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PAULO ROBERTO DA ROCHA JUNIOR

IMPACT OF SOIL MANAGEMENT ON WATER, SEDIMENT AND NUTRIENTS LOSSES: FIELD, LABORATORY AND MODELING EXPERIMENT

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2016

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Thesis submitted in partial fulfillment of the requirements for the degree of Doctor Scientific in Plant Production – Soil Science and Plant Nutrition in the Graduate program of the Universidade Federal do Espírito Santo.
Adviser: Prof. Dr. Felipe Vaz Andrade
Co-Adviser: Prof. PhD. Eduardo de Sá Mendonça

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To God for the gift of life.

To my parents, Paulo and Silvania.

To my wife, Namara.

And to my brothers and sisters.

"The fear of the Lord is the beginning of knowledge".

Proverbs 1:7

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RESUMO

ROCHA-JUNIOR, Paulo Roberto da, D.r, Universidade Federal do Espírito Santo, fevereiro de 2016. **Impacto do manejo do solo nas perdas de água, sedimento e nutrientes: experimentos de campo, laboratório e modelagem.** Orientador: Felipe Vaz Andrade. Co-orientador: Eduardo de Sá Mendonça.

Embora muito esforço venha sendo realizado, os estudos visando mitigar os efeitos da erosão ainda são insuficientes. Neste contexto a presente tese buscou estudar os efeitos do manejo do solo em dois grandes países produtores agrícolas, Brasil e Estados Unidos, focando nas particularidades encontradas em cada país. Os Capítulos 1 e 2 da presente tese tiveram como objetivo estudar os efeitos da recuperação ou renovação de pastagens sob diferentes manejos de solo (controle, escarificada, adubada, queimada, integração lavoura-pecuária e arada e gradeada em nível). Foram avaliados sob chuva natural as perdas de sedimento, água, nutrientes (Ca, Mg, P e K) e carbono orgânico (COT, C lábil, C menos lábil e C recalcitrante). Além disso, estudou-se qual compartimento (água ou sedimento) e granulometria de sedimento (maior ou menor que 0,250mm) perdeu mais nutriente e carbono. Para cada manejo foram calculados o fator cobertura e manejo do solo (fator-C) usado na Equação Universal de Perda de Solo (USLE/RUSLE), os valores calculados foram calibrados com os observados a campo. Nos Capítulos 3 e 4 o objetivo foi estudar o efeito da mudança de manejo do solo adotado na produção agrícola dos Estados Unidos (plantio direto, preparo em contorno, preparo do solo morro abaixo e solo exposto) avaliando a influência da alteração do manejo nas perdas de sedimento, água e P, sob chuva natural e simulada. Além disso, foram avaliados os efeitos destas práticas na rugosidade do solo com experimentos de chuva simulada, e a possibilidade de modelagem dos dados observado a campo utilizando o *software* WEPP (*Water Erosion Predict Project*). No capitulo 1 verificou-se de uma maneira geral que os manejos de pastagens que levam aos maiores valores de perda foram o controle (10,31 t ha^{-1} e 119,58 mm ou 9,1%) e a pastagem queimada (5,34 t ha^{-1} e 90,37 mm e 6,8%). Valores intermediários de perda foram de solo foram observados nos manejos de integração lavoura-pecuária (1,25 t ha^{-1} e 125,87 mm ou 9,5%) e escarificada (1,70 t ha^{-1} e 84,74 mm ou 6,4%). Os valores mais baixos de perdas de solo e água foram verificados nos manejos de pastagens arada e gradeada em nível (0,01 t ha^{-1} e 9,23 mm ou 0.7%) e adubada (0,31 t ha^{-1} e 32,47 mm ou 2,4%). Recomenda-se a utilização da adubação em pastagens estabelecidas na Mata Atlântica tendo em vista reduzir as perdas e elevar a produção de capim. O manejo da queima e o manejo extensivo semelhante à pastagem controle devem ser evitados. Independente do manejo as maiores perdas de Ca (98,63 %), Mg (99,30 %), K (90,57 %) e P (65,29 %) estiveram associadas a água de escoamento, enquanto as maiores perdas de CO (79,93 %) estiveram associadas ao sedimento. Os sedimentos grossos (granulometria maior que 0,250 mm) foi responsável pela maior perda de Ca, Mg, K e CO, enquanto o a maior parte do P foi perdido pelo sedimento fino. No capitulo 2 verificou-se que os dados estimados pela USLE/ RUSLE utilizando o fator-C calculado foram próximos aos observados a campo. Recomenda-se o fator-C para estimativa de perda de solo em áreas de pastagens estabelecidas na Mata Atlântica. Os valores encontrados quando calculados em 4 meses foram: 0.007300 t ha t^{-1} ha^{-1} pastagem controle, 0.009700 t ha t^{-1} ha^{-1} pastagem escarificada, 0.001900 t ha t^{-1} ha^{-1} pastagem adubada, 0.017300 t ha t^{-1} ha^{-1} pastagem queimada, 0.0090 t ha t^{-1} ha^{-1} pastagem integração lavoura-pecuária e 0.000400 t ha t^{-1} ha^{-1} pastagem arada e gradeada. O fator-C calculado para 24 meses foram: 0.001380 t ha t^{-1} ha^{-1} pastagem controle, 0.002350 t ha t^{-1} ha^{-1} pastagem escarificada, 0.000470 t ha t^{-1} ha^{-1} pastagem adubada, 0.003210 t ha t^{-1} ha^{-1} pastagem queimada, 0.002240 t ha t^{-1} ha^{-1} pastagem integração lavoura-pecuária e 0.000110 t ha t^{-1} ha^{-1} pastagem arada e gradeada. No Capitulo 3 verificou que o manejo do solo com plantio direto deve ser mantido nos Estados Unidos tendo em vista evitar as perdas de sedimento e água, os menores valores foram observados neste manejo 0,45 t ha^{-1} e 152,35 mm. Quando não for possível manter todo o resíduo sob o solo o preparo em contorno deve ser adotado, isso porque neste manejo foi registrado o segundo menor valor de perdas 5,71 t ha^{-1} e 166,51 mm e a menor perda de P com 216.26 g ha^{-1}. Os manejos de solo com a colheita total de resíduos (semelhante ao solo exposto) e o preparo do solo morro abaixo devem ser evitados onde foram registradas as maiores perdas de sedimento, água e P. Quando realizado a modelagem foi observado superestimação das perdas de água e subestimação das perdas de sedimento, recomendando mais pesquisas com modelagem, buscando uma melhor caracterização do solo ao longo do tempo. No Capitulo 4 observou-se que o preparo do solo em Contorno (7,03) e Morro abaixo (7,17) tiveram efeito na elevação da rugosidade do solo quando comparado aos manejos Plantio Direto (4,34) e Solo exposto (4,26). Este efeito levou a menor perda de água na chuva de menor intensidade (50 mm). No entanto nas perdas de sedimento a rugosidade teve pouco efeito, sendo mais importante a direção do preparo e o fator cobertura do solo, onde os valores totais de perda de sedimento foram: solo exposto 9,77 t ha^{-1}; morro abaixo 8,85 t ha^{-1}; preparo em contorno 1,30 t ha^{-1}; e plantio direto 0,59 t ha^{-1}.

Palavras-chave: Manejo de pastagens, Preparo do solo, Fator C, Rugosidade do solo.

ABSTRACT

ROCHA-JUNIOR, Paulo Roberto da, D.r, Universidade Federal do Espírito Santo, february 2016. **Impact of soil management on water, sediment and nutrients losses: field, laboratory and modeling experiment**. Adviser: Felipe Vaz Andrade. Co-Adviser: Eduardo de Sá Mendonça.

Although much efforts have been made to mitigate the effects of soil erosion, studies are still insufficient. In this context the present thesis aimed to study the effects of soil management in two major agricultural countries, Brazil and the United States, focusing on the specific characteristics found in each country. Chapters 1 and 2 of this thesis aimed to study the effects of recovery or renewal of pastures under different soil management (control, chisel, fertilized, burned, integrated crop-livestock and plowing and harrowing in level). Sediment, water, nutrients (Ca, Mg, P and K) and organic carbon (OC, C labile C less labile and recalcitrant C) losses were evaluated under natural rainfall, in pastures established at an early stage. In addition, we studied which compartment (water or sediment) and size of sediment (greater or less than 0.250mm) lost more nutrient and carbon. In each management was calculated the coverage and soil management factor (*C*-factor) using the Universal Soil Loss Equation (USLE/RUSLE). The calculated values were calibrated with the observed values obtained in field. In Chapters 3 and 4, the objective was to study the effect of soil management changes adopted in agricultural areas in the United States (no-tillage, contour tillage, downhill tillage and bare soil). The influences of the soil management in losses of sediment, water and P under natural and simulated rainfall were evaluated. In addition, we evaluated the effects of these practices on soil roughness in simulated rainfall, and the possibility of modeling the data observed in field using the software WEPP (Water Erosion Predict Project). In chapter 1 the managements of pastures that lead to high values of sediment and water loss were the control (10.31 t ha^{-1} and 119.58 mm or 9.1%) and burned (5.34 t ha^{-1} and 90.37 mm or 6.8%) management. Intermediate values of loss were observed in the pasture integration crop-livestock (1.25 t ha^{-1} and 125.87 mm or 9.5%) and chisel (1.70 t ha^{-1} and 84.74 mm or 6.4%) managements. The lowest values of losses were recorded in the pasture plowing and harrowing (0.01 t ha^{-1} and 9.23 mm or 0.7%) and fertilized (0.31 t ha^{-1} and 32.47 mm 2.4%). It is recommended the use of fertilizer on pastures established in the Atlantic Rainforest in order to reduce losses and increase grass production. The management of burn and extensive management similar to pasture Control should be avoided. Regardless the managements, high losses of Ca (98.63%), Mg (99.30%), K (90.57%) and P (65.29%) were associated with runoff water. While high losses of OC (79.93%) were associated with the sediment. Course sediment (particle size greater than 0.250 mm) was responsible for the greatest loss of Ca, Mg, K and OC, while most of P was lost by the fine sediment. In Chapter 2, we found that the data estimated by USLE/RUSLE using the *C*-factor calculated were close to those observed in the field. It is recommended *C*-factor for estimating soil loss in pastures established in the Atlantic Rainforest. The values in 4 months were: 0.007300 t ha t^{-1} ha^{-1} for pasture control, 0.009700 t ha t^{-1} ha^{-1} for pasture chisel, 0.001900 t ha t^{-1} ha^{-1} for pasture fertilizer, 0.017300 t ha t^{-1} ha^{-1} for burned pasture, 0.0090 t ha t^{-1} ha^{-1} for integrated crop-live-stock and 0.000400 t ha t^{-1} ha^{-1} at plowing and howring pasture, respectively. The *C*-factor for 24 months for the respective managements of pastures were 0.001380 t ha t^{-1} ha^{-1} for pasture control, 0.002350 t ha t^{-1} ha^{-1} for pasture chisel, 0.000470 t ha t^{-1} ha^{-1} for pasture fertilizer, 0.003210 t ha t^{-1} ha^{-1} for burned pasture, 0.002240 t ha t^{-1} ha^{-1} for integrated crop-live-stock and 0.000110 t ha t^{-1} ha^{-1} at plowing and howring pasture respectively. In Chapter 3, we found that the soil management with tillage should be kept in the United States in order to avoid the sediment and water losses. The lowest values of sediment and water losses were observed in the No-tillage management with 0.45 t ha^{-1} and 152.35 mm. When it is not possible, keep any residue on the soil, preparation in contour should be adopted. Due to the contour management, was recorded the second lowest values of sediment and water losses (5.71 t ha^{-1} and 166.51 mm), and the lower values of P losses (216.26 g ha^{-1}). The soil management with total harvest of crop residues (similar to bare soil) and the preparation of the soil in downhill should be avoided. The high sediment and water losses were recorded in the bare soil and downhill tillage. It was observed overestimation of water losses and underestimation of sediment losses. More researches seeking a better characterization of the soil over time is required. In Chapter 4 was observed that soil preparation in contour (7.03) or in downhill (7.17) had an effect on the increase of the soil roughness when compared to the no-tillage (4.34) and bare soil (4.26) managements. This effect led to low values of water loss in the lower intensity of rain (50 mm). However, in the sediment losses the roughness had little effect, and most importantly were the direction of soil preparation and the soil cover factor. The total amounts of sediment loss were: bare soil 9.77 t ha^{-1}; downhill Tillage 8.85 t ha^{-1}; contour tillage 1.30 t ha^{-1}; and no-tillage 0.59 t ha^{-1}.

Keywords: Pasture management, Soil tillage, *C* factor, Soil roughness.

INTRODUCTION

Among the negative human actions on the environment, soil degradation is one of the most worrying, as it has directly affected the life of human. In this sense, the main cause of degradation is related to the misuse of soil, resulting in the increase of erosion promoting water and sediment losses mediated by water erosion (JAKELAITIS et al., 2008; MARTINS et al., 2010).

Despite the erosion being inserted into a concept of natural leveling of the landscape in certain geological time, inappropriate anthropogenic land use has accelerated this action, creating social, economic and environmental problems (MACHADO, 2007), and such aspect is observed worldwide (MUÑOZ R. et al., 2011; PODWOJEWSKI et al., 2008; TEAGUE et al., 2011).

Water erosion in most of the planet is an important form of erosion, which intensifies when there is replacement of native vegetation for the establishment of areas for agricultural use (ZACHAR, 1982). Generally, the conversion of these areas occurs without regarding proper planning, and the usability of natural resources involved. The consequences of such practices are significant changes in the hydrological regime of rivers with an increase in flows at the peak of the rainy season and a drastic reduction in periods of drought. Moreover, water erosion is one of the most important causes of reduced soil productivity and increased environmental degradation (BRITO et al., 2005); several factors can influence this process. In this sense, the soil type, land slope, ramp length, vegetation cover and management practices are closely related to erosion (WISCHMEIER; SMITH 1965, 1978). Among these factors, the vegetation cover and management practices are one of the main factors, due to are easily changeable.

In Brazil, it is commonly that management practices adopted in conversion areas forest/pastures are inadequate, being observed large areas of degraded pastures, which have promoted high exposure of the soil, and consequently, increasing water and soil losses (CHAVES et al., 2008; GEMER et al., 2010; JAKELAITIS et al., 2008). In the United States, the expansion of the energy matrix through the use of plant straw aiming at the production of cellulosic ethanol in short future may cause in agriculture areas similar situation to that observed in Brazilian pastures (DOWNING et al., 2011).

In areas of Brazilian pastures where they are maintained with natural vegetation or the management of grazing adopted appropriately, the losses can be reduced (PIRES et al., 2006; TEAGUE et al., 2011). Similar finding is observed in the areas of no-tillage and minimum tillage in the United States, where lower loss values are observed (LOCKE et al., 2015; RHOTON et al., 2002). It is noteworthy that the productive longevity of tropical and temperate soils is strongly associated with soil management, which must be based on practices that maximize nutrient cycling and minimize your losses, prioritizing nutrients entering the system (KARLEN et al., 1997).

In this sense, to study different soil managements and ways of estimating the soil and water losses becomes imperative in order to properly conduct a soil management and reduce erosion study costs, taking into account different intrinsic characteristics the different regions of the world.

Over the past decades, many researchers have tried to develop mathematical models to facilitate soil erosion estimation. These models can be useful tools to guide public policy and decision making. Different types of models were developed using mathematical expressions based on physical equations and empirical observation to produce useful results (ARNOLD et al., 1998; FLAGANAN et al., 1995). However, such models still need to be adjusted to different conditions in the world.

Regarding soil management practices studies need to be guided to identify the practices that aim to reduce the loss of nutrients and carbon that can promote environmental contamination off-site erosion origin, because the transported sediment can be enriched in nutrients, especially when the sediment are thin and made of clay particles in suspension. In this way, the probabilities of these nutrients come to the rivers and reservoirs are high especially compared to the coarser sediments (BARROS et al., 2009; DEFERSHA et al., 2010).

Associated with the losses of sediment and water has been found an increase of the loss of nutrients and organic carbon, which are essential to maintaining the productivity of crops and soil quality (AGUIAR et al., 2006; AGUIAR et al., 2010; BERTOL et al., 2004). Such this behavior has been observed in several regions of the world, where a number of studies has been demonstrated the importance of management practices incorporated within a conservation context as a factor to reducing sediment, water, nutrients and carbon losses (NUNES et al., 2011; PENNINGTON et al., 2008; SHAKESBY et al., 2013).

In this sense, this thesis aims to study various aspects related to the loss of sediment and water in areas under different soil managements in Brazil and the United States, as well as identifying the most appropriate managements taking into account different realities.

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CHAPTER 1

SOIL MANAGEMENT ALTERNATIVES FOR DEGRADED PASTURE IN ATLANTIC RAINFOREST BIOME: EVALUATION OF SEDIMENT, WATER AND NUTRIENTS LOSSES

1. ABSTRACT

The objectives of this study were evaluate soil management alternatives for pasture establish in Atlantic Rainforest biome and compare differences in organic carbon (OC) and nutrient loss in runoff and in fine and coarse sediment from various pasture managements. A field study was carried out in Alegre-ES, Brazil, from September 2013 to August 2015 on an Udults clayey soil. Different pasture managements studied were: control (CON), chisel (CHI), fertilizer (FER), burned (BUR), plowing and harrowing (PH), and integrated crop-livestock (iCL). *Brachiaria brizantha* was planted for all managements. After each rainfall event, runoff and sediment samples were collected. The water and sediment (fine and coarse) samples were analyzed to determinate Ca, Mg, K, P and OC concentration. From observed rainfall data, rainfall erosivity was calculated. Soil and plant attributes such as hydraulic conductivity (K_o), macroporosity (M_a), microporosity (M_i) total porosity (TP), geometric mean diameter of aggregates (GMD), aggregation index (AI), litter and roots were measured. High values of water losses were found in the first year (2013/2014) of study in the iCL (125.87 mm or 9.5%), CON (119.58 mm or 9.1%), BUR (90.37 mm or 6.8%) and CHI (84.74 mm or 6.4%) managements, the lower values were found in the FER (32.47 mm 2.4%) and PH (9.23 mm or 0.7%) managements. The highest values of sediment losses were observed for CON and BUR managements which resulted in 10239.08 kg ha^{-1} and 5195.81 kg ha^{-1} sediment loss, respectively. Sediment losses were smaller for PH and FER managements. It was observed that the erosivity had influence on water (R^2 = 0.33) and sediment losses (course sediment R^2 = 0.15; fine sediment R^2 = 0.18). However the sediment fractions and water losses were also impacted by the soil attributes, where the coarse sediment was correlated to GMD (r = 0.97) and IA (r = 0.92), while the fine sediment was correlated to K_o (r = 0.81). The water losses was correlated to IA (r = 0.72). Regarding the management, a large fraction of nutrients (98.63 % of Ca, 99.30 % of Mg and 90.57 % of K) was lost in water, whereas a large fraction of OC (79.93 %) was lost in sediment. Larger fraction of P (65.29 %) loss occurred in water compared to sediment. Except for P, nutrients (Ca, Mg and K) and OC losses were higher in coarse sediment compared to fine. Among the managements compared, sediment, OC and nutrients losses were the highest for the CON followed by BUR management. Our findings confirmed that pasture management adopted in the basin of river *Alegre* and most part of Atlantic Rainforest need be rethought the, and indicate that burned soil management should be avoided. In case of integrated-crop-livestock and chisel soil pasture managements, a longer period of assessment is necessary, to stabilize these areas. Although, the findings of this study indicated that lower losses of sediment, water, nutrient and OC lost were observed in the plowing and harrowing soil pasture management, the best relation between losses and soil and plant attributes was observed in the fertilized pasture, suggesting that this management can be the best environmental and economic option to pastures establish in Atlantic Rainforest region.

Key words: Soil management, Calcium, Magnesium, Potassium, Phosphorus, Carbon fractions.

2. INTRODUCTION

Soil is a valuable resource and was formed slowly over the years by many specific processes. However, the process of soil erosion has led to soil degradation, thus becoming a severe problem worldwide (ALEXANDRIDIS et al., 2013). It is estimated that 1094 million ha around the world are affected by water erosion process (LAL, 2004). Mediated by runoff, organic carbon and valuable nutrients such as P, K, Ca and Mg are lost along with soil and water from hill slopes (AGUIAR et al., 2010; OLIVEIRA et al., 2013). These nutrients are important factors for plant growth, good yield, and also to increase or maintain the soil quality (BALIGAR et al., 2001; KARLEN et al., 1997).

Past studies have demonstrated that nutrient loss can cause a decline of soil fertility and watercourse eutrophication (CASALÍ et al., 2008; JARVIE et al., 2013; PIMENTEL et al., 1995; ROCHA JUNIOR, 2012). The soil and water losses by the erosion process can reduce the physical quality of soil, and generate solid residues that bring on, a series of negative impacts and environmental problems such as sedimentation (aggradation), and elevation of water turbidity (ATUCHA et al., 2013; FORTIN et al., 2015; ROBERTSON et al., 2006).

In Brazil as well as in other parts of the world, most studies with erosion have been restricted to agriculture areas, and these studies concentered on cover changes and soil management practices in different types of soil. However, few studies have been conducted to evaluate soil and water losses from pasture lands (JEMAI et al., 2013; SHAKESBY et al., 2013; TEAGUE et al., 2010). Even in agricultural areas, the majority of the studies have ignored the differences of nutrients and OC losses in water and sediment (BERTOL et al., 2010; DEFERSHA et al., 2011; OLIVEIRA et al., 2013). Similarly, the amount of nutrient and OC lost in fine and coarse sediment has not been quantified. There are very few studies which quantified OC fractions in sediment (SCHAEFER et al., 2002). Earlier studies have demonstrated that most part of OC, P, Ca and Mg were lost in particulate form, while K was lost in the soluble form (AGUIAR et al., 2006; AGUIAR et al., 2010; ANDERSON et al., 2011; DURÁN-ZUAZO et al., 2011). However, due to the differences between soil mineralogy and physical characteristics a conflicting findings have been reported in few other studies (AGUIAR et al., 2013; BERTOL et al., 2004; BERTOL et al., 2005).

In the literature, there is a consensus that the OC losses by erosion process in most part are lost in particulate form (AGUIAR et al., 2006; AGUIAR et al., 2010). Nevertheless, the management of soil that promotes the lower amount of OC loss, and the size of sediment (fine or coarse) that results in lower OC loss is still overlooked. In case of phosphorus (P), Anderson et al. (2011) found that high vegetal coverage promoted fewer P losses in pasturelands management in Jacup, Australia. They also reported that the most part of P was lost in particulate form.

In terms of K losses, Durán Zuazo et al. (2011) in Spain found that a large fraction of K loss occurred in soluble form, 65% higher compared to losses in particulate form in different vegetation covers. They also observed higher overall losses in management with bare soil. However, Aguiar et al. (2006) and Aguiar et al. (2010) found that the most part of the K was lost in particulate form in Ceará Brazil. They demonstrated that the agro-silvi-pastoral management was responsible to higher K losses. They also reported that the higher losses of Ca and Mg occured in particulate form, and the native vegetation "*caatinga*" was responsible for high K losses. Bertol et al. (2005) found that the higher amount Ca and Mg losses occurred in runoff water compared to runoff sediment in different soil managements in agricultural areas (except for bare soil).

Pastures are cover 22% of the soil throughout the world, 67% of the global agricultural land (RAMANKUTTY et al., 2008). In Brazil, approximately 20% land is used as pasture (IBGE, 2006), some of them are in degraded stage (ROCHA JUNIOR et al., 2014). Considering that studies in the literature are inconclusive, there is a need to investigate how different pasture managements impact nutrients and OC losses in water and sediment. Since the pasture areas are also responsible for producing meat and carbon sequestration (LAL, 2004), such study will provide new insight on management practice effect on soil health. Investigations of soil, water and nutrient losses from pasture areas can guide the producer in decisions making, such as characterizing the best way to renew or maintain a pasture area to reduce the soil degradation and increase the soil and water quality. In order to avoid the economic loss and maintain the environmental resources, it will be valuable to reduce the soil erosion from pasture and find ways to maintain the soil and nutrients on the field. The objectives of this study were evaluate soil management alternatives for pasture establish in Atlantic Rainforest biome and compare differences in OC and nutrient loss in runoff and in fine and coarse sediment from these pasture managements.

