Water erosion in Caatinga and degraded pasture areas in semiarid region

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Abstract

Soil erosion causes great damage to the agricultural productive process, as it causes soil, water and nutrient losses. The present study aimed to evaluate soil and water losses under simulated rainfall in areas of caatinga and degraded pasture in the Brazilian semiarid. For that, a series of 20 simulated rains were implemented in the municipality of Serra Talhada, semiarid of the State of Pernambuco, under the following treatments: (1) preserved caatinga - CP; (2) caatinga with angico - CA; (3) Intermediate caatinga - CI; (4) degraded pasture - PD. The sediment concentration of the degraded pasture was lower than that of CP, CA and CI, with a 4.2 fold higher concentration for IC than PD. The lower sediment concentration in the PD is due to soil compaction due to grazing and the loss of the soil surface layer due to the erosion process of the last years. The area of CI was the one that presented the largest loss of soil, where it was observed an increase of 245.86% in relation to CP.

Key-words: Sediment Concentration, Infiltration Rate, Soil Losses

Introduction

Caatinga vegetation, like other biomes, has been affected by an intense process of devastation promoted by the unsustainable use of natural resources. The disorderly deforestation for coal production and the development of agricultural and livestock activities are constant threats and has contributed to the existence of mosaics of fragments that are in different stages of secondary succession. The ability of the Caatinga vegetation withstanding to the impacts caused by rain and its consequent superficial exhaustion, in the form of water erosion, is very little known.

Erosion rates and the consequent exhaustion of agricultural soil have assumed major proportions with physical, financial and social implications worldwide (Oliveira et al., 2010). Water erosion is one of the main forms of degradation of agricultural soils in the Brazil. It is a process of runoff by runoff water, in which there is disaggregation, transport and deposition of soil particles, nutrients and organic matter (Dechen et al., 2015). This process is conditioned by the factors of rain, soil, topography and soil cover, being the latter a factor of great importance in the control of water erosion.

Due to limitations or scarcity in the availability of long historical series of pluviometric events, authors such as Freitas et al. (2008), Bezerra et al. (2009) and Cantalice et al. (2016), have used artificial precipitation produced by rain simulators to enable studies of water erosion in shorter periods, especially in semiarid regions.
Evaluating the inter-rill erosion under semi-shrub caatinga and agricultural crops Freitas et al. (2008) verified that natural vegetation and bean cultivation corresponded to the lower values of sediment concentration and lower rate of soil aggregates disintegration.

Although water erosion is the main agent of soil impoverishment and water resources contamination, few measurements are made in the field. The low availability of data obtained in a point scale is due to the high cost and difficulties in the effectiveness of these measurements, especially in semiarid regions. In view of the above, the objective of the present study was to evaluate soil and water losses under simulated rainfall in areas of caatinga and degraded pasture in the Pajeú watershed, semiarid region from Brazil.

Material and Methods

Caatinga vegetation, like other biomes, has been affected by an intense process of devastation promoted by the unsustainable use of natural resources. The disorderly deforestation for coal production and the development of agricultural and livestock activities are constant threats and has contributed to the existence of mosaics of fragments that are in different stages of secondary succession. The ability of the Caatinga vegetation withstanding to the impacts caused by rain and its consequent superficial exhaustion, in the form of water erosion, is very little known.

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Results and discussion

According to the granulometric analysis of the collected soils, the mean values of the sand, silt and clay fractions were 675.57, 187.13 and 137.30 g kg⁻¹, respectively, allowing to classify the soil of the areas as being sandy loam texture in the 0-0.2 m layer (Figure 1). In relation to soil bulk density, particle density and total porosity (Table 1), no differences were observed between the areas. Considering soil bulk density and total porosity, this property is the ideal value of 50% (Portugal et al., 2010), are considered as indicators of soil physical quality, as it influences several other properties, such as infiltration and water retention, and important processes such as root growth (Stolf et al., 2011), good aeration and growth of biological activity.

![Fig. 1. Soils extural class of the studied areas. FAr – Sandy Loam; F - Loam; FAAr – Sandy Clay Loam; AAr - Sandy clay; ArF – Sandy Loam.](image-url)
It was observed, therefore, that in relation to the porosity all areas are very close to the ideal value. However, the slight increase in soil density in the PD area led to low values of saturated hydraulic conductivity, sorption and infiltration (Table 2). Contrary to the results found for soil bulk density for the study, Oliveira Júnior et al. (2014) verified that soil management with pasture significantly altered the soil density, which for the pasture was 1.39 g cm\(^{-3}\) and for the Caatinga vegetation was 1.30 g cm\(^{-3}\), proving that the intensive use of these grazing areas promotes changes in the physical characteristics of the soil.

In relation to saturated hydraulic conductivity (Ksat) and the sorptivity (S), it was verified that both measures reduce according to the state of deterioration of the areas, that is, they reduce from CP to PD, with a decrease of 81.60% and 62,63%, for Ksat and S, respectively.

