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Geoinformação e Sensoriamento Remoto em Geografia

Automated calculation of the susceptibility to mass movements through the phyton/arcgis interface

Cálculo automatizado da suscetibilidade a movimentos de massa através da interface phyton/arcgis

Cálculo automático de la susceptibilidad a movimientos de masas a través de la interfaz phyton/arcgis

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RESUMO

Este trabalho teve como objetivo o desenvolvimento e implementação de um algoritmo em linguagem Python, que integra as diversas etapas que compõem o cálculo da distribuição espacial da suscetibilidade a movimentos de massa, automatizando o fluxo de tarefas que caracteriza o processo. A estruturação do fluxo de operações foi baseada na lógica da avaliação multicritério através de uma combinação linear ponderada. O algoritmo inclui operações de geoprocessamento para a geração dos planos de informação, padronização das variáveis, ponderação dos critérios condicionantes e posterior integração através da média ponderada dos fatores. Tal algoritmo foi implementado na linguagem de programação Python, incluindo a utilização de módulos e funções disponibilizadas pelo pacote ArcPy, e incluído como uma ferramenta (script tool) no software ArcGIS através das funcionalidades permitidas pela possibilidade de criação e edição de ferramentas com o uso de scripts em Python. A ferramenta foi submetida a testes em dois estudos de caso diversos, como forma de simular a utilização da ferramenta em situações reais e validar o seu funcionamento através da análise dos produtos obtidos na execução do processo. Os resultados demonstraram significativas vantagens no uso da ferramenta, principalmente através de ganhos em eficiência, flexibilidade e suporte auferidos ao usuário. A ferramenta se demonstrou eficaz no auxílio às políticas de planejamento urbano, ordenamento territorial e monitoramento de riscos geológicos, podendo auxiliar nas avaliações de suscetibilidade a este tipo de fenômeno, fundamentais para a consolidação dos aglomerados urbanos e prevenção de desastres naturais.

Palavras-chave: Movimento de massa; Modelagem, Deslizamento; PhytonToobox

ABSTRACT

This work aimed to develop and implement an algorithm in the Python language, which integrates the various steps to calculate the spatial distribution of the susceptibility to mass movements, automating the flow of tasks that characterizes the process. The structuring of the flow of operations was based on the logic of multicriteria assessment through weighted linear combination. The algorithm includes geoprocessing operations for the generation of information plans, standardization of variables, weighting of conditioning criteria and subsequent integration through the weighted average of factors. This algorithm was implemented in the Python programming language, including the use of modules and functions provided by the ArcPy package, and included as a tool (script tool) in the ArcGIS software through functionalities allowed by the possibility of creating and editing tools using scripts in Python. The tool was submitted to tests in two different case studies, as a way to simulate the use of the tool in real situations and to validate its operation through the analysis of products obtained in the process execution. The results demonstrated significant advantages in the use of the tool, mainly through efficiency and flexibility gains and support to the user. The tool proved to be effective in assisting policies for urban planning, territorial occupation and monitoring of geological risks, and can assist in assessments of the susceptibility to this type of phenomenon, which are essential for the consolidation of urban agglomerations and prevention of natural disasters.

Keywords: Mass movements; Modeling, Landsides; PhytonToobox

RESUMEN

El objetivo de este trabajo fue desarrollar e implementar un algoritmo en Python que integre las diversas etapas que componen el cálculo de la distribución espacial de la susceptibilidad a los movimientos en masa, automatizando el flujo de tareas que caracteriza el proceso. El flujo de operaciones se estructuró a partir de la lógica de evaluación multicriterio mediante combinación lineal ponderada. El algoritmo incluye operaciones de geoprocesamiento para generar planos de información, normalizar las variables, ponderar los criterios condicionantes y posteriormente integrarlos mediante la media ponderada de los factores. Este algoritmo se implementó en el lenguaje de programación Python, incluyendo el uso de módulos y funciones proporcionados por el paquete ArcPy, y se incluyó como herramienta script en el software ArcGIS a través de las funcionalidades que permite la posibilidad de crear y editar herramientas utilizando scripts de Python. La herramienta fue probada en dos casos de estudio diferentes, como forma de simular el uso de la herramienta en situaciones reales y validar su funcionamiento mediante el análisis de los productos obtenidos de la ejecución del proceso. Los resultados mostraron ventajas significativas en el uso de la herramienta, principalmente a través de ganancias en eficiencia, flexibilidad y apoyo al usuario. La herramienta demostró ser eficaz en la asistencia a las políticas de planificación urbana, ordenación del territorio y vigilancia de riesgos geológicos, y puede ayudar en las evaluaciones de susceptibilidad a este tipo de fenómenos, fundamentales para la consolidación de las aglomeraciones urbanas y la prevención de catástrofes naturales.

Palabras-clave: Movimiento de masas; Modelización, Deslizamiento; PhytonToobox

1 INTRODUCTION

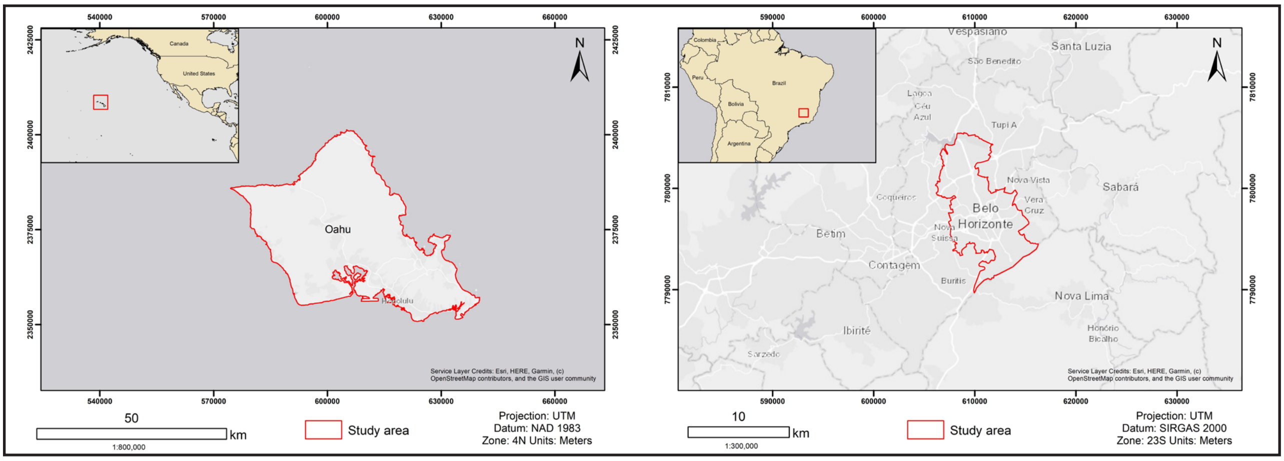
Over time, anthropic occupation of the geographic space was driven by the growing and accentuated use of natural resources, a process inherent to the current development mode (Boudet *et al.*, 2020). This process was marked by intense and unbridled growth of cities, driven by population growth associated to the displacement of rural populations to urban agglomerations, among other factors (Caglar and Schiller, 2018). As a consequence, the current occupational model is oblivious to the environmental characteristics of occupied spaces, such as slopes, soil types, geology and geomorphology (Fuchs and Glade, 2017). The occupation process that occurred in the beginnings of civilization majority in the flatter and lower areas close to river beds, climbed up the hillside due to the uncontrolled housing demand and State's organizational inability to meet this demand. That is, there was a shift to the occupation of naturally inadequate areas, periodically subject to landslides, putting life and goods at risk, generating socioeconomic and environmental losses for cities with this type of occupation (Froude and Petley, 2018) and (Wallemacq, 2019). The traditional association between landslides and occupation in steep and rugged terrain does not fully reflect the nature of the phenomenon. In theory, mass movements can occur in different configurations, depending on conditioning factors. (Varnes, 1984) points out that the elements that cause slope instability and landslides are numerous and diverse and interact with each other through complex and subtle mechanisms. (Press *et al.*, 2006) propose three primary factors that govern the mechanism by which mass movements occur: the nature of materials that compose the slope, the amount of water contained in these materials and the slope itself. Changes in these parameters can reduce the resistance to movement, making slopes more susceptible to be controlled by the gravitational force, which would trigger mass movements. When analyzing data from 13 years of landslides in the world from 2004 to 2016, (Froude and Petley, 2018) registered more than 4800 landslides, which resulted in the death of almost 56,000 people. In this reality, the need for significant efforts on the part of the public administration to promote a solid territorial occupation policy is clear, preventively acting in areas that are still unoccupied and employing risk mitigation policies in areas already occupied or in the process of occupation. In this context, it is fundamental for the planning and management of territorial occupation to consider the susceptibilities and possibilities of the occurrence of mass movements and to foresee the potential damage that they may cause (Dias *et al.*,2020). Therefore, spatial distribution and the analysis of susceptibility to landslides and related phenomena are critically important to support public policies for territorial occupation (Mateos *et al.*, 2020) Thus, techniques and methodologies to assist this process must constantly be sought in order to maximize efficiency and reduce costs, when possible. In this sense, the use of geotechnologies is more and more frequent, mainly because they are a set of techniques with decreasing cost, which are able to provide valuable information in a precise, comprehensive and effective way (Ali *et al.*, 2020). Such techniques are applied in geoprocessing and include a set of computational and mathematical processes for the treatment of geographic data, allowing analysis that involves the simultaneous combination of maps and interdisciplinary data, a characteristic inherent to environmental phenomena, which take into account the physical-biotic environment, anthropic aspects and their interrelationship (Press *et al.*,2006). In the geoprocessing scope, Geographic Information Systems (GIS) deserve special mention, which are tools that geoprocessing uses and constitute a set of computational applications that implement storage, processing and display of spatial data (Longley *et al.*, 2010). Therefore, GIS allow complex analyses by integrating data of different natures, storing them in databases and providing functionalities for an efficient presentation of cartographic products, also providing the automation of map processing Longley *et al.* (2010). In this context, the general aim of this study was to explore the applicability of geoprocessing techniques in conjunction with Python programming to the analysis of susceptibility to mass movements. The specific focus was the development of a computational tool (script) based on a predictive spatial modeling through a Multicriteria Assessment by the method of Weighted Linear Combination of conditioning factors, which are selected, standardized and later aggregated and combined. In other words, an attempt was made to offer a generic tool capable of adapting to a wide range of situations and offering a quick solution, optimizing the time that would be used in the various necessary processing steps. Once the script is developed, simulations can be performed with different scenarios to model real situations in order to support the monitoring of geodynamic risks, the management of the territorial occupation and, consequently, save lives and avoid material damage in urban areas.

