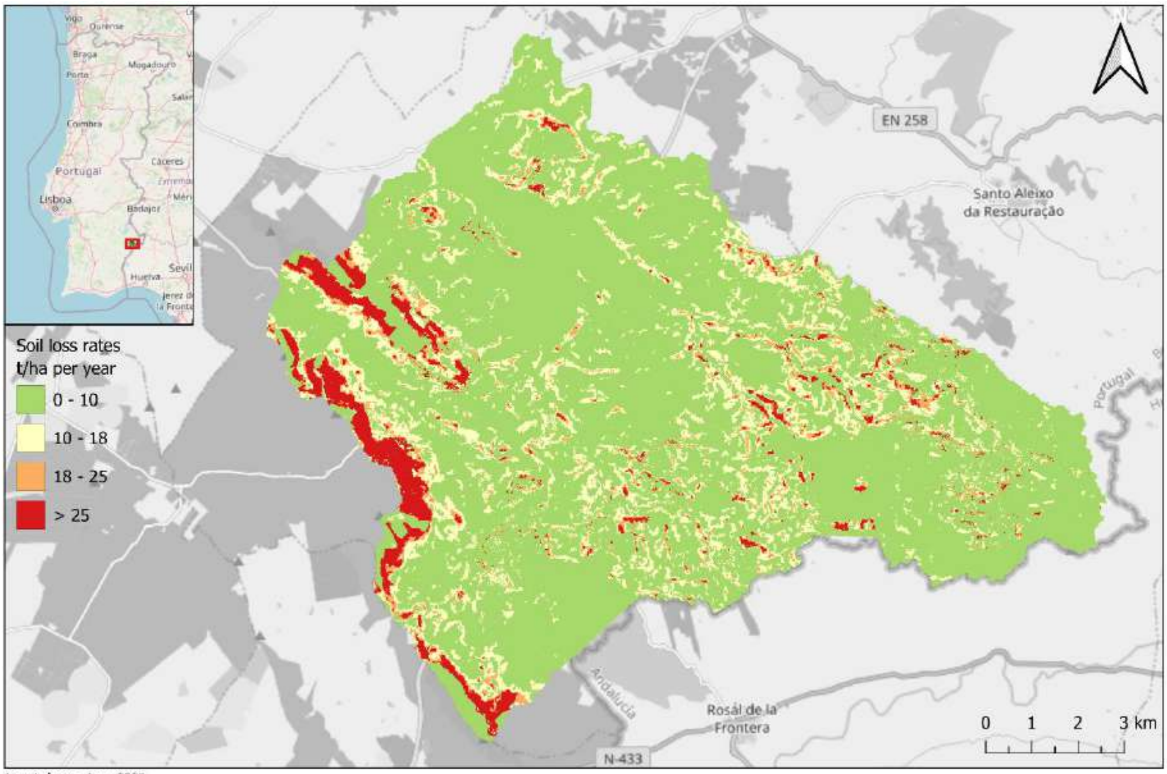
Soil Erosion Risk Assessment:

A Southern Portuguese Case Study



Juan Lahore - June 2025

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Student:

Juan Lahore

Aeres University / IPBeja

Scientific Supervisor:

Prof. João Filipe Fragoso dos Santos

IPBeja / CREATE / INTERLAYER Project

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1. Introduction

Soil erosion by water is a major form of land degradation, especially in semi-arid and Mediterranean landscapes. It refers to the detachment and movement of soil particles by rainfall and surface runoff. While erosion is a natural geomorphological process, human activity has significantly accelerated its rate, threatening agricultural productivity, water quality, and ecosystem stability (Serpa et al., 2015).

In regions like Alentejo, several factors combine to intensify water erosion. Steep slopes, seasonal rainfall with high intensity, sparse vegetation cover, and unsuitable agricultural practices create a setting where soil is highly vulnerable to loss. The main drivers of erosion include rainfall erosivity, soil texture and structure, land use and cover, and topographic features such as slope length and steepness. Anthropogenic factors such as deforestation, tillage, and poor ground cover management increase the exposure of bare soil to rainfall, making erosion events more severe (Rodríguez Sousa et al., 2023).

Soil erosion significantly alters the physical and chemical properties of soil. Physically, it degrades structure, compacts the subsoil, and reduces water-holding capacity and infiltration, promoting runoff and further erosion. Chemically, it results in the removal of nutrient-rich topsoil, diminishing organic matter and reducing fertility. Repeated erosion events cause lasting damage to the soil's productive capacity, especially in areas where natural soil formation rates are slow (Bouchoms et al., 2019).

To evaluate erosion risk, empirical models such as the Revised Universal Soil Loss Equation (RUSLE) are widely used (Ghosal & Bhattacharya, 2020). RUSLE estimates long-term average annual soil loss using five factors: rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), cover-management (C), and conservation practice (P). GIS integration allows these parameters to be modeled spatially, producing erosion risk maps that help inform land management decisions (Ismail & Ravichandran, 2008).

Numerous case studies, including those in Sri Lanka, Greece, Ethiopia, and the Philippines, show how land use (e.g. deforested or agricultural land) and slope gradient are closely linked to erosion hotspots. These studies reinforce the importance of aligning land cover with conservation strategies and demonstrate how erosion modeling can guide local interventions (Panditharathne et al., 2019) ; (Kouli et al., 2009) ; (Dapin & Ella, 2023) ; (Hajisheko et al., 2025). In the context of the catchment studied in this internship, many of the same erosion risks apply. The basin includes sloped terrain, varying soil textures, and significant agricultural land use. Based on literature insights, areas with steep slopes and bare or poorly managed land cover are likely to experience soil loss and sediment transport. These patterns are expected to influence not only surface erosion but also aquifer recharge processes and streamflow behavior in the basin (Fernandez et al., 2016).

The main objective of this internship is to evaluate the risk of soil erosion through water, by assessing uniquely the potential detachment of soil particles and loss due to sheet and rill erosion by rainfall and surface runoff and not sediment transport and deposition by the stream network inside the study area.

2. Materials and Methods

2.1 Study Area

The study was conducted in the Toutalga/San Pedro Basin, located in the municipality of Moura, Beja District, within the Alentejo region of southern Portugal. The geographic center of the basin lies at approximately 38.03168°N, 7.24961°W. The basin is part of a semi-arid Mediterranean landscape and is representative of typical land degradation dynamics found in the region.

Covering an area of approximately 136.21 km^2, the basin exhibits a varied topography with a mean elevation of 246.2 m. Elevation ranges from a minimum of 144.8 m to a maximum of 522.3 m. There are two prominent mountainous zones located in the western portion of the basin, one centrally situated and another forming the basin's western boundary, visible in Figure 1. These higher elevation zones contribute to steeper local slopes and influence surface runoff dynamics.

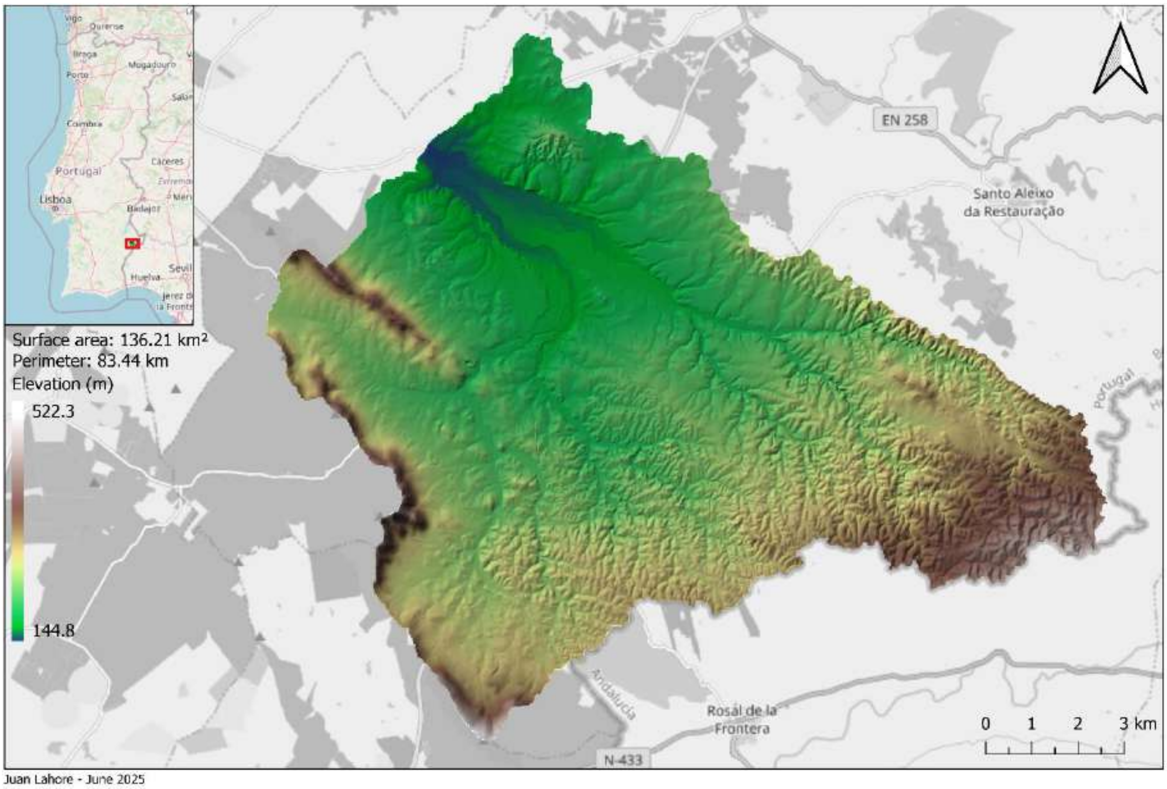

Figure 1 - Digital Elevation Model for the Toutalga/San Pedro Basin, derived from the public data portal dados.gov.pt (AMA, 2025).

The climate within the area is Mediterranean, with average annual precipitation of approximately 610.59 mm/year for the period between 2008 and 2018 (IPMA, 2018). Vegetation and land use patterns correspond closely with topographic gradients: agricultural crops and herbaceous cover dominate flatter areas, while the slopes and ridges are mainly occupied by tree-dominated systems, including ancient traditional olive groves and patches of forest consisting mainly of holm oaks and ash trees (see Appendix A).

Hydrologic soil characteristics (HSG) within the basin are predominantly classified as type C, covering over 93% of the area (see Appendix B). These soils exhibit moderately high runoff potential and typically contain less than 50% sand and 20–40% clay. Smaller portions of the basin fall into HSG type C/D, indicating high runoff potential unless adequately drained (ORNL DAAC, 2018). These soil properties contribute to increased surface runoff generation, particularly under conditions of sparse vegetation or compacted topsoil. Hydrologically, the basin is intersected in the west by the Moura–Ficalho main aquifer system, which is a confined karstic aquifer that generally follows the contours of the terrain and interacts with surface flow conditions within the selected overlapping areas (see Appendix C). There is also an aquifer subsystem called Toutalga, closely linked to the recharge of the Toutalga and S. Pedro streams, which connects to the main aquifer system in the mountain range (NW direction).

Field visits were conducted to ground-truth land use categories, identify erosional features, and observe water flow patterns. Selected photographs documenting land cover conditions and terrain features are associated with specific locations within the basin, visible in Figure 2 (see Appendix G for additional photographs).