According to Oliveira Júnior et al. (2014), the sorptivity translates the capacity of the soil to absorb water by capillarity and depends essentially on the variation of the volumetric water content between the beginning and the end of the infiltration. These same authors also contacted reductions in Ksat and S in pasture area, with a reduction of 20% when compared to soil under Caatinga vegetation for S. According to Parente et al. (2010), a well-structured, less compacted soil can have higher values of sorptivity and hydraulic conductivity and, due to the organic matter content, can retain more water.

It was expected, without doubt, that the soil of the preserved caatinga presented higher values of S than in the soil under degraded pasture. In a similar way, the Ksat presented higher values for soil under preserved caatinga than under PD, a difference that can be attributed to both the particle size distribution of the sand fraction and the slight increase in soil density in PD.

The average rainfall was 124.8, 111.6, 99.6, and 142.4 mm h\(^{-1}\) for the areas of CP, CA, CI and PD, respectively. It was verified that the simulated rainfall in the CI and PD areas differed from the projected rainfall of 120 mm h\(^{-1}\), by the t test at the 5% probability level, generating a deficit of 17% and an excess of 18.66% of the rain. Comparing the simulated precipitation between the treatments (Figure 2), there was a difference between the areas. These differences are explained by the wind action, because in the degraded pasture area there were no shrubs as in the other areas of preserved caatinga, caatinga with angico and intermediate caatinga, to serve as windbreak.

Table 2 shows the values of infiltration rates obtained with the rain simulations in the different treatments. Considering that the infiltration reflects the physical conditions of the soil (texture, structure and porosity) and that it has been modified according to the use, it is perceived that the rate of infiltration in the CP is higher, however, it does not differ from other areas (CA, CI and PD). Comparing CP with PD, where the soil use is more intense due to grazing, a reduction of the infiltration rate of 44.83% is verified, accompanied by the percentage reduction of Ksat and S, previously mentioned (Table 1).

As infiltration and flow are antagonistic processes, when one increases the other decreases, the
lowest observed flow rate (ECobs) was for CP followed by IC. The observed flow start time (TEobs) ranged from 2.90 to 4.42 min (Table 2). There was no difference between the values of TEobs in the areas of CP, CA and CI, in the area of PD differs from CA and CI. The highest TEobs for the PD was due to low land slope (0.0330 m m⁻¹), allied to the presence of soil cover (63%), providing greater surface roughness.

Table 2. Infiltration rate, observed runoff rate, observed stabilization time for the rainfall simulation tests of the experimental areas.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>I</th>
<th>ECobs</th>
<th>TEobs</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>1.45a</td>
<td>0.65a</td>
<td>3.40ab</td>
</tr>
<tr>
<td>CA</td>
<td>0.78b</td>
<td>1.10bc</td>
<td>2.90a</td>
</tr>
<tr>
<td>CI</td>
<td>0.67b</td>
<td>0.99ab</td>
<td>3.16a</td>
</tr>
<tr>
<td>PD</td>
<td>0.80b</td>
<td>1.44c</td>
<td>4.42b</td>
</tr>
<tr>
<td>Average</td>
<td>0.92</td>
<td>1.04</td>
<td>3.47</td>
</tr>
<tr>
<td>CV</td>
<td>31.52</td>
<td>28.56</td>
<td>26.22</td>
</tr>
</tbody>
</table>

I - infiltration rate; ECobs - constant flow rate observed; TEobs - observed flow start time. Means followed by the same letter in the column do not differ by Tukey test at the 5% probability level.

The discharge (q), runoff coefficient (C), sediment concentration (Cs), disaggregation rate (D) and soil loss (Ps) is shown in Table 3. The discharge per unit of width was of the order of magnitude of 10⁻⁵ with the area of the degraded pasture (PD) differing from the preserved caatinga (CP). There was an increase of 87.5% in water loss in relation to CP, which corresponds to the high surface runoff rate, low infiltration rate and high intensity of the simulated rainfall, which averaged 140 mm h⁻¹ in the area of degraded grass. These values corroborate with the results obtained by Freitas et al. (2008), when studying runoff in areas of caatinga and agricultural crops, also verified that the magnitude of the discharge (q) was of the order of 10⁻⁵ m² s⁻¹. Lima et al. (2015), evaluating the hydraulic characteristics of the runoff for different agricultural practices, found values of the order of 10⁻⁵ and 10⁻⁶ m² s⁻¹.

The results of the referred research are also in accordance with those of Cantalice et al. (2016), who observed values of the order of 10⁻⁵ m² s⁻¹ in pasture under different slopes. According to Freitas et al. (2008), the greater detention of the liquid discharge by the CP is related by the greater physical-hydraulic resistance to the flow designated by its canopy and litter layer.

