Modeling soil losses by water erosion in a coffee growing area in Southeastern Brazil

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ABSTRACT
Water erosion is one of the main soil degradation problems, especially in tropical areas due to high rainfall rates. Several factors affect water erosion, especially anthropic actions related to land use and occupation. In this scenario, the objective of the work was to estimate the rates of soil loss by water erosion in a coffee production area in the south Minas Gerais State, compare them with the soil loss tolerance limits and evaluate the sustainability of the agricultural production system. The hypothesis of this work is that the adoption of conservationist practices in coffee production areas has the potential to reduce soil losses in areas of steep relief, highly susceptible to water erosion. The methodology employed was based on the application of the Revised Universal Soil Loss Equation and the calculation of soil loss tolerance. The results showed a variation of soil loss rates between 0.08 and 21.97 Mg ha⁻¹ year⁻¹, with the highest soil loss rates obtained in the bare soil and the lowest in the native forest. In areas with coffee plantations, low soil losses were observed, indicating that conservation practices adopted in this crop, such as level planting and management of plant residues and soil cover, have the potential to reduce soil loss, especially in high slope areas. Therefore, soil loss modeling was an efficient tool to evaluate the stage of soil degradation and to define sustainable agricultural management practices and preservation of the vegetation cover.

Keywords: RUSLE; land use and land cover; soil loss tolerance.

Modelagem das perdas de solo pela erosão hídrica em uma área de produção de café no Sudeste do Brasil

RESUMO
A erosão hídrica é um dos principais problemas de degradação dos solos, especialmente em áreas tropicais em virtude dos índices pluviométricos elevados. Vários fatores afetam a erosão hídrica, especialmente as ações antrópicas relacionadas ao uso e ocupação do solo. Neste cenário, o objetivo do trabalho foi estimar as taxas de perdas de solo por erosão hídrica em uma área de produção cafetière no sul do Estado de Minas Gerais, comparar com os limites de tolerância de perda de solo e avaliar a sustentabilidade do sistema de produção agrícola. A hipótese do presente trabalho, é que a adoção de práticas conservacionistas nas áreas de produção de café tem o potencial de reduzir as perdas de solo em áreas de relevo íngreme, altamente susceptíveis a erosão hídrica. A metodologia empregada foi baseada na aplicação da Equação Universal da Perda deSolo Revisada e no cálculo da tolerância de perda de solo. Os resultados mostraram uma variação das taxas de perdas de solo entre 0,08 e 21,97 Mg ha⁻¹ ano⁻¹, com as maiores taxas de perdas de solos obtidas nas áreas de solos expostos e as menores nas de mata nativa. Nas áreas com plantações de café foram observadas baixas perdas de solo, indicando que as práticas conservacionistas adotadas nesta cultura, como plantio em nível e o manejo de resíduos vegetais e da cobertura do solo, têm o potencial de reduzir a perda de solo, especialmente em áreas de alta declividade.

Portanto, a modelagem das perdas de solo foi ferramenta eficiente para avaliar o estágio de degradação do solo e definir práticas de manejo agrícola sustentáveis e de preservação da cobertura vegetal.

Palavras-chave: RUSLE; uso e ocupação do solo; tolerância de perda de solo.

**Introduction**

Currently, one of the main problems that affect soils is water erosion (Guo et al., 2019; Milazzo et al., 2022; Khosravi et al., 2023). Water erosion can be defined as the process of soil wear by the action of rain and surface runoff, causing disaggregation, removal, transport and deposition of particles and removed material to other locations (Dechen et al., 2015; Alewell et al., 2019). Although it is a natural phenomenon, erosion has been continuously intensified by human activities (Severiano et al., 2017; Oliveira and Selva, 2019).

Several factors influence water erosion. These are the intrinsic properties of the soil, rainfall, topography, vegetation cover and human activities (Mosavi et al., 2020; Chen et al., 2023). The factors act together, however, human activities exert more significant influence, especially those involving land use and occupation, because it is the variable that changes rapidly over time (Fernández and Vega, 2016; Borrelli et al., 2017; Luetzenburg et al., 2020). For example, the conversion of native forests into pastures or croplands can intensify water erosion, increasing on average 10% to 12% of total greenhouse gas emissions in the atmosphere (Campos et al., 2022), leveraging climate change, decreasing soil organic carbon stocks and lowering human resilience to global crises and pandemics (Rumpel et al., 2022).

