Soil erosion, Serra de Grândola (Portugal)

Helena M. Fernandez, Fernando M. G. Martins, Jorge M. G. P. Isidoro, Lorena Zavala & Antonio Jordán

To cite this article: Helena M. Fernandez, Fernando M. G. Martins, Jorge M. G. P. Isidoro, Lorena Zavala & Antonio Jordán (2016) Soil erosion, Serra de Grândola (Portugal), Journal of Maps, 12:5, 1138-1142, DOI: 10.1080/17445647.2015.1135829

To link to this article: https://doi.org/10.1080/17445647.2015.1135829

© 2016 Helena M. Fernandez
Soil erosion, Serra de Grândola (Portugal)

Helena M. Fernandeza,b, Fernando M. G. Martinsa,b, Jorge M. G. P. Isidoroa,c, Lorena Zavala,b,d and Antonio Jordánb,d

aDepartment of Civil Engineering, Institute of Engineering, University of Algarve, Faro, Portugal; bMED_Soil Research Group, Seville, Spain; cMarine and Environmental Sciences (MARE), Coimbra, Portugal; dDepartment of Crystallography, Mineralogy and Agricultural Chemistry, University of Seville, Seville, Spain

ABSTRACT
Soil erosion has long been the subject of attention for environmental management researchers because it implies the loss of a key natural resource for sustaining life. Several methodologies for soil erosion assessment have been developed; many of these are supported by Geographic Information Systems. This study aims to classify the susceptibility of rainfall-induced erosion at the Serra de Grândola (Portugal), based on the Priority Actions Programme/Regional Activity Centre guidelines for mapping soil erosion on the Mediterranean coast. Results show a low-to-moderate susceptibility to rainfall-induced erosion in the lowlands, becoming moderate to high in the highlands of the Serra de Grândola.

KEYWORDS
Soil erosion; landsat; DEM; PAP/RAC; NDVI; Serra de Grândola

1. Introduction

Erosion is a global threat to sustainability and soil productivity. Understanding the genesis of this process is a central key for environmental management because it allows people to model, quantify and classify the susceptibility of land to soil erosion. In the Iberian Peninsula, soil erosion is the most common process of land degradation and a symptom of desertification (Castillo, 2000), and rainfall-induced erosion is responsible for the degradation of Mediterranean soils (Cerdà, Hooke, Romero-Diaz, Montanarella, & Lavee, 2010; Grimm, Jones, & Montanarella, 2002; Kosmas, Danalatos, & Gerontidis, 2000). Understanding the characteristics and the spatial and temporal variability of rainfall is thus crucial for soil erosion assessment, and for the adoption of sustainable land management strategies minimizing the loss of soil (Nunes & Lourenço, 2015).

The Mediterranean region is characterized by a seasonal climate and the resulting specific ecological and soil conditions. The fragile environment and low biomass production rates during dry periods make it one of the most vulnerable ecosystems in Europe. According to Hanson et al. (2007), projected changes of precipitation in the Mediterranean area caused by climate change suggest higher extreme precipitation events in the future. An increase in susceptibility to soil erosion is also expected (Figueroedo & Gonçalves, 2008).

The Priority Actions Programme/Regional Activity Centre (PAP/RAC) was established in 1977 as a main component of the Mediterranean Action Plan (MAP), within the scope of the United Nations Environment Programme (UNEP). The MAP included 21 countries form the Mediterranean as well as the European Union, with the common goal of contributing to a healthier and more sustainable Mediterranean environment. The model proposed by PAP/RAC (1997) to predict rainfall-induced erosion in the Mediterranean coastal areas is simple and versatile, and does not require the use of complex parameters that may be difficult to obtain, such as those needed in the Universal Soil Loss Equation model (Zavala et al., 2005).

Geographic information systems (GIS) can be used for the assessment of natural resources as it allows the integration and representation of several biophysical attributes (e.g. Bastian, 2000; Bocco, Mendoza, & Velázquez, 2001). The incorporation of digital elevation models (DEMs) allows the representation of topographic characteristics and so the simulation of the environmental processes.

