Soil and nutrient loss under different vegetation covers in the Andean region in Colombia

Pérdidas de suelo y nutrientes bajo diferentes coberturas vegetales en la zona Andina de Colombia

J. Alexander Rodríguez[1], Isabel Cristina Sepúlveda[1], Juan C. Camargo García[1] y Jesús H. Galvis Quintero[2]

[1]Facultad de Ciencias Ambientales, Universidad Tecnológica de Pereira, Colombia. pauloalejo@yahoo.com,

[2] International Center for Tropical Agriculture – CIAT. j.h.galvis@cgiar.org

Rec. Acep.

Abstract

Soil and nutrient (calcium, magnesium, potassium, phosphorus) losses were measured over a 7-month period in the El Ciprés Natural Reserve, located in the Bellavista rural community, municipality of El Dovio, in the western cordillera of the Andes of the department of Valle del Cauca, Colombia. At 1700-1800 meters above sea level, the area presents an average temperature of 18 °C, an average annual precipitation of 2500-2700 mm, 90% relative humidity, and a 62% slope. According to the Holdridge climate classification system, it corresponds to a lower montane rain forest. Measurements were taken in runoff plots, each 32 m^2, with seven types of vegetation cover: giant bamboo (*Guadua angustifolia* Kunth); secondary forest; pastures (*Brachiaria decumbens*); coffee (*Coffea arabica); p*rotein bank (*Trichanthera gigantea*); forage cane (*Saccharum officinarum*), and a clean crop formed by cassava (*Manihot esculenta*), maize (*Zea mays*), and arracacha (*Arracacia zanthorrhiza* Brancroft). Results showed differences ($P < 0.05$) between the different types of vegetation cover. The greatest loss of soil and nutrients occurred in clean crops (2.61 t/ha) and the lowest in giant bamboo (0.08 t/ha). These results suggest the advantages of conserving giant bamboo forests in this part of Colombia. Not only do they contribute to soil conservation and maintenance of fertility, but they are a complementary economic alternative for rural producers.

Key words: Soil, erosion, cover plants, nutritional loss, soil conservation, Andean zone, Colombia.

Resumen

El estudio se realizó en la reserva natural El Ciprés, ubicada en la vereda Bellavista, municipio de El Dovio (Valle del Cauca). La vereda se encuentra en la zona Andina de la cordillera

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[1] Respectively: Environmental Administrator and M.Sc. student, Ecotechnology; Environmental administrator, Ph.D. Forest Science; y Associate Professor, Faculty of Environmental Sciences, Universidad Tecnológica de Pereira.

[2] MSc. Agricultural Science, Research Assistant, CIAT.

occidental, en el departamento del Valle del Cauca, entre 1700 y 1800 m.s.n.m., con una temperatura promedio de 18 °C. Según la clasificación climática de Holdridge, corresponde a una zona de bosque húmedo Montano Bajo, con una precipitación promedio entre 2500 y 2700 mm/año, una humedad relativa de 90% y una pendiente del suelo de 62%. Las mediciones se hicieron en parcelas de escorrentía de 32 m^2 cada una y siete tipos de coberturas: guadua (*Guadua angustifolia* Kunth), bosque secundario, pastura (*Brachiaria decumbens*), café (*Coffea arabica*); banco de proteína (*Trichanthera gigantea*), caña forrajera (*Saccharum officinarum*) y cultivo limpio conformado por yuca (*Manihot esculenta*), maíz (*Zea mays*) y arracacha (*Arracacia zanthorrhiza Brancroft*). Para la evaluación se midieron las pérdidas de suelo y los nutrientes calcio, magnesio, potasio y fósforo en un periodo de 7 meses. Los resultados mostraron diferencias ($P < 0.05$) entre las coberturas evaluadas. Las pérdidas más altas de suelo y nutrientes ocurrieron bajo cultivos limpios (2.61 t/ha) y las más bajas en guadua (0.08 t/ha). Estos resultados sugieren ventajas de los bosques de guadua en esta zona de Colombia, ya que además de contribuir a la conservación de los suelos y al mantenimiento de la fertilidad, es una alternativa económica complementaria para los productores rurales a partir de su manejo y aprovechamiento.

Palabras clave: Suelo, erosión, *Guadua angustifolia*, plantas de cobertura, pérdidas nutritivas, nutrientes, conservación de suelos, zona Andina, Colombia.