The main consequence of water erosion is the loss of soil, water, organic matter and nutrients. These losses can lead to the impoverishment of arable land, the reduction of productive capacity and generating unsustainability of agricultural production systems (Bertol et al., 2007; Oliveira et al., 2007; Shi and Schulin, 2018; Gomes et al., 2021; Phinzi et al., 2021). It is estimated that there are losses of approximately 75 billion tons of soil annually in the world with a cost of USD 400 billion (FAO and ITPS, 2015). The impact on food security is the reduction of global agri-food production by 33.7 million tons (Sartori et al., 2019). In Brazil, losses of 3 billion tons of soil annually are estimated; of this total, 29.5% come from cultivated areas and 61.4% from pastures. Considering the costs of replacing fertilizers (organic and mineral) and limestone, this soil loss generates an economic impact of USD 15.7 billion per year (Polidoro et al., 2021).

Coffee is one of the most vulnerable crops to negative environmental impacts affecting climate (Pham et al., 2019). Factors such as temperature increase, changes in rainfall patterns and accelerated climate variations influence directly the flowering, fruiting and coffee quality processes, and also the incidence of pests, reducing productivity (Souza et al., 2023).

Brazils is the world's largest coffee producer, with a predominant activity in the South/Southwest region of the Minas Gerais State (CONAB, 2022). Many of the coffee growing areas are located on steep slopes, with conventional production systems, planting on gradients and the absence of vegetation between the rows, practices that can degrade soil quality and favour water erosion and sediment generation (Aslam et al., 2021). On the other hand, areas with coffee plantations where conservationist practices are adopted, such as the management of spontaneous vegetation in between the rows of coffee trees, green manuring and level planting, have the potential to reduce soil losses and contribute to the sustainability of the agricultural system (Lense et al., 2019a). Thus, it is essential to develop studies that evaluate water erosion and soil loss rates in coffee areas.

Water erosion and soil losses rates can be evaluated using simulation models (Eniyew et al., 2021; Boussetta et al., 2022; Aouragh et al., 2023). These models, when combined with Geographic Information Systems (GIS) and Remote Sensing (RS), enable low-cost, quick and accurate assessments compared to traditional empirical models (Ayer et al., 2015; Oliveira et al., 2023). One of the most used simulation models in the world is the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997).

The RUSLE allows for mapping the intensity of erosion and estimating annual soil losses (Wischmeier and Smith, 1978; Ganasri and Ramesh, 2016; Maqsoom et al., 2020; Getu et al., 2022). To assess the sustainability of an agricultural production system, RUSLE can be combined with soil loss tolerance (T) (Ostovari et al., 2021; Räisänen et al., 2023). The T represents the maximum limit of soil loss that can occur while maintaining its productive capacity (Beach and Gersmehl, 1993; Fonseca et al., 2023). It is considered a complementary tool to soil loss estimates, as it allows a more accurate assessment of the state of soil degradation by establishing a critical loss threshold (Bertol and Almeida, 2000; Di Stefano and Ferro, 2016; Ranathunga et al., 2021). According to the Food and Agriculture...
Organization of the United Nations and the Intergovernmental Technical Panel on Soils, T levels are considered useful for defining short-term goals on edaphic sustainability (FAO and ITPS, 2015); however, for long-term sustainability, it is necessary to reduce soil loss rates to levels close to zero (Mondal et al., 2023).

In this way, this work aims to: (i) estimate the rates of soil loss by water erosion in a coffee production area in the south of Minas Gerais State by RUSLE and (ii) compare soil loss rates with T limits. The hypothesis of this work is that the adoption of conservationist practices in coffee production areas has the potential to reduce soil losses in areas of steep relief, highly susceptible to water erosion.

**Material and methods**

**Study area**

The study area corresponds to the Capoeirinha Unit, owned by Ipanema Agrícola S.A. It is located in the Municipality of Alfenas, south Minas Gerais State, southeastern region of Brazil (Figure 1). It consists of a set of 3 farms: Capoeirinha, São Joaquim and Marlene. It has an area of 2,238.44 ha and is part of the Rio Grande hydrographic basin. According to Köppen, the climate is classified as Mesothermal Tropical (Cwb), with an average annual temperature of 22° C and an average annual rainfall of 1,500 mm (Alvares et al., 2013). The geological framework is composed of garnet-biotite gneisses and biotite gneisses, superimposed by quaternary soil covers and deposits of unconsolidated river gravel, sand and mud (SISEMA, 2019).

