Erosion and nutrient loss reduction with an alternative planting method for coffee *(Coffea arabica)*[1,2]

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ABSTRACT

Coffee *(Coffea arabica)* planting in the interior mountainous region of Puerto Rico is usually performed on steep slopes after vegetation removal. The construction of individual terraces around the tree, such as the "Media Luna" planting method, prior to planting could reduce sediment and nutrient losses and could increase yields by improved on-site water and nutrient retention. Experiments were conducted to test the hypothesis that the "Media Luna" planting technique could reduce sediment, total phosphorus (TP), and total Kjeldahl nitrogen (TKN) in runoff during and after the establishment of a coffee plantation in Puerto Rico. The experiments were conducted on a commercial farm where the predominating soils were Múcara (Dystric Eutrudepts) in Phase 1, and Humatas (Typic Haplohumults) in Phase 2. In Phase 1 (recent plantings), sediment and nutrient runoff losses were similar in the conventional countour planting method and in the "Media Luna" treatments. Nutrient concentrations in runoff increased in events following fertilization. Recently loosened unconsolidated sediment material in the "Media Luna" treatment may be more susceptible to losses during the initial establishment phase. In phase 2 (mature plantings), sediment and nutrient losses were greater from soils planted with the conventional contour planting method than from those with the "Media Luna" treatment. The lower TP concentrations measured during Phase 2 suggests that the "Media Luna" technique could be a beneficial practice for coffee production in some areas of Puerto Rico.

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Key words: coffee, *Coffea arabica*, erosion control, nutrients in runoff, planting methods, individual terrace

RESUMEN

Una alternativa de siembra para el control de erosión y nutrientes en café *(Coffea arabica)*

La siembra de café *(Coffea arabica)* en la zona montañosa del interior de Puerto Rico usualmente ocurre en grandes pendientes luego de que se remueve la vegetación aérea y la capa vegetativa del suelo. La construcción de terrazas individuales alrededor de los árboles previo a la siembra, como por ejemplo el método de "Media Luna", podría reducir las pérdidas de sedimento y nutrientes y aumentar los rendimientos al mejorar la retención de humedad del suelo y de nutrientes. Se realizaron dos experimentos para probar la hipótesis de que el método de "Media Luna" era efectivo para reducir pérdidas de sedimento, fósforo total (TP), y nitrógeno total Kjeldahl (TKN) en escorrentía proveniente de siembras de café. Los experimentos se realizaron en una finca comercial donde el suelo predominante pertenecía a la serie Múcara (Dystric Eutrudepts) en la Fase 1 y Humatas (Typic Haplohumults) en la Fase 2. Las concentraciones de sedimento y nutrientes en escorrentía fueron similares en los tratamientos de siembra al contorno convencional y el método de "Media Luna" en siembras recién establecidas. En la Fase 1, las concentraciones de nutrientes en la escorrentía aumentaron en eventos posteriores a la fertilización. El sedimento no consolidado recién relocalizado puede ser más susceptible a pérdida por erosión. En la Fase 2, las pérdidas de sedimento y nutrientes en siembras de más de dos años fueron mayores en el tratamiento de siembra al contorno convencional que las pérdidas en el método de "Media Luna". Las reducciones en las concentraciones de sedimento y nutrientes en el tratamiento de "Media Luna" en la Fase 2 pueden justificar la implantación del método de "Media Luna" como práctica de siembra del café en algunas áreas de Puerto Rico.

Palabras clave: café, *Coffea arabica*, control de erosión, nutrientes en escorrentía, métodos de siembra, terraza individual

INTRODUCTION

Coffee (*Coffea arabica*) was introduced to Puerto Rico during the early eighteenth century as part of the general distribution of the African plant through the Antilles, and was firmly established as a market crop by the 1790s in highland areas easily accessible to ports (Carvajal, 1984; Vega, 2008). Production and market value peaked in 1899 only to decline throughout the early twentieth century because of land, labor and capital organization problems (Bergad, 1978). There was a rapid decline in agricultural land uses, especially in coffee production, and consequent reversion to secondary forest from 1959 to 1974 (Rudel et al., 2000). To date, coffee production occurs primarily in the mountainous western-interior parts of the island on an estimated land area of 30,315 ha with an average annual production at 8.75 t (175 hundred weight) (DA, 2004).