The coefficient of deflation (C) (Table 3) shows an amplitude of 0.23, and was only different only between CP and CA, agreeing with the values found by Freitas et al. (2008), which found values of 0.32, 0.51, 0.54 and 0.96, respectively, in a semi-arid environment under semi-shrub caatinga, pigeon pea, sweet potato and exposed soil. Bertol et al. (2008), evaluating different management systems, found a variation of the C coefficient from 0.29 to 0.71. Cantalice et al. (2016) in pasture area verified values between 0.15 and 0.41 for different terrain slope conditions. Thus, this variation found in the mentioned work is related to the use of the soil.

Table 3. Discharge per unit width (q), runoff coefficient (C), sediment concentration (Cs), disaggregation rate (D), soil loss (Ps), slope (DEC) and soil cover (CO) in the areas of Preserved Caatinga (CP), Caatinga with Angico (CA), Intermediate Caatinga (CI) and Degraded Pasture (PD).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>q</th>
<th>C</th>
<th>Cs</th>
<th>D</th>
<th>Ps</th>
<th>DEC</th>
<th>COB</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>2.08 10⁻⁵</td>
<td>0.30a</td>
<td>0.0016b</td>
<td>1.8 10⁻³</td>
<td>57.96ab</td>
<td>0.0658ab</td>
<td>47.60a</td>
</tr>
<tr>
<td>CA</td>
<td>3.27 10⁻⁵</td>
<td>0.53b</td>
<td>0.0014b</td>
<td>2.0 10⁻³</td>
<td>116.24b</td>
<td>0.0536ab</td>
<td>57.00a</td>
</tr>
<tr>
<td>CI</td>
<td>2.32 10⁻⁵</td>
<td>0.43ab</td>
<td>0.0021b</td>
<td>2.4 10⁻³</td>
<td>199.80c</td>
<td>0.0803b</td>
<td>67.40a</td>
</tr>
<tr>
<td>PD</td>
<td>3.30 10⁻⁵</td>
<td>0.42ab</td>
<td>0.0005a</td>
<td>7.0 10⁻⁶a</td>
<td>32.88a</td>
<td>0.0330a</td>
<td>63.00a</td>
</tr>
<tr>
<td>Average</td>
<td>2.75 10⁻⁵</td>
<td>0.42</td>
<td>0.0014</td>
<td>1.73 10⁻⁵</td>
<td>101.72</td>
<td>0.0582</td>
<td>58.75</td>
</tr>
<tr>
<td>CV</td>
<td>30.42</td>
<td>33.36</td>
<td>40.10</td>
<td>47.20</td>
<td>58.21</td>
<td>42.00</td>
<td>36.30</td>
</tr>
</tbody>
</table>

CV - Coefficient of variation

Regarding the sediment concentration (Cs), the area of the PD presented a lower value than the CP, CA and CI, with a 4.2 fold increase in IC concentration in relation to PD, even though a lower magnitude of mean rainfall intensity for IC (99.6 mm h⁻¹). The lower sediment concentration in the PD is due to soil compaction due to grazing and the loss of the superficial layer due to the erosion process of the last years. Topography also interfered with soil loss, evidenced by the simple linear regression analysis between slope and sediment concentration (Figure 3). However, the relationship was linear and positive, indicating that with increasing slope sediment concentration also increased.
To CP, and an increase of 0.04, 0.08, 0.06. These changes from a Preserved condition to a Degraded Pasture condition, K.R.J.; and lower runoff rate in 0.0006, 0.09, 0.05, 0.07, reserved in relation to the other studies areas, it can attributed to the higher soil cover presented lower soil losses in Caatinga to Degraded Pasture occur because this process negatively affect hydraulic conductivity, sorptivity of soils, and consequently, infiltration rate.

Caatinga with Angico and Degraded Pasture. Because the soil bulk density doesn’t differ between the studied areas, we attribute that increasing on runoff due to soil use changes from a Preserved Caatinga to Degraded Pasture occur because this process negatively affect hydraulic conductivity, sorptivity of soils, and consequently, infiltration rate. Although the area of Degraded Pasture have presented lower soil losses in relation to the other studied areas, it can attributed to the higher soil cover at this site associated to its lower slope.

**Conflicts of interest:** All authors declare no conflict of interest.

**Conclusion**

Our study shown that Preserved Caatinga had higher infiltration rate and lower runoff rate in relation to the other studies areas – Intermediate Caatinga, Caatinga with Angico and Degraded Pasture. Because the soil bulk density doesn’t differ between the studied areas, we attribute that increasing on runoff due to soil use changes from a Preserved Caatinga to Degraded Pasture occur because this process negatively affect hydraulic conductivity, sorptivity of soils, and consequently, infiltration rate.

Although the area of Degraded Pasture have presented lower soil losses in relation to the other studied areas, it can attributed to the higher soil cover at this site associated to its lower slope.

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