Journal of Sustainable Development; Vol. 16, No. 4; 2023
ISSN 1913-9063 E-ISSN 1913-9071
Published by Canadian Center of Science and Education

Erosion Pins: Installation, Readings, and Calculations of Soil Losses under the Effect of Hydrogel

José Falcão-Sobrinho[1], Simone Ferreira Diniz[2], Francisca Edineide Lima Barbosa[3] & Pedro Henrique Eleoterio de Assis[4]

[1] Prof. doctor of the Graduate Program in GeographyVale do Acaraú State University/UVA. Leader of the Semiarid Research and Extension Network/CNPq and CNPq Productivity Fellow – 2. https://orcid.org/0000-0002-7399-6502; falcao.sobral@gmail.com

[2] PhD in Geosciences and Environment, State University Vale do Acaraú-UVA. http://orcid.org/0000-0001-6127-9883; dinfersim@hotmail.com

[3] PhD in Soils and Plant Nutrition, PNPD scholarship holder. Postdoctoral student in Geography at the State University Vale do Acaraú/UVA. edineidelb@gmail.com; https://orcid.org/0000-0002-1342-8263

[4] Graduated in Geography. Master's degree in Geography, State University Vale do Acaraú-UVA

pedrosaodomingo345@gmail.com; https://orcid.org/0000-0002-7404-4167

Correspondence: José Falcão-Sobrinho. Prof. doctor of the Graduate Program in GeographyVale do Acaraú State University/UVA. E-mail: falcao.sobral@gmail.com

Received: April 10, 2023 Accepted: May 21, 2023 Online Published: May 22, 2023

doi:10.5539/jsd.v16n4p57 URL: https://doi.org/10.5539/jsd.v16n4p57

Abstract

Erosion pins are considered a simple and inexpensive way to estimate soil losses due to erosion and have been used in different environments with different degrees and types of erosion. Despite the advantages of this technique, there is a shortage of studies that demonstrate how data systematization and soil loss calculations are performed using this technique. Therefore, this study aimed to present the step-by-step data systematization process of erosion pins obtained in the field and the calculation of soil losses, with the measurement of soil losses under the effect of hydrogel. Readings from 16 pins installed in an area cultivated with soursop trees planted on contour lines and associated with stone rows were monitored weekly between 19/02 and 19/03/2022 by measuring the distance between the soil surface and the end of each pin. The readings were organized by pin and date of measurement. Subsequently, soil lowering and burial, soil density, useful area of each pin, and soil loss in kg/m3 and Mg/ha-1 were determined, enabling statistical analysis and technical interpretation of the data.

Keywords: sheet erosion, experimental data systematization, soil degradation

1. Introduction

Undoubtedly, soils are of great importance for maintaining life on Earth. Despite this, soil degradation is increasing in various regions of the planet, mainly due to the intensification of erosive processes, including water erosion, potentiated by the inadequate use and management of soils (SILVA et al., 2019; VALE and PEREZ-ALBERTI, 2021; WANG et al., 2021).

In this context, understanding the dynamics of erosive processes and determining their magnitudes becomes essential to support the identification of more sensitive areas; to propose mitigation measures and to plan the use and occupation of soils by governmental or non-governmental agents.

According to the literature, erosion determination methodologies are divided into direct and indirect methods. Among the indirect methods, erosion pins stand out, which are rods, bars, or stakes made of metal, wood, or other materials with good resistance and incapable of affecting the speed of surface runoff and the sediment-carrying capacity of the runoff (BERTONI and LOMBARDI-NETO, 2014; HAIGH, 1977; HUDSON, 1993).

Pins are widely used to measure the retreat of gully edges and riverbanks. On slopes, pins have enabled measurements of sheet erosion and estimates of soil losses (HART et al., 2017; JUGIE et al., 2018; KEARNEY et al., 2018; MYERS et al., 2019; GUERRA et al., 2020; GHOLAMI et al., 2021).

