

SALINITY OF THE SOIL AND THE RISK OF DESERTIFICATION IN THE SEMIARID REGION

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Abstract

The salinity of the soils is one of the problems that most contribute to the degradation of the soils of the regions susceptible to desertification. This problem is present in many parts of the world, including Brazil. In this context, the objective of this article is to analyze the process of salinity of the soils in different land uses in municipalities of the Mesoregion of São Francisco (semi-arid of the State of Pernambuco). For this, samples of soils collected on diverse uses and occupations of the lands were submitted to chemical tests besides the identification of the class of soil to which each sample belongs. The results indicate that the areas on irrigated agriculture present the main sources of salinity, mainly in the places where the irrigation is performed through underground water. Unidentified problem on the samples collected in the Caatinga and partially found on the areas of exposed soils and those submitted to temporary agriculture (dryland). In the study region, inadequate agricultural management is one of the main responsible for salinity of the soils, and the impacts contribute to the increase of the risks to local desertification.

Keywords: Soil degradation; Salinization; Semi-arid; Desertification.

Resumo / Resumen

SALINIDADE DO SOLO E RISCO DE DESERTIFICAÇÃO NA REGIÃO SEMIÁRIDA

A salinização dos solos é um dos problemas que mais contribuem para degradação dos solos das regiões suscetíveis à desertificação. Problema presente em várias partes do mundo inclusive no Brasil. Nesse contexto, o objetivo desse artigo é analisar o processo de salinização dos solos em diferentes usos das terras em municípios da Mesorregião do São Francisco Pernambucano (semiárido do estado de Pernambuco). Para isso, amostras de solos coletadas sobre diversificados usos e ocupações das terras, foram submetidas a testes químicos além da identificação da classe de solo a qual pertence cada amostra. Os resultados indicam que as áreas sobre agricultura irrigada apresentam os principais focos de salinização, principalmente nos locais onde a irrigação é desenvolvida através de água subterrânea. Problema não identificado sobre as amostras coletadas nas caatingas e, parcialmente encontrados sobre as áreas de solos expostos e as submetidas à agricultura temporária (sequeiro). Na região de estudo o manejo agrícola inadequado é um dos principais responsáveis pela salinização dos solos e, os impactos contribuem para ampliação dos riscos à desertificação local.

Palavras-chave: Degradação dos solos; Salinização; Semiárido; Desertificação.

SALINIDAD DEL SUELO Y RIESGO DE DESERTIFICACIÓN EN LA REGIÓN SEMIÁRIDA

La salinización de los suelos es uno de los problemas que más contribuyen a la degradación de los suelos de las regiones susceptibles a la desertificación. Problema presente en varias partes del mundo incluso en Brasil. En este contexto, el objetivo de este artículo es analizar el proceso de salinización de los suelos en diferentes usos de las tierras en municipios de la Mesoregión del San Francisco (semiárido del Estado de Pernambuco). Pernambucano. Para ello, muestras de suelos recolectadas sobre diversos usos y ocupaciones de las tierras, fueron sometidas a pruebas químicas además de la identificación de la clase de suelo a la que pertenece cada muestra. Los resultados indican que las áreas sobre agricultura irrigada presentan los principales focos de salinización, principalmente en los lugares donde la irrigación es desarrollada a través de agua subterránea. Problema no identificado sobre las muestras recogidas en las caatingas y, parcialmente encontradas sobre las áreas de suelos expuestos y las sometidas a la agricultura temporal. En la región de estudio el manejo agrícola inadecuado es uno de los principales responsables de la salinización de los suelos y los impactos contribuyen a la ampliación de los riesgos a la desertificación local.

Palabras-clave: Degradación del suelo; Salinización; Semiárido; Desertificación.

INTRODUCTION

Desertification is a dynamic process developed from land degradation in arid, semi-arid, and dry sub-humid areas of the world, resulting from the environmental characteristics of these areas, as well as from the anthropic practices of resource exploitation in the mentioned areas. (UNNCCD, 2014).

It is estimated that much of the land located in dry climates present problems or marked risks to desertification (D'ODORICO et al., 2013). You can name cities such as Mexico (BECERRIL-PIÑA et al., 2015); India (VARGHESE & SINGH, 2016) and in other parts of the world. In Brazil, the scenario is no different. In the Brazilian region where the climate can be considered semi-arid, the risks of desertification are eminent, and in some places the degree of land degradation is so severe that they have become a desertification core. (BRASIL, 2007; PEREZ-MARIN et al., 2012).

