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Survey of current and potential soil erosion through the Universal Soil Loss Equation (USLE) for the municipality of Castelo-ES, Brazil

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***Abstract*— *Studies related to soil erosion are extremely important as they help to determine areas with greater environmental vulnerability and assist in territorial management. The objective of this work was to evaluate the current erosion and potential of the soil from the Universal Soil Loss Equation (USLE) for the municipality of Castelo, state of Espirito Santo, Brazil, as a way to subsidize improvements in the area. The procedures were performed in the ArcGIS® program, having as digital cartographic bases the Integrated System of Geospatial Bases of Espírito Santo, the National Water Agency and the Jones dos Santos Neves Institute. The Digital Elevation Model of the area was generated to then obtain the direction and accumulated water flow. The maps of potential and current soil erosion were generated from the data of: erosivity, erodibility, land use, conservation practices and topographic factor. Erosion was mapped and quantified, and potential erosion was quantified by local community. To assist in the studies, photographic records were made depicting some local environmental problems. The municipality has a large area (83,77%) vulnerable to potential erosion due to its physical characteristics, while there are communities that have most of their area with high risk of soil loss. As for the current erosion, which considers land use and conservation practices, most of the municipality (43,64%) has a low risk of soil loss. However, there are degraded areas of agriculture, harming water courses, for example. Government action and the implementation of conservation practices are some suggestions to minimize environmental problems.*
***Keywords*— Soil Erosion, Geoprocessing, Environmental Impacts, Territorial Planning, Mitigation Measures.**

I. INTRODUCTION

The lack of planning in the use and occupation of geographic spaces, as well as investments in equipment and services to meet the needs created by the population, induced the imbalance of the environment [28]. In the state of Espírito Santo, the lack of planning and environmental imbalance originated in two important cycles of the Espírito Santo economy: the 1st cycle (from the 19th century until the 1950s), which was centered on coffee, and the 2nd cycle. (1950-2000), characterized by industrialization [5].

Changes in vegetation cover and management by agricultural and livestock activities affect hydrology, dynamics and carbon stocks in the ecosystem and lead to loss of environmental services such as biodiversity maintenance, water cycling and stocks. that prevent the aggravation of the greenhouse effect [6].

Soil erosion is a process that consists in the separation of isolated particles from the soil mass and their transport by erosive agents such as runoff and wind incidence. When available energy is no longer sufficient for particle transport, so-called deposition occurs [30] [39].

Water erosion is one of the main forms of degradation of agricultural soils in Brazil. It means the process of runoff by runoff water, in which there is disintegration, transport and deposition of soil particles, nutrients and organic matter. The occurrence of erosive processes is determined, among other factors, by rainfall erosivity, soil erodibility and soil cover, which is a very relevant factor in the control of water erosion [10].

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In this sense, soil erosion occurs in urban and rural spaces and with different types (laminar or linear) and intensities (appearance of furrows, ravines and gullies). Management and conservation practices act on the temporal rhythm of erosive processes [16]. Agricultural areas in Brazil suffer annual losses of 822.7 million tons of soil, with erosion causing a loss of $ 2.9 billion annually on land ownership. The external costs to the rural property resulting from the erosion process add another $ 1.3 billion. Thus, erosion causes a total loss of approximately US $ 4.2 billion to Brazil [19].

Geoprocessing is the discipline of knowledge that uses mathematical and computational techniques for the treatment of geographic information and has increasingly influenced the areas of cartography, natural resource analysis, transportation, communications, energy and urban and regional planning. Computational geoprocessing tools, called Geographic Information Systems (GIS), allow you to perform complex analyzes by integrating data from multiple sources and creating georeferenced databases. They also make it possible to automate the production of cartographic documents [40] [37] [38].

An important tool in data geospatialization is ArcGis, which is a set of computational applications of Geographic Information Systems developed by the company Environmental Systems Research Institute, which has advanced tools for spatial analysis, data manipulation and cartography [36]. The use of a GIS becomes an important tool to be used in environmental control and monitoring, since it can provide, in addition to the storage of images and information, the crossing of them, allowing a broader and more accurate view of the environment. study site [32].

Although Espírito Santo is a small state, it has prominence in some productive sectors, making it important for the Brazilian economy, such as pulp production, which represents 28.3% of the national production, papaya (40, 2%), coffee (19.8%), iron ore (28%), coal (29.9%), roasted coffee (18.7%), non-metallic mineral products (20.3%) and steel (14.2%) [34]. However, this production affects the existence of forest fragments and soil use, being a major cause for concern when done in a disorderly manner.

Given the above, the objective of this work was to conduct a survey of the current erosion and potential of the soils of the municipality of Castelo (ES), from geotechnologies, with a view to offering subsidies for improvements in the studied area.

II. MATERIALS AND METHODS

The study site adopted was the municipality of Castelo, located in the south mesoregion of the state of Espirito Santo. With an area of 66307,58 hectares, its economic base is agriculture and coffee is the main agricultural activity. It has altitudes ranging from 92 to 2082 meters and covers 1.45% of the state territory [20]. Fig 1 shows the location of the municipality of Castelo.

