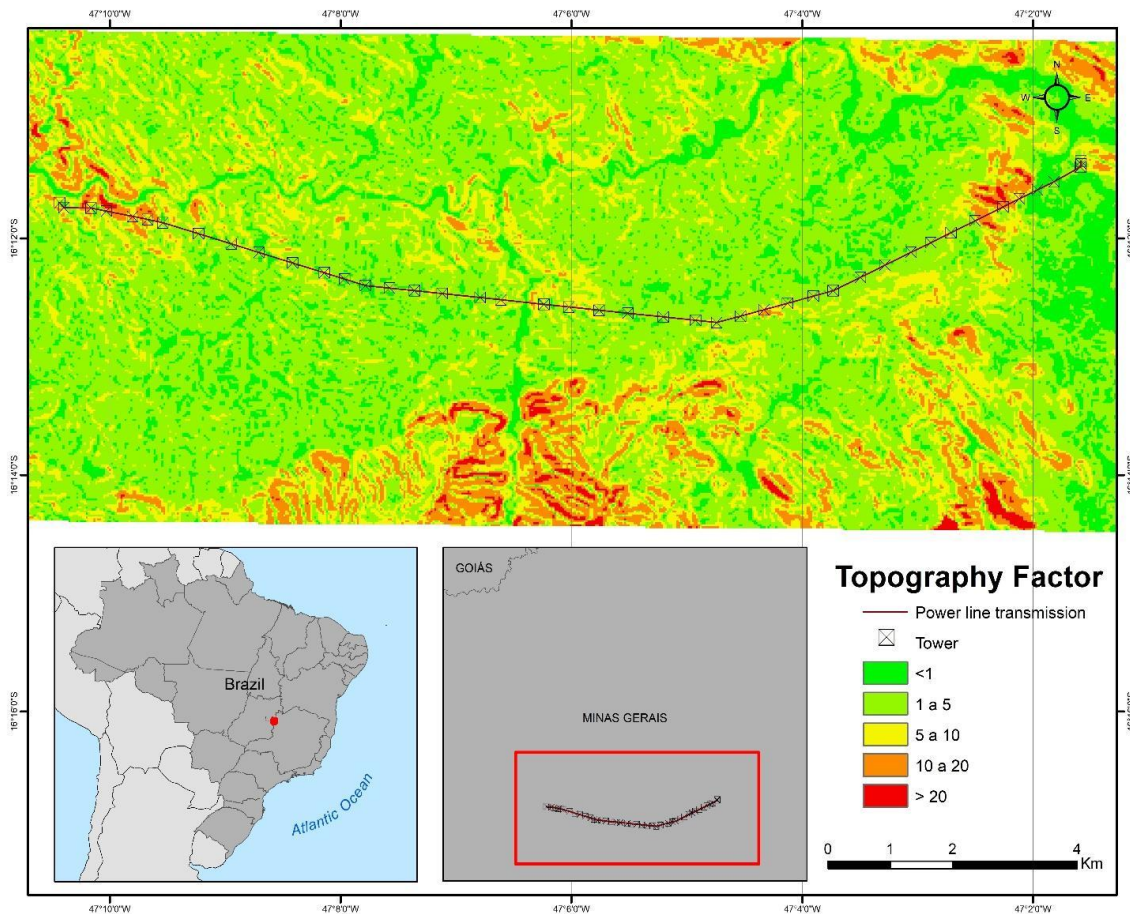


Figure 4. Map of the topography factor – clipping of the area of interest

Source: Methodology of Bertoni and Lombardi (2008) elaborated and adapted by the Authors, 2022.

The methodology proposed by the authors assigns dimensionless values to represent the topography of a given area.

These dimensionless values are obtained through equations performed with the products resulting from the processing of SRTM images and were grouped according to the proposal of the cited authors. Table 5 presents the classes and the respective weights adopted for this factor, following the recommendation of Bertoni and Lombardi (2008).

Table 5. Weight attributed to the Topography factor

Topography	Weight
< 1	1
1 to 5	2
5 to 10	3
10 to 20	5
> 20	8

All numerical values for the weights of all proposed factors were defined from the Fibonacci sequence, which starts at 1, goes to 2, the next value being the result of the sum of the last two, in this case 3, being the next 5 (resulting from the sum of 2 and 3), and so on. Weight 0 was assigned to null classes from the point of view of erosion risk.

The weights of this sequence were used differently for each of the factors, that is, not all of them started from weight 1.