Something in common unites more than half of the risk areas, or in an advanced state of desertification, it is the dynamics of land use and occupation. According to D'ODORICO et al. (2013), the use of agricultural land and dry forests without proper planning and management favors the degradation of soils and the reduction of biodiversity in these environments. Among the engines of desertification is soil salinization, which is the result of the accumulation of soluble salts in the arable land layers (LUO et al., 2017). As a consequence, there is plant poisoning and increased osmotic pressure on the vegetation inserted in salinized areas. (PEDROTTI, 2015; GKIOUGKIS et al., 2015), resulting in vegetation cover and agricultural production losses.

The salinization process is due to environmental characteristics and anthropic actions (DALIAKOPOULOS et al., 2016). Natural characteristics include the transport of salt sediments from salinized areas to unsalted sites; actions of ascent by capillarity of the soils to surface; high rates of evapotranspiration, among other factors (RIBEIRO, 2010; BRADY & WEIL, 2012; PEDROTTI, 2015; WALTER et al., 2018).

The human actions that contribute to salt accumulation are varied, highlighting: the use of water containing high quantities of salts (DALIAKOPOULOS et al., 2016); irrigation practice without drainage system; application of fertilizers and pesticides with a high salt concentration in their composition (RIBEIRO, 2010; KANZARI, et al., 2012; PEDROTTI, 2015; SALVATI & FERRARA, 2015).

The impacts of soil salinization directly affect the dynamics of the spatial organization of populations, promoting the reduction of agricultural production, population displacement, highlighting the food security and economy of affected communities. Several studies point to the problems previously mentioned, especially Haron and Dragovich (2010) in Australia, Xu et al. (2014) in China, and in the Northeast of Brazil with Souza, Queiroz, and Gheyi (2000) and Vasconcelos et al., (2013).

Assessing the degree of salinization, the risks and the main contributing factors to the excess salt in the soils of desertification-susceptible areas becomes crucial, since it is a fundamental factor for the planning and promotion of public actions and policies for the proper management of each environment. In this context, the present study aims to analyze the degree of soil salinization in different land uses in municipalities of the Mesoregion of São Francisco, semi-arid state of Pernambuco, and its possible contribution to the process of local desertification.

The study area was selected based on the survey developed by Castro and Santos (2015), which showed that the municipalities studied have 39% of their territories with medium susceptibility to salinization. Other factors affected the selection and development of this study. These include the importance of the part of the local lands for the development of irrigated agriculture, frequent use of underground water for irrigation in non-irrigated agriculture areas, and rudimentary knowledge about the process and impacts of salinization of local soils

MATERIALS AND METHODS

Study Area

The study was performed in the municipalities of Petrolina, Lagoa Grande, Dormentes, Afrânio,

and Santa Maria da Boa Vista, western Pernambuco state (Figure 1), and belonging to the São Francisco Pernambucano Mesoregion. Both municipalities are under semi-arid climate, with an annual average rainfall of 700 mm concentrated at the end and beginning of each year; caatinga vegetation; soils with medium to few degrees of development; terrain marked by the "Sertaneja" Depression and inselbergs (BELTRÃO et al., 2006).