All maps were produced in the software ArcGIS version 10.8 (ESRI, 2020). The land use and occupation map was produced from Landsat-8 satellite images, spatial resolution of 30 m, from May 2022 (orbit/point 219/75) and obtained from the United States Geological Survey digital platform (USGS, 2023). The visual classification was performed based on the TM4 (red), TM5 (near-infrared) and TM6 (mid-infrared) bands. Predominante in the area the coffee cultivation and native forest with 1,310 ha and 504 ha, respectively. Others land use classes are bare soil (access roads and coffee streets / 104.11 ha), facilities (24.44 ha), sugarcane (10.5 ha), waterbodies (62.09 ha), eucalyptus (69 ha), corn (80 ha) and pasture (74.3 ha) (Figure 1).

Figure 1. Location and land use and occupation maps of the Capoeirinha Unit.

At the Capoeirinha Unit, coffee occupy 35% of the total area and are harvested manually and mechanized, in about 15 and 85%, respectively. The average age of coffee plantations in the study area is 24 years. Coffee is planted in

The main varieties of coffee are acaiá and bourbon.

The soil classes map (Figure 2) was produced digitally, as per McBratney et al. (2003), based on the soil map of the Minas Gerais State, on a 1:650,000 scale (UFV et al., 2010). The soils are Red Latosol (LV), Red-yellow Latosol (LVA) and Red-yellow Argisol (PVA), in 36.5%, 56.4% and 3.5% of the area, respectively. There are also Indiscriminated Floodplain Soils (IFS), which were counted from 30 m on each side of the waterbodies. The IFS occupy 0.82% and the waterbodies occupy 2.78% of area.

The Digital Elevation Model (DEM) was obtained from the L-band image of the Alos Palsar Satellite (JAXA, 2020), from February 2011 (absolute orbit No. 27875), 30 m resolution resampled to 12.5 m for better resolution. Altitudes vary between 793 and 965 m and were categorized into five different levels, every 34 or 35 m (Figure 3).
The slope map (Figure 4) was generated from the DEM by the application of the tool Slope in the ArcGIS 10.8 (ESRI, 2020). The slope was classified according to EMBRAPA (1979) as flat (0 - 3%), smooth wavy (3 - 8%), wavy (8 - 20%) and strong wavy (20 - 45%).

![Slope map of the Capoeirinha Unit.](image)

Revised Universal Soil Loss Equation (RUSLE)

Annual soil loss was estimated by the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997) (Equation 1).

\[
A = R \times K \times LS \times C \times P
\]  
(1)

In which: \(A\) is the average annual soil loss, Mg ha\(^{-1}\) yr\(^{-1}\); \(R\) is the rainfall erosivity factor, MJ mm ha\(^{-1}\) h\(^{-1}\) yr\(^{-1}\); \(K\) is the soil erodibility factor, Mg h MJ\(^{-1}\) mm\(^{-1}\); \(LS\) is the topographic factor which involves the length and steepness of the slope (dimensionless); \(C\) is the factor for land use and management (dimensionless) and \(P\) is the factor for conservation practices (dimensionless) (Wischmeier and Smith, 1978).

The \(R\) factor was obtained from Aquino et al. (2012) of the rainfall erosivity map of the Minas Gerais State. The \(K\) factor for latosols was obtained from Mendes Júnior et al. (2018) and for the argisols from Lense et al. (2019a), from the indirect method of Silva et al. (1999).

The \(LS\) topographic factor was estimated according to the equation by Moore and Burch (1986), expressed in ArcGIS 10.8 (ESRI, 2020) (Equation 2), from the DEM, using the Raster Calculator tool.

\[
LS = \left(\frac{FA \times 12.5}{22.13}\right)^{0.4} \times \left(\frac{\sin S}{0.0896}\right)^{1.3}
\]  
(2)

In which: \(LS\) is a dimensionless topographic factor; \(FA\) is flux accumulation, expressed as the number of cells in the DEM grid; \(\sin S\) is the slope sine of the area (in degrees) and 12.5 m is the spatial resolution of the DEM.

The \(C\) factor expresses the influence of soil use and management on the erosion process. It ranges from close to 0 to 1, where higher values indicate less soil protection. The \(P\) factor also ranges from close to 0 to 1 and expresses the potential that conservationist practices have to reduce soil erosion, in which smaller values indicate efficient practices. The \(C\) and \(P\) values below were adapted from the specialized literature (Table 1).