An empirical logic which assumed that the lowest degree of risk to erosion of a given factor may be more relevant than the class with the lowest degree of risk of another was followed.

The steps taken were based mainly on the ESRI ArcMap version 10.5.1 program. The *ArcToolBox Reclassify* tool allowed the established weights to be linked to the pixels of the respective matrix files.

The R platform was also used to convert the IMERG data provided by the GPM via programming language, which comes in RT-H5 format. This format is not easily read in ArcMap and therefore it was necessary to convert it to .GeoTIFF format.

The QGIS program was also used for processing the topography factor due to its ease of execution in some computational routines.

All matrix files were cut according to the area of interest to optimize the response time of the processes carried out.

With the respective weights attributed to the *pixels* of the matrix files, a way was sought to represent how they relate to each other, since a certain land use, for example, can impact the erodibility of soils (Dedecek, 1989), making it clear the non-uniform representativeness between these factors for triggering erosions.

This condition can be expressed in the form of a hierarchy, where the most relevant factors stand out in values instead of those that alone are not determinant to establish the degradation.

In this case, it is assumed that in addition to rainfall volumes, soil cover is essential to accelerate or minimize the effects of erosion on the soil (Devátý *et al.*, 2019; Lense *et al.*, 2021), therefore attention should be paid to the construction of the methodology so that both are preponderant to some degree in relation to the others.

To express this relationship of importance, hierarchical values defined by the *Analytic Hierarchy Process* (AHP) were applied. This is an important method to determine the weight of certain variables because it is a subjective assessment (Chen *et al.*, 2021).

The Land Use factor was considered the most representative, with 34% of importance in the model, since it is understood that the coverage

conditions are determinant for the risk, both for practically canceling the erosive effect when it is a densely vegetated area, and for accelerating the dynamics in cases of absence of vegetation cover.

The Rainfall factor had 29% of importance, followed by the Accumulated rainfall factor with 15%. With less representativeness, the factors Erodibility and Topography were considered, with 11% each.

It is important to consider that the Accumulated rainfall factor is composed of three variables (24 h, 96 h and 360 h), which were assigned previous hierarchical values to classify the importance between them, respectively 74%, 20% and 6%.

These values were multiplied in the matrix file of each variable and then, after being added, they formed a single product that represents the Accumulated rainfall factor.

When obtained a single matrix file for the Accumulated rainfall factor, it is ready to receive the hierarchy determined in the set (11%).

The algebraic processes were carried out using the *Raster Calculator* tool of the ArcMap program version 10.5.1, using the multiplication operators to relate the hierarchical value, and the sum to congregate the layers of each factor.

Once these steps are completed: acquisition of files, application of weights, algebraic processing with the AHP hierarchy and summation between the final layers, a single product is obtained.

The details of the applied methodology are shown in Figure 5.