3. MATERIAL AND METHODS

3.1. General characterization of study area

The study was conducted at an experimental farm of CCA-UFES, situated in the municipality of *Alegre*, *Espírito Santo*. The study area is located at 22˚ 44' E longitude and 41˚ 21' W latitude (Figure 1). The 84 ha farm houses a total of 20 beef cattle and milking herd. The pasture area is planted with *Brachiaria brizantha* cv. Marandú. The soil of the study area is an Udults clayey (USDA, 2013), and the predominant native vegetation in the area is semi-deciduous Atlantic Rainforest.

The climate of the region is the Aw type (tropical, with a dry season in winter, when the average temperature in the coldest month is higher than 16.9 ˚C, and the driest month rainfall is less than 60 mm), according to the Köppen classification (KÖPPEN, 1931). The average annual rainfall is 1346 mm, with the majority of rainfall occurring between November and March. According to the meteorological station of *Universidade Federal do Espírito Santo*, the annual average temperature is 22.2 ˚C, with maximum and minimum averages at 29.0 ˚C and 16.9 ˚C respectively.

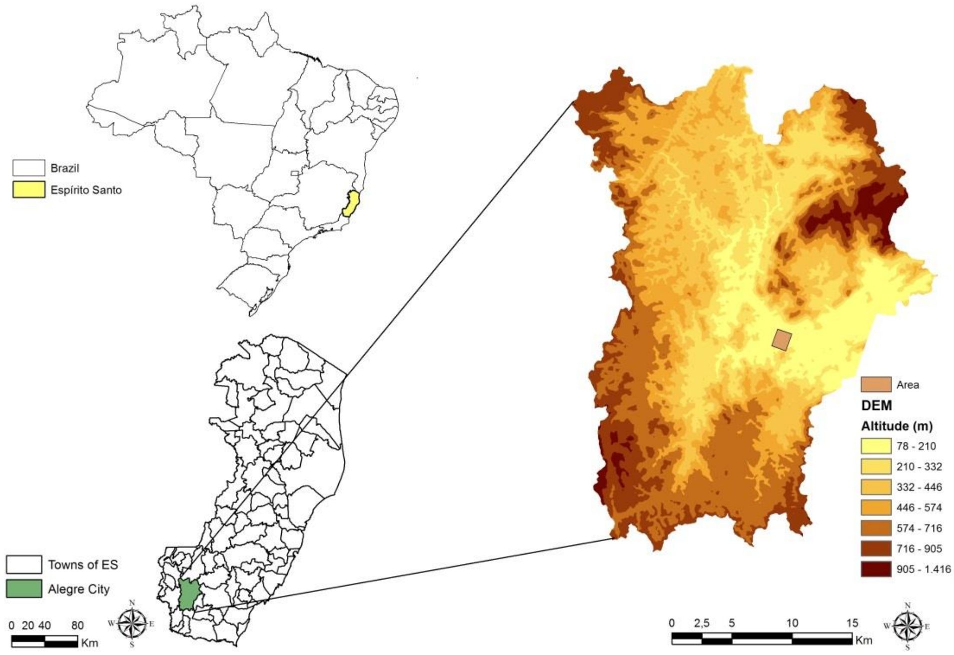

FIGURE 1. Study area, south state of *Espírito Santo*, Brazil.

3.2. Plots of soil losses and experimental design of the pastures managements

The field experiments were carried out for two years from September 2013 to August 2015.

The treatments consisted of six plots with dimensions of 11 m x 3.5 m (38.5 m^2), allocated on the middle third of the landscape in a convex landform with a slope 38 ± 4 % (Figure 2). Metal borders surrounding the plots were inserted to a depth of 0.15 m to avoid overland flow losses or gains from adjacent plots. To evaluate and collect overland flow, each plot was equipped with two tanks with capacity of 310 L each. The first was a sedimentation tank with an edge collector type GEIB with 1/7 times overland flow splitter. It was connected to a decantation tank to collect the overflow from the first tank. In each plot, the following managements of pastures were established:

Control Pasture (CON) – Control pasture had been managed for more than 10 yrs at the site. In this area, when the grass reached 0.25 ± 0.02 m, the vegetal extract was cut for 0.10 ± 0.05 cm, and all residues were removed from the plots. A similar pasture management practice was adopted in the others managements as well.

Pasture Chisel (CHI) – Chisel management was started on August 16, 2013, which involved manual row in contour, taking 0.50 m of gap between each row and 0.10 m of depth-row. Lime was applied at 1 t ha^{-1} rate to achieve a desired value of acidity 10 days before the chisel application. The fertilizer was applied fifteen days after liming, using 30 kg ha^{-1} K, 110 kg ha^{-1} P together with the seeding 30 kg ha^{-1} of *Brachiria brizhanta*. A manual planter was used for seeding and 100 kg ha^{-1} of N was applied after the emergence of grass.

Pasture Fertilize (FER) – Fertilizer management was initiated on August 06, 2013. Fertilizer was applied after fifteen days of application of 1 t ha^{-1} of lime for maintaining the acidity of the soil. The fertilizer applied was 200 kg ha^{-1} K and 50 kg ha^{-1} of P under cover. The grass was re-seeded using a manual planter on bare "*peladores*" places. After the emergence of grass, split application of N was performed through three equal doses of 50 kg ha^{-1} each (total of 150 kg ha^{-1} N).

Pasture Burned (BUR) – Burned management was initiated on 20 August, 2013 which is primarily a fire management. All residues were burned including *Brachiaria* plants aerial part, invasive narrow leaf, invasive broadleaf, and litter. The fire was rapid and was produced using a flamethrower attached to a gas canister. Grass seeds were applied using a manual planter in the entire study area and no lime or fertilizer was applied to the soil.

Integrated crop-livestock management (iCL) – Integrated crop-livestock management was implemented by adopting the no-tillage practice. Operations in this management were started on July 25, 2013. Initially residues of *Brachiaria brizhanta*, invasive narrow leaf, and invasive broadleaf were chemically desiccated with glyphosate. Soil acidity was modified with the application of 1 t ha^{-1} lime in the entire area 12 days after glyphosate application. Manual row planting was implemented in contour with 0.50 m of distance between each row. 80 kg ha^{-1} K and 120 kg ha^{-1} P was applied to the soil after fifteen days of lime application. Legumes *Feijão de Porco* (*Canavalia ensiformis*) and *Feijão guandú* (*Cajanus cajan*) were planted and used as cover plants. The legumes were planted by adopting intercalary distributed of seeds, that was done manually along the rows leaving a gap of 0.10 m for each plant. After 60% of the plants flowered (118 days), all of them were cut and the residues maintained under cover. The grass seeds were planted using a planter with 30 kg ha^{-1} of *Brachiria brizhanta*.

Plowing and Harrowing (PH) – Plowing and harrowing management was initiated on August 15, 2013. Plowing and harrowing harrowing was carried out manually in contours. All the residues (plant aerial part and litter) were incorporated into the soil to a depth of 0.15 m. Lime or fertilizer was not applied for this practice. The grass seeds of *Brachiria brizhanta* were planted at 30 kg ha^{-1} using a manual planter for the entire area.

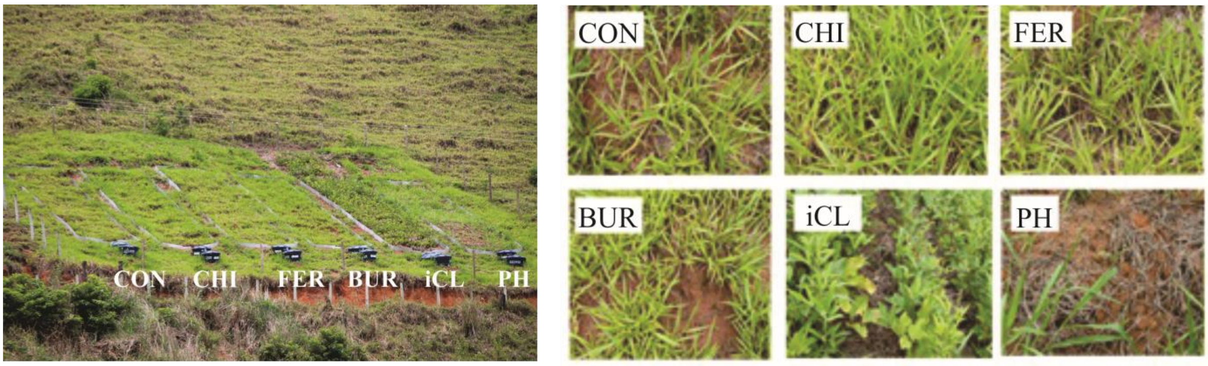

FIGURE 2 – Plots studied. CON: control; CHI: chisel; FER: fertilizer; BUR: burned; iCL: Integrated crop-livestock; PH: plowing and harrowing.

3.3. Soil physical and chemical characterization

The soil chemical and physical characteristics were identified using laboratory experiemnts. The soil texture (sand, silt and clay) was determined using granulometric analysis which included pipette method at 50 rpm for 16 h (RUIZ, 2004). The soil chemical attributes were determined using standard lab procedure (EMBRAPA, 2011). Soil pH was determined using a 1:5 soil to deionized water ratio. Exchangeable acidity (Al^{3+}) was extracted with 1 mol L^{-1} KCl and titrated with 0.025 mol L^{-1} NaOH. Potential acidity (H+Al) was extracted with 1 mol L^{-1} calcium acetate at pH 7.0 and titrated with 0.060 mol L^{-1} NaOH. Calcium and magnesium (Ca^{2+} and Mg^{2+}) were extracted with 1 mol L^{-1} KCl and determined by atomic absorption spectrometry (THERMO SCIENTIFIC ICE-3000). Phosphorus (P) and potassium (K^+) were extracted with Mehlich-1 and K^+ determined by flame photometry (DIGIMED DM-62) while P determined by photocolorimetry (EMBRAPA, 2011).

Table 1.

Chemical and physical characterization of the soils under different Pasture Managements

Pasture Managements	**pH**	**P**	**K**	**Ca**	**Mg**	**Al**	**Sand**	**Silt**	**Clay**
	H_2O	mg dm^{-3}		$cmol_c$ dm^{-3}			%		
0.00-0.05 m									
Control	5.91	1.33	124.80	0.98	1.44	0.02	59.19	7.91	32.90
Chisel	5.73	4.73	143.40	1.25	2.12	0.04	51.28	8.05	40.68
Fertilizer	5.60	4.65	160.86	1.26	2.22	0.06	44.32	9.03	46.65
Burned	6.08	2.41	176.60	1.24	2.34	0.01	56.54	6.35	37.11
iCL	5.56	6.23	130.60	0.82	2.02	0.06	58.27	6.32	35.41
PH	5.65	1.79	129.66	1.16	2.50	0.04	43.44	6.94	49.62

iCL: pasture on integrated-crop-livestock; PH: pasture on plowing and harrowing.

3.4. Soil sampling, physical and biometric (grass aerial part, litter and roots) analyses

The soil samples for laboratory analysis were collected at depth of 0.00-0.05 m. The disturbed soil samples were grounded and sieved through a 2-mm sieve to remove root material and the stone fraction. The soil sieved was air dried for determining physical parameters. To determine the dry mass of roots and aggregate stability, undisturbed samples were collected (blocks of soil) with dimensions of 0.10 x 0.10 x 0.05 m.

The physical attributes of the soil determined were: (a) hydraulic conductivity: determined using the Minidisck infiltrometer (Decagon) in the field; (b) microporosity by tension table (60 cm water column); (c) total porosity following the methodology by Danielson and Sutherland (1986). The difference in total porosity and microporosity resulted in macroporosity. The aggregate stability was computed at wet condition (KEMPER; CHEPIL, 1965), using the Yoder equipment with different sizes of sieves (0.106, 0.25, 0.5, 1, and 2 mm mesh diameter). The weight of soil on each sieve, total soil weight, and ratio of aggregate weight on each sieve to the total soil weight were then calculated. With the values, aggregate stability was calculated based on the aggregation index and geometric mean diameter of aggregates.

Litter production was collected from one 0.35 × 0.35 m square in each plot for dry mass determination during the study period. All samples were dried in an oven at 60°C for 72 h and weighed to calculate the total dry weight (g m^{-2}).

Soil roots were collected from undisturbed samples collected in blocks with dimensions 0.10 x 0.10 x 0.05 m. Samples of 50 g was added to a solution of 0.1 mol L^{-1} NaOH and left for 12 h (BARTLLET; ROSS, 1988). The solution was passed through a 0.1 mm sieve. Roots were handpicked, oven dried at 60 °C for 72 h (SHRESTHA; LAL, 2010) and weighed to calculate the total dry weight (g kg^{-1}).

3.5. Rainfall erosivity

The rainfall erosivity was estimated using the rainfall data, obtained from a meteorological station. To determine the rainfall erosivity intensity, the equation proposed by Carvalho et al. (2005) was used:

$$EI_{30} = 33.856 \times Rc + 67.991 \qquad \text{(Eq. 1)}$$

Where, EI_{30}: Energy time intensive (MJ mm^{-1} ha^{-1} h^{-1} ano^{-1}); Rc: Rainy coefficient (mm) and computed as $Rc = p^2P^{-1}$ where p: mean monthly precipitation (mm); P: mean annual precipitation (mm).

3.6. Water and sediment losses

The runoff generated after each rainfall event was collected to quantify sediment and water losses from the plots. All the materials collected inside the tanks were weighed. Sediments retained on 0.25 mm sieve was considered coarse sediment. The sediment collected by 0.250 mm sieve were dried at 45 °C and weighted to determine the coarse sediment fraction. The fine sediment fraction was determined by separating the sediment passing through 0.25 mm sieve and the water using a solution of HCl 0.1 mol L^{-1}, where the sediments were coagulated, and settled. The settled material was and dried at 45 °C and weighed to determinate the fine sediment fraction. The total amount of sediments and water losses were converted to kilogram of sediments per hectare, and mm of water.

3.7. Chemical analyses of water and sediment

To analyze sediment, triplicates of 0.5 g of fine and coarse sediment samples were digested using a mixture of concentrated nitric acid (9 mL) and hydrochloric acid (3 mL) (EPA 3051A, 2007). For water analyses, triplicates were centrifuged to remove particles in suspension. Ca and Mg contents were determined by atomic absorption; K was determined by emission flame photometry; and P by colorimetry (EMBRAPA, 2011). Dissolved organic carbon (DOC) in water sample was determined by colorimetric analyses (495 nm) (BARTLETT; ROSS, 1988). The total organic carbon (OC) concentration in the sediment (fine and coarse) was analyzed using wet oxidation method (YEOMANS; BREMNER, 1988). C fractions in coarse sediment were also determined: FII- labile fraction was determined based on organic C oxidizable with 6 mol L^{-1} of H_2SO_4; FIII- less labile fraction was determined based on organic C oxidizable with 9 mol L^{-1} of H_2SO_4; and FIV- non-labile fraction was determined using the difference in soil organic C extracted with 9 mol L^{-1} of H_2SO_4 and total organic carbon (CHAN et al., 2001). The total amount (g ha^{-1}) of Ca, Mg, P, K, OC and C fractions (FII, FIII and FIV) in sediment and water were calculated as total mass (for sediments) and volume (for water) for ha.

3.8. Statistical analyses

To analyze soil and water losses, the results for each month were summed up and were considered one representative sample of all population to each pasture management. Thus, the analysis was based on the amount of soil and water losses in each year of study. For the nutrients losses Ca, Mg, P, K, OC and C fractions, the results was based on means followed by their respective standard error. This was possible because the analytical analysis were conducted in triplicates. The monthly losses of sediments and water were correlated (Pearson) against biometric data (litter and roots) and soil properties (hydraulic conductivity, macroporosity, microporosity, total porosity, geometric mean diameter of aggregates and aggregation index). Principal component analysis was conducted to explore general trend between the variables and the soil pasture managements. The results were interpreted in terms of general trends, and all descriptive statistical procedures were performed in using Statistic (STATSOFT INC. 2004) software.

4. RESULTS

4.1. Multivariate analysis

The principal component analysis demonstrated that the attributes of plant and soil studies, as well the loss of water and sediment, explained largely the variations found among the managements of pastures studied (Table 2 and Figure 3). The PC_1, PC_2 and PC_3 explained up to 91.22% of the generated discriminant function, and the largest of percentage in accumulated variance was found for the first component with 44.21 %. Highest value of eigenvalue was found for the same component.

Except for the hydraulic conductivity (K_o), all others soil and plant attributes, as well soil and water losses studied correlated with the main components, which showed values above 0.70 (Table 2). This result demonstrates that all attributes chosen was possible to explain greater part of the variation found between the managements of pasture.

Table 2.

Principal component analysis for the first five principal components (PC)

Principal components	**PC_1**	**PC_2**	**PC_3**	**PC_4**	**PC_5**
Eigenvalue	5.31	3.56	2.08	0.99	0.06
Total variance (%)	44.21	29.68	17.33	8.25	0.53
Cumulative %	44.21	73.89	91.22	99.47	100.00
Factor coordinates of the variables:					
Water	0.80	0.41	0.05	0.42	-0.09
Fine sediment	0.72	-0.53	-0.19	0.40	0.08
Coarse sediment	0.95	-0.22	0.01	-0.18	-0.11
Plant aerial part	0.16	0.07	-0.72	-0.67	0.01
Litter	-0.19	0.95	-0.22	0.13	-0.02
Roots	0.07	-0.94	-0.33	-0.02	0.00
Ko	-0.68	0.26	0.67	-0.16	0.07
Ma	-0.26	-0.81	0.52	-0.07	-0.05
Mi	-0.57	-0.01	-0.77	0.28	0.03
TP	-0.65	-0.74	-0.10	0.15	-0.02
GMD	-0.98	0.03	-0.14	0.16	0.02
IA	-0.98	0.00	-0.12	0.04	-0.16

CON: pasture control; CHI: pasture chisel; FER: pasture fertilizer; BUR: pasture burned; iCL: pasture on integrated-crop-livestock; PH: pasture on plowing and harrowing.

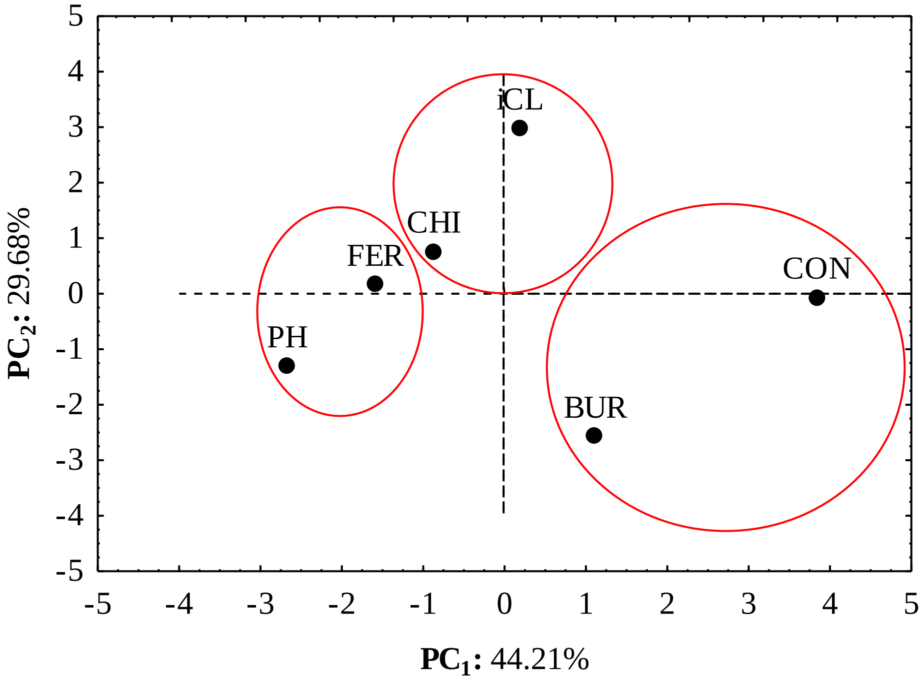

FIGURE 3. Dispersion of soil pasture managements depending on the scores of the principal components. CON: pasture control; CHI: pasture chisel; FER: pasture fertilizer; BUR: pasture burned; iCL: pasture on integrated-crop-livestock; PH: pasture on plowing and harrowing.

The dispersion graph showed that CON and BUR pasture managements demonstrated close relationship with the PC_1 (Figure 3). For PC_2 the highest close relationship was observed for iCL and CHI management while FER and PH managements indicated a close relationship with PC_3.

4.2. Physical and biometric characterization

Table 3 illustrates that the mean values of plant and soil data collected during two years in different pasture management (2013-2015) showed a large variation. There was a trend to higher values for plant aerial part production in the managements that did not received any soil preparation, such FER and CON managements. However, the fertilization of soil promoted a tendency of high plant aerial part production in the FER management. It was observed that CHI management also resulted in the high value of plant aerial part production.

Table 3.

Mean values of roots, litter, hydraulic conductivity (K_o), macroporosity (M_a), microporosity (M_i) total porosity (TP), geometric mean diameter of aggregates (GMD) and aggregation index (AI) in different soil pastures managements

Variables	**Soil pasture managements**					
	CON	**CHI**	**FER**	**BUR**	**iCL**	**PH**
0-5 cm						
Plant aerial part (g m^{-2})	946.21	686.49	1061.84	276.84	272.04	399.03
Roots (g kg^{-1})	4.67	4.87	5.01	6.07	3.44	4.11
Litter (g m^{-2})	192.02	357.02	302.22	88.92	457.04	141.24
K_o (cm^2 h^{-1})	6.2	8.6	9.4	6.6	14.6	17.8
M_a (m^3 m^{-3})	0.12	0.11	0.11	0.17	0.09	0.20
M_i (m^3 m^{-3})	0.27	0.34	0.35	0.31	0.29	0.29
TP (m^3 m^{-3})	0.39	0.45	0.46	0.48	0.39	0.49
GMD (mm)	1.61	1.81	1.83	1.74	1.76	1.83
AI > 2 mm (%)	73.60	85.56	84.86	79.27	80.48	86.77

CON: pasture control; CHI: pasture chisel; FER: pasture fertilizer; BUR: pasture burned; iCL: pasture on integrated-crop-livestock; PH: pasture on plowing and harrowing.

The BUR management was the most productive in terms of root production, which yielded a value of 6.7 g kg^{-1}. In the FER management, measured root value was 5.01 g kg^{-1}. This demonstrated that the liming and fertilization practiced in this management also had an influence on root growth. The combination of soil inputs (lime + fertilization) with mechanical practices such as scarification of pasture also demonstrated to have positive effect on root growth, promoting numerically higher values in the CHI management (4.87 g kg^{-1}) compared to iCL and PH managements. The adoption of isolated mechanical practice, as carried out in the PH management or inputs associated with vegetative practices as adopted in iCL pasture, tended to result in numerically lower values of root production. The absence of soil management as observed in the CON pasture also led to lower values for root production (Table 3).

Higher value of litter was observed for iCL management, which was followed by CHI and FER pasture managements. On the other hand, the lowest value of litter was observed for BUR pasture management (Table 3).

The PH pasture harrowing resulted in the highest value of hydraulic conductivity (K_o), macroporosity (M_a) and total porosity (TP), while the lowest values of K_o and TP were observed in CON pasture (Table 3). Although FER pasture had numerically lowest values of M_a fallowed by iCL management, those management also showed intermediate values of K_o. In the meantime, the FER pasture demonstrated numerically higher M_i values compared to other managements (Table 3).

The highest values of geometric mean diameter (GMD) were observed for FER and PH managements with a value of 1.83 mm. With the exception of CON and BUR pastures, all others showed aggregation index (AI) greater than 80 %. Those two managements also resulted in lower values of GMD compared to other managements (Table 3).

4.3. Precipitation, water and sediment losses

The precipitation data and computed erosivity (EI_{30}) for the years 2013/2014 and 2014/2015 are shown in Figure 3. The first year of study (2013/2014) received higher rainfall compared to the second year (2014/2015) (Figure 4). Erosivity (EI_{30}) followed a similar trend as precipitation data, where the higher computed values of EI_{30} was obtained for first year (2013/2014). For December 2013, erosivity was computed to be 6060.75 MJ mm^{-1} ha^{-1} h^{-1}, which is much higher than erosivity values for other months of during this study (Figure 4).