Introduction

According to the Geographical Institute Agustin Codazzi, worrying levels of soil degradation are seen in Colombia (IGAC, 1998). Soil loss is of the order of 170,000 to 200,000 t/ha per year. Close to 56 million hectares are affected by erosion, and of these 60% are located in the Andean region (Rivera & Gómez, 1991). In the coffee growing region, the traditional coffee crop has been replaced with other vegetation cover, mainly treeless pasture with conventional management, and crops such as citric fruits, cassava and plantain (Mette, 2001). This conversion has increased the deterioration of resources associated with the young soils found on long, steep slopes (greater than 70%), in particular as a consequence of their high susceptibility to erosion under abundant high intensity precipitation events (Rivera & Gómez, 1991). These events directly influence the hydraulic erosion, and the contamination of water sources with increased sediment and leached nutrients.

In the face of such a situation, it is necessary to find alternative vegetation covers that bring economical as well as ecological benefits. Some species are already considered potential alternatives for the Andean region of Colombia, being important generators of additional benefits, such as soil conservation, biodiversity conservation, and protectors of water quality and abundance (Giraldo & Sabogal, 1999; Londoño et al., 2002; Gritsch et al., 2004; García, 2004; Held, 2005; Camargo, 2006). Nevertheless, a deeper understanding of these natural resources would provide greater support to management decisions amongst the productive systems that are promoted.

This study assessed the benefits for soil protection against runoff losses of the following different vegetation cover: giant bamboo (*Guadua angustifolia* Kunth); secondary forest (the result of natural succession); pastures (*Brachiaria decumbens*); coffee (*Coffea arabica*); and a clean crop formed by cassava (*Manihot esculenta*), maize (*Zea mays*), and arracacha (*Arracacia zanthorrhiza* Brancroft); a protein bank (*Trichanthera gigantea*); and forage cane (*Saccharum officinarum*).

Materials and methods

Study Area. The study area was located in the El Ciprés Nature Reserve, in the rural community of Bellavista, municipality of El Dovio (Department of Valle del Cauca). The community is located on the Western cordillera of the Andes between 1700 and 1800 m.a.s.l., with a mean temperature of 18 °C. According to the Holdridge life zone classification, the site corresponds to low humid montane forest, with a precipitation of between 2500 and 2700 mm/year and a relative humidity of 90%. This area was selected taking into account the potential to find distinct use and soil coverage within a single productive unit, and under similar ecological conditions.

Soil and nutrient losses. To estimate the soil and nutrient losses, three erosion plots were established in each of the different use and vegetation cover categories evaluated. The plots were designed following Hernández et al. (1995) with modifications, so that each one measured 8 m x 4 m (32 m^2), and were located on homogenous slopes of 62% within each of the land use and vegetation cover categories.

Each plot consisted of a sediment trap at the bottom, covered with a polypropylene fiber cloth to filter the runoff water, and separate the sediments. Each plot was enclosed along its borders with strips of bamboo matting covered in black plastic to prevent soil adhesion to the separated material. Plastic was used to prevent runoff bringing sediments from outside the plot. Total soil loss through hydraulic erosion, and nutrient loss through leaching were determined from the soil collected in the traps.

The analysis of nutrients in collected soils was carried out in the Analysis laboratory for Soils and Foliage at the Universidad Tecnológica de Pereira. Organic material content was determined using the photometric method of Walkley-Black, the pH with a potentiometer, the calcium (Ca), magnesium (Mg) and potassium (K) using atomic absorption with ammonium acetate and phosphorus (P) using the Bray II photometric method.

Analysis of results. Differences in soil and nutrient loss between evaluated treatments were determined using the non-parametric test of Kruskall-Wallis. This test was used as the

evaluated sites were not selected randomly, and so the conditions for an analysis of variance were not met. Analyses were carried out using the software SPSS 8.0 for Windows.

Results and discussion

Soil loss. The greatest loss of soil over the study period occurred in the clean crop with 2.61 ± 0.9 t/ha, with the least loss in the giant bamboo 0.08 ± 0.07 t/ha ($P < 0.05$) (Figure 1). These values coincide with the results obtained by León (2000) who found an annual soil loss of 0.7 t/ha in areas with slopes between 12% and 25%. The high losses incurred under the clean cultivation practices are associated with the minimal cover, and deficient soil management practices, which, although performed manually, weaken the soil structure, thus increasing its susceptibility to erosion. The impact of raindrops falling on bare soil damages the aggregates, causing structure deterioration (Stallings, 1962, Pla, 1993; Galvis et al., 2005), which increases the infiltration of water, runoff, particle removal, and eventually results in the formation of gullies.

