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Scientific Article

EFFECT OF THE REHABILITATION OF BAUXITE MINING AREAS ON THE INFILTRATION AND REPELLENCY OF THE SOIL TO WATER

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ABSTRACT

Brazil, the fourth-largest holder of bauxite reserves worldwide, plays a prominent role in global mineral production. However, open-pit mining can alter soil hydrological attributes due to vegetation removal and intensive soil disturbance. This study evaluated the effects of rehabilitation practices implemented by Companhia Brasileira de Alumínio (CBA) on water infiltration, unsaturated hydraulic conductivity, and soil water repellency. Six study areas were selected in the municipality of São Sebastião da Vargem Alegre, Minas Gerais State, Brazil, comprising three rehabilitated areas (0610, 0630, and 0123) and three reference areas. Assessments were conducted using a MiniDisk infiltrometer, and the results were compared using the Mann–Whitney test. The rehabilitated areas exhibited significantly higher values of infiltration rate (293.88 mm h^{-1}), infiltration capacity (308.78 mm h^{-1}), and unsaturated hydraulic conductivity (48.44 mm h^{-1}) than the reference areas, which showed mean values of 129.38 mm h^{-1}, 147.53 mm h^{-1}, and 9.19 mm h^{-1}, respectively ($p \leq 0.05$). Soil water repellency was significantly lower in the rehabilitated areas (1.48%) than in the reference areas (6.22%) ($p \leq 0.05$). These findings demonstrate that rehabilitation practices promoted the recovery of soil hydrological functionality by enhancing water infiltration, increasing the soil's capacity to transmit water through the profile, and reducing the expression of soil hydrophobicity.

Keywords: Soil water repellency, Hydrological restoration, Land reclamation

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EFEITO DA REABILITAÇÃO DE ÁREAS DE MINERAÇÃO DE BAUXITA NA INFILTRAÇÃO E NA REPELÊNCIA DO SOLO À ÁGUA

RESUMO O Brasil, quarto maior detentor de reservas de bauxita, destaca-se mundialmente na produção mineral. Entretanto, a mineração a céu aberto pode promover alterações nos atributos hidrológicos do solo em decorrência da remoção da cobertura vegetal e da movimentação do solo. Este estudo avaliou os efeitos da reabilitação de áreas mineradas pela Companhia Brasileira de Alumínio (CBA) sobre a infiltração de água, a condutividade hidráulica não saturada e a repelência do solo à água. Foram selecionadas seis áreas localizadas no município de São Sebastião da Vargem Alegre, Minas Gerais, Brasil, sendo três áreas reabilitadas (0610, 0630 e 0123) e três áreas de referência. As avaliações foram realizadas utilizando infiltrômetro MiniDisk e os resultados comparados pelo teste de Mann-Whitney. As áreas reabilitadas apresentaram valores significativamente superiores de taxa de infiltração (293,88 mm h^{-1}), capacidade de infiltração (308,78 mm h^{-1}) e condutividade hidráulica não saturada (48,44 mm h^{-1}) em comparação às áreas de referência, que apresentaram valores médios de 129,38 mm h^{-1}, 147,53 mm h^{-1} e 9,19 mm h^{-1}, respectivamente ($p \leq 0,05$). A repelência do solo à água foi significativamente menor nas áreas reabilitadas (1,48%) em relação às áreas de referência (6,22%) ($p \leq 0,05$). Os resultados demonstram que as práticas de reabilitação favoreceram a recuperação da funcionalidade hidrológica do solo, promovendo maior infiltração, maior capacidade de transmissão de água no perfil e menor expressão da hidrofobicidade.

Palavras-Chave: Repelência do solo à água, Restauração hidrológica, Reabilitação de áreas degradadas

1. INTRODUCTION

Brazil holds a prominent position in global mineral reserves and production, ranking as the fourth-largest holder of bauxite reserves, with approximately 30 gigatonnes, behind Guinea, Vietnam, and Australia (IBRAM, 2025). Bauxite mining is carried out through open-pit operations, resulting in vegetation removal and substantial soil disturbance, which may affect nutrient cycling, soil biota, organic matter content, soil structure, and several hydrological processes (Cugula et al., 2021; Freitas, 2018; Grant et al., 2007; Silveira, 2017). Inadequate management can intensify soil exposure to raindrop impact and surface runoff, altering soil physical properties and reducing water infiltration (Albuquerque et al., 2002; Sousa & Paula, 2019). In this context, effective rehabilitation strategies are essential to restore soil functionality and ensure the proper functioning of ecosystem processes.

Water infiltration plays a fundamental role in soil hydrological functioning, contributing to the reduction of surface runoff, soil erosion, and flood risk (Brandão et al., 2012). In addition, hydraulic conductivity is an important indicator of soil physical quality because it reflects the soil's capacity to transmit water through its pore network, directly influencing water movement and storage within the soil profile. In degraded areas, structural changes in the soil may impair these processes, reducing the efficiency of water infiltration and redistribution.

However, soil hydrophobicity may reduce infiltration capacity, increase surface runoff, and intensify erosive processes (Davis & Park, 2024; Maia et al., 2005; Perera et al., 2024; Vogelmann et al., 2015a). This phenomenon is associated with the presence of hydrophobic organic compounds that hinder the wetting of soil particles (Mao et al., 2019; Vogelmann, 2014). Soil water repellency directly affects surface and subsurface hydrological dynamics by restricting water entry into the soil profile and potentially compromising the functional recovery of degraded areas.

Despite the widespread adoption of rehabilitation practices in mined areas, knowledge gaps remain regarding their effects on soil hydrological attributes, particularly water infiltration, hydraulic conductivity, and soil water repellency.

Understanding the effectiveness of these rehabilitation strategies is essential for improving restoration practices, promoting long-term recovery of soil functions, and enhancing ecosystem stability. Therefore, this study aimed to evaluate the effects of bauxite mine rehabilitation on water infiltration and soil water repellency through a comparison between rehabilitated and reference areas belonging to Companhia Brasileira de Alumínio (CBA), located in the municipality of Miraí, Minas Gerais State, Brazil.

2. MATERIAL AND METHODS

The study was conducted in three mined and rehabilitated areas managed by Companhia Brasileira de Alumínio (CBA/ Miraí), identified by the codes 0610, 0630, and 0123, located in the municipality of São Sebastião da Vargem Alegre, Minas Gerais State, Brazil (Figure 1). The areas are located at the following UTM coordinates (Zone 23K): 750337 E/7676902 S (0610), 751034 E/7676090 S (0630), and 753019 E/7673629 S (0123). The study compared rehabilitated and reference areas using data collected between May and October 2022. In all areas, the predominant vegetation was Brachiaria spp., except in reference area 0610, where molasses grass (*Melinis minutiflora*) predominated. The soil was classified as a Typical Dystrophic Red-Yellow Oxisol (Borges, 2013). Mean annual precipitation in the region is 1,336 mm, and mean annual temperature is 19 °C (Alvares et al., 2013).

