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Study of susceptibility to gravitational movements of mass and floods in the urban region of Patos de Minas, Minas Gerais

Study of gravitational movements and flood susceptibility in urban region of Patos de Minas, Minas Gerais

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Summary

Every year Brazil records thousands of accidents considered natural disasters, to which the State of Minas Gerais contributes annually, mainly with accidents linked to intense rains. Therefore, the present study aims to indicate areas that are prone to the development of natural physical processes linked to mass movement and flooding in the urban perimeter of the city of Patos de Minas. Using maps of land use and occupation, soil classes, hypsometry, average annual rainfall, slope, road network and NDVI (Normalized Difference Vegetation Index), map algebra and the analytical hierarchy process were applied. As a result, the susceptibility classification of the area was obtained. It was concluded that the urban perimeter has medium to high susceptibility to mass movements and flooding, it is emphasized that preventive measures must be taken to avoid major accidents.

Key words: Geotechnics. Susceptibility. Slipping. Inundation. SIG.

Abstract

Every year Brazil registers thousands of accidents considered natural disasters, where the State of Minas Gerais contributes yearly, mainly accidents linked to the intense rains. Thus, this study aims to indicate areas that have the propensity to develop natural physical processes linked to mass movement and flooding in the urban perimeter of the city of Patos de Minas. From maps of land use and occupation, soil classes, hypsometry, average annual precipitation, slope, road mesh and NDVI, map algebra and analytical hierarchy process was applied. As the result, the susceptibility classification of the area was obtained. It was concluded that the urban perimeter has medium to high susceptibility for mass movements and flooding, preventive measures should be taken to avoid major accidents.

Keywords: Geotechnical. Susceptibility. Sliding. Flood. SIG.

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1. Introduction

Nowadays, natural disasters are increasingly present in our daily lives. Natural disasters initially lead us to imagine earthquakes, volcanoes, hurricanes, tsunamis and other major events, but this term also includes landslides, floods, subsidence, everything that leads to the exposure of people and properties to dangers and losses caused by processes of natural origin or anthropic (TOMINAGA; SANTORO; AMARAL, 2009). The great and disorganized advance of urbanization continues according to the economic possibilities of each group of people, without taking into account the characteristics of the area. This situation demonstrates the lack of planning, since unsuitable areas are added to the lack of urban infrastructure resulting from the abandonment of public authorities. The municipal master plan, which is a basic instrument of urban development and expansion policy, is not always followed and other urban plans, which are details of the master plan, must be in a coherent relationship with it (ALVES, 2014). In this context, the letter of suitability for urbanization, which must be carried out after the susceptibility letter, is important as it contains the result of an assessment of hazards associated with physical environmental processes and recommendations for urban land use in accordance with the limitations and potential. of each delimited geotechnical unit (BITAR, 2015).

Removing soil and vegetation from areas that are naturally stable to erosion processes and sealing the soil without considering rainwater infiltration can worsen rainwater runoff, putting areas on river plains at risk (SILVA, 2016). These factors favor the occurrence of erosive processes, mass movements and floods, which could be naturally stabilized or with less aggravating susceptibility. In this context, prior knowledge of areas naturally susceptible to flooding, erosion and mass movements is a tool for responsible bodies to put together an action plan to avoid as much damage as possible (SILVA, 2016).

Federal law 12,608/2012 establishes the National Social Protection and Defense Policy (PNPDEC) which introduced changes to the city's Statute, establishing the mandatory mapping of areas susceptible to natural disasters, in which the product must be a map or susceptibility chart. The cards indicate areas susceptible to phenomena and processes in the physical environment, whose dynamics can generate natural disasters (BITAR; FREITAS; MACEDO, 2015).

Therefore, it is necessary for all municipalities in the country to have this susceptibility chart or map. Checking the municipalities in Minas Gerais that attract attention in journalistic headlines through Barbosa (2019) on the G1 website and Rocha (2018) on the Patos Hoje website, which explore landslides and floods, Patos de Minas was selected. This will encourage the generation of susceptibility maps to gravitational mass movements and flooding in a GIS environment, divided into zones that demonstrate degrees of possibility of damage, to support the city's civil defense agency.

The general objective of this work is to provide complementary information for public policies in the city of Patos de Minas, identifying zones of natural susceptibility to gravitational mass movements and flooding.

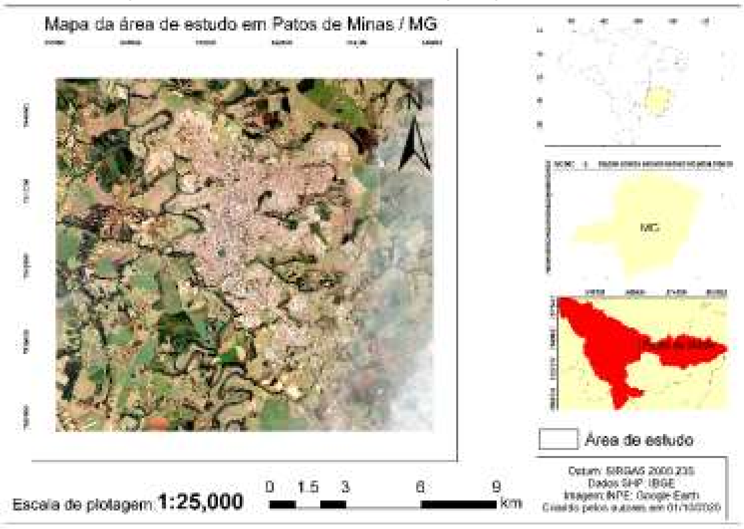
The specific objectives of the work are: Generate maps of natural susceptibility to gravitational mass movements and flooding, in a Geographic Information System (GIS) environment; edit cartographic products generated in digital format so that they can be used to support the review of the master plan, as well as the preparation of geotechnical maps of urban suitability and risk areas, among other planning and territorial management instruments.

1.1 Location and access

The study area is approximately 50 km wide by 30 km long (Figure 1) and is located in the Municipality of Patos de Minas, close to the Triângulo Mineiro region (MG). The headquarters district of Patos de Minas is at an average altitude of 833 meters, with a territorial extension of 1,197.78 km², including 50 km² of urban area. Its limits are: to the north the municipality of Presidente Olegário, to the south the municipality of Lagoa Formosa and the district of Santana de Patos, to the west the district of Pilar, to the east the districts of Pindaíbas and the district of Chumbo and to the southwest the municipalities of Coromandel and Guimarânia.

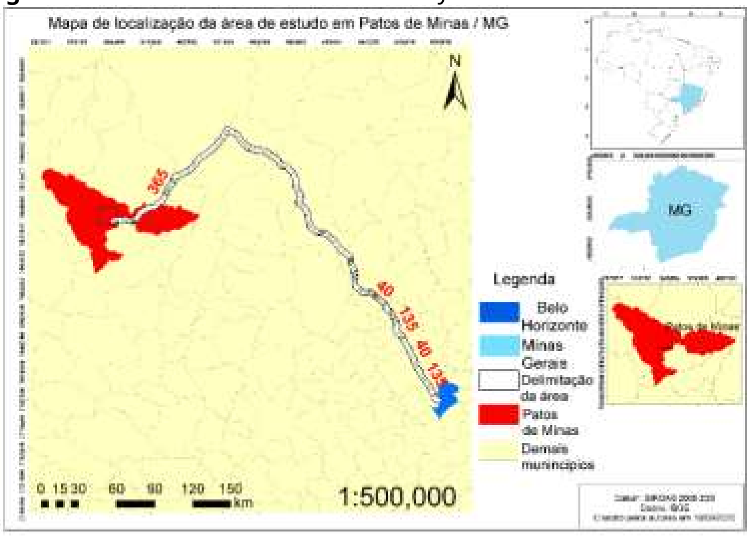
The city of Patos de Minas is 462 km away from Belo Horizonte, capital of the state of Minas Gerais, access to the area is via the federal highway BR-135 to the municipality of Esmeraldas, then BR 040 to the municipality of Sete Lagoas (Figure two). The route varies between BR 040 and 135 to Varjão de Minas where we have access to BR 365 to Patos de Minas. The study area is located in the northern portion of the urbanized area of the city, limited to the north by the Residencial Barreiro neighborhood, to the south Industrial District to the west, Copacabana and to the east Alto Marabá.

Figure 1: Location of the study area, located in the municipality of Patos de Minas, Minas Gerais.



Source: AUTHORS, 2020.

Figure 2: Access roads between the study area and Belo Horizonte.



Source: AUTHORS, 2020.

2 Theoretical foundation

Soil is fundamental for the development of various human activities, however, there are several uses or activities that involve soil degradation. Soil degradation is one of the biggest environmental problems, and occurs across the planet. The result is the direct and indirect impact on human beings: direct due to the fact that it made and continues to make people who live in unstable areas victims of floods and landslides; indirect due to the imbalance in ecosystems that soil impoverishment causes, silting of water bodies, among others. One of the wear factors that has most seriously contributed to soil degradation is erosion (OLIVEIRA*et. al*., 2017).

Erosion is a word that comes from Latin*erode*, which means to corrode, devour, etc. In this way, all wear processes carried out by water, wind and glaciers that respectively generate water, wind and glacial erosion are called. Therefore, erosion is the performance of work and its product is furrows, gullies, etc. Its main conditioning factors, namely: climate, vegetation cover, nature of the soil and the topography of the land (OLIVEIRA*et. al*., 2017).

Crozier (1986) specifically defines that gravitational movements of mass, frequent phenomena that can be defined as an exogenetic process, characterized as the transport of material with or without the help of water with a transport agent, without a defined speed. Bini*et. al*. (2017) describes gravitational mass movements more specifically as categorical processes of changing slopes, since there is removal and deposition of large quantities of materials at once. Its frequency of occurrence is normally small in relation to the action of running waters, however, the transformations in the landscape are generally more significant.

The occurrence of a mass movement event, especially landslides, leaves marked evidence on the landscape that are defined as scars (MARTINS*et. al*., 2015). Another important feature within gravitational mass movements is the gully, since it is the result of deep erosion to the point of reaching the water table (EMBRAPA, 2007).

The study of erosion features can help in understanding the environmental dynamics of the area and thus assist in a possible better choice for housing, plantations and other projects, therefore, mapping them is necessary. According to Fernandes and Amaral (1996), mapping inventories are identified and located using aerial photographs or satellite images, field visits, historical data, etc. Spatial location, together with other relevant information about the process, such as typology, shape, size, range and lateral volume, often assist other methods by providing records of processes occurring in the past and present.

martins*et. al*., (2015) proves that, based on the analysis of mass movement events, different classifications were proposed that consider characteristics of the type of material moved, speed and its morphometry. In addition to classification, factors

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intrinsic factors such as the physical properties of the slopes, as well as triggering agents, both natural and induced, are also considered for the analysis of these phenomena. Crozier (1986) states that mass movements can occur with the help of water, which makes this natural agent also attract attention, since in addition to saturating the soil, thus facilitating landslides, it can also cause floods. Sousa*et. al.* (2013) corroborates that floods can be intensified through soil exposure due to the removal of vegetation cover, demonstrating that this problem is the result of inefficient land use.

According to Tucci; Bertoni (2003), floods generally occur when precipitation is intense and the amount of water that reaches the river is greater than its drainage capacity, resulting in its waters overflowing the riverside areas. The main natural variables for the occurrence of flooding are the relief, quantity and intensity of rainfall, vegetation cover, and soil drainage capacity. The main artificial conditions arise from the use and management of the soil, such as hydraulic works, degree of soil sealing, deforestation and reforestation (GOLDONI; VESTENA, 2006).

The characteristics of the physical environment that can naturally cause some event of mass movement or flooding associated with urban expansion processes without adequate planning and real estate speculation in inappropriate locations or with some risk potential, can result in the precariousness of vegetation cover and resources natural resources of soil and water. As a result, watercourses become silted due to the accumulation of sediments that result in excess material in the bed, thus placing citizens at high risk. There is also the establishment of subdivisions and invasions in areas unsuitable for human occupation, in addition to the release of channeled rainwater in inappropriate locations and the intensification of the soil waterproofing process. This situation has led to the occurrence of several erosion processes and, as a consequence of these processes, the emergence of ravines and gullies (MENDES, 2014).

Currently in Brazil, natural disasters have caused a lot of socio-environmental damage and are mainly associated with the area's hydro-climatic regime. Among the main causes of disasters are floods, floods, droughts, floods, landslides and/or rocks and storms, associated with intense and prolonged rain events (TOMINAGA*et. al.*, 2009).

Therefore, it is of great importance to understand how erosive dynamics can occur, to minimize risks to the population. The identification and mapping of areas most susceptible to flooding are also essential for decision-making, mainly for urban planning. Geotechnical cartography is a planning tool that integrates data and basic information about the geotechnical characteristics of land and, in this way, we can understand interactions with human interventions related to the process of land use and occupation (BITAR*et. al*., 2015).