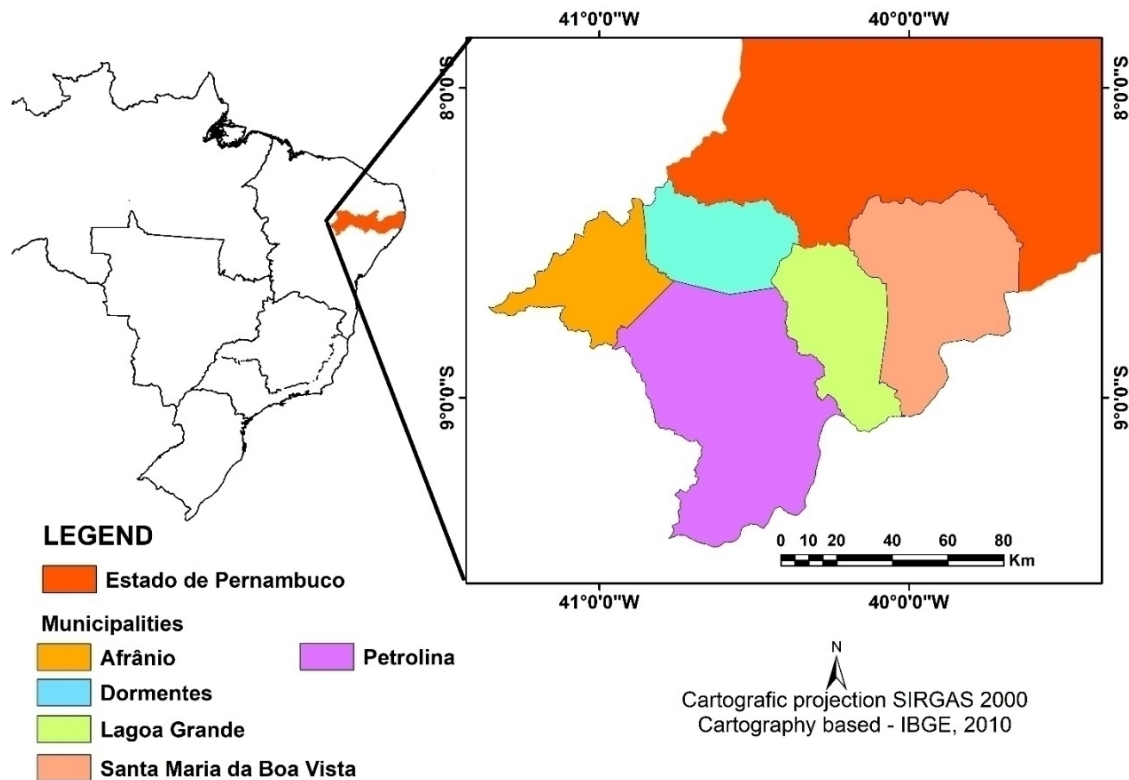


Figure 1 - Location of the municipalities where the study was performed. Source: elaborated by the authors, 2018.

The economic structure in these municipalities varies, even though the basis is the agricultural production with an emphasis on the irrigated fruit sector in the municipalities of Petrolina, Lagoa Grande, and Santa Maria da Boa Vista, and the goat and sheep livestock in the other municipalities. (IBGE, 2017).

Methodological procedures

For the development of the present study, sixteen samples of soils were collected, together with pieces of information regarding land use and occupation (Table 1). For data collection, we used: field books, Global Positioning System (GPS) receiver apparatus, plastic packages, cameras, and tape measures.

The criteria for choosing the locations for soil sampling considered the use and occupation of the land in the following categories: caatingas, rainfed/exposed soil and irrigated agriculture. Each sampling was performed in a 30 cm profile (root area of the plants) with the removal of approximately 1 kg of soil.

The samples were sent to the Soil Laboratory of the Federal Institute of Sertão Pernambucano (IFSertão), a rural zone campus, where the analysis of pH (Hydrogenionic potential), EC (Electrical Conductivity) and ESP (Exchangeable Sodium Percentage) was performed. Analyses were performed according to the EMBRAPA Soil Analysis Methods Manual (2011).

Sample	Land Use	Soil Class	Sample	Land Use	Soil Class
AM1	Irrigated Agriculture - Mango	Neosol Quartenozenic	AM9	Exposed Soil - Human Deterioration	Luvisol
AM2	Irrigated Agriculture - Corn	Luvisol	AM10	Exposed soil	River Neosol
AM3	Irrigated Agriculture - Papaya	Argisol	AM11	Pasture (Goat, sheep and cattle farming)	Red Argisol
AM4	Irrigated Agriculture - Banana	Planosol	AM12	Exposed soil/ agricultura de sequeiro	River Neosol
AM5	Irrigated Agriculture - Banana	Planosol	AM13	Caatinga shrub - presence goat and cattle	Red Argisol
AM6	Irrigated Agriculture - Corn (well water)	River Neosol	AM14	Open tree caatinga with the presence of shrubs	Cambisol
AM7	Pasture	Argisol	AM15	Sparse Caatinga - preserved rock	Neosol Litolic
AM8	Exposed soil - human deterioration	Luvisol	AM16	Sparse Caatinga	Red Argisol

Table 1 – Sample, land uses, and soil classes of sample collection sites. Source: Elaborated by the authors, 2017.

In the laboratory, the first step was the exposure of the collected materials for moisture loss, followed by the screening process with 2 mm mesh. For pH definition, a table pH meter was used. The pH “is a measure that allows describing the acidic or basic character that predominates in an aqueous medium, considering its value determined on a scale from 0 to 14” (LEPSCH, 2011, p.210-211). The pH below 7 classifies the soil as acidic, the pH 7 is neutral while the pH above 7 indicates an alkaline soil. (MCCAULEY, OLSON-RUTZ & OLSON-RUTZ 2017).

For the EC analysis, a vacuum pump was used to remove the liquid part of the samples that were moistened 6 hours before the analysis. The sample taken was analyzed through the table Conductivity meter and the results presented in dS.m-1.