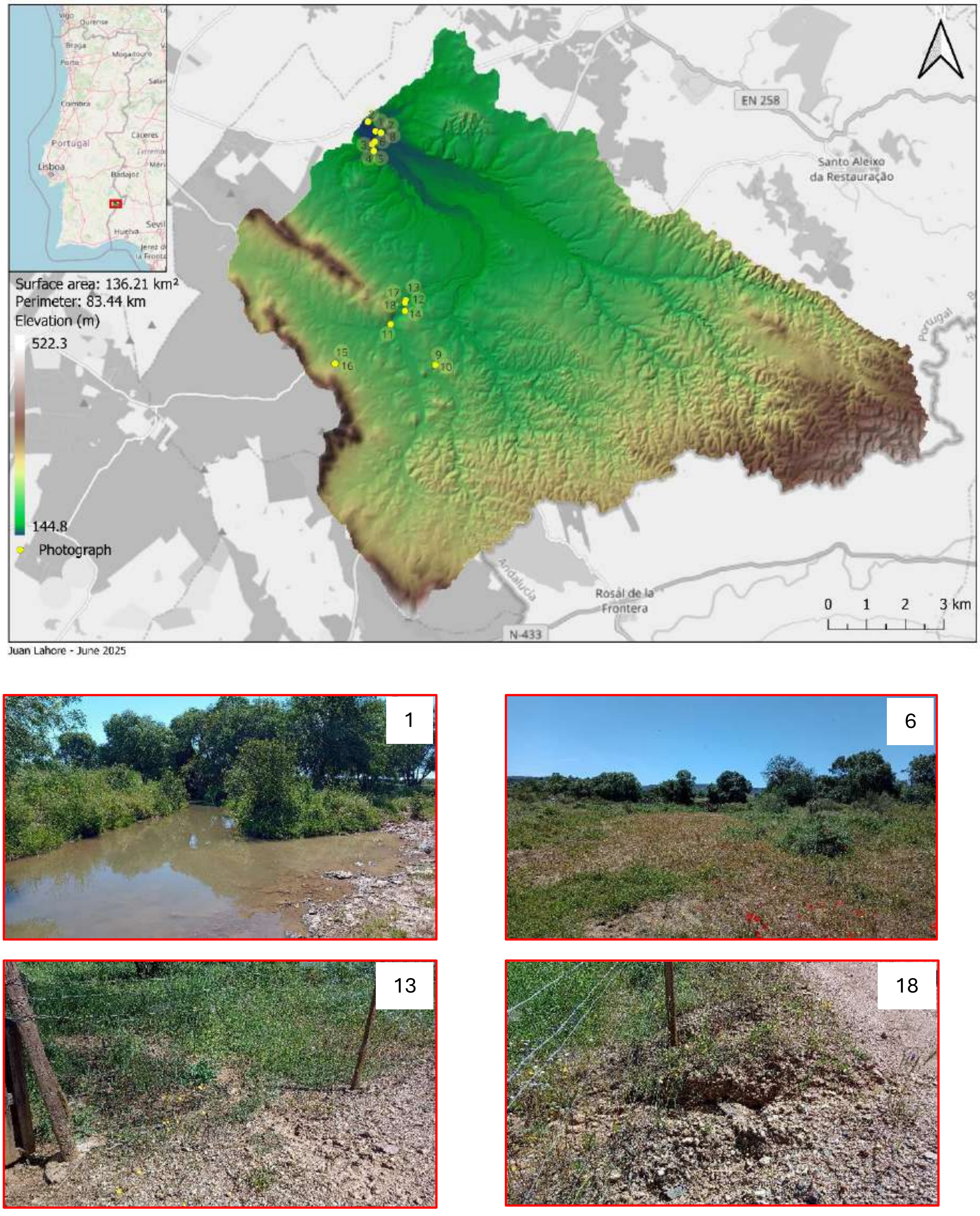

Figure 2 - Spatial reference map with field photographs illustrating stream conditions and erosion features at selected locations across the Toutalga/San Pedro Basin.

2.2 Natural Drainage System

To better understand the physical conditions influencing soil erosion in the Toutalga/San Pedro Basin, drainage density and stream slope profiles were analyzed. These characteristics help describe how terrain structure and runoff concentration contribute to erosion processes.

Drainage density was calculated using a Strahler order 4 stream network (visible in Figure 8), which most closely aligned with visible channels in topographic and satellite maps (see Appendix F). The total stream length was 608.80km across a basin area of 136.21km^2, resulting in a drainage density of 4.47km/km^2. In comparison, using a Strahler order 5 network yielded a much lower value of 2.33km/km^2, highlighting how stream order affects perceived landscape dissection.

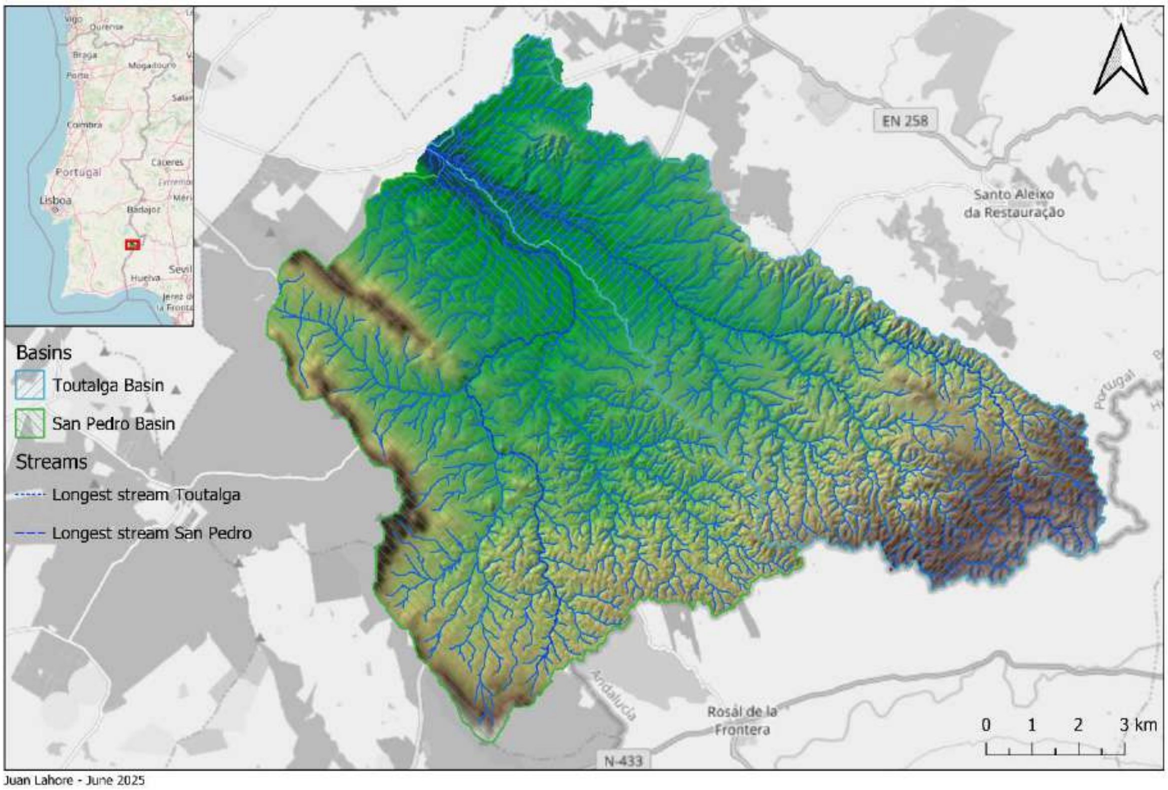

Figure 3 - Stream network in the Toutalga/San Pedro Basin classified by Strahler order 4, used for drainage density analysis.

Separate calculations for each sub-basin showed that San Pedro had a drainage density of 4.34km/km^2, while Toutalga had a slightly higher value of 4.66km/km^2. These values indicate a moderately to highly dissected drainage system in both basins, which favors faster runoff and can amplify erosion, especially in areas with steep slopes or poor vegetation cover.

To complement this, slope profiles of the longest stream in each sub-basin were extracted from the 10m DEM. The Toutalga stream, located in the north of the basin, measures ~21.5km and begins at an elevation of ~410m, the corresponding slope profile is visible in Figure 4. The San Pedro stream, located in the south of the basin, has a total length ~18km and begins at an elevation of ~290m, the corresponding slope profile is visible in *Figure 5*. The Toutalga stream shows a steeper initial descent.

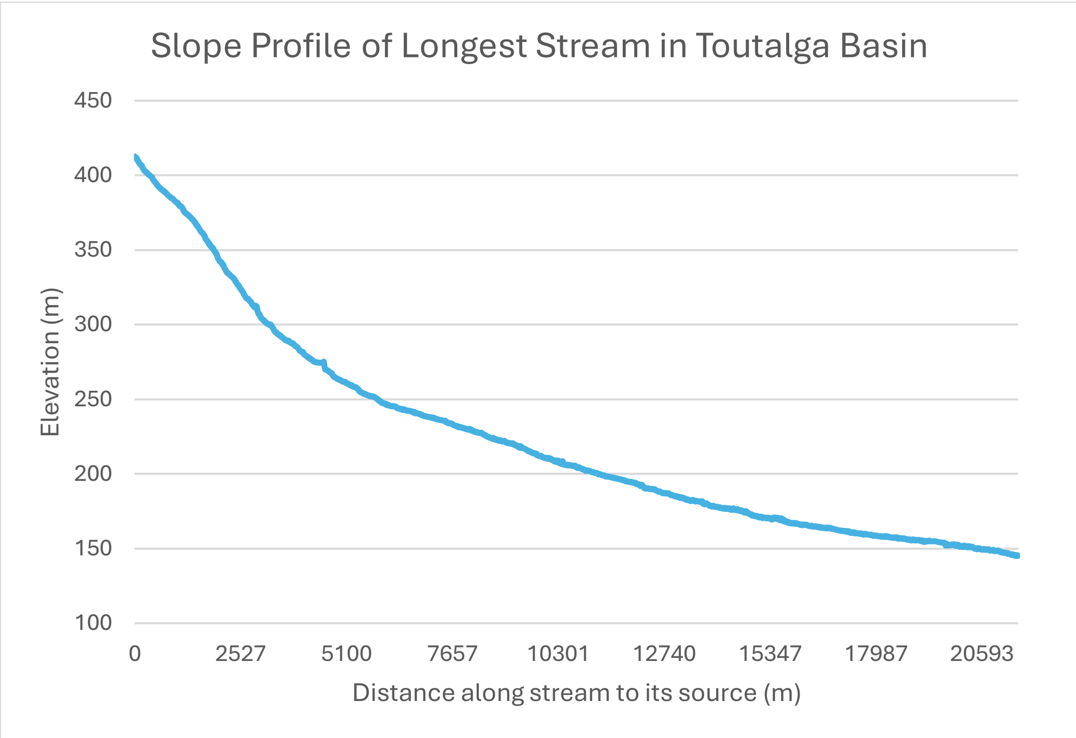

Figure 4 - Slope profile of the longest stream in Toutalga Basin, elevation and distance along the stream to its source in meters.

