

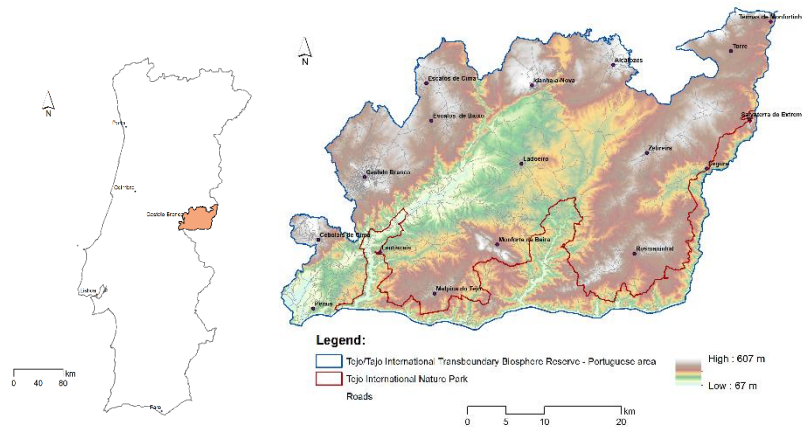
45 changes in terms of soil loss, providing planners and decision-makers with data that allows them to make
46 decisions aimed at mitigating the expected impacts.

47 2 Materials and Methods

48 The study area is located in the central-eastern part of Portugal, and includes the Tagus International
49 Nature Park (PNTI) and the surrounding area belonging to the Tagus International Transboundary Bio-
50 sphere Reserve, with an extent of 1,692 sq. km (Fig. 1). It is an area with altitude ranging between 120
51 and 390 m, with steep relief as a result of the embedding of the Tagus and its tributaries on the edge of
52 peneplain.

53 The climate is typical Mediterranean, sub-humid to dry, with mild winters and warm summers. The
54 annual mean precipitation is about 600 mm yr⁻¹, with peaks in autumn and winter. Very weakly developed
55 mineral soils with a low content in organic matter are dominant in the region, mainly leptosols and reg-
56 osols.

57 Most of the vegetation is made up of sclerophyllous formations of holm oak and cork oak, as well as
58 abundant patches of scrub, which alternate with cultivated areas and pastures. In the Park area are also
59 present several plant communities typical of Mediterranean ecosystems classified as priority habitats by
60 the EU Habitats Directive.



61
62
63 **Fig. 1.** Location of the study region

64
65 The annual potential soil erosion rate, denoted as E (t ha⁻¹ yr⁻¹), was estimated using the Revised Uni-
66 versal Soil Loss Equation (RUSLE) according to the following equation [9]:

$$67 \quad E = R \times C \times K \times LS \times P \quad (1)$$

68 where:

69 R (R-factor): This represents the erosivity factor due to rainfall and is quantified as MJ mm ha⁻¹ h⁻¹
70 yr⁻¹. It characterizes the meteorological conditions influencing erosion, primarily driven by precipitation
71 intensity.

72 C (C-factor): The cover-management factor accounts for the protective role of land cover, particularly
73 vegetation, against soil erosion. Lower C-factor values indicate better protection and reduced erosion risk.

74 K (K-factor): The erodibility factor expresses the vulnerability of soil to erosion, and is related to soil
75 properties, measured in units of t ha h ha⁻¹ MJ⁻¹ mm⁻¹.

76 LS (LS-factor): Serves as a representation of the topographic attributes of a given area. It considers
77 slope length and steepness, which have a direct impact on the potential for soil erosion.

78 P (P-factor): Evaluates the effectiveness of erosion control and land management practices in mitigat-
79 ing erosion.

80 To obtain data for the rainfall erosivity in the present and in future scenarios, we have considered the
81 data from the last decade and from two representative concentration pathways (RCPs): RCP 4.5 and RCP

82 8.5, fitted for 2050, obtained from the Dataset Rainfall erosivity in Europe [10]. RCP 4.5 represents a
 83 probable baseline scenario, considering the limited availability of non-renewable fuels. Under this sce-
 84 nario, emissions are expected to peak around 2040 and then decrease. This would result in a global tem-
 85 perature increase of 1.1 to 2.6 °C by 2081-2100 compared to the 1986-2005 period. In contrast, RCP 8.5
 86 represents a less favorable climate change scenario. Emissions are expected to increase continuously
 87 throughout the 21st century, leading to a more substantial global temperature increase of 2.6 to 4.8 °C by
 88 2081-2100 [11].

89 Land cover data from 2018 and the predicted land cover of 2050, used to estimate the C-factor, were
 90 obtained from [12]. The soil data for the study area were obtained from [10] and were used to calculate
 91 the soil erodibility based on a table made available from the same source. The LS-factor was estimated
 92 from a raster DEM with a 25-meter spatial resolution [13].

93 3 Results and discussion

94 Fig. 2 shows the annual potential soil erosion rate estimated for the study area for the present and future
 95 scenarios, considering a spatial resolution of 500 meters.