It is important to note that the original soil with giant bamboo and forest cover has a good aggregate structural stability, as it is not subjected to disturbance, and has received a high incorporation of vegetation material ('mulch'). With giant bamboo cover, various factors may contribute to improving the soil properties. These include the accumulation of mulch, which, in some cases, may reach 9 t/ha per year, contributing to soil conservation, reducing the energy of raindrops, and favoring the decomposition of organic material, with the consequent formation of aggregates (De Wilde, 1994). According to Sánchez (1981) mulch protects the soil from high temperature, increases water storage, and prevents runoff and erosion. Thus, it is important to highlight the inverse relationship that exists between soil loss and soil structural stability.

During the evaluation period, three levels of soil loss were observed: (1) those covers with the least loss (< 0.1 t/ha per month), comprising giant bamboo, forest and pasture; (2) Cane, coffee and protein bank crops, with soil losses between 0.1 and 0.6 t/ha per month. Amongst these cases, soil loss in the protein bank was notable in having peaks of loss associated with crop management activities, such as pruning to obtain cattle forage; and (3) the clean cultivations with the highest levels of soil loss (between 0.2 and 0.9 t/ha) (Figure 2). It is important to note that both the protein bank and the clean crops regularly received 1 kg of vermicompost that was not incorporated into the soil, and could have increased the soil loss values in these cases.

Figure 2 shows the fluctuations between soil loss and precipitation, with the loss

between August and October, when precipitation was greatest, being notable.

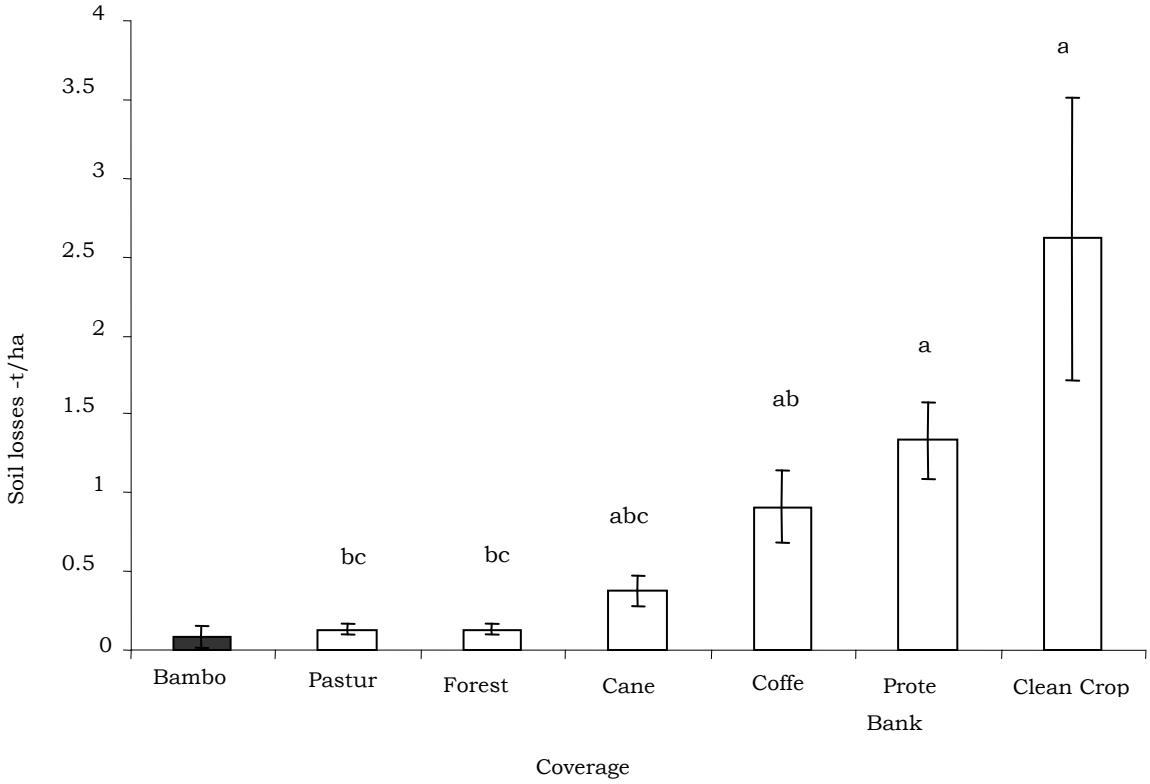

Figure 1. Soil losses (t/ha) under distinct vegetation cover over a period of & months in the El Ciprés Nature Reserve. Vertical lines represent standard deviation. Means with the same letters are not significantly different ($P < 0.05$).