<table>
<thead>
<tr>
<th>Land use and occupation</th>
<th>C factor</th>
<th>Source C factor</th>
<th>P factor*</th>
</tr>
</thead>
</table>

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Soil Loss Tolerance (T)

The RUSLE results were compared with soil loss tolerance (T) values. T limit values for latosols and argisols were determined by Lense et al. (2019b), who calculated according to the method of Bertol and Almeida (2000). Is the most used method in Brazil, as it considers a greater variety of soil properties, which reflect its formation processes (Cândido et al., 2014; Mendes Júnior et al., 2018; Lense et al., 2019b).

The soil loss tolerance was obtained from Equation 3:

\[ T = h \times ra \times m \times p \times 1.00^{-1} \]  

In which: \( T \) is the soil loss tolerance (Mg ha\(^{-1}\) yr\(^{-1}\)), corrected from the original equation considering soil density; \( h \) is the effective soil depth (mm), limited to 1,000 mm; \( ra \) is a relationship that expresses, at the same time, the effect of the textural relationship between the B and A horizons and the clay content of the A horizon; \( m \) is the factor that expresses the effect of organic matter on the top 0.20 m of soil; \( p \) is a factor that expresses the effect of soil permeability and 1.00\(^{-1}\) is the constant that expresses the time required to erode a soil layer 1,000 mm thick.

T values were correlated with soil losses estimated by RUSLE in ArcGIS 10.8 (ESRI, 2020).

Results and discussions

The R factor is 6,500 MJ mm ha\(^{-1}\) h\(^{-1}\) yr\(^{-1}\) (Aquino et al., 2012). This value is considered high and influenced by topography and regional climate variation (Teixeira et al., 2022). There is greater erosivity at higher altitudes, areas more favorable to coffee production. The K factor was 0.021 for LVA, 0.024 for LV and 0.039 for PVA (Mendes Júnior et al., 2018; Lense et al., 2019a). The LS factor ranged from 0 to 825, with a mean of 4.99.

The highest average soil losses were estimated for bare soil, sugarcane and eucalyptus and the lowest for native forest, corn and coffee (Figure 5). The total annual soil loss was 7,642.83 Mg yr\(^{-1}\).

The estimated soil losses in the waterbodies areas were considered null, since they are sites of sediment deposition.

Figure 5. Soil loss rates map by RUSLE of the Capoeirinha Unit.

Regarding the average soil losses, the highest values were obtained in bare soil and eucalyptus planted downhill (Table 2). Access roads, being larger and extensive, enhance the

*Senanayake et al. (2022).
kinetic energy of surface runoff, especially in areas with greater slopes, intensifying soil losses (Zhang et al., 2019). According to Kumar et al. (2023), increases in slope steepness from 2% to 9% can elevate runoff rates and soil losses by 1.84 and 3.84 times. The values of bare soil were lower than the results of Thompson (2015), from 20 to 100 Mg ha\(^{-1}\) yr\(^{-1}\); and by Sakuno et al. (2020), from 19.34 to 26.05 Mg ha\(^{-1}\) yr\(^{-1}\).

Eucalyptus areas are associated with greater slopes, and in their initial stages provide low rates of soil vegetation cover, characteristics that favor water erosion and soil loss (Ayer et al., 2015; Bispo et al., 2023). Soil loss rates in eucalyptus were higher than the values reported by Silva et al. (2016), from 0.12 to 0.81 Mg ha\(^{-1}\) yr\(^{-1}\), due to downhill planting in undulating slopes and lack of conservationist management practices. At the Capoeirinha Unit, they were initially planted to mitigate the risk of frost, which forms in the lower areas of the land, over waterbodies, impacting negatively the coffee plantations.

The values of soil loss observed in areas with coffee plantations were low when compared to other crops, such as eucalyptus and sugar cane (Table 2). The practice of inter-row vegetation management adopted in the study area was directly responsible for the reduction of soil losses, as well as planting in contour lines (Ajayi et al., 2021). The vegetation in the inter-row, the plant residues from coffee plants, such as leaves and branches that are deposited on the soil and the organic fertilization with plant residues ensure greater soil protection against the action of rain and favor the stability of soil aggregates (Iijima et al., 2003; Alele et al., 2023). The result indicates that these practices adopted on coffee farms can reduce water erosion levels (Didoné et al., 2019).