According to Haigh (1977) and Hudson (1993), this technique presents advantages such as the ease of data collection, low maintenance requirements which reduces operational costs, the possibility of data collection at flexible intervals, whether weekly, monthly, or annually, ease of detection in areas where erosion is occurring, and particularly the low technical level required for data collection

Despite the advantages of this methodology, there is a scarcity of studies that demonstrate the systematization of data from erosion pin readings, as well as the calculations of soil losses under the application of hydrogels from the field readings. In order to address this demand, this study aimed to present the step-by-step systematization of data obtained from erosion pins and the calculations used in determining soil losses.

2. Materials and Methods

The experimental area from which erosion pin data were obtained is a community-use agricultural property located precisely in the São Domingos community, in the district of Jaibaras, in Sobral, state of Ceará, Brazil (Figure 01).

The local climate is classified as hot semi-arid tropical, with an average temperature ranging from 26°C to 28°C and a rainy season from January to May (IPECE, 2017). The average annual precipitation is 642.1 mm, with a maximum of 1,325.70 mm and a minimum of 325.30 mm, considering a historical series of seventeen years obtained from the official station of FUNCEME - Ceará Foundation for Meteorology and Water Resources, located in the district of Jaibaras, which is about four kilometers from the study area.

The installation of the erosion pins took place in an area managed under conservationist practices. This management consists of planting soursop in contour lines, associated with level stone ridges. It consists of 20 soursop plants spaced 7.0 x 7.0 m and distributed in four rows of 05 plants, with the central 06 plants considered useful plants.

The erosion pins used were made of iron and were 70 cm long, and they were installed between the central rows of the aforementioned treatment and distributed in 04 rows, with 04 pins each and in an intercalated manner with respect to the next row (forming a triangular mesh) with a spacing of 1.5 m x 2.0 m, totaling 16 pins, as represented in the schematic drawing of Figure 2.

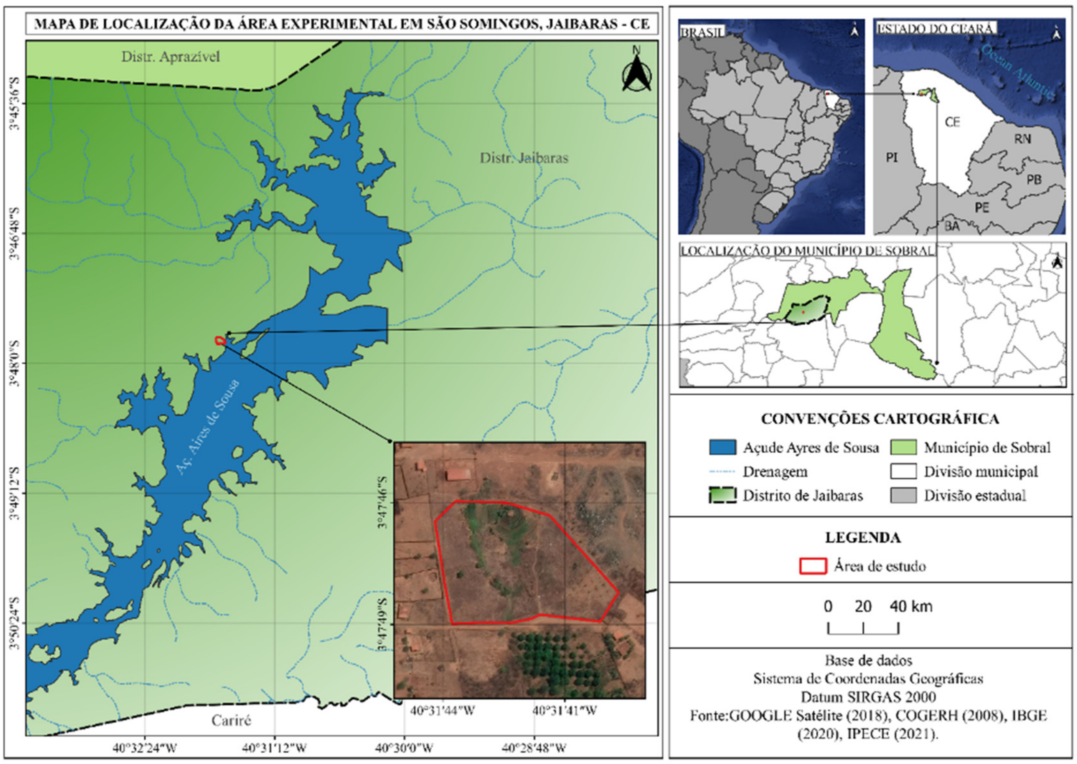

Figure 1. Experimental area location map

Source: Organized by the authors.

