Soil Erosion and Nutrient Losses in Highly Degraded Soils (Oxisols) of the Eastern Savannas of Colombia

J. J. Ramírez-Avila[1], E. F. Almansa-Manrique[2], S. L. Ortega-Achury[3]

[1]Geosystems Research Institute, Mississippi State University, Mississippi State, MS

[2]Corporacion Colombiana de Investigacion Agropecuaria (CORPOICA), Villavicencio, Colombia

[3]Civil and Environmental Engineering Department, Mississippi State University, Mississippi State, MS

Introduction

The Eastern Savannas of Colombia, better known as the Colombian Orinoquia (4.5 ha - 15% of the entire Colombian extension), is an extensive area of flat high plains lying northeast of the Eastern Cordillera of the Colombian Andes (Fig 1.).

Currently underused on extensive livestock production on low quality native savanna pastures (Fig. 2).

High potential for agricultural and animal production in tropical areas as the soils (Oxisols and Ultisols) have acceptable physical, chemical and biological properties, but productive and sustainable only if appropriately managed.

Productivity and sustainability would be significantly affected by the predominant conditions of strong rainfall seasonality and high soil susceptibility and vulnerability to erosion and fertility losses.

Soil erosion rates along the native Eastern Savannas are relatively low to moderate. Establishment of continuous agricultural exploitation on these areas, soil erosion and nutriment losses could be extremely high.

The main goal of the study was to identify the potential effect caused by water erosion on the productivity of soils on the Eastern Savannas of Colombia.

Fig. 1. The Eastern Savannas of Colombia

Fig. 2. Extensive livestock production along the Eastern Savannas of Colombia

Materials and Methods

The study was carried out at the "La Libertad" Research Center of the Colombian Corporation of Agricultural Research (CORPOICA) near Villavicencio, Meta in Colombia during four years.

The experimental site had an altitude of 336 m (amsl) along the Alluvial Plain of Piedmont Agro-ecological zone with slopes ranging from 1% to 4%.

Erosion plots of 50 m^2 were established on a well drained soil taxonomically classified as Tropeptic Haplorthox.

Two different substudies with randomized blocks experimental design (3 treatments, 3 repetitions) were carried out.

First substudy evaluated susceptibility of soils to land use changes: bare soil, pastures (*Brachiaria decumbens*) and crop rotation (Rice, Soybean).

Second substudy evaluated effects of three different tillage practices: conventional (2 drag), reduced (1 vibratory chisel and 1 rigid chisel), and non-tillage.

Soil losses, suspended sediment concentrations, and runoff depth were quantified after each rainfall event.

Organic matter and nutrient losses (Ca, Mg, K, B, Mn, and P) on soil eroded were quantified.

Weather conditions were continuously monitored in site.

Results

Substudy 1

Mean annual runoff depth on bare soil plots (553 mm) represented 20% of the mean annual precipitation depth (2712 mm).

Pastures (*Brachiaria decumbens*) and rotational crops had an average runoff depth of about 41 mm and 324 mm, respectively.

Comparison of annual depths of runoff and soil loss showed significant differences (α=0.05) between bare soil and grass plots (Table 1 and Figs. 3 and 4).

Average soil losses from rice and soybean plots were 15 Mg ha-1 and 8 Mg ha^{-1}, respectively, while soil erosion from corn plots in the first semester of 1998 were 5.2 Mg ha^{-1} (Table 2).

In general, semester soil losses from crop rotational plots were significantly higher than plots under grass cover (Table 2).

Average annual rates of soil loss were 96.4 Mg ha^{-1}, 2.3 Mg ha^{-1} and 19.7 Mg ha^{-1} for bare soil, grassed and crop rotation plots, respectively. Annual rates of soil loss were determined from 0.1 Mg ha^{-1} to 75.6 Mg ha^{-1} during the four years of study.

Soybean and Corn yield were significantly affected by the occurrence of the "El Niño" phenomenon during the second semester of the second year and the first semester of the third year (Table 3).

A trend toward the reduction of yields in time was observed on both established crops.

Table 1. Semester runoff depth for an Oxisol of the Eastern Savannas in Colombia under three different conditions of land use

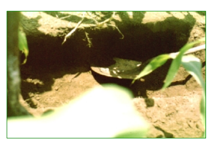
Treatment	Runoff depth (mm)							
	1 - 1	2 - 1	1 - 2	2 - 2	1 - 3	2 - 3	1 - 4	2 - 4
Bare soil*	362.4^a	439.7^a	200.9^a	226.4^a	214.4^a	174.0^a	324.2^a	270.0^a
Grass	33.5^b	122.2^b	11.2^b	23.1^b	27.7^b	15.6^b	34.2^b	10.2^b
Crop Rotation	-	-	Rice 138.2^a	Soybean 106.0^a	Corn 184.0^a	Soybean 99.7^{ab}	Rice 228.0^a	Soybean 105.8^b