The native forest presented the lowest average soil loss rates. The values were lower than those obtained by Silva et al. (2016), who found losses of 0.01 to 0.38 Mg ha\(^{-1}\) yr\(^{-1}\) in native forests in Rio Grande do Sul State and by Pinto et al. (2020), with losses of 0.17 Mg ha\(^{-1}\) yr\(^{-1}\) in native forest of the Córrego do Pântano II subbasin, in the Municipality of Alfenas, emphasizing that the maintenance of the vegetation cover increases water infiltration and, thus, decreases runoff and sediment production (Villatoro-Sánchez et al., 2015). The vegetation cover has a significant impact on soil loss, preventing the release of soil particles by surface runoff (Fekadu et al., 2022). According to He et al. (2023), even if an area is degraded, vegetation restoration can substantially reduce soil loss. Corn also obtained reduced values of soil loss (Table 2), as it is cultivated on flat and smooth wavy terrains, which attenuates the velocity of surface runoff and the production and transport of sediments (Lima et al., 2014). In many other studies, slope is the major factor controlling water erosion under corn cultivation (Oshunsanya et al., 2023). However, mechanized harvesting increases soil compaction and can reduce the infiltration rate and raise surface runoff, degrading soil quality, which does not occur in the area because the corn is harvested by hand.

Pastures also show reduced values of soil loss of 2.44 Mg ha\(^{-1}\) yr\(^{-1}\). Because they are located on flat slopes close to sediment deposition sites, pastures offer more efficient protection than bare soil and eucalyptus, according to Sparovek et al.

### Table 2. Soil loss estimate rates according to the RUSLE for land use and occupation.

<table>
<thead>
<tr>
<th>Land use and occupation</th>
<th>Area (ha)</th>
<th>Area (%)</th>
<th>Average soil loss (Mg ha(^{-1}) yr(^{-1}))</th>
<th>Total soil loss (Mg yr(^{-1}))</th>
<th>Soil loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare soil</td>
<td>104.11</td>
<td>4.65</td>
<td>21.97</td>
<td>2,834.13</td>
<td>37.08</td>
</tr>
<tr>
<td>Coffee</td>
<td>1,310</td>
<td>58.52</td>
<td>2.91</td>
<td>3,899.40</td>
<td>51.03</td>
</tr>
<tr>
<td>Eucalyptus</td>
<td>69</td>
<td>3.09</td>
<td>7.61</td>
<td>525.09</td>
<td>8.68</td>
</tr>
<tr>
<td>Native forest</td>
<td>504</td>
<td>22.52</td>
<td>0.08</td>
<td>40.32</td>
<td>0.52</td>
</tr>
<tr>
<td>Corn</td>
<td>80</td>
<td>3.57</td>
<td>0.56</td>
<td>53.20</td>
<td>0.69</td>
</tr>
<tr>
<td>Pasture</td>
<td>74.3</td>
<td>3.31</td>
<td>2.44</td>
<td>202.52</td>
<td>2.70</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>10.5</td>
<td>0.47</td>
<td>5.28</td>
<td>86.99</td>
<td>1.12</td>
</tr>
<tr>
<td>Waterbodies</td>
<td>62.09</td>
<td>2.78</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Facilities</td>
<td>24.44</td>
<td>1.09</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>2,238.44</td>
<td>100</td>
<td>5.84</td>
<td>7,641.65</td>
<td>100</td>
</tr>
</tbody>
</table>

The average soil loss rate for coffee was 2.91 Mg ha\(^{-1}\) yr\(^{-1}\), higher than those obtained by Mendes Júnior et al. (2018) and Tavares et al. (2019) of 1.58 Mg ha\(^{-1}\) yr\(^{-1}\) and by Lense et al. (2019b) of 2.12 Mg ha\(^{-1}\) yr\(^{-1}\) that evaluated soil losses in subbasins inserted in the evaluated farms. This is because the articles have addressed only one subbasin of the Capoeirinha Unit. However, loss rates were lower than those obtained by Bolleli et al. (2020), of 4.50 Mg ha\(^{-1}\) yr\(^{-1}\), in steeper areas of Serra da Mantiqueira, also in Minas Gerais south.


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Furthermore, the lack of livestock in the studied area contributes to the maintenance of pastures, since there is no soil compaction due to livestock trampling.

In sugarcane, the average loss rate was 5.28 Mg ha\(^{-1}\) yr\(^{-1}\). The values were lower than that of Corrêa et al. (2018), from 49.04 to 84.85 Mg ha\(^{-1}\) yr\(^{-1}\), in soils with higher levels of fine sand and in the early stages of crop development. In the study area, the use of no-tillage favors the presence of straw from the previous harvest, mitigating erosive processes, generating higher rates of organic matter, increasing water infiltration and reducing surface runoff (Bezerra and Cantalice, 2006; Villatoro-Sánchez et al., 2015).