96 Despite the average values of soil erosion being similar between the present situation ($0.092 \text{ t ha}^{-1} \text{ yr}^{-1}$
 97 ± 0.0266), and both future scenarios RCP 4.5 ($0.061 \text{ t ha}^{-1} \text{ yr}^{-1} \pm 0.019$) and RCP 8.5 ($0.074 \text{ t ha}^{-1} \text{ yr}^{-1} \pm$
 98 0.023), the highest values of erosion rate simulated by RUSLE model for the present situation and for the
 99 two studied scenarios show significant differences: $1.512 \text{ t ha}^{-1} \text{ yr}^{-1}$ (present), $1.946 \text{ t ha}^{-1} \text{ yr}^{-1}$ (RCP 4.5),
 100 and $2.668 \text{ t ha}^{-1} \text{ yr}^{-1}$ (RCP 8.5).
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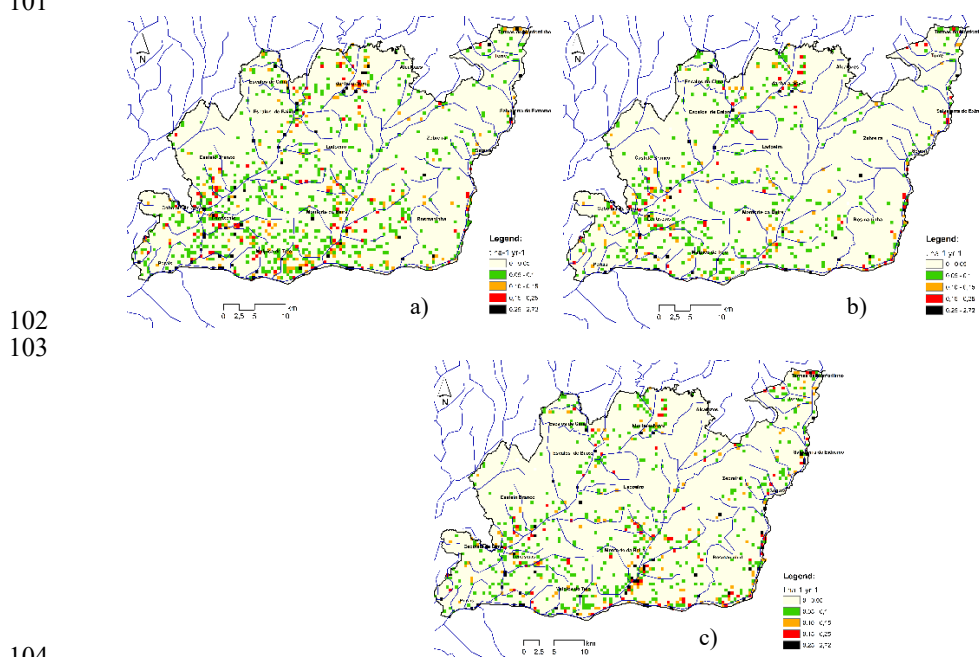
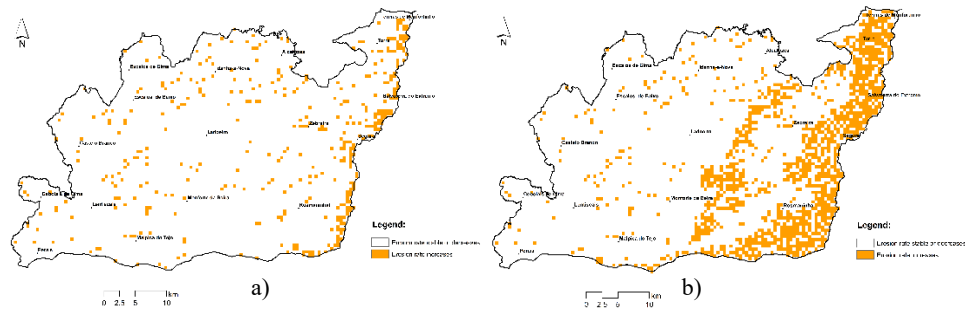


Fig. 2. Estimates of mean annual soil erosion rates: a) Present; b) RCP 4.5 - 2050; c) RCP 8.5 - 2050.

Comparing the present situation and predicted pathways of the annual potential soil erosion rate (Fig. 3), we verify that the erosion values increase for the RCP 8.5 pathway in 19% of the study area, with a highest difference of $0.532 \text{ t ha}^{-1} \text{ yr}^{-1}$. For the RCP 4.5 pathway, the erosion increases in 6% of the study area, with the highest increase of $0.283 \text{ t ha}^{-1} \text{ yr}^{-1}$. Our results align with the conclusions drawn in recent studies regarding the impact of climate change on soil erosion [6] [8].



113
114 **Fig. 3.** Changes in soil erosion rates: a) present to 2050 (RCP 4.5); b) present to 2050 (RCP 8.5).

115 4 Conclusion

116 The use of global models, such as RUSLE, to create spatial associations between climate change, soil
 117 erosion, and alterations in land cover is essential for improving spatial management strategies. These
 118 models play a crucial role in this enhancement. Both studied scenarios anticipate a slight increase in the
 119 soil erosion rate. Even in the least aggressive scenario, the soil erosion will increase in 6% of the study
 120 area, with a maximum increase of 0.283 t ha⁻¹ yr⁻¹. For the most unfavorable scenario, the maximum
 121 increase in the mean soil erosion rate will be 0.532 t ha⁻¹ yr⁻¹, verified in 19% of the total area of this
 122 study. These findings call for considering the necessity for better soil management practices due to the
 123 vulnerability of this type of soils to water erosion, and, although erosion rates are not very high, we must
 124 always bear in mind that the class of particles preferentially lost are those with the greatest importance in
 125 soil properties.

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