This paper presents a GIS-based methodology developed from PAP/RAC (1997) to map the susceptibility of the Serra de Grândola to rainfall-induced erosion. The map coordinate system is the ETRS-1989-Portugal-TM06 (EPSG: 3763). The datum is ETRS89 and the ellipsoid is the GRS80. The Transversal Mercator projection has its origin at the Portuguese geodetic centre (Melriça, Portugal). Susceptibility to erosion is presented as a colour scheme on the map (1:35,000) in which five classes are differentiated (very low, low, moderate, high and very high).

2. Study area

The Serra de Grândola is a mountain range in the Alentejo region, South of Portugal (N 38° 0’ to N 38° 13’ and W 8° 32’ to W 8° 44’) (Figure 1). Annual rainfall
ranges from 600 mm (in the lowlands) to 1050 mm (in the highlands). The climate is moderate, with an average annual temperature of 17°C. The most important lithologic group is the Flysch formation of the lower Alentejo (DGM, 1984).

The Serra de Grândola is noted for its ecologic and landscape value, and for the low-impact natural resource management practices of the local population. The Mediterranean climate produces specific ecological conditions mainly because of the distinctive high-contrast relief with the mountain area surrounded by lowland plains and because of close proximity to the Atlantic Ocean. Temporary ponds are extremely important for some species of amphibians and macroinvertebrates (Pereira, 2011), and dense riparian vegetation provides habitats for various species of birds, and for mammals such as the otter (Lutra lutra) (Salgueiro, 2009).

3. Methods

Assessment of the susceptibility of the Serra de Grândola to rainfall-induced erosion is based on a GIS method that integrates the physical and meteorological driving properties (vegetation cover, relief, soil use, lithology and rainfall). The methodology follows Paixão (2012), who combined the impact of the mechanical action of rainfall (erosivity) with the susceptibility to soil erosion (erosion status) in order to map the susceptibility of the Serra de Grândola to rainfall-induced erosion (Figure 2).

The rainfall erosivity map was generated by combining the slope and lithofacies maps. The slope map was produced from a 10-m resolution DEM (Supplementary Figure 1) using 526,770 points digitized from contours of a 1:25,000 topographic map (Geographical Institute of the Portuguese Army; IGeoE, 2004). Elevations were interpolated using ordinary kriging, in which the variogram was modelled from a spherical model.

Slopes were calculated from the elevation differences of the adjacent cells, for each cell of the DEM. The slope of each pixel in line $l$ and column $k$ is found based on the elevation values ($H$) of neighbouring pixels and on the spatial resolution of the DEM, $E$. The slope is calculated using the following equation:

$$\delta = \sqrt{\left(\frac{H(l,k+1)-H(l,k-1)}{2E}\right)^2 + \left(\frac{H(l-1,k)-H(l+1,k)}{2E}\right)^2}$$

(1)

Five classes of slopes (%) were derived from the DEM: [0, 3], [3, 16], [16, 21], [21, 31] and ≥31 (Supplementary Figure 2).

3.1. Erodibility map

The erodibility map was generated by combining the slope and lithofacies maps. The slope map was produced from a 10-m resolution DEM (Supplementary Figure 1) using 526,770 points digitized from contours of a 1:25,000 topographic map (Geographical Institute of the Portuguese Army; IGeoE, 2004). Elevations were interpolated using ordinary kriging, in which the variogram was modelled from a spherical model.

Slopes were calculated from the elevation differences of the adjacent cells, for each cell of the DEM. The slope of each pixel in line $l$ and column $k$ is found based on the elevation values ($H$) of neighbouring pixels and on the spatial resolution of the DEM, $E$. The slope is calculated using the following equation:

$$\delta = \sqrt{\left(\frac{H(l,k+1)-H(l,k-1)}{2E}\right)^2 + \left(\frac{H(l-1,k)-H(l+1,k)}{2E}\right)^2}.$$
The lithofacies map (Supplementary Figure 3) was produced from the 1:200,000 Geological Map of Portugal (DGM, 1984) by aggregating lithological units with similar characteristics with the material resistance. Five classes of lithofacies were defined: A – very high, B – high, C – moderate; D – low and E – very low. Slope was combined with lithofacies according to Supplementary Table 1 to generate the erodibility map (Supplementary Figure 4). The outcome was five classes of erodibility: a – very low; b – low; c – moderate; d – high and e – very high.