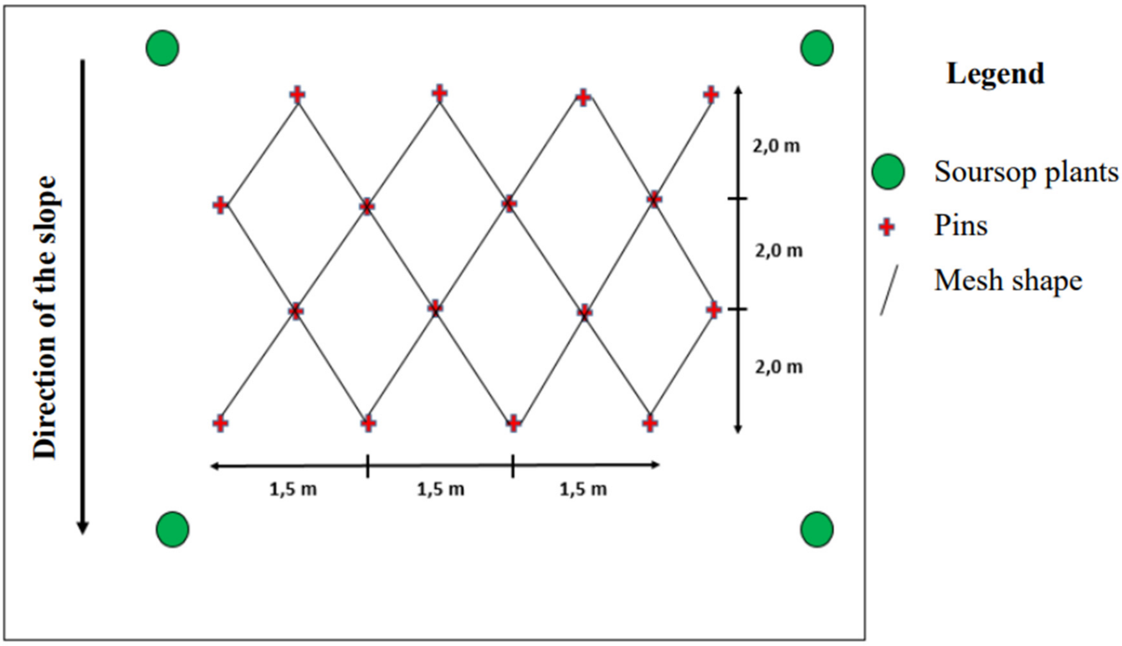

Figure 2. Schematic drawing of the distribution of erosion pins in the field

Considering that the distribution of the erosion pins was triangular, the useful area of each pin must be calculated based on the area of the triangle. In this case, using the following formula:

$$\boldsymbol{A(m^2) = \frac{b(m)x \;\; h \;\; (m)}{2}}$$

A = Área útil de cada pino, in m2;

b = Base of the triangle, corresponding to the spacing between pins in the same row, in m;

h = Height of the triangle, corresponding to the spacing between rows of pins, in m.

The installation depth of the erosion pins was 45 cm, leaving 25 cm exposed from the surface. It is worth noting that smaller values are also commonly used by other authors (GUERRA et al., 2020). The installation was aided by a sledgehammer and a 50 m tape measure. The part of the pins that remained exposed was painted red for the purpose of facilitating their visualization. The following figure presents photographic records of the distribution of the pins in the study area.

Figure 3. Photographic record of erosion pins installed in the field

Source: Author's own elaboration.

The readings of the erosion pins were taken individually, during the period from 02/19/2022 to 03/19/2022, at regular intervals of 07 days. The measurements were taken from the soil surface to the top of each pin and aimed to determine whether there was soil lowering, that is, the removal of soil from the base of the pins, or burying (arrival of soil in the vicinity of the pins) between the reading intervals.