ESP is the percentage of exchangeable sodium relative to CEC (Cation Exchange Capacity). ESP determination was performed in phases. First, the following elements were defined separately: Ca²⁺ (Calcium); Mg²⁺ (Magnesium); Na⁺ (Sodium); K⁺ (Potassium); H+Al (Hydrogen + Aluminum) and then calculated ESP using equation 1.

$$ESP=(NA^{+}/CEC)*100$$

Where: is the exchangeable sodium content in cmolckg⁻¹, and the CEC is the capacity of cation exchange in cmolckg⁻¹ obtained by summing Ca, Mg, Na, K, and H+Al.

The exchangeable sodium grade was assessed according to the EMBRAPA (2015) classification, in which the soil with ESP: less than six is considered low; 6 to 15 is medium, and values above 15 are rated high.

Classification of the soils	Parameter Limits		
	pH	EC – dS.m ⁻¹	ESP - %
Normals	<8,5	<2	<15
Salines	<8,5	>2	<15
Alkaline	>8,5	<2	>15
Saline-Alkaline	<8,5	>2	>15

Table 2 - Criteria for classification of soils as to the presence of salts. Source: Bohn et al. (1985).

For the classification of soils taking into account the presence of surface salts, from pH, CE, and

ESP, the initially proposed methodology by Bohn et al. (1985) was used and presented in Table 2. The salinity effect on vegetation was assessed according to Richards (1954) was used, as described in Table 3, using CE.

EC (dS.m ⁻¹)	Classes
<2	Non-salino
2 – 4	Slightly Saline
4 – 8	Moderately Saline
8 – 16	Highly Saline
>16	Extremely saline

Table 3 - Soil salinity classes according to effects on vegetation cover. Fonte: Richards (1954).

RESULTS AND DISCUSSION

Irrigated agriculture

Figures 2A, 2B, and 2C show the pH, EC, and ESP of the 6 soil samples, respectively, collected in areas under irrigated agriculture. The data highlight that the pH ranged from 5.35 to 6.88, among the samples. These values can be classified below neutrality with slight degrees of acidity (Figure 2A). AM1 presented pH 6.88, which was the closest to neutrality. In this context, none of the samples in irrigated agriculture presented alkaline pH.

The acidic pH values in irrigated agriculture environments result from the frequent presence of water that contributes to the leaching of non-acid cations responsible for increasing the pH values. Generally, when the amount of acid cations increases, the pH of the soil solution tends to decrease (BRADY & WEIL, 2012). Provin and Pitt (2017) described similar results. The authors claimed that the high amount of water used in the irrigated systems plays a crucial role in reducing pH through the leaching process.

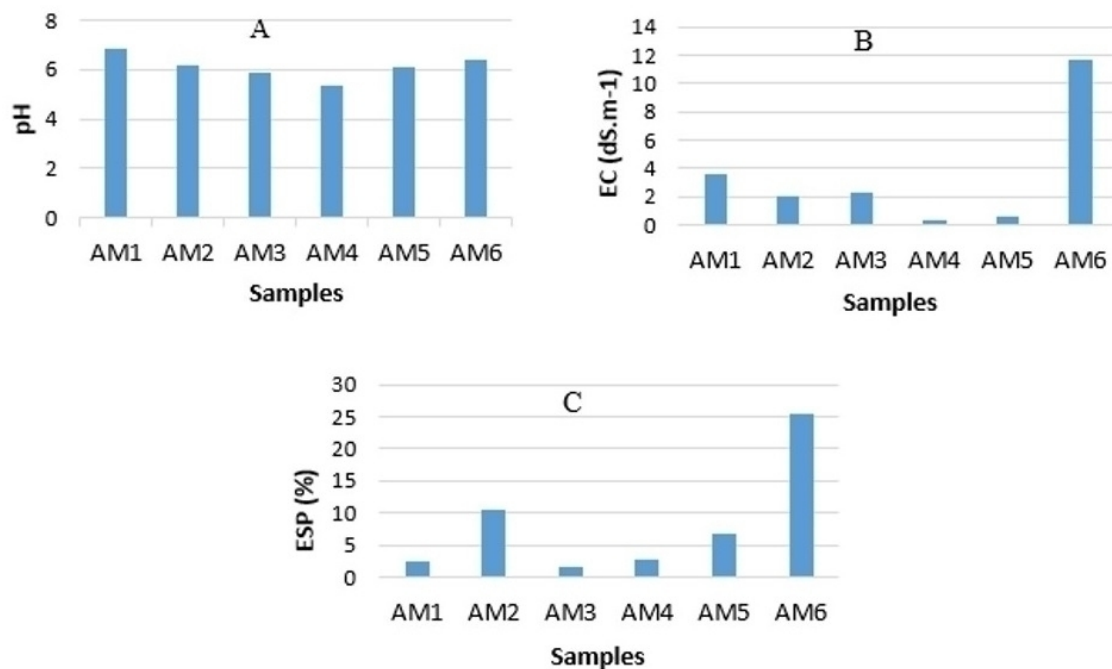


Figure 2 - (A) pH; (B) EC and (C) ESP land in an area under irrigated agriculture. Source: elaborated by the authors, 2017.