3.2. Soil protection map

Red and near-infrared bands of Landsat 8 OLI scenes (WRS path: 203; WRS row: 34; file date: 2013/08/16) were used to calculate the Normalized Difference Vegetation Index (NDVI) (Rouse, Hass, Schell, & Deering, 1974), which was then used to produce the vegetation cover map. Four classes of vegetation cover (%) were mapped: [0, 25], [25, 50], [50, 75] and [75, 100] (Supplementary Figure 5).

Land use data were obtained from the Corine Land Cover map (CLC, 2006) by merging classes with similar characteristics (Supplementary Figure 6).

Vegetation cover was combined with soil use (see Supplementary Table 2) to produce the soil protection map (Supplementary Figure 7). The outcome was five levels of soil protection: a – unprotected, b – very low, c – low, d – moderate and e – high.

3.3. Erosion status map

Erodibility was combined with soil protection (see Table 1) to produce the erosion status map (Supplementary Figure 8). The resulting erosion status values were categorized into: 1 – very low, 2 – low 3 – moderate 4 – high and 5 – very high.

3.4. Rainfall erosivity map

Rainfall erosivity is a parameter of major importance for soil erosion assessment purposes. However, often there is a lack of rainfall data for the area under study. In the Serra de Grândola, there is only one climatological station (Grândola 24F/01C, Portuguese Figure 2. Methodology used to assess the susceptibility to rainfall-induced erosion.

| Soil protection class | a | b | c | d | e |
|-----------------------|---|---|---|---|---|
| A                     | 1 | 1 | 1 | 2 | 2 |
| B                     | 1 | 1 | 2 | 3 | 4 |
| C                     | 1 | 2 | 3 | 4 | 4 |
| D                     | 2 | 3 | 3 | 5 | 5 |
| E                     | 2 | 3 | 4 | 5 | 5 |
| Unprotected            | 3 | 4 | 5 | 5 | 5 |

| Rainfall erosivity class (CORINE – CEC) | 1 | 2 | 3 | 4 | 5 |
|------------------------------------------|---|---|---|---|---|
| Rainfall erosivity class (MFI)           | <60 | 60–90 | 90–120 | 120–160 | >160 |
| Rainfall aggressivity                    | Very low | Low | Moderate | High | Very high |
Ministry for Agriculture, Sea, Environment and Land Planning). To overcome this issue, a model for annual precipitation using multi-linear regression was developed (for further details of this model, see Paixão, 2012). Input data were the monthly average rainfall for the period from 1 January 1911 to 31 December 2010, not only from station 24F/01C but also from 28 climatologic stations closest to the Serra de Grândola (all stations within the same drainage basin). Rainfall erosivity was classified according to CORINE-CEC (1992) (Table 2) (Supplementary Figure 9).

### 3.4. Susceptibility to rainfall-induced erosion map

Erosion status was combined with rainfall erosivity (see Table 3) to produce the susceptibility to rainfall-induced erosion map (see Main Map). The outcome was five classes of susceptibility to water erosion: I – very low, II – low, III – moderate, IV – high and V – very high. The susceptibility to erosion map was classified according to slope, lithofacies, soil coverage and rainfall erosivity (Table 4).

### 4. Conclusions

Environmental biophysics requires knowledge about the resources and processes affecting ecological system conservation, as well as about planning and land management.

The integration of GIS with DEMs allows good representation of topographic characteristics and easy simulation of the environmental processes. This paper presents a methodology based on GIS tools for mapping and classifying the susceptibility to rainfall-induced erosion in the Serra de Grândola (Portugal). A DEM is used as the starting point for the automatic classification, which is based on the Priority Actions Programme/Regional Activity Centre (PAP/RAC) procedures, with regional specifications for the Southern Iberian Peninsula. The data sets used for computation included slope, lithofacies, NDVI and land use. The integration in a GIS was an important tool for simulating erodibility and soil protection, to produce the erosive state information and to combine it with rainfall data. PAP/RAC proved to be a useful set of guidelines for predicting rainfall-induced erosion in the Serra de Grândola.