Water infiltration and soil water repellency were evaluated using a MiniDisk

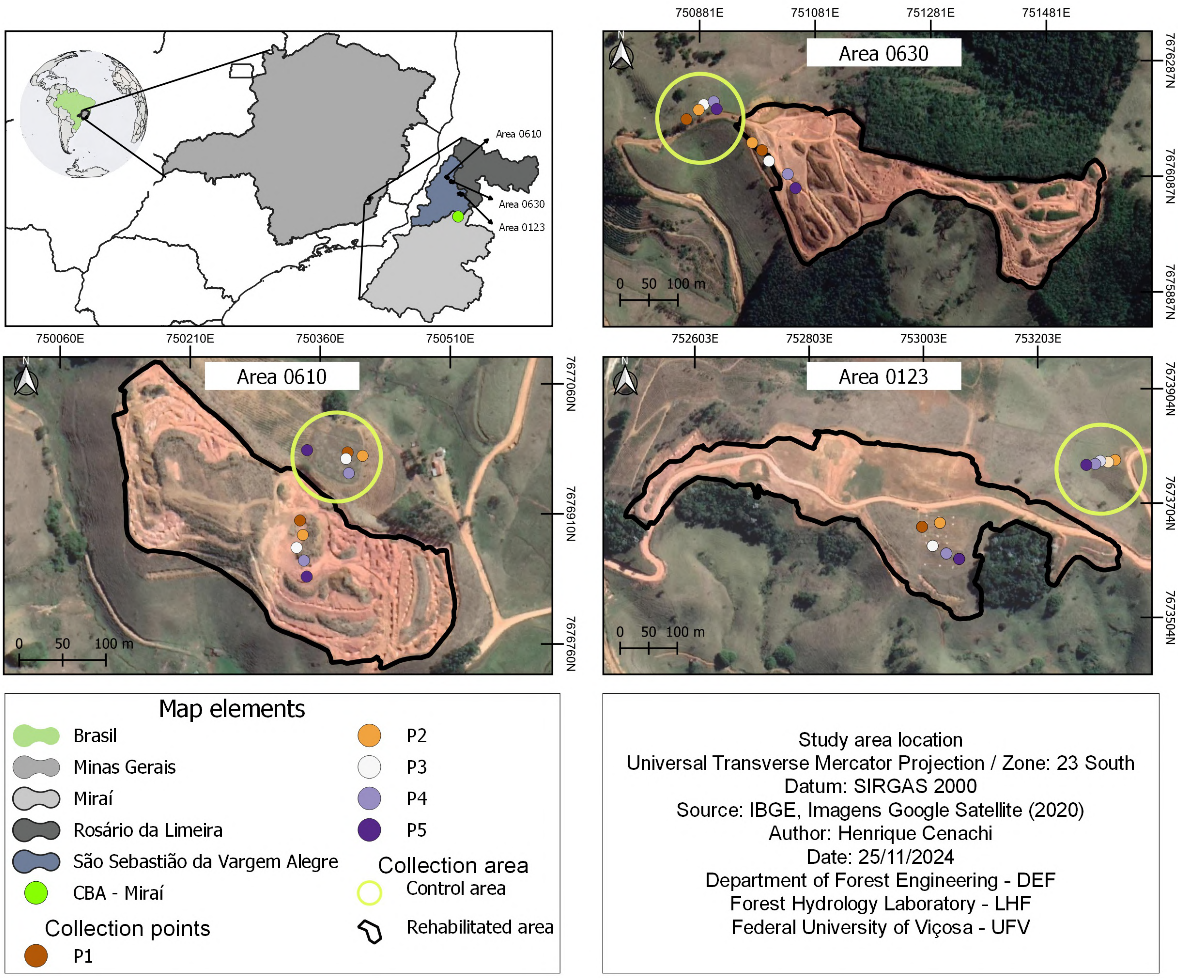

Figure 1. Study areas (0123, 0610 and 0630) in the municipality of São Sebastião da Vargem Alegre, Minas Gerais, Brazil, em 2024
Figura 1. Área de estudos (0123, 0610 e 0630) no município de São Sebastião da Vargem Alegre, Minas Gerais, Brasil, em 2024

tension infiltrometer (Figure 2). This instrument allows the estimation of unsaturated hydraulic conductivity and the assessment of infiltration behavior under unsaturated conditions, acting predominantly on soil micropores (Pavão, 2017; Shenga, 2019). Because it operates under tension, the instrument minimizes the influence of preferential flow commonly observed under saturated conditions (Chávez et al., 2014). Its main advantages include portability, rapid field application, and low water consumption (Meter Group, 2025). A tension infiltrometer provides a time series of cumulative infiltration measurements from which hydraulic conductivity can be estimated (Nimmo & Voss, 2023).

Before each test, the soil surface was cleaned and leveled with a thin layer of sieved soil to ensure proper contact between the porous disk and the soil surface. The infiltrometer was operated at a matric potential of −2 cm, following the manufacturer's recommendations.

For infiltration tests, both the upper and lower reservoirs of the instrument were filled with water. For soil water repellency determination, the upper reservoir was filled with water and the lower reservoir with 90% ethanol. Due to its lower viscosity and lower surface tension, ethanol penetrates soil pores more readily and is not affected by soil hydrophobicity (Ribas, 2018; Vogelmann et al., 2017).

Measurements were recorded every 30 s in an electronic spreadsheet until three consecutive intervals presented the same infiltrated volume or until a cumulative infiltration volume between 15 and 20 mL was reached, according to the manufacturer's recommendations. The resulting data were entered into the analysis spreadsheet provided by the MiniDisk Infiltrometer manufacturer, which estimates unsaturated hydraulic conductivity according to the procedure proposed by Zhang (1997). Values originally expressed in cm s^{-1} were subsequently converted to mm h^{-1}.

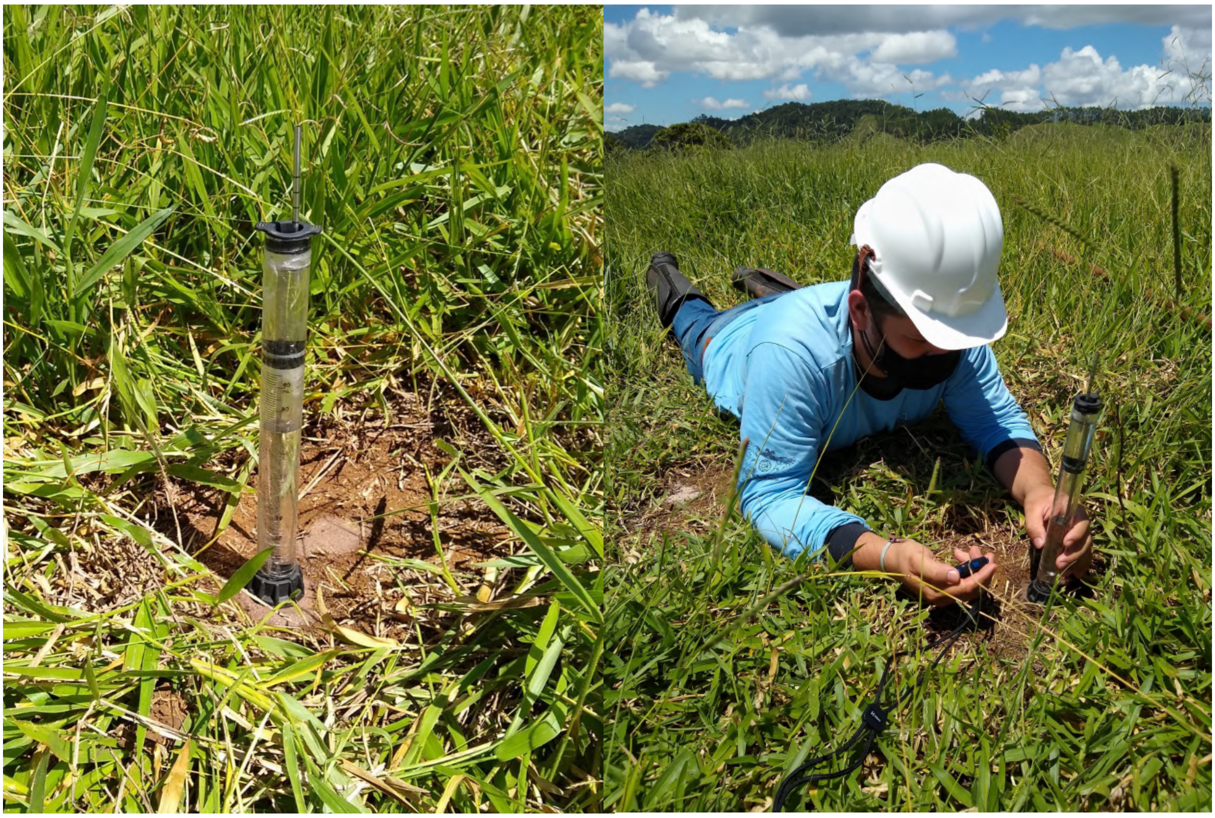

Figure 2. MiniDisk infiltrometer used for infiltration and soil water repellency measurements in the municipality of São Sebastião da Vargem Alegre, Minas Gerais, in 2022
Figura 2. Aparelho infiltrômetro MiniDisk usado nas medições de infiltração e repelência do solo à água no município de São Sebastião da Vargem Alegre, Minas Gerais, em 2022