3 Methodology

The proposed study was carried out according to the following steps in Figure 3.

Figure 3: Flowchart of the steps carried out in the study.

Source: AUTHORS, 2020

The database used to carry out this work consists of: 30m SRTM image (Earth Explorer); aerial image of the June 26, 2020 flight of the 30m LANDSANT 8 satellite for vectorization of erosive features (INPE); municipal limits of Minas Gerais and Patos de Minas from 2010 (IBGE); historical rainfall data of average annual isohyets from 1977 to 2006 on a scale of 1:1,000,000 (CPRM); land use and occupation 2015 at scale 1:1,000,000 (Embrapa); geological maps of Patos de Minas and Carmo do Paranaíba on a scale of 1:100,000 (Geology Portal and CPRM); soil classes, on a scale of 1:50,000 (DEGET - Department of Territorial Management (CPRM/ERJ 2009)); city's road network (Google Earth).

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The bases of lithology, land use, soil classes, isohyets, road network, land use and occupation were used to create thematic maps. From the SRTM image, slope and hypsometry information was acquired and from the LANDSANT image, the Normalized Difference Vegetation Index (NDVI) was obtained and used for vectorization of erosive features.

The NDVI calculation is made from the difference between the reflectances of bands 4 (near infrared) and 3 (visible - red) divided by the sum of the reflectances of the two bands. The result varies from -1 to 1, so the closer to 1, the greater the indication of the presence of vegetation, and the closer to -1, the greater the indication of the presence of bare soil and rocks.

The information processing and map creation procedures were carried out using the*software*of GIS*ArcGIS*10.6 and QGis 3.12, All maps were prepared at a plotting scale of 1:25,000, to be compatible with the IPT manual of geotechnical maps and the explanatory note on the construction of maps of susceptibility to gravitational mass movements and flooding of the CPRM (BITAR, 2014). Since the country has a deficit in its cartographic information base, and there is no standardization of scales, it is up to private companies and even municipalities to create updated and detailed data, when it is beneficial.

3.1 Construction of the susceptibility model to gravitational mass movements and flooding

To qualify natural susceptibility to gravitational mass movements, maps of soil classes, land use and occupation, lithology, vegetation vigor (NDVI), slope, road network, historical rainfall isohyet, hypsometry were used, which were subdivided in classes. To qualify the flood area, important factors that directly influence the water level reached by a flood, regardless of the incident precipitation, were evaluated: altitude, slope, land use and soil type (SANTOS; LOUZADA; EUGENIO, 2010).

Each mapping class received values from 1 to 5 (Table 1), taking into account interference and impacts that the classes could contribute to triggering mass movements. So the higher the score, the greater the natural susceptibility to gravitational mass movements and flooding (1: very low; 2: low; 3: medium; 4: high; 5:

very tall). To define the notes for lithology variables, soil classes, vegetation index, slope, road network, land use and occupation, rainfall, vegetation vigor and hypsometry, information from the authors SANTOS was used as a parameter.*et. al.*, (2018); CREPANI*et. al*(2001) and SILVA (2014). It should be noted that the variable scores underwent changes in relation to the references consulted, so that they were consistent with the study area. The mapped erosion features were superimposed on the evaluated themes, to identify possible relationships and make adjustments to the notes.

Table 1: Map classes subdivided with their respective weights.

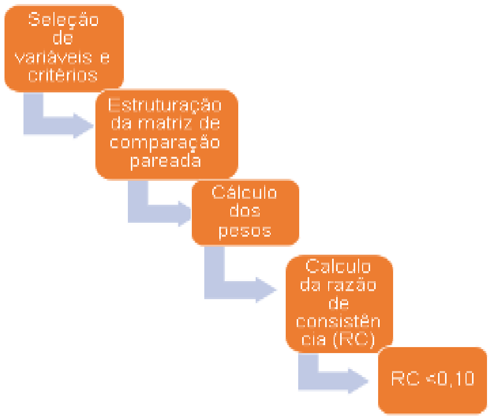
VARIABLE	SUBTITLE COMPONENT	NOTE (1 to 5)
Lithology	Basalts and pyroxenites unsaturated in silica and rich in alkalis	two
	Undifferentiated detrital coverage: Unconsolidated sandy, sandy-clayey and silty-claystone sediments, locally with occurrence of canga and gravel levels.	4
	Metasiltstone, Sandstone, Metaclaystone	3
	Siltstones, laminated mudstones, conglomerates and sediments turbidites	3
	Eluvial-colluvial cover: Uncosolidated sandy sediments, clayey sandy silt.	3
	Congolemeratic sandstone	3
Soil classes	Purple Oxisol	two
	Dark Red Latosol	two
	Cambisol	5
Slope	0-3	1
	3-8	two
	8-20	3
	20-15	4
Road network	25 m buffer	3
Use and occupation of ground	Natural pasture	1
	Planted pasture	3
	Agricultural area	4
	Urban stain	5
	Mosaic of forest vegetation with Agricultural Areas	two
Rain gauge	High	4
Vegetation vigor (NDVI)	Low	5
	Moderately low	4
	Average	3
	Moderately high	two
	High	1
Hypsometry	775 - 824	5
	824 - 869	4
	869 - 927	3
	927 - 1,007	two
	1.007 - 1.091	1

Source: AUTHORS, 2020.

3.2 Ahp (analytical hierarchy process)

After applying values to the classes of each map generated, the analytical hierarchy process was used to correlate the maps used. The method was proposed by Wharton in 1977 and is widely used in the analysis of problems involving multi-criteria analysis (Figure 4). The method consists of ranking the elements that make up the analysis using weights, according to their degree of importance. The process is the simplification of a complex system into a matrix of paired comparisons of variables in a linear definition of the hierarchy of importance, on a scale from 1 to 9 (Table 2), based on decomposition, comparative judgment and synthesis of priorities (PARK*et. al.,*2010; SAATY, 1977; SANTOS*et. al.*, 2010; VASILJE-VIC*et. al.*, 2012).

Figure 4: Steps developed in the analytical hierarchy process.



Source: AUTHORS, 2020

Table 2: AHP importance scale

PESO	IMPORTÂNCIA
1/9	Extremamente menos importante que
1/7	Muito fortemente menos importante que
1/5	Fortemente menos importante que
1/3	Moderadamente menos importante que
1	Igualmente importante a
3	Moderadamente mais importante que
5	Fortemente mais importante que
7	Muito fortemente mais importante que
9	Extremamente mais importante que
2,4,6 e 8 valores intermediários	

Source: SAATY; VARGAS, 1979.

Mapping areas susceptible to risk is an analysis that requires numerous variables and involves specific relationships of tangible and intangible criteria. For demanding valuation judgments, for Vasiljevic*et. al.*, (2012), AHP is an inflexible mathematical method, which carefully hierarchizes decision-making, simplifying the process and reducing significantly errors related to the judging stages. Through paired analysis, the variables are subjected to hypotheses, enabling the best alternative to be reached, which provides greater accuracy to the results. Feizizadeh and Blaschke (2012), comparing several multi-criteria assessment methods applied to the determination of susceptibilities, AHP appears to be the best technique, as there is greater consistency in the mapping and validation of the model. Accuracy is supported by the possibility of verifying the consistency of the analysis evaluation, that is, verifying the coherent assignment of weights through the calculation of the Consistency Ratio (RC), between 0 and 0.10 to satisfy the simulations (SAATY; VARGAS, 1979). The matrix is determined based on the study variables, expressed in Figure 5.

Figure 5: Example of matrix used in the method.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & a_{3n} \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

Source: WEISS; PIPPI, 2019.

Therefore, according to the steps described in figure 3, paired comparison matrices were constructed using the AHP CALCULATOR website, in which the names of the variables are entered and then requests scores from 1 to 9 as proposed by Saaty and Vargas in 1979. After the scores are defined, the site automatically calculates the RC (RC = IC/IR) being IC (consistency index), IR (random index), not allowing it to progress until it is between 0 and 0.10, being within the reliable limit, after RC within from the standard, the website gives you the static weights of the variables (Table 3).

The RC given for natural susceptibility to gravitational mass movements was 0.05 while for susceptibility to flooding was 0.03, being within the standard indicated previously and concluding that the defined weights are acceptable. The weight values were assigned based on a preliminary analysis of each variable based on other authors who applied the methods in similar areas. In this way, the highest values for the natural susceptibility map were assigned to the following classes: vegetation index, which expresses the quality of vegetation and its photosynthetic quality; pluviometry, as it is the main modifying agent that intensifies the studied phenomenon; soil classes, linked to the infiltration, saturation and transmissivity properties that the soil may have. While for susceptibility to flooding, slope and soil class had the highest weights. Since low-lying areas have a greater possibility of flooding, and the classes of

Soil are important in the hydraulic parameter of recharge of rivers and aquifers. There is also interference from the scales of the maps, since the database provided free of charge by the government has little detail and is not standardized, this can cause overestimation of values.

Table 3: Statistical weights of variables.

NATURAL SUSCEPTIBILITY TO MOVEMENT MASS GRAVITATIONAL	
VARIABLE	**WEIGHT**
Vegetation Index	26.3
Rain gauge	31.9
Use of the soil	5.1
Soil class	20.6
Lithology	9.2
Slope	3
Road system	3.9
Total	100
SUSCEPTIBILITY TO FLOOD	
VARIABLE	**WEIGHT**
Slope	61.2
Soil classes	21.5
Use of the soil	13
Hypsometry	4.3
Total	100

Source: AUTHORS, 2020.

With the values of the weights defined, the final phase of the analysis consists of the integration of the variables from the map algebra, which multiplies each variable with its weight and we add the results, determining the natural susceptibility of gravitational movements of mass and flooding with the following equations:

SNMG (SUSCEPTIBILITY NATURAL A MOVEMENTS GRAVITATIONAL MASS)=*(Vegetation index * 26.3) + (Rainfall * 31.9) + (Land use * 5.1) + (Soil class * 20.6) + (Lithology * 9.2) + (Slope * 3.0) + (Road system * 3.9)*

RIP (RISK OF FLOODING IN PATOS DE MINAS)=(*Slope * 61.2) + (Soil classes * 21.5) + (Land use and occupation * 13) + (Hypsometry * 4.3)*

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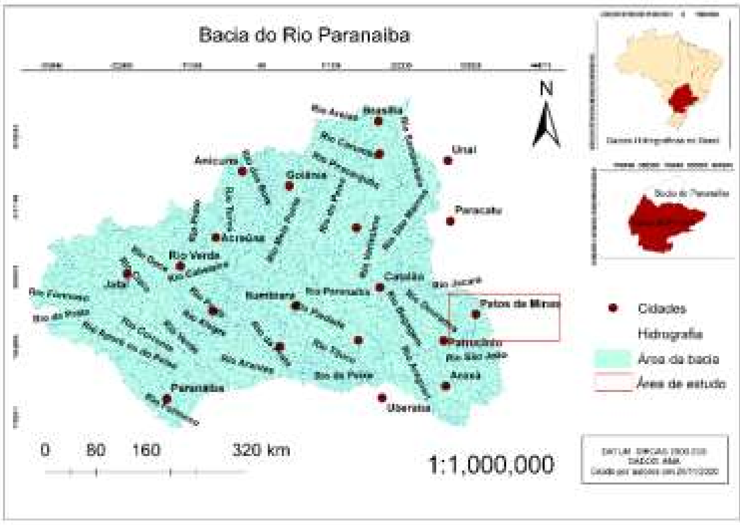
4 Results and discussions

4.1 Physographic aspects

4.1.1 Hydrography

The study area is located in the Paranaíba Basin (Figure 6), which is one of the six units that make up the Paraná Basin Hydrographic Region. This system is made up of four main rivers in its area, namely: Rio Paranaíba, Rio São Marcos, Rio Corumbá and Rio Aporé. The Paranaíba River is present in the study region in addition to being one of the tributaries that makes up the Paraná River and forms the natural border between Minas Gerais, Goiás and Mato Grosso do Sul (PRBHBP, 2011). In the area of this basin (Figure 6), it is possible to identify nine aquifer systems, with the Bambuí aquifer present in the research region (PRBHBP, 2011).

Figure 6: Location of the study area in the Paranaíba Basin.