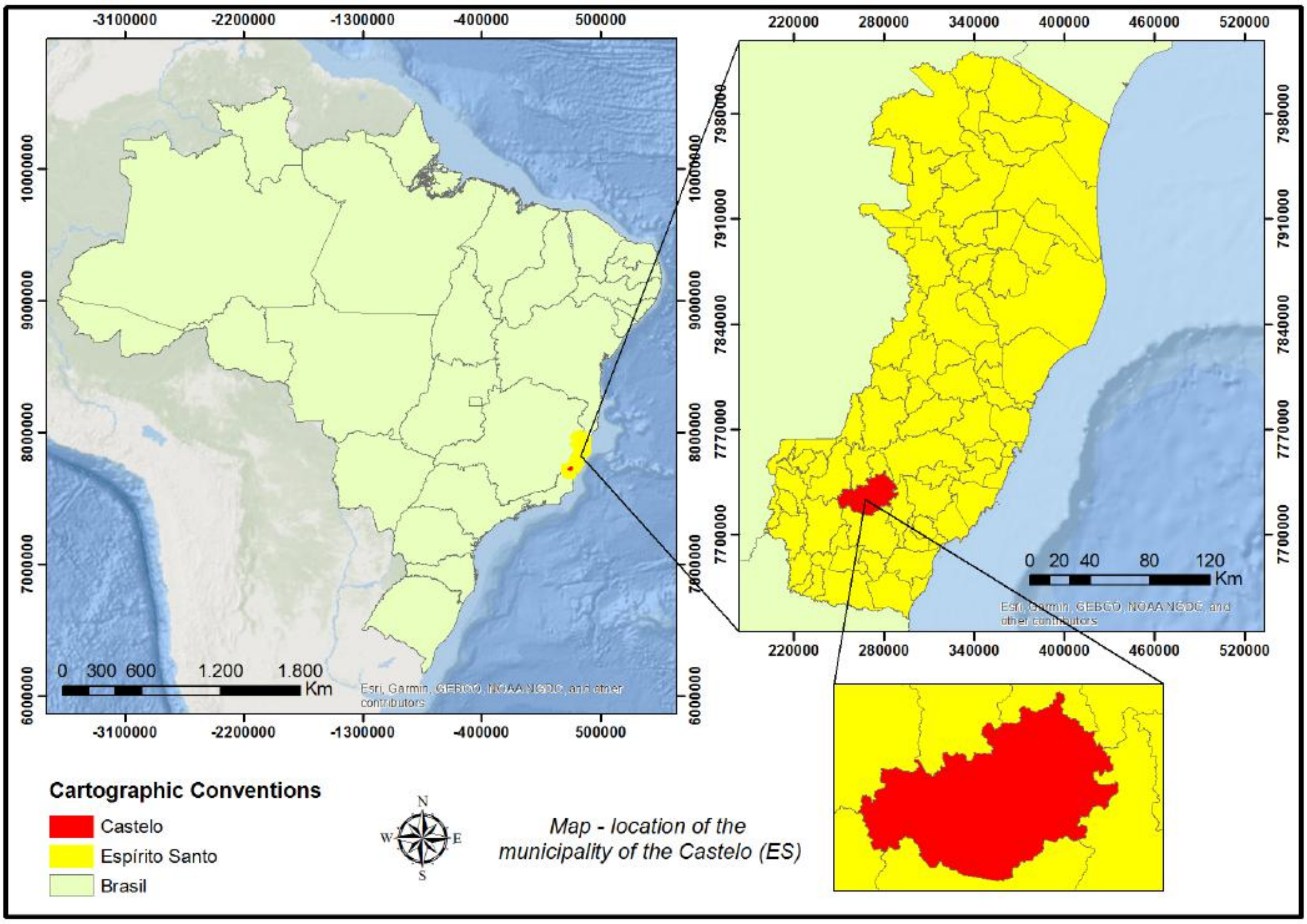

Fig. 1: Location of the municipaliy of Castelo, in the state of Espírito Santo, Brazil

The procedures were performed using the computer program ArcGIS® 10.2. All data collection operations were based on annual rainfall series extracted from the National Water Agency database [31], land use and occupation data, soil types and contours available at the base of digital data from the Integrated System of Geospatial Bases of the State of Espirito Santo [17] and archives related to the mapping of the cities of the State of Espírito Santo [21], aiming to favor the subsequent statistical interpolations of the data.

In ArcGIS®, the file referring to the municipalities of the state of Espírito Santo was added, and subsequently edited, considering only the area covered by the municipality of Castelo / ES. From data of contour lines acquired in GEOBASES, it was possible to generate the so-called Digital Elevation Model (MDE) of the municipality, through the interpolation of contour lines and the subsequent conversion of the generated file to raster format. MDE is one of the most important data for geospatial analysis, and it means a digital representation of a section of the surface, given by a matrix of planimetric (x, y) coordinates and a pixel intensity value, corresponding to the elevation [24]. For this work, it was adopted the value of 25 for the pixel size, thus having high resolution for the considered area.

From the MDE, it was possible to define the direction and the accumulated drainage flow of the municipality, through the items "flow direction" and "flow accumulation", contained in the program attributes table. The estimation of the average soil loss rate was performed by the universal soil loss equation (USLE). The equation was elaborated aiming to predict the average soil losses over long periods and specific conditions. It expresses the action of the main factors that affect water erosion, being expressed as a function of six environmental and management variables [8]. The USLE is expressed by equation:

$$A = R \times K \times L \times S \times C \times P$$

At where:"A": is soil loss in ton / ha.year; "R": is the erosivity factor of rain, in MJ.mm/(ha.h); "K": is the soil erodibility factor in ton. ha.h. / ha (MJ.mm); "L": is the ramp length factor (dimensionless); "S": is the slope factor, based on% slope; "C": is the land use and management factor (dimensionless); "P" is the practical conservation factor.