To determine soil water repellency, ethanol sorptivity (Se) and water sorptivity (Sw) were calculated using Equations 1 and 2:

$$I = S_e\sqrt{t} \quad \text{(for ethanol)} \qquad \text{(Eq. 1)}$$

$$I = S_W\sqrt{t} \quad \text{(for water)} \qquad \text{(Eq. 2)}$$

where I is infiltration and t is time. Using the calculated sorptivity values, the repellency index (R) was determined using the Equation 3:

$$R = 1.95\ X\left(\frac{S_e}{S_w}\right) \qquad \text{(Eq. 3)}$$

as proposed by Tillman et al. (1989), with R expressed as a percentage (%).

Using infiltration (mm) and time (h) data generated by the manufacturer's software, infiltration rate and infiltration capacity were calculated in Microsoft Excel® spreadsheets (Cenachi, 2023). Infiltration rate was obtained by dividing infiltration by time (h), whereas infiltration capacity was calculated from cumulative infiltration and time values. The infiltration rate was considered when measurements began to stabilize, and the corresponding infiltration capacity was determined at the same stage. The obtained values represent infiltration behavior during the initial stages of the process evaluated using the MiniDisk infiltrometer.

Soil moisture was determined from samples collected from the 0–20 cm layer using a Dutch auger. Samples were placed in previously weighed aluminum containers, sealed, and transported to the Forest Hydrology Laboratory of the Federal University of Viçosa (UFV). Subsequently, the samples were weighed, oven-dried at 105 °C for five days, and weighed again to determine dry mass. Soil moisture content was calculated according to the procedures described in ABNT NBR 6457:2016.

Data normality was initially assessed using the Shapiro–Wilk test. Because the data did not meet the assumptions of normality, the non-parametric Mann–Whitney test was applied to compare treatments. All statistical analyses were performed using Microsoft Excel® and RStudio®.

3. RESULTS

The results of the hydrological and soil moisture analyses are presented as overall averages for the rehabilitated and reference areas, without distinguishing among areas 0610, 0630, and 0123. The statistical analyses and hydrological results for the evaluated variables are summarized in Table 1.

The presence of gravel in the areas rehabilitated by CBA may have contributed to greater pore continuity and facilitated water movement through the soil profile (Figure 3). Regarding infiltration rate, the rehabilitated areas exhibited a higher initial value than the reference areas, reaching 372.23 mm h^{-1} and 238.93 mm h^{-1}, respectively (Figure 4), suggesting that the rehabilitation practices adopted may have enhanced water infiltration.

Soil water repellency data are presented both as overall averages and individually for areas 0123, 0610, and 0630 under rehabilitated and reference conditions, illustrating the spatial variability of this property. Tables 2, 3, and 4 present soil water repellency values for each replicate (P1–P5) throughout the evaluation period. At the beginning of the test (t = 0 s), no repellency values were recorded because the first measurement was obtained after 30 s.

In the reference areas, soil water repellency generally increased over time, whereas the rehabilitated areas exhibited lower repellency values and reduced temporal variability (Figure 5).

4. DISCUSSION

The successful rehabilitation of mined areas is directly associated with appropriate soil management and the rapid re-establishment of vegetation cover, both of which are essential for soil conservation, maintenance of hydrological cycles, and the functional recovery of ecosystems. In this context, several studies have demonstrated that integrated management practices can promote significant improvements in soil physical, chemical, and biological attributes. Cavalcante (2023), for example, verified the feasibility of rehabilitating bauxite-mined areas through the integrated use of fertilizers, cover crops, and coffee cultivation. Among the evaluated species, brachiaria (*Urochloa*

Figure 3. Presence of gravel in the area rehabilitated by CBA, in the municipality of São Sebastião da Vargem Alegre, Minas Gerais, in 2024
Figura 3. Presença de cascalho na área reabilitada pela CBA, no município de São Sebastião da Vargem Alegre, Minas Gerais, em 2024

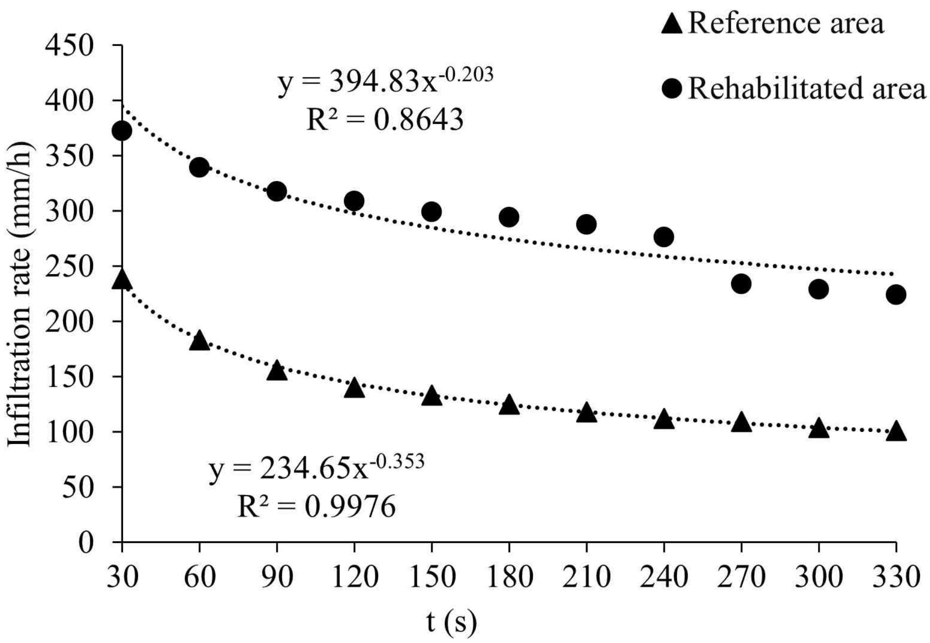

Figure 4. Water infiltration rate curves for the CBA rehabilitated area and the reference area in the municipality of São Sebastião da Vargem Alegre, Minas Gerais State, Brazil, in 2022
Figura 4. Comportamento da curva da taxa de infiltração de água no solo na área reabilitada pela CBA e na área de referência, no município de São Sebastião da Vargem Alegre, Minas Gerais, em 2022

Table 1. Statistical analysis results for infiltration rate (Ti), infiltration capacity (Ci), hydraulic conductivity (Ch), and soil moisture (Um) in reference and rehabilitated areas in the municipality of São Sebastião da Vargem Alegre, Minas Gerais State, Brazil, in 2022
Tabela 1. Resultado da análise estatística para as variáveis taxa de infiltração (Ti), capacidade de infiltração (Ci), condutividade hidráulica (Ch) e umidade (Um) para a área de referência e área reabilitada no município de São Sebastião da Vargem Alegre, Minas Gerais, em 2022

Variable	Unit	n	Area								U	p-value
			Reference				Rehabilitated					
			Min	Max	Avg	SD	Min	Max	Avg	SD		
Ti	mm/h	15	22.35	378.56	129.38	90.21	87.33	968.26	293.88	247.18	176	0.0075
Ci	mm/h	15	25.3	432.1	147.53	102.08	95.47	995.47	308.78	253.4	174	0.0099
Ch	mm/h	15	0.52	29.69	9.19	9.35	6.7	168.48	48.44	46.19	197	0.0002
Um	%	15	19.31	50.78	31.91	9.95	16.22	37.74	23.27	5.69	61	0.0329

U = Mann–Whitney test statistic.
U = teste estatístico de Mann-Whitney.