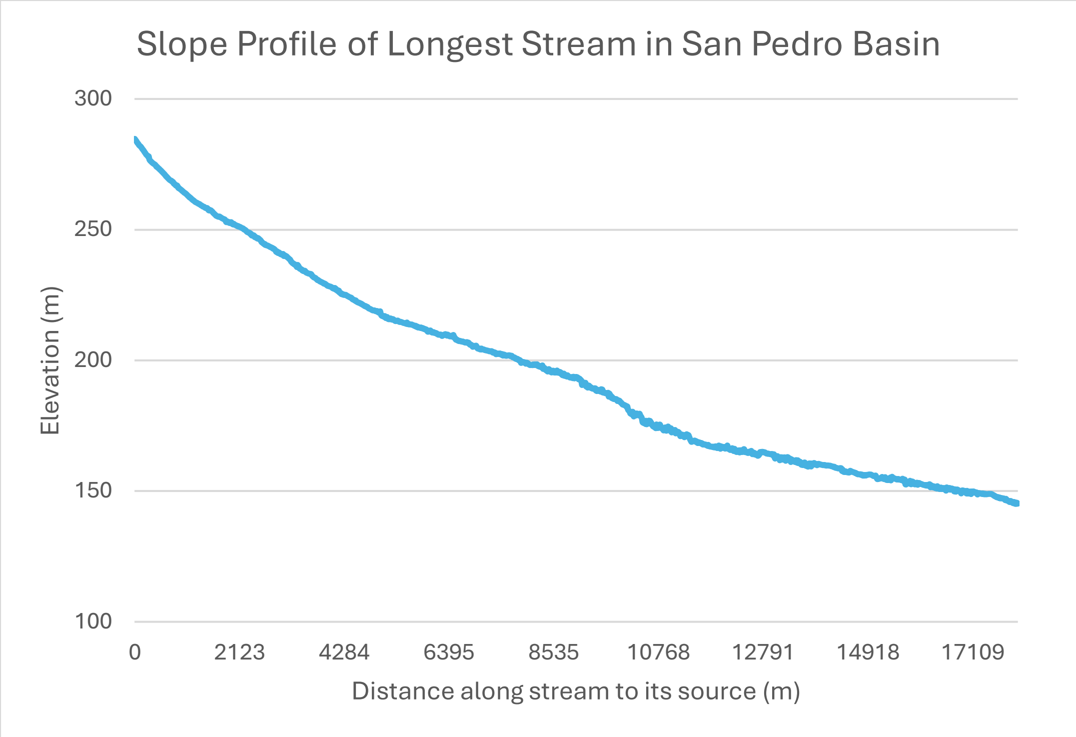

Figure 5 - Slope profile of the longest stream in San Pedro Basin, elevation and distance along the stream to its source in meters.

2.3 Data Sources

A summary of all spatial datasets used in the RUSLE modeling is provided in Table 1. These processed layers were integrated to calculate the A-factor (average annual soil loss), serving as the basis for erosion risk mapping.

Table 1 - Summary of spatial datasets used in the calculation of the A-Factor in the RUSLE model.

Name	Source	Data Type	Expression Unit	Resolution	CRS
R Factor	ESDAC	Rainfall erosivity	MJ mm ha^{-1} h^{-1} yr^{-1}	500m	ETRS89
K Factor	ESDAC	Soil erodibility	t ha h ha^{-1} MJ^{-1} mm^{-1}	500m	ETRS89
LS Factor	ESDAC	Slope length and steepness	Dimensionless	25m	ETRS89
C Factor	ESDAC	Cover Management Factor	Dimensionless	100m	ETRS89
P Factor	ESDAC	Support Practice Factor	Dimensionless	100m	ETRS89
Land Use/Land Cover	COSc 2024 – dados.gov.pt	Land use and coverage	Categorical classes (no physical unit)	10m	EPSG:3763
DEM	dados.gov.pt	Digital Elevation Model	Elevation in meters (m)	0.5m	EPSG:3763
Military Maps	CIGeoE	Topographic reference	Not applicable	2.5m	EPSG:3763
HYSOGs	ORNL DAAC – Dataset 1566	Hydrologic Soil Groups	Categorical classes (A, B, C, etc.)	250m	WGS84
Google Satellite	Google XYZ Tile	Satellite imagery	Not applicable	~1m	WGS84
OpenStreetMap	OSM XYZ Tile	Roads/places (tile layer)	Not applicable	~1m	WGS84

2.3.1 Rainfall Erosivity Factor (R)

The rainfall erosivity factor (R), which quantifies the erosive force of rainfall, was obtained from the European Soil Data Centre (ESDAC). This dataset provides average annual R-factor values for Europe, expressed in megajoules millimeter per hectare per hour per year (MJ mm ha^{-1} h^{-1} yr^{-1}). The data are based on a 40-year climatological period, with a predominant reference decade of 2000–2010 (ESDAC, 2015a).

The ESDAC R-factor raster has a spatial resolution of 500m and is projected in ETRS89 Lambert Azimuthal Equal Area. It was developed from long-term precipitation records and harmonized across Europe to support RUSLE-based soil erosion assessments.

For integration into this study, the R-factor raster was imported into QGIS, clipped to the Toutalga/San Pedro Basin boundary, and resampled to 10m resolution to align with other RUSLE input layers. The dataset was used directly in the GIS-based modeling workflow to estimate potential soil loss across the basin.

2.3.2 Soil Erodibility Factor (K)

The soil erodibility factor (K) represents the susceptibility of soil particles to detachment and transport by rainfall and surface runoff. In this study, the K-factor was obtained from the ESDAC, which provides a standardized dataset for Europe at a spatial resolution of 500m.

The K-factor values are expressed in tonnes hectare hour per hectare per megajoule per millimeter (t ha h ha^{-1} MJ^{-1} mm^{-1}) and reflect long-term average soil properties such as texture, organic matter content, permeability, and structure. The dataset was developed based on harmonized European soil databases and is suitable for regional to local-scale applications of the RUSLE model (ESDAC, 2014).

The ESDAC K-factor raster was imported into QGIS, clipped to the Toutalga/San Pedro Basin boundary, and resampled to a resolution of 10m to match the spatial scale of other RUSLE input layers. The processed K-factor layer was then used directly in the soil loss estimation.

2.3.3 Topographic Factor (LS)

The LS-factor, representing slope length and steepness, was derived from a 10m resolution national Digital Elevation Model (DEM) projected in EPSG:3763. Two independent methods were applied to estimate LS values for the Toutalga/San Pedro Basin.

The first method followed the procedure outlined in the *DGT Manual for Soil Erosion Risk Areas* (Reis & Pena, 2019). Slope was calculated in radians using QGIS, and flow accumulation was derived using the "Flow Accumulation (Parallelizable)" tool in SAGA GIS. The slope length factor (L) was calculated as:

$$L = ((FlowAccumulation * CellSize) / 22.13) ^ {0.5}$$

Slope steepness (S) was computed conditionally based on slope in radians. For slopes less than 0.089 radians (approximately 5.1°), the following equation was used:

$$S = 10.8 * \sin(Slope) + 0.03$$

For slopes equal to or greater than 0.089 radians:

$$S = 16.8 * \sin(Slope) - 0.50$$

The LS-factor was obtained by multiplying the L and S components.

The second method implemented the guidelines from the *Comissão Nacional do Território* (CNT, 2015) for delineating areas at high risk of water-induced soil erosion (AEREHS). In this approach, slope was converted to percent, and an m coefficient was assigned according to defined slope class thresholds. Slope length was extracted from DEM profiles and capped at 122m to avoid overestimation in low-gradient accumulation zones. The LS-factor was then computed using the empirical expression recommended by CNT, which incorporates slope length, slope steepness, and the m coefficient.

For final modeling, the LS-factor raster from the ESDAC, developed in 2015, was adopted. The dataset, originally at 25m resolution, was clipped to the Toutalga/San Pedro Basin and resampled to 10m to match the spatial resolution of the other RUSLE input layers (ESDAC, 2015b).

2.3.4 Cover-Management Factor (C)

The cover-management factor (C) represents the effect of vegetation cover and land use practices on soil erosion rates. In this study, the C-factor was derived using the 2024 edition of the COS land cover dataset (COSc2024), which provides detailed land use classification for continental Portugal at a spatial resolution of 10m.

Land cover classes were reclassified to representative C values according to national guidelines outlined in *Diretrizes para a Aplicação da Equação Universal de Perda dos Solos em SIG – Factor* *de Cultura C e Factor de Erodibilidade do Solo K* (Pimenta, 1999). C-values were assigned to each land cover class using a standardized lookup table, reflecting the degree of surface protection provided by different land uses (see Appendix D). Forests and natural vegetation were assigned low C values, while agricultural and unvegetated areas received higher values, consistent with their increased susceptibility to erosion.

The resulting C-factor raster was clipped to the Toutalga/San Pedro Basin and maintained at 10 m resolution. For comparison, a harmonized C-factor layer from the ESDAC was also imported and visually evaluated (ESDAC, 2015c). The national reclassified layer was used in the final RUSLE model due to its higher thematic specificity and resolution.

2.3.5 Support Practice Factor (P)

The support practice factor (P) accounts for the presence of erosion control measures that reduce surface runoff and associated soil loss. In this study, areas with identified practices, primarily agricultural terraces and contour-managed fields, were manually digitized in QGIS based on field observations and visual interpretation of aerial imagery.

Although further research is needed the classification applied was as follows: areas with support practices were assigned a value of P = 0.5, while all remaining areas were assigned the default value of P = 1.0. The resulting raster layer was created using QGIS Raster Calculator and resampled to a 10m resolution to align with other RUSLE inputs.

The digitized erosion control areas encompassed approximately 4.55km^2, representing 3.34% of the Toutalga/San Pedro Basin. The remaining 96.66% of the basin was assumed to lack formal support practices and retained the default P value. This spatially explicit P-factor raster was integrated into the final RUSLE modeling framework.

2.4 Revised Universal Soil Loss Equation (RUSLE)

The Revised Universal Soil Loss Equation (RUSLE) is an empirical soil erosion model developed by the United States Department of Agriculture (USDA) as an update to the original Universal Soil Loss Equation (USLE) introduced by Wischmeier and Smith in the 1960s (Renard et al., 1997; USDA ARS, n.d.). RUSLE improves on the original model by including updated rainfall erosivity data, better soil and land cover parameters, and enhanced topographic and conservational factors. It also supports use in GIS and other computer-based systems (De Vente et al., 2013). Its main goal is to estimate long-term average annual soil loss from sheet and rill erosion, helping guide land use planning and conservational efforts (Renard et al., 1997; USDA ARS, n.d.). The potential average annual soil loss (A) in the Toutalga/San Pedro basin was estimated using RUSLE which combines the following five spatially distributed input factors: rainfall erosivity (R), soil erodibility (K), topographic factor (LS), cover-management (C), and support practices (P). The equation used was:

$$A = R \times K \times LS \times C \times P$$

Where:

A - average annual soil loss (t ha^{-1} yr^{-1})

R – rainfall erosivity (MJ mm ha^{-1} h^{-1} yr^{-1})

K - soil erodibility (t h MJ^{-1} mm^{-1})

L - slope length ( )

S - slope steepness ( )

C – cover-management ( )

P - support practices ( )

Each input factor was prepared as a raster layer with a common spatial resolution of 10m, aligned and clipped to the Toutalga/San Pedro Basin extent. The layers were multiplied in QGIS using raster calculator to produce a composite soil loss map, with results expressed in tonnes per hectare per year (t ha^{-1} yr^{-1}). The resulting A-factor raster served as the final output of the GIS-based RUSLE modeling and provides a spatially explicit estimate of erosion potential across the basin.

3. Results

3.1 Spatial Distribution of RUSLE Input Factors

3.1.1 Rainfall Erosivity (R-Factor)

Figure 3 shows the distribution of rainfall erosivity (R) values across the Toutalga/San Pedro Basin. The values range from about 766 to 955 MJ mm ha^{-1} h^{-1} yr^{-1}, with slightly higher values found in the southeastern area. Overall, the map shows only small differences across the basin in comparison to the European dataset, which is expected since rainfall patterns do not vary much over short distances. These values represent the amount of energy that rainfall can apply to the soil, and they are one of the main factors that influence how much erosion might happen. This layer was derived from the ESDAC dataset and used in final modeling.