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The ability of rain to erode an unprotected area in a given locality is expressed by the numerical factor R [41], and is calculated from monthly erosion indices obtained by equation [23]:

$$EI\,i = 67{,}355 \times \left(\frac{ri^2}{Pi}\right)^{0{,}85}$$

Being: "EI i": monthly average erosion index (MJ ha^{-1} mm^{-1}); "ri": monthly average rainfall (mm); "Pi": mean annual rainfall (mm) ($1 \leq i \leq 12$).

The factor R corresponds to the sum of the monthly erosion indices [2].

Some soils are more prone to erosion than others, even when vegetation cover, rainfall, slope and erosion control practices are the same. This difference is called soil erodibility, and is due to the inherent properties of the soil [2]. From the MDE of the studied area, a local slope map was generated to determine the so-called topographic factor. (LS) of the equation from the generation of two maps. The L factor map was obtained using the the following expressions [26], [27], [32] [11]:

$$F = \frac{\sin C/0{,}0896}{0{,}56+3(\sin C)^{0,8}}$$

$$m = \frac{F}{1+F}$$

$$L = \frac{[\![A+D^2]\!]^{(m+1)} - A^{m+1}}{x^m D^{m+2}\,(22{,}13)^m}$$

Where: D = pixel size (determined by the file properties icon); A = accumulated drainage flow (determined through the flow accumulation icon in ArcGIS®); C = slope (expressed and converted to radians); x = shape coefficient (adopted x = 1 for pixel systems).

Then, the S factor map was generated by an algorithm consulted in the literature [26], [27], starting from the following mathematical conditions, considering the slope: when tan C <0.09, adopt S = 10.8 sin (C) + 0.03 e; when tan C ≥ 0.09, adopt S = 16.8 sin (C) + 0.5.

The equations were inserted in the raster calculator tool, also known as map algebra, which allows working the maps from the equations inserted in the program. Subsequently, the LS factor map was plotted and interpreted according to the data contained in the literature consulted. Ramp length and slope factors have been researched separately, however, it is more convenient to consider them together as an LS factor [3].

Some soils are more prone to erosion than others, even when vegetation cover, rainfall, slope and erosion control practices are the same. This difference is called soil erodibility (factor K), and occurs due to the inherent properties of the soil [2]. The K factor was initially determined by mapping the soil types of BHCP and then by consulting the data in the literature.

After obtaining all components of the equation, the maps of potential erosion (EP) and current erosion (EA) were generated. For this, the erosion classes were classified for the municipality of Castelo through the methodology consultation in the literature [12]. The area was also quantified in percentage (%) and in hectares (ha) for each current and potential erosion class.

In order to evaluate the potential erosion for each community in the municipality of Castelo, initially, with the Jones dos Santos Neves Institute [21], a file referring to the communities of the municipality to later evaluate the potential erosion for each community. This step was of fundamental importance in order to identify the regions with the greatest potential or not to soil erosion considering only their physical factors.

To justify the results achieved, some rural areas of the municipality were covered, recording images referring to visualized forms of soil erosion, when there is no proper management and planning of land occupation. For each photographed image, the location coordinate and community name were also recorded to provide more accurate results. Possessing the maps of potential erosion and current erosion, in addition to the photographs, mitigation measures were proposed according to the vulnerability to soil erosion for the referred municipality.

III. RESULTS AND DISCUSSIONS

According to the data from the historical series acquired from the National Water Agency and, from the equation that estimates the monthly erosion rates [41], the R factor obtained was 6454,68 MJ ha^{-1}. mm^{-1}. Based on data edited in the layout of the ArcGIS® program, it was possible to determine the predominant soil types in the municipality of Castelo, supporting further work.

Table 1 presents the description of the soil types and their respective K (soil erodibility) values, consulted in the literature. And table 2 contains the values adopted for the product of multiplying the CP factor (conservationist practices and land use) [44], [38], [45], [22], [39], [38], [25].

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Table 1: Erodibility factor (K) data for each soil type determined.

Soil type	Factor K
Cambissolo háplico	0,037
Latossolo amarelo	0,041
Chernossolo argilúvico	0,028
Argissolo vermelho-amarelo	0,034
Argissolo vermelho	0,044
Neossolo litólico	0,048

Table 2: CP factor data for each land use and occupation of the municipality of Castelo (ES).

Class (land use and occupation)	Factor CP
Rock outcrop	0
Built area	0
Marsh	0
Rock Field/Altitude	0,01
Agricultural prodution – banana	0,25
Agricultural prodution – cofee	0,25
Agricultural prodution – sugar cane	0,05
Agricultural prodution – coconut tree	0,25
Other permanent crops	0,25
Other temporary crops	0,20
Mineral extraction	0
Macega	0,01
Body of water	0
Native forest	0,00013
Native forest at na early stage of regeneration	0,00013
Other classes	0
Pasture	0,025
Reforestation – Eucalyptus	0,0026
Reforestation – Pine	0,0026
Reforestation – Rubber tree	0,0026
Soil exposed	1

Therefore, the study area covers 6 different soil types and 20 identified land use and occupation classes. Numerical information was considered for the USLE estimate of current and potential erosion. Fig 2 presents the slope (S) and topographic maps of the factors (product of slope length by slope).