Nutrient loss. Amongst all the coverage treatments, the giant bamboo presented the lowest loss, while the clean crop and the protein bank presented the highest ($P < 0.05$). Losses of organic material varied between 0.06 and 2.26 kg/ha, which is approximately equivalent to total nitrogen loss of 0.002 to 0.09 kg/ha. Amongst the nutrients, calcium showed the highest loss at 1 to 25 kg/ha (Box 1).

The loss of soil nutrients and organic material has direct effects on its productivity, although this may be ameliorated in part through fertilization. In contrast, degradation of soil physical properties is irreversible (Ruppenthal, 1995). Soil nutrient content depends upon the recycling of these nutrients in the system through rainfall, fertilization and symbiotic fixation (Alpízar, 1985). Processes that extract nutrients from the system include leaching towards the freatic layer, the absorption by plants, and erosion (León, 2000).

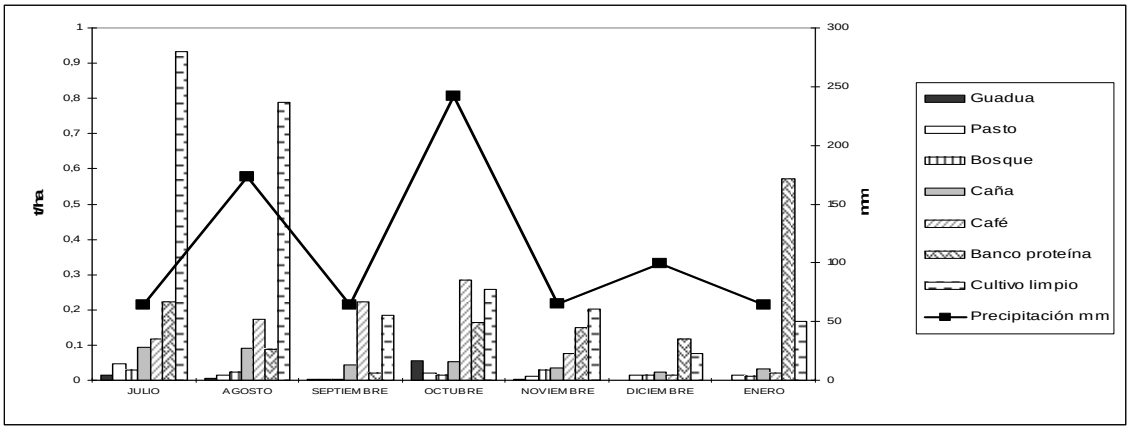

Figure 2. Monthly soil loss (t/ha) under distinct soil and vegetation cover, and rainfall distribution (mm) for the experimental period. El Ciprés Nature Reserve, El Dovio, Valle del Cauca.

Clave:
Guadua = Bamboo
Pasto = pasture
Bosque = forest
Caña = cane
Café = coffee
Banco proteina = protein bank
Cultivo limpio = clean crop
Precipitación mm – rainfall mm

In the present study the relationship between nutrient loss and total soil content shows that giant bamboo presented the lowest losses of between 0.01% and 0.2% (Box 2), except for phosphorus which presented a loss of 37.8%, although this was the lowest registered amongst all the covers. The greatest losses occurred in the plots with protein bank (between 0.5% and 7%). Phosphorus losses varied between 38% and 544%, being greatest in the organic coffee, and lowest in the giant bamboo, followed by forest and pasture, which were not significantly different ($P < 0.05\%$). These losses are proportionate to the amount of soil lost in each type of coverage.

Stallings (1962) considered that losses of soil and macro and micro nutritive elements is related to the amount of vegetation cover, as without this, it is difficult to maintain the organic material content in the soil, and impossible to avoid the loss of nutritive elements.