The application of RUSLE demonstrated that severe erosion occurs mainly in areas of bare soil and eucalyptus plantations downhill, on steeper slopes and in crops with no conservationist agronomic practices. The data are similar to those obtained in the study by Lense et al. (2020) that were validated from the IGAM Hydrosedimentological Station, which demonstrates the accuracy and reliability of the results.

The T values were 7.2 Mg ha\(^{-1}\) yr\(^{-1}\) for latosols and 5.6 Mg ha\(^{-1}\) yr\(^{-1}\) for argisols. Figure 6 shows the areas with soil losses below and above the T limits. Areas below T represent 93.14% and above 3.80%, while 3.06% are deposition areas. The areas above the T were eucalyptus planted downhill and bare soil in strong wavy slopes; areas below T are mostly flat or smooth wavy slopes with native forest, coffee, corn and pasture. This scenario highlights the importance of soil cover to mitigate erosion processes. Therefore, in areas with steeper slopes, it is recommended to use practices that increase soil protection against erosion, such as reforestation, direct planting and management of vegetation between rows of crops, according to Baldassarini and Nunes, 2014, Silva et al., 2022 and Guduru and Jilo, 2023.

The modeling of soil losses, by RUSLE, at the Capoeirinha Unit demonstrated that bare soil, especially on access roads and steeper slopes, is the main cause of increased soil losses above the T limits. In this context, Amorim et al. (2010) evaluated the performance of soil loss prediction models by comparing them with data from experimental plots and noted that the models are more efficient in areas with greater potential for soil loss. Therefore, the results obtained should only be taken as indicative, as they were not verified in experimental plots. This suggests the need for further research to certify the results and incorporate methodological innovations for assessing and monitoring soil losses (Zolin et al., 2011).

The erosion potential obtained by RUSLE, despite the modeling limitations, indicated the areas that had the highest rates of soil loss and needed priority measures for soil conservation. Although only 3.80% of the area is above the T limits, it is necessary to highlight that there are no safe levels of soil loss. Even in areas with rates below the T, mitigation practices can and should be carried out, such as infiltration basins, greater density in the coffee streets, building terraces in the steepest areas and contour planting and direct planting. Therefore, this study shows that it is possible to mitigate the impacts of erosion and promote the sustainability of the agricultural production system. It is worth noting that in the area in question, conservationist measures are already being carried out, such as contour planting, terracing, preservation of native riparian forests and maintenance of Permanent Preservation Areas and Legal Reserves (Brasil, 2012; Teixeira et al., 2022).

The combination of RUSLE and T models made it possible to evaluate and spatialize the occurrence and intensity of soil losses (Guduru and Jilo, 2023). The results are similar to data published by scientific research that analysed soil losses in the same region, consistent with both the RUSLE (Renard et al., 1997) and the Erosion Potential Method (EPM) by Gavrilovic (1962). Mendes Júnior et al. (2018), Lense et al. (2019a) and Tavares et al. (2019) concluded that coffee planting in the region has been adopting practices to reduce environmental problems.
Finally, it should be noted that, due to climate change, is likely to occur the intensification of the water erosion (Li and Fang, 2016; Eekhout and de Vente, 2022; Raj et al., 2022; Rau et al., 2023). Brazil is highly dependent on agricultural (Riquetti et al., 2022) and, given this, the pressure on the agricultural production system will be increasing and will demand sustainable management. In this context, the Capoeirinha, São Joaquim and Marlene farms are good examples of how conservationist practices can reduce water erosion and contribute to the sustainability of agricultural production systems.

Conclusions
1. The Revised Universal Soil Loss Equation estimated an average water erosion rate of 2.91 Mg ha\(^{-1}\) yr\(^{-1}\) in areas with coffee plantations, indicating that the conservationist practices adopted in this crop, such as level planting and management of plant residues and soil cover, have the potential to reduce soil loss, especially in areas of high slope.

2. On Capoeirinha, São Joaquim and Marlene farms there are predominant areas with low soil loss (93.14%), but there are still areas with soil loss above the tolerable limits (3.80%), which are located in eucalyptus cultivation on slopes and in places with bare soil. These areas should be prioritized in the adoption of erosion mitigation practices.

3. This study demonstrated that the Revised Universal Soil Loss Equation is an efficient and low-cost tool for obtaining water erosion data, since experimental plots are costly and require several years.

4. The results obtained contribute to (i) the development of predictive scenarios of susceptibility to water erosion and (ii) suggest alternatives for the management of public and private policies for the conservation of soils, waters and vegetation cover.

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