EC values ranged from 0.30 to 11.72 dS.m⁻¹ (Figure 2B). The samples AM4 and AM5 displayed values of 0.30 and 0.61 dS.m⁻¹, respectively, being the lowest conductivity results found for irrigated agriculture. Values that classify these as non-saline, according to the Richards (1954) classification. However, when analyzing the management implemented in the sampling area, concerns arise about the future chemical status of some of the soils in irrigated agriculture areas. These concerns arise because, in these samples, farmers use furrow irrigation (Figure 3B) over a Planosol.

Planosols present, in the A horizon, sandy or medium sandy texture; however, in the B horizon, there is a high activity clay, thus providing drainage difficulty (EMBRAPA, 2006). Lepsch (2011) observes that in many places in northeastern Brazil the Planosols are Natric. That is, they have characteristics of high sodium saturation.

Based on the two studies mentioned above, drainage deficiency and high sodium saturation are risk factors for the salinization of these soils if they are poorly managed, as it has been occurring in the case study area.

The AM1 samples, taken from a Quartzarenic Neosol, AM2 over a Luvisol, and AM3 over an Argisol present an EC of 3.55; 2.07 and 2.20 dS.m⁻¹, respectively (Figure 2B). Although Quartzarenic Neosols are well-drained, the EC value found in their sample is the result of years of irrigation and lack of drainage engineering built in the area under Carica papaya (papaya) plantation in Petrolina (Figure 3A). The soils of the AM2 and AM3 samples have a textural B horizon that hinders rapid infiltration, a feature that favors the permanence of water over the arable horizon and, consequently, accumulating salts.



Figure 3 - Areas under irrigated agriculture where samples were collected.

(A) papaya plantation in Petrolina; (B) planting of banana with furrow irrigation in Santa Maria da Boa Vista and (C) planting of grass and sugar cane in the municipality of Dormentes. Source: elaborated by the authors, 2017.

Taking into account the number of salts found in the soils of the AM1, AM2, and AM3 samples, the Richards (1954) classification classifies these samples as slightly saline based on the values found for EC, which ranged between 2 and 4 dS.m⁻¹.

The highest value found for EC was in the sample AM6, municipality of Dormentes, totaling 11.72 dS.m⁻¹, classifying this sample as highly saline, according to Richards (1954). One of the factors justifying the high EC is the use of water extracted from local aquifers to irrigate corn (*Zea mays*) and buffelgrass crops (*Cenchrus ciliaris*) (Figure 3C). Much of the underground water in the municipality of Dormentes have high salt concentrations according to Ramos (2014). Consequently, the use of these waters in irrigated agricultural activities increased the concentration of salts to the Fluvic Latosol significantly, where the samples AM6 was sampled, and, consequently, contributing to increasing the risks of desertification in these areas.

Another feature that favors the high EC value in sample AM6 is its location, which is just after foothills and in the flood area of an intermittent stream. As for the proximity of the foothills, according to Ribeiro (2010), this favors salinization by receiving salts from the higher surrounding areas, by the gravitational effect. About the flooded areas, the soils located there tend to present salinization problems due to the almost constant presence of water during the rainy season, which results in the accession and

accumulation of salts in the superficial horizons.

ESP (Exchangeable Sodium Percentage) values for irrigated agriculture ranged from 1.62% to 25.21% (Figure 2C). The samples with the lowest ESP were AM1, AM3, and AM4, with values of 2.35%, 1.67%, and 2.56%, respectively. In samples, AM2 and AM5 the ESP, with values between 6 to 15% was considered average, according to EMBRAPA (2015). In sample AM6, underground water irrigated agriculture area in the Dormentes municipality, ESP was 25.34%, above 15%, which according to EMBRAPA (2015) is considered high. The value in sample AM6 is due to soil characteristics as well as local land-use practices, as previously mentioned. Above 15% ESP, according to Pistocch et al. (2017) indicates severe soil deterioration due to excess sodium.