The amount of runoff volume and sediments loss for each soil pasture management followed a trend similar to erosivity and the losses were higher for the first year compared to the second year (Figure 4 and Table 4).

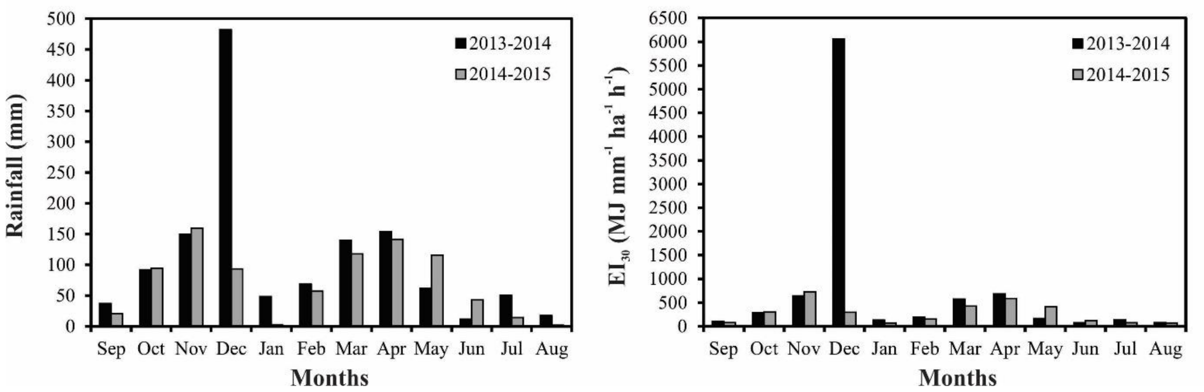

FIGURE 4. Rainfall, and monthly erosivity estimated from the rainfall database recorded in Alegre-ES, in the years 2013/2014 and 2014/2015.

Table 4.

Losses of fine and coarse sediment by run-off evaluated in 2013/2014 and 2014/2015 in different soil pastures managements

Soil pasture managements	**Fine Sediment (<0.250 mm)**		**Coarse sediment (>0.250 mm)**		**Total Sediment**	
	2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015
	kg ha^{-1} year^{-1}					
CON	459.63	16.74	9779.45	59.62	10239.08	76.35
CHI	189.11	24.68	1347.13	143.28	1536.24	167.96
FER	160.60	9.25	101.23	46.49	261.83	55.74
BUR	693.69	28.58	4502.12	116.15	5195.81	144.73
iCL	96.12	24.69	988.47	149.21	1084.59	173.90
PH	1.93	0.77	10.48	1.97	12.42	2.75

CON: pasture control; CHI: pasture chisel; FER: pasture fertilizer; BUR: pasture burned; iCL: pasture on integrated-crop-livestock; PH: pasture on plowing and harrowing.

Water losses in 2013/2014 were numerically higher for iCL (125.87 mm), CON (119.58 mm), BUR (90.37 mm) and CHI (84.74 mm) managements compared to other managements. The lowest runoff volume was observed for PH (9.23 mm) and FER (32.47

mm) managements (Figure 5). For the second year (2014/2015), water losses were observed for BUR (8.44 mm) and CHI (5.45 mm) managements compared to the other managements as observed for the first year (2013/2014). Runoff losses were smaller for PH (0.75 mm) and FER (3.08 mm) managements in the second year compared to the other managements (Figure 5).

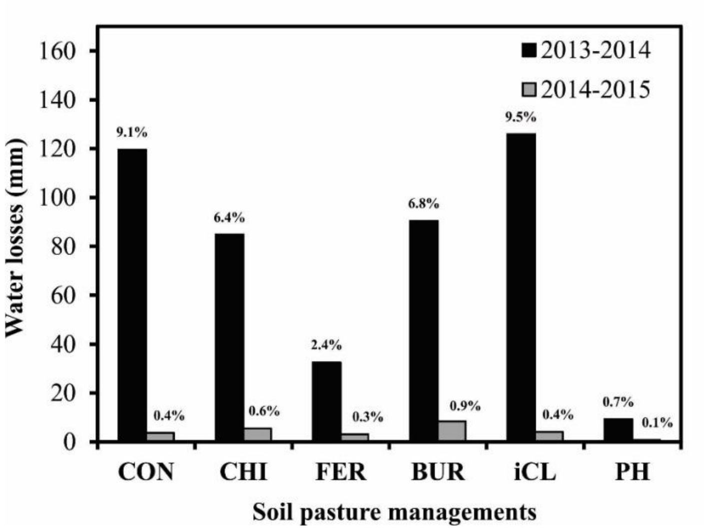

FIGURE 5. Measured run-off volume in 2013/2014 and 2014/2015 for different soil pastures managements. CON: pasture control; CHI: pasture chisel; FER: pasture fertilizer; BUR: pasture burned; iCL: pasture on integrated-crop-livestock; PH: pasture on plowing and harrowing.

In 2014/2015, the total sediment loss was numerically lower for the PH management compared to other managements, however the differences in sediment loss among the management in this year was small. Compared to other managements, CON and BUR managements resulted in higher amount of total sediment losses with 10239.08 kg ha^{-1} and 5195.81 kg ha^{-1}, respectively in 2013/2014. Sediment losses were smaller for PH and FER managements in 2013/2014 (Table 4).

Table 4 illustrates that the BUR management resulted in the highest fine sediment loss with 693 kg ha^{-1} in 2013/2014, and 28.58 kg ha^{-1}in 2014/2015 compared to other managements. With regard to the coarse sediment, CON management yielded the highest loss (9779.693 kg ha^{-1}) in the year 2013/2014, while the iCL management resulted in the highest coarse sediment loss (149.21 kg ha^{-1}) in the following year compared to the other managements.

4.4. Patterns of sediment and water losses and the relation of losses with erosivity (EI_{30}), biometric and soil physical attributes

Figure 6A shows the relationship among monthly sediment (total) loss, water loss and rainfall erosivity (EI_{30}). The Figure 6B, 6C and 6D shows the relationship among monthly fine and coarse sediment, and water losses and the respectively relations of these eroded material with the rainfall erosivity (EI_{30}).

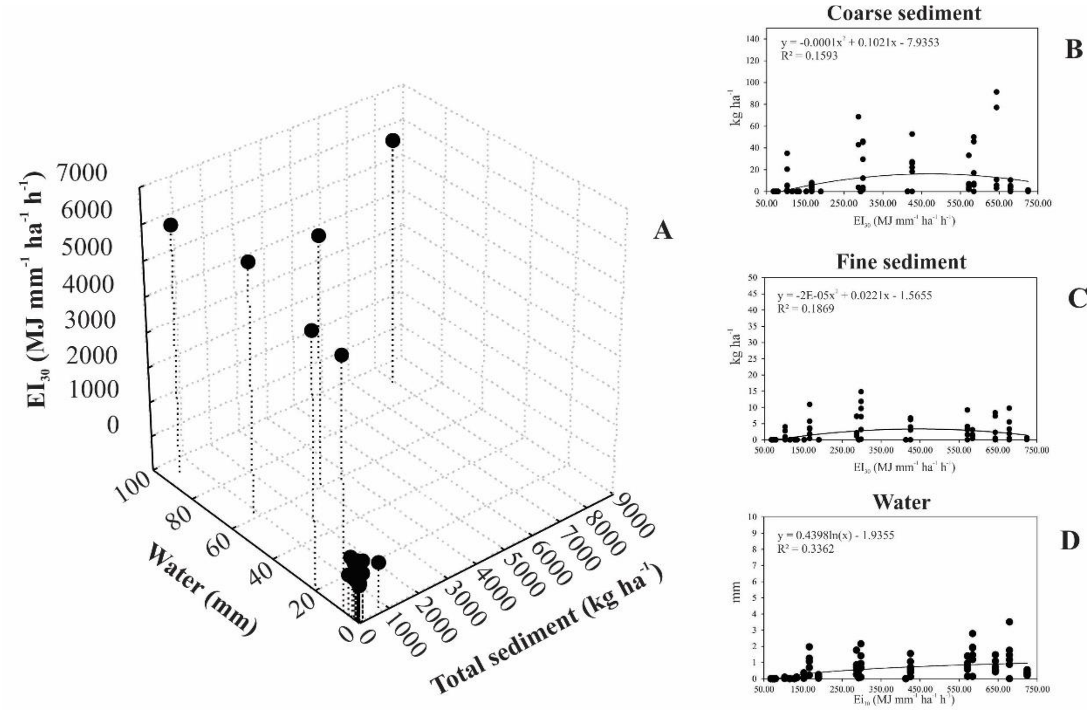

FIGURE 6. Scatted 3D plot between EI_{30} (MJ mm^{-1} ha^{-1} h^{-1}), water (mm) and total sediment (kg ha^{-1}) (A); relation between EI_{30} (MJ mm^{-1} ha^{-1} h^{-1}) and coarse sediments (kg ha^{-1}) (B); relation between EI_{30} (MJ mm^{-1} ha^{-1} h^{-1}) and fine sediment (kg ha^{-1}); relation between EI_{30} (MJ mm^{-1} ha^{-1} h^{-1}) and water losses (mm); considerate all soil pasture managements in the years of 2013/2014 and 2014/2015.

As observed in Figure 6A, water and sediment losses were related to rain with erosivity with values lower than 1.000 MJ mm^{-1} ha^{-1} h^{-1}.

It was also observed that there was an increase in sediment and water losses with the increase in erosivity (Figures 6B, 6C, 6D). The R^2 value was highest (0.33) between water loss and erosivity. Similarly, the R^2 values were 0.18 between erosivity and fine sediments, and 0.15 for erosivity and the coarse sediment.

Although water and sediment losses were correlated with erosivity, the low values of R^2 indicated that other variables also play role in the water and sediment losses. For example, the water loss was negatively correlated to TP (-0.77) and AI (-0.76), which indicated the increases in these variables would result in the decrease in runoff and water losses. Coarse sediment had a negative correlation with the GMD (-0.97). For fine sediment, K_o (-0.81) was the variable with the highest negative correlation (Table 5).

Table 5.

Correlation among Water, Fine and Coarse sediments from runoff in different soil pasture managements

Variable	Water	Fine sediment	Coarse sediment
Plant aerial part	-0.16^{ns}	-0.05^{ns}	0.25^{ns}
Roots	-0.36^{ns}	0.60^{ns}	0.27^{ns}
Litter	0.28^{ns}	-0.55^{ns}	-0.42^{ns}
K_o	-0.48^{ns}	-0.81^{*}	-0.67^{ns}
M_a	-0.54^{ns}	0.12^{ns}	-0.04^{ns}
M_i	-0.38^{ns}	-0.14^{ns}	-0.60^{ns}
TP	-0.77^{*}	0.00^{ns}	-0.48^{ns}
GMD	-0.71^{ns}	-0.62^{ns}	-0.97^{**}
AI	-0.76^{*}	-0.68^{ns}	-0.92^{**}

**, * significant at 0.05 and 0.10, respectively. Hydraulic conductivity (K_o); Macroporosity (M_a); Microporosity (M_i); Total porosity (TP); Geometric mean diameter of aggregates (GMD); and aggregation index (AI).

4.5. Losses of nutrients and carbon

Nutrient and OC losses from various pasture management are presented in Table 6. Total nutrient losses were numerically higher for the first year compared to the second. The CON management followed by BUR managements resulted in more nutrient losses in 2013/2014. For the second year (2014/2015), higher nutrient loss was observed the CHI management compared to other managements. Nutrient losses were smaller for PH and FER pasture managements for both years (Table 6).

The BUR and iCL managements had the higher nutrient loss in water for the first year. However, CHI management produced the highest amount of nutrient loss in the water in the second year. In terms of nutrient lost in sediment, PH management resulted in the lowest nutrient loss compared to the other managements (Table 6).

Table 6.

Means of amounts of organic carbon (OC) and nutrients (g ha^{-1}/year) losses in sediments (fine and coarse) and water from soil pasture management in different seasons in 2013/2014 and 2014/2015

Variable	Compartment	Pasture Management					
		CON	**CHI**	**FER**	**BUR**	**iCL**	**PH**
		2013/2014					
		g ha^{-1} $year^{-1}$					
Ca	Sediment F.	2.00±0.04	0.21±0.03	1.40±0.21	4.83±0.67	0.36±0.05	0.06±0.00
	Sediment C.	3.71±0.51	1.14±0.04	0.07±0.01	1.39±0.17	2.16±0.32	0.10±0.01
	Water	247.65±6.51	488.16±16.86	221.47±6.30	838.58±20.21	582.51±24.97	362.38±16.30
Mg	Sediment F.	6.21±1.13	2.75±0.36	2.62±0.36	11.45±1.58	1.28±0.14	0.08±0.01
	Sediment C.	80.48±11.83	11.68±1.27	0.82±0.37	34.45±4.36	7.28±0.87	0.13±0.01
	Water	4686.04±187.17	5274.24±214.70	1955.10±57.49	2604.72±45.03	5149.15±202.53	888.68±30.82
P	Sediment F.	72.63±12.34	39.32±4.17	55.90±7.60	179.95±22.94	35.22±3.27	3.37±0.49
	Sediment C.	49.76±8.25	25.48±0.65	5.82±1.75	31.22±2.47	38.19±4.42	0.82±0.12
	Water	259.53±12.46	173.98±10.12	87.20±5.15	38.56±1.62	86.57±4.43	210.31±11.68
K	Sediment F.	170.62±8.55	60.67±5.38	56.76±1.99	186.33±2.81	20.22±7.56	2.48±31.04
	Sediment C.	1829.21±268.38	234.27±23.49	17.09±8.25	470.18±53.28	103.69±12.48	0.53±0.07
	Water	4281.62±176.24	4668.44±189.18	3101.30±114.33	5025.33±195.06	3922.83±89.38	989.84±49.18
OC	Sediment F.	7056.91±1270.59	3243.58±403.989	4364.80±599.145	15942.50±2099.11	2768.01±286.56	347.57±51.49
	Sediment C.	132200.44±19436.06	15874.87±1658.19	2029.68±488.95	50546.52±6099.96	18336.72±2462.44	1658.32±147.77
	Water	2352.33±112.97	1664.27±76.40	640.29±27.25	1770.41±76.79	2462.03±114.72	213.65±8.91
		2014/2015					
		g ha^{-1} $year^{-1}$					
Ca	Sediment F.	0.93±0.07	0.98±0.09	0.67±0.05	1.26±0.13	1.25±0.10	0.08±0.01
	Sediment C.	3.02±0.34	5.91±0.65	2.87±0.35	4.42±0.33	5.73±0.43	0.02±0.00
	Water	90.77±3.19	235.85±7.26	56.15±1.88	148.56±5.63	134.17±5.05	18.07±0.52
Mg	Sediment F.	0.32±0.03	0.37±0.03	0.14±0.01	0.38±0.05	0.27±0.03	0.02±0.00
	Sediment C.	0.60±0.05	1.33±0.14	0.36±0.03	1.42±0.19	1.69±0.22	0.02±0.00
	Water	54.24±2.02	178.39±5.15	68.96±2.66	210.66±8.85	71.23±2.43	10.79±0.32
P	Sediment F.	11.04±1.30	16.98±1.95	5.08±0.59	13.89±1.85	10.82±1.25	0.49±0.05
	Sediment C.	6.10±0.65	34.38±3.00	4.77±0.48	9.87±0.99	19.08±2.24	0.91±0.13
	Water	71.40±3.27	147.00±6.61	66.86±2.63	51.93±2.14	36.11±1.73	15.70±0.61
K	Sediment F.	23.00±2.16	31.56±3.55	5.70±0.60	13.16±1.63	9.46±0.93	0.47±0.05
	Sediment C.	20.63±2.63	122.66±13.30	19.30±2.52	22.20±1.98	30.50±2.89	1.10±0.16
	Water	381.17±11.52	685.05±20.23	331.03±12.23	403.34±12.16	176.75±6.84	139.87±6.44
OC	Sediment F.	564.56±76.82	656.98±112.32	85.91±10.74	142.40±21.09	110.95±16.90	5.78±0.85
	Sediment C.	1653.13±186.86	3955.95±489.90	591.87±61.23	2598.19±265.81	4041.39±517.21	0.00±0.00
	Water	67.92±1.87	214.04±6.13	57.60±1.92	156.47±5.13	73.40±2.23	14.36±0.45

CON: pasture control; CHI: pasture chisel; FER: pasture fertilizer; BUR: pasture burned; iCL: pasture on integrated-crop-livestock; PH: pasture on plowing and harrowing.

Regardless of the management and considering both years (2013/2014 and 2014/2015), in general, most part of Ca (98.63%), Mg (99.30 %), K (90.57 %) and P (65.29 %) were lost in water. In case of organic carbon (OC), the high percentage (79.93 %) was lost in the adsorbed form, associated with the sediment (Table 6).

The BUR management followed by iCL produced the higher amount of total Ca and Mg loss, with 999.04 g ha^{-1} of Ca and 2863.08 g ha^{-1} of Mg in the BUR management, and 726.18 g ha^{-1} of Ca and 5230.9 g ha^{-1} of Mg in the iCL management. In the meantime, CON and CHI management tended to produce higher amount of P loss with 470.45 g ha^{-1} and 437.13 g ha^{-1}, respectively. Similarly, CON and BUR management resulted in greater amount of OC and K losses that were, 6706.24 g ha^{-1} of K and 143895.30 g ha^{-1} of OC in the CON management, and 6120.54 g ha^{-1} of K and 71156.5 g ha^{-1} of OC in the BUR management (Table 6).

While comparing OC loss in two sediment sizes, it was observed that the OC loss was higher in coarse sediment, and the same was true for Ca, Mg and K. However, higher P losses occurred in fine sediment (Table 6).

Most part of OC loss in the sediment evaluated in the different pasture managements was found in the fraction less labile in the first year (2013-2014) (Table 7). In this year the higher amount of less labile OC loss was found in the management CON (67692.38 g ha^{-1}) followed by BUR management (23547.27 g ha^{-1}).

Table 7.

Organic carbon (OC) fractions losses in sediments from pasture management in 2013/2014 and 2014/2015

Variable	Pasture Management					
	CON	CHI	FER	BUR	iCL	PH
	2013-2014					
Labile C (g ha^{-1} year^{-1})	31968.80	4406.56	122.80	12243.15	2092.53	0.00
Less labile C (g ha^{-1} year^{-1})	67692.38	6151.75	6614.39	23547.27	5716.75	180.00
Recalcitrant C (g ha^{-1} year^{-1})	6994.69	3971.21	4893.24	22761.90	4598.40	81.89
	2014-2015					
Labile C (g ha^{-1} year^{-1})	350.36	2025.18	268.30	540.57	740.32	0.00
Less labile C (g ha^{-1} year^{-1})	99.80	709.15	96.27	272.16	288.13	0.00
Recalcitrant C (g ha^{-1} year^{-1})	477.12	3081.81	411.38	764.30	1047.76	0.00

CON: pasture control; CHI: pasture chisel; FER: pasture fertilizer; BUR: pasture burned; iCL: pasture on integrated-crop-livestock; PH: pasture on plowing and harrowing.

In the second year, the most part of OC was lost in the recalcitrant form, and the CHI followed by iCL management were responsible for high tendency of recalcitrant OC losses with 3081.81 g ha^{-1} and 1047.76 g ha^{-1}, respectively. It was observed that PH and FER managements presented generally low OC losses in all compartments, and the higher losses generally was found in CON and BUR managements (Table 7). Regardless of the management, the highest OC losses was found in the less labile compartment (50.11 %), followed by recalcitrant (32.29 %) and labile (17.6 %) (Table 7).

5. DISCUSSION

5.1. Multivariate analysis

The result of principal component analysis (PCA) suggests that all variable used (soil properties, biometric plant, water and soil losses) explained the variations in the different practices of soil pasture managements. According to Regazzi (2000), it is desirable that the cumulative variance in the first two principal components to exceed 70-80 %, a fact that has been verified in the present study. According to Kaiser criterion (KAISER, 1960), the minimum number of components to retain was equal to three of the eigenvalues started to be lower than 1 at PC_3, which is in agreement with the present study. An interesting finding was that the CON and BUR treatments were associated with the PC_1, the iCL and CHI soil pasture management was associated with PC_2 and the PH and FER soil pasture managements were associated with the PC_3. This separation was very similar to the finding based on soil attributes and the loss of sediment and water.

5.2. Physical and biometric characterization and water and sediment losses

The first year the high amount of rain and the short effects of the management practices adopted on the soil could be the reason of the high values of losses found. These results corroborate the finding from a previous study by Aguiar et al. (2010). Due to the stability of some management associated with the reduction in amount of rain in the second year (2014/2015) may have led to the tendency of lower values of sediment and water loss in the second year (Figure 5).

Conservational soil management practices improve soil structure (COMTE et al., 2012; JAKELAITIS et al., 2008) and consequently reduce the loss of sediments. In the present study, the PH, FER, CHI and iCL managements demonstrated greater values of GMD, AI and K_o (Table 3), and consequently demonstrated lower values on total loss of sediment and water (Table 4). On the other hand, the CON and BUR managements provided lower values for these attributes, and in general were the managements with the higher losses of soil and water (Table 4).

Since the CON pasture management yielded higher total soil losses compared to BUR management, it is not recommended management for soil conservation (MENDONÇA et al., 2015). From this result, it can assumed that livestock management in the sub-basin of river *Alegre* and many parts of the pastures in Atlantic Rainforest have to be rethought, since most of the pastures in this region have similar management. As CON and BUR managements resulted in higher values soil loss compared to other practices, especially in the first year (2013/2014) which was the year with higher rainfall, it reinforces the hypothesis that implementation of these managements should be rethought in the region.

Even with low production of plant aerial part, BUR management in the present study resulted in less soil loss compared to CON pasture management. Due to the initial deposition of ash on the soil after burn, that consequently led to the improvement in the soil chemical properties it resulted in a rapid regrow of the *Brachiria* which coincided with the period with high amount of rainfall (December of 2013). Initially burning can raise soil pH and increase the levels of Ca^{2+}, Mg^{2+} and K^{+} by the deposition of ash, creating a better grass growth condition (KNICKER, 2007; PIVELLO et al., 2010). Furthermore, the burning can stimulate the grass regrowth, eliminating more lignified parts not consumed by grazing and increasing soil cover (BEHLING; PILLAR, 2007; KASCHUK et al., 2012). However, the management can temporarily increase the exposure of the soil. The soil exposure can facilitate erosion, increasing soil erosion and nutrients losses leading to degradation process (TEAGUE et al., 2010).

Considering the two years studied, the CON and BUR pastures showed strong relationship with losses of coarse and fine sediments, respectively. The results of this study showed that these management are responsible to high losses of these sediments (Table 4). The high regrowth of grass in the BUR pasture compared to CON pasture, influenced the root growth, increased the soil aggregation (Table 3) and consequently decreased the breakdown capacity of larger aggregates to rain, raising the transport of fine material. Furthermore, the poor soil structure led to a higher capacity to rain break and transport a larger amount of sediment in CON pasture management.

It is interesting to note that the low sediment and water losses associated with PH and FER pastures managements, were related to soil roughness and the high cover soil. The tillage operation in contour performed in PH management or the higher litter deposition and management in FER management created physical barriers for surface runoff, reducing drastically the runoff and increasing the water infiltration in the soil profile (BERTOL et al., 2010). In addition, the greater root growth in the FER pasture management stimulated soil aggregation (Table 3).

Although the PH management had the lowest sediment and water loss among all the managements, it is noteworthy to mention that satisfactory production of grass was not observed for a long time due to low values of plant aerial part and root production and litter deposition for this management (Table 3). This result suggests that the application of this management practice may not be the most productive in terms of economic point of view. However the addition of fertilizer (NPK) led to further growth of the pasture, high levels of root growth and litter improving soil cover, in addition, the management resulted in higher values of GMD (Table 3). Previous studies in different parts of Brazil have shown that addition of nutrients on soil led an improvement of its quality, especially in pasture of *Brachiaria* (NORONHA et al., 2010; TOWNSEND et al., 2010).