Table 2. Semester erosion rate for an Oxisol of the Eastern Savannas in Colombia under three different conditions of land use

Treatment	Soil Loss (Mg ha^{-1}) Sem - Yr							
	1 - 1	2 - 1	1 - 2	2 - 2	1 - 3	2 - 3	1 - 4	2 - 4
Bare soil*	50.4^a	75.6^a	42.1^a	59.1^a	52.3^a	22.7^a	46.2^a	37.3^a
Grass	1.3^b	3.0^b	1.6^c	0.2^b	0.6^b	1.1^b	0.6^b	0.1^b
Crop Rotation	17.6^b	34.0^b	Rice 18.5^b	Soybean 17.2^b	Corn 5.2^b	Soybean 4.4^b	Rice 11.0^b	Soybean 2.9^b

Table 3. Observed effects on rice and soybean crop yields in soils of the Eastern Savannas of Colombia

Year	Yield (Mg ha^{-1})	
	Rice	Soybean
Year 1	4.61 a	1.42 a
Year 2	-	0.97 b
Year 3	4.00 b	0.83 b
Year 4	2.44 c	-



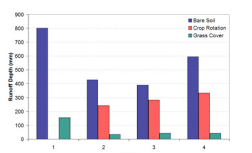


Fig. 3. Annual runoff depth for an Oxisol of the Eastern Savannas in Colombia under three different conditions of land use

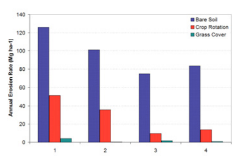


Fig. 4. Annual soil loss for an Oxisol of the Eastern Savannas in Colombia under three different conditions of land use

Substudy 2

The reduced tillage treatment (chisels) plots presented the higher average of soil erosion during an entire crop rotation cycle (3.75 Mg ha^{-1}).

Crop rotations under conventional tillage (drag) presented an erosion rate of 3.18 Mg ha^{-1}, while the non-tillage practice yielded 3.02 Mg ha^{-1} of soil erosion.

Runoff depth presented similar trends than the observed for soil erosion (Figs. 5 and 6).

Soil eroded from non-tillage plots presented the higher concentrations of organic matter and nutrients (Table 4).

Rice yield was not significantly different between tillage methods, however the conventional tillage presented the lower yields (Figs. 7 and 8).

Soybean and Corn yield were significantly affected by the occurrence of the "El Niño" phenomenon during the second semester of the second year and the first semester of the third year.

The highest soybean yield was observed under reduced tillage and the lowest under non-tillage plots.

A trend towards the reduction of crop productivity was observed for both semester crops (rice soybean) under all three tillage methods (Fig. 9).

Table 4. Nutrient losses in soil eroded from an Oxisol under three different tillage systems

	Conventional	Reduced	Non-tillage
OM (%)	3.1	3.2	3.6
P (ppm)	35	32.1	52.3
Mn (ppm)	15.3	19.1	24.2
Ca (meq/100 g)	1.25	1.57	2.48
Mg (meq/100 g)	0.4	0.5	0.7
K (meq/100 g)	0.3	0.32	0.33

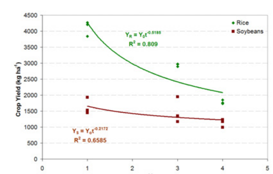


Fig. 9. Reduction in rice and soybean crop yields under three different tillage methods in soils of the Eastern Savannas of Colombia

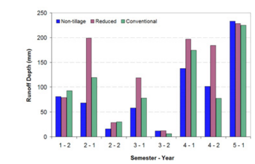


Fig. 5. Annual runoff depth for an Oxisol of the Eastern Savannas in Colombia under three different tillage systems

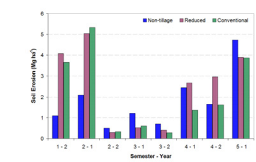


Fig. 6. Annual soil loss for an Oxisol of the Eastern Savannas in Colombia under three different tillage systems

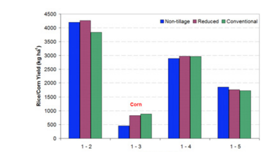


Fig. 7. Rice/Corn yield under three different tillage systems on an Oxisol of the Eastern Savannas in Colombia

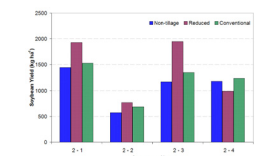


Fig. 8. Soybean yield under three different tillage systems on an Oxisol of the Eastern Savannas in Colombia

Conclusions

Assessment of soil erosion rates on the Eastern Savannas of Colombia evidenced a potential risk of accelerating degradation processes on these soils by changing natural or current land use conditions to intensive agricultural production.

Continuous agricultural production under conventional practices decreased soil productivity. Development of new management practices are required to guarantee agricultural sustainability.