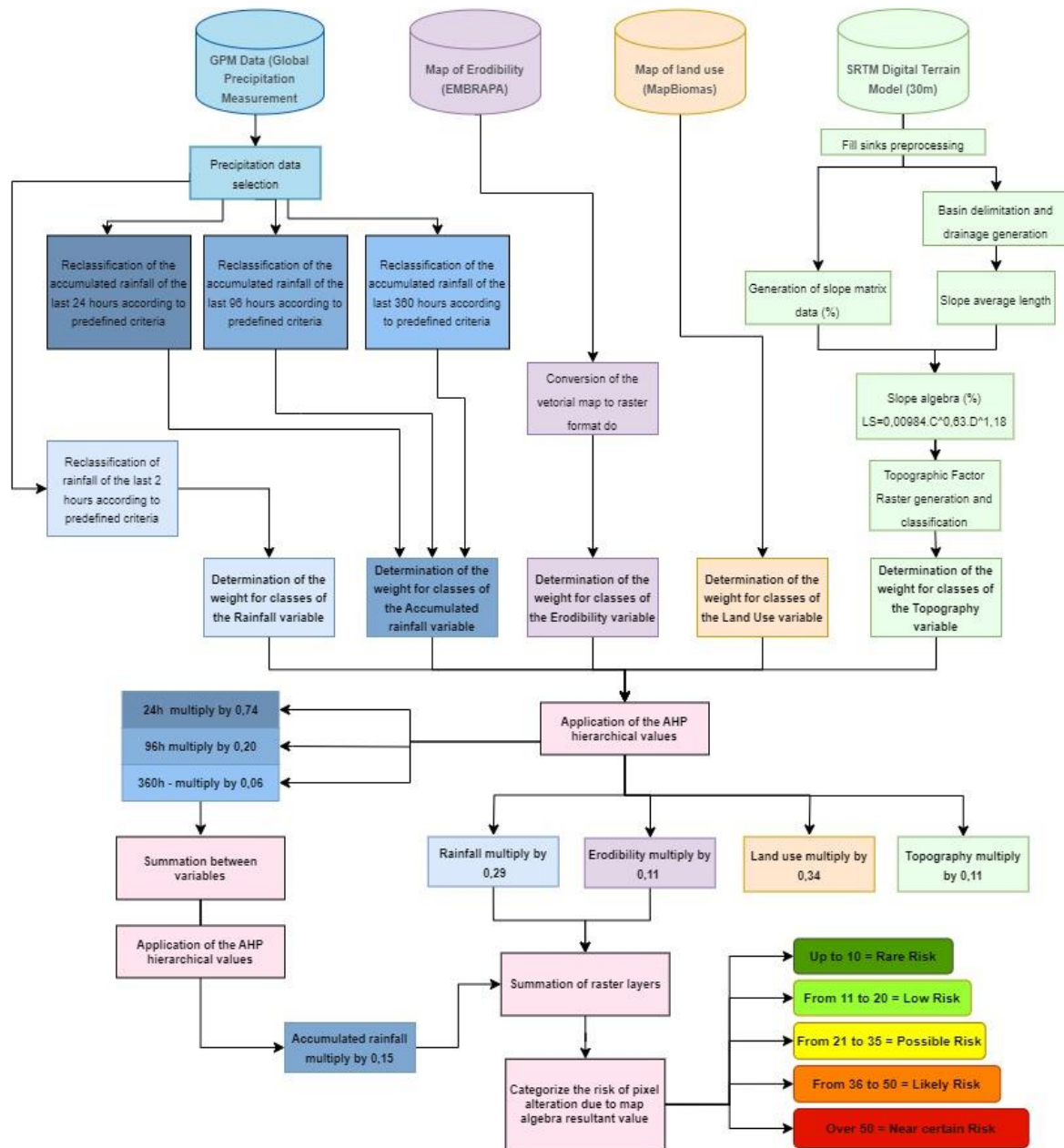


Figure 5. Flowchart with phases of the proposed methodology for the final classification of risk
Source: Authors, 2022.

Since it is a model applied to the layout of Transmission Lines, this classification was serialized by gap, whose length is variable and makes up the area of influence of each two towers, extrapolating the width beyond the cables and towers.

Thus, even if a lower risk predominates over a gap, if there is a certain location in this gap with a higher risk, this greater risk is assumed throughout the gap.

Pixel values ≤ 10 indicate areas with rare risk for the development of an erosion process. Low risk is set to pixel values between 11 and 20.

The possible risk is assigned for pixel values between 21 and 35. Likely risk corresponds

to the range of pixel values between 36 and 50, and almost certain risk is determined by pixel values > 50 .

Results

The final product achieved represents the susceptibility to erosion risk along the pilot tracing and is shown in Figure 6.

The result corresponds to the time 7:00' on April 6, 2022, considering the arrangement of static factors recorded in the period between 5:00' and 7:00' on April 6, 2022 (for the 2 h rainfall factor in this case), for the area of interest.

