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Original Research

Evaluation and modeling of runoff and sediment yield for different land covers under simulated rain in a semiarid region of Brazil

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ABSTRACT

This paper quantifies the runoff and sediment yield for four different land covers in a semiarid region of Brazil. The WESP model, a distributed, event-oriented runoff-erosion model, was applied and its physical parameters, N_s and K_R, were adjusted based on observed runoff and sediment yield data using simulated rainfall with an average intensity of 53 mm h^{-1}. The sediment yield obtained was 53.02 kg ha^{-1} (*caatinga* vegetation), 231.96 kg ha^{-1} (bare soil), 309.75 kg ha^{-1} (beans), and 847.38 kg ha^{-1}(corn). The results showed that *caatinga* cover yields the lowest erosion and runoff when compared to the other treatments. The results also show that the sediment yield and runoff values simulated with N_s, K_I, and K_R parameters were well calibrated, within acceptable deviations. The *caatinga* vegetation was more effective in protecting the soil, when compared to the other types of coverage. The beans and corn covers had the highest values of runoff and sediment yield, even higher than those observed for bare soil.

1. Introduction

Semiarid regions cover a large percentage of the planet and in these areas the soil erodibility and rain erosivity are key parameters for modeling soil erosion. However, field data on the impacts of erosion, due to high operational costs and measurement difficulties, are scarce, especially for such regions (Santos et al., 2011a; Zhang et al., 2013). One way to solve this problem is to do outdoor experiments using a small scale rainfall simulator (RS) to increase our understanding of temporal and spatial variability of the soil erosion processes for different land covers. RS studies also have the advantage of their ability to emulate natural rainfall in a controlled manner.

Studies under simulated rainfall for analyzing runoff and sediment yield are not a new idea, but they offer a great opportunity for increased experimental control over the many variables that govern natural rainfall (Khaleghpanah et al., 2016). Thus, there are a range of simulator types and applications for different scales to study the influence of land cover on runoff and erosion in semiarid regions, considering the complexity of pedological and geomorphological processes (Lascelles et al., 2000). Until recently, there has not been any coordination of efforts to collate all the available information about runoff and erosion using simulated rainfall, or to discuss future developments relating to the use of this technique (Parsons & Lascelles, 2000). However, several experiments have been done in nations where capital and skilled labor are abundantly available (Joshi & Tambe, 2010). During the last decades, research on hillslope runoff-erosion processes has been done in many parts around the world, especially in humid landscapes (Zemke, 2016), but few studies have been undertaken in semiarid and arid environments when compared to the ones in humid environments (Martínez-Murillo et al., 2012). Moreover, few studies have considered different local vegetation cover and other biomes using simulated rainfall in Brazil (Bertol et al., 2015), where studies more commonly used natural rainfall (Montenegro et al., 2013) or different soil management systems for cropland (Engel et al., 2007). Furthermore, arid and semiarid zones are considered fragile environments in which vegetation cover is scarce and where soil erosion processes occur rapidly and severely after rainfall events.

Most of the studies have been reported from Europe (Chamizo et al., 2017; Comino et al., 2016; Martínez-Zavala et al., 2008), North America (Ramos-Scharrón & MacDonald, 2005), and Asia (Sun et al., 2016). In northeastern Brazil, few studies have been

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reported and focused on studies of sediment yield under different land covers based on experiments with simulated rainfall (de Paula et al., 2016; dos Santos et al., 2016; Montenegro et al., 2013; Silva et al., 2005), especially research which studies sediment and runoff under different land uses and different land covers.

For this purpose, an experimental study was done in an experimental basin in the northeastern region of Brazil using a rainfall simulator to study the relation between the runoff and sediment yield for different land covers. The northeastern region of Brazil suffers from a great spatiotemporal variability of precipitation and evapotranspiration, and the mean annual rainfall in the region, sometimes known as the polygon of droughts, is less than 600 mm and normally occurs during a short period between January and March (da Silva, 2004), but intense rainfall can cause extreme runoff and soil erosion events. In this sense, there is a need to improve and deepen the knowledge of these processes in the Brazilian semiarid region. Information about the characteristics of the runoff and sediment yield under different land covers are essential for the good management of water resources and soil management, mainly in regions affected by water scarcity. Due to the importance of soil erosion to cropland in semiarid regions, and with the goal to evaluate and model the runoff and erosion processes for different land covers under simulated rainfall, the objective of this study is to quantify the runoff-erosion process for four different land covers (beans, corn, bare soil, and *caatinga* vegetation) in the semiarid region of Brazil.