It is worth noting that at the end of each reading, care was taken to leave each pin in the initial position, that is, with 25 cm from the soil surface. The figure below shows the moment of the pin readings.

Figure 4. Photographic record of pin readings in the field

Source: Author's elaboration.

The soil density of the aforementioned treatment was also determined using undisturbed soil samples collected in triplicate at a depth of 0-8 cm. Metal cylinders of known volume were used for sampling, taking care to avoid soil compaction inside the cylinder. The analysis followed the recommendations of the Soil Analysis Methods Manual (Embrapa, 2017), which indicates the following formula for determining density:

$$Ds(g \cdot cm^3) = \frac{ma(g)}{V(cm^3)}$$

Where:

V = Volume do cilindro, em cm3;

D = Diâmetro interno do cilindro, em cm;

H = Altura interna do cilindro, em cm.

To determine the volume of the cylinder in cm3, the following formula was used:

$$V = \pi \quad x \ \ r^2 x \ \ h$$

Where:

π = 3.14159... resulting from the division between the circumference and diameter of a circle.

r = Radius of the cylinder in cm;

h = Height of the cylinder in cm.

The readings of the pins and density values were systematized using spreadsheets in Microsoft Excel software. Subsequently, the soil lowering and burial were determined, and then the soil loss calculations were carried out for each individual pin using a formula adapted from Baldassarini & Osvaldo (2018), which consisted of:

$$P \ = RS \quad x \ \ Ds \quad x \ \ 10$$

Where: P = Perda de solo em megagramas por hectare (Mg ha-1), which means soil loss in megagrams per hectare; RS = Rebaixamento do solo é a medida da alteração da superfície medida com os pinos em metros (m), which means the change of the soil surface measured with the pins in meters (m); Ds = Densidade do solo em quilograma por metro cúbico (kg m-3), which means soil density in kilograms per cubic meter (kg m-3).

3. Results and Discussion

For the proper systematization of the data from the pins readings installed in the field, the first step is to sequence the readings values of each pin by date, as presented in Table 1.

Table 1. Systematization of pin readings data by evaluation date

Pins (nº)	Date / reading (cm)				
	19/02/2022	26/02/2022	05/03/2022	12/03/2022	19/03/2022
1	25	25	25	25	25,2
2	25	25	25	25	25,2
3	25	25	25,5	25	25,2
4	25	24	25	25	25,1
5	25	25	25	25	25,3
6	25	25	25	25	25,2
7	25	25	25	25	25
8	26	25	25	25	25
9	25	25	25	25	25
10	25	25	25,5	24	24
11	25	25	25,5	25	25,3
12	25	25	25	25	25
13	25	25	25	25	25
14	25	25	25	25	25,2
15	25	25	25	24	25
16	25	25	24,5	24	25,2

Considering that 25 cm was adopted as the reference value for the exposed part of the pins, that is, the part of the pin that remained above the soil surface after each reading, the calculation of soil depression or burial will be equal to the difference between the reference value (corresponding to 25 cm) and the value obtained during each reading, that is:

Pinning or burying depth of the pin in (cm) = 25 (cm) - reading (cm).

To convert the value found in centimeters (cm) to meters (m), it must be divided by 100. Table 2 presents the soil subsidence or burial data in meters obtained for each of the readings presented in Table 1.

Table 2. Systematization of data from pin readings on each evaluation date

Pins(nº)	Dates / Soil subsidence or burial (m)				
	19/02/2022	26/02/2022	05/03/2022	12/03/2022	19/03/2022
1	0	0	0	0	-0,002
2	0	0	0	0	-0,002
3	0	0	-0,005	0	-0,002
4	0	0,01	0	0	-0,001
5	0	0	0	0	-0,003
6	0	0	0	0	-0,002
7	0	0	0	0	0
8	-0,01	0	0	0	0
9	0	0	0	0	0
10	0	0	-0,005	0,01	0,01
11	0	0	-0,005	0	-0,003
12	0	0	0	0	0
13	0	0	0	0	0
14	0	0	0	0	-0,002
15	0	0	0	0,01	0
16	0	0	0,005	0,01	-0,002