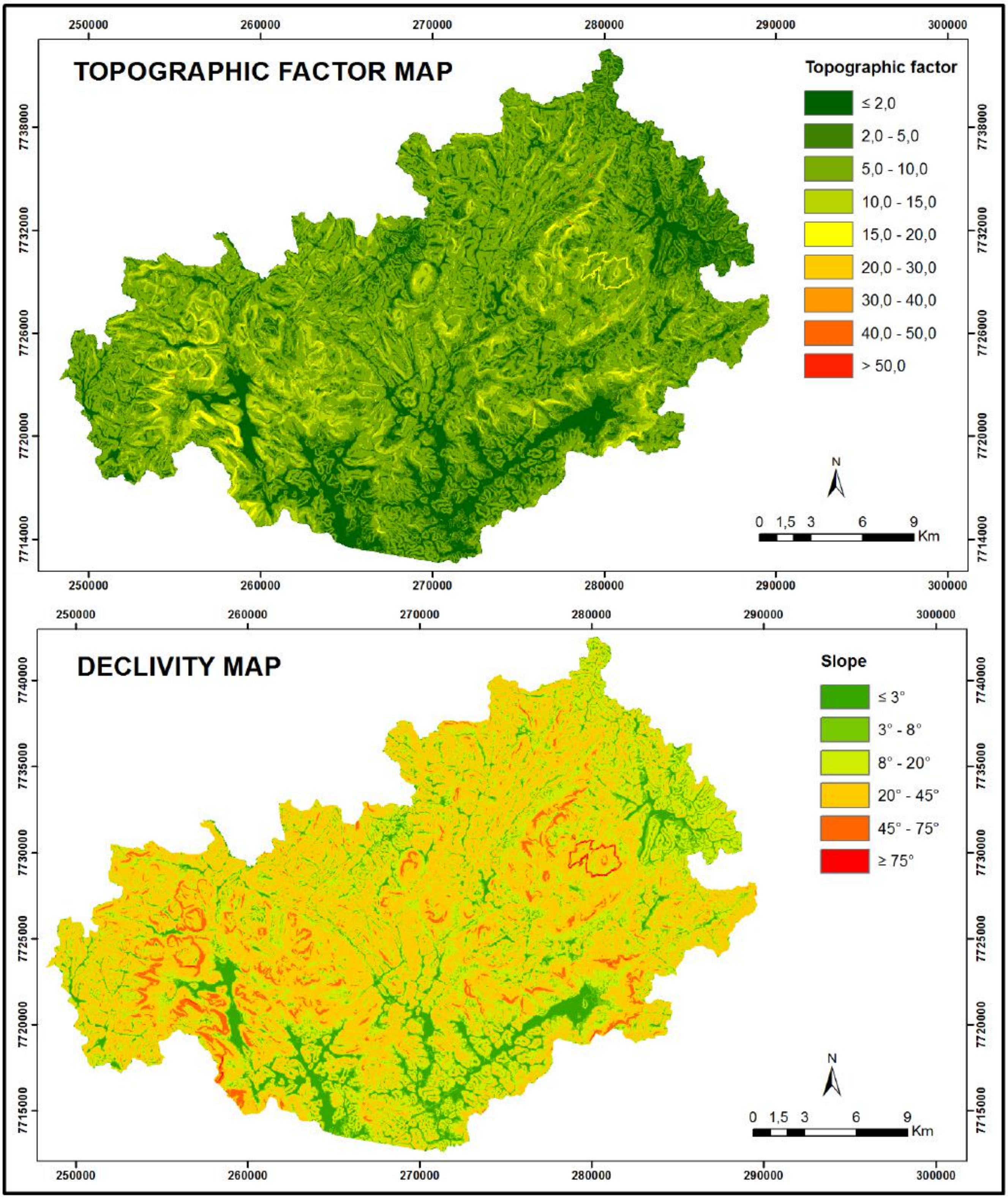

Fig. 2: LS factor maps and slope of the municipality of Castelo (ES)

Topographic factor values above 1,5 are significant [35]. Therefore, the topographic factor is high in most of the municipality of Castelo, with the predominant values being from 0 to 20,0.

High values for the topographic factor, as seen in this paper, indicate areas with greater sediment transport capacity, that is, with greater vulnerability to erosive processes [7], due to the higher surface runoff velocity [3].

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Therefore, the municipality of Castelo, according to the LS factor data, is vulnerable to erosive processes of water occurrence for the most part, which can be attributed mainly to the steep slope in its territory. In the case of the slope, it has greater influence than the ramp length in the calculation of the topographic factor [33].

Table 3 presents the area data, in hectares (ha) and percentage (%), according to the current soil erosion classes.

Table 3: Area data for each current soil erosion class for Castelo municipality.

Soil type	Area (ha)	Area (%)
Slight	28935,44	43,64
Mild to moderate	2604,00	3,93
Moderate	2123,63	3,20
Moderate to high	1936,20	2,92
High	4374,28	6,60
Very high	14857,11	22,41
Extremely high	11525,77	17,30

Therefore, according to current erosion data, about 43,64% of the municipality's area has mild erosion, which is a positive factor for maintaining the quality of local soil and water resources. However, approximately 42,40% of the area corresponds to erosion rates classified as high or extremely high. Considering the “mild” and “mild to moderate” and moderate classes, about 47,6% of the municipality is prone to acceptable soil loss.