Table 2. Soil water repellency values (%) obtained in rehabilitated and reference area 0123 for replicates P1, P2, P3, P4, and P5, over a measurement period from 0 to 330 s, in the municipality of São Sebastião da Vargem Alegre, Minas Gerais State, Brazil, in 2022
Tabela 2. Valores de repelência (%) obtidos na área reabilitada e na área de referência 0123 para as repetições P1, P2, P3, P4 e P5, com tempo variando de 0 a 330 s, no município de São Sebastião da Vargem Alegre, Minas Gerais, em 2022

Time (s)	Rehabilitated area					Reference area				
	P1	P2	P3	P4	P5	P1	P2	P3	P4	P5
‘0	-	-	-	-	-	-	-	-	-	-
30	1.95	1.95	1.46	1.95	0.84	3.12	1.95	0.98	1.46	1.17
60	1.95	1.30	1.95	1.46	0.65	3.90	1.73	0.98	1.39	1.22
90	2.51	1.30	2.28	1.76	0.69	4.39	1.95	0.98	1.30	1.17
120	2.60	1.24	2.51	1.79	0.65	5.36	1.80	1.08	1.24	1.30
150	2.48	1.20	2.68	1.81	0.62	5.63	1.82	1.06	1.30	1.17
180	2.40	1.17	2.82	1.82	0.61	5.85	1.84	1.14	1.25	1.26
210	2.34	1.15	2.73	1.95	0.59	6.63	1.85	1.20	1.30	1.23
240	2.44	1.13	2.84	1.95	0.58	6.38	1.86	1.25	1.26	1.27
270	2.38	1.11	2.76	2.05	0.57	7.09	1.87	1.22	1.23	1.19
300	2.34	1.10	2.81	2.15	0.58	7.15	1.95	1.26	1.27	1.30
330	2.30	1.09	2.85	2.13	0.58	7.80	1.95	1.30	1.24	1.28
Mean	2.34	1.25	2.52	1.89	0.63	5.76	1.87	1.13	1.30	1.23
Overall Mean	1.73%					2.26%				

The symbol (-) was assigned to time zero (0). Measurements are recorded 30 seconds after the start of the test, every 30 seconds. R values ≤ 1 indicate non-repellent soils, and R values ≥ 1.95 indicate extremely repellent soils.

O símbolo (−) foi atribuído ao tempo zero (0). As medições são anotadas 30 segundos após o início do teste, a cada 30 segundos. Valores de R ≤ 1 indicam solos não repelentes, e valores de R ≥ 1,95 indicam solos extremamente repelentes.

Table 3. Soil water repellency values (%) obtained in the rehabilitated and reference areas of site 0610 for replicates P1, P2, P3, P4, and P5 during the 0–330 s evaluation period, in São Sebastião da Vargem Alegre, Minas Gerais State, Brazil, in 2022
Tabela 3. Valores de repelência (%) obtidos na área reabilitada e na área de referência 0610 para as repetições P1, P2, P3, P4 e P5, com tempo variando de 0 a 330 s, no município de São Sebastião da Vargem Alegre, Minas Gerais, em 2022

Time (s)	Rehabilitated area					Reference area				
	P1	P2	P3	P4	P5	P1	P2	P3	P4	P5
0	-	-	-	-	-	-	-	-	-	-
30	0.65	0.56	0.28	0.65	3.25	1.95	0.98	31.20	0.59	16.99
60	0.49	0.60	0.29	0.56	1.95	2.60	0.98	19.50	0.75	18.48

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Time (s)	Rehabilitated area					Reference area				
	P1	P2	P3	P4	P5	P1	P2	P3	P4	P5
90	0.56	0.69	0.30	0.35	1.95	2.34	1.17	25.35	0.80	17.31
120	0.50	0.57	0.26	0.42	1.79	2.60	0.98	33.15	0.84	16.18
150	0.55	0.59	0.27	0.33	1.82	2.44	1.11	27.30	0.94	15.19
180	0.57	0.53	0.28	0.44	1.84	2.60	1.22	23.40	0.98	14.86
210	0.59	0.57	0.29	0.39	1.85	2.73	1.13	27.30	1.01	14.50
240	0.60	0.58	0.33	0.34	1.86	2.44	1.06	30.23	1.03	14.13
270	0.59	0.56	-	0.34	1.87	2.60	1.14	33.15	1.05	13.77
300	0.60	0.58	-	0.32	1.88	2.51	1.13	29.64	1.07	13.43
330	0.62	0.60	-	0.38	1.82	2.60	1.11	31.98	1.09	13.10
Mean	0.57	0.58	0.29	0.41	1.99	2.49	1.09	28.38	0.92	15.27
Overall Mean			0.77%					9.63%		

The symbol (-) was assigned to time zero (0). Measurements are recorded 30 seconds after the start of the test, every 30 seconds. R values ≤ 1 indicate non-repellent soils, and R values ≥ 1.95 indicate extremely repellent soils.

O símbolo (−) foi atribuído ao tempo zero (0). As medições são anotadas 30 segundos após o início do teste, a cada 30 segundos. Valores de R ≤ 1 indicam solos não repelentes, e valores de R ≥ 1,95 indicam solos extremamente repelentes.

Table 4. Soil water repellency values (%) obtained in the rehabilitated and reference areas of site 0630 for replicates P1, P2, P3, P4, and P5 during the 0–330 s evaluation period, in São Sebastião da Vargem Alegre, Minas Gerais State, Brazil, in 2022
Tabela 4. Valores de repelência (%) obtidos na área reabilitada e na área de referência 0630 para as repetições P1, P2, P3, P4 e P5, com tempo variando de 0 a 330 s, no município de São Sebastião da Vargem Alegre, Minas Gerais, em 2022

Time (s)	Rehabilitated area					Reference area				
	P1	P2	P3	P4	P5	P1	P2	P3	P4	P5
0	-	-	-	-	-	-	-	-	-	-
30	1.63	7.80	1.30	2.60	0.98	4.88	6.83	10.14	6.50	3.90
60	1.37	3.90	1.30	2.73	0.98	5.85	7.15	7.37	6.24	3.90
90	1.35	2.73	1.30	2.51	1.06	4.88	6.83	7.45	6.13	4.33
120	1.22	2.93	1.24	2.38	1.05	5.07	6.63	7.80	6.34	4.61
150	1.23	3.06	1.25	2.73	1.10	4.46	6.50	8.06	6.50	4.88
180	1.21	2.60	1.26	2.44	1.19	4.63	7.80	8.26	6.38	5.40
210	1.14	2.73	1.23	2.37	1.11	5.12	7.52	8.42	7.09	5.46
240	1.20	2.66	1.15	2.73	1.19	5.20	8.36	9.24	7.15	5.85
270	1.18	2.40	1.22	2.64	1.17	5.63	8.04	9.29	7.20	6.42
300	1.17	2.37	1.16	2.71	1.23	6.07	8.78	10.21	7.80	7.11
330	1.16	2.47	1.14	2.63	1.17	6.36	8.95	10.17	8.40	7.37
Mean	1.26	3.24	1.23	2.59	1.11	5.29	7.58	8.76	6.88	5.38
Overall Mean			1.89%					6.78%		

The symbol (-) was assigned to time zero (0). Measurements are recorded 30 seconds after the start of the test, every 30 seconds. R values ≤ 1 indicate non-repellent soils, and R values ≥ 1.95 indicate extremely repellent soils.