The maximum value of soil subsidence found during the evaluation period was 0.01 m, while the lowest value was -0.01 m. Positive subsidence values indicate that erosive processes occurred between evaluations that favored the removal of soil from the base of the pins, thus the soil was lowered and the reading obtained during the measurements was higher than 25 cm (reference value). Negative values indicate that the pin in question received soil from adjacent areas, being buried, so the recorded reading was less than 25 cm. Zero values indicate that no erosion occurred during the evaluated period.

Soil density data obtained in g cm-3, as described in the previous section, were converted to kg m-3. To do so, the density value was multiplied by 1000. The aim of the conversion was to standardize the units for use in the soil loss formula, a variable primarily represented in kg (kilograms) and Mg (megagrams). The table below presents the variables used for calculating soil density. The arithmetic mean of the density of the triplicate samples was considered as the soil density of the treatment used in the present study. Its value was equal to 1.483 g cm-3 or 1,483 kg m-3.

Parte superior do formulário

Table 3. Systematization of soil density data and variables used in its determination

Identification	height (cm)	diameter (cm)	volume (cm3)	mass (g)	density (g cm-3)
Repetição 1	5,314	4,885	99,589	149,493	1,501
Repetição 2	5,319	4,872	99,1397	150,069	1,514
Repetição 3	5,299	4,858	98,2321	141,061	1,436
		MÉDIA			**1,483**

In the erosion pin methodology, soil losses can be considered as the amount of soil capable of occupying the three-dimensional area formed by multiplying the spacing between the pins by the soil depression or burial. The schematic drawing below aims to present in a didactic way the three-dimensional useful area mentioned.

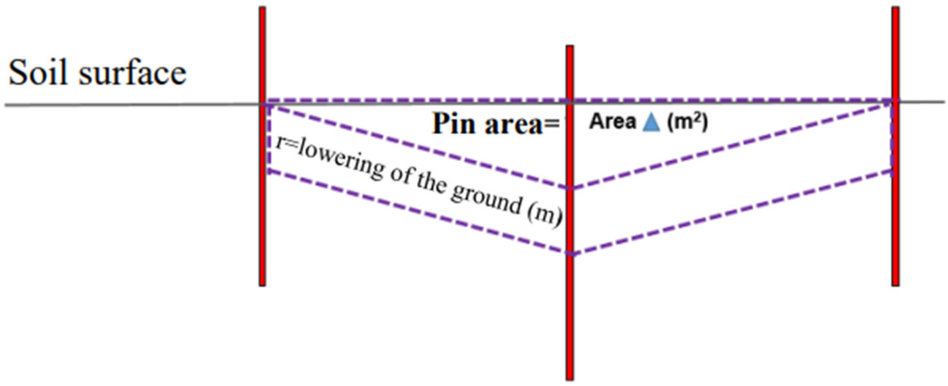

Figure 5. Three-dimensional useful area (m3) used for calculating soil losses by the erosion pin method
Source: Author's own elaboration.

Para o presente estudo, a área útil dos pinos é correspondente a 1,5 m2, conforme demonstra a figura abaixo.