The values found are mainly influenced by the forms of use and occupation of local soils. Inadequate forms of land use trigger various processes that degrade environmental conditions, such as increased runoff and, consequently, greater sediment transport [1]. Another relevant factor is related to planning and territorial planning. The presence, for example, of high slope agricultural crops (considered as Permanent Preservation Area - APP) favors the loss of soils.

Given this scenario, to control soil erosion, land use readjustment is necessary, which can be accomplished in the following ways: the first one is through readjustment of use, adopting covers that are capable of protecting the soil. soil properly; and another is the adoption of mechanical conservation practices that fragment the ramp length and reduce the surface runoff space [14], linked to a correct planning of land use and occupation. These measures are fundamental for the areas of the municipality of Castelo with high incidence of soil loss, considering the influence of the CP factor.

Table 4 contains the area, in hectares (ha) and percentage (%), for each potential erosion class.

Table 4: Area data for each class of potential soil erosion for the municipality of Castelo.

Class	Area (ha)	Area (%)
Weak	7915,66	11,94
Moderate	2842,33	4,29
Moderate to strong	25037,08	37,76
Strong	18043,67	27,21
Very strong	12465,25	18,80

Most of the municipality (37,76%) is vulnerable to moderate to strong classified soil losses, while only around 16.40% have a low to moderate framed soil loss incidence. Approximately 83,77% of the municipality has an incidence of soil loss ranging from “moderate to strong” to “very strong”, which is a matter of concern for preserving the quality and structure of most local soils. The potential of a soil to water erosion can be an important indicator of environmental vulnerability in a given location [30].

Thus, disregarding the CP factor, most of the municipality of Castelo has a tendency to soil loss, attributed to local physical characteristics such as slope and soil type.

Therefore, they are areas of high environmental vulnerability that need conservationist measures to minimize soil loss. With regard to measures for greater soil protection in these locations, environmental planning actions can be considered to discipline use and occupation by matching the use classes to the environmental conditions of the site [29].

For the municipality of Castelo, the need for erosion control is essential, given the characteristics of the relief (mainly), soil erosivity and erodibility.

Fig 3 and Fig 4 show, respectively, the current and potential erosion maps for the municipality of Castelo (ES).

