MINIMUM CULTIVATION OF EUCALYPTUS, AND SOIL AND WATER LOSSES BY HYDRIC EROSION ON COASTAL PLAINS OF ARACRUZ (ES) REGION, BRAZIL

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Abstract
The constant reduction of soil productivity has been mainly attributed to hydric erosion and inadequate soil management. Very little information is available in Brazil concerning soil losses by hydric erosion in forest plantations. This study aims to evaluate the soil and water losses by hydric erosion in forest of eucalyptus production, under minimum cultivation, relating them to those observed in native forest, and to compare the soil losses with the tolerable limits for the main soils (Argisols or Ultisols and Plinthosols or Oxisols) of the Coastal Plains of Aracruz, Espirito Santo state, Brazil. Data from 1997 to 2002 is used. The climate of the region is Aw, with temperature and mean annual precipitation of 23°C and 1,400 mm/yr, respectively. The evaluation of soil and water losses was performed througt standard plots installed in the field with 12x24 m for the soil under eucalyptus and 4x12 m for the soil under native forest. The soil losses ranged from 0.0 to 3.2 ton/ha/year for native forest and eucalyptus in the steepest soil, respectively. In average terms, the soil losses ranged from 0.05 to 1.15 ton/ha/year. The water losses for different conditions ranged from 5.63 to 98.40 mm, corresponding to 0.5-8.75% of the total precipitation, respectively. Soil losses in the eucalyptus plots lay well below the calculated maximum tolerable soil losses in all soil classes (10-13 ton/ha/year), which indicates adequacy of management in this production system regarding hydric erosion. The fact that soil losses in eucalyptus were relatively close to those in native forest indicates the sustainability of the former environment regarding erosion.

Additional Keywords: hydric erosion, plantations forest, eucalyptus forest, native forest, soil and water losses

Introduction
The constant reduction of soil productivity has been mainly attributed to hydric erosion and inadequate soil management. Other aspect of great importance is that the accumulation of sediments originated from areas subjected to erosion promotes the silting up of rivers and lakes, harming the water quality and altering the aquatic life, mainly through the water eutrophization. The hydric erosion is one of the criteria to be considered when it is evaluated the sustainability of the soil environments under forest. The soil resistance to hydric erosion presents great amplitude due to the climatic variability, which influences the rain capacity in causing erosion, the soil classes variability with differential attributes, and management.

In Brazil, there are very few studies related to soil and water losses in forest systems, mainly in homogeneous eucalyptus systems, which have been expanded and occupy large areas, creating a gap in this knowledge area. The monitoring of soil losses by hydric erosion, in comparison with the established limits of tolerance losses, is fundamental for the adequate management of agricultural activities. The FAO admits losses around 12.5 ton/ha/year for deep, permeable and well drained soils, 2-4 ton/ha/year for shallow or impermeable soils, and for other soils losses intermediate to those limits. The evaluation of soil and water losses is of fundamental importance on choice and adoption of practices which aim to minimize the soil degradation.

In this way, this study has as objectives to evaluate the soil and water losses by hydric erosion in forest of eucalyptus production, under minimum cultivation, relating them to those observed in native forest, and to compare the soil losses with the tolerable limits for the main soils of the Coastal Plains of Aracruz, Espirito Santo state, Brazil.

Materials and Methods
The study was out in a 286.12 ha hydrographic small watershed and in experimental areas of Aracruz Celulose S.A., at Aracruz (ES) county. Data of soil and water losses during January 1997 to December 2002 period were obtained. The climate of the region is Aw, by according to Köppen classification, with temperature and mean annual precipitation of 23°C and 1,400.0 mm/yr, respectively. The region where the research unity is included is located between 19°35’ and 20°15’ latitude south and 40°00’ and 40°20’ longitude west. In the study period, the

