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Soil, water, nutrients and soil organic matter losses by water erosion as a function of soil management in the Posses sub-watershed, Extrema, Minas Gerais, Brazil

Perdas de solo, água, nutrientes e matéria orgânica do solo por erosão hídrica em função do manejo na sub-bacia das Posses, Extrema, MG

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Abstract

Knowledge of the quantity and quality of the material lost by soil erosion due to soil management is a basic need to identify land management zones in catchments. The aim of this study was to investigate the influence of soil management on the quantity and quality of soil material lost by erosion in the Posses sub-watershed, Municipality of Extrema, State of Minas Gerais, Brazil. Water and sediments lost by natural rainfall erosion were sampled from erosion plots located on a Red-Yellow Argisol (PVA) under the following systems: bare soil, subsistence farming (maize/beans/pumpkin/jack-beans/fallow), degraded pasture, well-managed pasture, and reforestation set up in 2013; and in a Argisol: reforestation set up in 2008, bare soil, and native forest. Ca, Mg, K, P, N and soil organic matter (SOM) contents were determined in sediment and soil samples (at 0-5 cm depth) for the determination of the runoff enrichment ratios. Management influences soil losses more so than water losses. Minor losses were found in reforestation set up in 2013 (soil); in well-managed pasture (water); and in reforestations (nutrients and SOM). These losses tend to stability with time. The general sequence of nutrient losses was N > Ca > Mg > K > P in PVA; and N > Ca > K > Mg > P in Argisol. Loss rates of SOM and N followed the order: bare soil > subsistence farming > degraded pasture > well-managed pasture > reforestation, in PVA; and bare soil > native forest > reforestation, in Argisol. Reforestation and well-management pasture are effective conservation strategies in order to lower the erosion process in the Posses sub-watershed. Soil losses, as well as nutrients and organic matter losses were more influenced by soil management than water losses. The safeguarding native forest under Argisol is essential to the conservation of this pedoenvironment, especially in steep slopes.

Key words*:* Soil degradation. Conservation management. Environmental quality. Soil and water safety.

Resumo

O conhecimento da quantidade e qualidade de material perdido por erosão hídrica em função do manejo do solo constitui uma necessidade básica para a definição de zonas de manejo em áreas de recarga de água. O objetivo desse trabalho foi verificar a influência do manejo do solo sobre a quantidade e

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qualidade de material perdido por erosão hídrica na sub-bacia hidrográfica das Posses, Extrema-MG. Para isso, foram coletados água e sedimentos erodidos através de parcelas de erosão, instaladas, sob chuva natural, em Argissolo Vermelho-Amarelo (PVA) nos manejos: solo descoberto, rotação cultural (milho/feijão-de-porco/pousio), pastagens degradada e bem manejada, e reflorestamento implantado em 2013; e em Argisol nos manejos: reflorestamento implantado em 2008, solo descoberto e mata nativa. Nas amostras de sedimentos e de solos (coletadas na profundidade de 0-5 cm) foram determinados os teores de Ca, Mg, K, P, N (NT) e de matéria orgânica do solo (MOS) e com isso, calculada a taxa de enriquecimento de enxurrada. O manejo exerce maior influência nas perdas de solo do que nas perdas de água. Menores perdas foram encontradas no reflorestamento implantado em 2013 (solo), pasto bem manejado (água) e reflorestamentos (nutrientes e matéria orgânica). Há uma tendência de estabilização dessas perdas com o tempo de implantação dos sistemas. A tendência geral das perdas de nutrientes no PVA foi NT > Ca > Mg > K > P; e no Argisol foi de NT > Ca > K > Mg > P. As taxas de perdas de MOS e NT seguem a ordem: solo descoberto > rotação cultural > pasto degradado > pasto bem manejado > reflorestamento, no PVA; e solo descoberto > mata nativa > reflorestamento, no Argisol. O reflorestamento e o manejo das pastagens são estratégias conservacionistas que minimizam as perdas por erosão hídrica na sub-bacia das Posses, Extrema-MG. O manejo exerce maior influencia nas perdas de solo e de materiais a ele relacionados do que nas perdas de água. A manutenção da mata nativa sob Argissolo é essencial para a conservação deste pedoambiente, sobretudo, em declives acentuados.