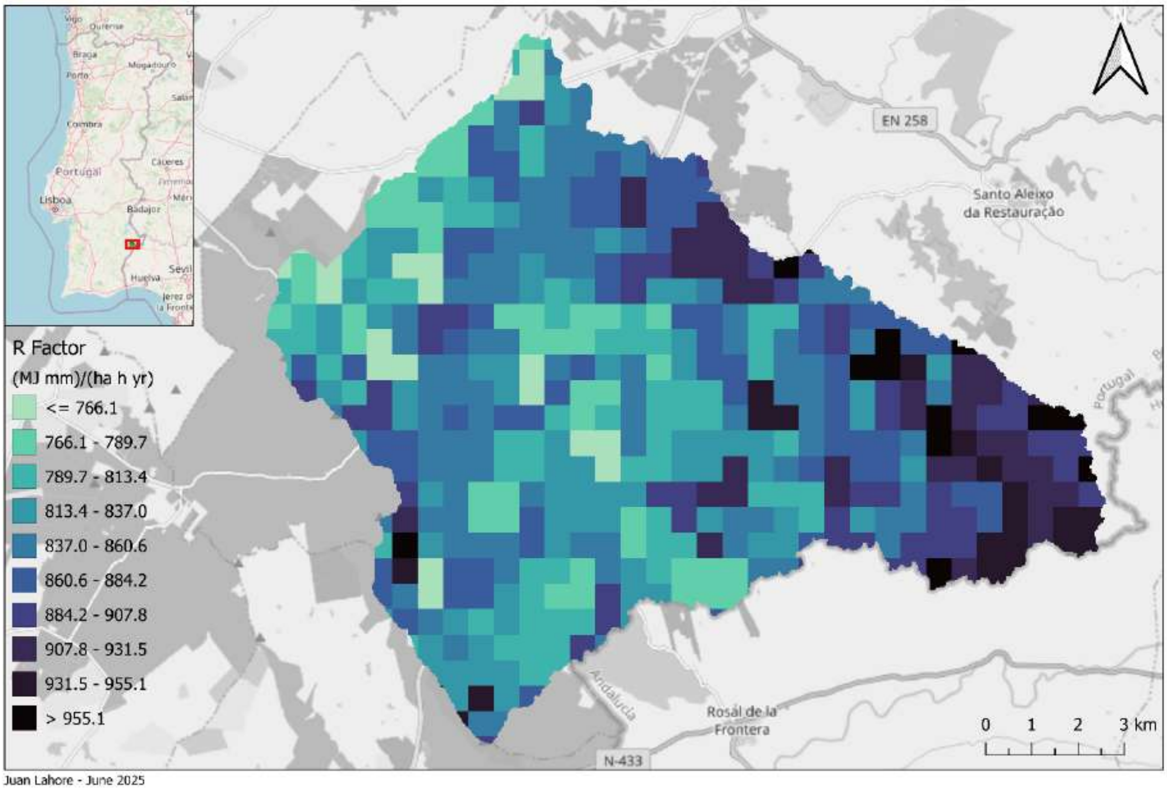

Figure 6 - Rainfall erosivity (R-factor) map for the Toutalga/San Pedro Basin, derived from the ESDAC dataset.

3.1.2 Soil Erodibility (K-Factor)

Figure 4 shows the soil erodibility (K) values across the Toutalga/San Pedro Basin. The values range from about 0.0345 to 0.0444 t h MJ^{-1} mm^{-1}, with slightly higher values mostly found in the central southern parts of the basin, where soil texture and organic matter conditions are less favorable for erosion resistance. These values represent how easily the soil can be detached and carried away by rain or surface water. Soils with higher K values are more vulnerable to erosion, especially when combined with steep slopes or little vegetation cover. This layer was derived from the ESDAC dataset and used in final modeling.

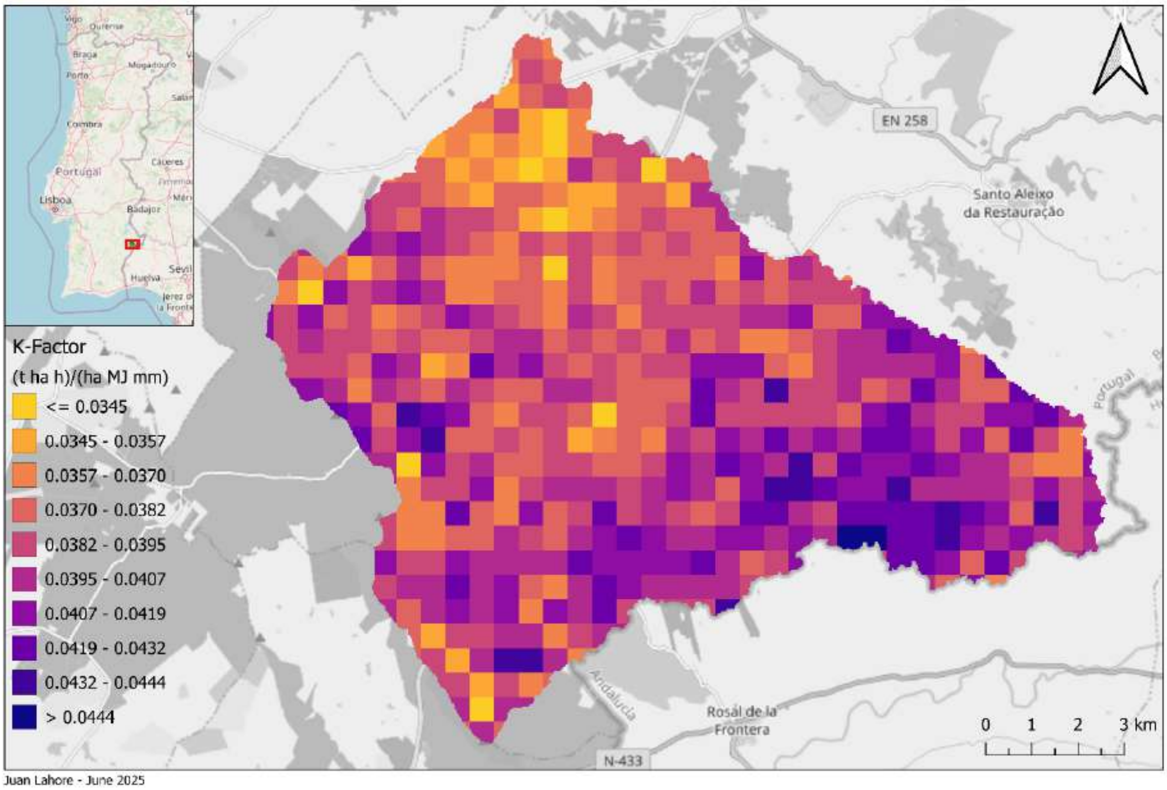

Figure 7 - Soil erodibility (K-factor) map for the Toutalga/San Pedro Basin, based on the ESDAC dataset.

3.1.3 Topographic Factor (LS-Factor)

Multiple LS-factor layers were generated using national-level methods. Visual inspection showed that all outputs exhibited similar spatial patterns, with high LS values generally following steep and elongated slopes. However, statistical analysis revealed that the LS values calculated through both local methods were significantly higher than those provided by the ESDAC dataset.

Histograms confirmed notable differences in value distributions, indicating that the manually derived layers consistently overestimated LS magnitudes (see Appendix E). Based on these results, the LS-factor from the ESDAC dataset was selected for the final RUSLE modeling.

Figure 5 shows the LS-factor values in the Toutalga/San Pedro Basin, as provided by the ESDAC dataset. Most of the basin has moderate values (0.5 – 2.0), while the highest LS values are found in the western areas, where the terrain is steeper and more rugged. These areas are more likely to experience soil erosion, especially if combined with erodible soils or limited vegetation. In contrast, flatter zones show much lower LS values, meaning less topographic contribution to erosion.

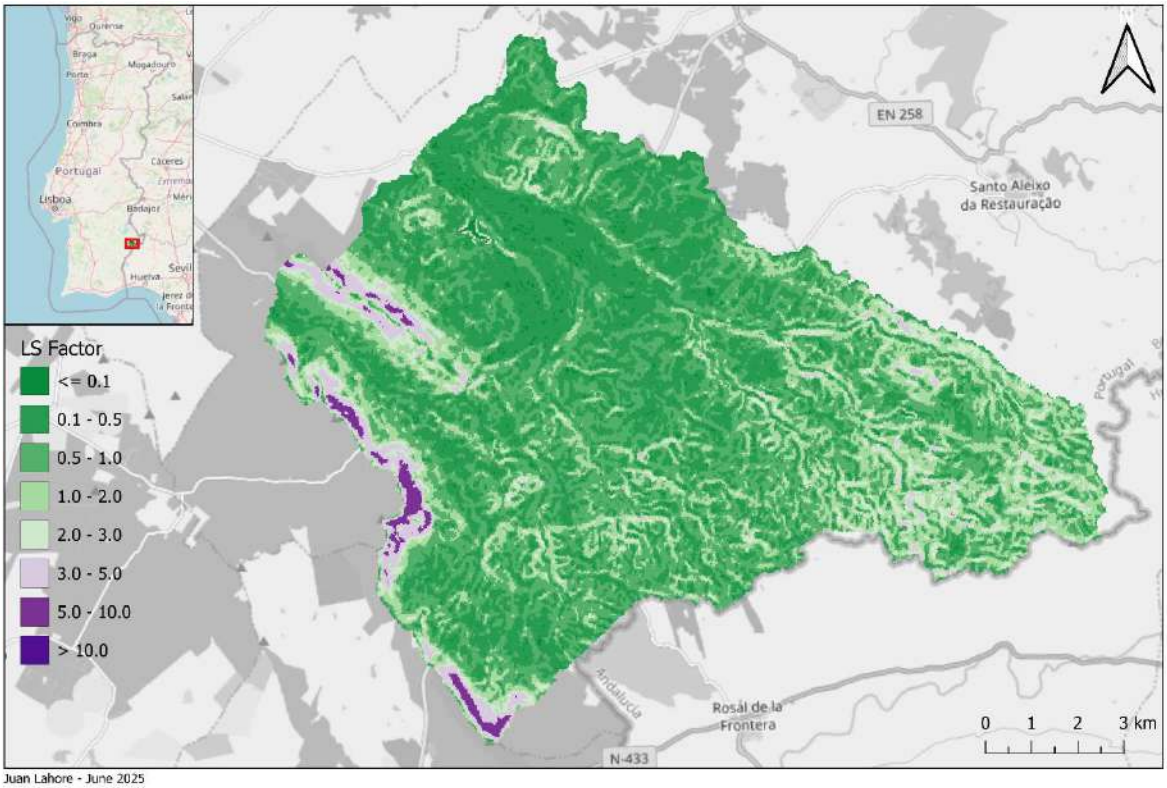

Figure 8 - Slope length and steepness (LS-factor) map for the Toutalga/San Pedro Basin.

3.1.4 Cover-Management Factor (C-Factor)

Figure 6 shows the distribution of the C-factor across the Toutalga/San Pedro Basin, based on land use data (COSc2024). The values range from 0 to 0.4, where lower values are mostly found in forested and natural areas, and higher values appear in zones used for agriculture or with less vegetation. The central and southeastern parts of the basin show the highest C values, reflecting cropland and areas with limited ground cover. These areas are more exposed to erosion because the soil is less protected from rainfall and surface runoff. This layer was derived from the COSc2024 dataset and used in final modeling.