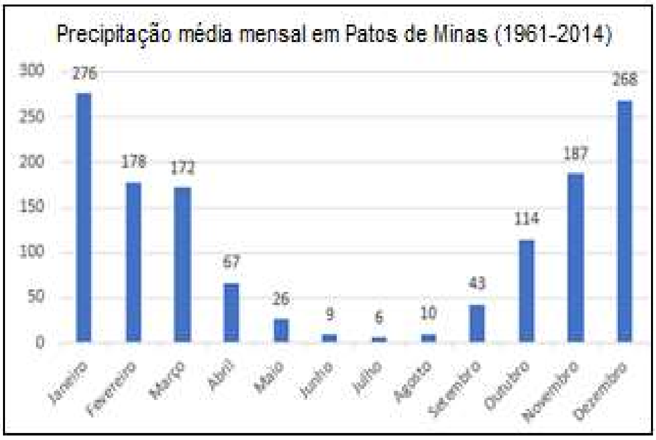


Source: AUTHORS, 2020.

4.1.2 Climate

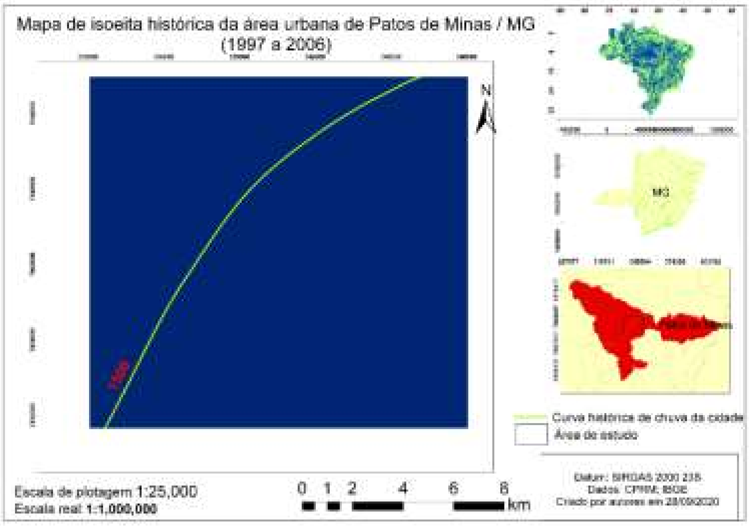
The climatic dynamics of the region in which Patos de Minas is located is mainly dominated by Tropical Continental, Equatorial Continental, Tropical Atlantic and Polar Atlantic air masses, with spatial variations determined by continentality and topography (SILVA, 2012). According to Flauzino*et. al.*, (2010), based on the Köppen classification, the city's climate is characterized by a tropical regime with a dry period in the months from April to September and the rainy season from October to March, as shown in Figure 7, generated from data from the National Water Agency (ANA) (2020). The city's average annual rainfall, from 1961 to 2014, is 133 mm and the city has a historical average from 1997 to 2006 of 1500 mm (Figure 8), with 150 mm annually in almost a decade, the same is shown with the isohyet of the region, data taken from CPRM (2020).

Figure 7: Annual average, from 1961 to 2014, of precipitation in the municipality of Patos de Minas, Minas Gerais.



Source: ANA, 2020

Figure 8: Rainfall map with the historical curve (isohyet) from 1996 to 2007



Source: AUTHORS, 2020.

4.1.3 Land use and occupation

The research area is mainly located in the Cerrado, a biome that covers a large part of the state of Minas Gerais. The typical vegetation of this biome is composed of forest, savanna and grassland formations, presenting a great physiognomic variation. At mesoregion of the Triângulo Mineiro/Alto Paranaíba, occur predominantly in dirty fields (shrub vegetation) in the higher portions and, as the elevation of the land decreases, savanna phytophysiognomies of the cerrado (dense, typical, thin and rocky), characterized by the presence of trees low, tortuous and bushy. In regions at lower altitudes, such as around the Paranaíba River, remnants of semi-deciduous forest characteristic of the Atlantic Forest biome can be identified, with arboreal nature and canopy formation, formed in fertile soils due to the proximity of watercourses. These are known as dry forests, due to the loss of leaves during the winter and dry period (RIBEIRO; WALTER, 1998).

Soil use and occupation occurs mainly in agriculture and pasture activities, these are the common activities in the use and occupation of the biome in Minas Gerais, being responsible for almost 45% of all activities.

However, the natural/non-vegetated natural composition covers almost half of the Cerrado of Minas Gerais. In Patos de Minas, these compositions stand out alongside the urban occupation (BRASIL, 2015).

To better understand and complement Embrapa's 2015 land use and occupation shapefile, the NDVI calculation (Figure 9) of the area was made, using INPE's 2020 area image. The calculation is the difference between the reflectances of bands 4 (near infrared) and 3 (visible - red) divided by the sum of the reflectances of the two bands. The result varies from -1 to 1, so the closer to 1, the greater the sign of the presence of vegetation, and the closer to -1, the greater the sign of the presence of bare soil and rocks (ROCHA, 2018).

The red portions of the map designated as low vigor are completely deforested areas such as the urban area (Figure 10) or bodies of water and the orange areas designated as modernly low are areas with very little vegetation or shrub vegetation, while the green portions are areas that have vegetation (ROCHA, 2018).

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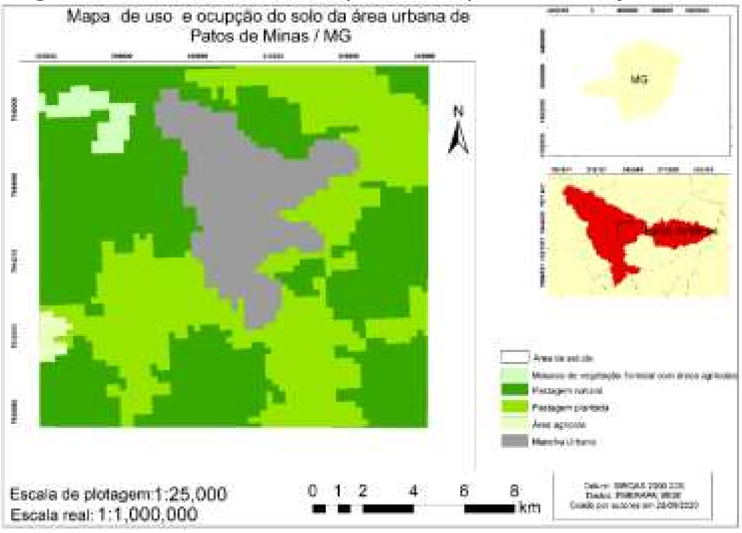
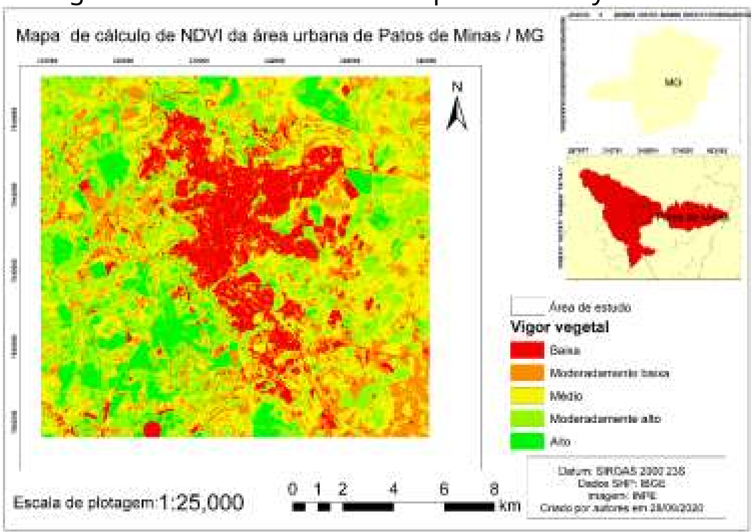
Figure 9: Land use and occupation map of the study area.



Source: AUTHORS, 2020.

Figure 10: NDVI calculation map of the study area.



Source: AUTHORS, 2020.

4.1.4 Soil

The soils present in the Patos de Minas region are predominantly Oxisols (red and purple), in addition to the presence of Cambisols as shown in the shapefile (Figure 11) of scale 1:50,000 from DEGET – Department of Territorial Management (CPRM/ERJ 2009) .

Oxisols are characterized by their advanced weathering phase, highly evolved as a result of this energetic process of their constituent material. They are composed of primary or secondary minerals that are less resistant to the weathering process and originate from the most diverse rocks and sediments that are in different climate and vegetation conditions. Generally, they are strongly acidic soils, with low

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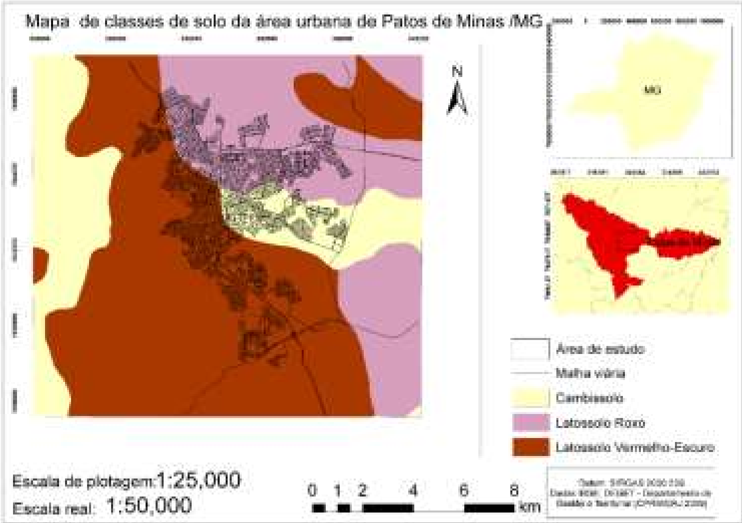
base saturation, dystrophic or aluminum, and soils with medium and even high base saturation may occur, which are found in regions that have a dry season or are influenced by basic or limestone rocks. They have a silt content of less than 20% and clay varying between 15% and 80%. These are soils with high water permeability (porous), and can be worked in a wide range of humidity. The red ones are not very efficient for agriculture, requiring correctives and fertilizers. Purple ones are excellent for agriculture, as they come from volcanic rocks such as basalt. The strong, very small and granular structure leads clayey latosols to behave similar to sandy soils. Furthermore, in clayey to very clayey oxisols, when intensely mechanized, the structure is destroyed, leading to a reduction in porosity. Oxisols occur in equatorial and tropical regions as well as in subtropical zones and distributed in large and ancient areas of erosion, pediments or ancient river terraces, mainly in flat and gently undulating relief, and can occur on more rugged surfaces, including mountainous relief (EMBRAPA , 2018).

In general, Oxisols, in their natural state, have high porosity, low resistance, low susceptibility to erosion, low support capacity, and may be collapsible in addition to having a high degree of resistance to erosion compared to other types of soil. When properly compacted, they have high resistance and support capacity, along with low permeability. These soils, when immersed in water, lose little bearing capacity. The plastic varieties of these are contractile, but contrary to expectations, they are not very expansive (GODOY, 1997).

Cambisols are of little advanced pedogenesis represented by the presence of development of the soil structure, with alteration of the source material marked by the almost extinct structure of the rock or sediment stratification. Due to the heterogeneity of the source material, relief forms and climate, the properties of these soils vary greatly from one location to another. Therefore, this class ranges from strongly to imperfectly drained soils, from shallow to deep, from high to low base saturation and chemical activity of clay minerals (EMBRAPA, 2018).

Figure 11:Map of soil classes present in the study area



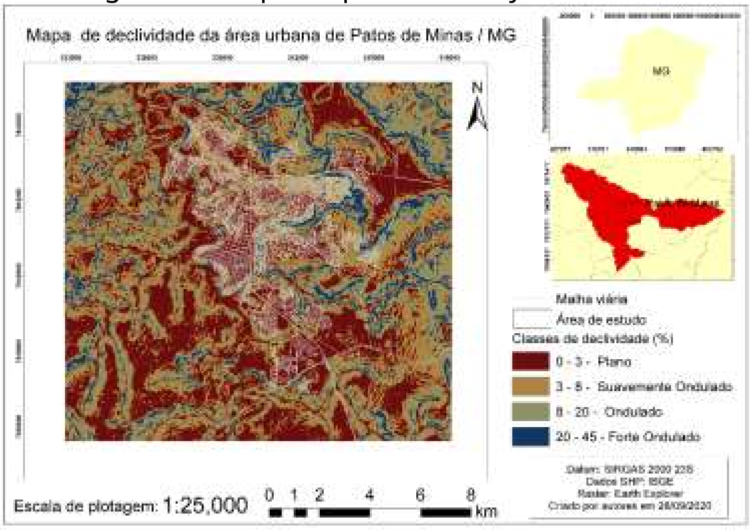
Source: AUTHORS, 2020.

4.1.5 Geomorphology

The geomorphological patterns indicated by the Compartmentation of the Relief of the State of Minas Gerais (CPRM, 2010) mapping, points to the predominance of Flattened Relief Domain patterns in the Patos de Minas region, such as the Retouched or Degraded Flattened Surfaces and the Reliefs Residuals. The same work also points to a Domain of Aggradational Units present in the study area, referring to the River Plains (CPRM, 2010).