Palavras-chave: Degradação do solo. Manejo conservacionista. Qualidade ambiental. Segurança do solo e da água.

Introduction

Inappropriate soil management may favor the transport of sediments, nutrients and soil organic matter (SOM) by water erosion from very important areas, such as the recharge areas of a watershed, to water courses. This phenomenon may trigger a series of both economic and environmental problems, and may affect the productivity of agricultural land and the quality of water supply. The situation is aggravated when considering water bodies as integrators of phenomena that occur in watersheds, since they may receive and transport the material lost by erosion away from the sediment source, which also hinders the quality of the sites where they are deposited.

Several studies have attempted to relate the magnitude of the erosion process with changes in soil properties, promoted by land use and management (OLIVETTI et al., 2015; SCHICK et al., 2000; SILVA et al., 2005; SILVA et al., 2016; CARDOSO et al., 2012; SILVA et al., 2012; SOUZA et al., 2014). Some of them have shown that in certain types of soil, loss of water, soil and its constituents can reach critical values. However, in general, lower losses were obtained for systems that maintain the vegetation cover for longer periods and with less mobilization of the soil. In this sense, conservation systems have stood out as effective strategies for sustainable development, especially in tropical regions, such as Brazil, promoting lower soil, water, nutrients, and SOM losses when compared with more intensive systems (CAIRES et al., 2006; LEITE, et al., 2009; PANACHUKI et al., 2011; LIMA et al., 2014).

Facing the impacts caused by water erosion on the sustainability of environmental resources, the watershed is the unit to be considered in order to evaluate the effects of soil management systems on the quality and quantity of material disposed during erosive events (ALVAREZ et al., 2014). Thus, due to water deficit in the last two years in several regions of Brazil, which affected large cities, especially the city of São Paulo (RICHARDS et al., 2015), the Payment for Environmental Services Program (Pagamento por Serviços Ambientais – PSA) has encouraged researches that contribute to the conservation of environmental resources in national watersheds. This program was created by the National Agency of Waters (Agência Nacional das Águas – ANA), which chose Posses as pilot sub-watershed for the national implementation of the PSA program (AVANZI et al., 2011). The Posses sub-watershed is located in the municipality of Extrema, Minas Gerais, and is part of the watershed of Jaguari River, which is a large tributary of the reservoir responsible for providing water to more than 10 million people of the metropolitan region of São Paulo, the Cantareira System (PEREIRA et al., 2010).

Given the importance of the Posses sub-watershed, due mainly to its strategic geographical location, studies that aim to relate soil management systems with the magnitude of water erosion in this location can work as important strategies in the improvement and viabilization of conservation management of national watersheds. In this sense, the objective of this study was to determine the influence of soil management on the quantity and quality of material lost by water erosion in the sub-watershed of Posses, Extrema-MG.

Material and Methods

Study area

The study was carried out for two hydrological years, from October 2013 to September 2015, with erosion plots installed in the Posses sub-watershed, municipality of Extrema, south of the state of Minas Gerais, Brazil (Figure 1). Posses covers an area of 1,200 ha, with altitudes between 1,144 and 1,739 m. The climate is Cwb, mesothermal, with mild summers and dry winter, according to Köppen classification. The average annual temperature is 18°C; the hottest and coldest months have average temperatures of 25.6°C and 13.1°C, respectively (ANA, 2008). Figure 2 shows the distribution of rainfall and erosivity for the study period, which were 1,050 mm and 4,957 MJ mm ha^{-1} h^{-1} for the hydrological year of October 2013 to September 2014, and of 1,536 mm and 8,971 MJ mm ha^{-1} h^{-1} in the hydrological year of October 2014 to September 2015, respectively.