O símbolo (−) foi atribuído ao tempo zero (0). As medições são anotadas 30 segundos após o início do teste, a cada 30 segundos. Valores de R ≤ 1 indicam solos não repelentes, e valores de R ≥ 1,95 indicam solos extremamente repelentes.

spp.) stood out for substantially increasing the Soil Quality Index (SQI), particularly under fertilized conditions, thereby enhancing the recovery of the physical, chemical, and organic properties of the substrate. Complementarily, Balestrin et al. (2025) observed that assisted natural regeneration efficiently promotes the

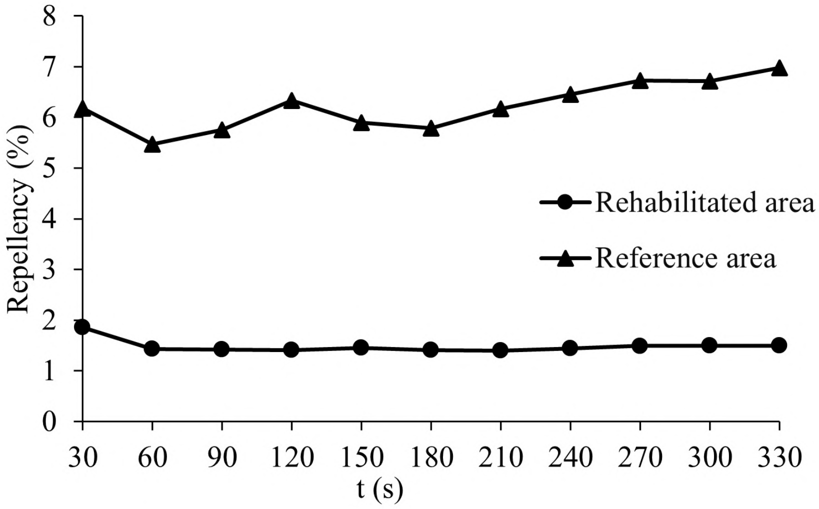

Figure 5. Soil water repellency curves for the rehabilitated and reference areas in the municipality of São Sebastião da Vargem Alegre, Minas Gerais State, Brazil, in 2022
Figura 5. Comportamento da curva de repelência à água do solo na área reabilitada e na área de referência, no município de São Sebastião da Vargem Alegre, Minas Gerais, em 2022

recovery of vegetation cover and soil attributes in mined areas. Fonseca et al. (2023) also demonstrated that green manure contributes to the physical, chemical, and biological recovery of soils while promoting important ecosystem services, such as protecting the soil surface from direct raindrop impact and reducing erosive processes.

The results of the present study demonstrate that rehabilitation practices applied in bauxite-mined areas promoted substantial improvements in key soil hydrological attributes, particularly water infiltration, hydraulic conductivity, and soil water repellency. Mean hydraulic conductivity, infiltration rate, and infiltration capacity were significantly higher in rehabilitated areas than in reference areas, with increases of 427%, 130%, and 109%, respectively.

Although related, infiltration rate and hydraulic conductivity represent distinct attributes of soil hydrological behavior. Infiltration rate describes the intensity at which water enters the soil over time, whereas hydraulic conductivity expresses the soil's capacity to transmit water under a given hydraulic gradient. Therefore, structural changes promoted by rehabilitation can simultaneously influence both variables, although their controlling mechanisms and temporal dynamics are not identical.

Water infiltration into the soil depends on multiple factors, including soil structure, aggregate stability, surface roughness, bulk density, pore connectivity, vegetation cover, soil moisture, and management practices (Bertol et al., 2015; Brandão et al., 2012; Vereecken et al., 2019). When these attributes are degraded, water entry into the soil is restricted, reducing water storage and increasing the potential for surface runoff generation. Thus, the higher infiltration rate and infiltration capacity observed in rehabilitated areas indicate that the adopted practices were effective in restoring soil hydrological functioning.

Despite the higher values observed in rehabilitated areas, the large standard deviations recorded for infiltration rate, infiltration capacity, and hydraulic conductivity indicate considerable spatial variability in these attributes, possibly associated with the heterogeneous pore network formed after rehabilitation interventions. Local differences in macropore distribution and connectivity directly influence infiltration and near-saturated hydraulic conductivity, potentially resulting in contrasting hydrological responses even within the same management area (Kelishadi et al., 2014). In this context, soil disturbance associated with gravel incorporation (Silveira, 2017) may have promoted the formation of larger pores and increased surface roughness, reducing soil sealing and facilitating water entry. Unsaturated hydraulic conductivity, estimated using the MiniDisk infiltrometer, represents the soil's capacity to transmit water under tension conditions and is strongly influenced by pore distribution, connectivity, and continuity (Macedo et al., 2017). The higher values observed in rehabilitated areas suggest more favorable conditions for water movement through the soil profile during the initial stages of infiltration assessed by the MiniDisk infiltrometer.

The maximum infiltration rates recorded in some rehabilitated areas exceeded 900 mm h^{-1}. However, these values represent point measurements obtained during the initial stages of infiltration under controlled tension conditions imposed by the MiniDisk infiltrometer. In well-structured soils with high pore continuity and efficient internal drainage, elevated initial water-entry rates may occur locally and do not necessarily represent steady-state infiltration under prolonged rainfall events. Consequently, such values should be interpreted as indicators of soil hydraulic functioning under the specific measurement conditions rather than as direct estimates of infiltration behavior throughout an entire rainfall event.

The considerable depth, natural drainage, and granular structure of Oxisols naturally favor infiltration and vertical water flow, allowing high initial water-entry rates when associated with favorable soil structural conditions (Borges, 2013; Embrapa, 2018; Sartori et al., 2005). In addition to these intrinsic characteristics of Oxisols, Cenachi (2023) highlighted that conditions created through rehabilitation may also contribute to increased infiltration.

The results obtained are consistent with previous studies addressing hydrology in post-bauxite-mining environments. Silveira (2017), evaluating bauxite-mined areas in the Zona da Mata region of Minas Gerais, found that rehabilitated areas exhibited hydrological behavior similar to that of natural areas. Similar results were reported by Spletozer et al. (2022; 2024), who observed not only the restoration of infiltration in rehabilitated areas but also a substantial reduction in surface runoff, reaching values up to fourteen times lower than those observed before mining activities. Tang et al. (2019) emphasized that soils with greater infiltration capacity tend to generate less surface runoff and exhibit lower susceptibility to erosion.

In the reference areas, lower infiltration values indicate physical restrictions to water flow. These areas were predominantly covered by brachiaria (*Urochloa* spp.), used for grazing and subjected to animal trampling, a condition that promotes surface compaction and reduces soil macroporosity. Brito et al. (2019), evaluating riparian forest areas converted to pasture using a MiniDisk infiltrometer, reported significantly higher infiltration rates in natural areas (556.9 mm h^{-1}) compared with pasture areas (242 mm h^{-1}). According to the authors, the reduction in infiltration resulted from surface compaction caused by livestock management, a situation similar to that observed in the reference areas of the present study. Kelishadi et al. (2014) reported higher hydraulic conductivity values in agricultural areas (91.23 mm h^{-1}) and lower values in pasture areas (44.06 mm h^{-1}), attributing these differences to the greater frequency and connectivity of macropores in agricultural soils and the higher degree of compaction observed in pasturelands, factors that directly influence soil water movement. Klein & Klein (2014) emphasized that conservation practices and management systems that minimize compaction tend to substantially increase infiltration and reduce surface water losses.