2 MATERIALS AND METHODS

2.1 Study area

The selection of study areas to validate the model took place according to data availability, since the main aim was the development and execution of tests to validate the tool / model. Therefore, it was necessary to acquire a complete data set that would satisfy the needs of the tool's input parameters, guaranteeing the test in its full functionality. Two areas with different characteristics were chosen (Figure 1): an island in the northern hemisphere (Oahu, Hawaii, USA) and an intensely urbanized intracratonic region in the southern hemisphere (Central Portion of the Municipality of Belo Horizonte).

Figure 1 – Location maps of study areas: A) Oahu Island - Hawaii; B) Metropolitan area of Belo Horizonte, the limit of the study area was superimposed on an image, demonstrating the insertion of the area, almost entirely, in an urban area



Source: Prepared by the authors

2.1.1 Oahu, Hawaii, USA

It constitutes the most complete data set among the two study areas, which is why the area was used as initial basis for the implementation of the model in GIS. Data obtained are summarized in Table 1:

Table 1 – Specifications of data collected for the first study area, including resolution, scale, representation format and source

Variable	Format	Source
Digital elevation model (resolution = 10 m)	Raster	Honolulu Land Information System
Lithology (scale= 1:100 000)	Vectorial	USGS Hawaiian Volcano Observatory / Sherrod *et al.*,(2007)
Geological structures (scale= 1:100 000)	Vectorial	USGS Hawaiian Volcano Observatory / Sherrod *et al*. (2007)
Coastline (study area)	Vectorial	Hawaii Statewide GIS Program
Pedology (scale= 1:100 000)	Vectorial	Hawaii Statewide GIS Program
Land use/Land cover (resolution: 30 meters)	Raster	Hawaii Statewide GIS Program
Average anual rainfall (resolution: 250 meters)	Raster	Rainfall Atlas of Hawaii (Giambelluca *et al.*, 2013)

Source: Prepared by the authors

2.1.2 Central portion of the municipality of Belo Horizonte

This study area was selected due to the availability of an MDE generated from the LiDAR technology, which allowed obtaining data in extremely detailed spatial resolutions. Collected data and their characteristics are shown in Table 2:

Table 2 – Specifications of data collected for the study area located in Belo Horizonte

(Continue...)

Variable	Format	Source
Digital elevation model LiDAR (resolution = 1 m)	Raster	Lidar OnLine Maps / LIDAR ONLINE (2015)
Lithology (scale:1:1.000.000)	Vector	Geology Portal / Heineck *et al*. (2003)

Table 2 – Specifications of data collected for the study area located in Belo Horizonte (Conclusion...)

Variable	Format	Source
Geologycal structures (scale:1:1.000.000)	Vector	Geology Portal / Heineck *et al*. (2003)
Pedology (scale:1:1.000.000)	Vector	EMATER (1993)
Average annual precipitation (resolution – 1km)	Raster	AMBDATA / Hijmans *et al*. (2005)

Source: Prepared by the authors

2.2 Development of the conceptual model

In order to determine the conditioning factors for mass movements, there was an arduous literature search with various conceptual, heuristic and statistical approaches applied to the process, present in works by (Crepani *et al*., 2001), (Dai and Lee, 2002), (Silva and Goes, 2003), (Marcelino, 2003), (Zêzere, 2005), (Martini *et al*., 2006), (Vanacôr, 2006), (Pedrosa, 2013), (Feizizadeh *et al*., 2014) and (Pinto *et al*., 2014). Considering the influence on the nature of materials, the slope and the water content of slopes and according to literature and data availability, the following conditioning elements of mass movements were selected: a) elevation; b) slope; c) distance to drainages; d) lithology; e) lithological gradient; f) pedology; g) distances to geological structures; h) land use and cover; i) rainfall.

2.3 Implementation of the model in GIS

This stage corresponds to the expansion of the conceptual model, that is, the stages of geoprocessing operations were defined, which were initially organized in a flowchart (Figure 2), generated through the ModelBuilder application of the ArcGIS software and later implemented through Python programming in the IDE PyScripter.

2.3.1 Generation of the information plans

Information plans for elevation, lithology, pedology, land use / cover and rainfall are equivalent to pre-processed data, with no need to be derived from other types of data. The slope, the lithological gradient of differences, and the distances to drainages and geological structures are information plans obtained through the derivation of other data. The slope was obtained from the application of the Slope tool (ArcGis) to MDE. Similarly, the lithological gradient of differences was also obtained through the Slope operation, applied after the standardization of the information plan corresponding to the lithology. The process enabled detecting variations in rock resistance, allowing the identification of discontinuities that could configure greater susceptibility to mass movements. In order to eliminate the requirement of an input parameter for drainages, an operation (ExtractStreams) was implemented so that the drainages were extracted, in vector format, from MDE. Drainages and geological structures, both in vector format, were submitted to a distance calculation process (EuclideanDistance), which consists of calculating the distance of each cell to the considered geographic entity.