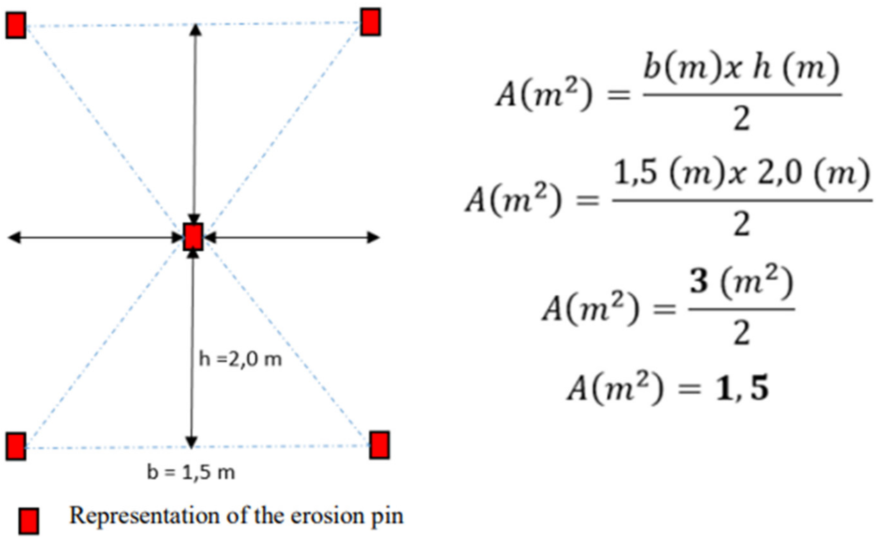

Figure 6. Representation of variables and calculation of the useful area of erosion pins
Source: Author's own elaboration.

With the values of the useful area of each pin in m2, the soil density in Kg m-3, and the soil depression or burial, it is possible to determine the soil losses that occurred in each pin on each monitoring date. The table below presents the data of soil losses in kg/m3 and Mg/ha-1, estimating the erosion potential for the area corresponding to 10,000 m2.

To determine soil losses in kg/m3, multiply the value of the pin's useful area by the soil density and the soil depression or burial. To determine soil losses in Mg/ha-1, the formula adapted from Baldassarini & Osvaldo (2018) is used, as described in the methodology of this study.

Table 4. Soil losses in kg/m3 and Mg/ha-1 for each pin, in each evaluation

Pinos	Datas / Perdas de solos (m)									
(nº)	19/02/2022		26/02/2022		05/03/2022		12/03/2022		19/03/2022	
	Kg m^3	Mg ha^{-1}	Kg m^3	Mg ha^{-1}	Kg m^3	Mg ha^{-1}	Kg m^3	Mg ha^{-1}	Kg m^3	Mg ha^{-1}
1	0	0	0	0	0	0	0	0	-4,449	-44,49
2	0	0	0	0	0	0	0	0	-4,449	-44,49
3	0	0	0	0	-11,1225	-111,225	0	0	-4,449	-44,49
4	0	0	22,245	222,45	0	0	0	0	-2,2245	-22,245
5	0	0	0	0	0	0	0	0	-6,6735	-66,735
6	0	0	0	0	0	0	0	0	-4,449	-44,49
7	0	0	0	0	0	0	0	0	0	0
8	-22,245	-222,45	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	-11,1225	-111,225	22,245	222,45	22,245	222,45
11	0	0	0	0	-11,1225	-111,225	0	0	-6,6735	-66,735
12	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	-4,449	-44,49
15	0	0	0	0	0	0	22,245	222,45	0	0
16	0	0	0	0	11,1225	111,225	22,245	222,45	-4,449	-44,49

From this point on, soil loss data can be subjected to various statistical analyses, including descriptive statistics, tests of normality, analysis of variance, mean tests, as well as multivariate statistics, which involve the analysis of the correlation matrix, principal component analysis, and other statistical tests that evaluate the occurrence of significant differences in soil losses between evaluation dates and enable data interpretation.

4. Final Remarks

The data systematization presented in this study has the potential to assist students, producers, and researchers in the installation of erosion pins in the field, systematization of the data obtained during their monitoring, and determination of soil losses, enabling the performance of statistical analyses and technical interpretation of soil loss data obtained in the field. This is essential for the correct analysis and interpretation of data from research using erosion pins, as well as for comparison with other methodologies.

Acknowledgments

This research acknowledges the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES, the National Council for Scientific and Technological Development - CNPq, and the Ceará Foundation for Scientific and Technological Support - FUNCAP, for their continuous financial support, as well as the Universidade Estadual Vale do Acaraú - UVA for the technical, scientific, and structural support provided.

References

Baldassarini, J. S., & Rodrigues Nunes, J. O. (2018). *Análise da estimativa de perda de solo por processos erosivos em parcelas de monitoramento com pinos de erosão em propriedades rurais do Estado de São Paulo*. Confins-revue Franco-bresilienne De Geographie-revista Franco-brasileira De Geografia. Paris: Revues Org. Retrieved from http://hdl.handle.net/11449/185569

Bertoni, J., & Lombardi Neto, F. L. (2014). *Conservação do solo* (9th ed.). São Paulo: Ícone.