In addition to the effects on infiltration and hydraulic conductivity, a substantial reduction in soil water repellency was observed. In general, the reference areas exhibited higher repellency indices than the rehabilitated areas. The reference areas showed an average repellency of 6.22%, whereas the rehabilitated areas presented an average value of 1.48%, corresponding to a 77% reduction in soil repellency. This result indicates that the interventions adopted during rehabilitation contributed to reducing the expression of soil hydrophobicity, thereby creating more favorable conditions for water infiltration compared with non-rehabilitated areas.

In area 0610, the rehabilitated site exhibited repellency in only one of the evaluated replicates, resulting in an overall mean value of 0.77%, indicating the virtual absence of this property. Compared with the reference area, this result corresponds to an approximate 92% reduction in soil repellency, demonstrating the effectiveness of rehabilitation practices in mitigating soil hydrophobicity. In contrast, the reference area recorded high values at specific sampling points, reaching an average of 9.63%, which classifies the soil as extremely water repellent according to the classification proposed by Tillman et al. (1989). This behavior may be associated with the predominant vegetation cover, composed of molasses grass and brachiaria. Molasses grass produces large amounts of biomass, and its decomposition releases organic compounds into the soil. In addition, oils secreted by the glandular hairs of this species (Chagas, 2001) may contribute to increased hydrophobicity during the decomposition process.

In area 0630, indications of water repellency were observed in both the rehabilitated and reference areas. However, the highest values occurred in the reference area, classifying the soil as extremely water repellent according to the criteria established by Tillman et al. (1989).

Unlike areas 0610 and 0630, area 0123 presented relatively similar mean repellency values under rehabilitated and reference conditions, indicating that the response of soil hydrophobicity to rehabilitation practices may vary spatially according to local soil characteristics and vegetation cover.

Water repellency exhibited high spatial and temporal variability throughout the evaluation period, corroborating the findings of Vogelmann et al. (2015b), who highlighted the difficulty of establishing consistent patterns of hydrophobicity distribution in soils due to its pronounced heterogeneity. This behavior is associated with the partial or complete coating of soil particles and pore surfaces by hydrophobic compounds, resulting in different levels of water repellency (Mattos et al., 2022). Because it is a transient property, soil hydrophobicity may change over short time intervals and often exhibits a reversible character (Oliveira et al., 2023; Lozano-Baez et al., 2020). Similar results were reported by Wang et al. (2025), who evaluated soil water repellency in four pasture areas in China and observed wide spatial variation, with values ranging from 65.78% to 100%.

In addition to this heterogeneous behavior, the distribution of hydrophobic compounds also influences the intensity of soil repellency. In this regard, Vogelmann et al. (2015a) emphasized that the homogenization of these compounds tends to reduce soil hydrophobicity. This mechanism may partially explain the lower repellency observed in the rehabilitated areas. Soil water repellency reduces or delays infiltration, resulting in water accumulation at the soil surface, which may subsequently be lost through evaporation or surface runoff (Davis & Park, 2024; Hewelke et al., 2022). This phenomenon directly affects the rate of water entry into the soil and is particularly critical in highly hydrophobic soils (Alagna et al., 2019). In the present study, the reference areas, characterized by higher repellency indices, exhibited lower infiltration rates during the MiniDisk infiltrometer tests, whereas the rehabilitated areas presented higher values, highlighting the influence of hydrophobicity on the initial infiltration process. Carvalho (2024) reported a positive correlation between soil wetting resistance, surface runoff, and sediment production, with more hydrophobic soils generating greater runoff and sediment yields.

Soil moisture also influences water repellency. Drier soils tend to exhibit greater hydrophobicity, whereas increasing moisture content generally reduces this behavior (Simkovic et al., 2023). In the present study, the reference areas showed a higher mean moisture content (32%) than the rehabilitated areas (24%).

Although the reference areas exhibited higher moisture contents, the greater repellency indices observed suggest that factors related to soil composition, vegetation cover, and the presence of hydrophobic compounds exerted a stronger influence on this property than soil moisture alone. The lower moisture contents observed in rehabilitated areas may be associated with greater water entry and redistribution within the soil profile. Under these conditions, water can percolate more rapidly into deeper layers, reducing its residence time in the surface

Revista ÁRVORE
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layer evaluated. These findings demonstrate that soil water repellency is controlled by the interaction of multiple factors and cannot be explained exclusively by soil moisture conditions at the time of assessment.

Mielnik et al. (2021) emphasized that soil moisture directly affects soil physical, chemical, and biological properties. Brito et al. (2022), studying a tropical riparian forest in the Federal District of Brazil using a MiniDisk infiltrometer, observed greater repellency during the dry season and virtually no repellency during the rainy season. Similar results were reported by Oliveira et al. (2023), who observed increased repellency during less rainy months in the Brazilian Cerrado. Confessor et al. (2024) also found a progressive reduction in repellency following the onset of soil wetting, promoting increased infiltration. To date, no studies have been identified that evaluated soil water repellency in bauxite-mined areas using the MiniDisk infiltrometer.

Taken together, the results indicate that the rehabilitation practices adopted promoted significant improvements in soil hydrological attributes by increasing initial infiltration rates, enhancing unsaturated hydraulic conductivity, and reducing the expression of soil hydrophobicity. These processes constitute essential components for the restoration of ecohydrological functionality and the long-term sustainability of bauxite-mined landscapes.

5. CONCLUSION

The rehabilitation of bauxite-mined areas promoted significant improvements in soil hydrological attributes, as evidenced by higher infiltration rates, infiltration capacity, and unsaturated hydraulic conductivity, together with reduced soil water repellency compared with the reference areas. These findings demonstrate the effectiveness of the rehabilitation practices in restoring soil hydrological functionality by enhancing water entry, redistribution, and movement throughout the soil profile.

The lower hydrophobicity observed in the rehabilitated areas indicates more favorable conditions for water infiltration and soil water dynamics, potentially contributing to water percolation through the soil profile and local groundwater recharge processes.

In addition to demonstrating the benefits of rehabilitation, this study expands current knowledge regarding the application of the MiniDisk Infiltrometer in mined and rehabilitated areas, a topic that remains poorly explored in the scientific literature. The findings highlight the need for further research to improve understanding of the use of this equipment and of hydrological processes under different rehabilitation conditions.

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AUTHOR CONTRIBUTIONS

Cenachi, H. de A.: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Visualization, Writing – Original Draft, Writing – Review & Editing; Dias, H. C. T.: Conceptualization, Methodology, Resources, Supervision, Validation, Formal Analysis, Writing – Review & Editing; Lino, B. F. G.: Investigation, Data Curation, Writing – Review & Editing; Souza, B. Q. de: Data Curation, Visualization, Writing – Review & Editing; Paiva, J. M. de: Investigation, Writing – Review & Editing; Cordeiro, P. C. M.: Investigation, Writing – Review & Editing; Almeida, R. S. de: Validation, Writing – Review & Editing; Azevedo, M. de A.: Validation, Writing – Review & Editing; Leite, H. G.: Formal Analysis, Validation, Writing – Review & Editing.

DATA AVAILABILITY

The entire dataset supporting the findings of this study has been published within the article.