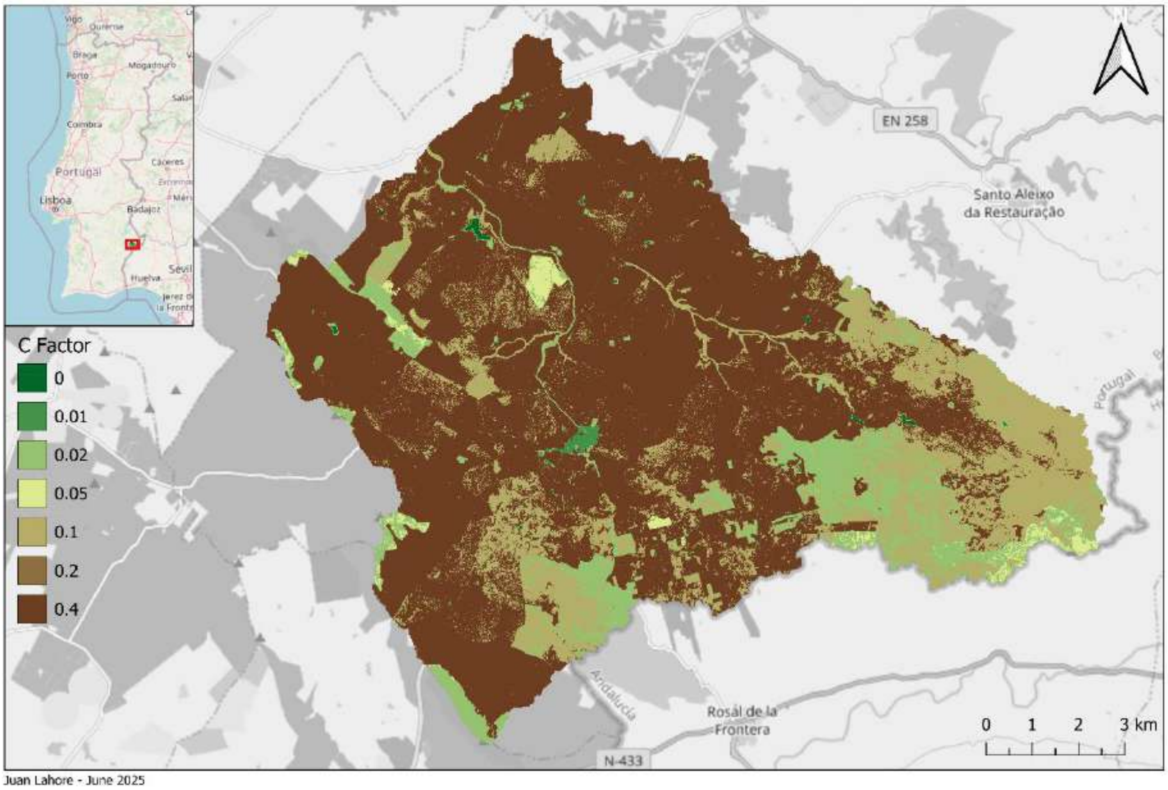

Figure 9 - Cover-management (C-factor) map reclassified from the COSc2024 land cover dataset.

3.1.5 Support Practice Factor (P-Factor)

Figure 7 shows where erosion control practices are present in the Toutalga/San Pedro Basin. Most of the area was assigned a P value of 1.0, meaning no specific support practices were identified. Only about 3.34% of the basin, mainly located on steep cultivated slopes, was manually mapped as having terraces or contour farming and given a value of P = 0.5. These areas are expected to reduce soil erosion by slowing down surface runoff and improving infiltration. This layer was derived from the Google Satellite imagery and used in final modeling.

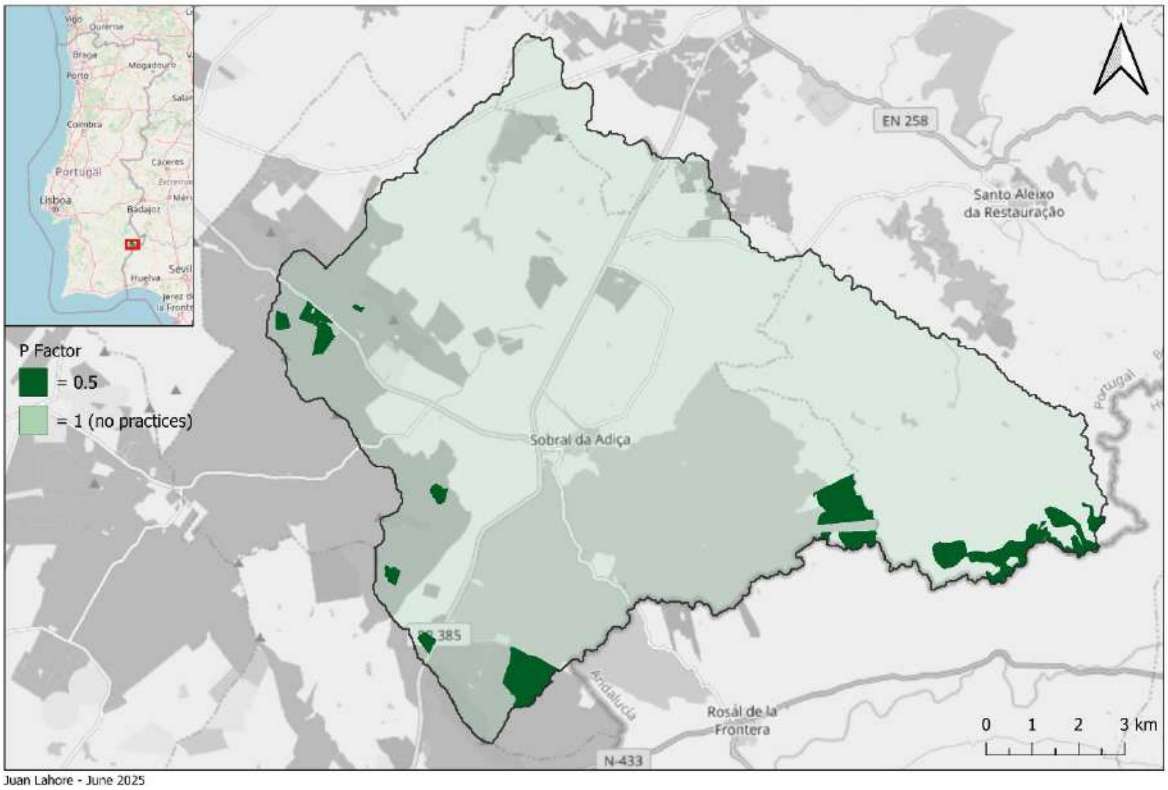

Figure 10 - Support practice (P-factor) map, showing areas with mechanical or vegetative erosion control.

3.2 Soil Loss Estimation (A-Factor)

Figure 11 shows the estimated average annual soil loss across the Toutalga/San Pedro Basin, based on the combined RUSLE factors. Values are grouped into four classes, ranging from under 10 t ha^{-1} yr^{-1} in low-risk areas to over 25 t ha^{-1} yr^{-1} in the most vulnerable zones. The highest erosion rates occur in the western sector of the basin, where steep slopes, intersect with sparse vegetation and rocky outcrops. In contrast, forested areas, gentle terrain, and zones with erosion control measures show minimal soil loss. These results help identify priority areas for future land management interventions and erosion mitigation.

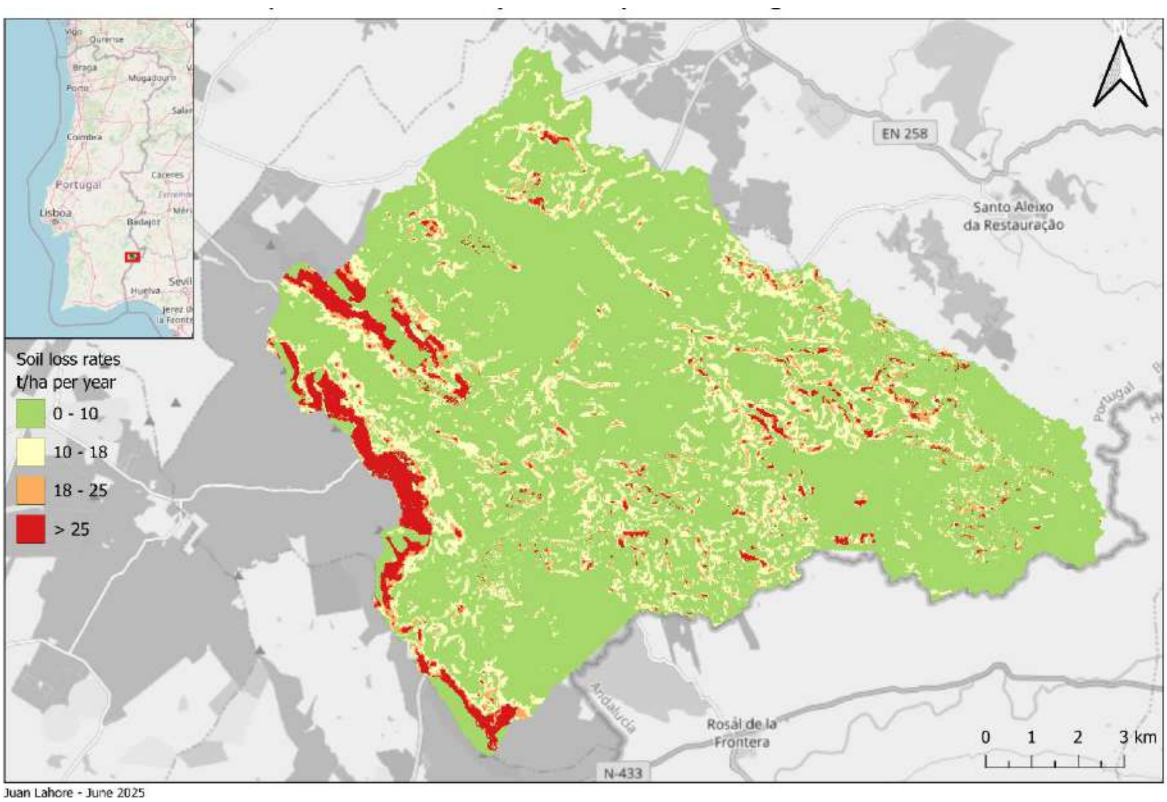

Figure 11 - Estimated soil loss (A-factor) map for the Toutalga/San Pedro Basin, calculated using the RUSLE model.

4. Discussion

The RUSLE model successfully identified spatial variability in soil erosion risk across the Toutalga/San Pedro Basin. Results indicate that erosion is primarily concentrated in the western and southwestern sectors, where steep slopes, higher LS values, and low vegetation cover coincide. This pattern aligns with expectations based on terrain and land use characteristics, as well as the slope profiles and drainage density patterns described earlier.

Among the RUSLE factors, the LS component showed the greatest influence on the final A-factor distribution. While two national-level methods were tested for calculating LS, the values generated were substantially higher than those provided by the ESDAC dataset. Although the spatial patterns were similar, histograms revealed that local methods tended to overestimate LS magnitudes. As a result, the ESDAC-derived LS layer was selected for final modeling due to its more conservative and harmonized estimates.

The drainage density analysis also supports the observed erosion trends. Both sub-basins exhibit moderately high drainage densities, 4.34km/km^2 in San Pedro and 4.66km/km^2 in Toutalga, which facilitate surface runoff and channel development (Dragičević et al., 2019).

The slope profiles of the longest streams in each sub-basin provide insight into terrain structure, but do not fully explain the erosion risk distribution observed in the A-factor results. While the Toutalga stream, located in the northeast, begins at a higher elevation and has a steeper initial descent, the overall erosion risk is greater in the San Pedro sub-basin to the southwest. This discrepancy is likely due to the higher average elevation and more extensive exposed slopes in San Pedro, which amplify runoff and soil detachment, especially in areas with less vegetation cover. These findings emphasize the need to interpret stream profiles in conjunction with broader topographic and land cover patterns.