The Corine-CEC classification shows the study area as having low- and moderate-rainfall erosivity. Lower rainfall erosivity values correspond to the surroundings of the central part of the mountain range, which shows moderate MFI values. It was found that the study area has a low-to-moderate susceptibility to rainfall-induced soil erosion. The highlands are more susceptible because of the higher amount of rainfall and steeper slopes, although the soil material is more resistant to erosion (flysch formation). Valleys with steep hillslopes presented a very high susceptibility to rainfall-induced erosion (e.g. Ribª da Lagoa de Melides, Ribª Cascalheira, Ribª Ponte and Ribª de Sê André).

The authors hope that this work may contribute to better planning of land use at the Serra de Grândola, which is particularly sensitive to the erosive process due to its ecological and landscape qualities.

### Acknowledgements

The authors wish to thank the MED_SOIL Research Group for support offered during fieldwork and to IGeoE for providing the information needed to produce the DEM. The authors also wish to acknowledge Dr Colin Pain for his detailed revision of the manuscript.

### Disclosure statement

No potential conflict of interest was reported by the authors.

### Software

IDRISI Taiga was used as the analysis platform for modelling the susceptibility to water erosion. Esri ArcGIS 10.2 was also used to design the maps.

### ORCID

Helena M. Fernandez [http://orcid.org/0000-0002-3677-1064](http://orcid.org/0000-0002-3677-1064)

Fernando M. G. Martins [http://orcid.org/0000-0002-2709-804X](http://orcid.org/0000-0002-2709-804X)

Jorge M. G. P. Isidoro [http://orcid.org/0000-0002-6901-5652](http://orcid.org/0000-0002-6901-5652)
Lorena Zavala  http://orcid.org/0000-0003-0592-1274
Antonio Jordán  http://orcid.org/0000-0003-3165-5846

References

Arnoldus, H. M. (1978). An approximation of the rainfall factor in the Universal soil loss equation. In M. De Boodt, & D. Gabriels (Eds.), Assessments of erosion (pp. 127–132). New York, NY: John Wiley & Sons.

Bastian, O. (2000). Landscape classification in Saxony (Germany) – A tool for holistic regional planning. Landscape and Urban Planning, 50, 145–155.

Bocco, G., Mendoza, M., & Velázquez, A. (2001). Remote sensing and GIS-based regional geomorphological mapping – A tool for land use planning in developing countries. Geomorphology, 39, 211–219.

Castillo, V. M. (2000). Problems and practices of erosion control management in Spain. In PAP/RAC. National reports on problems and practices of erosion control management in the Mediterranean region. UNEP-MAP-PAP. Split. 81–106.

Cerdà, A., Hooke, J., Romero-Díaz, A., Montanarella, L., & Lavee, H. (2010). Soil erosion on Mediterranean type-ecosystems land degradation and development. Land Degradation & Development, 21(2), 71–74. doi:10.1002/lrd.968

CORINE-CEC. (1992). CORINE soil erosion risk and important land resources. An erosion risk. Office for official publications of the European Communities. EUR 13233. Luxemburg.

CORINE-CLC. (2006). Cartografia CORINE land cover 2006 for Portugal continental [CORINE land cover 2006 cartography for Portugal]. Lisboa: Instituto Geográfico do exército. Grupo de Detecção Remota.

DGM. (1984). Carta Geológica à escala 1:200000 [Portuguese geologic map at 1:200000 scale] [Map]. Lisboa: Direcção-Geral de Minas e Serviços Geológicos.

Figueroedo, T., & Gonçalves, D. (2008). Erosividade das precipitações e erosão hídrica dos solos: exercícios de esti-mativa face a cenários de alteração climática [Rainfall erosivity and soil water-erosion: Trends on climate-change scenarios]. Workshop Internacional sobre Clima e Recursos Naturais nos países de língua portuguesa (WSCRA08). Ilha do Sal, 1–8.

Grimm, M., Jones, R., & Montanarella, L. (2002). Soil erosion risk in Europe. Ispra: European Commission, Institute for Environment and Sustainability: European Soil Bureau.