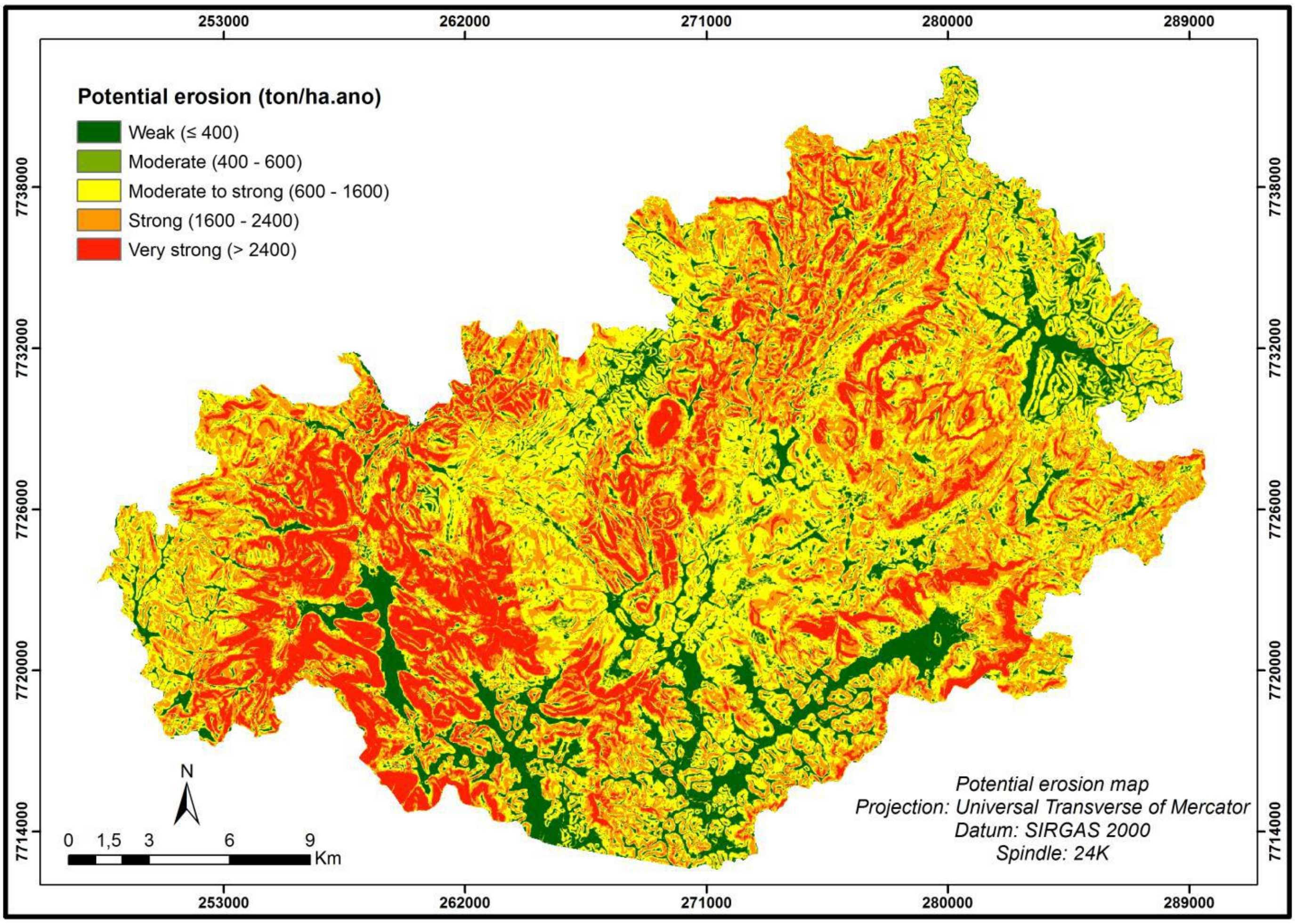

Fig. 3: Potential erosion map of the municipality of Castelo (ES).

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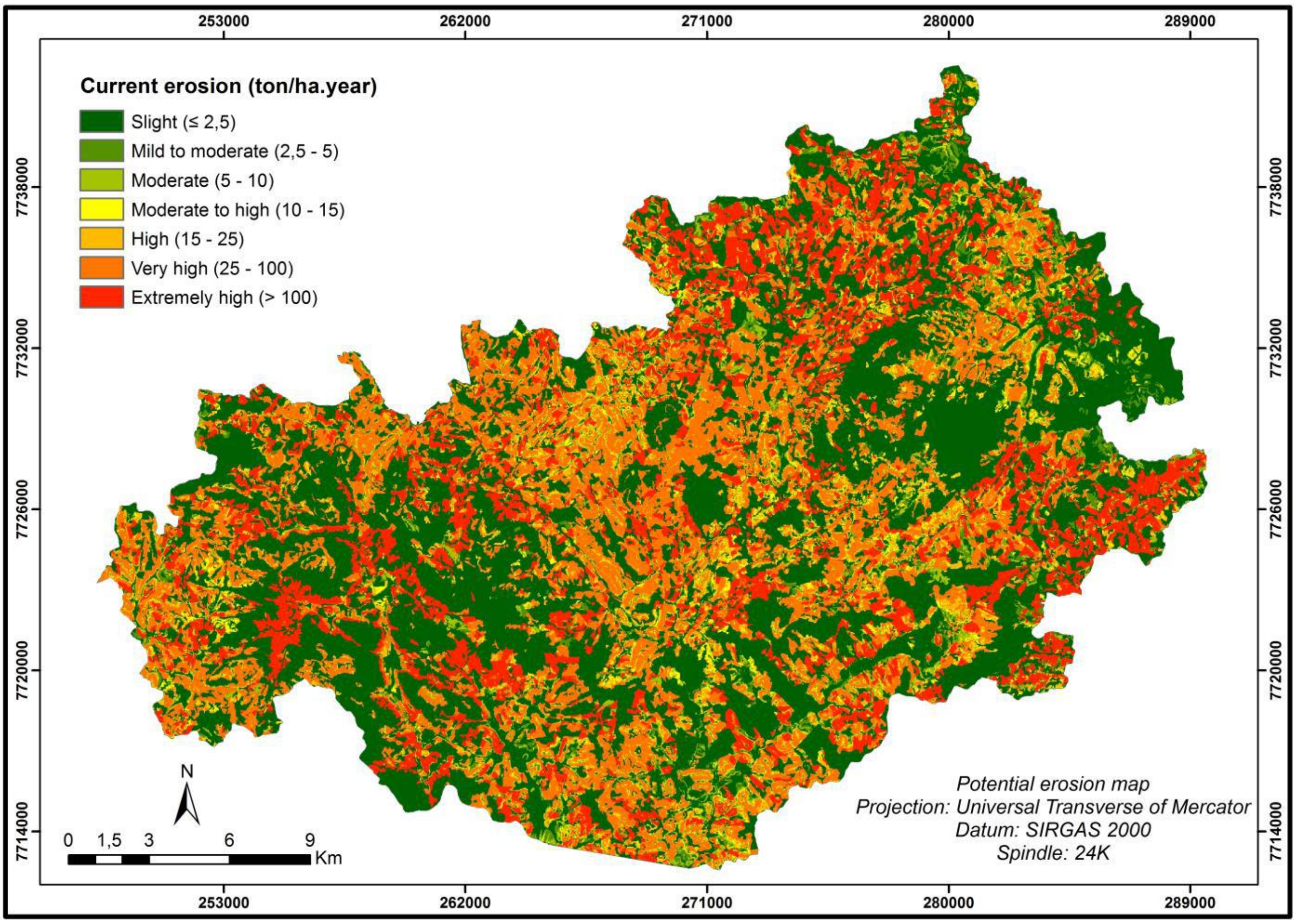

Fig. 4: Current erosion map of the municipality of Castelo (ES).

In the current erosion map, it is noted that there are large areas with a high incidence of erosion, whereas areas with erosion classified as “mild” were clustered in most of the municipality, which can be attributed to the forms of use and occupation. of the soils. As for potential erosion, the highest incidence of soil loss is in the western portion of the municipality, which may be justified by the steep slope and soil type of these sites.