Results from experiments evaluating fertilizer levels, coffee cultivars, liming, and management practices were published in the 1950s and 1960s (Bonnet et al., 1958; Abruña et al., 1959; 1963; 1965a; 1965b). These and other management practices required for producing high economical yield of coffee in Puerto Rico were detailed by Vicente-Chandler et al. (1968), and emphasized the use of high-yielding cultivars, high plant density, the use of full sunlight, and intensive use of fertilizers. As early as 1955, Smith and Abruña (1955) quantified the effects of ground cover, and of terracing, on sediment yields from coffee. They found that the amount of ground cover was the most important variable controlling sediment losses from coffee plantations. Various living mulches within coffee plantations reduced sediment losses in the range of 90 to 99% relative to losses from between-row non-mulched coffee (Semidey et al., 2002). Vicente-Chandler et al. (1968) mentioned that there were no reliable experimental data regarding the value of individual terraces in terms of coffee yields or soil conservation. They described individual terraces as "small level benches built around each coffee tree by digging into the slope above it". Although the authors speculated about the positive influence of the practice in reducing runoff, they were highly skeptical about the effectiveness because digging around old coffee trees would destroy or disturb their root systems, and young seedlings planted in a constructed terrace would be growing in less fertile subsoil.

Based on our experiences and previous published work, we hypothesized that individual terraces could reduce sediment and nutrient concentrations in runoff relative to those in coffee grown using traditional planting methods. We named the construction of individual terraces around coffee trees, as described by Vicente-Chandler et al. (1968), as "Media Luna" conservation practice (Figure 1). The objective of this paper is to present quantitative evidence for the evaluation of the efficacy of the conservation practice dubbed "Media Luna" for control of erosion and nutrient loss during and after the establishment of a coffee plantation in Puerto Rico.

MATERIALS AND METHODS

Overview of the study area: The study area was a private farm near Road 106 km. 18 in the municipality of Las Marías, with a total area of 28.3 ha (70 acres). Approximately 2.4 ha (six acres) was dedicated to coffee production; 60% of the coffee plants were mature trees more than five years old, and the rest of the plants were in an establishment phase. The cultivar used throughout the farm was Caturra, which is described as having intermediate growth height (AES, 1999). Most of the coffee on the farm was planted according to the conservation practice of contour planting, whereas a small part was planted ac-