2.3.2 Standardization of criteria

Once all information plans were generated, conditioning factors were individually standardized. When it comes to standardizing different data on the same scale, it is common to decide on a defined scale, such as 1 to 10 or 0 to 5, for example. However, the decision about the range comprised by each class ends up by being subjective, because for different ranges, a given value may belong to one class or another. Thus, in order to mitigate subjectivity, the fuzzy logic was adopted for the reclassification of information plans, initially introduced by (Goguen,1973) and described in greater detail by (Coelho, 2008). The advantage of using fuzzy logic is that it eliminates the concept of classes defined by abrupt limits based only on the probability that such value belongs to a certain class. The Fuzzy Membership tool, part of the ArcGIS software toolset, was used for these transformations. Data were reclassified to a scale from 0 to 1, with 0 representing null susceptibility and 1 maximum susceptibility. The following information plans were submitted to fuzzy reclassification: elevation, slope, distance to drainages, distance to geological structures and rainfall. Thus, intermediate products or intermediate maps were obtained. Some observations should be made about the intermediate products of the tool. In the elevation factor, topographic tops have lower standardized values (in yellow and green), while intermediate altitudes have the highest susceptibility (red) and low areas are little susceptible (green). This result is the product of the fuzzy reclassification from a Gaussian curve, according to what was established in the conceptual model. Slope and rainfall factors increase continuously with the values of these variables, from 0 to 1, due to the use of an increasing linear function. On the other hand, values corresponding to the distances to drainages and geological structures behave in the opposite way, with maximum value attributed to the null distance. In this way, physical entities corresponding to drainages and geological structures receive the highest susceptibility value. In the lithology factor, the greatest susceptibility is mainly attributed to unconsolidated materials. In the case of the lithological gradient, resistance and cohesion properties were used to define the susceptibility level. The standardized information plans corresponding to pedology and land use and cover highlight, respectively, highly erodible soils and highly urbanized areas, which receive the highest susceptibility values.

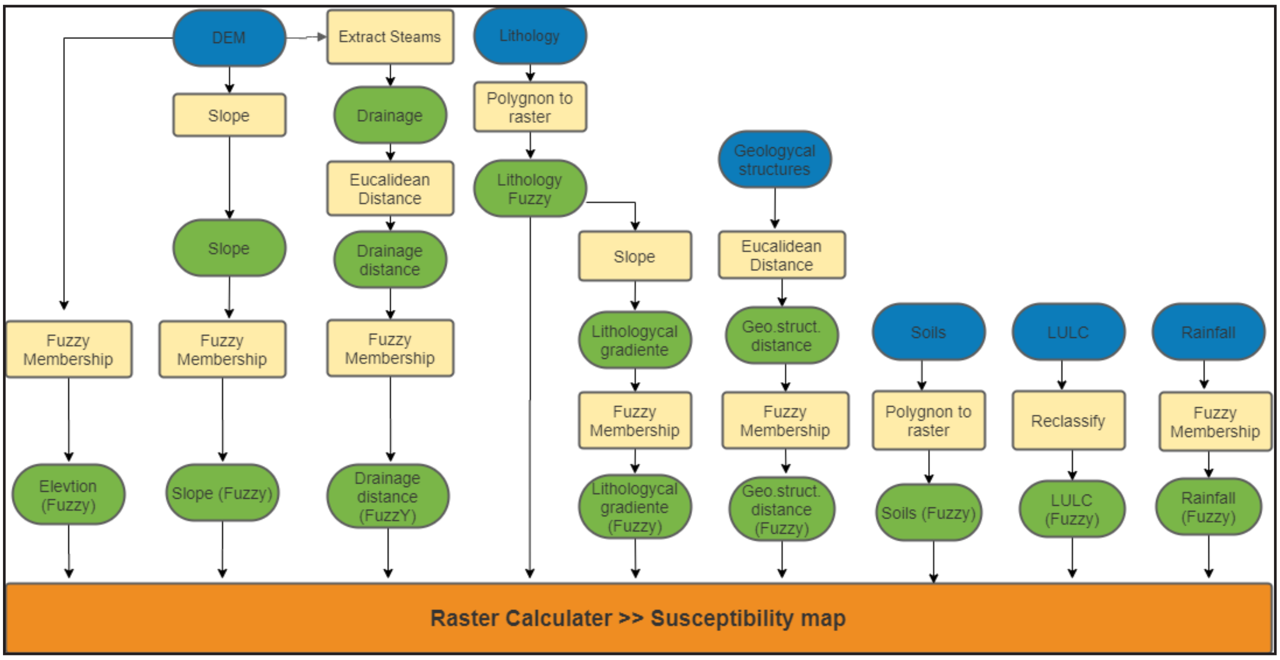
2.3.3 Weighting of variables

Considering that variables adopted as conditioning factors of mass movements can present different influences in areas with different characteristics, after the fuzzy standardization, it is necessary to carry out the weighting of variables. For this purpose, the developed tool does not use any specific technique, offering only functionality so that values are chosen by the user. Thus, the aim was to provide the user flexibility in the methodology of weighting variables. The tool allows the decision about criteria weights to be made through the use of heuristic (subjective), statistical or deterministic methods.

2.3.4 Weighted linear combination

Once factors are properly standardized and the weighting of variables has been completed, the aggregation operation among conditioning elements involved proceeds. The tool used for this purpose was the RasterCalculator, in the flowchart developed in ModelBuilder (Figure 2), which allows direct operation through an expression involving raster-type objects in Python. The cells of each variable are basically multiplied by their respective weights and then added together in a local operation, resulting in the final map of susceptibility to mass movements. To reduce subjectivity, the weights of each variable were defined using the AHP (Analytical Hierarchy Process) technique, developed by Saaty, (1980). This final product is also classified on a scale from 0 to 1, being subject to further reclassification depending on the purpose of presenting results.

Figure 2 – Flowchart that summarizes the set of geoprocessing operations used by the tool developed in this study. Inputs are represented in blue and the output corresponds to the final map of susceptibility to mass movements