The Posses sub-watershed was chosen as study area for its great national and environmental importance.

Figure 1. Location of erosion plots installed in the Posses sub-watershed, Extrema, Minas Gerais, Brazil.

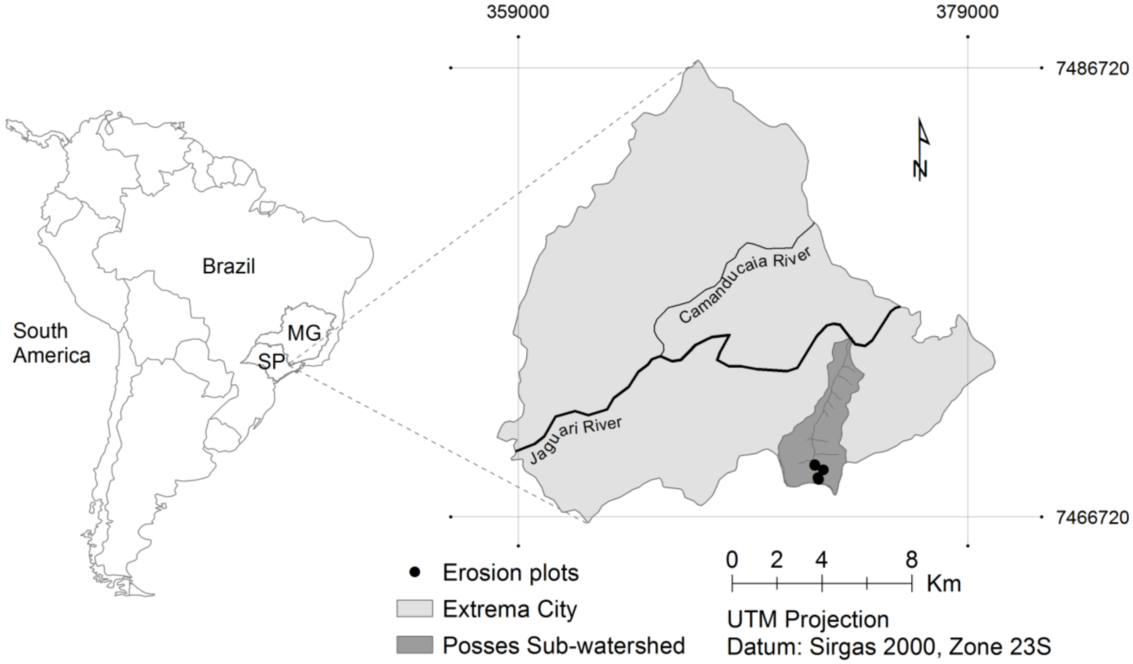
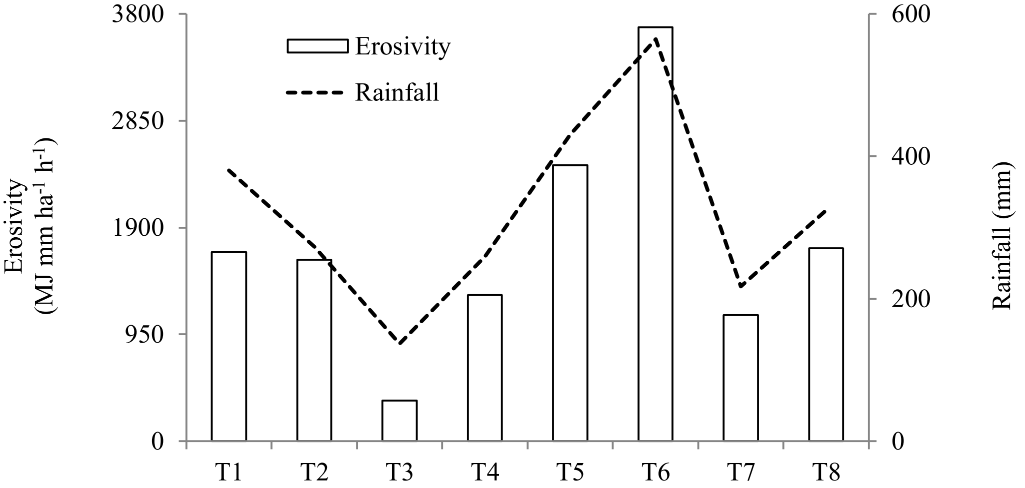