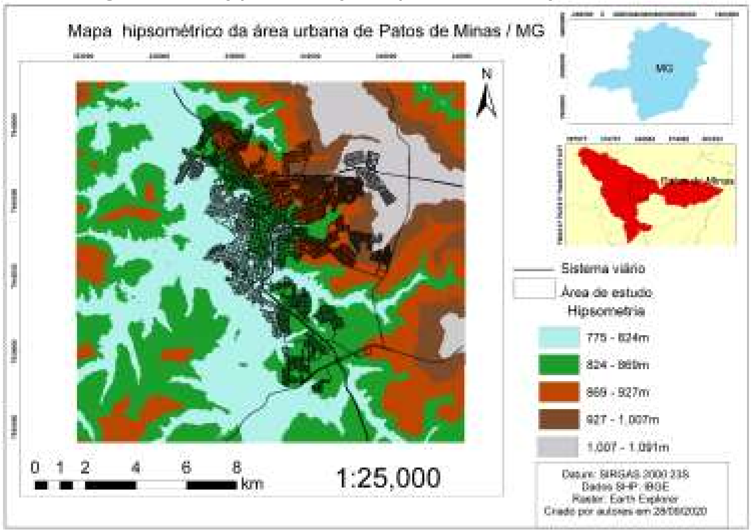
The Retouched or Degraded Flattened Surfaces, identified on the slope map (Figure 12) are flat surfaces, which may have a slight degree of undulation, extensive and monotonous, but they are not composed in a hilly environment due to the very low relief amplitudes and long slopes very low slope. The Residual Relief features are products of general land displacement, being highlighted and isolated in the flattened landscape. The River Plains are periodically floodable surfaces, converging towards watercourses, composed of sediments with clay and sand grain sizes (CPRM, 2010). The urban perimeter of Patos de Minas is between altitudes of 775m and 1091m, with a greater concentration at the lowest elevation, identified by CPRM (2020) as river plains (Figure 13).

Figure 12: Slope map of the study area.



Source: AUTHORS, 2020.

Figure 13: Hypsometry map of the study area.



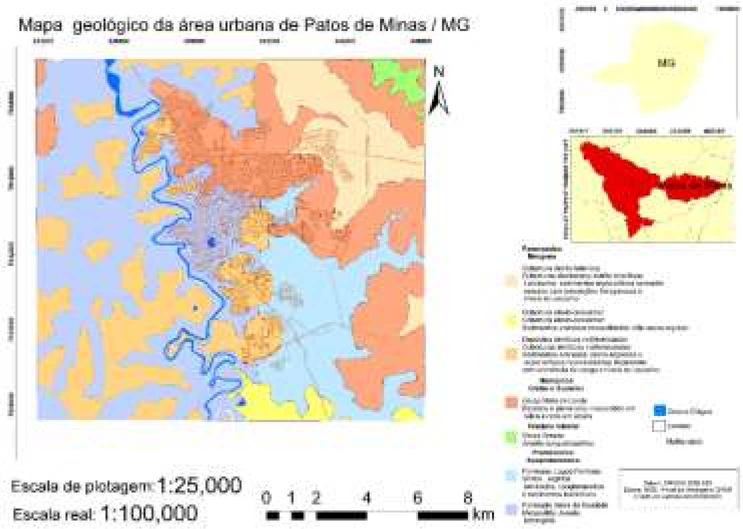
Source: AUTHORS, 2020.

4.1.6 Regional geology

The municipality of Patos de Minas is located in the extreme west of the São Francisco Craton, on the border with the Brasília Belt. The geology (Figure 14) of the studied region is composed of rocks belonging to the São Francisco basin represented by the Bambuí group, being present with the Serra da Saudade formation (CPRM, 2013). This formation is still accompanied by undifferentiated Cenozoic detrital covers and by the undivided Mata da Corda group, which is made up of alkaline volcanic rocks (BATISTA, 2004). The Serra da Saudade Formation consists of siltstones, sandstones and mudstones (SIGNORELLI*et. al.,*2008). The coverage

Undifferentiated Cenozoic detritals are marked by the presence of sandy, sandy-clayey and unconsolidated clayey-silty sediments, with local occurrence of canga and gravel levels (CPRM, 2013). Such Cenozoic detrital covers are located in areas of top and high/ middle slopes, overlapping the Serra da Saudade formation, which crops out in the middle/low slopes.

Figure 14: Geological map of the study area.



Source: AUTHORS, 2020.

4.1.6.1 São Francisco Basin

The São Francisco Basin corresponds to an intracratonic basin that covers the basement of the São Francisco Craton. Covers areas of the states of Minas Gerais, Bahia, Goiás and Tocantins. The filling of this basin presents a polyhistorical evolution represented by stratigraphic units with distinct characteristics and ages that vary from the Paleo/Neo-proterozoic to the Upper Cretaceous (ALKMIM & MAR-TINS-NETO, 2001) comprising the São Francisco basin, the Bambuí Groups and their respective Serra da Saudade formations and Lagoa Formosa Formation.

The Areado, Mata da Corda Groups and the detrital covers belong to the Sanfransiscana basin, which constitutes another sedimentation regime with the presence of volcanic rocks of Paleozoic age, distinguishing it from the São Francisco basin of Neoproterozoic age. (ALKMIM; MARTINS-NETO 2001).

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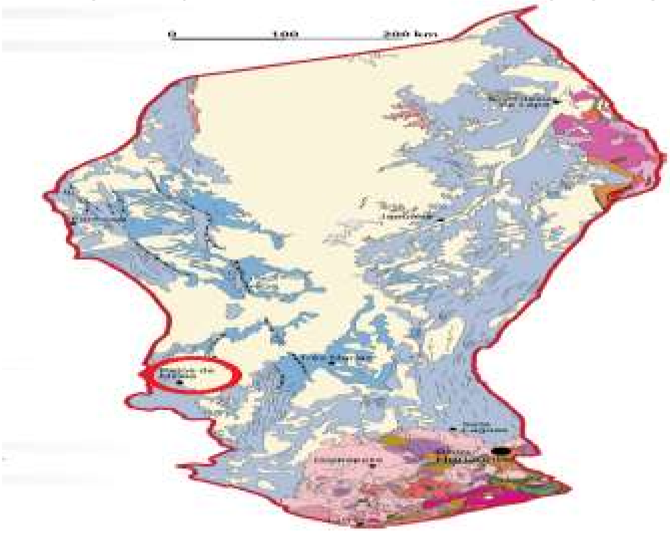
Figure 15: Geological map of the São Francisco Craton, highlighting the study area.



Source: KOSIN*et. al*., 2004.

4.1.6.1.1GBambui group

The Bambuí Group (750-600 Ma) constitutes the Neoproterozoic cover with the greatest distribution in the São Francisco Craton. It represents an association of siliciclastic and biochemical lithofacies, in the form of platform sediments deposited in an extensive epicontinental sea. Regionally, the classic formations of the Bambuí Group were identified, as defined in the RADAMBRASIL Project (1982).

4.1.6.1.1.1 Serra da Saudade Formation

It only crops out in the western portion of the map and is around 200m thick. Apparently, this unit is stratigraphically above the Lagoa Formosa Formation, however, the relationships between these units have not yet been well defined, with a transitional contact being interpreted here, represented by a change in the lithological association (LIMA; UHLEIN; BRITTO,2007). The predominant lithotype corresponds to a siltstone, sometimes clayey, with constant plane-parallel lamination. The outcrops are normally well weathered, which gives the rock an ocher to pinkish color. Calcisiltite and, subordinately, fine calcarenite occur in lenses of maximum 1m (LIMA; UHLEIN; BRITTO, 2007).

They present flat-parallel and tabular cross stratifications. Interspersed in the siltstone are also metric lenses of verdigris, which corresponds to a green siltstone enriched in potassium, and may also have high levels of phosphorus. The greenish color is due the presence of the potassium phyllosilicate glauconite, as per. This characteristic lithotype is similar to the green pelites and diamictites with a greenish matrix observed in the Lagoa Formosa Formation, which may represent a correlation between these units (LIMA; UHLEIN; BRITTO, 2007).

4.1.6.1.1.2 Lagoa Formosa Formation

It corresponds to the Neoproterozoic unit with the largest area in the Patos de Minas region. It crops out throughout the central portion along the embedded valleys. Its thickness is difficult to determine due to the effects of deformation – folds and repetitions due to faulting that are often covered by the Cretaceous sediments of the Areado Group. A thickness of around 200m is estimated here. It is composed predominantly of siltstone with small intercalations of clayey siltstone, mudstone and, to a lesser extent, sandstone (LIMA; UHLEIN; BRITTO,2007). They present plane-parallel lamination and stratification marked by the granulometric variation of the sediments and/or the change in color. In general, the outcrops are intensely fractured and highly weathered, displaying colors that vary from beige to pink. When fresh, they are dark green to gray in color. Associated with the siltstone, there is, subordinately, diamictite with a silt-clay matrix and a framework composed of pebbles and subangular blocks of laminated and massive siltstone (LIMA; UHLEIN; BRITTO, 2007).

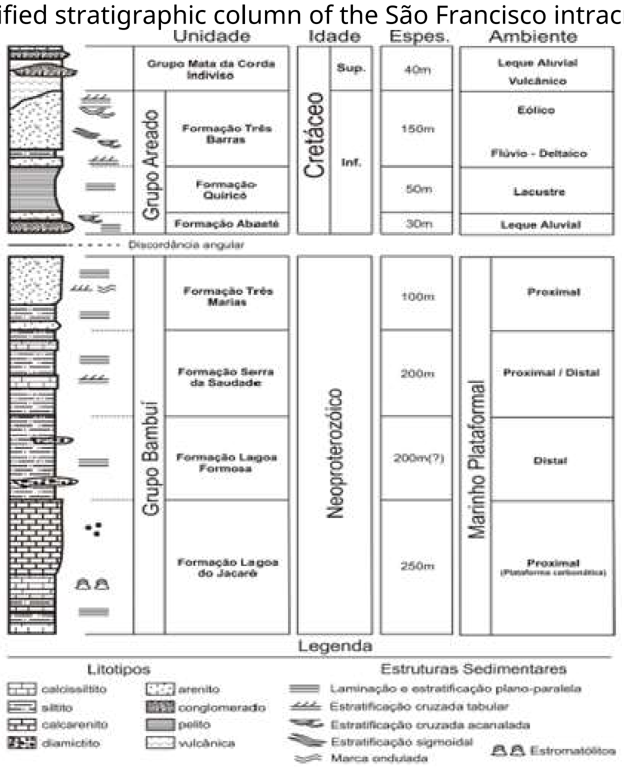
4.1.6.1.1.3 Lateritic and eluvial covers

Cenozoic covers are units with a wide distribution in the area, the result of intense erosion processes that affected the formations studied. They are unconsolidated, with variable thicknesses and can be classified as alluvial, colluvial and eluvial covers (CHIAVEGATTO 1992, UHLEIN*et. al.,*2004).

4.1.6.2 Sanfranciscana Basin

The Sanfranciscana Basin is an intracratonic Brazilian sedimentary basin located in the central-eastern portion of Brazil, with an area of 150,000 km2 and covering the states of Tocantins, Bahia, Goiás and Minas Gerais. It corresponds to the Phanerozoic record of the São Francisco Basin, with rocks aged between 300 m.y. and 70 m.y., that is, from the Permocarboniferous period until the lower Cenozoic (Phanerozoic Eon), representing the last geodynamic megacycle of the São Francisco Basin (SGARBI, 1989).

Figure 16: Simplified stratigraphic column of the São Francisco intracratonic basin.



4.1.6.2.1 Areado Group

The Areado Group represents the second filling cycle of the basin, with its sedimentation occurring in the Lower Cretaceous. The group is made up of three formations, namely: Abaeté Formation, Quiricó Formation and Três Barras Formation (SGARBI, 1989). The Abaeté Formation is the basal formation of the Areado Group, representing gravitational deposits, in the form of alluvial fans and sporadic and torrential aqueous flows, originating deposits (SGARBI, 1989). The Quiricó Formation is represented by massive sandstones and siltstones, as well as massive mudstones and lenses of finely laminated yellow limestones with hummocky stratifications, "cone-in-cone" and teepee structures. There are also oxidized marls with bioturbations at the top of the sequence. Ostracod shells and fragments of fish bones and scales are also common (SGARBI, 1989).

The Três Barras Formation is the top formation of the Areado Group. It can be divided into two members: Quintinos Member and Olegário Member. The Formation is mainly composed of sandstones which, in general terms, were cemented by calcium carbonate. That

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The formation was developed in an arid climate environment, meaning the advancement of wind dunes over the lakes of the Quiricó Formation (SGARBI, 1989).