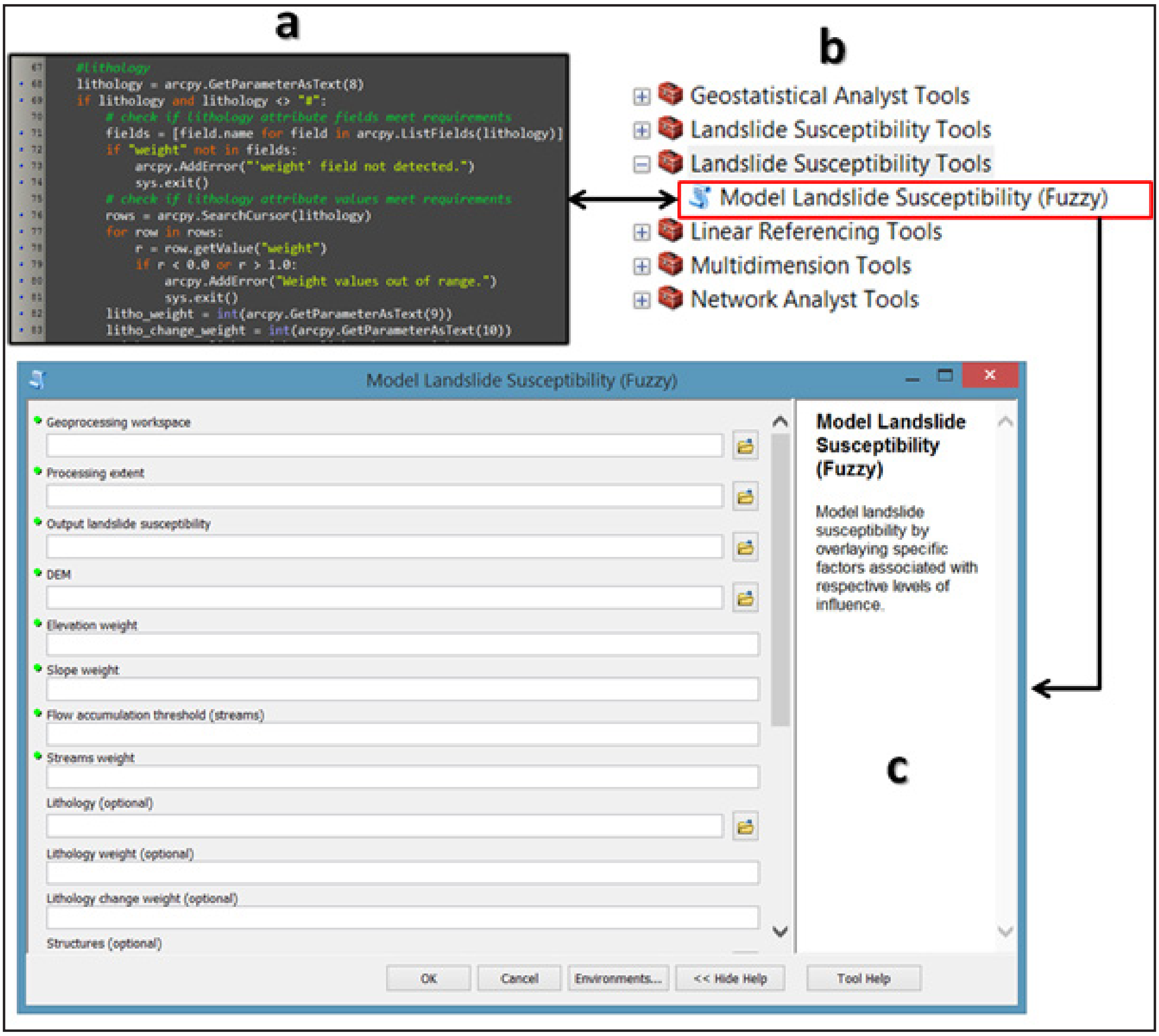


Source: Prepared by the authors

The susceptibility value can be extracted from the final map and applied to urban planning and geological risk monitoring. The map analysis can take place with the extraction of susceptibility values using the Extract by Mask tool, whose mechanism is based on the extraction of cells that intercept the entities under study (roads, buildings, tunnels, etc.), which are used as "masks" (as in case study 1), or the final map can be divided into classes and zones corresponding to high and very high susceptibilities extracted using the RasterCalculator and RastertoPolygon tools (as in case study 2).

2.3.5 Implementation in modelbuilder and python

Figure 3 – Link between the developed script and the user through the graphical interface offered by the ArcGIS software. (a) Part of the script was developed in IDE PyScripter. (b) Script tool added in a toolbox in the ArcGIS software. (c) Graphical interface with the user through which input parameters are provided



Source: Prepared by the authors

The flow of geoprocessing tasks was initially implemented in ModelBuilder, whose flowchart is outlined in Figure 2. Then, the code for the implementation of the algorithm in Python was developed, later used to add a tool (script tool) to a set of tools (Toolbox) in the ArcGIS software (Figure 3). As can be seen in Figure 3, the graphical interface of the tool within the scope of the ArcGIS software, is basically the bridge for the user, who provides the input parameters. The input parameters for the tool are of two types: mandatory and optional. Mandatory parameters are imperative for the execution of the tool and optional ones can be supplied or not (Supplementary material A). The flow accumulation threshold is among mandatory parameters, defined according to data resolution and characteristics of the considered area (ESRI, 2020). It should be noted that the tool can be executed even if some optional parameter is not available, presenting great flexibility in adapting to study areas, even if for which there is shortage in the availability of georeferenced data, either by scale incompatibility or lack of necessary parameters. The process is performed by the script, which consists of using input parameters in the various combinations of previously described geoprocessing operations. At the end, it returns an output. The output is the final map of susceptibility to mass movements. Thus, any individual who has the added tool and the required input parameters can use it for the intended purpose.

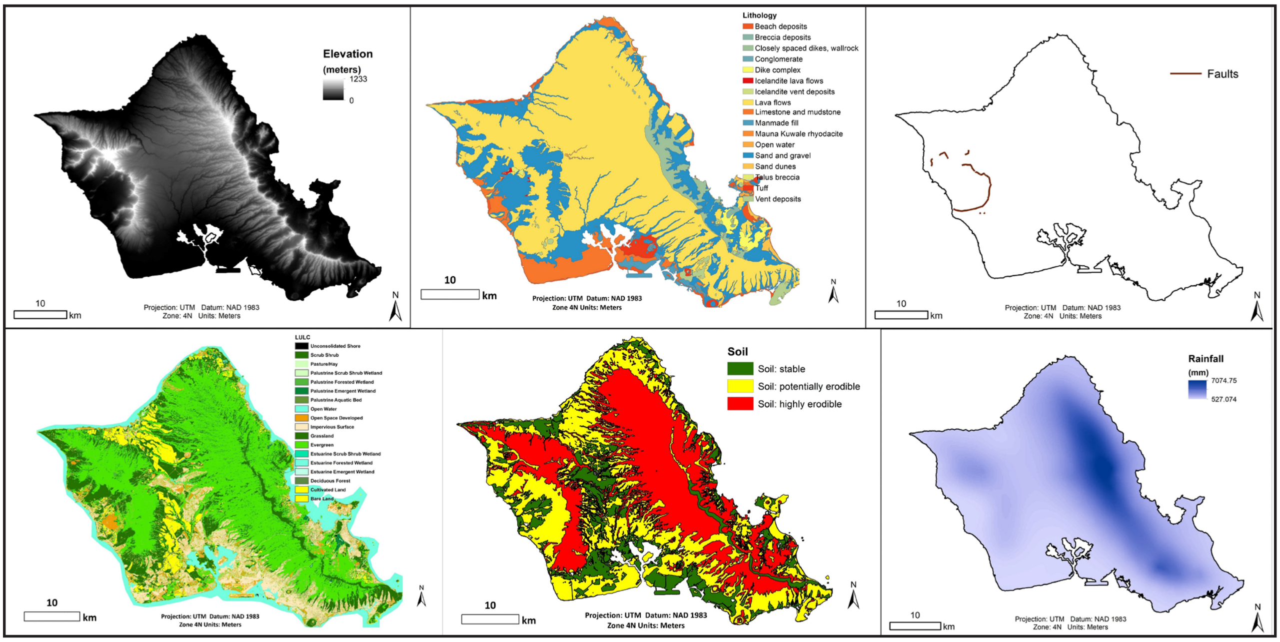
3 RESULTS AND DISCUSSSION

3.1 Model validation (case studies)

3.1.1 Oahu, Hawaii, USA

The standardized values attributed to the respective attributes of the information plans regarding lithology, pedology and land use / cover for Oahu are summarized in supplementary material B. With the definition about the weights of variables, the maps with input parameters (Figure 4) were elaborated to be processed by the tool (Figure 3). It is interesting to note the geological control in the elevation and rainfall distribution in the island. In turn, geomorphology played a decisive role in the use and occupation of the region.

Figure 4 – Maps with input parameters for the study area corresponding to the Oahu island; (A– MDE; B - Lithology; C– geological structures; D- LULC; E - Soils, F- Rainfall)