Hanson, C. E., Palutikof, J. P., Livermor, M. T. J., Barring, L., Bindi, M., Corte-Real, J., … Ulbrich, U. (2007). Modelling the impact of climate extremes: An overview of the MICE project. Climatic change 81: PRUDENCE Special Issue, Prediction of regional scenarios and uncertainties for defining european climate change risks and effects: the PRUDENCE project, 163–177.

Igœl. (2004). Carta Militar de Portugal à escala 1:25000 [Portuguese Military Map at 1:25000 scale] [Map]. Lisbon: Instituto Geográfico do Exército.

Jordán, A., & Bellinfante, N. (2000). Cartografía de la Erosividad de la Lluvia Estimada a Partir de Datos Pluviométricos Mensuales en el Campo de Gibraltar (Cádiz) [Mapping rainfall erosivity estimated from pluviometric monthly data in the Campo de Gibraltar (Cádiz)]. Edafología, 7, 83–92.

Jordán, A., Zavala, L. M., Bellinfante, N., & González, F. (2005). Cartografía Semiquantitativa del Riesgo de Erosión en Suelos Mediterráneos [Semiquantitative cartography for erosion risk mapping in mediterranean soils]. In R. J. Ballesta & A. M. González (Eds.), Control de la Degradación de Suelos (pp. 701–706). Madrid: Autonomous University of Madrid.

Kosmas, C., Danalatos, N. G., & Gerontidis, S. (2000). The effect of land parameters on vegetation performance and degree of erosion under Mediterranean conditions. Catena, 40, 3–17. doi:10.1016/S0341-8162(99)00061-2

Nunes, A. N., & Lourenço, L. (2015). Precipitation variability in Portugal from 1960 to 2011. Journal of Geographical Sciences, 25(7), 784–800. doi:10.1007/s11442-015-0212-y

Paixão, H. (2012). Elaboração de um modelo digital do terreno da zona norte da Sierra de Grândola (Alentejo, Portugal) [Development of a digital terrain model of the northern part of the Sierra of Grândola (Alentejo, Portugal)] (Unpublished doctoral dissertation). University of Seville, Seville.

PAP/RAC. (1997). Guidelines for mapping and measurement of rainfall-induced erosion processes in the Mediterranean coastal areas. PAP-8/PP/GL.1. PAP/RAC (MAP/UNEP). Split.

Perera, A. M. C. L. B. (2011). Biodiversidade de charcos temporários de diferentes idades na Serra de Grândola, Portugal [Biodiversity temporary ponds of different age in the Serra de Grândola, Portugal] (Unpublished master dissertation). FCUL.

Rouse, J. W., Hass, R. H., Schell, J. A., & Deering, D. W. (1974). Monitoring the vernal advancement and retrogra-dation (Greenwave effect) of nature vegetation. Greenbelt, MD: NASA/GSFC Type III Final Report.

Salgueiro, V. F. M. (2009). Variabilidade temporal na disponibilidade de presas e dieta da lontra em ribeiras intermi-nentes na Serra de Grândola: Implicações de conservação [Temporal variability in the availability of prey and otter diet in intermittent streams in Serra de Grândola: Conservation Implications] (Unpublished master dissertation). FCUL.

Zavala, L. M. (2001). Análisis territorial de la comarca del Andévalo Occidental. Una aproximación desde el medio físico [Territorial analysis of the region of Western Andévalo. An approach from the physical environment] (Tesis Doctoral). Sevilla: Universidad de Sevilla.

Zavala, L. M., Bellinfante, N., Jordán, A., & Paneque, G. (2002). Evaluation of the erosion risk in Andévalo (SW Spain): An approach to semi-detailed erosion mapping. En J. L. Rubio, R. P. C. Morgan, S. Asins, & V. Andreu (Eds.), Man and soil at the third millennium (Vol. II, pp. 1277–1290). Logroño: Geoforma Ediciones.

Zavala, L. M., Jordán, A., Gómez, I. A., Anaya-Romero, M., Girón, V., & Segura, D. (2005). Estudio del riesgo de erosión potencial en la cuenca alta del Río Hozgarganta [Study of the potential risk of erosion in the upper basin of the Río Hozgarganta]. Almoraima, 31, 111–118.