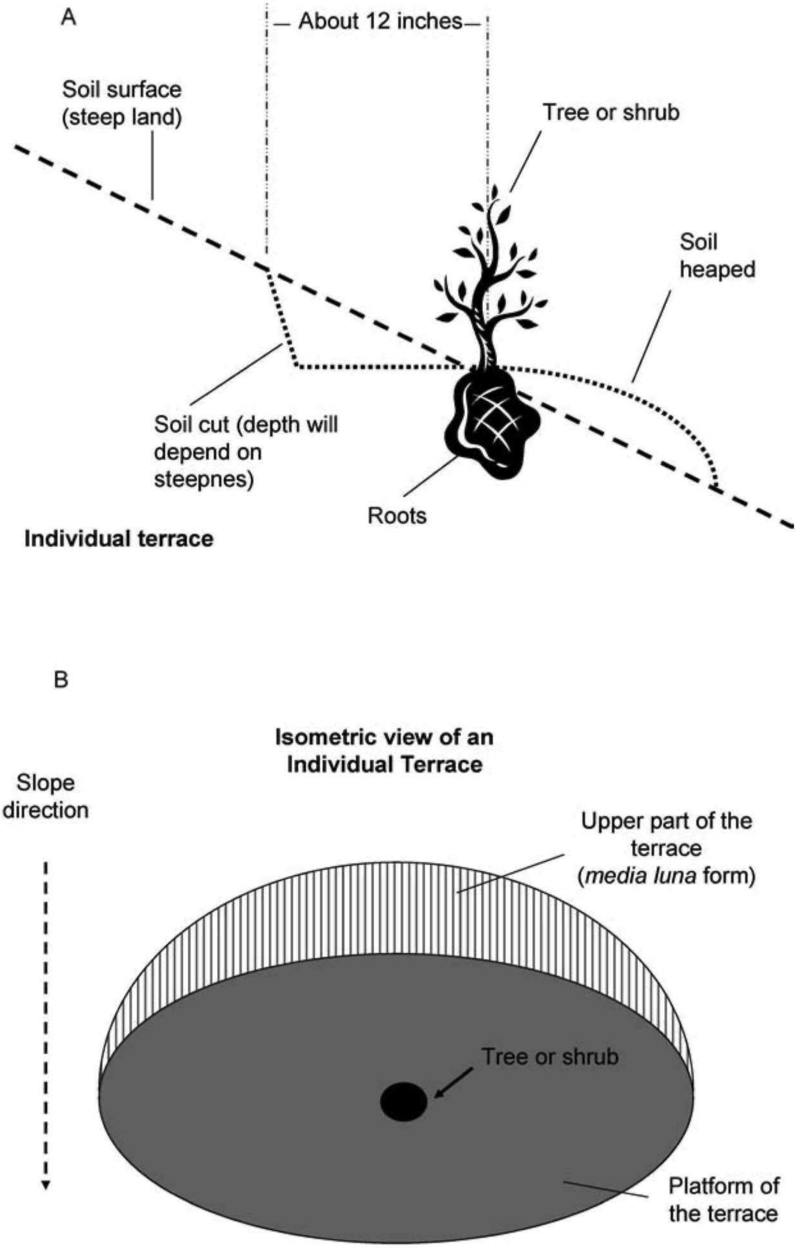

FIGURE 1. Conceptual diagram of (A) "Media Luna" terrace and (B) isometric view.

cording to the "Media Luna" method (Figure 1). The experiment was divided in two phases. In Phase 1, sediment, total phosphorus (TP), and total Kjeldahl nitrogen (TKN) concentrations in runoff were measured in recently established coffee plantings. In Phase 2, sediment, TP, and TKN concentrations in runoff were measured from areas that already had established mature coffee trees and that were planted by either the "Media Luna" conservation planting method or the conventional method. The soil in Phase 1 belonged to the Múcara series (Fine-loamy, mixed, superactive, isohyperthermic Dystric Eutrudepts). The soil particle size distribution was 27.3, 39.7, and 33% for clay, silt and sand size separates, respectively (Mount and Lynn, 2004). The soil in Phase 2 belonged to the Humatas series (Very-fine, parasesquic, isohyperthermic Typic Haplohumults). Precipitation depth and intensity were gathered from a rain gauge connected to a datalogger placed at the farm.

Phase 1: A field plot with an approximate area of 0.10 ha was chosen for the study. The field contained an overstory of trees which are typically found in the area. Vegetation within the field was removed by hand, hoe and machete. Glyphosate was applied to remove the emerging and remaining small shrubs, so that the whole field was without vegetation prior to establishment. The ground-cover with vegetative and surface residue averaged 42% as measured by the line-intersect method. Mean slope in the area was 42%.

Eight paired-runoff plots were established within the field. The experimental layout consisted of two paired treatments, which were conventional planting and the conservational planting "Media Luna", with four replications in a randomized complete block design. Each individual plot measured 5.8 m downslope and 2.4 m across the slope. The plots were surrounded by 15-cm polyethylene liners inserted 6 cm into the soil to exclude run-on water and to direct runoff water to runoff collectors placed at the lowest drainage point of each plot. A collection device with lid was designed to channel runoff water into collecting buckets. The buckets had a total volumetric capacity of 16 L and had an automatic shutoff valve to exclude runoff water once the bucket filled.