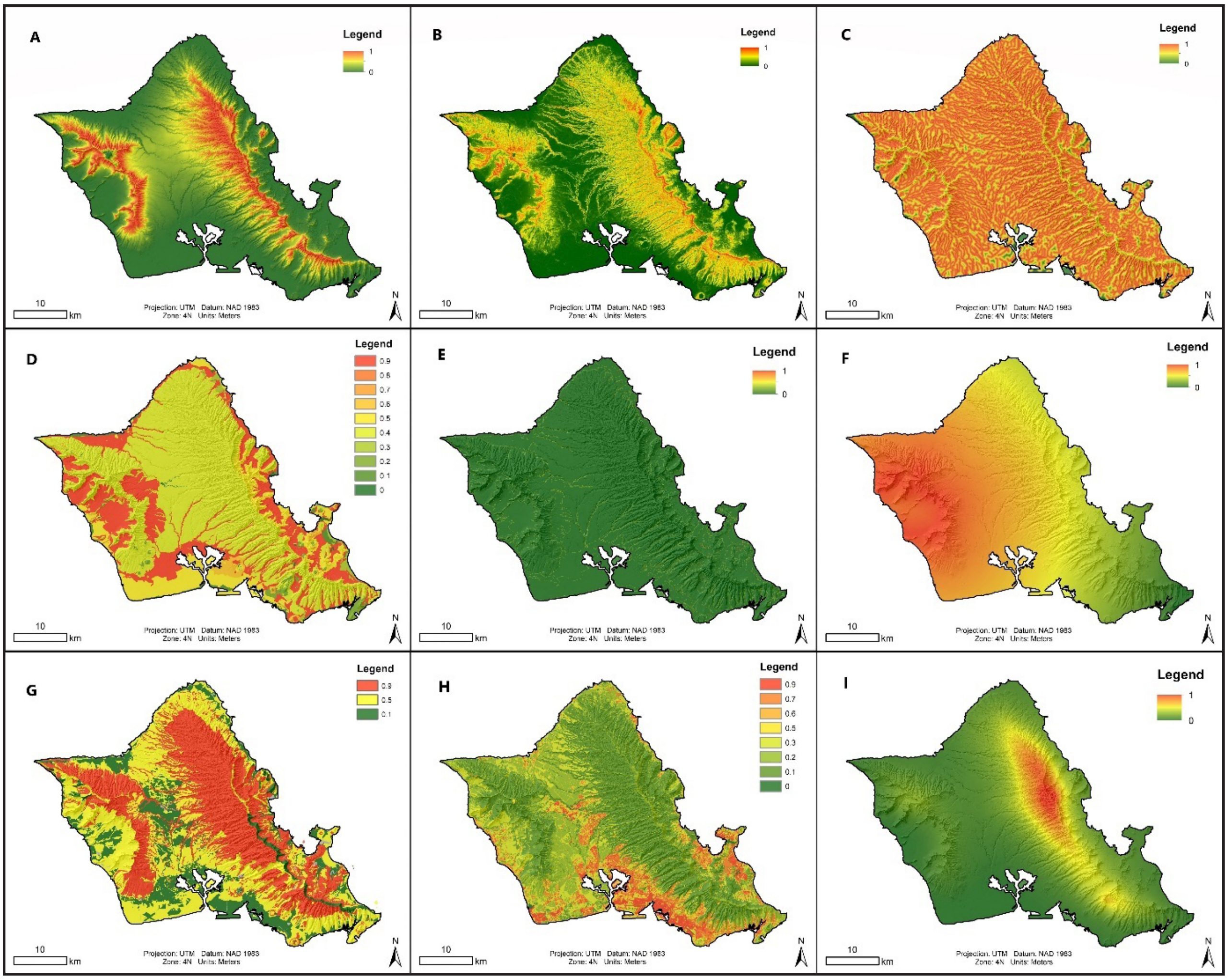
Source: Prepared by the authors

Table 3 – Result of the weighting process for variables involved in the susceptibility study for both study areas

Variable	**Belo Horizonte**	**Oahu**
Elevation	0,031	0,050
Slope	0,255	0,200
Distance to drains	0,061	0,150
Lithology	0,129	0,100
Lithological gradient	0,044	0,050
Distance to geological structures	0,201	0,050
Pedology	0,230	0,150
Rainfall	0,049	0,100
TOTAL	**1,000**	**1,000**

Source: Prepared by the authors

Figure 5 – Intermediate maps of conditioning factors (intermediate products of the tool) of susceptibility to mass movements for the Oahu island. A - elevation; B- slope; C - distance to drainages; D - lithology, E - lithological gradient; F - distance of structures; G - pedology; H- land use and cover; I - Rainfall

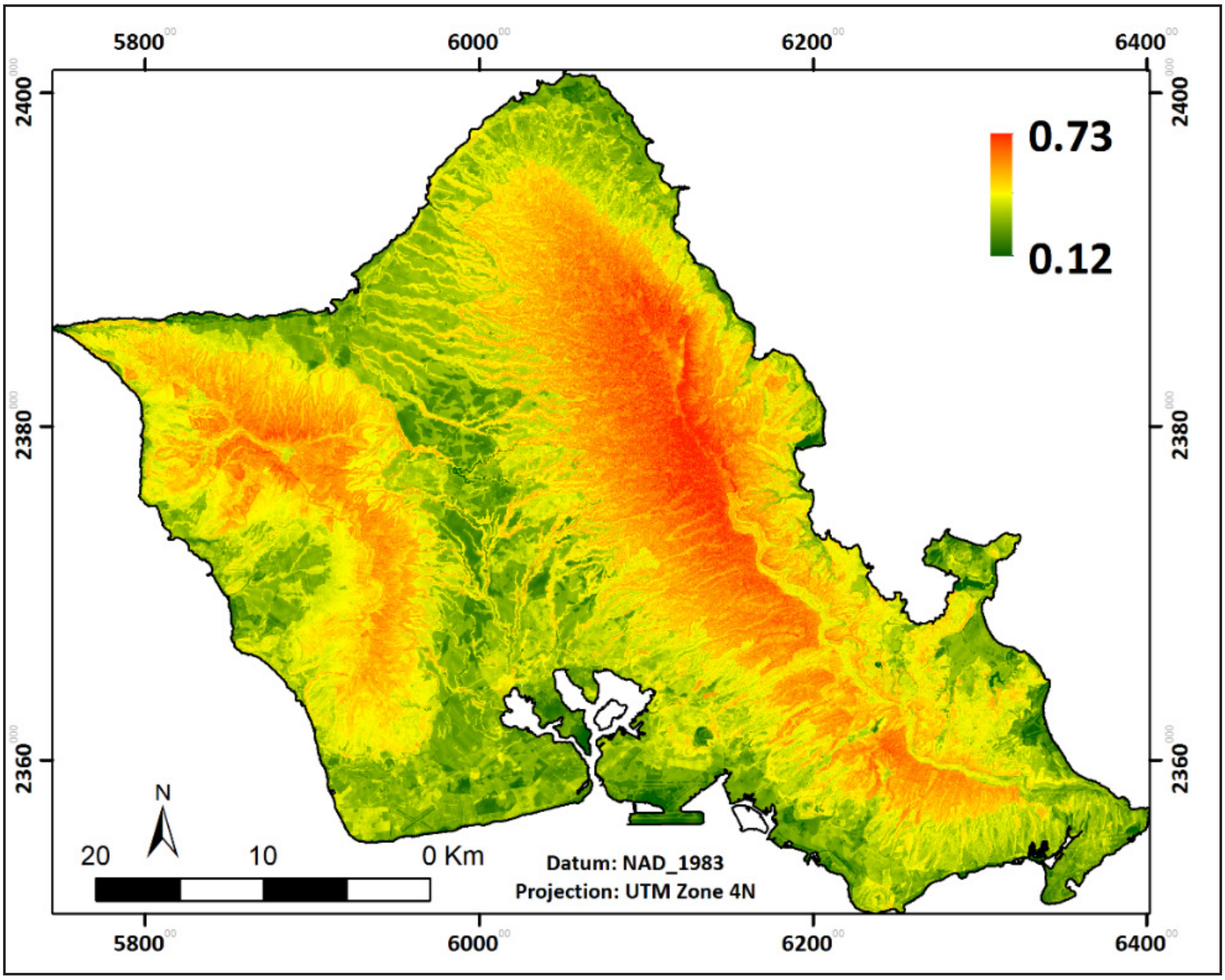


Source: Prepared by the authors

For Oahu, the value 1000 was chosen as the flow accumulation threshold due to the size of the study area and the amount and scale of available data. Intermediate products, corresponding to the susceptibility to mass movements according to each individual factor, are presented in Figure 5. In the lithology factor, the greater susceptibility mainly attributed to unconsolidated materials throughout drainages and talus deposits, both highlighted in red, can be observed. In the lithological gradient, differences are almost imperceptible, since only the area corresponding to the contact between lithologies with contrasts in resistance and cohesion properties are considered as having high susceptibility (highlighted in red). The standardized information plans corresponding to pedology and land use and cover highlight, respectively, highly erodible soils and highly urbanized areas, which received the highest susceptibility values. The final map of susceptibility to mass movements (Figure 6) presents aspect resulting from the merger of standardized conditioning factors, being more marked by factors considered most influential in the weighting (Table 3).