7. REFERENCES

Associação Brasileira de Normas Técnicas - ABNT. (2016). *ABNT NBR 6457:2016: Amostras de solo: Preparação para ensaios de compactação e ensaios de caracterização*. ABNT.

Alagna, V., Lovino, M., Bantarello, V., Mataix-Solera, J., & Lichner, L. (2019). Alternative analysis of transient infiltration experiment to estimate soil water repellency. *Hydrological Processes, 33*(4), 661–674. https://doi.org/10.1002/hyp.13352

Albuquerque, A. W., Neto, F. L., Srinivasan, V. S., & Santos, J. R. (2002). Manejo da cobertura do solo e de práticas conservacionistas nas perdas de solo e água em Sumé, PB. *Revista Brasileira de Engenharia Agrícola e Ambiental, 6*(1), 136–141. https://doi.org/10.1590/S1415-43662002000100024

Alvares, C. A., Stape, J. L., Sentelhas, P. C., Moraes Gonçalves, J. L. de, & Sparovek, G. (2013). Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift, 22*(6), 711–728. https://doi.org/10.1127/0941-2948/2013/0507

Balestrin, D., Martins, S. V., & Fonseca, W. da S. da. (2025). Regeneração natural como técnica para restaurar uma área após mineração de bauxita em Minas Gerais, Sudeste do Brasil. *Revista Thema, 24*(2), 1–16. https://doi.org/10.15536/revistathema.24.2025.3568

Bertol, I., Barbosa, F. T., Bertol, C., & Luciano, R. V. (2015). Water infiltration in two cultivated soils in southern Brazil. *Revista Brasileira de Ciência do Solo, 39*(2), 573–588. https://doi.org/10.1590/01000683rbcs20140304

Borges, S. R. (2013). *Qualidade do solo em áreas em recuperação com forrageiras e cafeeiro pós-mineração de bauxita* (Tese de doutorado, Universidade Federal de Viçosa).

Brandão, V. S., Cecílio, R. A., Pruski, F. F., & Silva, D. D. (2012). *Infiltração da água no solo* (3ª ed.). Editora UFV.

Brito, G. Q., Sampaio, J. A. G., Luiz, G. P., Melo, A. C. V., Simões, V. P., Martins, P. R., Neves, G., Murta, J. R. M., Mendonça Filho, S. F., Carvalho Júnior, A. F., Vieira, L. C. G., Teixeira, A. C. O., & Salemi, L. F. (2019). Efeitos da conversão de floresta ripária em pastagem sobre as propriedades físico-hídricas do solo. *Espaço e Geografia, 22*(1), 73–89. https://doi.org/10.26512/2236-56562019e40154

Brito, G. Q., Murta, J. R. M., Mendonça Filho, S. F., & Salemi, L. F. (2022). Can rainfall seasonality trigger soil water repellency in a tropical riparian forest? *Journal of Forestry Research, 34*(3), 773–780. https://doi.org/10.1007/s11676-022-01501-5

Carvalho, L. B. O. (2024). *Eficácia do uso de geossintéticos na mitigação da erosão do solo pós-incêndio florestal* (Dissertação de mestrado, Universidade de Coimbra).

Cavalcante, D. M., Silva, I. R. da, & Oliveira, T. S. de. (2023). Soil quality indicators for monitoring the short-term effects of mined soil rehabilitation strategies for bauxite. *Revista Brasileira de Ciência do Solo, 47*, 1–22. https://doi.org/10.36783/18069657rbcs20220126

Cenachi, H. A. (2023). *Efeito da reabilitação de áreas de mineração de bauxita na infiltração e na repelência do solo à água* (Dissertação de mestrado, Universidade Federal de Viçosa). https://doi.org/10.47328/ufvbbt.2023.694

Chagas, A. C. S. (2001). *Efeito acaricida de produtos naturais e sintéticos de plantas e solventes sobre Boophilus microplus (Canestrini, 1887) (Acari: Ixodidae)* (Tese de doutorado, Universidade Federal de Minas Gerais).

Chávez, A. G. T., Kientz, D. G., & Fernández, E. E. (2014). *Manual de infiltrometría: Infiltrometro de tensión INDI*. Instituto de Ecología.

Confessor, J. G., Silva, L. L., Lima, N. A. R., & Santos, A. B. P. (2024). Dinâmica hídrica do solo de zona ripária do Chapadão do Diamante–Serra da Canastra, Minas Gerais. *Sociedade & Natureza, 36,* e72336. https://doi.org/10.14393/SN-v36-2024-72336

Cugula, J. S., Araujo, R. A., Freire, L. S., Paschoal, J. P., Morgado, C. R. V., & Esteves, E. M. M. (2021). Análise temporal da recuperação de área de mineração em Paragominas pela técnica de regeneração natural por meio de índices de vegetação. *Journal of Environmental Analysis and Progress, 6*(4), 379–395. https://doi.org/10.24221/jeap.6.4.2021.3676.379-395

Davis, P., & Park, D. M. (2024). Food security in a changing climate starts with managing soil water repellency. *Geoderma, 447,* 116922. https://doi.org/10.1016/j.geoderma.2024.116922

Empresa Brasileira de Pesquisa Agropecuária - EMBRAPA. (2018). *Sistema brasileiro de classificação de solos* (5ª ed.). Embrapa Solos.

Fonseca, W. da S., Martins, S. V., & Villa, P. M. (2023). Green manure as an alternative for soil recovery in a bauxite mining environment in Southeast Brazil. *Floresta e Ambiente, 30*, e20220041. https://doi.org/10.1590/2179-8087-FLORAM-2023-0041

Freitas, J. P. O. (2018). *Processos hidrológicos em área de mineração de bauxita na Zona da Mata de Minas Gerais* (Tese de doutorado, Universidade Federal de Viçosa).

Grant, C. D., Ward, S. C., & Morley, S. C. (2007). Return of ecosystem function to restored bauxite mines in Western Australia. *Restoration Ecology, 15*(Suppl. 4), S94–S103. https://doi.org/10.1111/j.1526-100X.2007.00297.x

Hewelke, E., Gozdowski, D., Korc, M., Małuszyńska, I., Górska, E. B., Sas, W., & Mielnik, L. (2022). Influence of soil moisture on hydrophobicity and water sorptivity of sandy soil no longer under agricultural use. *Catena, 208*, 105780. https://doi.org/10.1016/j.catena.2021.105780

Instituto Brasileiro de Mineração - IBRAM. (2025). *Contribuição da indústria da mineração para o G20: Construindo um mundo justo e um planeta sustentável*. https://ibram.org.br/publicacoes/

Kelishadi, H., Mosaddeghi, M. R., Hajabbasi, M. A., & Ayoubi, S. (2014). Near-saturated soil hydraulic properties as influenced by land use management systems in Koohrang region of central Zagros, Iran. *Geoderma, 213*, 426–434. https://doi.org/10.1016/j.geoderma.2013.08.008

Klein, C., & Klein, V. A. (2014). Influência do manejo do solo na infiltração de água. *Revista Monografias Ambientais, 13*(5), 3915–3925. https://doi.org/10.5902/2236130814989

Lozano-Baez, S. E., Cooper, M., Ferraz, S. F. B., Rodrigues, R. R., Lassabatere, L., Castellini, M., & Prima, S. (2020). Assessing water infiltration and soil water repellency in Brazilian Atlantic Forest soils. *Applied Sciences, 10*(6), 1950. https://doi.org/10.3390/app10061950

Macedo, S. F. S., Grimaldi, M., Medina, C. C., Cunha, J. E., Guimarães, M. F., & Tavares Filho, J. (2017). Physical properties of soil structures identified by the Profil Cultural under two soil management systems. *Revista Brasileira de Ciência do Solo, 41*, e0160503. https://doi.org/10.1590/18069657rbcs20160503

Maia, C. B. F., Dedecek, R., & Malucelli, C. S. (2005). *Identificação de repelência à água em solos sob plantios florestais* (Comunicado Técnico). Embrapa Florestas.