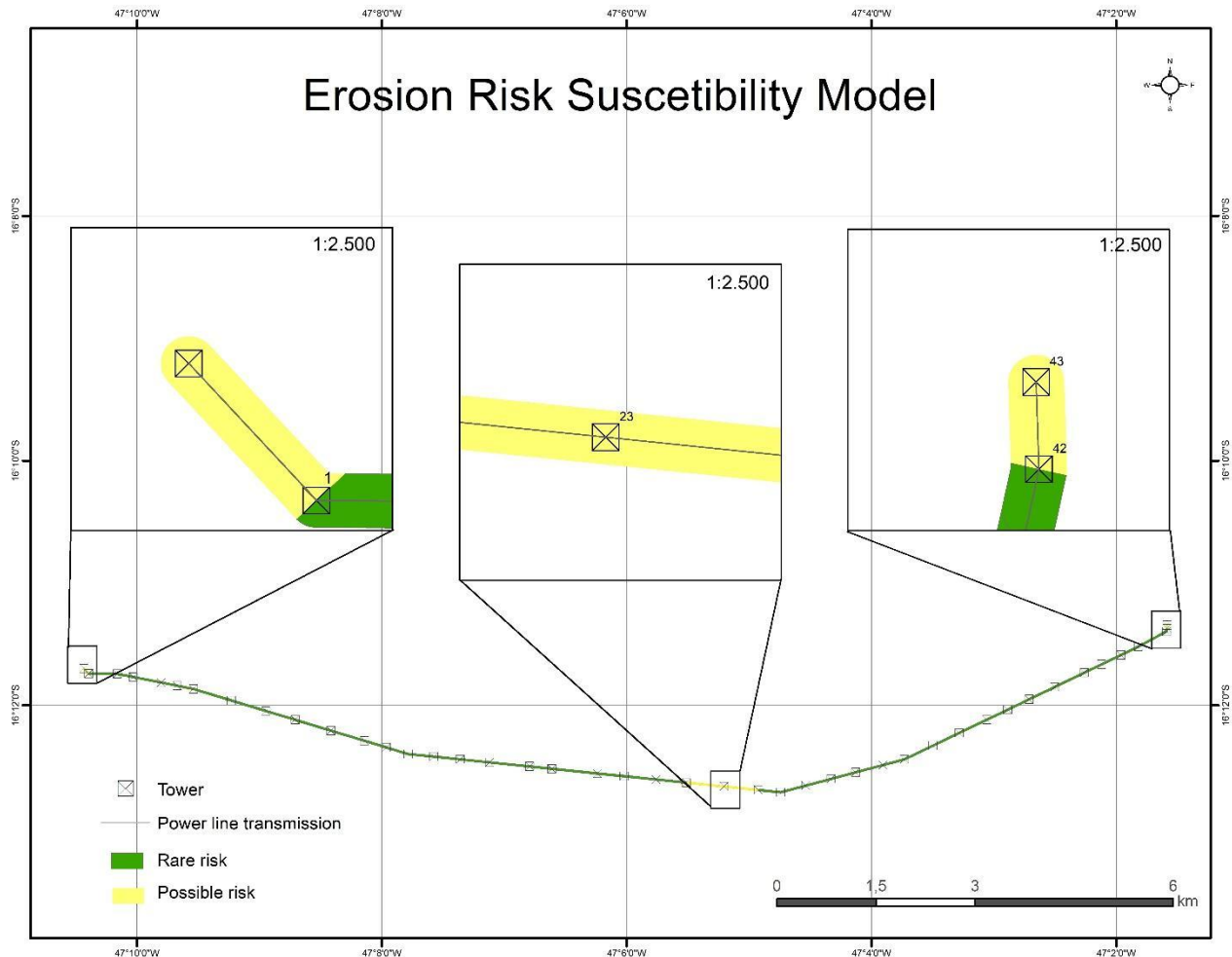


Figure 6. Map of risk of soil erosion. The three highlights present the areas with “possible” risk
Source: Authors, 2022.

In the green areas, the pixel value is ≤ 10 , which represents a rare erosion risk. According to the methodology used, 39 gaps were classified at this risk level, identified with the green color in Figure 6.

In the yellow areas, the pixel value is between 21 and 35, which indicates a possible erosion risk. This risk level was identified in four spans, highlighted in yellow in Figure 6.

In the yellow areas, the pixel value is between 21 and 35, which indicates a possible

erosion risk. This risk level was identified in four gaps, highlighted in yellow in Figure 6.

The colors follow the palette established in the methodology, as shown in Figure 5, and the linguistic risk terms are those used by the company responsible for the pilot route.

In Figure 7, the four gaps of possible risk (indicated by the lines) and their respective weights for each factor (discriminated in the columns) are detailed, mirroring the Table of attributes of the final generated file.

Tower	id	Rain 2h	24h	96h	360h	Erodibility	Land Use	Topography	Final Value	Risk
1	{8BED9247-2DB8-489D-8CC8-090C944F7837}	0	0	0	0	55	55	2	25	Possible
23	{F53B8DFF-317D-48A0-8AC5-5399631464F2}	0	0	0	0	21	55	2	21	Possible
24	{F53B8DFF-317D-48A0-8AC5-5399631464F2}	0	0	0	0	21	55	2	21	Possible
43	{D4EF30B7-0428-43C4-9B0D-E9E734A91A35}	0	0	0	0	21	55	2	21	Possible

Figure 7. Excerpt of the table of attributes with the weight attributed to the gaps that are classified with possible risk of erosion
Source: Authors, 2022.