However, comparing the two figures, it is clear that there are areas with high potential for soil loss due to physical characteristics and, however, present low current soil loss. This fact can be attributed to land use and land cover, such as the occupation of native vegetation and rocky outcrops. In the case of native vegetation, it has a relevant factor in the protection of soil and water resources, regardless of local physical conditions, contributing to the improvement of the environmental quality as a whole.

However, in less clarity, there are places with low tendency to soil loss and that, due to the CP factor, have high soil loss. Given this scenario, it is essential the action of the local government and other authorities, with a view to orienting the population on areas with a greater tendency to erosive processes and, mainly, to subsidize better planning in the forms of land occupation.

In addition, the importance of geotechnologies in environmental studies is highlighted, as this paper approaches, in order to serve as an instrument for planning and management of areas [44], such as the municipality of Castelo.

In this case, the mapping of current and potential erosion allowed a clearer and more dynamic visualization of the situation of soil loss in the municipality, in order to prioritize mitigation and mitigation actions of environmental impacts from anthropic action to specific regions and regions. contribute to improving the management of areas less vulnerable to erosion.

Table 5 presents the area data for potential erosion classes by community of Castelo municipality.

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Table 5: Area data (%) for each class of potential soil erosion for the communities of Castelo municipality.

Communities	Weak	Moderate	Moderate to strong	Strong	Very strong
Aparecida	23,44%	6,04%	39,83%	25,52%	5,17%
Apeninos	8,66%	3,96%	47,19%	31,07%	9,12%
Aracuí	20,72%	4,48%	33,98%	26,93%	13,89%
Arapoca	16,61%	2,83%	20,99%	21,78%	37,79%
Bateia	10,98%	4,60%	48,04%	30,86%	5,52%
Campestre	3,59%	2,87%	36,00%	32,50%	25,04%
Castelo (cidade)	22,57%	6,01%	42,70%	17,42%	11,30%
Caxixe Quente	7,85%	4,66%	46,25%	31,85%	9,39%
Cedro	8,70%	4,87%	55,96%	25,33%	5,14%
Conduru	22,58%	6,72%	40,23%	25,87%	4,60%
Córrego da Prata	4,68%	3,73%	40,92%	41,82%	8,85%
Corumbá	7,00%	4,84%	48,14%	32,23%	7,79%
Crimeia	8,85%	7,15%	55,02%	20,87%	8,11%
Estrela do Norte	13,31%	1,51%	13,44%	18,25%	53,49%
Fazenda da Prata	19,52%	3,80%	27,74%	22,94%	26,00%
Fazenda das Flores	10,37%	3,70%	40,42%	23,88%	21,63%
Fazenda do Centro	11,79%	4,21%	41,59%	30,25%	12,16%
Fazenda Velha	8,47%	2,79%	34,12%	32,90%	21,72%
Forno Grande	21,40%	9,28%	52,46%	14,57%	2,29%
Grécia	3,62%	1,33%	14,89%	28,03%	52,13%
Jabuticabeira	6,02%	4,00%	41,53%	30,50%	17,95%
Lembrança	4,21%	2,14%	26,00%	32,26%	35,39%
Limoeiro	4,70%	2,42%	24,43%	41,08%	27,37%
Mamona	7,47%	8,48%	56,43%	23,09%	4,53%
Mata das Flores	28,52%	7,18%	43,36%	17,98%	2,96%
Monte Alverne	4,75%	3,02%	28,65%	39,71%	23,87%
Monte Pio	24,15%	4,21%	32,79%	23,09%	15,76%
Mundo Novo	23,82%	3,08%	24,76%	22,53%	25,81%
Nogueira	13,67%	5,17%	36,42%	23,06%	21,68%
Pati	5,48%	2,33%	28,78%	34,78%	28,63%
Patrimônio do Ouro	3,70%	3,10%	44,63%	32,75%	15,82%
Pedra Lisa	9,09%	3,95%	51,05%	31,42%	4,49%
Pedregulho	4,23%	3,23%	40,21%	38,78%	13,55%
Pico do Forno Grande	1,02%	1,29%	33,80%	42,15%	21,74%
Pontãozinho	4,68%	3,74%	46,36%	27,88%	17,34%
Pontões	5,01%	3,21%	43,29%	26,47%	22,02%
Quilombo	5,50%	2,52%	26,23%	30,90%	34,85%
Santa Clara	7,21%	1,56%	15,56%	20,97%	54,70%
Santa Helena	11,42%	4,79%	70,69%	12,00%	1,10%
Santa Justa	4,88%	2,25%	28,90%	39,80%	24,17%
Santa Maria de Baixo	10,48%	4,55%	44,26%	26,54%	14,17%
Santa Maria de Cima	7,51%	3,56%	42,45%	39,03%	7,45%
São Cristóvão	10,38%	4,40%	42,90%	28,48%	13,84%
São José	32,18%	7,07%	37,55%	15,55%	7,65%
São Manoel	9,84%	5,16%	45,04%	23,58%	16,38%
São Pedro	12,52%	6,66%	58,30%	20,62%	1,90%
Seleta	4,13%	1,42%	17,96%	32,19%	44,30%

Taquaral	23,61%	4,56%	34,33%	29,90%	7,60%
Ubá	5,44%	3,75%	39,16%	37,98%	13,67%
Vai e Vem	13,86%	8,12%	59,57%	17,37%	1,08%

Regarding the quantification of the area and respective descriptions of vulnerability to potential soil erosion by community, most of the communities of the studied municipality presented moderate to strong soil loss index. However, in the fifty communities considered, eight of them had the highest predominance of the "very strong" soil loss class, and three of these communities (Grécia, Estrela do Norte and Santa Clara) have more than half of their territory with classified soil loss. as very strong.