For a better understanding of the concentration and distribution of the salts in the soils was used the Bohn et al. (1985) classification described in Table 2. This classification combines pH, EC, and ESP. Among the six samples, AM6 presented the worst result. The result is because this sample presented ESP higher than 15%, EC higher than two dS.m⁻¹, and pH lower than 8.5. Combinations that classify the soil in this sample as saline-sodium. Problems reported previously because of high-salt concentrations in underground water used on a Fluvic Neosol.

Saline-sodium soil is characterized by the presence of soluble salts and sodium (EMBRAPA, 2006). The amounts of sodium and soluble salts found in the analyzed samples are sufficient to cause osmotic stress and other damage to vegetation development (FERREIRA, SILVA & RUIZ, 2010).

The samples AM1, AM2 and AM3 displayed a slightly better situation. According to the classification of Bohn et al. (1985), they are considered saline. The classification is defined because the pH was below 8.5, EC above 2 dS.m⁻¹, but the ESP did not exceed 15%.

Saline soil presents an accumulation of soluble salts, which usually are flocculated and which permeability is similar to that observed in non-saline soils (FERREIRA, SILVA & RUIZ, 2010; RIBEIRO, 2010). Despite the favorable permeability, care should be taken in the studied samples due to the presence of salts on their surfaces and the high susceptibility of these soils to salinization, since the soil of AM2 is Luvisol and in the sample AM5 Planosol.

For the other samples, AM4 and AM5, the combinations of the three analytical parameters classify them as normal according to the classification of Bohn et al. (1985). The classification of these soils as normal was performed according to the individual EC and pH assessments presented above. These samples derived from soils susceptible to salinization (Table 1), but the use of irrigation techniques without the use of furrows, the distance from the São Francisco river in comparison to the other samples, and the recent banana cultivation performed in these same locations probably influenced the results of normality of these samples.

Rainfed agriculture/Exposed soil

Figures 4A, 4B and 4C show the pH, EC, and ESP of soil samples, respectively, collected in areas under rainfed agriculture (cultivation in the rainy season) and exposed soil (Figure 5).

The results displayed small pH variations, between 4.79 to 7.04 (Figure 4A). Considering the land use of the collection points, our analyses displayed that almost all the samples were taken from exposed soil sites. Only AM12 was collected from rainfed agriculture, resulting in a pH of 6.64 considered slightly acidic. The AM8 samples displayed the lowest pH value -4.79, being considered as acid and unproductive soil for several crops. The pH of the sample AM9 was 7.09, characterizing this soil as very close to the neutralized one.

For the EC values, the points on rainfed agriculture/exposed soil displayed a discrepancy of 0.21 to 35.94 dS.m⁻¹ (Figure 4B). AM12 (Figure 4B) presented the lowest EC value for rainfed agriculture/exposed soil, which was 0.21 dS.m⁻¹. According to these results, the sample could be classified as non-saline soil. What would you expect from a flat area over Fluvic Neosol, which according to Silva, Silva, and Barros (2008) has relative salinity potentiality? An area with salinization problems would be expected if not for management. In this area, located in the municipality of Petrolina, family farming practices use water only during the rainy season. This factor, compared to areas on Fluvic Neosols under active furrow irrigation, do not present salinization problems.