Limitations of the model stem from resolution mismatches between datasets, potential classification errors in land cover, and the assumption of uniform factor values within reclassified layers. Additionally, although erosion control measures were mapped and integrated as a P-factor layer, their actual field effectiveness was not verified, which may affect local accuracy.

Overall, the modeling framework offers a reliable approximation of erosion risk at the basin scale. It highlights specific zones where conservation efforts and land management interventions would be most beneficial. Future improvements could include the use of higher-resolution precipitation and soil data, field validation of erosion hotspots, and integration of temporal dynamics such as land use change or rainfall variability.

5. Conclusion

This study applied the Revised Universal Soil Loss Equation (RUSLE) within a GIS framework to assess spatial patterns of potential soil erosion in the Toutalga/San Pedro Basin. The final model integrated datasets for rainfall, soil, topography, land cover, and erosion control practices.

Erosion risk was found to be highest in the southwestern areas, particularly the San Pedro sub-basin, where steep slopes and sparse vegetation coincide. The LS-factor contributed most strongly to these spatial differences. While multiple calculation methods were tested, the harmonized LS dataset from ESDAC was selected due to its more consistent and conservative estimates.

The model outputs provide a valuable foundation for targeting erosion mitigation strategies. As a recommendation, planting, especially of tree crops, should be planned with careful attention to slope direction. Vegetation rows should be aligned perpendicular to runoff flow to maximize erosion reduction as seen in the P-factor calculation. Future improvements may include integrating land use change data, more accurate local rainfall records, and ground-truth validation.

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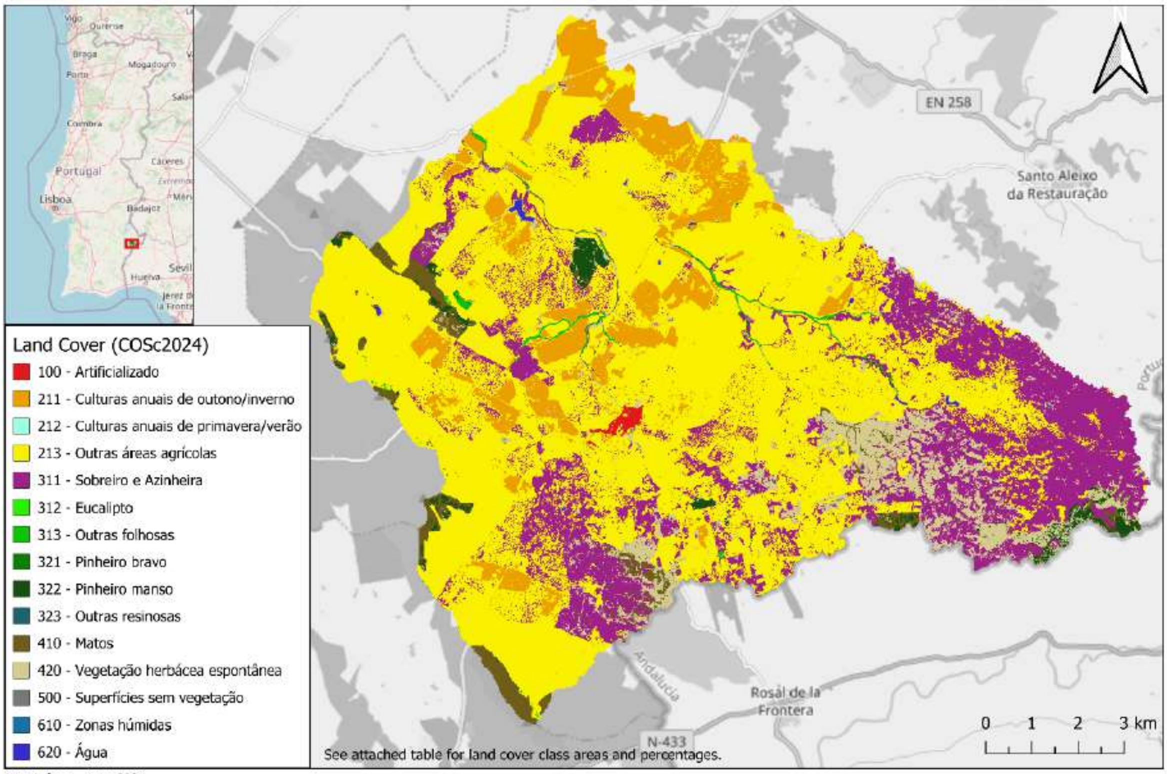
Appendix

Appendix A (Land use/Land cover)

Land Use / Land Cover (COSc2024) — Toutalga/San Pedro Basin



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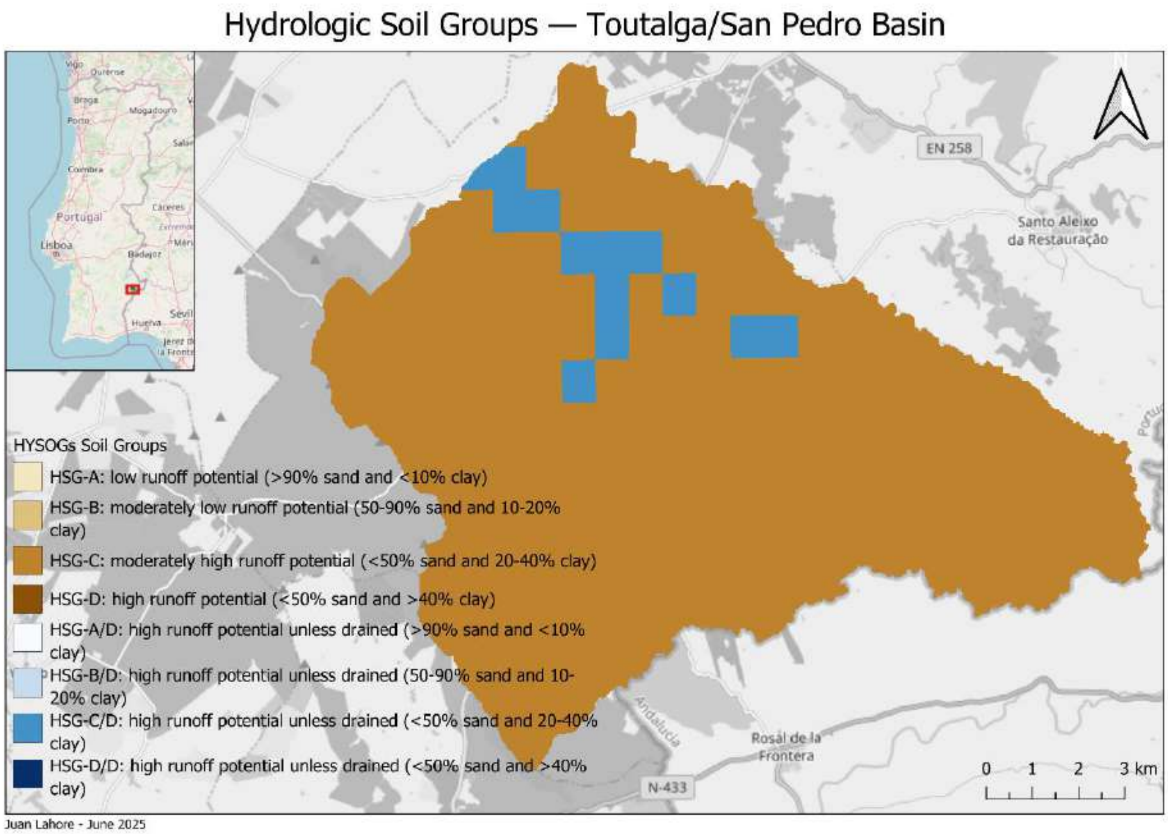
Land Use Coverage and Percentages – Toutalga Basin

	Code	Label (from QML)	Pixel count	Area (km²)	Area (m²)	% of Basin
	100	Artificializado	3507	0.35	350700	0.26%
	211	Culturas anuais de outono/inverno	115930	11.59	11593000	8.51%
	212	Culturas anuais de primavera/verão	11	0.00	1100	0.00%
	213	Outras áreas agrícolas	812405	81.24	81240500	59.65%
	311	Sobreiro e Azinheira	272600	27.26	27260000	20.01%
	312	Eucalipto	131	0.01	13100	0.01%
	313	Outras folhosas	6367	0.64	636700	0.47%
	321	Pinheiro bravo	3	0.00	300	0.00%
	322	Pinheiro manso	18600	1.86	1860000	1.36%

	410	Matos	38214	3.82	3821400	2.81%
	420	Vegetação herbácea espontânea	90516	9.05	9051600	6.64%
	500	Superfícies sem vegetação	1849	0.18	184900	0.14%
	620	Água	1947	0.19	194700	0.14%

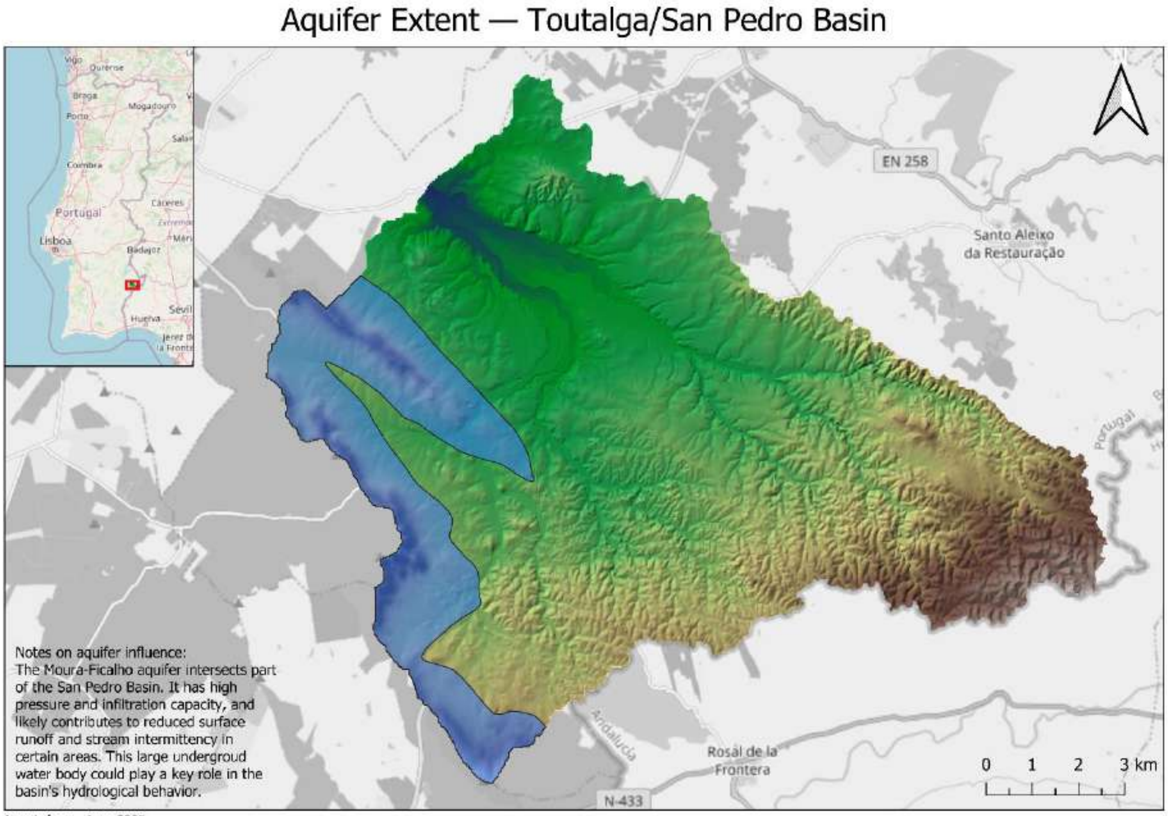
Appendix B (Hydrologic Soil groups)