precipitation ranged from 901 to 1,342 mm, data collected in automatic climatic stations. The experiment was installed in the main soil classes existing in the region, originated from sediments of Barreiras Formation, as follows: medium/clayey texture Yellow Argisol (PA1), Haplic Plinthosol (FX), and moderately rocky Yellow Argisol (PA8). The treatments were soil under eucalyptus cultivation and soil under native forest. The soil preparation for implantation of eucalyptus plantation was the minimum cultivation, with 30x30x30 cm manual pits. The evaluation of soil and water losses was performed through standard plots installed in the field with 12x24 m for the soil under eucalyptus and 4x12 m for the soil under native forest. The higher dimension followed the slope sense, being selected areas with the maximum characteristic slope of each studied soil class (Table 1). The samplings were performed at each rain event considered to be erosive. For the erosivity calculation, pluviometric data from January 1997 to December 2002 obtained in automatic climatic stations was used, generating data at 5 minutes intervals. From the precipitation data, it were calculated the total kinetic energies of the rains for each event. The EI_{30} index was obtained from the product of the total kinetic energy (E) of an erosive rain by the maximum intensity occurred in a consecutive 30 minutes period (I_{30}). The soil samples for physical and chemical analyses were collected at various depths, with three replications. The soil permeability was evaluated in the field, using the Guelph permeameter.

Table 1. Maximum slope and relief class for the different soils and covers studied.

Soil	Cover	Maximum Slope (%)	Relief Class
PA1	eucalyptus	1.8	Plain
	Native Forest	8.2	Undulated
FX	eucalyptus	1.3	Plain
	Native Forest	12.4	Undulated
PA8	eucalyptus	28.8	Strongly Undulated
	Native Forest	35.5	Strongly Undulated

For the calculation of value of soil losses tolerance it were utilized data from representative soil profiles of the region and complemented with field observations and measurements. The method takes into consideration the soil effective depth, the textural relation among superficial and subsuperficial horizons, the permeability and organic matter amount. For every profile studied, it was calculated the thickness of soil layer, in meters, possible to be removed without harming the environment (Martins, 2001; Martins *et al.* 2003).

Results and Discussion

The total annual and average soil losses can be observed in Table 2. The observed variability among the study years, for the different conditions, can be attributed to the non-homogeneous rain distribution during the studied years, since the soil losses are reflex, among other factors, of rain intensity and its physical characteristics. The erosivity values ranged from 8,817 to 4,635 MJ mm/ha/h/year for the study years, presenting an average value of 6,969.5 MJ mm/ha/h/year (Table 2). In general, it was observed that was more common high erosivity rains producing higher soil losses. Situations different from these ones were also observed and are probably related to the variability of soil antecedent moisture degree when the rains occurred.

The soil losses ranged from 0.0 to 3.2 ton/ha/year for native forest and eucalyptus in PA8 soil, respectively. In average terms, the soil losses ranged from 0.05 to 1.15 ton/ha/year Table 2). The smaller losses were observed for the native forest, independently of soil and relief, what can be explained by the following aspects: (a) interception of rain drops by native forest dossel, which presents a very diversified vertical extract, resulting in higher soil protection; (b) existence of a richer leaf layer on the ground; and (c) higher organic matter amounts (Table 3), inducing higher stability aggregates and, as consequences, better structure and higher permeability (Table 3).

Table 2. Soil losses by hydric erosion for eucalyptus and native forest.

Soil	Year	Soil Losses (ton/ha/year)		Precipitation	Erosivity
		Eucalyptus	Native Forest	mm	MJ mm/ha/h/ year
PA1	1997	0.69	0.07	1,123.0	7,358.0
	1998	3.07	0.11	1,173.0	8,081.0
	1999	0.93	0.04	1,074.0	6,635.0
	2000	0.29	0.08	1,331.0	4,635.0
	2001	0.20	0.04	1,342.0	8,817.0
	2002	0.03	0.03	901.4	6,290.0
	Mean	0.86	0.06	1,124.0	6,969.5
	SD[1]	1.13	0.03	143.0	1,471.0
	CV%[2]	131	50	12.7	21.0
FX	1997	1.77	0.06	1,123.0	7,358.0
	1998	2.10	0.07	1,173.0	8,081.0
	1999	0.58	0.04	1,074.0	6,635.0
	2000	0.21	0.08	1,331.0	4,635.0
	2001	0.10	0.05	1,342.0	8,817.0
	2002	0.01	0.01	901.4.0	6,290.0
	Mean	0.91	0.05	1,124.0	6,969.5
	SD[1]	0.79	0.03	143.0	1,471.0
	CV%[2]	87.36	52.94	12.7	21.0
PA8	1997	3.20	0.15	1,123.0	7,358.0
	1998	0.32	0.21	1,173.0	8,081.0
	1999	2.38	0.10	1,074.0	6,635.0
	2000	1.52	0.06	1,131.0	4,635.0
	2001	0.28	0.01	1,342.0	8,817.0
	2002	0.04	0.00	901.4	6,290.0
	Mean	1.15	0.09	1,124.0	6,969.5
	SD[1]	1.23	0.08	143.0	1,471.0
	CV%[2]	106.0	90.9	12.7	21.0