Figure 2. Distribution of rainfall and erosivity index for the quarters of 2013/2014 (T1 to T4) and 2014/2015 (T5 to T8), in the Posses sub-watershed, Extrema, Minas Gerais.



Installation of erosion plots and description of treatments

In September 2013, eight 24 x 4 m plots were installed in such a way that the larger dimension was oriented along the slope direction, under natural rainfall, in order to monitor water erosion in two soil classes (Red-Yellow Argisol – PVA and Argisol) in the Posses sub-watershed. Plots were demarcated with 40 cm tall galvanized plates (20 cm buried into the soil), containing two sedimentation tanks at their lower ends. These sedimentation tanks were separated by 1/15 Geib type splitter with 15 outs.

Five plots were installed in PVA under the following systems: (i) bare soil; (ii) subsistence farming, traditional system adopted by local farmers, which brings together crops in rotation or consortium (maize/beans/pumpkin/jack-beans/fallow); (iii) degraded pasture, *Brachiaria brizantha* grown in the area for over 10 years, without fertilization history; (iv) well-managed pasture; and (v) reforestation with Atlantic Forest species, set up in 2013, on degraded pasture desiccated with glyphosate. In Argisol, three plots were installed under the following systems: (i) native forest, Atlantic Forest fragment with anthropic influence in recent decades; (ii) reforestation set up in 2008, with Atlantic Forest species; and (iii) bare soil. Table 1 presents other information on the experiment site and on soil properties (0-5 cm).

The amount and distribution (manual) of limestone and soil fertilizers used in the experiment followed the recommendations of Ribeiro et al. (1999): a) subsistence farming: 40kg dolomitic limestone (PRNT 61%) distributed superficially, incorporated through conventional soil tillage, and192 g NPK (4-14-8) in the planting hole (130 holes spaced 0.80 m apart), and 60 kg ha^{-1} urea, in topdressing (two applications); b) well-managed pasture: 10 kg dolomitic limestone and 10 kg NPK (4:14:8), distributed superficially on the pasture before the implementation of the experiment and; c) reforestations: 200 g NPK (4:14:8) distributed in the planting hole, and seedlings planted with hydrogel. The plots “bare soil”, “degraded pasture” and “native forest” did not receive neither liming nor fertilization. Weed control was carried out by hand in the bare soil and subsistence farming managements, and by glyphosate in the reforestation managements.

Table 1. Physical properties and organic matter of the 0-5 cm layer of soils under different management systems in the Posses sub-watershed, Extrema-MG.

Management systems	Slope	Sand	Silt	Clay	BD	SMRP	Porosity	
							Macro	Micro
	%	-----------g kg^{-1}-----------			g cm^{-3}	MPa	--------%--------	
Red-Yellow Argisol								
Bare soil	27	218	254	528	1.20	3.70	15.1	45.6
Subsistence farming	27	212	248	540	1.16	3.59	13.4	45.7
Degraded pasture	32	192	281	527	1.06	2.58	9.3	52.1
Well-managed pasture	32	212	240	548	1.12	2.58	11.2	50.5
Reforestation 2013	31	221	239	540	1.11	2.35	9.5	52.1
Argisol								
Native forest	53	398	292	310	1.15	1.45	17.87	43.20
Reforestation 2008	36	307	383	310	1.34	2.58	8.22	44.52
Bare soil	25	379	298	323	1.39	3.25	9.05	37.77

Reforestation 2013: reforestation set up in 2013; Reforestation 2008: reforestation set up in 2008; BD: soil bulk density; SMRP: soil mechanical resistance to penetration.