In forested areas a high accumulation of organic material occurs in the A horizon, as a result of the recycling of leaves and tree roots. This protective coverage conserves organic material content, and reduces the soil temperature (Sánchez, 1981), thus explaining the lesser

loss of nutritive elements and organi mterial under forest and giant bamboo. However, a good vegetation cover does not guarantee a reduction on soil and nutrient loss through erosion, as evidenced by the protein bank being the coverage type with the second highest levels of soil loss. For this reason, the management of this type of crop must be appropriate, minimising the area of pruning and also limiting pruning to the dry seasons.

Box 1. Means of losses of organic material and nutrients in different systems of vegetation cover. El Ciprés Nature Reserve, El Dovio, Valle del Cauca.

Coverage	Losses (kg/ha)					
	MO	Ca	Mg	P	N	K
Bamboo	0.061b*	1.04 ab	0.126	0.013 a	0.002 b	0.22ab
S.D.	0.026	0.96	0.129	0.006	0.001	0.002
Forest	0.172 b	2.03 c	0.213	0.04 a	0.006 b	0.8 ab
S.D.	0.069	0.7	0.072	0.023	0.002	0.263
Pasture	0.147b	1.39 bc	0.185	0.013 a	0.006 b	0.236 b
S.D.	0.047	0.66	0.060	0.001	0.002	0.046
Clean crop	2.259 b	25.21 bc	3.284	0.13 a	0.090 b	4.826 b
S.D.	0.557	6.14	1.097	0.04	0.025	0.697
Protein Bank	1.84 a	19.86 ab	2.160	0.6 b	0.071 a	7.165 b
S.D.	0.525	4.64	0.596	0.135	0.017	2.152
Cane	0.436[a]	4.26 ab	0.530	0.08 a	0.017 a	0.944 b
S.D.	0.169	0.707	0.156	0.012	0.007	0.273
Coffee	0.72 ab	9.17 a	0.989	0.28 a	0.033 ab	2.677 b
S.D.	0.086	2.937	0.299	0.228	0.006	0.527

S.D. – standard deviation

* Means with the same letter are not significantly different (P < 0.05).

Box 2. Total nutrients in the soil, and nutrient losses over 7 months in the El Ciprés Nature Reserve, El Dovio, Valle del Cauca (in kg/ha).

Coverage	Measure	O.M.	N	K	Ca	Mg	P
Bamboo	TS	420.87	1.28	627.32	4048.69	731.13	0.03
	PS	0.061	0.002	0.21	1.04	0.13	0.01
	%	0.01	0.19	0.03	0.03	0.02	37.80
Forest	TS	547.55	1.95	485.16	5733.54	817.20	0.03
	PS	0.17	0.01	0.80	2.03	0.21	0.04
	%	0.03	0.31	0.17	0.04	0.03	144.55
Pasture (*B. decumbens*)	TS	463.17	1.36	210.57	4970.11	784.78	0.03
	PS	0.15	0.01	0.24	1.39	0.19	0.01
	%	0.03	0.42	0.11	0.03	0.02	48.17
Clean crop	TS	605.60	1.77	805.77	5158.99	918.00	0.03
	PS	2.26	0.09	4.83	25.21	3.28	0.13
	%	0.37	5.10	0.60	0.49	0.36	388.82

Protein Bank	TS	462.24	1.09	1591.82	6650.75	1060.26	1.00
	PS	1.840	0.071	7.17	19.86	2.16	0.60
	%	0.40	6.51	0.45	0.30	0.20	59.81
Cane	TS	395.98	1.04	435.37	3883.39	681.94	0.04
	PS	0.44	0.02	0.94	4.26	0.53	0.07
	%	0.11	1.68	0.22	0.11	0.08	207.97
Coffee	TS	477.76	1.09	676.90	4855.82	807.47	0.05
	PS	0.72	0.03	2.68	9.17	0.99	0.28
	%	0.15	2.97	0.40	0.19	0.12	543.56

TS = Total content (kg/ha). PS = Loss in the soil (kg/ha). % = PS/PT x 100.

Conclusions

- Soil losses found under the different coverage types evaluated in this study may be considered low, when compared with the results of similar studies in tropical regions.
- Coverage with giant bamboo, pasture or forest had the lowest losses of soil and nutrients.
- The protein bank, despite being an important source of nutrients for cattle, presented a high soil loss through runoff, and so its strategic management should be seasonal.
- Given the complexity of the erosion processes in the soils of the Andean region and the high number of constituent variables, further study should be aimed at the identification of conservation alternatives using coverage that minimizes erosion.

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