Hydrologic Soil Group Coverage and Percentages – Toutalga Basin

Value	Class	Area (m²)	Area (km²)	% of Basin
3	HSG-C	127.078.767,37	127,08	93,47%
13	HSG-C/D	8.884.408,21	8,88	6,53%

Appendix C (Aquifer Extent)



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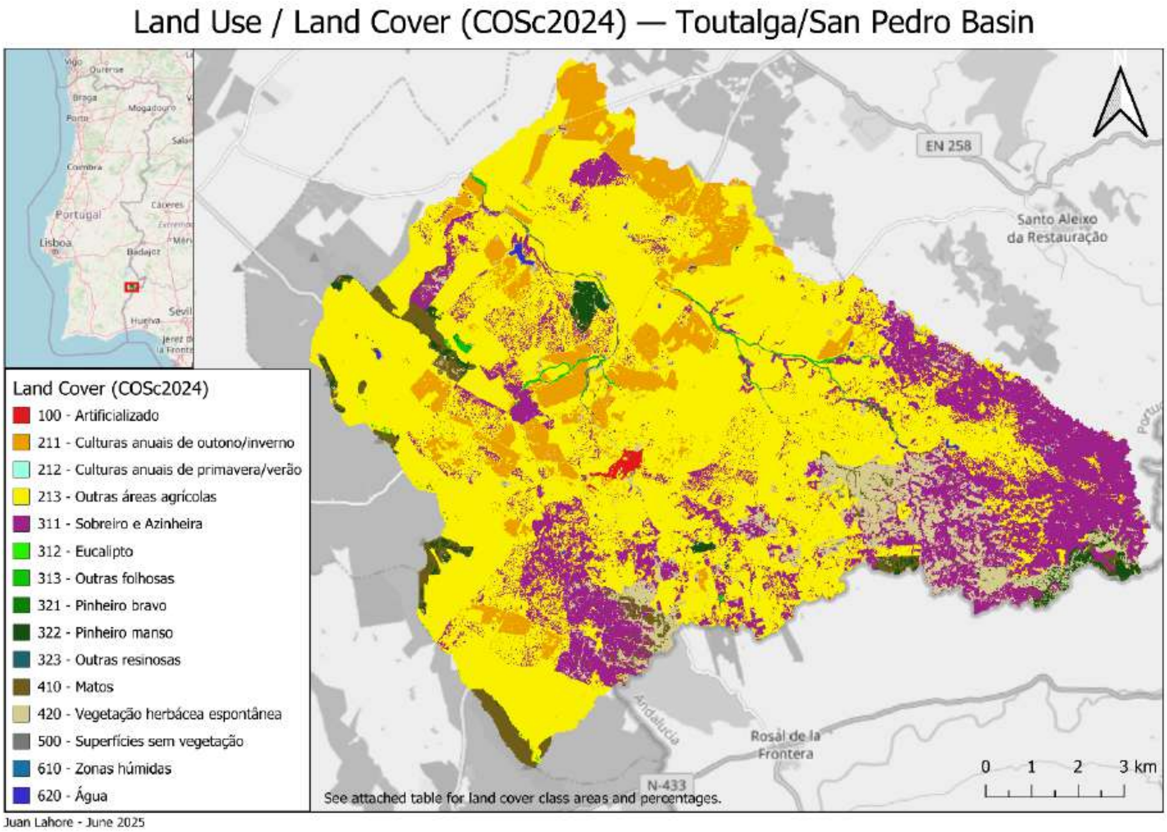
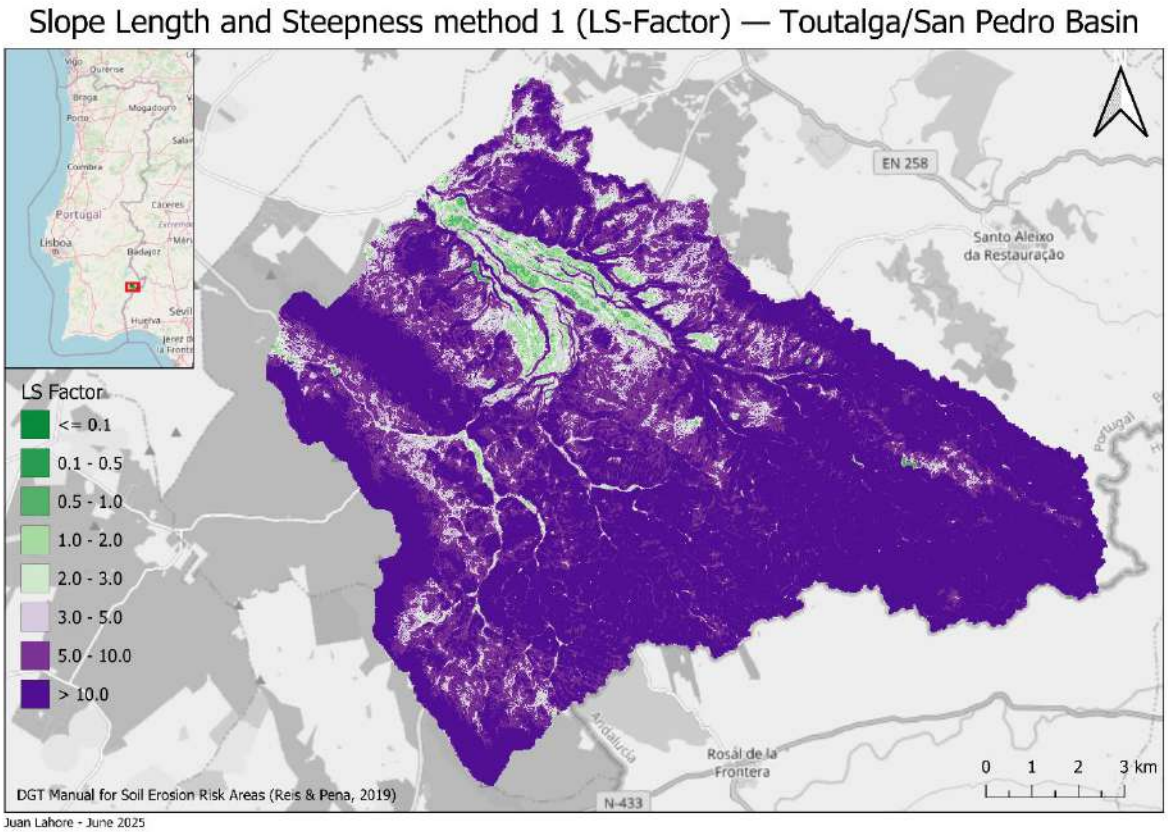
Appendix D (C factor based on Land use/Land cover)

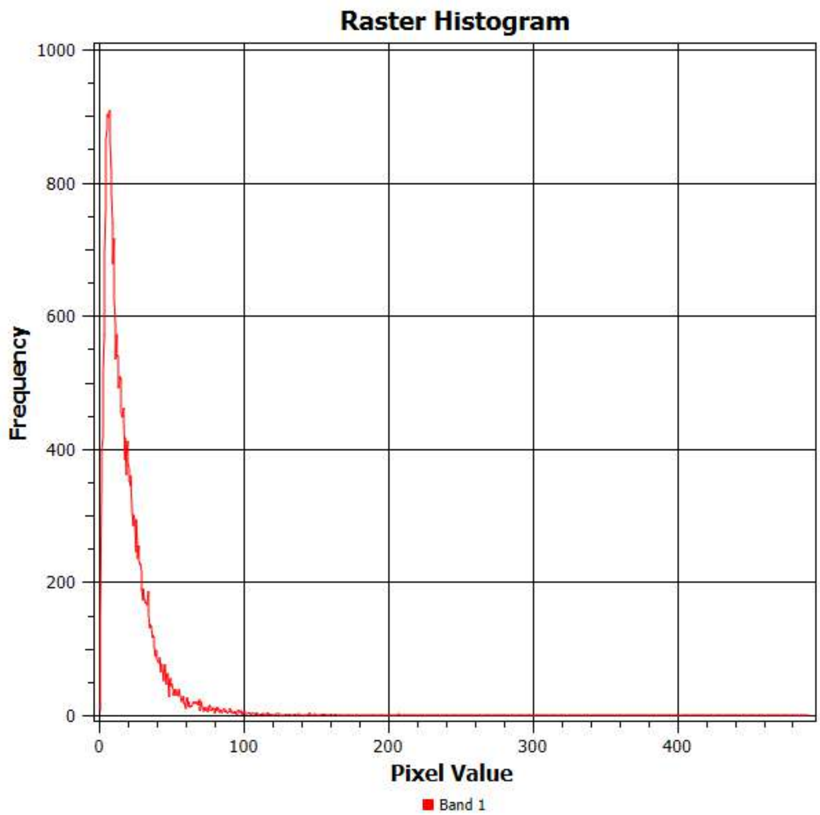


Code	**Description**	**C Factor**
100	Artificializado	0.01
211	Culturas anuais de outono/inverno	0.4
212	Culturas anuais de primavera/verão	0.2
213	Outras áreas agrícolas	0.4
311	Sobreiro e Azinheira	0.1
312	Eucalipto	0.2
313	Outras folhosas	0.1
321	Pinheiro bravo	0.05
322	Pinheiro manso	0.05
410	Matos	0.02
420	Vegetação herbácea espontânea	0.02
500	Superfícies sem vegetação	0.02
620	Água	0

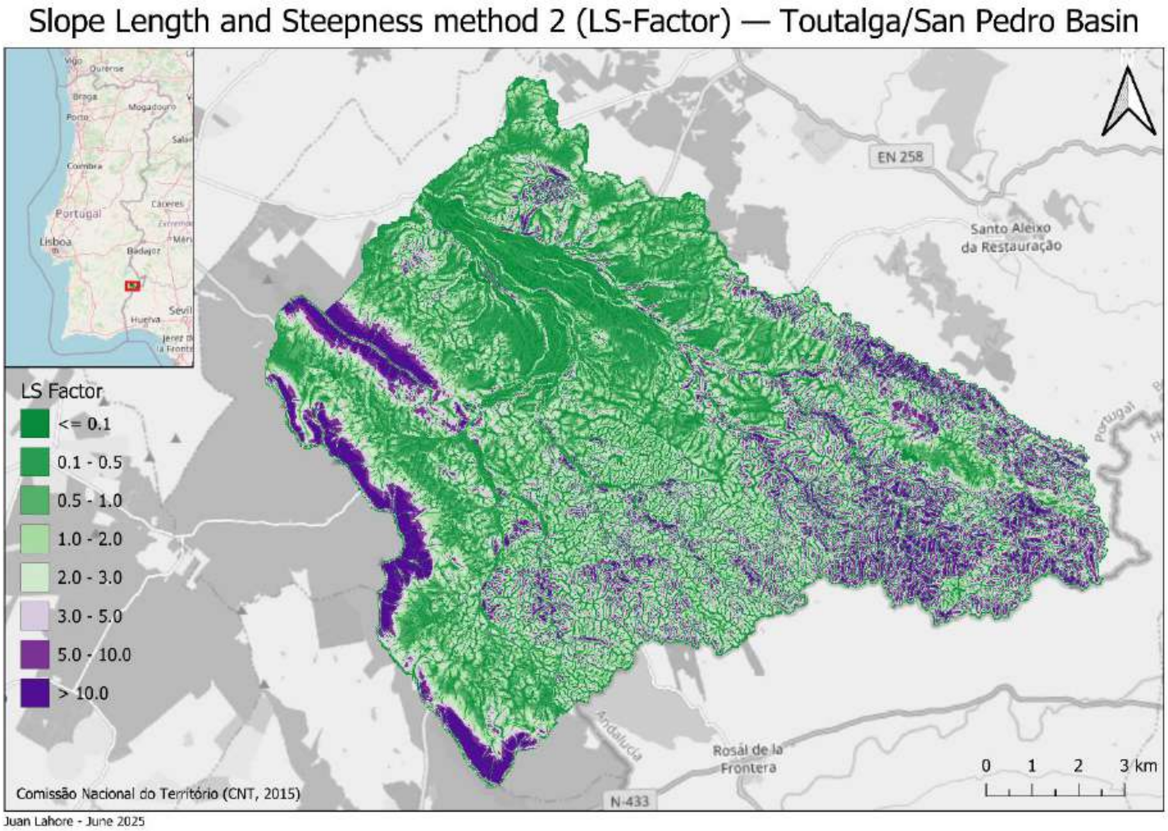
Appendix E (Various LS factor calculations and histograms)