2. Materials and methods

2.1. Study area

Four plots were constructed in 2010 at the São João do Cariri Experimental Basin of the Federal University of Paraíba, located in São João do Cariri municipality (7 °20′12″ to 7 °23′17″ south latitude, 36 °31′2″ to 36 °32′58″ west longitude, and 455 m average elevation above sea level) in northeastern of Brazil (Fig. 1). Hydrological data were recorded from September 2010 to March 2011. The soil classification used in this study was FAO (1974). The dominant soil type in 55.6% of the area is Luvisol, with the presence of gravel and stones over the crystalline bedrock for which little information is available about the influence of erodibility considering multiple step intermittent rainfall as well as uniform rainfall events.

The study area has a heterogeneous landscape characterized by a dry zone of semiarid climate. The local climate type is BSh – low latitude and elevation (Kottek et al., 2006), where the average daily temperature ranges from 20 to 28 °C and the annual rainfall is around 600 mm (Srinivasan & Paiva, 2009). The rainfall intensity is low/moderate and generally occurs during a single rainy season between February and May (Barbosa & Kumar, 2016).

2.2. Erosion field plots

The plots have a slope of 7%, width of 1 m, horizontal length of 3 m, and are 0.3 m deep, which permit the measurement of total surface runoff and erosion losses. Runoff hydrographs and sediment yield were measured manually at the downstream end of the flume by successive sampling of runoff at regular intervals of 15 seconds. Fig. 2 shows plots for four different land covers: (a) *caatinga* vegetation, (b) bare soil, (c) corn, and (d) beans.

Four types of land cover were considered in the present study, i.e., *caatinga* vegetation, bare soil, corn, and beans. *Caatinga* is a type of desert vegetation, and an ecoregion characterized by this vegetation is common to the interior of northeastern Brazil. The corn and beans were planted in the experimental erosion plots under conditions which the local farmers usually cultivate, i.e. along the direction of the slope (downhill). The corn and beans were initially planted on 11/11/2010 (plots #2 and #3) and the first rainfall simulation was performed on 14/12/2010, when corn and beans had already grown over a month.

The plots with corn and beans were cleared again and events#8 to #16 (01/02/2011 and 02/02/2011) were carried out in plots #1, #2 and #3 with native vegetation in the first and bare soli in the other two. After these simulations and the assurance that the RS was working well, corn and beans were planted again on 02/02/2011 in plots 2 and 3 and simulations from the day 28/02/2011 began to be carried out with the caatinga vegetation, corn, and beans.

All data collected from the plots were recorded between November 2010 and March 2011 (because it is the best period to perform outdoor rainfall simulation experiments since it is not the rainy season), totaling 43 events under different types of land cover (16 with bare soil, nine with *caatinga* vegetation, nine with corn, and nine with beans).

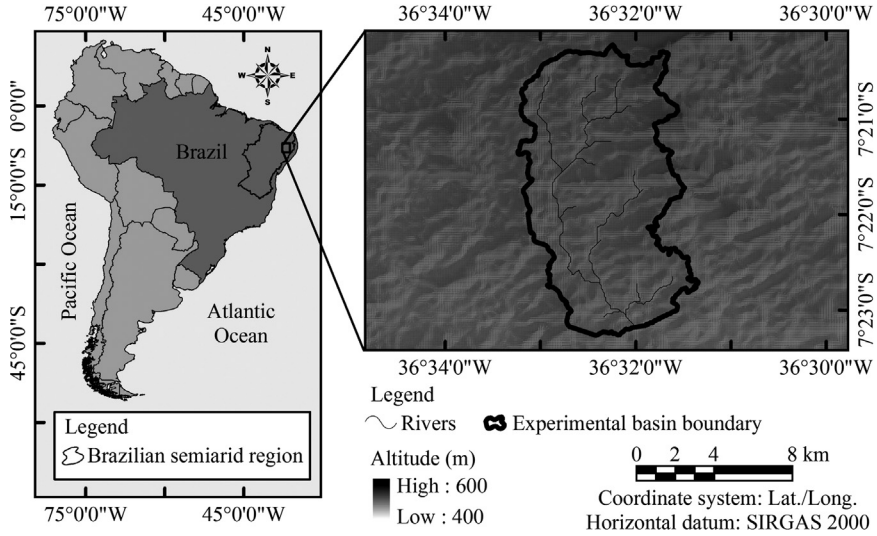

Fig. 1. Geographical location of São João do Cariri Experimental Basin in the Brazilian semiarid region.

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