4.1.6.2.2 Mata da Corda Group

The Mata da Corda Group is composed of mafic-ultramafic rocks that record volcanic activity in the Neocretaceous. Epiclastic rocks are also found in this group. As a strong interdigitation between volcanic and sedimentary lithotypes is observed, it is interpreted that magmatism occurred as pulses. The group is divided into the Patos and Capacete Formations (SGARBI; VALENÇA,1993).

The Patos Formation is the basal unit of the group and encompasses kamafugitic volcanic and subvolcanic (conduit) rocks (SGARBI; VALENÇA, 1993). It constitutes part of the mafic alkaline magmatism that constitutes the Minas-Goiás Alkaline Province. This magmatism is temporally associated with plutonic carbonate complexes (SILVA *et. al*., 1979; GOMES*et. al*.,1990), such as those of Araxá and Tapira. The Capacete Formation is composed of volcaniclastic – conglomerates and epiclastic sandstones, pyroclastic materials. They originated from pyroclastic flows, erosion and weathering of the rocks of the Patos Formation, which in turn were transported by alluvial fans and intertwined river torrents, forming para-conglomerates with clasts of alkaline igneous rocks, in addition to clasts of metamorphic rocks, such as quartzites. , with a sandy matrix (SGARBI; VALENÇA 1993).

4.1.7 Structural geology

The tectonic evolution of the study region was directly influenced by the Brazilian folds of the Brasília Belt, as well as the tectonic scenario that generated the Sanfranciscana Basin. Therefore, it is necessary to analyze, independently, the origin and tectonic evolution that generated the Neoproterozoic portion of the area, represented by the Bambuí Basin, and the Phanerozoic succession characterized by the Areado and Mata da Corda groups (ALKMIM; MARTINS NETO, 2001 ; CAMPOS; DARDENNE, 1997).

Figure 17: Geological framework and distribution of the São Francisco and Sanfranciscana Basins in the Craton namesake.

Source: ALKMIM, 2004.

4.1.7.1 Bambuí Basin

According to Alkmim*et. al*., (1993), the deformational variations observed in the Bambuí Group are correlated to the division of the São Francisco Basin into structural compartments. In this sense, the author classifies the basin into three main domains: central, western and eastern. In the central domain, lithotypes from the Bambuí Group are found almost undeformed. In the western portion, where the São Francisco Cráton meets the Brasília and Rio Preto belts, progressive deformation is noted, with systems of folds and thrust faults associated with transpression being found. In turn, the eastern compartmentation is marked by greater structural complexity, involving folds and thrust faults with duplex geometry and embricated fan, in addition to presenting a conjugate pair of joints with a NW/SE and NE/SW direction. However, unlike the western domain, deformation in this portion does not involve the basement, only its cover.

4.1.7.2 Sanfranciscana Basin

The Phanerozoic portion of the area represented by the Areado and Mata da Corda Groups, makes up a fraction of the intracratonic basin of the Sanfranciscana interior depression type, recognized as such by Silva*et. al.,*(2003), based on the Kingston Global Basin Classification System*et. al.,*(1983). In their work, Campos and Dardenne (1997) already proposed an intracontinental model for the evolution of this basin, and its genesis was controlled since the Paleozoic through distinct tectonic stages. After the end of the collisions that marked the Neoprotezoic, a period of glaciation marked the beginning of the sedimentation of the Sanfranciscana Basin (Santa Fé Group), which was attributed to the isostatic and flexural accommodations that occurred within the São Francisco Craton between the Permian and Cambrian (CAMPOS; DARDENNE, 1997). This stage is considered the Paleozoic tectonic stage of the basin, characterized by a period of weak tectonic activity, configured by the gradual cooling of the cratonic core, and which coincided with the stabilization of Gondwana. During the Neopaleozoic and early Mesozoic, the Sanfranciscana Basin was marked by tectonic quiescence. This period was marked by post-glacial events that culminated in the isostatic uplift of the basin and the accentuated erosion of glacial sediments from the Santa Fé group and the Bambuí group, which served as the basis for much of the sedimentary input (CAMPOS; DARDENNE 1997).

It is finally in the Cretaceous that there is the deposition of the Areado Group sediments and, subsequently, the incidence of alkaline magmatism in the Alto Paranaíba igneous province. The Eocretaceous marks the extension phase of the Sanfranciscana Basin, following the opening of the Atlantic Ocean, being responsible for the mechanical subsidence of the basin (CAMPOS; DARDENNE,1997). The process was the agent responsible for the subsidence of the crust in the southern portion of the basin, providing a favorable environment for the deposition of sediments, largely aeolian, from the Areado Group (SGARBI*et. al.*, 2001). The Mata da Corda Group is distributed only in the southern portion of the Sanfrancicana Basin and is related to the uplift of the Alto Paranaíba Arch during the Late Cretaceous. This stage of evolution was caused by the generation of a series of faults triggered by the development of the passive margin phase of the coastal basins, which reached the southernmost region of the basin more sharply (CAMPOS; DARDENNE,1997). The acid magmatism generated since then is discussed by many authors, as it gave rise to a series of pyroclastic flows with kamafugite affinity and which is peculiar to this area. Still in the Neocretaceous, the Alto Paranaíba Igneous Province suffered from an erosion process that reworked the effusive rocks found there, culminating in the epiclastic deposits that limit the top of the Mata da Corda Group. It is worth highlighting the occurrence of a final stage of evolution of the Sanfranciscana Basin, qualified, in the Cenozoic, by its neotectonic reactivation (HASUI,1990). This phase is represented by a set of faults well observed in the Bambuí Group, which determined the drainage pattern of the basin (CAMPOS; DARDENNE, 1997).

4.2 Susceptibility to gravitational mass movements

Susceptibility can be summarized as the predisposition or propensity of land to the development of a phenomenon or process in the physical environment (JULIÃO*et. al*., 2009; CORK CORK; SOUZA, 2012; DINIZ, 2012). Thus, susceptibility analyzes refer to the indication of areas prone to the development of processes in the physical environment that can generate natural disasters, due to the presence of basic predisposing factors in occupied and unoccupied land. Therefore, it does not include any type of analysis regarding danger or risk (BITAR, 2014)

Mass Movements are downward movements of soil and rocks under the effect of gravity, generally enhanced by the action of water. They are called landslides, landslides, slope failures, falling barriers, among others (GUIMARÃES, 2008).

Obtaining knowledge of geology helps in understanding the characteristics of the terrain, such as slope and relief (CAMARGO; SOARES; GIONGO, 2018). Understanding the geology allows the characterization of the area in relation to geomorphological factors. The lithologies analyzed provided an understanding of aspects of the region, such as agricultural suitability, areas susceptible to naturally occurring erosion processes. The lithology present in the area gives it, in some points, a high influence on the action of erosion, mainly areas of recent sedimentary coverage, and areas that belong to the Lagoa Formosa and Serra da Saudade Formations.

Vegetation vigor (NDVI) is an indicator of the presence and photosynthetic quality of the vegetation cover on the soil and it helps in the interception of raindrops, reducing the impact and disruption of the soil (splash effect), which mainly causes surface sealing by clay. Vegetation is also important in reducing the speed of water flow on the soil surface, as it favors infiltration, feeding the water table and favoring the flow of water bodies. The closer to the city, the less vegetation there is, and around it the vegetation has medium to moderately high vigor, which causes medium to high susceptibility to erosion (ROCHA, 2012).

Land use presents erosion susceptibility ranging from high to medium. The area belonging to the urban perimeter and areas where vegetation is scarce or insufficient has high susceptibility, as in the first case urbanization modifies the environment for better adaptation of people and in the second there is the interference of the type of vegetation present and the physiological integrity of the vegetation that is not always healthy, changing the type of vegetation for agricultural activities must be taken into account.

The soils highlighted in the area are the Red and Purple Oxisols, and the Cambissolo. Generally, oxisols have a high concentration of clay, great depths, are well structured and have high water permeability (CREPANI*et. al*, 2001). These soils generally have very low susceptibility, except in situations of high slopes and intense agricultural use. Cambisol, in turn, has a high concentration of clay, is shallow and has low permeability (JARBAS*et. al*., 2020).

Precipitation was the variable with the highest score in this study as it is an agent that enhances mass movements. The historical average (1996 to 2007) in the region is 1500mm, 150mm annually, with a well-divided temporal distribution. It is observed that the intensity of rainfall in the region is strong, being greater than 10mm/h, but less than 50mm/h, characterizing susceptibility as medium. Therefore, the susceptibility of rain to erosive risks is average.

The susceptibility map to gravitational mass movements (Figure 18) shows three types of susceptibility: high (red), medium (yellow), low (green), three points close to the urban area are marked to exemplify the mapping of movement scars and gullies in order to strengthen indications of susceptibility. Point 1 on the map of susceptibility to mass gravitational movements, which is located ESE of the city, indicates that the neighborhoods: Antônio Caixeta, Boa Vista, Jardim Recanto and others have high susceptibility to mass gravitational events, which mainly stands out in this area is the Cambisol (Figure 18A). Point 2, which represents the average susceptibility found in the NNE of the city, has the neighborhoods of Alto da Colina, Jardim Esperança, Morada do Sol, and others (Figure 18B). The low susceptibility indicated in point 3 is that the SSE of the city is a region with little housing, with only the Distrito Industrial neighborhood, close to BR 365, which has few public places, as demonstrated in the Google Earth satellite images (Figure 18C) . With the help of mapping erosive features such as gullies and ravines via remote sensing (Figure 19) plotted on the susceptibility map to gravitational mass movements. Surface ravines were observed that marked the preferred path of water descent, soil removal and gullies were observed according to their shape and tone between the eroded and non-eroded portion (BATISTA, VIEIRA, MARINHO, 2018). There is a greater expression of ravines and gullies on the left side of the map and not in the city, but this is associated with Agrosilvopastoral activities, which consist of agricultural activities, livestock and legal reserves (FILHO, 2012).

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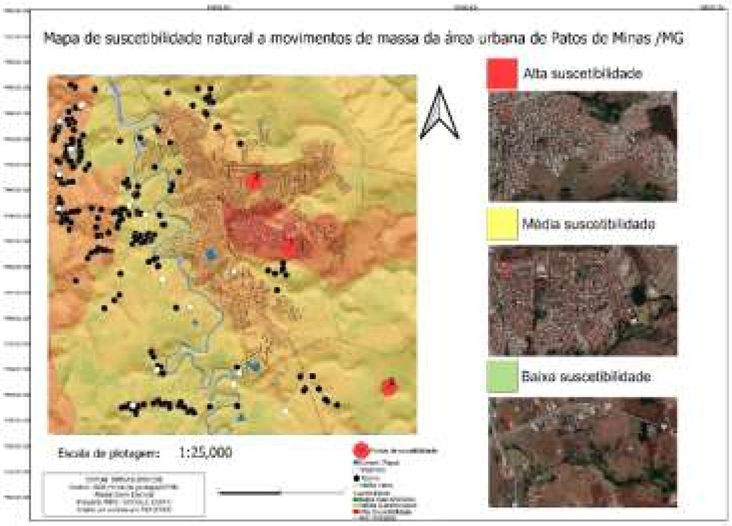
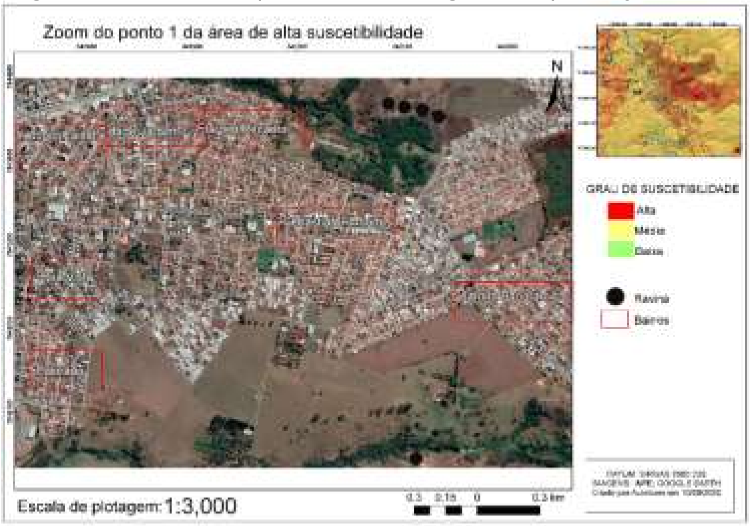
Figure 18:Map of natural susceptibility to mass movements in the urban area of Patos de Minas, Minas Gerais.