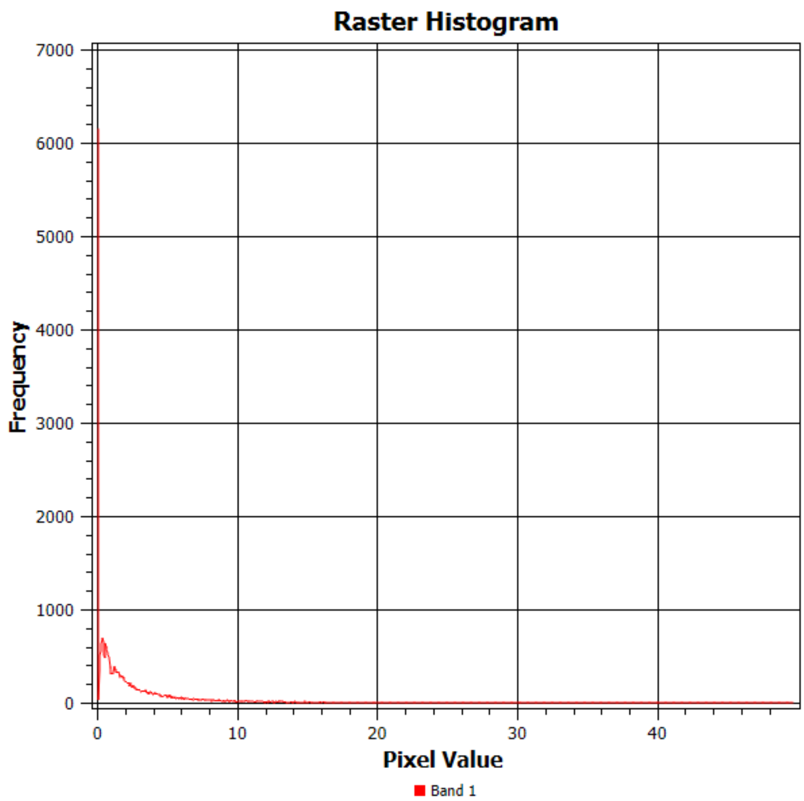
LS Factor method 1



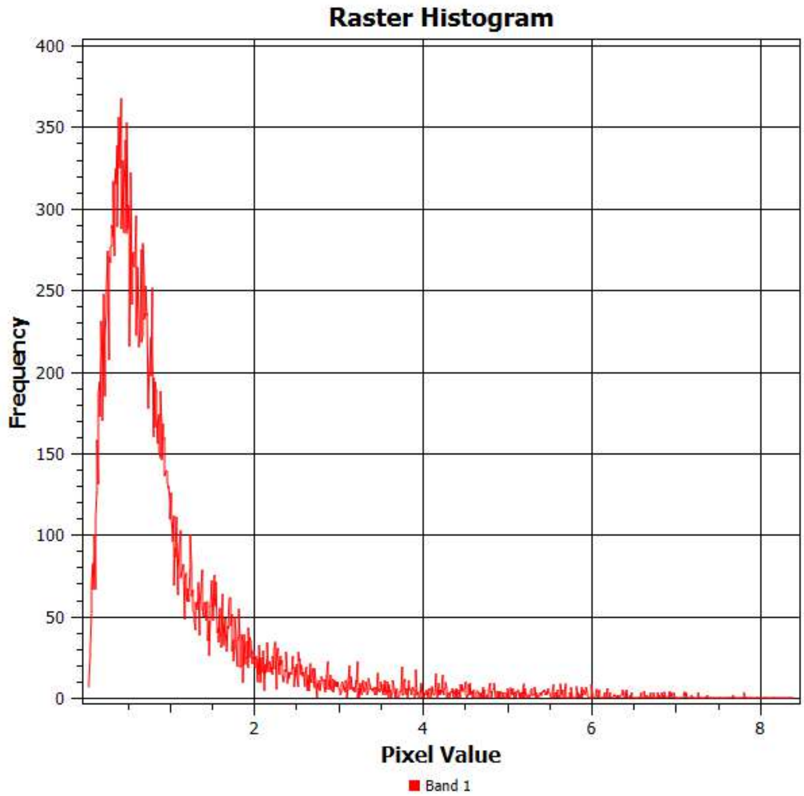

Raster Histogram
1000
800
600
400
200
0
Frequency
0
100
200
300
400
Pixel Value
Band 1

LS factor method 2



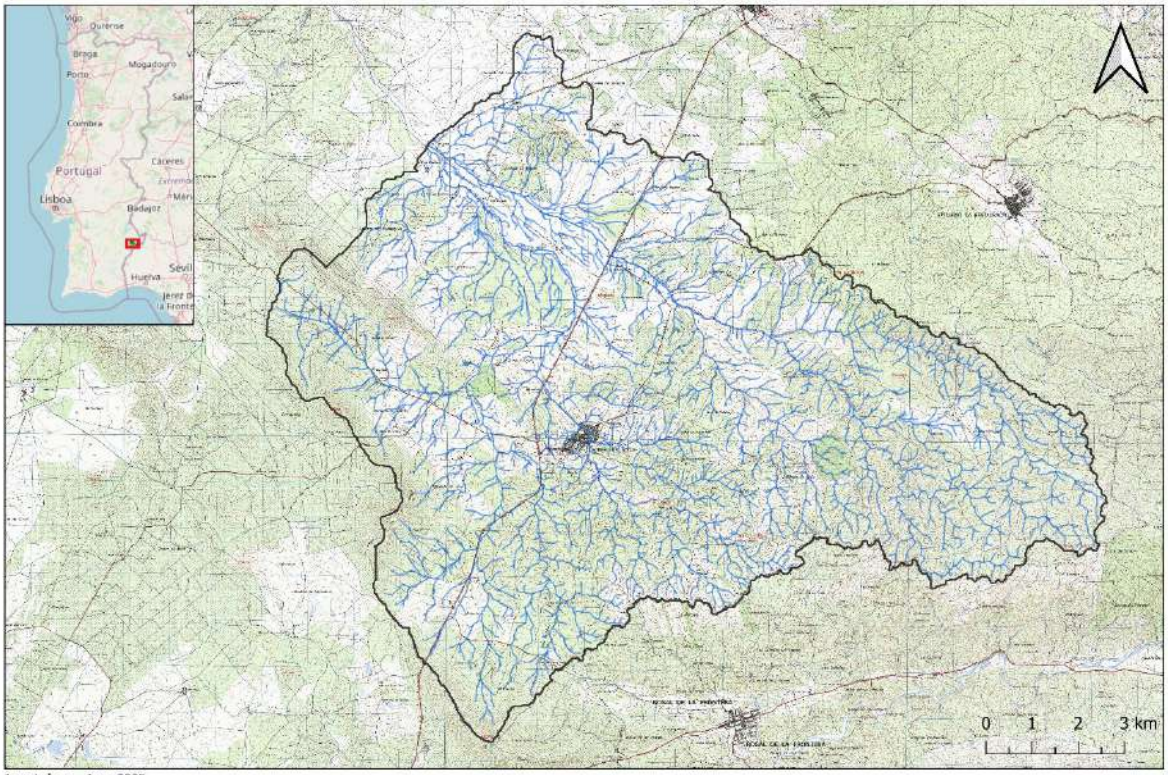


LS Factor ESDAC



Appendix F (Military map stream pattern comparison)

Military map Stream pattern comparison — Toutalga/San Pedro Basin



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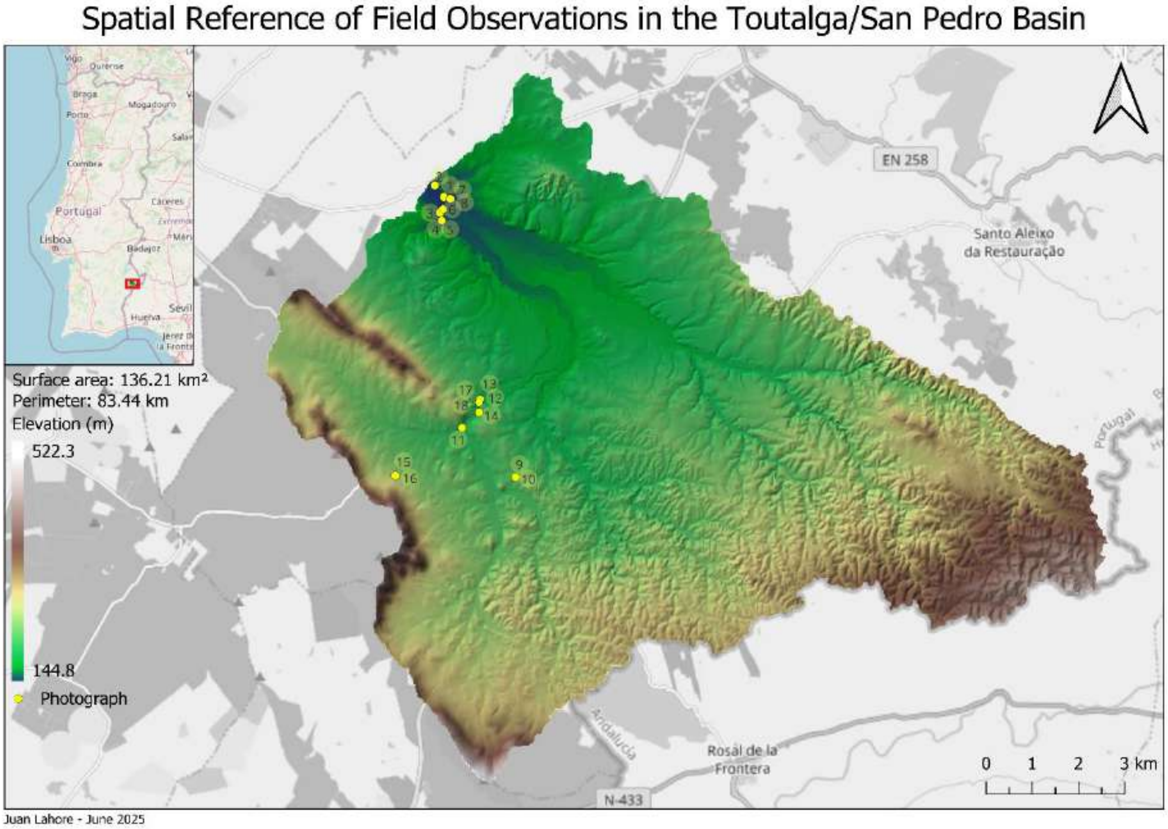
Appendix G (Field photographs)



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