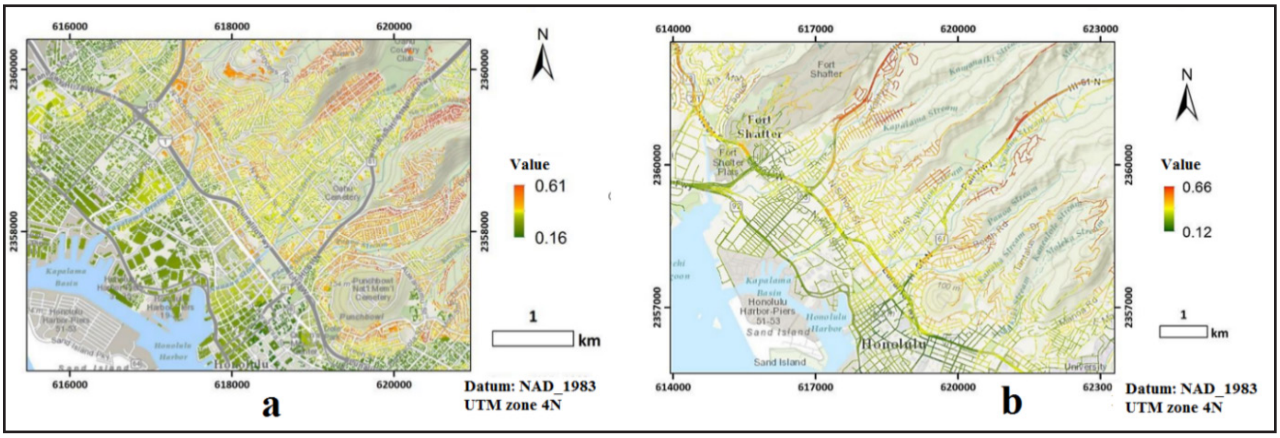
In this case study, an attempt was made in urban planning and geological risk monitoring. The susceptibility value was basically extracted from the final map for areas with the presence of properties (Figure 7a) and roads (Figure 7b) in the municipality used as “masks”.

Figure 6 – Final map of susceptibility to mass movements (Oahu)



Source: Prepared by the authors

Figure 7 – a - Susceptibility to mass movements applied to properties; b - Susceptibility applied to roads