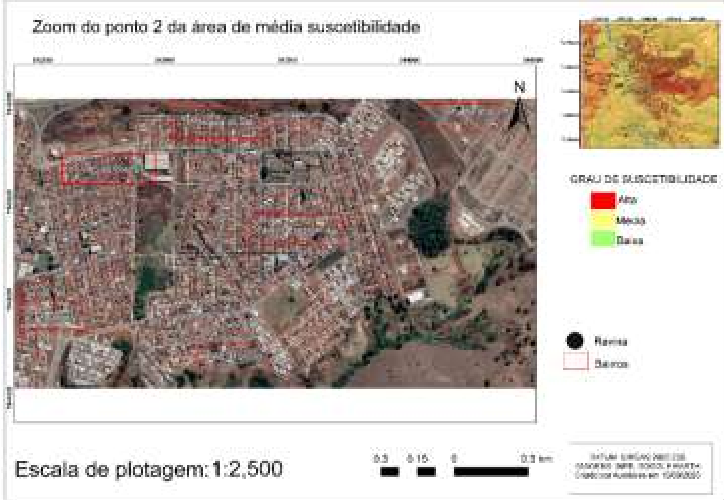
Source: AUTHORS, 2020.

Figure 18A: Zoom of point 1 of the high susceptibility area.



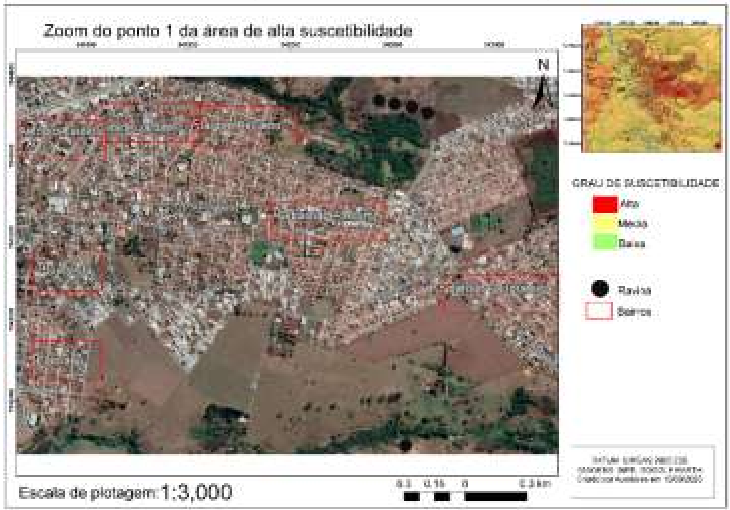
Source: AUTHORS, 2020.

Figure 19B: Zoom of point 2 of the high susceptibility area.



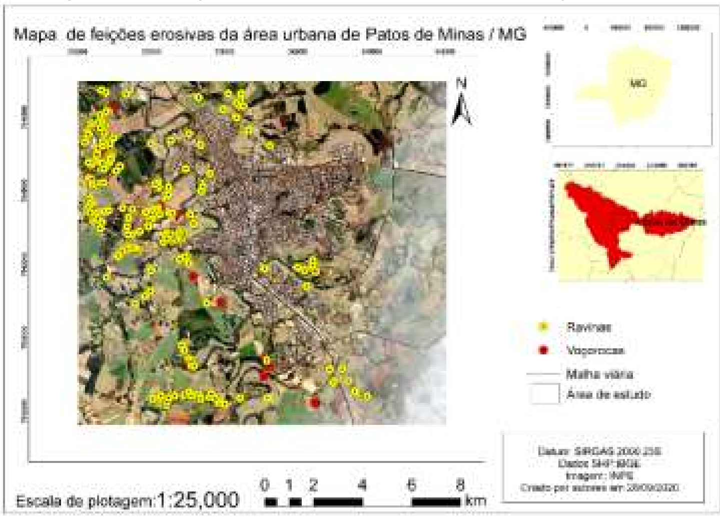
Source: AUTHORS, 2020.

Figure 18C: Zoom of point 3 of the high susceptibility area



. Source: AUTHORS, 2020.

Figure 19: Map of erosion features of the study area.



Source: AUTHORS, 2020

4.3 Susceptibility to flooding

The main component of flood assessment is slope. As previously stated, the greatest slopes are around the city, which causes transport of rocky material and water to the city and thus to the bodies of water present in the city and to the Paranaíba River. The slope directly influences the accumulation of water on the ground. Flat areas are more likely to suffer flooding than steep areas, being areas naturally unsuitable for housing (MAGALHAES*et. al*., 2011). For this reason, the slope of the area varies from high to medium susceptibility.

After the slope, land use becomes a major influence on the process, as land occupation influences water infiltration and surface runoff (MAGALHAES *et. al*., 2011). Areas with greater impermeability tend to accumulate more water on the surface than in soils with forest cover because they are less compacted. Land use presents medium and high susceptibility. The type of soil reflects the infiltration and runoff capacity. Oxisols have good permeability, while Cambisols, in turn, have low permeability, which can trigger greater transport of material and water. The susceptibility of these soils is medium to low (MAGALHAES*et. al*., 2011).

The map of natural susceptibility to flooding (Figure 20) presents three types of susceptibility: high (dark blue), medium (blue), low (light blue), three points close to the urban area are highlighted to illustrate. Point 1 is located in the city's ONO, indicating that the Sorriso, Coração Eucarístico and Laranjeira neighborhoods are highly susceptible to flooding (Annex 20A). Point 2 is the OSO of the city and indicates that the Copacabana neighborhoods; Guanabara, Sobradinho have medium susceptibility to flooding (Annex 20B). Point 3 is the SSE of the city and indicates that the Planalto neighborhood and Distrito Industrial II have low susceptibility to flooding (appendix 20C).

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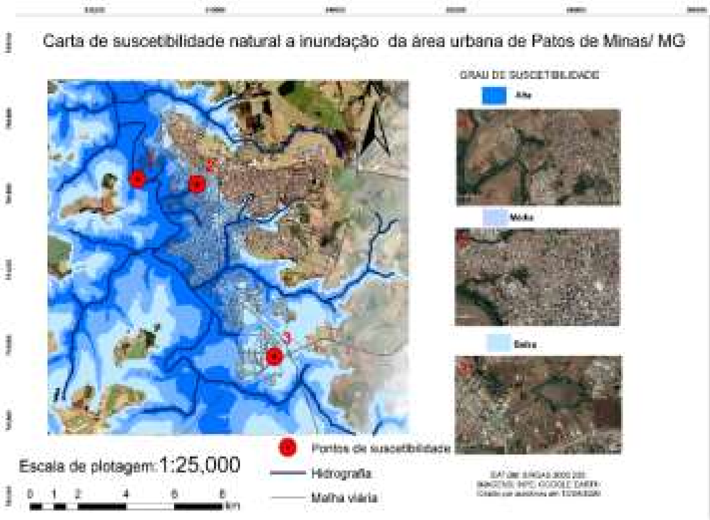
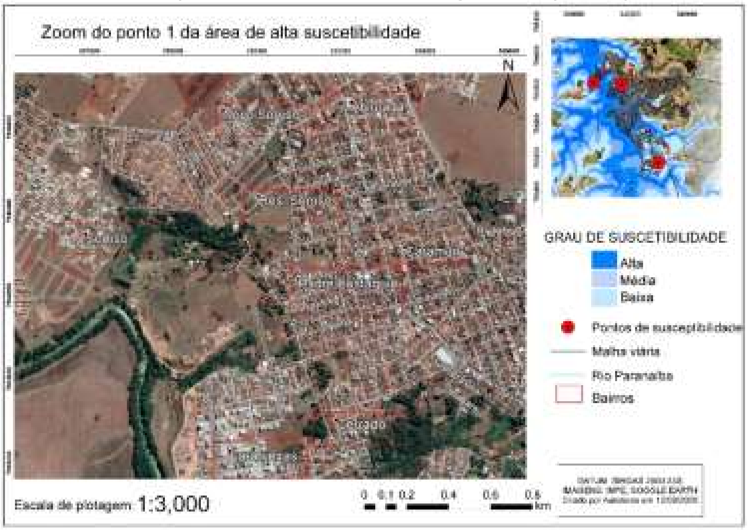
Figure 20: Chart of natural susceptibility to flooding in the urban area of Patos de Minas, Minas General.



Source: AUTHORS, 2020.

Figure 20A: Zoom on point 1 of the area of high susceptibility to flooding.



Source: AUTHORS, 2020.

Figure 20B: Zoom in on point 2 of the area of high susceptibility to flooding.

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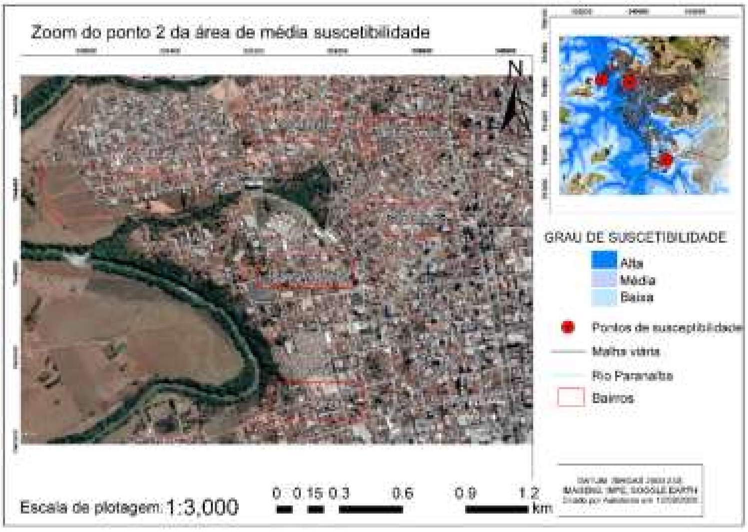
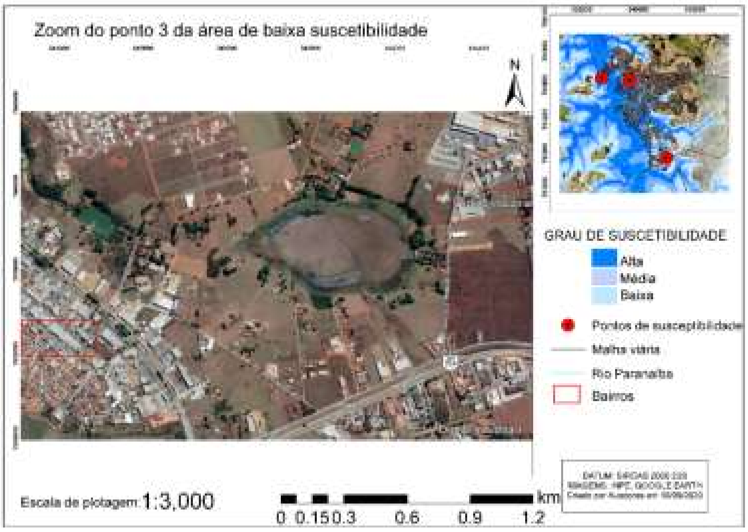


Source: AUTHORS, 2020.

Figure 20C: Zoom in on point 3 of the area of high susceptibility to flooding.



Source: AUTHORS, 2020.

Final considerations

Susceptibility analyzes to mass movements and floods are fundamental, as they are the basis for environmental verification, identifying relevant information to verify the propensity and promoting the search for forms of mitigation. Therefore, it is basic and important information for the master plan of all municipalities, and this information is important for the generation of other maps such as risk and suitability for urbanization, which are other projects that municipalities need to have, for better risk management. , protection of the population and effective evolution of urbanization. To use the bases in a GIS environment and generate maps, the scale used was that of plotting, so that each variable. As seen in the methodology, there is a large variation in scale between the data, which makes it difficult to carry out a study like this with a large inference of information on a scale of 1:25:000, only with data made available by the Government. This causes an overestimation in the weights of the multi-criteria analysis. Brazil as a whole has a long-standing lack of cartographic base and there is no standardization in map scales. It is often up to states, municipalities, and even private companies to carry out mapping to better understand the soil and subsoil, which only occurs when there is economic interest. The use of multi-criteria analysis is relevant and easily applicable, as through this tool it is possible to combine variables, prepare synthesis maps and unite information, allowing qualitative and quantitative assessment of susceptibility to mass movements and flooding. For the classification of susceptibility to mass movements, Rainfall was the most important variable because it is the main modifying agent that intensifies the phenomenon studied and because of its intensity in the region due to its tropical high-altitude climate. In terms of susceptibility to flooding, the most prominent variable, regardless of the rainfall regime, is the slope, since flat areas have a greater probability of flooding than steep areas (SANTOS; LOUZADA; EUGENIO, 2010).

The application of GIS tools was of great importance in carrying out this study, as they contribute to the generation of information capable of demonstrating the vulnerability of areas susceptible to mass movements and floods, being used in several works and recommended by bodies such as CPRM and the IPT.