Prior to initiation of the experiment, soils within each plot were sampled at two depths (0 to 5 and 5 to 15 cm) for characterizing the soil nutritional status. Soil pH was measured in 1:2 soil:water mixture (McLean, 1982); soil organic matter was quantified by the Wakley-Black dichromate oxidation procedure (Nelson and Sommers, 1982); soil extractable phosphorus (P) was quantified by the Bray 1 procedure (Olsen and Sommers, 1982).

The plots were established the last week of September 2003; planting was performed by using one of the two treatments on 13 October

2003. The conventional planting method consisted of digging a 15-cm diameter hole with an approximate depth of 30 cm within the slope of the field. After adding 112 g (4 oz) of triple superphosphate at the bottom of the hole, a coffee seedling was placed in the hole and covered with surrounding soil. Seedling plant height varied from 30 to 46 cm. Within each plot six seedlings were planted according to the corresponding field contour. Planting density corresponded to approximately 4,940 plants/ha. The "Media Luna" planting treatment consisted of removing soil material from the hill-slope and placing it on the downslope portion of the slope where the seedling was placed. This method reduces the slope where the seedling is planted and creates a "half-moon" shape on the soil surface (Figure 1). All other planting and management practices were similar to those of the conventional method. Weed control was performed 17 December 2003 by using glyphosate, and from 22 to 26 March 2004 by machete. On 14 December 2003 and 24 April 2004 plants were fertilized with 84 g/tree of 10-10-8 (N-P_2O_5-K_2O) complete fertilizer mixture.

The effect of treatment on reducing erosion losses was evaluated by quantification of sediment, TP, and TKN concentrations in runoff after each runoff event. Samples were collected from 15 October 2003 to 25 May 2004 (approximately eight months). The total volume of runoff water and water-sediment mixture collected was recorded in situ for each plot within 24 h after a rainfall event. Samples were homogenized, and a 500-mL subsample was taken to the laboratory for processing. Sediments remaining in the collection device (eroded sediments) were transferred to sterile Whirlpak® (Nasco, Modesto, CA) plastic bags and taken to the laboratory. Soil extractable P was quantified by using the Bray 1 procedure, which was used to quantify P enrichment in runoff relative to P in soil within plots. Suspended non-filterable residues (suspended sediments) were quantified in the laboratory by filtration as specified in EPA method 160.2 (USEPA, 1999). Unfiltered samples were immediately frozen until analysis. Unfiltered samples were measured for total phosphorus (TP) and total Kjeldahl nitrogen (TKN). Samples were digested by a Kjeldahl digestion. Unfiltered digested samples or filtered samples were quantified by the ascorbic acid method (Murphy and Riley, 1962) and ammonium-N was quantified with a Bran+Luebbe Autoanalyzer. Areal plant canopy coverage was measured by using a spherical densiometer; plant height and number of leaves per plant were quantified eight months after establishment at the conclusion of the runoff experiment.

The data were analyzed as a randomized complete block arrangement with four replications using SAS (SAS, 2001). All data were log10 transformed prior to analysis to homogenize variances and to normalize the distribution. The mean values are the inverse log10 transformation of LSMeans data. Regression and Pearson correlation analyses were performed by using the Proc REG and CORR procedures of SAS.

Phase 2: We evaluated nutrient and sediment losses from soils planted with mature coffee trees. One area was planted according to the "Media Luna" conservation planting method, and the other area was planted by the conventional method. All trees were between 2.5 and 3 yr of age. Four runoff collectors were established in each of the two planting systems. Runoff collectors were those described by Franklin et al. (2001) in which one-tenth (10×) or one-hundredth (100×) of total runoff was collected. Polyethylene tubing connected the runoff collector to the holding tanks, which were polyethylene buckets located down slope from the runoff fractionator with the top inserted approximately 5 cm below the soil surface. The buckets had lids to prevent rainfall from entering, and were modified from those used by Sotomayor-Ramírez et al. (2006) in which a shut-off valve prevented additional water from entering the bucket once full. Runoff was collected from the buckets within 24 h of each runoff event. Total volumes corresponding to each fraction were recorded. Collectors, tubing and buckets were rinsed with acid-solution and distilled water between events. Samples were processed as described previously. Average slope in both plots was approximately 55%. Sample collection was initiated 14 June 2004 and concluded 1 December 2004. Fertilization was 450 g/tree of 10-5-12 on 15 July 2004. Weed control was performed with machete during August 2004. Soil texture was quantified by using the Bouyucuos method (Montenegro and Malagón, 1990).