Evaluation of losses and of its relationship with soil properties

After each erosive event, the runoff volume was measured directly in the sedimentation tanks and sampled according to Cogo (1978). Samples were allowed to rest (24 hours) in oroder to separate the sedimented material by siphoning. The amount of material lost by erosion was calculated by the weight of the sediment sampled after oven drying (55 to 60°C) for 24 hours.

Soil samples were collected at 0-5 cm depth in three random positions within each erosion plot, in November of the years of 2013 and 2014. The levels of the available Ca, Mg, K, P (Mehlich-1), total N (N) and soil organic matter (SOM) were determined in both soil and sediment samples, according to Embrapa (1997).

Runoff enrichment ratio (RER) was obtained from the mean levels (two years of study) of nutrients and SOM contained in the soil and in the sediment, for each soil management system. RER was calculated by dividing the concentration of each nutrient or organic matter in the sediment by the concentration in the soil samples (BERTOL et al., 2004). When RER > 1 there is an increment in the sediment in relation to the soil; whereas RER < 1 indicates no enrichment (HERNANI et al., 1999). Loss reduction efficiency (LRE) of soil and water was obtained by the difference of the division between the losses in bare and covered systems, by losses in bare systems, and was expressed in percentage.

Results and Discussion

Soil and water losses

In general, losses were higher in the second year of study, especially water losses (Table 2). This was due mainly to the fact that rainfall and erosivity were higher in the second year (check “Study Area”). Also, there was an unusual weather behavior in the first year of the experiment, mainly for erosivity (Figure 2), in relation to the area’s average historical values: 1,477 mm yr^{-1} of rainfall and 8212.70 MJ mm ha^{-1} h^{-1} yr^{-1} of erosivity, with erosive events concentrated between October and March (ANA, 2008; PONTES et al., 2015).

Over the years, there was a decrease of soil losses in plots under degraded (18.8%) and managed pasture (41.1%), which explains the effect of vegetation cover in the reduction of erosion. This effect is also noticed by the reduction of soil and water losses, provided by the systems with vegetation cover, when compared with the bare systems indicated by LRE (Table 2).

Table 2. Soil and water losses by water erosion for two hydrological years (2013/2014 and 2014/2015) in soils under different management systems in the Posses sub-watershed, Extrema-MG.

Management systems	Soil loss				Water loss			
	2013/2014	2014/2015	Mean	LRE	2013/2014	2014/2015	Mean	LRE
	-------------t ha^{-1} yr^{-1}-------------			%	-------------mm yr^{-1}-------------			%
Red-Yellow Argisol								
Bare soil	0.147	1.142	0.644	-	23.0	40.5	31.8	-
Subsistence farming	0.075	0.999	0.537	17	18.8	33.2	26.0	18
Degraded pasture	0.064	0.052	0.058	91	16.1	21.1	18.6	41
Well-managed pasture	0.073	0.043	0.058	91	12.5	17.4	14.9	53
Reforestation 2013	0.031	0.032	0.031	95	15.6	20.7	18.2	43
Argisol								
Native forest	0.197	0.284	0.241	40	32.8	32.7	32.7	0
Reforestation 2008	0.235	0.122	0.178	56	16.5	25.1	20.8	20
Bare soil	0.135	0.672	0.403	-	17.9	34.0	25.9	-

Reforestation 2013: reforestation set up in 2013; Reforestation 2008: reforestation set up in 2008; LRE: loss reduction efficacy.