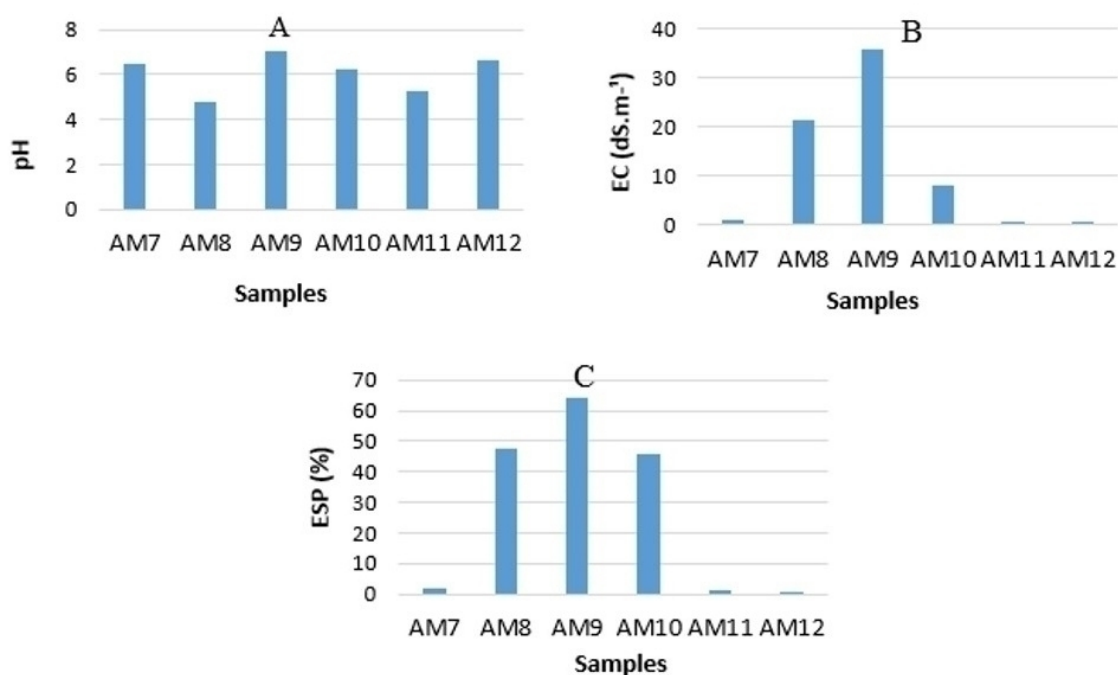


Figure 4 - (A) pH, (B) EC and (C) ESP of soils in rainfed agriculture and exposed soil. Source: elaborated by the authors, 2017.

However, the samples AM8, AM9 and AM10 displayed high EC values: 21.23; 35.94 and 7.97 dS.m⁻¹, respectively. AM8 and AM9 sampling points presented similar land use and soil types (Luvisols) and are currently in an area abandoned for productive disability resulting from decades-long rice cultivation using the flood irrigation method (Figure 5B).

Sample AM10 (EC: 7.97 dS.m⁻¹), on exposed soil without traces of agricultural activities, presented slightly lower EC values compared to the samples previously discussed. This sample belongs to a Fluvic Neosol that, according to Silva, Silva, and Barros (2008), has a susceptibility to salinization and is classified according to the methodology of Richards (1954) (Table 3) as moderately saline.



Figure 5 - Areas under rainfed agriculture/exposed soil where samples were collected. (A) exposed soil in salinized area in N7 irrigation project municipality of Petrolina; (B) salinized area in the 11 irrigation project municipality of Petrolina; (C) area intended for rainfed agriculture and exposed soil in the municipality of Afr nio. Source: elaborated by the authors, 2017.

For this class of use, also, the ESP values of the samples ranging from 0.77% to 63.90% (Figure 4C) were analyzed. Sample AM12 (Figure 4C) recorded the lowest result of ESP (0.77%), EC (0.21 dS.m⁻¹) and pH (6.64). Results that, according to the parameters of Bohn et al., (1985), classifies this sample as normal for the presence of salts, thus being indicated for agricultural use within the proper management practices. However, the alert should always be lit, since the local soil is a Fluvic Neosol,

which has great potential for salinization.

Samples AM8, AM9 and AM10 presented the highest ESP values for exposed soil/dryland use category: AM8 (47.43%); AM9 (63.90%); AM10 (45.68%). Given the values considered by EMBRAPA (2015) as high, due to being above 15%, the data of our research display that the places where these samples were taken presented a severe salinization process. Results also found in the field due to the presence of plants adapted to the presence of salts in soils such as Shoreline Purslane (*Sesuvium portulacastrum*) (figure 5A and 5B), as well as the presence of surface salts (Figure 5B).

When jointly analyzing pH, EC and ESP for the exposed soil/dryland samples the highlight remains the samples AM8, AM9, and AM10, both classified by the methodology of Bohn et al. (1985) as saline-sodium resulting from the past management and soil characteristics. The others were classified as normal.

Caatingas

Figures 6A, 6B, and 6C show the pH, EC, and ESP of soil samples, respectively, collected in areas on caatingas ranging from shrub to small-sized caprine and cattle cultures, to arboreal and conserved rupestrian. (Figures 7A, 7B e 7C).