The analysis meets the main objective of demonstrating the susceptibility of events, which in turn has the purpose of indicating areas prone to the development of processes in the physical environment that can generate natural disasters, in view of the presence of basic predisposing factors found in occupied land or not busy. Therefore, it does not include any type of analysis regarding danger or risk (BITAR, 2014).

When mapping ravines and gullies in the Patos de Minas area, he observed that, on the left side, where there is a greater concentration of agribusiness activities and native vegetation, there is also a greater expression of ravines and gullies than close to the urban area where there are some pastures and deforested land. This is due to intense soil management with agricultural and livestock activities that intensify preferential paths for water to reach the lowest area.

The high susceptibilities of mass movement were demonstrated where there is a greater presence of Cambisol, since it is less developed, more clayey and less permeable than oxisols (EMBRAPA, 2018). While medium susceptibility was identified in and near the city.

The high and medium susceptibility to flooding generated matches historical floods such as the Cerrado and Copacabana neighborhoods (BARBOSA, 2019) respectively. Due to what has been mentioned, it is clear that the susceptibility map to gravitational mass movements and flooding is of great importance for the prevention of natural accidents and it is advisable that it is initially drawn up for all municipalities. Municipalities that have areas of medium or high susceptibility to current legislation require a letter of suitability for urbanization and a geotechnical risk map (BITAR; FREITAS; MACEDO, 2015). The municipality of Patos de Minas and the others in the state of Minas Gerais, if equipped with studies like this, but carried out with a cartographic base of an adequate scale, can apply better territorial management, promoting efficient treatments that minimize accidents, material losses and lives.

References

AHP CALCULATOR, 2019. Available at: https://bpmsg.com/ahp/ahp-calc.php. Accessed on: October 2020.

A-N-A.**Hidroweb**. 2020. Available at: http://www.snirh.gov.br/hidroweb/presentacao. Accessed in: Oct. 2020.

ALKMIM FF What makes a craton a craton? The São Francisco Craton and its Almeidian revelations when delimiting it.*In:*MANTESCO-NETO V., BARTORELLI A., CARNEIRO CDR, BRITO-NEVES BB (Ed.)**Geology of the South American Continent:**Evolution of the work of Fernando Flávio Marques de Almeida. São Paulo: Ed. Beca, 2014, p. 17-35

ALVES, HR Management of natural disasters: the use of the principle of prohibiting socio-environmental setbacks and the participation of the population towards building urban resilience. João Pessoa: Environmental Law III:**XXIII CONPEDI National Congress.**Event Theme: The humanization of law and the horizontalization of justice in the 21st century. 30p-59p. Available at: http://publicadireito.com.br/publicacao/ufpb/livro.php?gt=206.Accessed on: Dec. 2020

BARBOSA, P.**Firefighters respond to almost 20 simultaneous incidents during heavy rain in Patos de Minas,**4 Dec. 2019. Available at: https://g1.globo.com/mg/triangulomineiro/noticia/2019/12/04/bombeiros-atendem-a-quase-20-ocorrencias-simultaneas-duranteforte-chuva-em-patos-de -minas.ghtml. Accessed in: Oct. 2020.

BATISTA, DCL; VIEIRA, AFSG; MARINHO, R R. Use of "Google Earth Pro" in mapping gullies in the urban area of Manaus (AM), Brazil**. Geoknowledge,**Fortaleza, vol.

10, no. 20, p. 1-12, Jan./Apr. 2019. Available at: http://repositorio.ufc.br/handle/riufc/54737. Accessed on: Dec. 2020.

BATISTA, M.C.**Stratigraphy and Geological Evolution of the Lagoa Formosa Region.**2004. Dissertation (Master's in Geology) – Institute of Geosciences, Federal University of Minas Gerais (UFMG), 2004.

BINI, GMP; LUIZ. EL; MANAGER. J; GEORGES. JR; PILLERIN. M. Use of planialtimetric mapping on slopes after occurrences of mass movements: Case study in the Arraial do Ouro basin, Gaspar- SC.**XVII Brazilian symposium on applied physical geography.** The challenges of physical geography at the frontier of knowledge. Institute of geosciences – UNICAMP. 28 June 2017 to 02 Jul. 2017, Campinas-SP. Available at: https://ocs.ige.unicamp.br/ojs/sbgfa/article/view/2547. Accessed on: Sep. 2020.

BITAR, OY; FREITAS, CGL; MACEDO, ES**Geotechnical maps guide: basic guidelines for municipalities**. São Paulo: Ipt, 2015. 28 p. Available at: http://www.ipt.br/publicacoes/62.htm. Accessed in: Oct. 2020.

BITAR., OY**Susceptibility charts to gravitational mass movements and floods - 1:25,000:**explanatory technical note. Brasília, Df: Ipt – Institute of Technological Research of the State of São Paulo, 2014. 50 p. Available at: http://www.cprm.gov.br/publique/Gestao-Territorial/Prevencao-de-Desastres/Cartas-de-Suscetabilidade-a-Movimentos-Gravitacionais-de-Massa-e-Inundacoes-5379.html . Accessed in: Oct. 2020.

BRAZIL. Ministry of the Environment.**Mapping the use and coverage of the Cerrado:** TerraClass Cerrado Project, 2013. Brasília, DF, 2015. Available at: https://www.mma.gov.br/publicacoes/biomas/category/62-cerrado.html. Accessed in: Oct. 2020.

CHIAVEGATTO JRS**Stratigraphic analysis of the tempestite sequences of the Três Marias Formation (Upper Proterozoic) in the southern portion of the São Francisco Basin.** MS Dissertation, Federal University of Ouro Preto, Ouro Preto, 1992, 216p. Available at: www.repositorio.ufop.br. Accessed in: Oct. 2020.

CPRM, Geological Survey of Brazil. Map of Geomorphological Domains of the state of Minas Gerais.*In:*MACHADO, MF; SILVA, SF (Org). Geodiversity of the state of Minas Gerais. Belo Horizonte:**CPRM,**2010.Available at: http://rigeo.cprm.gov.br/xmlui/handle/doc/16735?show=full. Accessed in: Oct. 2020.

CPRM, Geological Survey of Brazil. Geological Map:**Folha de Patos de Minas (SF.23-YA-VI), scale 1:100,000.**2013. Available at: http://geosgb.cprm.gov.br/downloads/. Accessed in: Oct. 2020.

CPRM. **Hydrology (Maps It is Publications).** 2020. Available in: https://www.cprm.gov.br/publique/Hidrologia/Mapas-e-Publicacoes-173. Accessed in: Oct. 2020.

CREPANI, E.; MEDEIROS, JS; HERNANDEZ FILHO, P; FLORENZANO, TG; DUARTE, V; BARBOSA, CCF**.**Remote sensing and geoprocessing applied to ecological-economic zoning and territorial planning. São José dos Campos.**Inpe,**2001. 103 p. Available at: http://sap.ccst.inpe.br/artigos/CrepaneEtAl.pdf. Accessed in: Oct. 2020.

CROZIER, M.J.**Landslides:**causes, consequences and environment. New Zealand. 1986.

DINIZ, NC Geotechnical cartography by classifying land units and assessing susceptibility and suitability.**Brazilian Journal of Engineering and Environmental Geology,**v. 2, no. 1, p. 29-77, 2012

DSG. Directorate of Geographic Services. Antonina Topographic Map.**Sheet SG.22-XD-II-4-SO**. 2002. Available at: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1745-7939.1989.tb01143.x. Accessed on: Sep. 2020.

EMBRAPA. **Trainings in gully.** Brasilia DF, 2007. Available in: https://www.agencia.cnptia.embrapa.br/gestor/agricultura_e_meio_ambiente/arvore/CONTAG01_58_210200792814.html.Accessed on: Sep. 2020.

EMBRAPA.**Brazilian system of soil classification.**5. ed. Brasília: Embrapa Solos, 2018. 355 p. Available at: https://www.embrapa.br/solos/busca-de-publicacoes/- /publicacao/1094003/sistema-brasileiro-de-classificacao-de-solos. Accessed on: Sep. 2020.

FEIZIZADEH, B; BLASCHKE, T. GIS-multicriteria decision analysis for landslide susceptibility mapping: comparing three methods for the Urmia lake basin, Iran. **Natural Hazards,**v. 65, no. 3, p. 2105-2128, 2012. Available at: https://link.springer.com/article/10.1007/s11069-012-0463-3.Accessed in Oct. 2020.

FERNANDES, NF; AMARAL, CP Mass Movements: A Geological-Geomorphological Approach**.***In:*WAR, AJT; CUNHA, SB (org.)**Geomorphology and Environment.**Rio de Janeiro: Bertrand Brasil. 1996. p. 123-194.

FILHO, P. AGROSSILVIPASTORIL:**Integration of Crop, livestock and Forestry.**29 Oct. 2012. FLORATIETE. Available at: http://www.floratiete.org.br/sistema-agrossilvipastorilintegracao-da-lavoura-pecuaria-e-floresta/. Accessed on: Dec. 2020.

FLAUZINO, FS; SILVA, MKA; NISHIYAMA. L; ROSA, R. Geotechnologies applied to the management of natural resources in the Paranaíba River basin in the Cerrado of Minas Gerais.**Soc. nat.**(Online), Uberlândia, v. 22, n. 1, P. 75-91, apr. 2010. Available at: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S19824513 2010000100006&lng=en&nrm=iso. Accessed on: Aug. 2020.

GODOY, H.**Identification and geotechnical classification of oxisols in the State of São Paulo using the MCT tablet method.**1997. Thesis (Doctorate in Geochemistry and Geotectonics) - Institute of Geosciences, University of São Paulo, São Paulo, 1997. Available at: https:// www.teses.usp.br/teses/disponiveis/44/44134/tde- 29102015-132258/pt-br.php. Accessed in: Nov.2020

GOLDONI, TR; VESTENA, LR Mapping of flood risk areas in the city of Guarapuava-PR. **XVIII National meeting of geographers.**The construction of Brazil: geography, political action and demography. 30 June 2016, São Luiz/MA. Available at: http:// www.eng2016.agb.org.br/resources/anais/7/1468193530_ARQUIVO_Thiago_Rob erto_Goldoni_Artigo_ENG2016.pdf. Accessed on: Sep. 2020.

GOMES, CR; RUBERTI, E.; MORBIDELLI, I. 1990. Carbonatite complexes from Brazil: a review.**Journal of South American Earth Science,**v. 3, p.51-63. Available at: https:// doi.org/10.1590/2317-4889201820170123. Accessed at: Oct. 2020.

HASUI, Y. Neotectonics and fundamental aspects of resurgent tectonics in Brazil.**1st. Workshop on neotectonics and continental Cenozoic sedimentation in southeastern Brazil.** SBG Núcleo Minas Gerais. Belo Horizonte, 1-31p, 1990.

JARBAS, T., SÁ, IB; PETRERE, VG; TAURA., TA Cambisols.*In:***Cambisols.**[S. l.],20out.2020.Available at: https://www.agencia.cnptia.embrapa.br/gestor/ bioma_caatinga/arvore/CONT000g798rt3o02w x5ok0wtedt3n5ubswf.html. Accessed on: October 2020.

JULIÃO, RP*et. al*. Methodological guide for the production of municipal risk cartography and for the creation of municipal-based Geographic Information Systems (GIS). Lisbon: **National Civil Protection Authority**; General Directorate of Spatial Planning and Urban Development; Portuguese Geographic Institute, 2009. Available at: http:// www.dgotdu.pt/detail.aspx?channelID=85E8AD30-00F8-417E-9F12-EBFAFE6A5B4&contentId=3B54E44B-603C-4445-8C8A-ECC879127CEE. Accessed on: Dec. 2020.

KINGSTON, D.R; DISHROON, CP; WILLIAMS, PA 1983**.**Global basin classification system.**AAPG Bulletin,**v. 67, 2175-2193p. Available in: https://www.monografias.ufop.br/bitstream/35400000/2275/1/MONOGRAFIA_AnaliseGeofi sicaRochas.pdf. Accessed on: October 2020.

KOSIN, M.; ANGELIM LA A; SOUZA J.D; GUIMARÃES JT; TEIXEIRA LR; MARTINS AA M; BENTO RV; SANTOS RA; VASCONCELOS A. M; WANDERLEY A. A; CARVALHO L. M; PEREIRA LH M; GOMES LP**Sheet Aracaju SC.24.**Geological Chart of Brazil to the Millionth, Information System, 2004. Available at: https://repositorio.ufrn.br/jspui/ bitstream/123456789/21886/1/LeonardoDaSilvaRibeiroMocit aiba_DISSERT.pdf Accessed on: nov. 2020.