In general, water losses were less influenced by vegetation cover than soil losses; i.e. soil LRE > water LRE (Table 2), corroborating the results of Dechen et al. (2015). The most effective reduction of losses was obtained for the reforestation system implemented in 2013 (soil) and for managed pasture (water) (Table 2). In PVA, soil loss rates were almost 21 times lower in the reforestation system than in the bare system. Cassol and Lima (2003), Cassol et al. (2004) and Xu et al. (2013) studied the effect of vegetation cover on water erosion in Argisols with erosion plots similar to those of this study, and obtained soil losses ten times smaller in systems with vegetation cover, when compared with those with bare soil.

Greater losses and lower soil and water LRE in subsistence farming, in relation to the other systems with vegetation cover (Table 2), may be due to tillage methods (conventional) and weed control (hoeing). These methods mobilize the soil surface, increasing its roughness. However, in short and long periods of time, they promote, respectively, the sealing and the decrease of soil surface roughness, which reduce its capacity of retaining and infiltrating water in the surface (BERTOL et al., 2007) and of resisting erosion.

LRE rate of water in native forest in Argisol was lower than in the reforestation system implemented in 2008 (Table 2). Similar behavior was observed by Cogo and Streck (2003), Streck and Cogo (2003), Volk et al. (2004), Castro et al. (2006) and Gilles et al. (2009) in studies on the effects of vegetation cover and soil management on soil erosion. The authors attributed the increased surface flow (higher water loss) to the increased consolidation of the soil surface in more conservationist systems, when compared with the conventional ones. The consolidation of the soil surface may also have contributed to the lower LRE in the reforestation system in PVA, which also suffered effect of degraded pasture existing in the area on which reforestation was implemented, despite having been implemented recently.

On the other hand, the highest LRE rates of soil and water, at least in Argisol, were observed for reforestation, and not for the native forest (Table 1). This may be related to the fact that the forest has suffered human impacts in recent decades, as well as to the disturbances that occurred at the time of implementation of the plot, which is not unusual in such experiments. Despite not having reduced water losses, native forest decreased soil loss by 40%, which evidences the importance of preserving this vegetation cover in this site. It should be noted that the slope in the plot under the forest system was 2.12 times greater than that of the bare plot (Table 1). If this slope was considered in the calculation of LRE, by standardization of loss mean data according to the slope of the bare plot (mean loss in the treatment x slope in the bare plot/slope in the treatment), an even greater effect of vegetation cover would have been observed on reduction of erosion, i.e., soil LRE equal to 72 and 69%, and water LRE of 40 and 62%, for native forest and reforestation system in Argisol, respectively.

Since there are few studies on erosion with natural rainfall in Argisol in Brazil, the data generated in this study may work as the basis for a series of studies, especially regarding the improvement of prediction models of water erosion, and in the provision of soil management tools. Also, since this type of soil usually occurs in water recharge areas, this data may have greater implication in management programs of these areas, such as PSA. In other words, by means of the quantitative data on the effects of soil management systems on water erosion, a ‘compensatory factor’ should be considered in the calculation of the valuation for environmental services, adopted by owners in areas within watersheds and sub-watersheds.

Losses of nutrients and soil organic matter

The reforestation systems presented, in general, lower nutrient losses via sediment than the other systems studied (Table 3). This may have occurred mainly due to lower soil losses in the reforestation systems (Table 2), since their nutrient contents in the 0-5 cm layer of the soil are not necessarily lower in relation to the others (Table 4). This fact, when analyzed in conjunction with the discussion in the previous topic, illustrates even more the importance of forests in preserving the physical and chemical properties of the soil, and therefore the maintenance of their sustainable capacity.

In Red-Yellow Argisol (PVA), the general tendency of nutrient losses was: N > Ca > Mg > K > P (Table 3). The same sequence for Ca, Mg, K and P was observed by Dechen et al. (2015), who evaluated nutrient losses and costs associated with water erosion in Oxisol in Campinas-SP. However, when comparing the management systems, subsistence farming showed the greatest nutrients loss, except for K and N, which had greater losses in bare soil. Soil mobilization, carried out at cultivation, disrupts the soil and makes nutrients more susceptible to entrainment by erosive processes, especially those containing a more intimate relationship with soil colloids, such as P, Ca and Mg (SCHICK et al., 2000). On the other hand, non mobilization of the soil results in the accumulation of nutrients in the surface due primarily to the decomposition of organic matter, what may explain the greater K and N losses in the soil without vegetation cover.