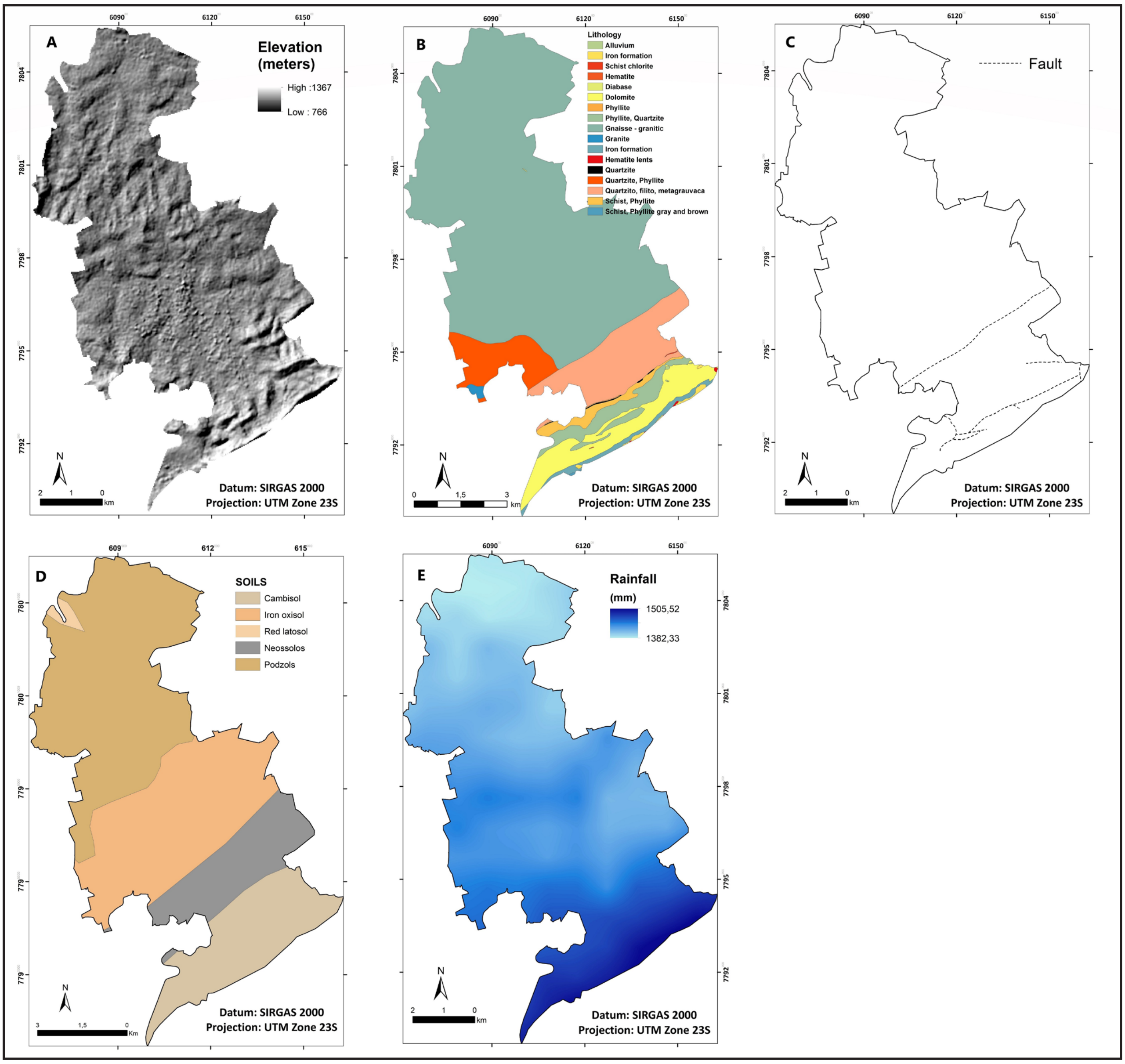


Source: Prepared by the authors

3.1.2 Central Portion of the Municipality of Belo Horizonte

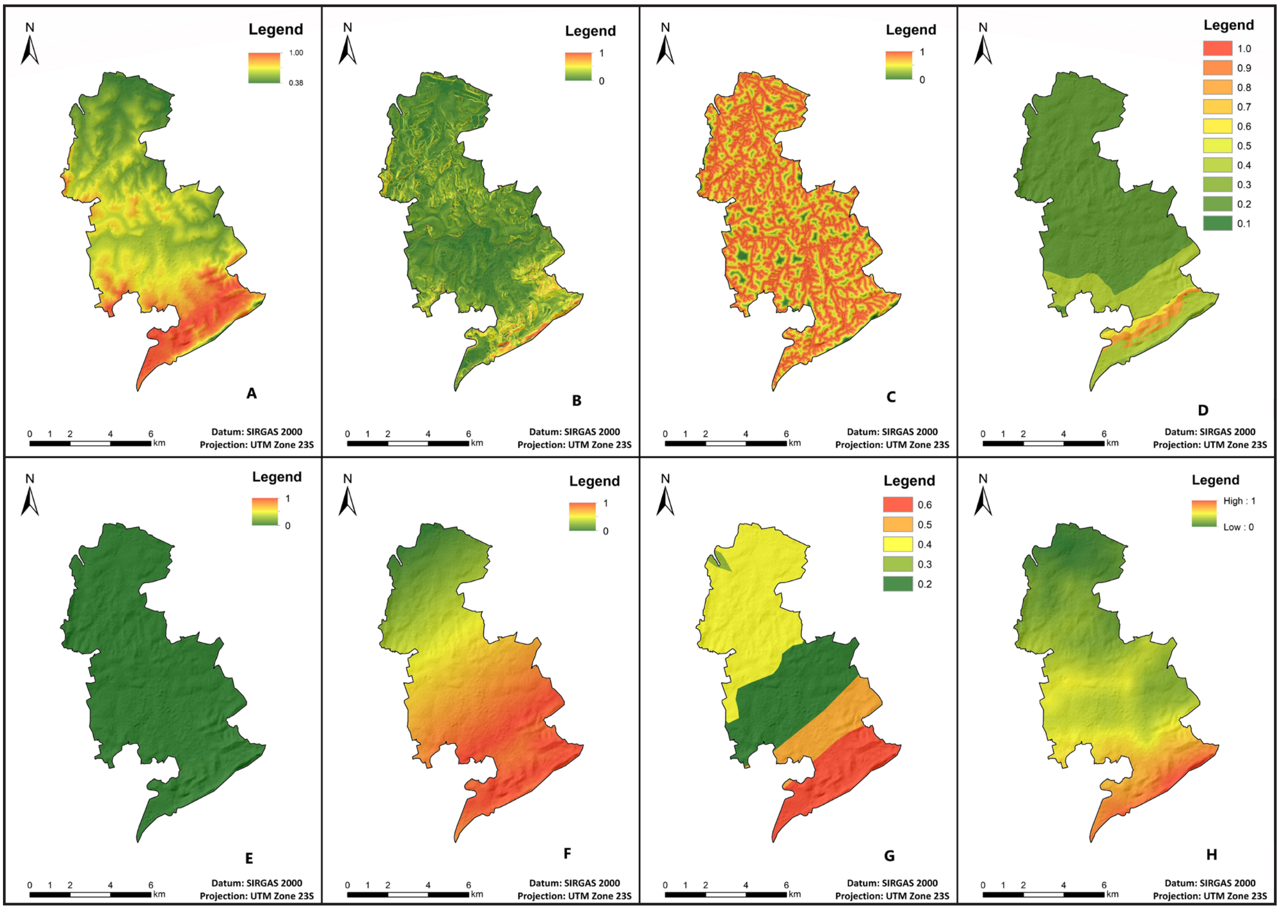
As the region encompassed by the case study is basically located in an urban area of relatively small dimensions, land use and cover maps on adequate scale for the study were not found. However, as shown in Figure 1b, the study area is almost fully inserted in the city of Belo Horizonte, except for the type of land use and cover that would not substantially influence the products obtained by the tool. On the other hand, it was possible to use a digital elevation model used with spatial resolution of the order of 1 m obtained through the LiDAR technology. The result of the standardization process of nominal variables, lithology and pedology, is summarized in supplementary material C. The weights defined for each variable, using the AHP technique, are shown in Table 3. Data used as input parameters are represented in Figure 8, while intermediate products and final map are shown in Figure 9, respectively. In this execution, a flow accumulation threshold of 10,000 was used, considered more suitable for the study area.

Figure 8 – Maps with input parameters for the study area corresponding to the city of Belo Horizonte (A– MDE; B - Lithology; C– geological structures; D - Soils, F- Rainfall)



Source: Prepared by the authors

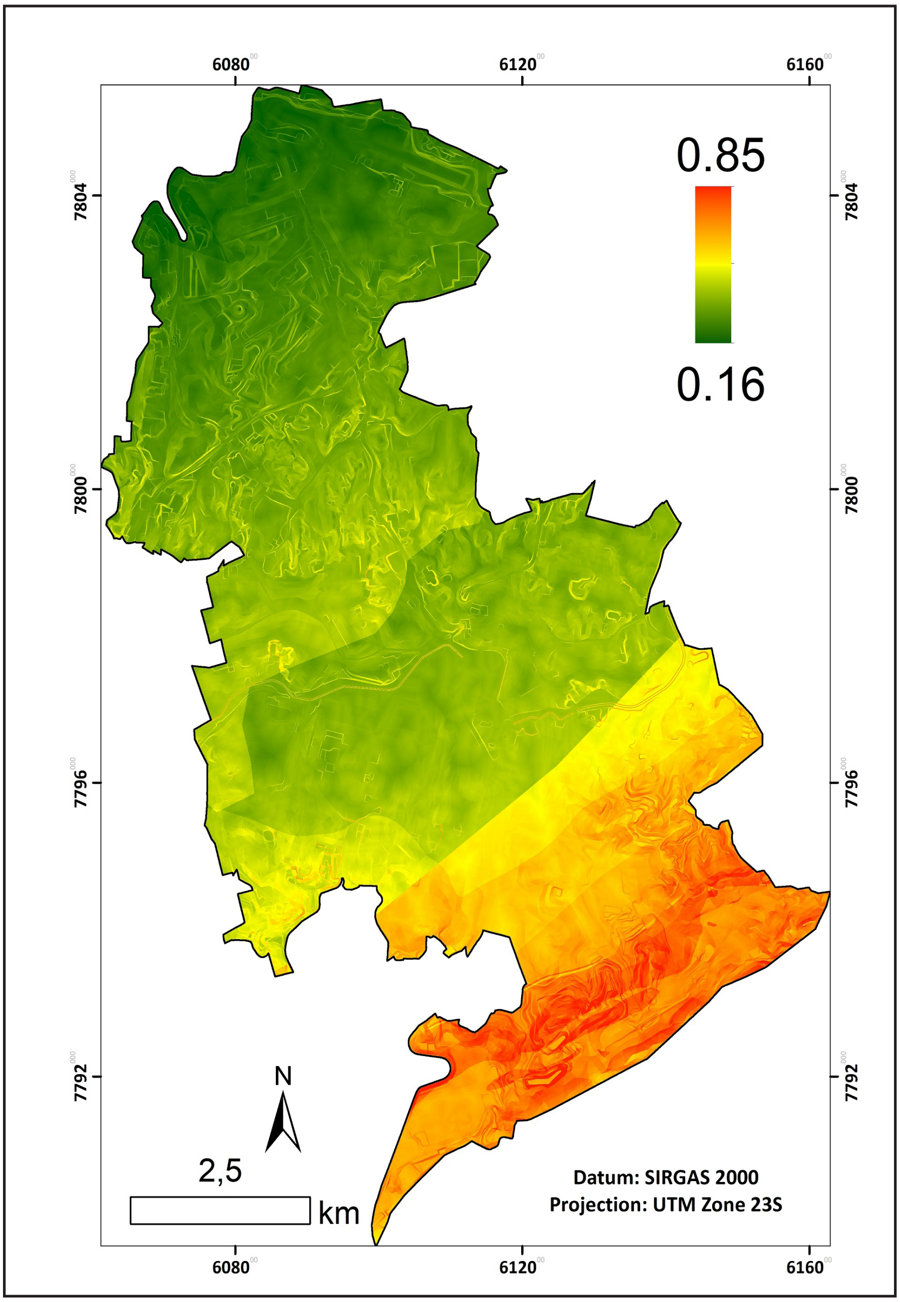
Figure 9 – Intermediate parameters for the study area corresponding to the central portion of the municipality of Belo Horizonte. A - elevation; B- slope; C - distance to drainages; D - lithology, E - lithological gradient; F - distance of structures; G - pedology; H– rainfall