LIMA ONB; UHLEIN A; BRITTO W. Stratigraphy of the Bambuí Group in Serra da Saudade and geology of the Cedro do Abaeté phosphate deposit, Minas Gerais.**Brazilian Journal of Geosciences**,v. 37, 204-215p., 2007. Available at: http://www.ppegeo.igc.usp.br/index.php/rbg/article/view/9235 . Accessed in: Oct.2020

MAGALHÃES, IA; LOPES TCRL; AGRIZZI, DV; SANTOS, AR Use of Geotechnology for Mapping Flood Risk Areas in Guaçuí, Es: A Comparative Analysis Between Two Methods.**Geoscience notebooks,**[sl], v. 8, ed. 2, 1 Nov. 2011. Available at: www.cadernosdegeociencias.igeo.ufba.br. Accessed in: Oct. 2020

MENDES, PPM Erosive process in urban area: Condomínio Privê, satellite city Ceilândia-DF. **VII Brazilian Congress of Geographers;**The AGB and Brazilian Geography in the context of social struggles against hegemonic projects 10 to 16 Aug. Vitória/ES. Available in:

http://www.cbg2014.agb.org.br/resources/anais/1/1404586983_ARQUIVO_Pedro_Paulo_Mesquita_Mendes_CBG.pdf. Accessed on: Nov. 2020.

MARTINS, TD; OKA-FIORI, C.; VIEIRA, BC Landslide Scar Mapping Using Multispectral Imaging.**Geography Department Magazine**–USP, vol. 30, p. 96-109, 2015. Available at: https://repositorio.usp.br/item/002752461 Accessed: Sep. 2020

MOURA, ACM Methodological Reflections as Subsidy for Environmental Studies Based on Multicriteria Analysis.**Proceedings of the XIII Brazilian Symposium on Remote Sensing,**Florianopolis, Brazil. apr. 2007. p.2899-2906. Available in: http://marte.sid.inpe.br/col/dpi.inpe.br/sbsr@80/2006/11.13.14.41/doc/2899-2906.pdf . Accessed in: Oct.2020

OLIVEIRA, FF; SANTOS, C.; V., RES; ARAUJO, RC**.**Erosive processes: dynamics, causative agents and conditioning factors.**Brazilian Journal of Scientific Initiation (RBIC),**Itapetininga, vol. 5, n.3, p. 60-83, Apr./Jun., 2018. Available at: https://periodicos.itp.ifsp.edu.br/index.php/IC/article/view/699. Accessed on: Sep.2020

PARANAÍBA, Cbh.**Domain of Surface Water Bodies.**2014. Available at: http:// www.cbhparanaiba.org.br/galeria-de-mapas. Accessed in: Oct. 2020

PARK, S.; JEON, S.; CHOI, C. Mapping urban growth probability in South Korea: comparison of frequency ratio, analytic hierarchy process, and logistic regression models and use of the environmental conservation value assessment.**Landscape and Ecological Engineering**, v. 8, no. 1, P. 17-31, 2010.Available at: https://www.researchgate.net/publication/238493306_Mapping_urban_growth_probability_in_South_Korea_Comparison_of_frequency_ratio_analytic_hierarchy_process_and_logistic_regression_models_a . Accessed in: Oct. 2020.

RASSI, R.; BICALHO, RL; PETRONZIO, Juliana Abreu Crosara.; SILVEIRA, A. Geological, geomorphological and pedological characterization of Patos de Minas (MG): contribution to the interpretation of erosion features.**XVII Brazilian Symposium on Applied Physical Geography and National Congress on Physical Geography**, 1., 2017, Campinas. Ebook. Campinas: Unicamp, 2018. p. 6434-6439. Available at: https://ocs.ige.unicamp.br/ojs/sbgfa/article/view/2334. Accessed in: Oct. 2020.

ROCHA, F. Large landslide on the Fátima Porto extension causes Civil Defense to close the road. Patos de Minas/MG. 12 nov. 2018.**Ducks Today.**Available at: https://www.patoshoje.com.br/noticia/grande-deslizamento-de-terra-no-prolongamento-dafatima-porto-faz-defesa-civil-interditar-pista.39335.html. Accessed in: Oct. 2020.

ROCHA, L.**ArcGIS:**generate NDVI for Sentinel-2 images. Digital Processing, São Paulo, 20 July. 2018. Available at: http://processamentodigital.com.br/2018/07/20/arcgis-gerar-ndvipara-imagens-sentinel2/#:~:text=THE%20WHAT%20IS%20NDVI&text=THE%20calculation%20of%20NDVI%20is,dthe%20reflectances%20ofthese%20two%20bands. Accessed in: Oct. 2020.

RIBEIRO, JF; WALTER, BMT Phytophysiognomies of the Cerrado biome.*In:*SANO, SM; ALMEIDA, SP (ed.). Cerrado: environment and flora. Brasilia:**Embrapa Cerrados,**1998. Available in: https://www.embrapa.br/busca-de-publicacoes/-/publicacao/554094/phytophysiognomies-do-bioma-cerrado. Accessed on: Sep. 2020.

SAATY, TL A scaling method for priorities in hierarchical structures.**Journal of Mathematical Psychology,**v. 15, no. 3, p. 234-281, 1977. Available at: https://www.scienceopen.com/document?vid=ce62fc56-3def-4e78-a242-a82fc09575a5 . Accessed in: Oct. 2020.

SAATY, T.L.; VARGAS, LG Estimating Technological Coefficients by the Analytic Hierarchy Process.**Socio-Economic Planning Sciences,**v. 13, no. 6, p. 333-336, 1979. Available at: https://www.sciencedirect.com/science/article/abs/pii/037722179090056H. Accessed in: Oct. 2020.

SAMPAIO, E. da S.**Multi-criteria analysis of alternatives for a new higher education course in a technological education institution.**2018. 48 f. Dissertation (Master's) - Production Engineering Course, Universidade Estadual Paulista, Faculdade de Engenharia de Guaratinguetá, Guaratinguetá - SP, 2018. Available at: https://repositorio.unesp.br/handle/11449/157509. Accessed in: Oct. 2020.

SANTOS, AR; LOUZADA, FLRO; EUGENIO, FC**ArcGis 9.3 Total-**Applications for Spatial Data. 2nd ed. Alegre: CAUFES, 2010. Available at: http://www.mundogeomatica.com.br/Livros/Livro_ArcGIS%209.3_Aplicacoes_Para_Dados_Espaciais/Livro_ArcGIS93_Total.pdf.Accessed at: oct. 2020.

SANTOS, AR dos.; LOUZADA, FL R de O.; EUGENIO, FC (Coord.).**ArcGIS 9.3 full:** applications for special data. Alegre, ES: Agricultural Sciences Federal University of

Spirit Santo/CAUFES, 180 P., 2010. Available in: http://www.mundogeomatica.com.br/Livros/Livro_ArcGIS%209.3_Aplicacoes_Para_Dados_Espaciais/Livro_ArcGIS93_Total.pdf . Accessed in: Oct. 2020.

SGARBI, GNC Geology of the Areado Formation, Middle to Lower Cretaceous of the São Francisco Basin, western Minas Gerais State.**Inst. of Geosciences,**Federal University of Rio de Janeiro, Rio de Janeiro, Master's Dissertation, 324p. 1989. Available at: http://bjg.siteoficial.ws/1997/n.3/5.pdf Accessed in: October/2020.

SGARBI GNC; SGARBI PBA; JE CAMPS; DARDENNE MA; PENHA UC 2001. Sanfranciscana Basin: the Phanerozoic record of the São Francisco Basin.*In:*PINTO CP; MARTINS-NETO MA São Francisco Basin-Geology and Natural Resources. Belo Horizonte,**SBG-MG,**93-138p.Available at: https://repositorio.ufop.br/bitstream/123456789/999/1/ARTIGO_ArcabouçoEstruturalBacia.p df . Accessed in: Oct. 2020.

SGARBI, PBA; VALENCIA, JG Kalsilite in Brazilian kamafugite rocks.**Mineralogical Magazine,**v. 57, 1993, p. 165-171. Available at: www.ppegeo.igc.usp.br. Accessed in: Oct. 2020.

SIGNORELLI, N.; FÉBOLI, WL; TULLER, MP; RIBEIRO, J.H..Areal extension of the Serra da Saudade Formation, Bambuí Group, to the central-southern region of Minas Gerais.**Annals, Institutional Geosciences Repository,**2008. Available at: http://rigeo.cprm.gov.br/xmlui/handle/doc/754acessado13-10-2020. Accessed in: Oct. 2020.

SILVA AJP; LOPES RC; VASCONCELOS A. M; BAHIA RBC Inland Paleozoic and Mesocenozoic sedimentary basins.*In:*BIZZI LA, SCHOBBENHAUS C., VIDOTTI RM, GONÇALVES JH (ed.) Geology, Tectonics and Mineral Resources of Brazil. Brasília, Geological Survey of Brazil.**CPRM/MME,**2003, p.55-85. Available at: http://www.cprm.gov.br/publique/media/recursos_minerais/livro_geo_tec_rm/capII.pdf. Accessed in: Oct. 2020.

SILVA, AN; MARCHETTO, M.; SOUZA, OM de. 1979.**Geology of the Araxá carbonate complex, Minas Gerais.**Mining and Metallurgy, v. 43, p. 14-18. Available at: repositorio.unb.br/2009_ElisaSoaresRochaBarbosa. Accessed in: Oct. 2020.

SILVA, MHCR**Paranaíba River Hydrographic Basin:**analysis of population dynamics, changes in land use and impacts on water availability. Dissertation (Master's) Federal University of Viçosa, Dec. 2012. Available at: https://www.locus.ufv.br/handle/123456789/5258. Accessed at: Oct. 2020.

SILVA, T.C.**Mapping of flood spots for the city of Matias Barbosa – MG.**2016.69 f. TCC (Undergraduate) - Sanitary and Environmental Engineering Course, Faculty of Engineering at Ufjf, Juiz de Fora, 2016. Available at: https://www.ufjf.br/engsanitariaeambiental/files/2014/02/TabathaCarvalho_TCC_FINAL.pdf. Accessed on: October 2020.

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ISSN 2675-9128
DOI 10.51473

SILVA VC B; AX PS; BAHIA RBC Sig in environmental analysis: Erosive susceptibility of the Mutuca stream watershed, Nova Lima- Minas Gerais.**Geography Magazine.**v. 31, no. 2, 2014, p. 1-22. Available in: https://periodicos.ufpe.br/revistas/revistageografia/article/view/229090 . Accessed in: Oct. 2020.

SOBREIRA, FG; SOUZA, LA Geotechnical cartography applied to urban planning. **Brazilian Journal of Engineering and Environmental Geology**, v. 2, p. 79-97, 2012. Available at: https://www.abge.org.br/volume-2-n-1. Accessed on: Jul. 2020.

SOUSA, M. E; FILHO, NES S; PEREIRA, L. A; LYRA, LHB Monitoring and characterization of siltation in the São Francisco River on the urban edges of Petrolina-PE and Juazeiro-BA. **Magazine of the Casa da Geografia de Sobral**(RCGS), Sobral-CE, v. 15, p. 68-80, 2013. Available at: https://rcgs.uvanet.br/index.php/RCGS/article/view/145 Accessed on: nov. 2020.

SOBREIRA, FG; SOUZA, LA de. Geotechnical cartography applied to urban planning. **Brazilian Journal of Engineering and Environmental Geology,**v. 2, no. 1, p. 79-97, 2012.

TOMINAGA, L. K; SANTORO, J; AMARAL, R. Natural disasters: knowing to prevent. São Paulo:**Geological Institute,**2009. 197p. Available in: http://www.sidec.sp.gov.br/defesacivil/media/OSDownloads/1438375861_DesastresNaturais. pdf. Accessed in: Oct. 2020.

UHLEIN, A.; DARDENNE, M A.; SEER, HJ; MORAES, LC; BAPTISTA, MC; NOCE, CM; FRAGOSO, DGC; DIAS, PHA; MOREIRA, GC The Lagoa Formosa Formation and the stratigraphy of the Bambuí Group in Minas Gerais.**XLV Brazilian Geology Congress,** 2010.

UHLEIN A.; LIMA ONB; FANTINEL LM; BAPTISTA, M. C Stratigraphy and geological evolution of the Bambuí Group, Minas Gerais.**SBG, Brazilian Geology Congress,**42, 2004, Geological Route, Excursion 2. Available at: periodicos.ufmg.br Accessed in: Oct. 2020.

VASILJEVIC, TZ; SRDJEVIC, Z.; BAJCETIC, R.; MILORADOV, MV GIS and the analytic hierarchy process for regional landfill site selection in transitional countries: a case study from Serbia.**Environ. Manag.,**v. 49, n. 2, p. 445-58, 2012. Available at: https://www.researchgate.net/publication/51847047_GIS_and_the_Analytic_Hierarchy_Process_for_Regional_Landfill_Site_Selection_in_Transitional_Countries_A_Case_Study_From_Serbia. Accessed in: Oct. 2020.