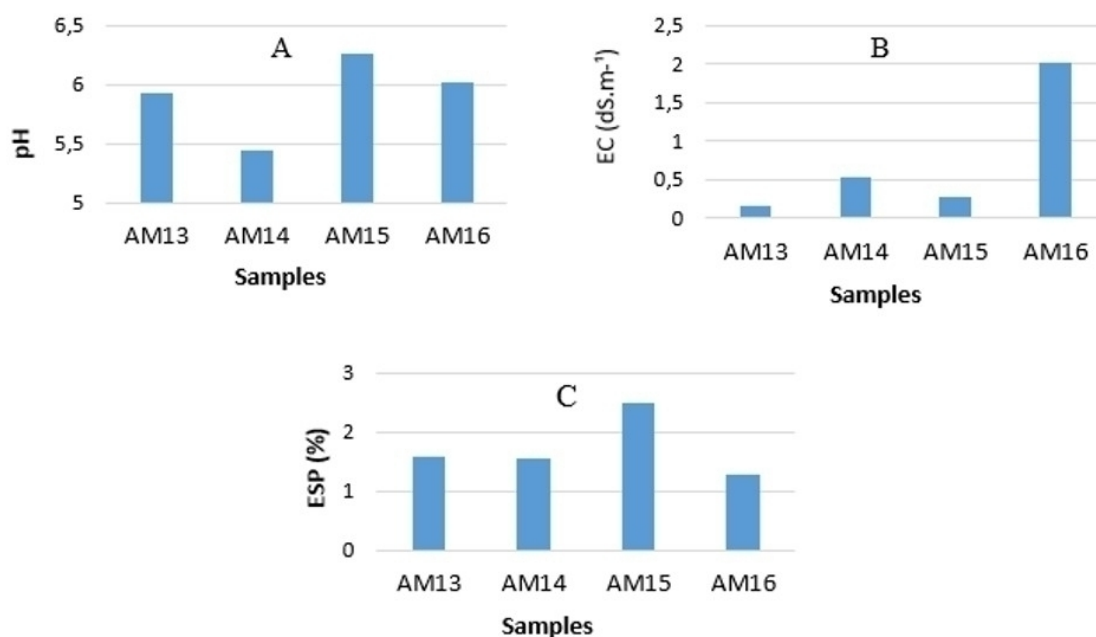


Figure 6 - (A) pH, (B) EC, and (C) ESP of soils under caatinga vegetation. Source: elaborated by the authors, 2017.

The pH values for the areas on the caatingas did not show large differences between the samples, ranging from 5.44 to 6.26 (Figure 6A). These values can be explained by the homogeneity of the caatingas that differ only in tree or shrub with small rocky areas, being areas without significant changes resulting from anthropic actions that favor the concentration of salts in soils.



Figure 7 - areas on the caatingas where samples were collected: (A) predominance of shrub caatingas - municipality of Lagoa Grande; (B) preserved rock caatinga - Petrolina municipality and (C) predominance of tree caatingas - Dormentes municipality. Source: elaborated by the authors, 2017.

For the values of EC, a variation of 0.16 to 2.00 dS.m⁻¹ was recorded (Figure 6B). The value of 0.16 dS.m⁻¹ was the lowest found for the caatingas, as compared to the areas of rainfed/exposed soil and irrigated agriculture. In the caatingas, all recorded values of EC were less than 2 dS.m⁻¹, which place the soils as non-saline according to the Richards classification (1954). Given this analysis, it can be observed that the anthropogenic interference in the soils is fundamental to make them saline because in the other classes of land use were recorded values of EC, which indicate the presence of salts in soils higher than those found in the caatingas areas.

Also, the ESP values for the caatingas samples were verified, which ranged from 1.26% to 2.49% (Figure 6C). According to EMBRAPA (2015), the amount of exchangeable sodium between the caatingas is classified as low, that is, values below 6%. The highest ESP caatinga area is located on Litholithic soil without human activities.

By jointly analyzing the pH, EC, and ESP for the caatingas, taking into account the Bohn et al. (1985) classification in all samples, the soils were classified as normal, i.e. without salinization problems. This result computed the structure of the land use, and the conservation of caatingas areas that have not been submitted to irrigation activities, even with soils that according to Barros, Barros and Silva (2008) present moderate risks to salinization such as Argisols and the Cambisols.

Among the land use classes, the caatingas present the smallest problems with salinization and, consequently, reduced contributions to the local desertification process. This is clear, considering only one of the indicators of this environmental problem.

CONCLUSIONS

In the study area, salinized soils, as expected, are mostly concentrated in areas intended for irrigated agriculture. The impact is more significant in environments where underground water is used for irrigation: underground waters have higher concentrations of dissolved salts, in addition to the features of the soil in which the agricultural activities are performed. Consequently, the contribution to the desertification process in these areas is more significant and follows a trend from various regions of the earth where agricultural management is a major contributor to the salinization and desertification correlation.

Regarding the areas of exposed soil, the samples that presented salinization problems were those derived from areas that had been abandoned from the agricultural activity due to salinization problems. The caatinga areas did not present salinization problems, although in some samples the soils are susceptible to salinization. These results prove that inadequate agricultural management in the study area is a major contributor to the salinization of local soils.

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