Mao, J., Nierop, K. G. J., Dekker, S. C., Dekker, L. W., & Chen, B. (2019). Understanding the mechanisms of soil water repellency from nanoscale to ecosystem scale: A review. *Journal of Soils and Sediments, 19*(1), 171–185. https://doi.org/10.1007/s11368-018-2195-9

Mattos, B. S., Bertolino, A. V. F. A., & Bertolino, L. C. (2022). A influência do fogo nas propriedades de um solo sob manejo de agricultura de corte e queima em ambiente serrano no bioma de Mata Atlântica. *Sociedade & Natureza, 34*, e63656. https://doi.org/10.14393/SN-v34-2022-63656

Meter Group. (2025). Mini Disk: Condutividade hidráulica insaturada. https://metergroup.com.br/agraria/produtos/minidisk/

Mielnik, L., Hewelke, E., Weber, J., Oktaba, L., Jonczak, J., & Podlasiński, M. (2021). Changes in the soil hydrophobicity and structure of humic substances in sandy soil taken out of cultivation. Agriculture, *Ecosystems & Environment, 319*, 107554. https://doi.org/10.1016/j.agee.2021.107554

Nimmo, J. R., & Voss, P. R. (2023). Improved calculation of hydraulic conductivity for small disk tension infiltrometers. *Water Resources Research, 59*, e2022WR032475. https://doi.org/10.1029/2022WR032475

Oliveira, J. F. de L., Mendonça Filho, S. F., & Salemi, L. F. (2023). Soil water repellency in the Brazilian neotropical savanna: First detection, seasonal effect, and influence on infiltrability. *Environmental Monitoring and Assessment, 195*(12), 1504. https://doi.org/10.1007/s10661-023-12097-6

Pavão, L. L. (2017). *Caracterização dos atributos físico-hídricos do solo da área de Acuri Pantanal Mato-Grossense* (Dissertação de mestrado, Universidade Federal de Mato Grosso).

Perera, H. T. M., Mori, Y., Maeda, M., & Leelamanie, D. A. L. (2024). Heat-induced alterations in moisture-dependent repellency of water-repellent forest soils: A laboratory approach with Japanese Andosols. *Journal of Hydrology and Hydromechanics, 72*(1), 25–33. https://doi.org/10.2478/johh-2023-0035

Ribas, M. S. (2018). *Hidrofobicidade e sua interação com as propriedades hídricas do solo* (Trabalho de conclusão de curso, Universidade Federal Rural de Pernambuco).

Sartori, A., Lombardi Neto, F., & Genovez, A. M. (2005). Classificação hidrológica de solos brasileiros para a estimativa da chuva excedente com o método do Serviço de Conservação do Solo dos Estados Unidos. Parte 1: Classificação. *Revista Brasileira de Recursos Hídricos, 10*(4), 5–18. https://doi.org/10.21168/rbrh.v10n4.p5-18

Shenga, J. A. H. (2019). *Efeito das características hidrológicas do solo e da época de sementeira no rendimento de duas variedades de milho* (*Zea mays* L.) (Dissertação de mestrado, Universidade do Porto).

Spletozer, A. G. (2022). *Monitoramento e predição do escoamento superficial em minas a céu aberto com foco na extração de bauxita* (Tese de doutorado, Universidade Federal de Viçosa). https://doi.org/10.47328/ufvbbt.2022.322

Spletozer, A. G., Fernandes Filho, E. I., Martini, A., Bramorski, J., Tonello, K. C., & Dias, H. C. T. (2024). Surface runoff in six years of rehabilitation of two areas after bauxite mining in Southeastern Brazil. *Ecological Engineering, 202*, 107231. https://doi.org/10.1016/j.ecoleng.2024.107231

Silveira, L. J. (2017). *Escoamento superficial em áreas de mineração de bauxita, pré e pós-lavra, na Zona da Mata Mineira* (Dissertação de mestrado, Universidade Federal de Viçosa). http://www.locus.ufv.br/handle/123456789/15186

Simkovic, I., Dlapa, P., & Schwarzinger, C. (2023). Elucidating the composition of organic matter in water-repellent forest soils using analytical pyrolysis combined with gas chromatography–mass spectrometry (Py-GC–MS). *Organic Geochemistry, 179*, 104586. https://doi.org/10.1016/j.orggeochem.2023.104586

Sousa, F. R. C. de, & Paula, D. P. de. (2019). Análise de perda do solo por erosão na Bacia Hidrográfica do Rio Coreaú (Ceará-Brasil). *Revista Brasileira de Geomorfologia, 20*(3), 491–507. https://doi.org/10.20502/rbg.v20i3.1393

Tang, B., Jiao, J., Yan, F., & Li, P. (2019). Variations in soil infiltration capacity after vegetation restoration in the hilly and gully regions of the Loess Plateau, China. *Journal of Soils and Sediments, 19*, 1456–1466. https://doi.org/10.1007/s11368-018-2121-1

Tillman, R. W., Scotter, D. R., Wallis, M., & Clothier, B. E. (1989). Water repellency and its measurement using intrinsic sorptivity. *Australian Journal of Soil Research, 27*(4), 637–644. https://doi.org/10.1071/SR9890637

Vereecken, H., Weihermüller, L., Assouline, S., Šimůnek, J., Verhoef, A., Herbst, M., Archer, N., Mohanty, B., Montzka, C., Vanderborght, J., Balsamo, G., Bechtold, M., Boone, A., Chadburn, S., Cuntz, M., Decharme, A., Ducharne, A., Ek, M., Garrigues, S., Goergen, ... & Xue, Y. (2019). Infiltration from the pedon to global grid scales: An overview and outlook for land surface modeling. *Vadose Zone Journal, 18*(1), 1–53. https://doi.org/10.2136/vzj2018.10.0191

Vogelmann, E. S., Reichert, J. M., Prevedello, J., Awe, G. O., & Cerdà, A. (2017). Soil moisture influences sorptivity and water repellency of topsoil aggregates in native grasslands. *Geoderma, 305*, 374–381. https://doi.org/10.1016/j.geoderma.2017.06.024

Vogelmann, E. S., Reichert, J. M., Prevedello, J., Awe, G. O., & Reinert, D. J. (2015a). Hidrofobicidade do solo: Estudo comparativo dos métodos usuais de determinação. *Ciência Rural, 45*(2), 260–266. https://doi.org/10.1590/0103-8478cr20140042

Vogelmann, E. S., Prevedello, J., & Reichert, J. M. (2015b). Origem dos compostos hidrofóbicos e seus efeitos em florestas de *Pinus* e *Eucalyptus*. *Ciência Florestal, 25*(4), 1067–1079. https://doi.org/10.5902/1980509820670

Vogelmann, E. S. (2014). *Relações da matéria orgânica com a hidrofobicidade do solo* (Tese de doutorado, Universidade Federal de Santa Maria).

Wang, J., Wang, W., Ren, X., Wu, Q., Chai, X., Qu, Y., Xu, X., & Du, F. (2025). Aliphatic carbon regulates soil water repellency in a chronosequence of grassland enclosure in the Loess Hilly Region. *Soil and Tillage Research, 246,* 106356. https://doi.org/10.1016/j.still.2024.106356

Zhang, R. (1997). Determination of soil sorptivity and hydraulic conductivity from the disk infiltrometer. *Soil Science Society of America Journal, 61*(4), 1024–1030. https://doi.org/10.2136/sssaj1997.03615995006100040005x