[1]SD: Standard deviation; [2]CV: Coefficient of variation.

Table 3. Soil quality indicators related to hydric erosion.

Soil	Cover	Bulk Density	Permeability	Organic matter
		------g cm^{-3}------	------mm h^{-1}-----	------g kg^{-1}-----
PA1	Eucalyptus	1.52	4.31	20.0
	Native Forest	1.52	15.83	41.0
FX	Eucalyptus	1.47	6.57	22.0
	Native Forest	1.24	35.35	31.0
PA8	Eucalyptus	1.52	19.53	22,0
	Native Forest	1.27	53.03	32.5

Under both covers, in almost all cases, the PA8 soil presented higher soil losses (Table 2), mainly because it is in a more undulated relief position, with slopes ranging from 28.8 to 35.5% (Table 1), favoring runoff and, consequently, higher removal of soil particles. Beyond this aspect, the PA8 soil has the sandiest texture in the superficial layer, inducing smaller particles cohesion and favoring the erosive processes. The soil losses for the PA1 and FX soils were close, being the relatively higher ones observed for the PA1 soil, which are probably related to its summit position in the landscape, compared with the FX soil, which occurs in gentle concave sites distributed within PA1 soil areas.

Very few information are available in Brazil concerning soil losses by hydria erosion in forest plantations. This work shows values (0.0 to 3.20 ton/ha/year) (Table 2) much lower than the tolerable limits for the soils region, which are 10, 13 and 11 ton/ha/year for the PA1, FX and PA8 soils, respectively, indicating the adequacy of management of this production system in relation to hydric erosion. The presence of underwood helps to explain these data. The soil losses should decrease for the eucalyptus as time passes by, as indicated by the trends observed from the 3rd to the 6th year after planting (Table 2). The average precipitation for this study period was 1,124.0 mm, somewhat lower than the mean annual precipitation for the region (1,400.0 mm). The water losses for the different conditions (Table 4) ranged from 5.63 to 98.40mm, corresponding to 0.5-8,75% of the annual total precipitation,

respectively. The water losses trend was the following: PA1>PA8>FX soils. The native forest had smaller losses of water for all soils.

Table 4. Water losses values for eucalyptus and native forest.

Soil	Year	Water losses (mm/yr)	
		Eucalyptus	Native Forest
PA1	1997	21.83	7.15
	1998	47.79	5.63
	1999	22.11	16.14
	2000	94.30	52.60
	2001	4.99	60.90
	2002	22.03	19.60
	Mean	35.51	27.00
	SD[1]	31.90	23.78
	CV%[2]	89.00	88.00
FX	1997	9.59	9.09
	1998	47.22	8.17
	1999	27.52	10.55
	2000	37.14	52.80
	2001	18.69	42.10
	2002	19.62	15.70
	Mean	26.63	23.00
	SD[1]	13.70	19.36
	CV%[2]	51.00	84.00
PA8	1997	23.35	6.68
	1998	46.27	5.76
	1999	25.13	62.09
	2000	98.40	31.00
	2001	23.50	31.00
	2002	21.40	16.80
	Mean	39.70	25.50
	SD[1]	30.20	21.06
	CV%[2]	76.00	82.00

[1]SD: Standard deviation; [2]CV: Coefficient of variation.

Conclusions

Soil losses in the eucalyptus plots lay well below the calculated maximum tolerable soil losses in all soil classes which indicates adequacy of management in this production system regarding hydric erosion. The fact that soil losses in eucalyptus were relatively close to those in native forest indicates the sustainability of the former environment regarding erosion.

References

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