Comparing the bare soil with the reforestation in PVA, it is observed that this management reduced losses of P (92%), K (93%) Ca (95%), Mg (95%) and N (96%). In relation to bare soil, reduction of losses in the degraded pastures was observed for P (95%), K (95%), Ca (89%), Mg (93 %) and N (92%) and in the second P (38%), K (94%) Ca (74%), Mg (47%) and N (93%). Considering that the managed pasture received agricultural inputs, reduction of losses are even higher, although still lower when compared with the degraded system. Additionally, under this system, there will be probably a better chemical conditioning of the soil for plant growth, and therefore better maintenance of physical and environmental quality in the sub-watershed.

In the Argisol, nutrient losses followed the decreasing order N > Ca > K > Mg > P for most management systems (Table 3). The greatest nutrients losses were found in the native forest, which may be related to the amount of eroded sediment (Table 2). Moreover, when compared with the bare system, significant reduction of losses of P (76%), K (62%) Ca (69%), Mg (76%) and N (76%) were found in the reforestation system.

Table 3. Nutrients and organic matter losses in the soil under different management systems in the Posses sub-watershed, Extrema-MG.

Management systems	P	K	Ca	Mg	N	SOM
	$g\ ha^{-1}\ yr^{-1}$					
			Red-Yellow Argisol			
Bare soil	3.7	43.8	271.1	50.9	1.546.1	23.931.8
Subsistence farming	6.4	36.0	505.5	257.7	1.476.0	20.261.4
Degraded pasture	0.2	2.3	29.1	3.5	116.1	1.370.4
Well-managed pasture	2.3	2.6	70.2	26.9	110.9	1.091.2
Reforestation 2013	0.3	3.0	13.9	2.3	66.0	741.8
			Argisol			
Native forest	5.2	57.4	429.1	49.7	1.852.4	15.204.1
Reforestation 2008	1.0	18.6	103.7	14.1	357.0	4.453.4
Bare soil	4.2	49.2	331.5	58.8	1.492.8	21.303.2

Reforestation 2013: reforestation set up in 2013; Reforestation 2008: reforestation set up in 2008; SOM: soil organic matter.

There was tendency of SOM losses in PVA (bare soil > subsistence farming > degraded pasture > managed pasture > reforestation) and in Argisol (bare soil >native forest > reforestation) similar to that found for N (Table 3). The largest amount of SOM and N lost in the native forest in relation to the reforestation system may have been mainly influenced by soil loss (Table 2) and by their concentrations both in sediments and in the 0-5 cm layer (Table 3). The higher amount of organic matter in natural condition is due to the large amount of decomposing plant material in the soil (SANTOS et al., 2007); therefore, there is increased availability of other nutrients, such as N, when compared with other treatments.

SOM is one of the first constituent to be removed from the soil, due to its low density (SCHICK et al., 2000). Thus, there was greater proportion of SOM lost in the eroded sediment (Table 3) in comparison with other soil components, as confirmed by Silva et al. (2005) and Leite et al. (2009). However, unlike the mineral nutrients, it is not usually feasible the short term replacement of SOM (DECHEN et al., 2015), which makes it even more serious the effect of its loss to the agricultural and environmental sustainability. The replacement of this constituent is a complex process that depends not only on the quantity, but also on the quality of the organic material deposited in the soil, on the decomposition rate of this material, on the climate and soil texture, among other factors.