The communities that presented the most satisfactory results were: Mata das Flores, São José, Monte Pio and Taquaral. Both, due to their physical characteristics, have the highest percentage of land with low soil loss linked to low percentage with very strong soil loss. Thus, the planning and management of local soils must be done correctly, in order to minimize the occurrence of erosive processes of water occurrence.

The occupation of areas, without prior knowledge of their susceptibilities and restrictions of use, can generate imbalances to the natural environment, often resulting in environmental and social damages [44].

Another relevant factor is the adoption of necessary soil conservation and protection measures in communities with higher erosive potential, with a view to mitigating the erosion caused by agriculture and eucalyptus, pine and rubber forest, present in the municipality.

Non-conservationist land use has numerous impacts on the environment, including biodiversity reduction, soil disaggregation, siltation of watercourses, among others [9]. Regarding pasture, agriculture and eucalyptus, both with a strong predominance in rural areas, if not properly managed, can present relevant erosive processes [45]. During the recording of the photographs, it was found that there are several places, such as those located in communities with a high potential erosion index, that suffer from intense erosion processes due to the non-consideration of conservationist practices and the incorrect planning of the forms of use and occupation. as shown in Fig 5 to Fig 7.

Fig. 5: Erosion in pasture area, in Estrela do Norte community.

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Fig. 6: Erosion in pasture area, in São José community.

Fig. 7: Eutrophic water resource in the community of Jabuticabeira.

As seen in figure 5, there is a strong erosive process in a pasture area, due to the physical characteristics of the site and the incorrect management of the areas. This is most often due to the adoption of the extensive livestock system, as it is characterized by low investment in formation (especially when the land already has some kind of pasture) and the maintenance of pasture. However, this system can have the following consequences: destruction of natural ecosystems (due to depletion or low productivity, which encourages the rancher to expand production on natural biomes and, consequently, to destroy them), soil degradation (causing erosion forms such as furrows and gullies) and pollution of water resources through the loading of nutrients, hormones, heavy metals and pathogens carried to the riverbed by leaching [13], as shown in the figure 7.

Given this scenario, to minimize erosion, the adoption of paddocks is of utmost importance in order to avoid overgrazing, to safeguard more forest preservation areas on farms and to assist in the restoration of grass, which in turn contributes to the protection of of the soil [15].

Other examples include: the adoption of pasture management systems (continuous grazing, for example), soil remediation and fertilization prior to grazing, mountain top protection and slope revegetation. These measures are essential to make production more sustainable and, especially, to minimize erosive processes in these areas [18]. Of great predominance in the municipality, coffee farming, if not handled correctly, can

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cause negative environmental impacts. One is the change in physical properties of surface water as a result of the surface runoff of rainwater, as shown in Fig 8.

Fig. 8: Water resource with high sediment content, in a seletion devoid of ciliary vegetation and with coffee vegetation.

A relevant factor contributing to the contamination of water resources is the absence of riparian vegetation due to non-compliance with legislation, which in turn requires a minimum of 30 meters in relation to a water course for the implementation of rural anthropogenic activities and, mainly protect the springs.

Given this scenario, some techniques are of great importance in the installation and maintenance of coffee crops, especially in areas with considerable potential for soil loss. Some of them are: using green manure, rotating crops, cultivating contour lines, adopting the practice of vegetative management called “alternating weeding” (contributes to the retention of land removed in the surface runoff), presence of cover dead soil (attenuates the impact of water droplets on the soil constitutes a physical barrier to runoff and provides organic matter to the soil) and adoption of no-tillage system (soil tillage is not necessary, maintaining its quality). Another relevant issue is the adoption of agroforestry systems to the detriment of coffee monocultures, bringing greater soil protection linked to greater economic and ecological gains [18].

In general, agricultural and livestock activities in the municipality need to be adapted to local relief, since, without proper care, they can cause high soil loss and, as a consequence, severe environmental damage to water resources, fauna and flora. Regardless of the potential erosion level of the communities studied, mitigation and mitigation of negative impacts from anthropic action should be implemented, along with other forms of subsidies for improvements in the environmental quality of the study space.

IV. CONCLUSION

The municipality of Castelo has a high vulnerability to soil loss considering the physical aspects of its relief, erodibility and erosivity. The high values of topographic factor and slope indicate irregularities in the relief, which requires even more attention in the execution of human activities, such as agriculture. As for current erosion, dictated by land use and conservation practices, the municipality has low soil loss in much of its area, which indicates a positive factor for soil preservation. However, in some communities such as North Star, Santa Clara and Grécia, there is a great tendency for soil loss, meaning the need for proper management of anthropic activities to avoid causing environmental problems, as seen in the photographic records.

Given this scenario, the action of local public authorities through territorial planning and management, together with the adoption of mitigation measures and mitigation of environmental impacts are extremely important, in addition to the expansion of vegetation cover near water courses, in order to minimize soil loss especially in communities where there is a high tendency to this phenomenon.

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