Since this is a result generated at a time when no volume of valid rainfall (above 10 mm) was recorded between 5:00 am and 7:00 am on April 6, 2022, and no valid volume was

accumulated in the 24 h, 96 h and 360 h before the analysis (above 10, 40 and 70 mm, respectively), the assigned weight was 0 (zero) for the dynamic variables.

In this case, the soil erosion risk values for the entire Mata Velha TL will be the same as those illustrated in Figure 6, throughout the entire time when no rain is recorded, as it mirrors the static conditions of the area of interest.

In gap 1, a weight of 55 was assumed for the Erodibility factor because it is an area mapped as an eroded phase.

Regarding the Land use factor, there were areas classified with weight 8 and 55 along this gap, respectively the vegetated areas (mosaic pasture/agriculture) and non-vegetated areas, prevailing the highest weight (55) for all gap 1.

For the Topography factor, there were also two weights (1 and 2) along gap 1, the largest of which also prevailed. Thus, when adding the weights, applying the established AHP hierarchy, the value 25 was obtained, which corresponds to the “possible” risk of erosion according to the risk classification adopted, shown in Figure 6.

The absence of vegetation cover (“other non-vegetated areas”) and the Erodibility factor areas with “eroded phase”, justify the risk indicated for gap 1.

Gaps 23 and 24 were also classified as “Possible” risk for erosion (Figure 3). As it is the same period for the analysis, the weights of the dynamic variables (rainfall) added up to 0 (zero).

For static factors, regarding Erodibility, both gaps were classified as “high” (weight 21) and regarding Land Use, they were located in a small area classified as “other non-vegetated areas” (weight 55).

Regarding the Topography factor, both gaps have areas with weight 1 and 2, with weight 2 prevailing. Applying the AHP hierarchy, the value 21 was obtained for the gaps 23 and 24, framing them equally at “possible” risk for water erosion.

In gap 43, also framed as a “possible” risk of erosion, the Erodibility factor had two classifications, respectively “low” and “high” (weight 8 and 21), with weight 21 prevailing throughout the gap.

The Land use factor recorded part of the gap with “agriculture and pasture mosaic”, weight 8 and “other non-vegetated areas”, weight 55, with the highest weight prevailing.

For the Topography factor, weight 2 was attributed to the entire gap. In the end, for this gap, the sum of the weights, applying the values of the AHP hierarchy, resulted in 21.

In the other 39 gaps, the soil was classified as at “Rare” risk for erosion, as they are related to values < 10 in these areas.

The works by Caldas et al. (2019) also used a similar methodology in the context of erosion,

assigning and scoring each class into which the variables were divided.

Other studies, highlighting Sinshaw's (2021a), also explored similar methodologies with similar criteria for classifying erosion processes.

According to Chen et al. (2021) the results obtained for the erosion risk level can be used to develop watershed conservation strategies and references for their control.

With the map produced, represented as proposed, a material indicative of erosion risk is available. Through it, the locations that – due to the arrangement of physical conditions combined with the volumes of rainfall that occurred – demand greater attention from the field teams.

It is a guidance document to direct containment actions at the points where there are greater chances of triggering the process.

The possibility of hourly updates based on rainfall volumes without data acquisition costs guarantees a response very close to the real one, even relying on inputs obtained remotely.

Discussion

The proposed methodology made it possible to suggest a model, aiming to guide anticipation in the face of a possible focus of degradation and to determine the risk conditions for the susceptibility of erosion processes according to a set of factors.

Among the dynamic factors, the differential of almost real-time rainfall data extracted from the *Global Precipitation Measurement* (GPM) constellation stands out.

In the period under analysis, there was no rain, but the GPM satellites provide products that allow investigating detailed precipitation over days, seasons and years, for the most different demands of the study, as proposed by Kirschbaum et al. (2017).

Frequent recording from orbital precipitation sensors ensures that the model is updated whenever weather conditions suggest close monitoring. It is an alternative for areas without adequate rainfall records due to the low density of rain gauges and radars, according to Skofronick-Jackson et al. (2017).

The availability of free and comprehensive data is advantageous, including static factors considered in the proposed model.

According to Kashiwar et al. (2022), in general, GIS significantly increased the efficiency of models to estimate the spatial distribution and magnitude of erosion at a very reasonable cost and with better accuracy.