EMBRAPA. (2017). *Manual de métodos de análise de solo* (3rd ed.). rev. e ampl. – Brasília, DF.

FUNCEME - Fundação Cearense de Meteorologia e Recursos Hídricos / Núcleo de Recursos Hídricos e Meio Ambiente (NURHA) Convênio: DNOCS/FUNCEME - Nº 26/2009. Projeto Zoneamento Ecológico-Econômico das Áreas Susceptíveis à Desertificação dos Núcleos Irauçuba/Centro-Norte e Inhamuns no

Estado do Ceará. Mapas do município de Sobral. Retrieved from http://www.funceme.br/wp-content/uploads/2019/02/Mapas-Munic%C3%ADpios-Sobral.pdf

Gholami, V., Sahour, H., & Amri, M. A. H. (2021). *Soil erosion modeling using erosion pins and artificial neural networks.* Catena. https://doi.org/10.1016/j.catena.2020.104902

Guerra, A. J. T., Jorge, M. Do C. O., Rangel, L. De A., Bezerra, J. F. R., Loureiro, H. A. S., & Garritano, F. do N. (2020). Soil erosion, different approaches and techniques applied to gullies and trail erosion. *William Morris Davis Revista de Geomorfologia, 1*(1), 75-117. https://doi.org/10.48025/ISSN2675-6900.vol1n1.p75-117.2020

Haigh, M. J. (1977). *The use of erosion pins in the study of slope evolution.* Technical Bulletin, Athens.

Hart, E. A., Mills, H. H., & Li, P. (2017). Measuring erosion rates on exposed limestone residuum using erosion pins: a 10-year-record. *Physical Geography, 38*(6), 541-555. https://doi.org/10.1080/02723646.2017.1342453

Hudson, N. W. (1993). *Field measurement of soil erosion and runoff.* Rome: Food & Agriculture Organization.

Jugie, M., Gob, F., Virmoux, C., Brunstein, D., Tamisier, V., Le Coeur, C., & Grancher, D. (2018). Characterizing and quantifying the discontinuous bank erosion of a small low energy river using Structure-from-Motion Photogrammetry and erosion pins. *Journal of Hydrology, 563*, 418-434. https://doi.org/10.1016/j.jhydrol.2018.06.019

Kearney, S. P.; Fonte, S. J.; García, E.; Smukler, S. M. (2018). Improving the utility of erosion pins: absolute value of pin height change as an indicator of relative erosion. *Catena, 163*, 427-432. https://doi.org/10.1016/j.catena.2017.12.008

Myers, D. T., Rediske, R. R., & Mcnair, J. N. (2019). Measuring streambank erosion: a comparison of Erosion Pins, Total Station, and Terrestrial Laser Scanner. *Water, 11*(1846), 19. https://doi.org/10.3390/w11091846

Silva, J. R. I., Souza, E. S. De, Souza, R., Santos, E. S. Dos, & Dantas A. C. A. (2019). Efeito De Diferentes Usos Do Solo Na Erosão Hídrica Em Região Semiárida. *Engenharia na Agricultura, 27*(3), 272-283. https://doi.org/10.13083/reveng.v27i3.867

Vale, R. M. C., & Perez-Alberti, A. (2021). Uso Das Terras E Processos De Desertificação Na Rpga Dos Rios Macururé-Curaçá. Revista de Geografia e Ordenamento do Território (GOT), nº 22 (Dezembro). Centro de Estudos de Geografia e Ordenamento do Território, p. 05 – 27. https://doi.org/10.17127/got/2021.22.001

Wang, H., Xie, T., Yu, X., & Zhang, C. (2021). Simulation of soil loss under different climatic conditions and agricultural farming economic benefits: The example of Yulin City on Loess Plateau. *Agricultural Water Management, 244*, 1-13. https://doi.org/10.1016/j.agwat.2020.106462

Copyrights