High water loss in the first year in iCL and high value of soil loss in the second year in CHI pasture, as well intermediate values of total loss for the both year, indicated that these managements were in transition and required a larger period of evaluation. The initial sequence of practices such as scarification in contour, chemical desiccation and use of cover plant, may have led to initial disturbances in the soil, and time for reestablishment was not enough for these areas to reach the true productive potential. In that sense, only two years of evaluation may not be enough to assess the effectiveness of these managements. However, these managements have potential for to be used as a grazing conservation practice to reduce soil and water loss based on the K_o values and litter production observed. Both managements have been recommended to promote the improvement in soil quality by raising their productive capacity (AGUIAR et al., 2010; SANTOS et al., 1998). Specially, the iCL management is characterized by the diversification of production capacity within the farm (MURGUEITIO et al., 2011).

5.3. Patterns of losses and the relation with erosivity (EI_{30}), biometric and soil physical attributes

As the calculated erosivity values were related to the loss of water and sediment, it indicated that the amount of rainfall and its distribution were important factors for the soil erosion. This explained the fact of the first year (2013/2014) with the higher volume of rain (1313.2 mm) produced a higher sediment and water losses. (Figure 6A). The result from this study indicated that the correlation coefficient between erosivity and water loss can explains part of the phenomena of water losses. The other part could be related to the total soil porosity (TP) and aggregation index (AI), that the improvement of these soil proprieties can raise the water infiltration in soil profile reducing the runoff.

Although a correlation was found between the losses of sediment with erosivity, low correlation values, especially for coarse sediments, indicated that sediment loss depends on other factors, such as management and the soil characteristics (Figure 6). An explanation for this phenomenon might be that the lower values of AI and geometric mean diameter (GMD) were responsible for the high loss of coarse sediments, while the low hydraulic conductivity (K_o) values were responsible for the highest loss of fine sediments (Table 5).

High aggregation (AI and GMD) led to low values of aggregate detachment and consequently decrease the load of coarse sediment. While low hydraulic conductivity increases the runoff and consequently led to high transport of fine sediment that is on the soil and are easily to transport. Prior studies have noted the importance of the soil structure for the reduction of soil erosion, which consequently decreases the sediment transport (JIEN; WANG, 2013), especially those of smaller size (PANUSKA et al., 2008). Improving the soil physical structure has a direct effect on soil porosity increasing the infiltration of water, which consequently promotes the reduction of surface runoff, reducing water loss (AGUIAR et al., 2010; DELAUNE; SIJ, 2012; SCHEFFLER et al., 2011).

5.4. Losses of nutrients and OC

The largest amount of Ca and Mg were lost in the BUR pasture management compared to others. Since the management involves the burning of the aerial part, it could enhance the availability of the nutrients (KNICKER et al., 2005; PIVELLO et al., 2010). These nutrients are also soluble and are capable of being transported on runoff; the same applies for the K in BUR management. In the iCL management, high values of Ca and Mg losses are related with liming that increased the levels of Ca and Mg in this soil. But the high water loss observed in this management consequently led to increased loss of these nutrients (Figure 5).

The higher P loss observed in CHI pasture is related to phosphate fertilizer associated with partial soil disturbance. The fertilization caused the P enrichment in sediment and runoff water. Similarly, the partial disturbance caused, especially in the second year, the higher losses of sediment and the second largest water loss, which led to higher loss P. For CON pasture the high values of P losses was related to the large amount soil and water loss, especially in the first year. The reason may be same for the high loss of OC in this management (Figure 5 and Table 6).

In general, the most part of Ca, Mg and K were lost in the runoff water. Surprising, the high loss of P occurred in soluble form (Table 6). For the cations (Ca, Mg and K) that are soluble and more easily to be transported by runoff, similar findings are reported in the literature (BERTOL et al., 2004; BERTOL et al., 2005; DURÁN-ZUAZO et al., 2011). However, the most part of P loss tended in adsorbed to sediment form (AGUIAR et al., 2006; AGUIAR et al., 2010) due to oxidic nature of soil and the high potential for adsorption of tropical soils (NOVAIS; SMYTH, 1999). In the present study, a possible explanation for the high losses of P in runoff water would be the large volume of water lost compared to the volume of soil. Another possible explanation is related to the study area that contained a large amount of coarse sandy in pasture areas, which reduced the adsorption capacity of the soil P (Table 1). For carbon, the majority of OC was lost in particulate form as expected. This can be attributed to the fact that much of the carbon in the soil is associated with the soil colloidal fraction and a small part in soluble form (SILVA; MENDONÇA, 2007).

With respect to the organic matter loss, it was noted that most common pathway for OC loss was in less labile fraction (2013/2014) and recalcitrant (2014/2015). This is associated with the fact that the carbon in the soil are found in higher chemical stability and molar mass coming from humification of soil organic matter in these fractions (LEITE et al., 2003; SILVA; MENDONÇA, 2007).

The CON and BUR managements were the managements which resulted in the high carbon loss in the less labile and recalcitrant fractions. The C loss in the labile fraction in these managements were also higher in amount compared to other managements. This result indicates that the loss of C in the different forms may result, in reduced the soil carbon sequestration, decreased aggregation and availability of nutrients (MAIA et al., 2007). Moreover, this can be observed with carbon selective loss, especially with the most labile, may be marked loss of CTC these soils is highly dependent on the organic matter (SCHAEFER et al., 1999).

6. CONCLUSIONS

The present study was designed to determine the effect of different pasture managements (maintenance or renew) on sediment and water losses, as well the influence of these managements in the losses of OC and nutrient's in fine and coarse sediments and water runoff. These experiments confirmed that pasture management adopted in the basin of river *Alegre* and most part of Atlantic Rainforest need be rethought, since the high values of sediment, OC and nutrients losses was found in the management, similar to the commonly used in this region. Our findings indicate also that the burned soil management should be avoided, since the practice resulted in higher values of sediment, OC and nutrients losses compared to other managements. In case of integrated-crop-livestock and chisel soil pasture managements, a longer period of assessment is necessary, to stabilize these areas and to obtain results closer to the real condition. Although, the findings of this study indicated that lower losses of sediment, water, nutrient and OC lost were observed in the plowing and harrowing soil pasture management, the best relation between losses and soil and plant attributes was observed in the fertilized pasture, suggesting that this management can be the best environmental and economic option among the management evaluated in this study. Rainfall erosivity was related with the water and sediment (fine and coarse) losses. The water loss was also influenced by the soil aggregation index (AI) and total porosity (TP). And the soil attributes played major role in soil losses. For example, the coarse sediment loss was related to geometric mean diameter (GMD) and aggregation index (IA), while the fine sediment loss was related to hydraulic conductivity (K_o). Almost Ca, Mg and K were lost in dissolved form, whereas the most OC was lost in adsorbed form. However, contrary to the earlier finding, the P loss mainly occurred in dissolved form rather than adsorbed form. These finding have significant implications for the future studies in tropical soil to assess the relationship among amount of water, soil texture and mineralogy and P losses. Except for P, all nutrients and OC were lost more in coarse sediment compared to fine sediment. Most part of OC was found in the compartments less labile and recalcintrat.

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CHAPTER 2

PROPOSITION OF LAND COVER MANAGEMENT *C*-FACTOR FOR USLE/RUSLE IN PASTURES IN BRAZILIAN ATLANTIC FOREST BIOME

1. ABSTRACT

The objective of this study was to determine the *C*-factor for USLE/RUSLE for different soil managements on pastures established in Brazilian Atlantic Rainforest, and to compare the soil loss estimate from USLE/RUSLE with the field observations. To calculate the *C*-factor under five managements of renew or recovery of pastures, soil and rainfall data from August 2013 to September 2015 were utilized. The studied pasture managements were: Control, Chisel, Fertilizer, Burned, Integrated crop-livestock and Plowing/harrowing. The pasture cycle was divided in initially stage, 4 months, and establishment stage, 24 months. To calibrate the soil losses determined by USLE/RUSLE, the results were compared with the losses measured in the field using statistical parameters. After calibrating *C*-factor values in small plots, the results were scaled up to compute soil losses from different pastures managements in the County of *Alegre* (ES)-Brazil. The results showed that there was a variation in *C*-factors for different pasture management, as estimated by USLE/RUSLE. An overall assessment based on statistical parameters indicated that the difference between observed and estimated soil loss using the computed *C*-factor was small. The average values of the *C*-factor in 4 months for the respective managements of pastures were 0.007300 t ha t^{-1} ha^{-1} for pasture Control, 0.009700 t ha t^{-1} ha^{-1} for pasture Chisel, 0.001900 t ha t^{-1} ha^{-1} for pasture Fertilizer, 0.017300 t ha t^{-1} ha^{-1} for Burned pasture, 0.0090 t ha t^{-1} ha^{-1} for Integrated crop-live-stock and 0.000400 t ha t^{-1} ha^{-1} at Plowing and howring pasture respectively. The *C*-factor for 24 months for the respective managements of pastures were 0.001380 t ha t^{-1} ha^{-1} for pasture Control, 0.002350 t ha t^{-1} ha^{-1} for pasture Chisel, 0.000470 t ha t^{-1} ha^{-1} for pasture Fertilizer, 0.003210 t ha t^{-1} ha^{-1} for Burned pasture, 0.002240 t ha t^{-1} ha^{-1} for Integrated crop-live-stock and 0.000110 t ha t^{-1} ha^{-1} at Plowing and howring pasture respectively.

Key words: Soil loss ratio, *C*-factor calibration, Soil losses determined, Soil losses estimate, up scaling.

2. INTRODUCTION

Soil erosion is the main cause of soil deterioration around the world, promoting sedimentation and eutrophication in water courses, which is accelerated by improper use and management practices of soil and lands (FENG et al., 2010; ZHAO et al., 2012). For this reason, soil erosion can be considered as an environmental problem facing humanity nowadays. Over the last few decades, many researchers have attempted to develop mathematical models to facilitate soil erosion estimation. These models can be helpful tools to guide public policy and decision making. Different kinds of models have been developed using mathematical expressions based on physical equations and empirical observation to produce useful outputs (ARNOLD et al., 1998; FLAGANAN et al., 1995). The fundamental model focus is to simplify the representation of reality reducing time, energy and costs of measuring soil losses in the field.

The lumped empirical models are commonly used in conservation planning, because their simplicity and data availability. One of those models, the Universal Soil Loss Equation (USLE) (WISCHMEIER; SMITH, 1965, 1978) stands out, providing the most widely used for soil loss estimation in the world (KINNELL, 2010).

The USLE equation predicts the long-term average annual soil loss (A) considering sheet and rill erosion and taking into account six factors (A = R.K.LS.C.P). The land cover-management (*C*-factor), which represent the effects of cropping and management practices on soil loss rates, indicates how the land uses affect the average annual soil loss (WISCHMEIER; SMITH, 1978). Originally, the *C*-factor was determined using natural rainfall in field from long-term erosion experiments. But based on the protective effect of crops varies during the year, the use of subfactors to estimate the *C*-factor has been preferred (KINNELL, 2010).

In the region of Atlantic rainforest, an important Brazilian biome, most of the degraded lands are covered by pastures, due to practices used for soil and grass management (DIAS-FILHO, 2011). Few studies have been conducted to evaluate *C*-factor on this biome but the those studies are focused on agricultural and planted forest areas (BERTOL et al., 2001; EDUARDO et al., 2013; MARTINS et al., 2010a; PROCHNOW et al., 2005). Few studies have been conducted in pastures, which is the larger land cover on that biome, and are in a critical stage of degradation (ROCHA JUNIOR et al., 2014; SILVA et al., 2010).

To our knowledge, there has not been any study to estimate *C*-factor for different soil management in pastures in Atlantic Rainforest in Brazil. This knowledge gap creates a challenge to any study aimed to evaluating *C*-factor in USLE/RUSLE. Considering the extent of degraded areas on pasture lands, which is 238.943 ha^{-1} just in Espiríto Santo State (CEDAGRO, 2012), this information can provide land management options to produce adequate grass for the farmers.

The objective of this study was to determine the *C*-factor of different soil management practices on pastures established in Brazilian Atlantic Rainforest, and compare the soil loss estimated by USLE/RUSLE using estimated *C*-factor to observed soil loss at the field.

3. MATERIAL AND METHODS

3.1. General characterization of study area

The study was carried at Experimental Farm of CCA-UFES (Center of Agriculture Science – Universidade Federal do Espírito Santo), situated in the municipality of *Alegre*, *Espírito Santo*, Brazil, which is located at geographic coordinates of 22° 44' E and 41° 21' W (Figure 1).

The 84 ha farm has a beef cattle and milking herd of 20 animals on a pasture planted with *Brachiaria brizantha* cv. Marandú. The soil in the area is an Udults clayey (USDA, 2013), and the predominant native vegetation in the area is semi-deciduous Atlantic Rainforest.

The climate of the region is the Aw type (tropical with a dry season in winter), according to the Köppen classification (KOPPEN, 1931). The rainfall distribution during two years study period (2013-15) is provided in Figure 2.

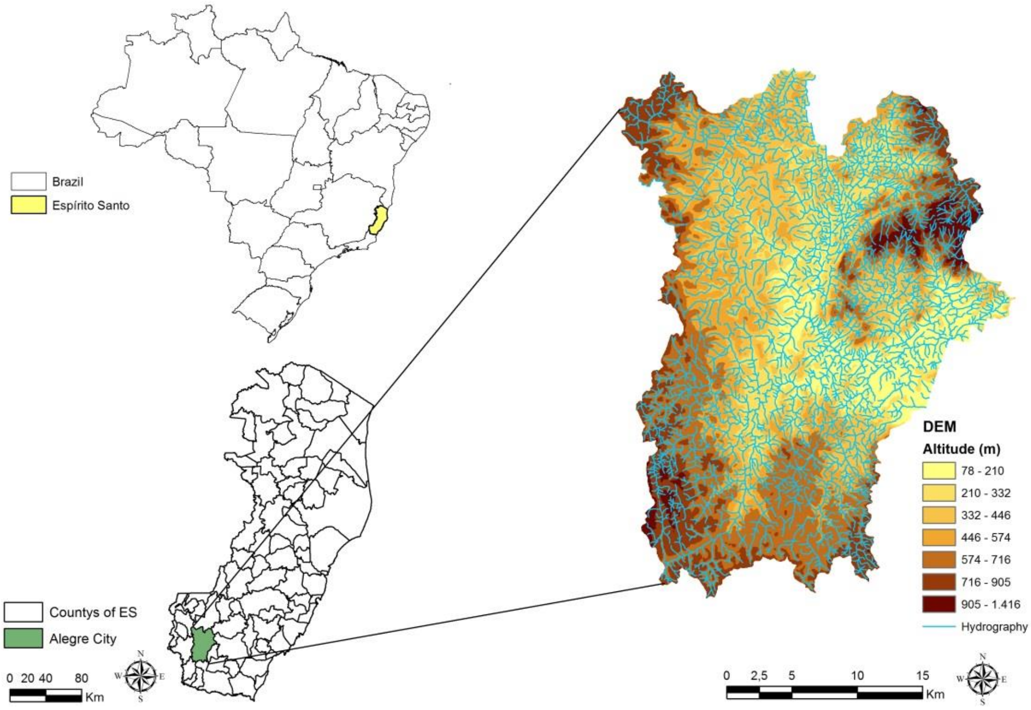

FIGURE 1. Study area in Atlantic Rainforest Biome, south state of Espírito Santo, Brazil.

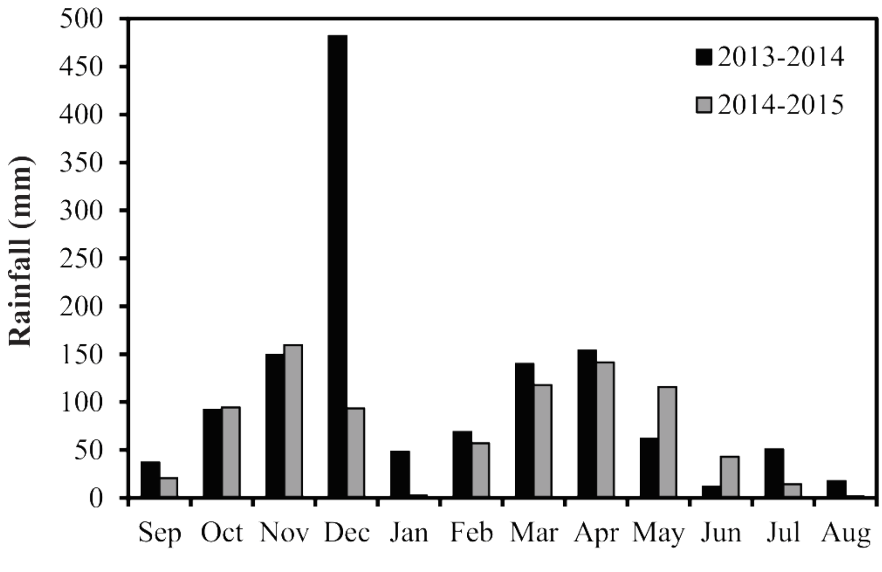

FIGURE 2. Monthly precipitation distribution at an experimental farm of CCA-UFES, situated in the municipality of *Alegre* during 2013-15.

3.2. Plots of soil losses and experimental design of the pastures managements

Field measurements of soil erosion were carried out from July 2013 to August 2015. The treatments studied consisted of six plots with dimensions of 11 m × 3.5 m (38.5 m^2), allocated on the middle third of the landscape in a convex landform with a slope of 21.72 ± 0.04 m m^{-1}. Metal borders surrounding the plots were inserted to a depth of 0.15 m to avoid overland flow losses or gains from adjacent plots. To evaluate and collect overland flow, each plot was equipped with two tanks with capacity of 310 L each. The first was a sedimentation tank with an edge collector type GEIB with 1/7 times overland flow splitter. It was connected to a decantation tank to collect the overflow.

The different pasture management practices evaluated during this experiment are as followed:

Pasture Control (CON): This represented a natural grassland area in stage similar to other pasture management in the area. When the grasses reach 0.25 ± 0.02 m height, the vegetal extract was cut for 0.10 ± 0.05 cm. Similar practices of simulation pasture was adopted in the others managements.

Pasture Chisel (CHI): The Chisel management was started on August 16, 2013, which involved manual row in contour, with 0.50 m of gap between each row and depth-row of 0.10 m. Ten days before the experiment started, 1 t ha^{-1} lime was applied to achieve a desired soil acidity (pH 5). Fertilizers were applied 15 days after liming, using 30 kg ha^{-1} K and 110 kg ha^{-1} P. Seeding of grass (30 kg ha^{-1} of *Brachiria brizhanta*) was performed using a manual planter and 100 kg ha^{-1} of N was applied after the grass was completely grown.

Pasture Fertilizer (FER): Fertilizer management was initiated on August 6, 2013. Fertilizer operations were performed 15 days after liming (1 t ha^{-1}) for maintaining pH = 5. The fertilizers application rate were 200 kg ha^{-1} K and 50 kg ha^{-1} of P on the surface. The grass was re-seeded using a manual planter on the exposed soil. After the grass was grown, splitting application of N was done through three equal doses of 50 kg ha^{-1} each (total of 150 kg ha^{-1} N).

Pasture Burned (BUR)*:* This management practice was initiated on 20 August, 2013 and is primarily a fire management. All residues were burned including

Brachiaria plants aerial part, invasive narrow leaf, invasive broadleaf, and litter. The fire was produced using a flamethrower attached to a gas canister. Grass seeding was done by using a manual planter in the entire area of study and no lime or fertilizer was applied to the soil.

Integrated crop-livestock (iCL): Integrated crop-livestock management was implemented adopting the no-tillage practice. Operations for this management started on July 25, 2013. At first, residues of *Brachiaria brizhanta*, invasive narrow leaf, and invasive broadleaf were chemically desiccated with glyphosate®. After 12 days, soil acidity was modified with the application of 1 t ha^{-1} lime in the entire area. Manual row planting was implemented in contour with 0.50 m of distance between each row and 0.10 m to depth-row. Fertilizers were applied at the rate of 80 kg ha^{-1} K and 120 kg ha^{-1} P to the soil 15 days after liming. Legumes: *Feijão de Porco* (*Canavalia ensiformis*) and *Feijão guandú* (*Cajanus cajan*) were planted as cover crops. Alternate legume seeds were planted manually at 0.05 m row spacing. After 60% of the plants flowered (118 days), all of them were cut and the residues were left on the surface. The grass seeds of *Brachiria brizhanta* were planted at 30 kg ha^{-1} rate using a planter.

Plowing and Howring (PH): Plowing and howring management was implemented on August 15, 2013. Plowing and howring was carried out manually in contours. All the residues (plant aerial part and litter) were incorporated into the soil to a depth of 0.15 m. The grass seeds of *Brachiria brizhanta* were planted at 30 kg ha^{-1} rate using a manual planter. Lime or fertilizer was not used for this practice.

3.3. Determination of soil losses

To determinate the soil losses, runoff water laden with sediment was collected after each rainfall event in a tank. A 0.1 mol L^{-1} HCl solution was used to separate the sediment from the water using coagulation. When the sediment settled, excess water was decanted. The remaining soil was dried at 45°C and weighed to determinate the soil erosion rate from the experimental plots.

3.4. USLE/RUSLE *C*-factor calculation

Since the pasture was planted with perennial plants, the soil and plant characterization was divided into two periods in a year. The periods were separated based on the initial establishment of the pasture with 4 months, and after the establishment of the pasture with 24 months.

$$C - factor = \frac{Determined\ soil\ losses}{R{-}factor \times LS{-}factors \times K{-}factor \times P{-}factor} \quad \text{(Eq. 1)}$$

Where *C*-factor: R-factor: rainfall–runoff erosivity; LS-factor: topographic factor; K-factor: soil erodibility; P-factor: soil conservation practices factor.

The 4 months and 24 months average *C*-factor was calculate by weighing the *C*-factor for each month during this time.

3.5. USLE/RUSLE R, K, LS and P factors

The rainfall–runoff erosivity (R factor) was calculated based on the relationship by Lombardi Neto (1977) and modified to Carvalho et al. (2005) as:

$$EI_{30} = 33.856 \times Rc + 67.991 \quad \text{(Eq. 2)}$$

$$Rc = p^2 P^{-1} \quad \text{(Eq. 3)}$$

Where EI_{30}: Kinetic energy of rainfall in 30 minutes [MJ.mm/ha.h.ano]; Rc: Rainy coefficient [mm]; p^2: mean monthly precipitation [mm]; P^{-1}: mean annual precipitation [mm].

The soil erodibility (K factor) was determined using the equation proposed by Foster et al. (1981) and Renard et al. (1997) as:

$$K = 2.8 \times 10^{-7} M^{1.14}(12 - a) + 4.3 \times 10^{-3}(b - 2) + 3.3 \times 10^{-3}(c - 3) \quad \text{(Eq. 4)}$$

Where M: particle size parameter [(%silt + %very fine sand) x (100 - % clay)]; a: organic matter content [%]; b: soil-structure code [very fine granular 1; fine granular 2; medium or course granular 3; blocky, plate or massive 4]; c: profile-permeability class [rapid 1; moderate to rapid 2; moderate 3; slow to moderate 4; slow 6; very slow 6].

The topographic factor (LS) was calculated based on the equations proposed by Wischmeier and Smith (1978) and modified by McCool et al. (1987) as:

$$L = (\frac{\lambda}{22.13})^m \quad \text{(Eq. 5)}$$

$$S = 16.8 \times \sin\theta - 0.50 \quad \text{(Eq. 6)}$$

Where λ: Slope leght [m]; m: dimensionaless exponent [$\frac{\sin\theta}{\sin\theta} + 0.269\ (\sin\theta)^2 + 0.5$]; θ: angle of slope.

The values of soil conservation practices factor (P) were obtained from Wischmeier and Smith (1978). The P factor values used in this study were 0.7 for the management planted in contour such as pasture Chisel and pasture Integrated crop-live-stock-forest, and 0.5 for pasture Plowing and howring planted tillage in contour and 1 for the management of pasture without tillage in contour.

3.6. USLE/RUSLE *C*-factor calibration

To calibrate C factor, soil losses measured in the field were compared with the values of soil losses obtained from USLE/RUSLE estimate. To test the model results, statistical parameters like coefficient of determination (R^2) and root mean square error (RMSE), were used.

The coefficient of determination (R^2) was the relationship between observed and simulated data. If R^2 = 0, no linear relationship exists. If R^2 = 1 a perfect linear relationship exists.