According to Cassol et al. (2002), nutrients and SOM losses increase with soil losses, while the runoff enrichment ratio (RER) tends to decrease; i.e., there is an inverse relationship between the amount of nutrient and SOM lost by erosion and RER. However, this relationship was not observed in this study (Table 2 and Table 4). This may have been due mainly to low erosivity observed for the first study period (check “Study Area”), which inhibited the manifestation of the “dilution effect” of the nutrient content in the sediment, which would have occurred if there had been high rates of soil lost by erosion.

Table 4. Chemical properties and runoff enrichment rate due to water erosion of soils under different management systems in the Posses sub-watershed, Extrema-MG.

Management systems	P	K	Ca	Mg	N	SOM
	------mg dm^{-3}------		----cmol$_c$ dm^{-3}----		g kg^{-1}	dag kg^{-1}
0-5 cm soil layer						
Red-Yellow Argisol						
Bare soil	2.58	80.33	1.12	0.45	2.97	3.51
Subsistence farming	3.73	83.33	1.55	0.80	2.90	3.13
Degraded pasture	4.37	118.33	1.32	0.63	3.75	4.81
Well-managed pasture	5.58	99.33	1.30	0.65	3.58	4.30
Reforestation 2013	3.88	81.67	1.07	0.40	3.88	6.49
Argisol						
Native Forest	3.34	169.33	4.13	1.00	5.10	4.55
Reforestation 2008	2.17	89.67	2.92	0.60	3.40	3.60
Bare soil	2.48	143.00	2.78	1.00	4.08	4.01
Runoff enrichment ratio						
Red-Yellow Argisol						
Bare soil	2.2	0.8	1.9	1.4	0.8	1.1
Subsistence farming	3.2	0.8	3.0	4.9	0.9	1.2
Degraded pasture	0.8	0.3	1.9	0.8	0.5	0.5
Well-managed pasture	7.1	0.4	4.6	5.8	0.5	0.4
Reforestation 2013	2.2	1.2	2.1	1.5	0.5	0.4
Argisol						
Native Forest	6.4	1.4	2.2	1.7	1.5	1.4
Reforestation 2008	2.5	1.2	1.0	1.1	0.6	0.7
Bare soil	4.2	0.9	1.5	1.2	0.9	1.3

Reforestation 2013: reforestation set up in 2013; Reforestation 2008: reforestation set up in 2008; SOM: soil organic matter.

In PVA, subsistence farming and managed pasture had the highest RER for SOM and all nutrients, except for K (Table 4). This may be related to fertilization and liming carried out in these systems, as observed by Souza et al. (2014). In bare systems, there was an increase of SOM and of most of the nutrients in the sediments (Table 4), except for K and N, which may be related mainly to the lack of protection that would be provided by vegetation cover. However, there was runoff enrichment in the native forest. This can be explained by the high rates of sediment, rich in nutrients and SOM (Table 3) lost in this system (Table 2).

By comparing the systems with the same type of cover, i.e., degraded pasture with managed pasture, and reforestation implemented in 2008 with that implanted in 2013, higher RER were generally obtained for the latter in both cases (Table 4). This fact suggests that fertilization in pre-installed systems, even if well managed, can increase nutrient losses. However, as noted by other authors (BEZERRA; CANTALICE, 2006; LIMA et al., 2014), it is expected that more developed are the crops, the more protected will be the soils, and the lesser will be the losses by water erosion.

Conclusions

Reforestation and pasture management are conservation strategies proven to minimize the amount of soil, water, nutrients and soil organic matter lost by erosion in the Posses sub-watershed, Extrema MG. The management has greater influence on losses of soil and of the materials related to it than on water losses. The maintenance of native forest under Argisol is essential for the conservation of this pedoenvironment, especially on steep slopes. A tendency of nutrients losses stabilization is observed with the implementation time in the reforestation and in the managed pasture. Since these results originated from only two study years, assessments on a larger time scale would help increase the consistency of the present results. However, in view of the urgent need to preserve natural resources in this pilot sub-watershed of the PSA program, results generated in this study serve as input to the improvement and viability of the management of Brazilian river basins.

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