In areas with a shortage of detailed inputs, a general characteristic of the Brazilian territory, the models with a reduced amount of information respond adequately to the input of data with a broader scale, according to Lense et al. (2021).

In his study also on erosion in TL Souza Filho (2019) pointed out the feasibility of using data obtained from mapping produced by public or non-profit entities.

The initiative is similar to that adopted in the proposed methodology, as MapBiomass and Embrapa products were used to establish classes for Land Use and Erodibility, respectively.

The MapBiomass mapping was of great relevance in the proposed method, as the representativeness of the Land Use factor is preponderant compared to the others, as evidenced in the applied hierarchy.

As for the inputs needed to calculate the Topography factor, studies such as that by Li et al. (2021a) suggested positive results with Digital Terrain Models generated by SRTM imaging with 30 meters of spatial resolution.

This proposition opted for the same product because it is free, covers the globe with greater availability and requires less computational demand.

Directly or indirectly, all factors were acquired from analyzes supported by satellites.

Although limited in scale, the input data used to feed the proposed methodological model are freely accessible, a condition that guarantees unrestricted propagation of the application, requiring only technical knowledge for its replication.

By proposing a methodology with less input data, with information on broader scales, more is required of the arrangement of variables in order to reach a model that reflects a result that is closer to the real conditions of erosion risk.

The results without significant rainfall - and therefore without alteration by dynamic factors - showed the influence of land use for the erosion risk classification.

As expected, the construction of the methodology reinforced that vegetation, or the absence of it, is certainly fundamental data (Bertoni and Lombardi Neto, 2008); (Lense et al., 2021) so that the models that intend to research erosion risk methodologies are assertive.

Monitoring conditions *in loco* and comparing the results obtained are necessary to improve the model, since due to the Covid-19 pandemic, displacements were disregarded in the process of constructing the methodology.

Even if it is not considered an abrupt degradation in terms of imminence, erosion, if not resolved in time, can in fact destabilize the physical structures of the system, whether towers or substations, harming its operation and all those that depend on it.

When close to the towers, erosions can cause damage to the tower structures, putting the transmission chain at risk due to the instability of the soil structure.

Having a model that can be updated in almost real time, with free inputs, favors the monitoring of scenarios in the event of frequent rain, becoming a guiding material. The model can help maintenance teams *in loco*, directing attention to the most sensitive points in relation to erosion.

Conclusion

The study presented a methodology that seeks to contribute to the determination of risk for the development of erosion based on factors that are recognized as important, but obtained and arranged in a simplified way, favoring its replication.

Spatialized, updatable and free inputs were valued in the proposition of the methodological model that empirically combined weights and hierarchies to dynamic and static factors.

The obtained result allowed us to observe that a risk is established for the set of static factors, which is enhanced as dynamic factors are added: rainfall volumes in the observed period and accumulated volumes in the days prior to the event under analysis.

The innovation of the proposition becomes notorious, among other aspects, by the use of data from the GPM constellation, which registers the volumes of precipitated precipitation continuously for the entire globe and provides its data free of charge.

The study and the methodological principle presented are structured in a condition of macro evaluation of the area of interest. This is considered the first procedure for assessing susceptibility to erosion processes in an iterative process. This stage precedes interventions *in loco* with the intention of mitigating erosion.

Once the answer is obtained through the erosion risk model established from static and dynamic factors - which is the first objective of this study - it is necessary to collect data and perform a specific analysis (larger scale of work/detail) of the site, updating the susceptibility to erosion.

With the indicative material, the concessionaires now have a material that promptly indicates the areas exposed to some risk of erosion,

depending on the observed conditions, fulfilling the second objective of the research. This is a powerful support for the process of mainly preventive actions, when a high degree of risk is identified.

In loco validation may indicate the need for updating as field comparisons are linked to the results presented by the model.

The proposition accepts adaptations in the methodology to bring it closer to real erosion risk conditions applied to other conditions and biomes.

Acknowledgements

The authors thank Companhia Paulista de Força e Luz - CPFL Energia and the National Electric Energy Agency - Aneel for funding the research through the Research and Development project PD-00063-3075/2020. They also thank the *National Aeronautics and Space Administration* - NASA, responsible for the GPM satellites and the SRTM images, for the unrestricted availability of data, the Empresa Brasileira de Pesquisa Agropecuária - Embrapa, which produced the Erodibility map and MapBiomass for preparing the coverage and land use map.

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