The RMSE indicate error in squared units of the constituent of interest, and values of 0 indicate a perfect fit of the data simulate in relation to determined data.

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(Y_{obs} - Y_{sim})^2}{n}} \qquad \text{(Eq. 7)}$$

Where RMSE: Root mean square error; Y_{obs}: measured data; Y_{sim}: simulate value; n: total numbers of pairs.

3.7. Up scaling of soil losses

In order to estimate soil loss from *Alegre* county, ArcGIS® 10 software (Environmental Systems Research Institute) was used. The topographic factor (LS) was obtained using slope (in percentage) from the Digital Elevation Model (DEM). A raster with length ramp (L) was obtained using the following relationship (Eq 8):

$$\text{L} = \sqrt{P^2 + } \; (\frac{S}{100} \times P)^2 \qquad \text{(Eq. 8)}$$

Where L = length ramp (dimensionless); P = pixel size (m); S = Slope (%).

Then the LS factor was computed using a relationship proposed by Bertoni and Lombardi Neto (2012):

$$LS = 0.00984 \times L^{0.63} \times S^{1.18} \qquad \text{(Eq. 9)}$$

Where LS = Topographic factor (dimensionless); L = length of the ramp (dimensionless); S = Slope percentage.

The erosivity factor (R) was computed based on of rainfall data, using a climate time series of 15 years from 12 stations distributed around and surrounding the study area. Kriging with spherical and exponential fit method was used for spatial interpolation to generate a rainfall matrix image (GUARDINAN JUNIOR et al., 2012). Monthly and yearly average of precipitation was used to calculate R factor following the relationships proposed by Carvalho et al. (2005) (Eq. 2 and 3).

Soil erodibility (K) factor was computed based on the method proposed by Foster et al. (1981) and Renard et al. (1997) (Eq. 4). The soil map was obtained from soils survey of Espírito Santo (EMCAPA, 1971).

The C factor map for the county was prepared based on computed C factor in the present study. The P factor values were obtained from Wischmeier and Smith (1978). Finally, each raster layers were multiplied in ArcGIS® to create the soil loss map for the county.

4. RESULTS

4.1. Soil cover and management (*C*-factor) determination

The results of kinetic energy of rainfall in 30 minutes (EI_{30}), and soil cover management factor (*C*-factor) are presented in Table 1. Higher precipitation in the year 2013 compared to year 2014/15 resulted in higher values of EI_{30} and *C*-Factor when evaluate the values calculated in 4 months. In the year of 2013, grassland management in control (CON) plot was at an early phase of degradation, and the burned (BUR) pasture in the earlier stage of renovation shown high values of *C*-factor, being 0.047824 t ha $t^{-1}ha^{-1}$ in the BUR management in October of 2013, and 0.022341 t ha $t^{-1}ha^{-1}$ in the CON management in December of 2013 (Table 1).

The low *C*-factor values in the initially 4 months where verified in months of September and December, when evaluated the plowing and harrowing (PH) management (0 t ha $t^{-1}ha^{-1}$), and November in the fertilizer (FER) management (0.000255 t ha $t^{-1}ha^{-1}$) (Table 1).

In general, the tillage of soil implemented along contour lines, and the liming and fertilization adopted in the respectively, PH (0.000400 t ha t^{-1} ha^{-1}) and FER (0.001900 t ha t^{-1} ha^{-1}) management led to low mean values of *C*-factor for the 4 months studied. On the other hand, high mean values of *C*-factor were found in the CHI (0.009700 t ha t^{-1} ha^{-1}) and BUR (0.017300 t ha t^{-1} ha^{-1}) managements. The absence of practice in the CON management (0.007300 t ha t^{-1} ha^{-1}), and the minimum soil disturbance combined with liming and fertilization in iCL management (0.009000 t ha t^{-1} ha^{-1}), result in intermediate mean values of *C*-factor in this period (Table 1).

Table 1.

Kinetic energy of rainfall in 30 minutes (EI_{30}) and *C*-factor values calculate respectively for 4 and 24 months in different pasture managements

Period	EI_{30}	Control	Chisel	Fertilizer	Burned	iCL	PH
		--------------------------------*C*-Factor--------------------------------					
	MJ mm^{-1} h^{-1} ha^{-1}	t ha t^{-1} ha^{-1}					
4 months							
13-Sep	103.275	0.003846	0.002285	0.000406	0.006603	0.001876	0.000000
13-Oct	287.087	0.002667	0.026733	0.006508	0.047824	0.025426	0.001310
13-Nov	643.264	0.000301	0.004450	0.000255	0.005890	0.005724	0.000355
13-Dec	6060.751	0.022341	0.005362	0.000534	0.009022	0.003149	0.000000
S.D.		0.007500	0.008500	0.002300	0.015200	0.008200	0.000400
Mean		0.007300	0.009700	0.001900	0.017300	0.009000	0.000400
24 months							
13-Sep	103.3	0.003846	0.002285	0.000406	0.006603	0.001876	0.000000
13-Oct	287.1	0.002667	0.026733	0.006508	0.047824	0.025426	0.001310
13-Nov	643.3	0.000301	0.004450	0.000255	0.005890	0.005724	0.000355
13-Dec	6060.8	0.022341	0.005362	0.000534	0.009022	0.003149	0.000000
14-Jan	128.4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
14-Feb	190	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
14-Mar	571.7	0.000273	0.000665	0.000165	0.000385	0.002429	0.000265
14-Apr	679.2	0.000165	0.000735	0.000085	0.000390	0.000509	0.000000
14-May	166.4	0.000879	0.002995	0.000544	0.001804	0.001640	0.000198
14-Jun	71.5	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
14-Jul	134	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
14-Aug	76.2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
14-Sep	79.1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
14-Oct	298.6	0.001106	0.006881	0.000613	0.002599	0.006969	0.000469
14-Nov	724.5	0.000041	0.000055	0.000017	0.000025	0.000068	0.000007
14-Dec	292.8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
15-Jan	68.2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
15-Feb	152.3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
15-Mar	425.6	0.001200	0.004989	0.001877	0.001024	0.002488	0.000000
15-Apr	584.8	0.000261	0.001134	0.000321	0.001406	0.003393	0.000051
15-May	413.6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
15-Jun	116.1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
15-Jul	73.2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
15-Aug	68.1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
S.D.		0.002060	0.003112	0.000643	0.004709	0.002827	0.000170
Mean		0.001380	0.002350	0.000470	0.003210	0.002240	0.000110

EI_{30}: Kinetic energy of rainfall in 30 minutes; PH: Plowing and harrowing; iCL: Integrated crop-live-stock; S.D.: Standart of Derivation.

The standard of derivation (S.D.) in 4 months of evaluation of *C*-factor estimative was highest for BUR (0.015200) and CON (0.007300), while the lowest S.D. value was observed for PH management (0.000400) (Table 1).

Generally during the 24 months, high EI_{30} value resulted in high *C*-factor values for all management practices, and during the two years of study, wide variations in *C*-factor values were observed. It demonstrates that the seasonality and plant growth effect on soil cover and soil erosion resistance (Table 1).

When evaluate the *C*-factor for 24 months the mean values for FER (0.000470 t ha t^{-1} ha^{-1}) and PH (0.000110 t ha t^{-1} ha^{-1}) management were still small. BUR

(0.003210 t ha t^{-1} ha^{-1}) and CHI (0.002350 t ha t^{-1} ha^{-1}) management once again provided higher values (Table 1).

However, the higher calculate *C*-factor value were observed for CON management in December of 2013, the high mean values for 4 and 24 months were observed in BUR management. In the meantime, *C*-factor values were numerically smaller for PH and FER management during 4 and 24 months of experiment compared to other management practices (Figure 2).

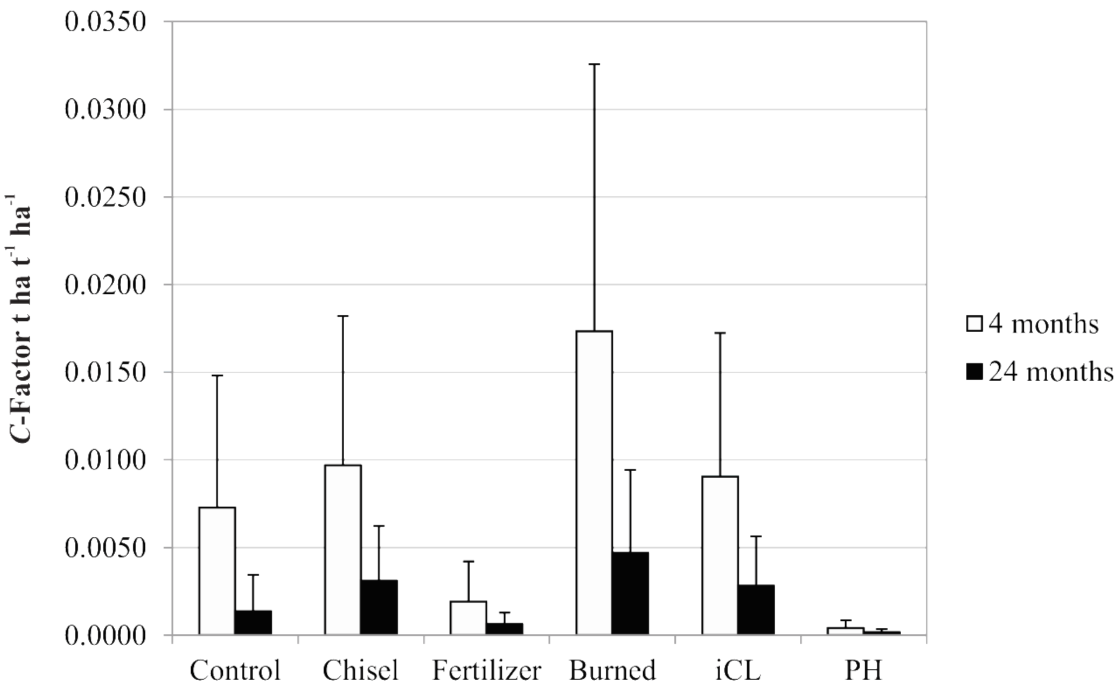

FIGURE 2. Mean values and standard o derivation of *C*-Factor in different pasture managements. iCL: Integrated crop-live-stock; PH: Plowing and harrowing.

The value of *C*-factor calculated for BUR management was 97.63 times higher than PH pasture management, and 89.03 times higher than FER management to the initially 4 months. To the 24 months the value calculated for *C*-factor in BUR management was 96.37 times higher than PH pasture management, and 86.34 times higher than FER management.

Among all pastures management evaluated, the sequence of *C*-factor values for 4 and 24 months were: BUR > CHI > iCL > CON > FER > PH (Figure 3).

4.2. USLE/RUSLE soil loss estimation and *C*-factor calibration

The mean soil loss values observed in the field and estimated by USLE/RUSLE using the calculate *C*-factor in 4 and 24 months, for different pastures management with their respective errors are provided in Table 2.

Table 2.

Mean soil loss observed in field and estimated by USLE/RUSLE using *C*-factor calculated in 4 and 24 months in different pastures managements and their corresponding error in relation to the observed data

Period	Observed	USLE/RUSLE	[a]Error (±)	Observed	USLE/RUSLE	Error (±)
	Control			Chisel		
	Soil losses (t ha^{-1})					
Sum 4 months	10.208	3.860	+6.348	1.489	2.370	-0.881
Sum 24 months	10.315	4.678	+5.637	1.777	2.944	-1.167
Mean of 4 months	2.552	0.965	+1.587	0.372	0.592	-0.220
Mean of 24 months	0.430	0.195	+0.235	0.074	0.123	-0.049
	Fertilizer			Burned		
	Soil losses (t ha^{-1})					
Sum 4 months	0.250	0.002	+0.248	5.140	0.644	+4.496
Sum 24 months	0.084	0.042	+0.042	5.371	1.565	+3.806
Mean of 4 months	0.063	0.001	+0.062	1.285	0.161	+1.124
Mean of 24 months	0.011	0.005	+0.005	0.224	0.065	+0.065
	Integrated crop-live-stock-forest			Plowing and harrowing		
	Soil losses (t ha^{-1})					
Sum 4 months	1.017	2.156	-1.139	0.010	0.046	-0.037
Sum 24 months	1.258	2.696	-1.437	0.015	0.059	-0.044
Mean of 4 months	0.254	0.539	-0.285	0.002	0.012	-0.009
Mean of 24 months	0.052	0.112	-0.060	0.001	0.002	-0.002

[a]Soil loss estimated by USLE/RUSLE minus observed (t ha^{-1}).

Both observed and estimated soil losses were the highest values for CON and BUR pasture management, while the lowest values were observed for PH and FER managements. These results are not consistent with the values calculated for the *C*-factor earlier (Table 1 and Figure 2).

The underestimation and overestimation of soil loss calculated by the USLE/RUSLE for all managements and periods suggested that a wide variation can occur in the modeled of soil losses studying different soil pasture managements (Table 2).

Generally were observed an underestimation of soil losses in the management CON, BUR and FER using the *C*-factor calculate to the respective 4 and 24 months. However, in the iCL, CHI and PH managements were observed an overestimation (Table 2).

While evaluating the coefficient of determination simulated and measured soil losses, most of the treatments resulted in high R^2 values exception for PH management which indicated a low relation with 4 and 24 months (4 months - R^2 = -0.514 and 24 months - R^2 = -0.014) and FER which indicated a low relation with 24 months (4 months - R^2 = -0.183). Coefficient of determination between observed and estimated soil loss in 4 months were found to be 0.997, 0.978, 0.973, 0.942 and 0.828, for CON, CHI, BUR, iCL and FER management, respectively. For 24 months the coefficients of determination were 0.993, 0.974, 0.936 and 0.896, for CON, CHI, iCL and BUR management, respectively (Table 3).

The RMSE values were high for the managements with high soil loss rate (for example CON and BUR managements). In the meantime, small RMSE values were obtained for the managements with small soil loss values (for PH) (Table 3).

Considering that all the pastures in the county of *Alegre* are under the same management, the soil losses were estimated for the county based USLE/RUSLE model. Estimated soil loss was the higher for BUR management and the lowest for PH management (Figure 4, 5 and Table 4). To values estimate using the *C*-factor calculate for 4 months were high than with 24 months.

For all managements, the maximum soil loss estimated ranged between 18.45 t ha^{-1} for BUR up to 0.21 t ha^{-1} for PH managements with 4 months, and between 3.47 t ha^{-1} for BUR up to 0.05 t ha^{-1} for PH managements with 24 months. It was noted that the average estimated losses for all *Alegre* pastures were smaller than the observed in the experimental plots in t ha^{-1} $year^{-1}$. It was observed that there was a variation in soil loss estimates based on computed standard deviation values (Table 4).

Table 3.

Statistical parameters for evaluation of soil losses estimates by USLE/RUSLE in different pastures managements

Calibration	**USLE/RUSLE**	
	Control	Chisel
4 months		
R^2	0.997	0.978
RMSE	0.853	0.116
24 months		
R^2	0.993	0.974
RMSE	0.284	0.039
	Fertilizer	Burned
4 months		
R^2	0.828	0.973
RMSE	0.022	0.431
24 months		
R^2	-0.183	0.896
RMSE	0.023	0.432
	Integrated crop-live-stock	Plowing and harrowing
4 months		
R^2	0.942	-0.514
RMSE	0.152	0.005
24 months		
R^2	0.936	-0.014
RMSE	0.153	0.004

R^2: Coefficient of determination;
RMSE: Mean root square of error.

Table 4.

Minimum, maximum, mean and standard of derivation of the soil losses estimates by USLE/RUSLE in different pastures managements

Pasture managements	**Max.**		**Mean**		**Std dev.**	
	Months					
	4	24	4	24	4	24
Control	7.92	1.41	0.72	0.12	0.56	0.1
Chisel	10.53	2.49	0.95	0.22	0.78	0.17
Burned	18.45	3.47	1.68	0.31	1.31	0.24
Fertilizer	2.06	0.43	0.18	0.03	0.14	0.03
Integrated crop-live-stock	6.07	1.67	0.55	0.15	0.43	0.11
Plowing and harrowing	0.21	0.05	0.01	0.00	0.01	0.00

Min.: Minimum;
Max.: Maximum;
Std dev.: Standard derivation.

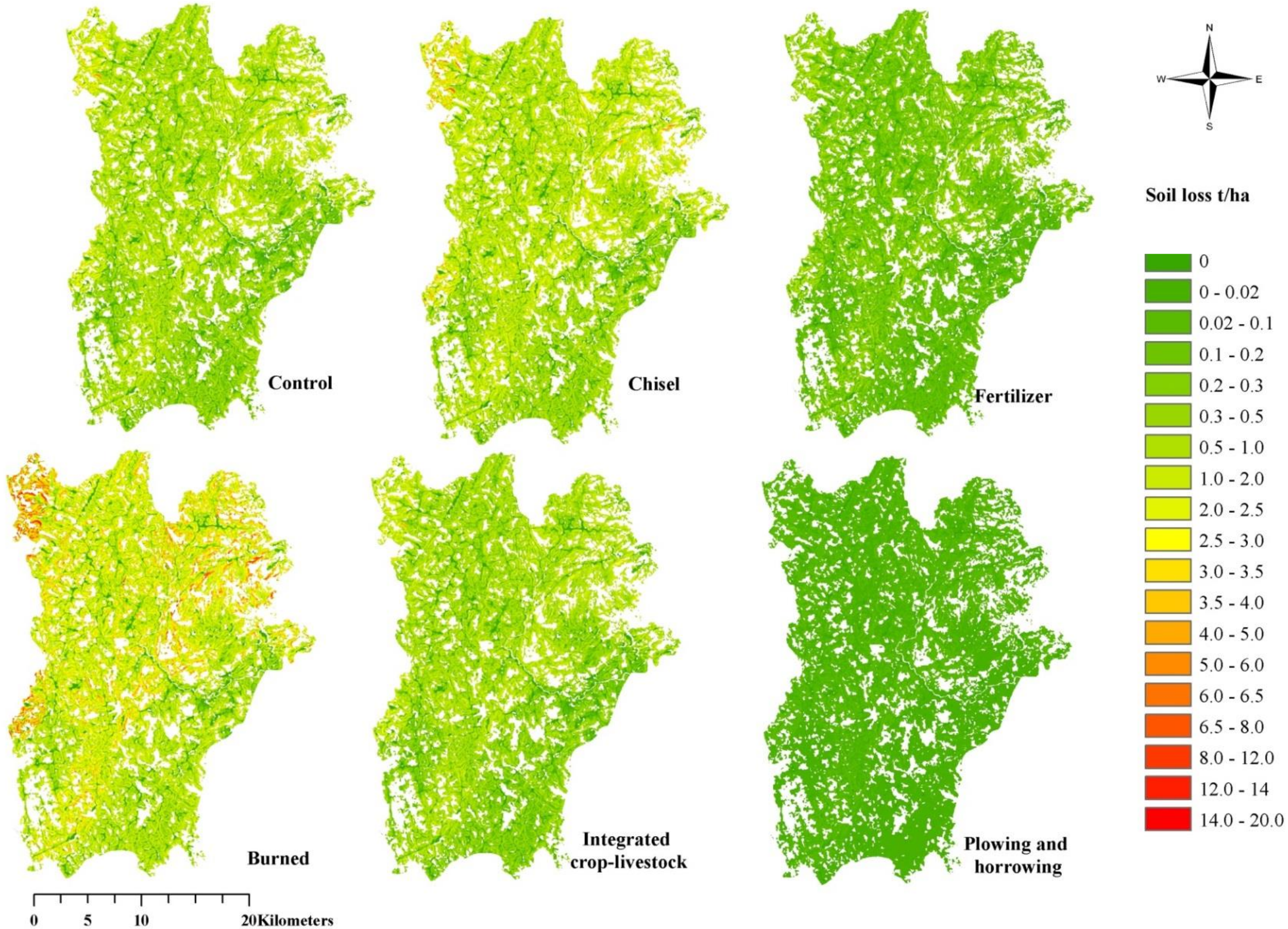

FIGURE 4. Soil loss estimate (t ha^{-1} year^{-1}) for different pasture managements in *Alegre* County in Espírito Santo, Brazil, using the calculate *C*-factor in 4 months.

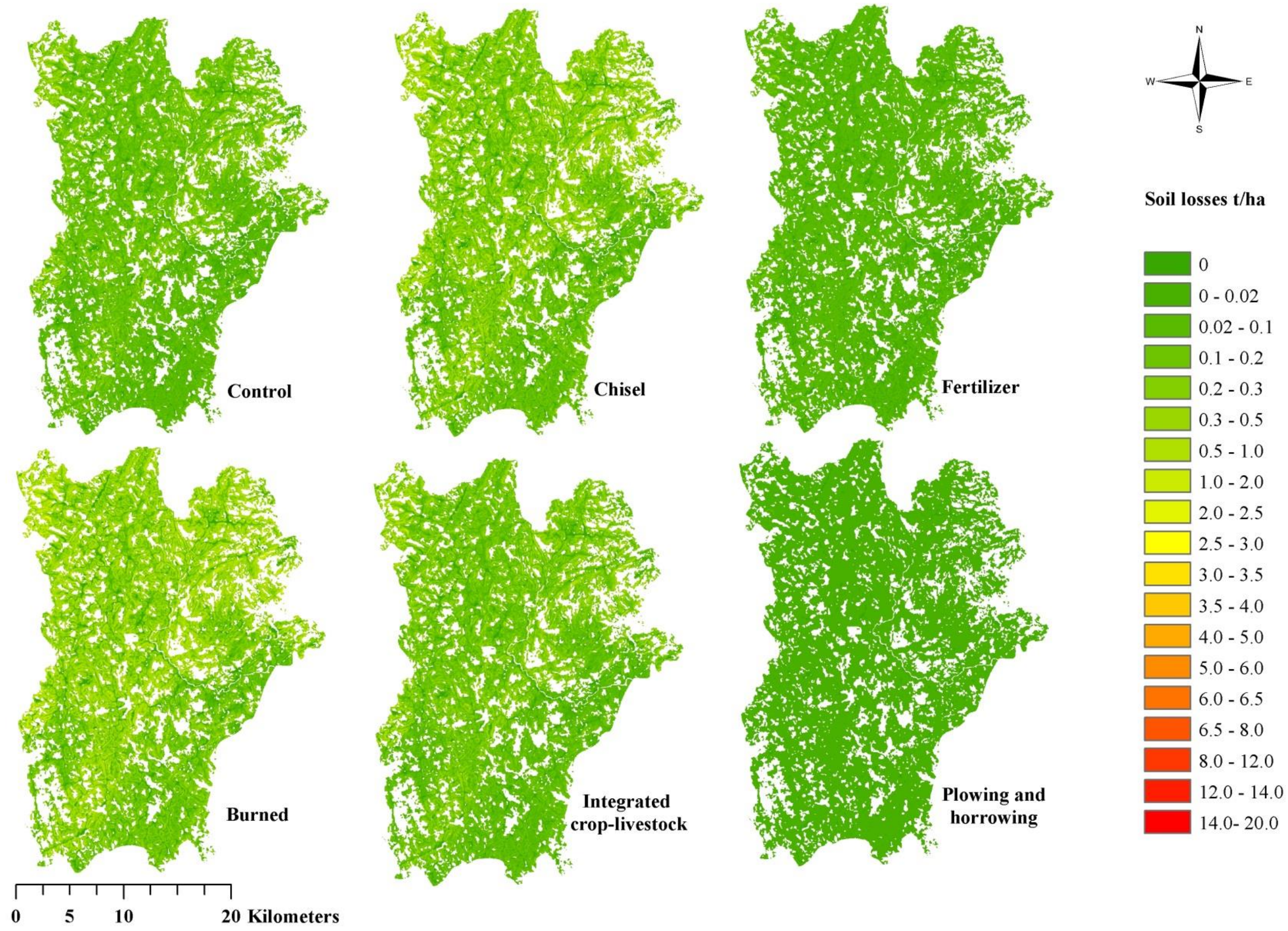

FIGURE 4. Soil loss estimate (t ha^{-1} $year^{-1}$) for different pasture managements in *Alegre* County in Espírito Santo, Brazil, using the calculate *C*-factor in 24 months.