Source: Prepared by the authors

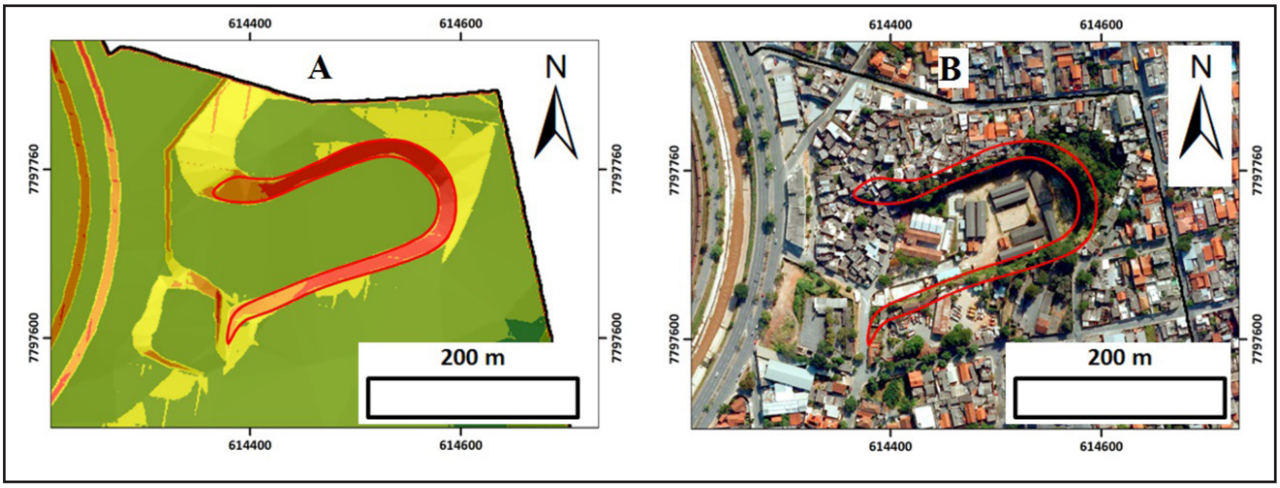
As can be seen in Figure 10, the highest susceptibility level is found for the SSE portion of the study area. As can be seen in intermediate maps, some dominant characteristics in this portion lead to this high susceptibility: intermediate altitudes, commonly associated with high frequency of landslides; slopes accentuated by the existence of rugged terrain; greater lithological variations in relation to the predominant uniformity in the northern part; failure concentration; domain of litossolos and cambissolos and high rainfall. Despite the existence of this concentration of high susceptibilities in the southern portion of the area, some features classified as high or very high susceptibility can be identified in the northern portion of the urban area. After analysis of the final map of susceptibility to mass movements, it was divided into five classes and zones corresponding to high and very high susceptibilities. Thus, it was possible to identify some features by overlapping zones of high and very high susceptibility and aerial images (Figures 11 and 12). The high resolution of topographic data allowed the identification of these features in details, which will facilitate the planning of technical visits by priority, optimizing time and resources.

Figure 10 – Final map of susceptibility to mass movements for the central region of the city of Belo Horizonte



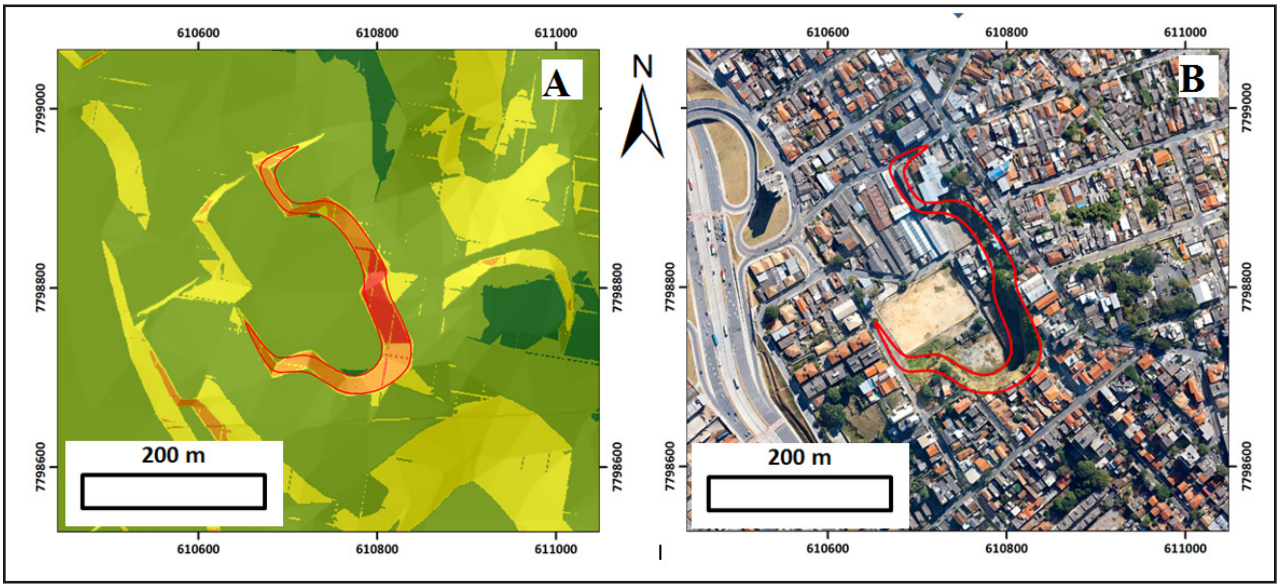
Source: Prepared by the authors

Figure 11 – Delimitation of a high susceptibility zone (A), coinciding with steep slope and reasonably without vegetation cover (B). The overload imposed by buildings on the slope is also highlighted



Source: Prepared by the authors

Figure 12 – Coincidence of an area of high susceptibility (A) with steep slope overloaded by buildings (B)



Source: Prepared by the author

3.2 Model applicability

The two cases presented, different in many aspects, show the flexibility of the tool, which can be adapted to different scales and data availability realities, in addition to confirming the efficiency gains obtained by the automatic calculations of the tool. This fact was demonstrated in practice, since, after the development of the tool, the data analysis and processing step was practically automated. In the specific case studies addressed, after the initial stages of collection, pre-processing, standardization and weighting of data and conditioning factors, the execution of the tool and obtaining the final maps contemplated a time interval of the order of ten minutes to thirty minutes, without the need for any supervision or action by the user. Thus, there is great flexibility in case a new execution with variations in input parameters or in values defined in the standardization or weighting of data is necessary. In addition, the functionalities that support the user in error management, monitoring the progress of operations flow and the check of input parameters must be highlighted. However, the relevance of the primary stages of data collection and manipulation must be stressed, since errors inherent to these will propagate through the tool's process chain, impacting the characteristics of the final product. In relation to the conceptual part of the methodology adopted, the effectiveness of using multicriteria assessment is demonstrated in simplifying the resolution of complex problems involving multiple variables. In addition, the use of the weighted linear combination technique promotes the compensation among conditioning factors of landslides, contributing to a multilateral and comprehensive approach. The scope in the application of the tool is also observed in the choice of conditioning factors. The greatest possible variety of criteria was selected; however, always observing the generalizing principle of the tool. Therefore, highly specific or specialized data were excluded from the sets of conditioning variables. As suggested by (Marcelino, 2003), one should choose, whenever possible, the use of mathematical and statistical methods in the standardization and weighting of variables, since this approach presents the best correlation results in the retroanalysis, which favors the reliability of obtained products. In addition, the use of this type of technique provides substantial reduction in the analysis subjectivity, despite creating the need for a good quantity and quality of field data (inventory of occurrences of mass movements).

4 CONCLUSION

The development of models aimed at producing maps of susceptibility to mass movements is a fundamental step in urban planning and monitoring of natural disasters. Therefore, it is imperative that the techniques used for this purpose are always improved and increased in order to obtain precision, reliability and efficiency gains. In this sense, geoprocessing and GIS techniques have proven to be robust instruments since data collection and pre-processing until obtaining the desired final products. Such techniques simplify and streamline procedures aimed at the elaboration of maps through functionalities that allow data organization and storage in a structure that provides easy data retrieval, manipulation and updating. In addition, computer programming techniques using the Python language, coupled with GIS methods, provide substantial efficiency gains. The computational tool (script), presented here, based on a predictive spatial modeling through Multicriteria Assessment by the method of Weighted Linear Combination of conditioning factors (selected, standardized and later combined), allows the performance of several simulations with different scenarios. The flexibility provided by the implementation of optional and mandatory input parameters proves the generalized proposal of the tool, which seeks to encompass a wider spectrum of scenarios among its applications. Even so, if adaptations in the algorithms used to meet specific needs of different realities are required, these are possible with the editing of the script codes linked to the tool. However, the most important thing is that a methodological line was created for the automation of the process chain inherent to the analysis of susceptibility to mass movements, paving the way for improvement alternatives in order to specialize or generalize the tool. Further studies carried out in order to improve the developed tool could aim at the incorporation of landslide inventories into algorithms through statistical methods. Therefore, in a future scenario, the tool would be able to accept the landslide inventory as an input parameter, which would be used in statistical calculations for the standardization and weighting of variables. At this level, the entire standardization and weighting processes would be automated, providing even greater increments to the tool's efficiency.

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