5. DISCUSSION

The concentration of rainfall in a short period increases the rain erosivity capacity, and consequently elevates the erosive power. It raises the potential of sediment drag, promoting increase in soil losses (SILVA et al., 2009). This explains why the EI_{30} and *C*-factor values were higher in the first 4 months, especially in December of 2013. These results are consistent with those reported by Martins et al. (2010b). They observed that the most critical period for rainfall erosivity was from October to March, with 85 % of annual rainfall erosivity accounted for this period in this region. Several studies have shown the relationship between rainfall and sediment losses, indicating that erosivity plays important role in raising the sediment load (AGUIAR et al., 2010; SILVA et al., 2009).

A possible explanation for higher *C*-factor values in the first 4 months was associated, beyond the higher precipitation, with the effect of adoption of different land management practices. This may be explained by the fact that the soil management practice has impact on the soil and plant properties which are used to calculate the K-factor and P-factor, and affected the proprieties such as ground cover, litter deposition and roughness of the soil the avoid the soil erosion.

The results of this study indicated the influence of adoption of burn of pasture led to a higher *C*-factor value in 4 months for BUR management practices. For 24 months, lower values of *C*-factor compare to the 4 months can be attributed to lower rainfall and restoration of vegetation cover, as well as the deposition of litter on pastures. However, the values in BUR management with 24 months were low the values were high then the other managements, indicating that the elimination of vegetation cover was quick and vegetation recovery was often slow for this management (JUNK; CUNHA, 2012).

Based on the differences in soil losses observed in the field for different pasture management practices, it can be inferred that the management practice adopted or absence of them, has significant impact on the rate of soil loss. It was observed that CON management resulted in intermediate *C*-factor, however presented high losses in field and estimates from USLE/RUSLE. This may support the hypothesis that the absence of fertilization, and high stocking rates employed before the experiment began, promoted a decline in nutrient content of soil, leading to reduced capacity of production as reported in the literature by Boddey et al. (2004) and Pereira et al. (2009).

The current study found that *C*-factor values in CON pasture (Figure 2) was lower to those compiled by Liane et al. (2009) on the Reventazón Basin in Costa Rica. They found the *C*-factor ranging between 0.009 to 0.015 t ha t^{-1} ha^{-1} for pastures under the same extensive management. However, *C*-factor in 4 months computed in this study was higher than 0.002 t ha t^{-1} ha^{-1} as proposed by Kinnell (2010) for Bermuda grass. Observed value of *C*-factor for BUR pasture management was 0.0173 t ha t^{-1} ha^{-1} fo 4 months which is higher than 0.0067 t ha t^{-1} ha^{-1} found in Ceará semi-arid pastures under the similar management (SANTOS et al., 2014), however was lower to the values found in 24 months. The discrepancy in *C*-factor values between these studies may be due to the differences in soil fertility and the amount of precipitation.

Earlier studies have noted the importance of analyzing the effect of fire on soil losses. Thomaz (2009) in an experiment conducted in South of Brazil evaluating the runoff and soil loss in a regeneration cycle for 5 years concluded that the practice of burning is more harmful for the first year, where it resulted in 55.6% of the total soil loss. This result is consistent with the present study, where higher soil loss was observed for the first 4 months (Table 2). Palacios et al. (2012) demonstrated that soil management with the removal of *Caatinga* vegetation succeeded by burning of pasture establishment raised soil loss. Junk and Cunha (2012) demonstrated that the frequent use of fire increased the sediment load in water courses.

Although the practice of burning should be avoided, the adoption of management practices such as liming and fertilization or tillage along contour lines should be advised to reduce the soil losses from pastures. It was observed that *C*-factor was small for PH and FER, led to lower estimates of soil loss by USLE/RUSLE, confirming the soil loss values observed in the field (Table 2 and Figure 5).

In the present study, *C*-factor for pasture management with total tillage, no tillage or minimum tillage, for renewal or recovery pasture presented low, intermediate and high values, however were lower than those found in the literature. Bertol et al. (2002) found that the adoption of plowing and harrowing, no tillage and chisel followed by plowing and harrowing on an oat plantation resulted in the average of *C*-factor of 0.0671, 0.0372, and 0.0409 t ha t^{-1} ha^{-1} respectively in South of Brazil. The PH management that received plowing and harrowing in contour, CHI management with minimum tillage and iCL management which was preceded by no tillage, resulted in *C*- factors of 0.00041, 0.00904 and 0.00970 t ha t^{-1} ha^{-1} respectively for 4 months, and 0.00017, 0.0028 and 0.0031 respectively for 24 months.

The soil tillage promotes increased roughness and soil tortuosity and increases the total porosity of the soil resulting in reduced soil resistance to root penetration and increased water infiltration (BOLUAL et al., 2011; BRAMORSKI et al., 2013). This fact was observed in the current study, where the PH management had the lowest *C*-factor values, soil loss estimates by the USLE/RUSLE and soil loss observed in the field, indicating that the soil loss can be reduced if this management is carried out in contour (Tables 2, 4 and Figures 5, 6).

The adoption of no-tillage practices could be an excellent option for reform and establishment of pastures. No-tillage increases the soil surface roughness but decreases sediment transport and hence reducing the erosion (ENGEL et al., 2009). This phenomenon was observed, however, more time for this management establish is necessary.

The partial soil disturbance, leading to changes in the micro relief, and reduced runoff (BERTOL et al., 2010; PANACHUKI et al., 2011) was observed in the CHI management. However plowing (the chisel type) in contour can result in decreased runoff, the rows in contour can be broken after rain, decreasing the roughness and tortuosity of soil and increasing soil losses (BRAMOSKI et al., 2013). This phenomenon was observed in the CHI management, which had high *C*-factor values.

Bertol et al. (2013) concluded that the adoption of fertilization is important for the minimum soil disturbance because it allows for more rapid development of vegetation and promotes the soil cover to reduce the soil loss. This observation was verified in the current study, where the pasture with the adoption of soil edaphic practices (liming + fertilizer) and without any soil preparation was responsible for reducing the *C*-factor and consequently the estimated soil loss, according to the data observed the field (Table 2, Table 5 and Figure 5). Liane et al. (2009) demonstrated *C*-factor values to cultivated pasture ranging from 0.003-0.040 t ha t^{-1} ha^{-1} in Costa Rica. Kuok et al. (2013) demonstrated that *C*-factor varied between 0.004 to 0.0010 t ha t^{-1} ha^{-1} in China for similar management practice. For the present study, the FER management had similar characteristics to the previous studies and resulted in the *C*-factor value of 0.001925 t ha t^{-1} ha^{-1} for 4 months and 0.00064 t ha t^{-1} ha^{-1} for 24 months.

The benefits of using fertilizer to improve soil fertility and decrease the soil losses from erosion were demonstrated by Cogo et al. (2003). They showed that the additions of lime and fertilizer improved soil fertility, increased the crop aerial biomass, consequently the crop residue mass resulting in reduction in soil loss by rainfall erosion, especially for the conventional tillage.

It was observed that there was a strong association between the estimated and observed soil loss since R^2 values were higher than 0.82 except for PH pasture management and FER when evaluate 24 months. It was observed that the RMSE values were close to zero which indicated a good fit between observed and estimated data (MORASI et al., 2007). The largest deviations were observed for CON and BUR management practices with higher soil loss compared to other practices. Even for these managements, RMSE values were lower than those estimated by Amorin et al. (2010) in different soils and vegetation cover indicating the efficiency of the estimated soil loss in the pastures of this study.

For calibration of the models it was observed that the overestimation or underestimation of soil loss by using the USLE/RUSLE agreed with other same characteristic studies developed in Brazil (AMORIN et al., 2010; CECILIO et al., 2009). This result may be related mainly to the uncertainties in the determination of the factors K, C and P that were developed for soil and climatic conditions for the USA. Conditions such as soil, climate, soil formation and relief are different from those in the USA. For example, oxidic character, it has great influence on the formation of microaggregates, causing even in soils with high clay content, you may have high permeability (AMORIN et al., 2010).

6. CONCLUSIONS

This study has identified that there is a great variation in *C*-factor values among the managements of pastures studied in Brazil. The soil losses estimated by USLE/RUSLE agreed with values measured at the field.

This study identified average values of the *C*-factor in 4 months for the respective managements of pastures of 0.007300 t ha t^{-1} ha^{-1} for pasture Control, 0.009700 t ha t^{-1} ha^{-1} for pasture Chisel, 0.001900 t ha t^{-1} ha^{-1} for pasture Fertilizer, 0.017300 t ha t^{-1} ha^{-1} for Burned pasture, 0.0090 t ha t^{-1} ha^{-1} for Integrated crop-live-stock and 0.000400 t ha t^{-1} ha^{-1} at Plowing and howring pasture respectively. The *C*-factor for 24 months for the respective managements of pastures were 0.001380 t ha t^{-1} ha^{-1} for pasture Control, 0.002350 t ha t^{-1} ha^{-1} for pasture Chisel, 0.000470 t ha t^{-1} ha^{-1} for pasture Fertilizer, 0.003210 t ha t^{-1} ha^{-1} for Burned pasture, 0.002240 t ha t^{-1} ha^{-1} for Integrated crop-live-stock and 0.000110 t ha t^{-1} ha^{-1} at Plowing and howring pasture respectively.

The Universal Soil Loss Equation (USLE/RUSLE) with the given *C*-factor, proved to be a reliable option for the annual estimates of soil losses in different managements pastures, recommending the use of the *C*-factor in tropical regions to pastures establish in the Atlantic Rainforest.

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CHAPTER 3

WATER AND SEDIMENT LOSSES IN VARIOUS SOIL MANAGEMENT AND CAPACITY OF WEPP MODEL IN PREDICTIVE THE EROSION PROCESS

1. ABSTRACT

This study aimed to evaluate the effect of soil management under water, sediment and P losses and the capacity of the Water Erosion Project (WEPP) in predictive the erosion process. Was conducted an experiment under natural and simulated rain, and were studied different managements of soil: tillage in contour (CT), tillage in downhill (DT), no –tillage (NT) and bare soil (BS). In the managements CT, DT and NT were planted Kentucky blue grass, and NT was added oat straw under cover. After collecting the data we used the WEPP model in order to modeling the sediment and water loss in the field experiment. The present study demonstrated that lower amount of loss were associated with the NT management that showed in the field experiment values of loss with 152.35 mm of water, 0.45 t ha^{-1} of sediment and 341.99 g ha^{-1} of P. To the laboratory experiment the values were 28.51 mm of water and 0 t ha^{-1} of soil. The CT management showed values of field experiment with of soil and 216.26 g ha^{-1} of P, and laboratory experiment: 47.57 mm of water and 0.07 t ha^{-1} of soil. Recommending the adoption of NT management in agriculture areas with high slope (32 %), when you cannot retain the straw on the soil, tillage in contour is the most recommended practice. The total harvest of cultural leaving the soil exposure, similar to the BS management and soil preparation towards the slope (similar the DT management) should be avoided, due to these management practice showed values of losses in field experiment with 315.25 and 280 mm of water; 87.27 and 39.10 t ha^{-1} of sediment; and 1806.06 and 1544.67 g ha^{-1} of P, respectively. Soil management practices have a little effect on water loss in rainfall with high intensive. The greatest influence of soil management was related to reduce the sediment and P losses, or reduce the water and P losses in rains with low insensitive. The enrichment rate of runoff with sediment was influenced by soil management practices and the DT (34.48 g L^{-1} min^{-1}) management shows the high peak. The first rains and the proximity of rainfall with soil management practices are the factors that most influence for increasing the enrichment rate of runoff with sediment. WEPP model did not show a good adjustment with data collected at field and generally overestimated the losses of water ranging from 33.16 to 186.18 %, and

underestimated the sediment losses ranging from 78.88 to 89.08 % studied different managements. Still need to work with a larger number of soil and cultural properties for estimating losses of sediment and water using WEPP in these managements with high slope.

Key words: Conservational practices, No-tillage, Erosion modeling.

2. INTRODUCTION

Soil erosion is the main cause of soil decline around the world (FENG et al., 2010; ZHAO et al., 2012), and this process have been related to the soil management patterns (GARCÍA-RUIZ, 2010; PODWOJEWSKI et al., 2008; WEI et al., 2010). Over the last decades, many researchers have study the sediment and water losses in different soil management, and several mathematical models have been developed in order to estimate the erosion process in these managements (ARNOLD et al., 1998; FLAGANAN et al., 1995; WISCHMEIER; SMITH, 1965).

A helpful tool that has been widely used in United State in order to study the erosion process in different soil management is the Water Erosion Predict Project (WEPP). This model is dynamic simulation that incorporates rill and inter-rill erosion concepts and simulates the processes occurring in a particular area taking in consideration soil, vegetation, crop residues and soil moisture. The WEPP model may be a viable alternative due to being a physical model, easy access and a good predictive ability (FLAGANAN et al., 1995). To our knowledge, in hilly slopes few studies have been calibrate the WEPP model using data collected with simulated data in different soil managements (SHEN et al., 2009; SHEN et al., 2010).

Among the soil management practice adopted to farmers in the USA agriculture conventional tillage with plowing and harrowing, and conservational tillage with no-tillage stands out. However, in function of the best soil conditions that conservational tillage brings this management is widely used (HOROWITZ et al., 2010).

In the USA agricultural areas estimate that 88 million acres have no tillage operations in 2009, and were managed with conservational tillage with high residue deposition (HOROWITZ et al., 2010).

However, this scenario can change with the expansion of energy matrix (DREWNIAK et al., 2015).

A study on the management practices followed by farmers of North America tells us that the residues generated in the fields can be widely used for the generation of the biofuel and ethanol for meeting the energy and food security goals (LYND et al., 2008). For example, maize residues are estimated as the source for about 40% of the agricultural biomass available for biofuel production in the USA (PERLACK et al., 2005). The Renewable Fuel Standard of the US Energy Independence and Security Act (EISA 2007) sets a national target of producing 136 billion litres of renewable fuels by 2022 (DREWNIAK et al., 2015). Of this, at least 61 billion liters is expected to come from cellulosic ethanol (BENISTON et al., 2015). Although this results in the gains of energy production, the exposure of soil due to the use of the residues can cause the increase of sediment, water and nutrients loss, especially P that is essential to plants grow and major problems to water bodies eutrophication (BALIGAR et al., 2001; JARVIE et al., 2013).

In this sense study the effect of the managements changes such as the erosion process, transport of nutrients, and calibrate the WEPP model in areas with a greater slope is indispensable. Studies with erosion process can reduce or mitigate the effects of possible management changes, and the calibration of WEPP using data collected in field can diminish the cost of sediment and water loss determination, allowing up-scaling estimation.

In this study we are looking at the three different factors relate the erosion process in the different agricultural management practices on hill slope regions. They are, change in the amount of sediment and water losses, the relation between the amount of phosphorus (P) and the capacity of WEPP model in estimate the water and soil losses.

3. MATERIAL E METHODS

Field experiments were carried out during summer season in 2015 at the University of Illinois experimental farm in Urbana, IL. Following the field experiments, laboratory experiments were conducted under a rainfall simulator at the Agricultural and Biological Engineering Department at the University of Illinois. The details of field and laboratory experiments are provided below.

3.1. Field experiments

3.1.1. Plots preparation and soil managements

The field experiment was conducted in the Erosion Control Research Training Center located at Agriculture and Biological Engineering research farm in southeast Urbana. The most predominant soil type is Molissoil clayey (USDA, 2013) (Table 1).

Table 1.

Chemical and physical characterization

pH	SOC	P	K	CEC
H_2O	%	----mg dm^{-3}----		$cmol_c$ dm^{-3}
6.45	4.00	26.00	276.50	12.20
Sand	**Silt**	**Clay**	**Bd**	**Ko**
	----------- % -----------		g cm^{-3}	cm h^{-1}
11.00	14.00	75.00	1.50	3.30

SOC: Soil Organic Carbon;
CEC: Cation Exchange Capacity;
Bd: Bulk Density;
Ko: Hydraulic conductivity.

Four plots were utilized, one for each soil management with 10.62 m of ramp length, 2.64 m of width and 32 % of slope. Metal borders surrounding the plots were inserted to a depth of 0.15 m to avoid overland flow losses or gains from adjacent plots. To evaluate and collect overland flow, each plot was equipped with a tank with capacity of 910 L at the downslope end.

Different soil management evaluated during this experiment is as followed. Except to the bare soil management, all management were planted seeds of Kentucky blue grass with a rate of 30 kg ha^{-1}, which was used as cover crop.

Contour tillage (CT) was implemented tilling the soil in the contrary sense of the hill adopting a depth of 15 cm. One day after the soil tillage, fertilizer was applied on the surface with a rate of 50 kg N, 30 kg K and 110 kg P per ha^{-1}. Similar practices of fertilization was adopted in the others soil managements. Downhill tillage (DT) was implemented tilling the soil following the direction of the slope to a depth of 15 cm. No-tillage (NT) procedure was simulated using equivalent 24 t ha^{-1} of oat straw under cover (DOWNING et al., 2011). Bare soil (BS) was used as a control area, no soil management was adopted, being held periodic weeding in order to eliminate all possible weeds (Figure 1)

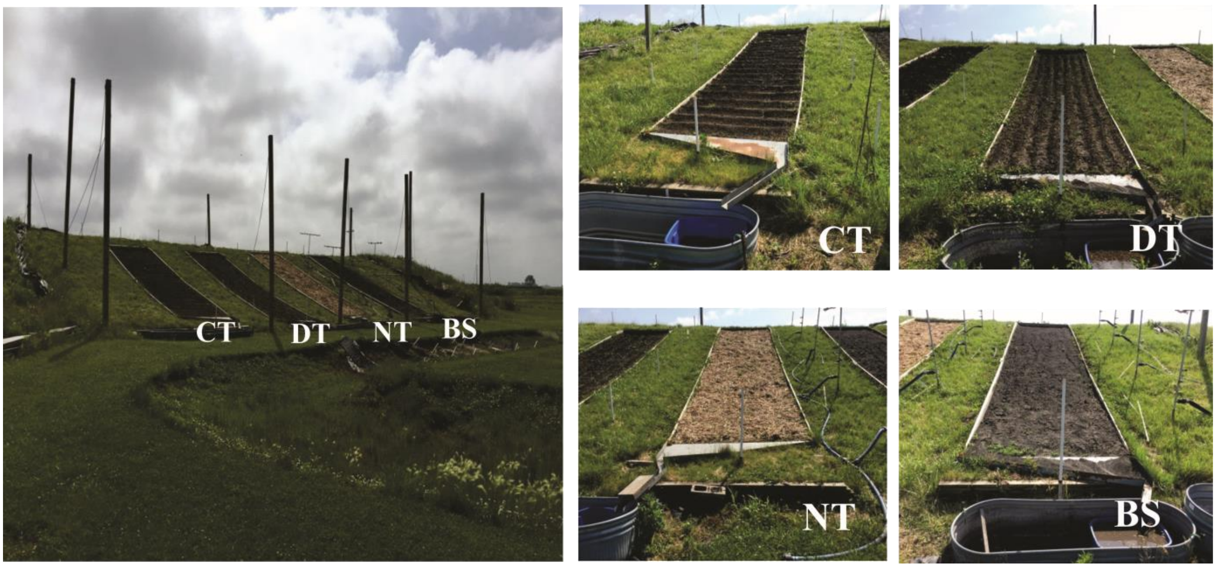

FIGURE 1 – Field plots studied. CT - Contour tillage; DT - Downhill tillage; NT – No tillage; BS- Bare soil.

3.1.2 Data collection

The loss of water was measured after each rainfall event using graduate buckets, and sub samples were collected for analysis of P. For determining the loss of sediment, all remaining material in the gutters and supernatants inside the boxes were collected. The sediment was air dried and weighed.

Water samples were previously filtered (0.7 μm), and were submitted to determined P contents by colorimetric, using automated ascorbic acid reduction method (SMO 4500-P-F., 2015).

Sediment samples of 0.5 g were digested using a mixture of concentrated sulfuric acid (4 mL) and hydrogen peroxide (50%) (10 mL) (USEPA 365.2, 1971), and the contents of P were determined by colorimetric, using automated ascorbic acid reduction method (SMO 4500-P-F., 2015).

3.2. Modeling sediment and water losses by WEPP

In order to model the sediment and water losses at the field experiment, the Water Erosion Predict Project (WEPP) program was used. Files were generated related to climate data, length and steepness of slope, soil and management.

For modeling the data, field climate data were collected in the rainfall station located in the experimental farm near the experiment. Isolated rain was studied using the function single storms, added data of storm amount (mm), storm duration (h), maximum intensity (mm h^{-1}) and duration to peak intensity (%). Lengths (m) and ramp slopes (%) were taken from the section plots preparation and soil managements.

The input data regarding the soil used was from Table 1, as the values of interrrill erodibility, rill erodibility and critical shear was not available, these variables were calculate on base of soil physical attributes, using a tool “have model calculate”. To the initial saturation level the values used were recommended for WEPP program, adopting 70% of initial level saturation, which is about 33 kPa (field capacity) for most soils. The data of management used are described in the section plots preparation and soil managements. And some information’s before the soil managements added were bulk density after the last tillage (1.1 g cm^{-3}), initial canopy cover (0 %), days after the lats tillage (200 days), cumulative rainfall since last tillage (500.1 mm), initial hidge height after last tillage (2 cm), initial roughness after last tillage (2 cm).

3.3. Laboratory experiments

3.3.1. Soil chambers preparation and soil managements

The lab experiment was conducted under a rainfall simulator at the Agricultural and Biological Engineering Department at the University of Illinois. Two horizontal tilting soil chambers were used to investigate soil erosion patterns from soil under different managements. The chambers contained 3.60 m of ramp length and 1.50 m of width.

The chambers were filled with similar soil to the field experiment; the unique difference was the SOC content (2.5 %). More details about the soil chamber and soil accommodation see Bhattarai et al. (2011) (Table 1).

.The managements of soil adopted in lab experiment, were similar to management describe in the field experiment. The difference between lab experiment was the tillage of soil, which this procedure was done manually with a hoe. Fertilization and seed input followed the same rate adopted in field.

Fertilizer was applied on the surface in all management with a rate of 50 kg N, 30 kg K and 110 kg P per ha^{-1}. Kentucky blue grass with a rate of 30 kg ha^{-1} were planted except to the bare soil management. To grow the grass the wagons were placed horizontally outside the laboratory. After 50 days when the grass reach 20 cm the wagons were placed inside the laboratory to simulate the rains (Figure 2).

FIGURE 2 – Laboratory plots studied. CT - Contour tillage; DT - Downhill tillage; NT – No tillage; BS- Bare soil.

3.3.2. Data collection

Two rainfall intensities were adopted: 50.3 mm h^{-1} (2 in h^{-1}) and 114.13 mm h^{-1} (4.5 in h^{-1}) for 30 minutes, which represents respectively, 1 and 50-year, of 30 minutes rainfall event in Central Illinois. The rainfall simulator consisted of two modules, 1.3 m apart, each containing five Spraying Systems (Wheaton, IL) Veejet 80100 nozzles that operate at 41 kPa (BHATTARAI et al., 2011). The rainfall simulator modules are located 10 m from the floor, this is because in this altitude majority of the drops attain terminal velocity by the time they hit the floor, thus simulating near-natural rainfall events (HIRSCHI et al., 1990). Since two different wagons were used in the study, it was assured that the wagon was placed at exactly the similar position before each rain as recommended to Bhattarai et al. (2011). This was adopted in order to minimize the variation of rainfall across the plots and between the runs. We ensured also, maintain the similar soil moisture (30 ± 5 %) in each soil management before the simulate rain, avoiding the interference of the water content in soil.

The laboratory experiments were carried out with a slope to 17 %, which is the maximum slope to the soil chamber. The runoff from each compartment was collected in large bottles with 23 L capacity. Seven representative runoff samples for each soil management were collected during the runoff time for each rain simulate It were separate in function to the initially runoff (time 0, 1, 2, 3, 4, 5 and 6). In the final of experiment (after each event of simulate rainfall) to determine the amount of sediment, five sub samples were collect. In each recipient the sub samples were strongly mixed withdrawn an aliquot of 25 ml. The aliquot samples were placed in the oven for 48 h until all the water was evaporated. Sediment concentration for each soil management was computed using the method:

$$LS = \left(\frac{\text{AW} \times \text{g of sediment per } 25\ ml^{-1}}{25\ ml}\right) \qquad \text{(Eq. 1)}$$

Where: LS: Loss of sediment (g per plot); AW: Amount of water (L per plot).

3.4. Statistical analysis

For statistical analyses we used the Software SISVAR (FERREIRA, 2011). To the field experiment we correlated loss of sediment and water with the amount of precipitation using regression equation. Data of sediment, water and P losses collected under natural rainfall were calculated and analyze a descriptive statistics (mean, maximum, minimum, standard deviation and total accumulated in each soil management).

The difference between soil managements were analyzed using *F*-test and ANOVA ($p \leq 0.05$). The randomized experimental design was adopted, using as repetitions each collection carried out after each rain event. The mean values were grouped using Skott-Knott ($p \leq 0.05$).

Water and sediment losses under each soil management obtained with simulated rainfall were presented in absolute values. Enrichment rates with sediment in runoff were calculated, and the the enrichment rate was described using regression.

To calibrate the WEPP model values, soil losses measured in the field were compared with the values of soil losses estimated by the model. To test the model results, statistical parameters as coefficient of determination (R^2), root mean square error (RMSE), and percent bias (PBIAS) were used.

4. RESULTS

4.1. Field experiment

Figure 3 shows the relationship between the amount of rainfall and water and sediment loss. Independent of soil management it was observed that exponentially water loss is related to increased precipitation (R^2 = 0.84). For sediment loss the high amount of rainfall leads to a logarithmic increase in soil losses, however, the relationship between these two variables is lower (R^2 = 0.31). These results suggest that other variables are involved in the process of sediment loss.

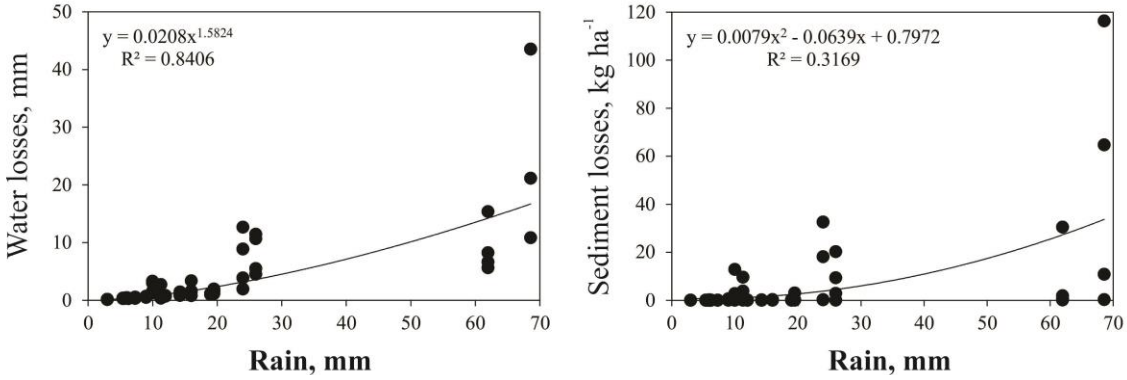

FIGURE 3. Relationships between rainfall event amount and runoff water and sediment in different soil managemets (n=72).

Table 2 presents that the contour tillage (CT) and no-tillage (NT), that is conservational managements, were more effective in reducing the water and sediment loss. By the other hand Bare soil (BS) and downhill tillage (DT) managements in general show the highest loss values. In the field experiment the grass planted had a little effect on sediment and water losses, due to the first rain eroded all seeds.

Assessing the loss of water and sediment, the following sequence between the managements was observed when evaluating the total accumulate amount: BS > DT > CT > NT (Table 2).

The highest value of water losses between the managements were observed in BS and DT managements that showed 63.46 mm. The lower value of loss (3.90 mm) and the greatest variation between each event (14.83 mm) was also observed in the BS management (Table 2).

Table 2.

Water and sediment losses in different soil managements (n = 18)

	CT	**DT**	**NT**	**BS**
Water (mm)				
Mean	9.25 c	15.58 b	8.46 d	17.51 a
Maximum	30.83	63.46	17.36	63.46
Minimum	4.20	4.20	4.80	3.90
Stad.	4.15	13.00	3.65	14.83
Total	166.51	280.53	152.35	315.25
% of loss in total rain	51.19	86.25	46.84	96.92
Sediment (t ha^{-1})				
Mean	0.31 c	2.17 b	0.02 d	4.84 a
Maximum	4.18	24.95	0.24	44.86
Minimum	0.00	0.00	0.00	0.00
Stad.	0.52	3.22	0.04	6.41
Total	5.71	39.10	0.45	87.27

CT: contour tillage;
DT: downhill tillage;
NT: no-tillage;
BS: bare soil;
Stad.: Standart derivation;
Skott-Knott $p \leq 0.05$.

The minimum value of sediment losses found in all soil managements were similar (0 t ha^{-1}). However, the maximum value of loss (44.86 t ha^{-1}) and the larger variation (6.41 t ha^{-1}) between losses was observed in the BS management (Table 2).

Majority of the losses of P in the NT and CT managements were found in the runoff water (Table 3). While the BS and DT managements, most of the loss of P were observed in sediment.

DT management showed statistically highest mean P loss value (42.12 g ha^{-1}) and total accumulated (758.17 g ha^{-1}) on runoff water. The most efficient management to reduce the loss of P in this compartment was the CT management (Table 3).

The sediment loss between all managements had similar behavior, shown equal minimal losses. However, by sediment respectively the BS (71.51 g ha^{-1}) and DT (24.95 g ha^{-1}) managements were statistically highest average to losses of P. Evaluating accumulated P in the two compartments (water and sediment) the following sequence between managements were found: BS > DT >> NT > CT.

Table 3.

P loss in water and sediment in different soil managements (n = 18)

	CT	DT	NT	BS
	P in water g ha^{-1}			
Mean	10.36 d	42.12 a	17.66 c	28.83 b
Maximum	45.49	347.99	143.03	358.22
Minimum	0.39	0.24	0.16	0.42
Stad.	9.43	60.26	24.14	43.61
Total P loss in water	186.43	758.17	317.87	518.92
	P in sediment g ha^{-1}			
Mean	1.66 c	43.69 b	1.34 c	71.51 a
Maximum	23.20	714.49	14.14	614.59
Minimum	0.00	0.00	0.00	0.00
Stad.	2.54	74.53	1.95	100.27
Total P loss in sediment	29.82	786.51	24.12	1287.14
Total amount of P loss	216.26	1544.67	341.99	1806.06

CT: contour tillage;
DT: downhill tillage;
NT: no-tillage;
BS: bare soil;
Stad.: Standart derivation.
Skott-Knott $p \leq 0.05$.

4.2. Erosion modeling

In all soil managements there was an overestimation of water losses when calculating the PBAIS. The highest values of overestimation were found in NT and CT managements that showed 186.18 % and 136.17 % respectively. The lowest PBAIS values were observed in the BS and DT managements (Table 4).

Table 4.

Statistical parameters for evaluating water and sediment losses estimates by WEPP in field experiment under different soil managements

	CT	DT	NT	BS
Water				
RMSE	14.37	6.64	15.48	14.54
PBAIS	-136.17	-33.16	-186.18	-63.10
Sediment				
RMSE	1.20	7.27	0.08	17.86
PBAIS	89.08	78.88	-77.41	86.82

Overall, the WEPP model underestimated the losses of sediment, and that ranging from 78.88 to 89.08 %, the exception was the NT management that the model overestimated the losses in 77.41 % (Table 4 and Figure 4).

Evaluating RMSE coefficient, was found in all managements higher values for water losses that range from 15.48 in NT management to 6.64 in DT management. For the sediment losses, the values ranged from 0.08 in the NT management to 17.86 in the BS management (Table 4).

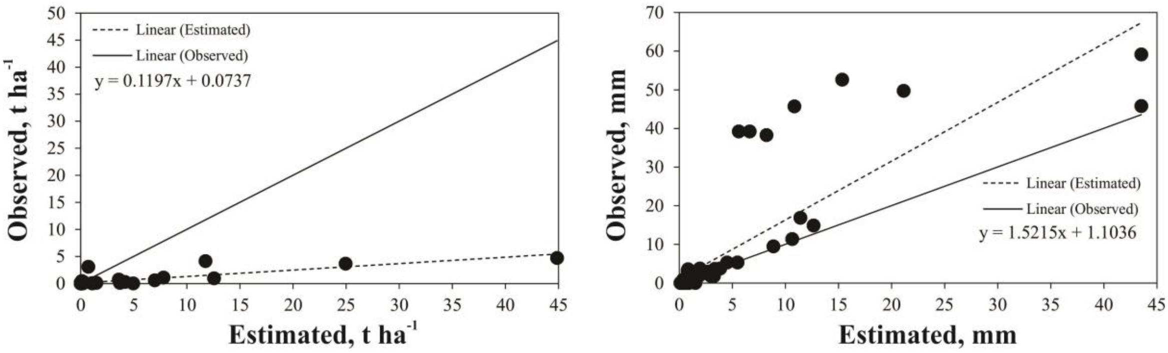

FIGURE 4. Relationships between observed soil and water losses in field and simulated by WEPP in different soil managemets (n=72).

4.3. Laboratory experiment

The loss of water and sediment under simulated rainfall are given in Table 5. Under the intensity 50.3 mm h^{-1} the NT management was effective in avoiding the water loss by runoff. Moreover BS management had the highest loss (10.33 mm). It is noted that BS management had two times the values of water loss than DT management and almost two and half times when compared to the CT management. It results show the influence that the pasture cover and litter cover has to avoid the water losses under low intensity of rain.

For the high rainfall intensity (114.13 mm h^{-1}) was verified water loss in the NT management, but the value found was half than the values observed in the BS management (53.34 mm). In this same intensity of rain when compared the BS management with CT and DT managements, it is clear that with the high amount of rain these soil management practices have lower effect in reducing the water loss (Table 5).

Table 5.

Water and sediment losses in different soil managements

Rainfall intensities	**CT**	**DT**	**NT**	**BS**
Water (mm)				
50.3 mm h^{-1}	4.15	4.88	0.00	10.33
114.13 mm h^{-1}	43.45	41.97	28.51	53.34
% of water loss in total rain simulated	28.93	28.49	17.33	38.72
Sediment (t ha^{-1})				
50.3 mm h^{-1}	0.03	0.71	0.00	0.42
114.13 mm h^{-1}	0.04	0.10	0.00	0.44

CT: contour tillage;
DT: downhill tillage;
NT: no-tillage;
BS: bare soil.

NT management was the most effective management to avoid sediment losses not being verified any loss in the two rainfall intensities studied. Also the CT management proved to be an effective management to reduce the sediment loss. This proves that the adoption of conservation practices associated with a cover crop such as grazing can significantly reduce sediment loss. A decrease of sediment loss was 92.85 % when compared the CT management with BS management in the intensity 50.3 mm h^{-1}, and 90.90 % in the intensity of 114.13 mm h^{-1} (Table 5).

The highest values of sediment losses were associated with DT management in the intensity of 50.3 mm h^{-1} (Table 5).

As shown in Figure 5, the BS management in the rainfall intensity 50.3 mm h^{-1} was the first management to initiate runoff (12 minutes). It was observed that from the beginning of the runoff the enrichment runoff rate was 2.91 g L^{-1} min^{-1}, and a tendency of increase was verified in the end of the experiment. The polynomial model was the best model to describe the enrichment rate of sediment in runoff (Table 6).

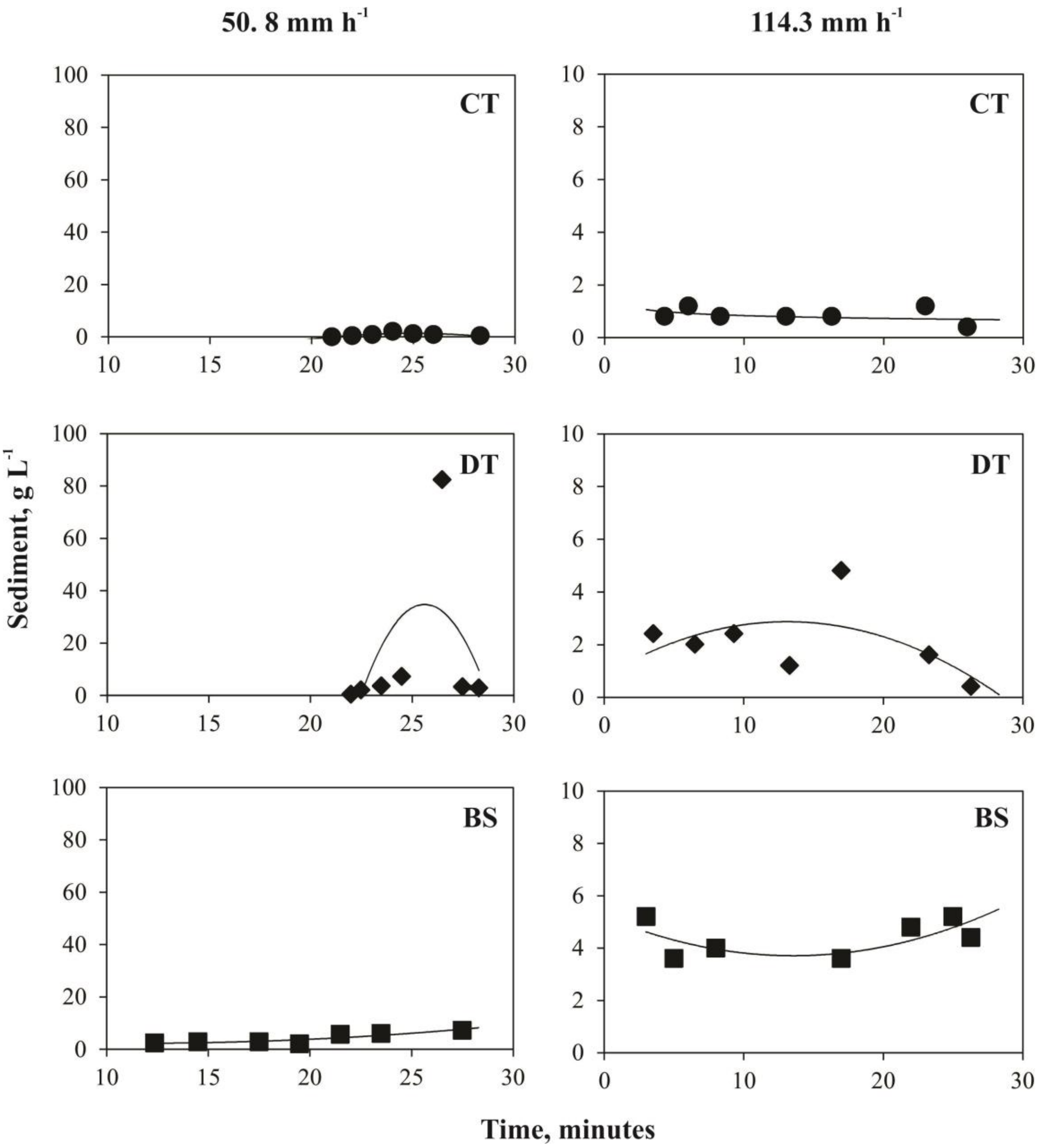

FIGURE 5. Enrichment rate of sediment in runoff (g L^{-1}) in 30 minutes evaluated in diferents soil managements. A- 50.3 mm h^{-1} and B- 114.13 mm h^{-1}. Bare soil (BS); Contour tillage (CT); Downhill tillage (DT).

The CT management presented beginning of the runoff after 21 minutes, nevertheless low enrichment rate of sediment in runoff. In the CT management was observed that with 25 minutes of experiment a small increase in the enrichment rate of sediment in runoff, reaching the rate of 1.25 g L^{-1} min^{-1}, however, in the end of the experiment a decrease was observed (Figure 5). The model that best described this behavior in this management was the polynomial (Table 6).

Table 6.

Equations of enrichment rate of sediment in runoff in different managements

Managements	Equations	R^2
	50.3 mm h^{-1}	
CT	$y = -0.0903(x^2)+4.4948(x)-54.614$	0.6753
DT	$y = -3.529(x^2)+180.85(x)-2282.2$	0.2858
BS	$y = 0.0207(x^2)-0.4729(x)+4.9906$	0.8091
	114.13 mm h^{-1}	
CT	$y = 1.3181(x)^{-0.197}$	0.1341
DT	$y = -0.012(x^2)+0.3145(x)+0.8132$	0.3001
BS	$y = 0.0082(x^2)-0.2211(x)+5.2084$	0.4024

CT: contour tillage;
DT: downhill tillage;
NT: no-tillage;
BS: bare soil;
R^2: Coefficient of determination.

DT management started the runoff after 23 minutes. The DT management showed the highest peak of enrichment rate. After 26 minutes, the enrichment rate in this management reached 81.48 g L^{-1} min^{-1}, which was numerically the highest value, even when compared to the BS management (Figure 5). The polynomial model was the best to describe the enrichment rate of sediment in runoff in this management (Table 6).

In general, the values of coefficient of determination that described the enrichment rate of sediment in runoff observed in the second simulated rain (114.13 mm h^{-1}) were lower compared to the first rain, especially for the CT management (BS - R^2 = 0.40; DT - R^2 = 0.30; CT - R^2 = 0.13) (Table 6). It was observed that during the evaluation period, the enrichment rate of sediment in runoff the levels were numerically lower compared to the first simulation (Figure 5).

As can see in Figure 5 in the second simulated rain (114.13 mm h^{-1}) in the BS management was observed that the runoff initiated after 3 minutes and the sediment concentration rate in the runoff was 4.61 g L^{-1} min^{-1}. After 15 minutes into the experiment, a small decrease of enrichment rate was observed (3.73 g L^{-1} min^{-1}) in this management causing a tendency to increase at the end of the experiment (5.67 g L^{-1} min^{-1}). The DT management also start the runoff after 3 minutes, and after 15 minutes was observed a small increase in the rate of enrichment of sediment in runoff (2.83 g L^{-1} min^{-1}). Although this behavior has been observed, the trend at the end of the experiment was the decrease in enrichment rate. The polynomial model was the best to describe the enrichment rate of sediment in runoff when evaluating the BS and DT managements in the second simulated rain (114.13 mm h^{-1}) (Table 6).

To the CT management the runoff started after 4 minutes. In this management in the beginning of experiment was observed higher values of the rate of enrichment of sediment in runoff with 1.3 g L^{-1} min^{-1}, and a tendency to decrease at the end of the experiment was observed (Figure 3). The potential model was best to describe this behavior (Table 6)

5. DISCUSSION

Based on the results, it was observed that in agriculture area with no-tillage, especially in regions with higher relief when the harvest procedure was done, the residue of the crop must be left constantly on the soil. When is not possible left the residue on the soil, a trend for the coming years, especially in areas of growing corn for the US ethanol production (DOWNING et al., 2011) should precede soil preparation in contour. Soil preparation in downhill unconditionally should be avoided, as well as the collection of all residues of the crops. The harvest of all crop residue or vegetation can lead to soil have a similar behavior to the Bare soil (BS) management, that can increase water, sediment and P losses.

As observed in the field and laboratory experiments, the highest intensity of rain independently to the management has direct implications for the increase in water losses, leading us to believe that the soil management practices have less effect on this variable when the volume of precipitated water is high. Thus, to preserve the quality of soil and water sources, it is necessary to associate these management systems, including the no tillage with other conservation practices such as terraces (HERNANI et al., 1999). The major influence of soil management practices is seen to reduce the sediment and P losses, or, reducing water and P losses in rainfall with low intensity (Figure 1 and Table 2 and 3).

As seen in the laboratory experiment the association of conservational practice with cover crop such pasture it could be a good option to reduce the sediment and water losses in areas with high slope.

The highest values of losses ($p \leq 0.05$) in BS and DT managements may be associated, in BS management, to the soil exposure and lack of straw that work as soil cover. In addition, any practice was adopted in this management and no physical impediment to runoff water and sediment was observed in this area. To the DT management, the highest values of losses may be associated with soil preparation towards the slope; this is the same sense of runoff, created a little physical impediment to runoff. Rows in the pending direction works as drains canals, where the runoff water can concentrate in the final slope, dissolving and carrying the soil with higher energy (LUCIANO et al., 2009).

The results of this study in the NT management corroborate the findings in literature (BAUMHARDT et al., 2012; HANSEN et al., 2012; HIEN et al., 2013). The minor loss in this management can be attributed to the deposition of straw on the soil, which leads to soil protection, avoiding the direct impact of raindrops and the aggregates break (NIELSEN et al., 2005). The reduction of the aggregates break causes a reduction of transportation of soil particles, in addition to the litter deposition hampering surface flow, thereby promoting greater water infiltration into the soil and lower runoff (BAUMHARDT; LASCANO, 1999; BAUMHARDT et al., 2012).

The low values of sediment, water and P losses found in the CT management can be assigned to the microdepressions in the opposite direction of the slope. Preparing the soil in an opposite direction of the slope creates structures similar to microterrace and serves as a physical impediment to the runoff, avoiding, especially the loss of sediment (LUCIANO et al., 2009). The advantages of cultivation in contour are indicated in literature, especially after the establishment of cultures (BARBOSA et al., 2010; QUINTON; CATT, 2004).

The lowest ($p > 0.05$) P loss in the NT and CT managements are connected to lower values of water and sediment losses. Also, greater cumulative loss of P in NT management compared to the CT management, even with lower losses of water and sediments may be related to the further enrichment of this nutrient in the NT management of the surface layer as pointed out by Daniel et al. (1994) with working in Arkansas and McDowell and McGregor (1980) in Mississippi.

The reduction of losses after the adoption of NT and CT management, and high losses values in managements BS and TD are very important to agricultural and environmental perspective. The reduction of losses means increased water recharge in the soil, soil quality maintenance, fertilizer efficiency; reduce financial loss and no contamination of the courses with sediment (PANDE et al., 2013; PIMENTEL et al., 1995; PIMENTEL, 2006). It also prevents erosion and transports at high levels of P, which is an essential nutrient for plants and is a major cause of eutrophication nutrient in watercourses (McDOWELL, 2012; CARPENTER, 2008).

Corroborating with the literature in different parts of the world, in the present study the managements where there were losses of sediment at higher levels, greater loss of P was verified in this compartment (AGUIAR et al., 2010; ANDERSON et al., 2011; DIAZ et al., 2013), like the BS and DT managements. Conversely, the managements which had lower values of sediment loss (NT and CT), higher losses of P was verified in the water flow. These results may be related also to the highest enrichment ratio of P (BERTOL et al., 2004; HERNANI et al., 1999).

The CT, DT and BS managements had the highest enrichment rate of runoff with sediment observed after the first simulation of rain, suggesting that the increase risk of sediment losses, and possible higher transport of P are associated to the first rainfall and the proximity to the tillage operations to the rainy events. Possibly this behavior is related to the power of the first rain in carry the material weakly added, and the directly impact of raindrops on the soil (LUCIANO et al., 2009). In addition, the CT and DT managements may be related to wear microrelief created after preparation.

As the TD management, preparation was performed following the slope that may have influenced to the highest enrichment peak of the runoff. High energy flow at the end of slope associated with the recently prepared soil with low aggregation may have facilitated the sediment transport.

Agreeing with the findings of Luciano et al. (2009) that found a decreased in sediment concentration in runoff over the testing, in the present study after the second intensity little increase on runoff sediment enrichment rate was observed. As the most of microdepressions have been undone after the first rain simulation, the second simulation even with great intensity and volume just having little effect.

Modeling results indicate that more variables related to soil and management practices, especially adopted prior to the establishment of the current management should be taken into account when estimating losses of sediment and water using the WEPP. The lack of information about initial saturation level, critical shear, interrrill and rill erodibility, soil roughness and others compromise the modeling. Although the WEPP program simulates these variables base on soil attributes, and recommend values base on several soil analyses, the better option is collect this information in the field seeking for a better simulation.

Even with the absence of more information the results obtaining showed similar behavior in losses, but with values different magnitude. However, the PBAIS values showed under-overestimation of data, and were higher than range established by Moriasi et al. (2007) ± 55% to consider a model satisfactory, which indicates that the model simulation demonstrate low accuracy. The values of RMSE far from zero (except to NT in sediment) indicated that not a good adjustment between observed and estimated data was found

(MORASI et al., 2007). It indicating that is necessary more studies to improve the accuracy of WEPP in hilly areas.

6. CONCLUSIONS

It is concluded that the No-tillage should be preferably adopted in the areas with high slope in order to reduce water, sediment and P losses. When cannot have the straw on the soil, the contour tillage is most recommended. The total collection of straw and soil preparation towards the slope should be avoided. The soil management practices have little effect on water loss in rainfall with high intensive of energy. The greatest influence of the soil management is related to the reduction of losses of sediment and P, or losses of water and P in lower intense rainfall. Soil management practices have a direct effect on the enrichment rate of runoff with sediment. The first rainfall and the proximity to the rainfall with soil management practices are the factors that have more influence to increase the rate of enrichment runoff with sediment. The application of WEPP model in different studied managements generally overestimated the losses of water and underestimated the sediment losses. Still need to work with a larger number of soil and cultural properties for estimating losses in large-scale.

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CHAPTER 4

SOIL ROUGHNESS EVOLUTION AND CONSEQUENCES FOR WATER AND SEDIMENT LOSSES

1. ABSTRACT

The objectives of this study were to determine the effects of soil management on soil surface roughness under a Molissoil clayey soil, and study the relation between soil surface roughness with sediment and water losses. The study was conducted with two intensities of simulated rainfall: 50.8 mm h^{-1} (2 in h^{-1}) and 114.3 mm h^{-1} (4.5 in h^{-1}) and the soil managements studied were: contour tillage (CT), downhill tillage (DT), no-tillage (NT) and bare soil (BS). This study demonstrated that the soil tillage in downhill or contour could promote the magnitude of the soil roughness in a rate of 2.90 and 2.76, respectively. This might lead to, lower values of water losses under low intensity of rain with 6.52 mm (or 12.83%) in the management DT, and 3.26 mm (or 6.41%) in the management CT. Soil surface roughness quickly changed after the onset of rains, high values of changes in soil roughness were observed in the CT management with 22.73% and 21.50% in the DT management. Soil coverage factor and the direction of tillage were the most important characteristics compared to soil surface roughness to reduce the sediment losses. NT (0.59 tha^{-1}) and CT (1.30 t ha^{-1}) were managements that showed lower values of sediment losses compared to the other managements. The input of litter under soil surface has an important role in reduce the sediment and water losses.

Key words: Runoff, Sediment losses, Water losses.

2. INTRODUCTION

Soil surface roughness is the microrelief and refers to wrinkling of the surface, caused by micro elevations and microdepressions spatially distributed that is directly related to soil management practices (BERTOL et al., 2008; BRAMORSKI et al., 2012; DALLA ROSA et al., 2012; VÁSQUEZ et al., 2005). Although ephemeral, the soil surface roughness is induced by various methods of preparation and is important in conservation tillage systems

(BRAMORSKI et al., 2012; VÁZQUEZ et al., 2010). In regions with high slope, where water erosion problem is prevalent (MENDONÇA et al. 2015), studies on soil roughness have been ignored. When soil roughness increases, it also elevates the water infiltration into the soil and the retention of water in surface. It may reduce the speed and volume of runoff, leading to diminish or mitigate the damage caused by water erosion (ÁLVAREZ-MOZOS et al., 2011; KAMPHORST et al., 2000).

Cover and surface roughness are two most important factors that influence soil erosion. They are responsible for almost all of water storage and sediment retention on soil surface (BERTOL et al., 2008; KAMPHORST et al., 2000). Previous studies have reported that the higher number of soil depressions lead to increase in water infiltration (BERTOL et al., 2007; BERTOL et al., 2008; BRAMORSKI et al., 2012; CHAPLOT et al., 2012). This occurs due to a greater number of depressions increasing the water infiltration in the soil profile allowing it to reduce runoff (BERTOL et al., 2008; BRAMORSKI et al., 2012). On the other hand, other studies have suggested that the presence of crop residue on soil may reduce the impact of raindrops, elevating the soil resistance to erosion process (BERTOL et al., 2007; CHAPLOT et al., 2012). Reducing the runoff in agricultural and livestock areas can result in an improvement in soil quality, since decreasing water loss, sediment and nutrients that are essential for optimum crop yield (THIERFELDER; WALL, 2012; TEAGUE et al., 2010; TEAGUE et al., 2011).

Many studies have demonstrated that soil preparation leads to increased soil roughness under no-tillage practice and the magnitude of roughness is influenced by soil type and soil mineralogy (BERTOL et al., 2006; BERTOL et al., 2008; BRAMOSKI et al., 2012). However, little is known regarding the direction of preparation influencing the roughness and the loss of water and sediments (BARBOSA et al., 2010; LUCIANO et al., 2009). In addition, studies relating soil cover to the roughness are very few.

Conventional, reduced or no tillage are common land management practices in most agricultural regions in the world. But part of agriculture and livestock regions are located in high slopes reliefs, information how the soil roughness and soil cover influenced these managements can be important in view to guide the soil management practices. In this sense, the objective of this study is to evaluate the effects of soil roughness on soil and water losses under simulated rainfall condition.

3. MATERIAL AND METHODS

3.1. Plots preparation and soil managements

A series of experiments were conducted under a rainfall simulator at the Agricultural and Biological Engineering Department of the University of Illinois. Two horizontal tilting soil chambers were used to investigate soil erosion patterns from soil under different managements. The chambers contained 3.60 m of ramp length and 1.50 m of width. More details about the soil chamber, please refer to Bhattarai et al. (2011). The chambers were filled with Molissoil clayey (USDA 2013) (Table 1).

Table 1.
Physical characterization

Sand	Silt	Clay	Bd	Pe
	-----------g kg^{-1}-----------		g cm^{-3}	cm h^{-1}
11.00	14.1	75.0	1.50	3.30

Bd: Bulk Density;
Pe: Permeability.

Four managements were studied: (a) Contour tillage (CT): implemented manually, tilling the soil opposite the slope in a depth of 15 cm; (b) Downhill tillage (DT): implemented manually, tilling the soil following the direction of the slope in a depth of 15 cm; (c) No-tillage (NT): simulate no-tillage implemented using equivalent 24 t ha^{-1} of wheat straw under cover; and (d) Bare soil (BS): without tillage and straw.

3.2. Rainfall simulator

Two rainfall intensities were used: 50.3 mm h^{-1} (2 in h^{-1}) and 114.13 mm h^{-1} (4.5 in h^{-1}) for 30 min, which represents 1 and 50-year events respectively in Central Illinois. The rainfall simulator consisted of two modules, 1.3 m apart, each containing five Spraying Systems (Wheaton, IL) Veejet 80100 nozzles that operate at 41 kPa (BHATTARAI et al., 2011). The rainfall simulator modules are located 10 m from the floor, because majority of the drops would attain terminal velocity by the time they hit the floor, thus simulating near-natural rainfall events (HIRSCHI et al., 1990). We ensured to maintain similar soil moisture (30 ± 5 %) in each soil management before simulating rain to avoid the interference of the water content in soil. The experiments were carried out with a slope of 17 %, which was the maximum adjustable slope of the soil chamber.

3.3. Soil surface scanner

The data collection of soil surface was carried out using a laser distancemeter (Leica 3D Disto®) programmed to make automatic readings spaced at 5 cm. The roughness of the soil was evaluated at zero stage, immediately after preparation of the soil, and after each rain event.

3.4. Soil and water collect

The runoff from each management was collected in large bottles with 23 L capacity. In order to determine the amount of sediment, five sub samples (25 ml each) were collected after thoroughly mixing the runoff water. The aliquot samples were placed in the oven for 48 h until all the water was evaporated. Sediment concentration for each soil management was calculated using the following relationship

$$LS = \left(\frac{\text{AW} \times \text{g of sediment per 25 } ml^{-1}}{25\ ml}\right) \qquad \text{(Eq. 1)}$$

Where: LS: Loss of sediment (g per plot); AW: Amount of water (L per plot).

3.5. Data analysis

The analysis of soil surface after collection of data was processed using Surfer® software (GOLDEN SOFTWARE, USA). To calculate the soil roughness, a method proposed by Allmaras et al. (1966) and modified by Currence and Lovely (1970) was used, by multiplying the standard deviation of the elevation logarithms by the mean elevations. The oil roughness values were computed before the rain (after the tillage), after each simulated rainfall. The results of water and sediment losses were presented as total accumulated volume in each simulated rain event, and the sum of two simulated rain events.

4. RESULTS

Figure 1 shows the soil surface before the rainfall simulation. The soil tillage raised part of the soil surface above the original level and that had a direct effect on the soil surface roughness for downhill tillage (DT) and contour tillage (CT) managements.

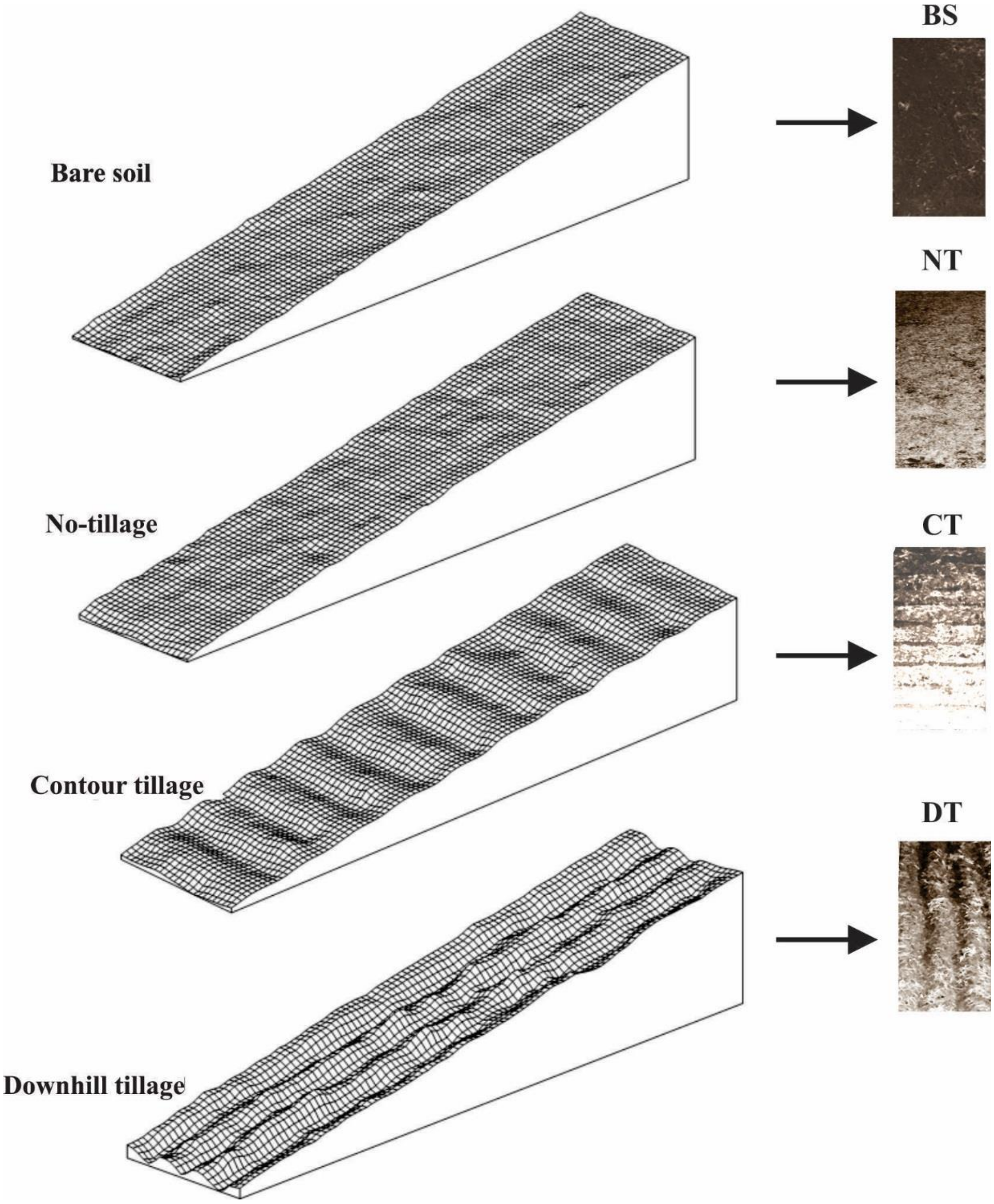

FIGURE 1. Diagram block of soil surface roughness before the rainfall simulations.

As observed in Figure 1, BS management exhibited similar characteristics to NT management, whereas CT and DT managements have distinct surface characteristics.

Numerically the highest roughness before the rain simulations was found in DT management (7.17) that was 4.85% higher than the CT management, and 65% higher than the NT management (Table 2).

Table 2.

Index of soil surface roughness in different soil managements prior and after two rainfall simulations

Treatments	**Surface roughness**		
	Before Rain	After rain	
		50.8 mm h^{-1}	114.3 mm h^{-1}
Bare soil	4.26	4.23	4.20
Contour Tillage	7.03 (2.76)	5.55	5.33
Downhill Tillage	7.17 (2.90)	5.54	5.52
No-Tillage	4.34 (0.08)	4.28	4.28

Note: Values in parentheses is show the increase in soil surface roughness in comparison to the bare soil.

As can be seen from the Table 2, in general there was a decrease in soil roughness after the rain simulations, especially after the first rain (50.8 mm h^{-1}). A greater decrease in the soil roughness was observed after the first simulated rain (50.8 mm h^{-1}) for CT and DT managements. The index of roughness decrease in these managements were 22.73% in the first and 21.5% for the second, while the decrease of soil roughness in the NT and BS management were 1.38% and 0.71% respectively (Table 2).

For the second rain intensity (114.3 mm h^{-1}), the decrease in soil roughness overall was smaller compared to the first rainfall event. The NT management did not change the soil surface after the second rain (114.3 mm h^{-1}), while the CT, DT and BS managements decreased the surface roughness by 3.97%, 3.96% and 0.70% respectively (Table 2).

It can be seen from the data in Table 3 that the water loss for 50.8 mm h^{-1} intensity event was lower for the CT (3.26 mm or 6.41%) and DT (6.52 mm or 12.83%) managements, and was higher for the NT (9.78 mm or 19.25%) and BS (13.04 mm or 25.66%) managements. For the second simulated rain (114.3 mm h^{-1}), the BS and CT management resulted in the high values of losses with 58.33 mm (or 51.03%) and 53.99 mm (or 47.23%), respectively. It indicates the influence of soil roughness on the water losses for these managements.

Table 3

Water and sediment losses in different soil managements in two rainfall simulations

Treatments	**Water (mm)**	**Sediment (t ha^{-1})**
	50.8 mm h^{-1}	
Contour Tillage	3.26 (6.41)	0.07
Downhill Tillage	6.52 (12.83)	0.04
No-Tillage	9.78 (19.25)	0.02
Bare soil	13.04 (25.66)	1.73
	114.3 mm h^{-1}	
Contour Tillage	53.99 (47.23)	1.22
Downhill Tillage	47.10 (41.20)	8.41
No-Tillage	45.65 (39.93)	0.56
Bare soil	58.33 (51.03)	8.03

Note: In parentheses is show the percentage of water loss in total rain.

Evaluating the sediment loss in the rain intensity of 50.8 mm h^{-1}, the soil coverage factor and the tillage were important factors to reduce the losses. Numerically lower values of sediment losses were found in NT (0.02 t ha^{-1}), DT (0.04 t ha^{-1}) and CT (0.07 t ha^{-1}) managements, while the higher value were found in the BS management with 1.73 t ha^{-1}. For the simulated rain with intensity of 114.3 mm h^{-1}, the soil cover factor and direction of cultivation seemed more important than the soil roughness, and NT and CT managements showed lower values of sediment loss with 0.56 t ha^{-1} and 1.22 t ha^{-1}, respectively (Table 3).

It was also observed that the mean value of soil roughness has a relation with the total amount of water lost (Table 4). For all three managements, it was observed that water losses were smaller when compared to BS management. It was observed that the average water loss decreased by 22.82% for these managements compared to BS management.

For sediment losses, similar pattern was observed. The management practices had an influence on the sediment losses. However, the direction of tillage and soil cover were found to be more important than soil roughness in this case. Compared to BS management, the NT and CT management reduced the sediment losses by 93.96 % and 86.69 %, while the DT management reduced the sediment losses by 9.41 % (Table 4).

Table 4

Mean of soil surface roughness and total amount of water and sediment losses in different soil managements in two rainfall simulations

Treatments	**Surface**	**Water**	**Sediment**
		mm	t ha^{-1}
Contour Tillage	5.97	57.25	1.30
Downhill Tillage	6.08	53.62	8.85
No-Tillage	4.31	55.43	0.59
Bare soil	4.23	71.38	9.77

5. DISCUSSION

An increase in soil roughness after the soil tillage in the present study confirms the findings from several earlier studies (BERTOL et al., 2006; BERTOL et al., 2008; BERTOL et al., 2010; BRAMORSKI et al., 2012). The soil roughness values obtained for the CT, DT, NT and BS managements for this study were close to those found in others studies with different soil and climate conditions (BERTOL et al., 2006; BRAMORSKI et al., 2012).

In general, the flow of water on a soil surface with high roughness results in low water losses compared to a surface with low roughness, resulting in lower total loss of sediment (COGO et al., 1984). However, in this study we found that the soil cover and the direction of cultivation were more influential than the increase in roughness for sediment losses.

It was observed that the NT management with high deposition of litter promoted a low increase in soil surface roughness. Litter deposition also lead to low values of sediment losses which agrees with the findings from Locke et al. (2015) and Rhoton et al. (2002). In the present study, the soil cover reduced the impact of rain drops falling directly on the soil, increasing the soil erosion resistance (POTTER et al., 1995). In addition, the litter deposited in the soil could be used as a filter holding the sediment in NT management.

CT and DT managements involved ridges of various sizes raising the soil roughness and this worked as a physical barrier to runoff, reducing the water losses. However, this was true for the rain with low intensity (50.8 mm h^{-1}) only. Cultivation following the slope direction functions as drainage canals, where water runoff is concentrated along the slope, dissolving the ridges and carrying the soil with greater energy (LUCIANO et al., 2009). This may explain the high value of sediment losses found in DT management.

In the CT management, the reduction in the sediment loss can be attributed to the increase in soil surface roughness along the contour. This creates ridges that are arranged transversely on a hill, reducing the speed of runoff and filtering the sediment contained therein (COGO et al., 2007; LUCIANO et al., 2009). Although the CT management in the present study has demonstrated lower boundary of sediment loss, when compared to the DT and BS managements (table 3) the high values of water loss found may be due to the partial breaking of lumps after rainfall agreeing with the results reported by Luciano et al. (2009).

This study has been able to demonstrate that the rainfall could reduce soil surface roughness, with a tendency of decreasing more markedly in CT and DT managements, confirming observations described in literature (COGO et al., 1984; BERTOL et al., 2006; BERTOL et al. 2008). This behavior was noted, particularly after the first rain simulation, where the decay rate was higher, reaching 22.73 % (table 2).

The decrease of soil roughness is related to the kinetic energy of drops impacting directly on the soil which broke the soil aggregates and micro elevations. This is associated with the surface runoff eroding the soil, increasing sediments transport and re-depositions (BERTOL et al., 2006). As the micro depressions were eroded after the first rain, in the second rain, even with great intensity and volume of water, the effect on the soil roughness was minimum. Although the decay rate has been considerable, the values were well below than those found by Bertol et al. (2008) with similar management that was 49 %, it was due to the climate and soil conditions were different from the present study.

The relative reduction in roughness while comparing the CT and DT managements with NT and BS managements is explained by the fact that the first two treatments had higher initial roughness values. However, the small superficial changes in rates of roughness after the rain simulations evaluating the BS management, associated with high values of losses in water and sediment may indicate that the runoff in this management was rather evenly, similar to what was observed in the field sheet erosion. In addition, two rain simulations were not sufficient to develop rills in this area, which could lead to increase in the surface roughness. It was observed that decrease in roughness was possibly due to lost soil that were deposited in the areas of micro-depressions. The small change in soil roughness noted in the NT management may be related to low soil loss values, which only promoted the accommodation of the litter in the soil surface after the first rain simulated (table 2).

6. CONCLUSIONS

This study demonstrated that the soil cultivation in downhill or contour can lead to increase in soil roughness, and this observation was prominent under low intensity of rain with lower values of water losses. However this experiment confirmed that this characteristic quickly changed after the onset of rains. It was observed that the soil coverage factor and the direction of tillage were the most important characteristics for sediment losses compared to soil surface roughness. NT and CT managements showed lower values of sediment losses. The principal theoretical implication of this study is that land use planning with agriculture or livestock must be designed to prevent the soil from being exposed or if exposed, tillage in contour should be adopted. Other important theoretical implication was which the input of litter under soil surface has an important role in reduce the sediment and water losses.

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FINAL CONSIDERATIONS

In chapter 1 we found that the extensive management of pasture adopted in majority of the Atlantic Forest biome should be rethought. The highest sediment loss and the largest values of water and nutrients loss associated with the control management, may partly explain the reduction of soil quality in these areas in the Atlantic region. Extensive pasture management, similar to the control management in the present study, also may be partly responsible for the water crisis that occurs in this region.

As seen, soils under extensive management can lead to lower aggregate stability, reduced water infiltration into the soil. This can lead to greater runoff, raising the losses of sediment and water and reducing the soil water recharge. Since burning management showed high values of sediment, water and nutrients loss were found. Therefore, even though this management is still being adopted by the farmers in the Atlantic region, it should be avoided. While plowing and harrowing level have shown satisfactory results with the purpose of the present study (low values of water, sediment and nutrients losses) the low grass production suggests that this practice is not the most satisfactory. It is noteworthy that the experiment was conducted with small plots without cattle trampling, therefore for farmers to obtain similar results; it would necessary to keep pasture closed for at least four months, a condition that does not always happen in the field.

This work strongly encourages the bi-annual adoption of liming and fertilization for the pasture management established in this region. This simple adjustment can increase the carrying capacity, which associated with the height grazing control can increase the productive capacity of livestock areas. Unfortunately, two years were not long enough to stabilize managements conservation integration crop-livestock and chisel in level associated with liming and fertilization. Given the stabilization of a pasture with integration crop-livestock in order to increase the straw in the soil, planting legumes, *Feijão de porco* and *Feijão guandú* is not recommended, it is necessary to test other cultures, especially grasses preceding planting of pasture.

In chapter 2 the absence of the animal component and the small size of the experimental plots may have influenced for low calculated values of *C*-factor for the Universal Soil Loss Equation or Revised Universal Soil Loss Equation (USLE/RUSLE). As generally in field, these factors involved the *C*-factor could of been higher, especially in the management of pasture control.

The empirical USLE/RUSLE can embed multiple errors in estimating soil loss. However, even if this occurs due to its ease of use, this equation demonstrated to be an effective tool for agricultural planning, and recommended its use with the *C*-factors calculated for estimating soil loss in different management of pastures.

The C-factor calculation at 4 and 24 months was necessary due to the major differences of losses were found in the initial phase of the establishment of pastures, this separation allows to get better results by reducing the over- or underestimation of soil loss. In order to increase the accuracy recommended for further study, redoing these managements every two years and seek at least a historical series of 10 years is necessary.

In chapter 3 it is encouraged further studies with the no-tillage and contour tillage. It should tested the combination of soil tillage in contour with rates of straw on the ground. It is necessary to know which is the best amount of straw that should be left underground, in order to keep low levels of sediment, water and P losses. The values adopted in the no-tillage management in this study were high, therefore, it should be investigated the values that lead to satisfactory results for reducing losses and ethanol production. The harvest of all straw and the tillage in downhill is discouraged.

Estimating water and soil losses using the WEPP program, proved to be a very important tool, but still needs more studies, particularly in regions with high slope. The WEPP program showed to be inconvenient, even for the United States conditions where this model has been created, requires a large database to obtain accuracy in estimating soil and water loss. This is often undesirable because it increases the cost of the estimates.

In Chapter 4, it was possible to verify the importance of roughness to prevent the loss of water in low-intensity rain. However, you must know which intensity that roughness can support. Moreover, it is necessary to know which rate of straw deposition (t ha^{-1}) is effective to reduce the losses of sediment and nutrients.