RESULTS AND DISCUSSION

Phase 1: Soil test P values (Bray 1) decreased after the initiation of the experiment, with no significant difference between treatments ($P > 0.05$) (Table 1). Soil pH values at the initiation and at the end of the assay were generally less than four, with no significant effect of time (initial vs. final) nor treatment effect ("Media Luna" vs. conventional). Soil organic matter values were not affected by time or treatment, with mean values of 3.34%. Trees planted under the "Media Luna" method had mean plant height of 116 cm, 64 leaves per plant, and 3.8% of areal canopy coverage. Trees under the conventional planting system had mean plant height of 100.0 cm, 50 leaves per plant, and 2.9% of areal canopy coverage. No significant differences between treatments were observed.

Between 15 October 2003 and 25 May 2004, there were 81 precipitation events corresponding to a total rainfall depth of 576 mm (22.6 in)

TABLE 1.—*Summary of general soil, plot and coffee plant parameters as affected by treatment at initiation and at the conclusion of runoff assays conducted in Phase 1.*

	Initial		Final	
Parameter	Conventional	"Media Luna"	Conventional	"Media Luna"
Soil Test P (mg/kg)	8.03	8.29	2.47	2.28
Organic matter (%)	3.38	3.37	3.23	3.38
Tree Height (cm)	78	84	100	116
pH	3.87	3.94	3.86	3.84
Groundcover (%)	42.3	41.8	28.4	33.7

(Figure 2A). There were 38 runoff events, 12 of which caused an amount of runoff significant enough to collect sediment in the runoff trap as eroded sediment. Cumulative sediment totals for the 12 events were 996.6 and 621.9 kg/ha for the "Media Luna" and conventional practice, respectively. Mean eroded sediment losses were 83.1 and 56.5 kg/ha for the "Media Luna" and conventional practices, respectively (Table 2). Greater sediment concentrations in runoff were observed during the initial runoff events (events 1 through 20) than during those occurring in the latter stages, probably because soil material is disturbed and relocated during the "Media Luna" construction. Vicente-Chandler et al. (1968) suggested that approximately 9 t/ha/yr (9.9 tons/acre/yr) of soil material is expected to be loosened and moved in the process of constructing the individual terraces which could be susceptible to erosion until settled and stabilized by vegetation. Mean sediment concentrations in runoff were 0.431 g/L and 0.489 g/L for "Media Luna" and conventional systems, respectively (Figure 3A) with no significant differences between treatments ($P > 0.05$).

Mean TP concentrations in runoff were 0.108 mg P/L (0.208) and 0.113 mg P/L (0.176) (standard deviations in parentheses) (Figure 3B) and mean TKN concentrations were 4.04 (0.79) and 4.31 (0.86) mg N/L under "Media Luna" and conventional planting systems, respectively (Figure 3C and Table 2). Treatments did not affect TP and TKN concentrations in runoff ($P > 0.05$). There was no statistical relationship between precipitation depth, precipitation intensity and nutrient and sediment concentrations. However, on the day following each of the two fertilization events there were precipitation events having either a great depth or intensity which coincided with high nutrient concentrations in runoff. For example, on 14 December 2003 (event number 21), there was a 41-mm precipitation event with a 30-min intensity maximum of 61 mm/h. In this runoff event, mean (standard error in parentheses) TP concentrations were 0.695 (0.400) and 0.161 (0.063) mg P/L

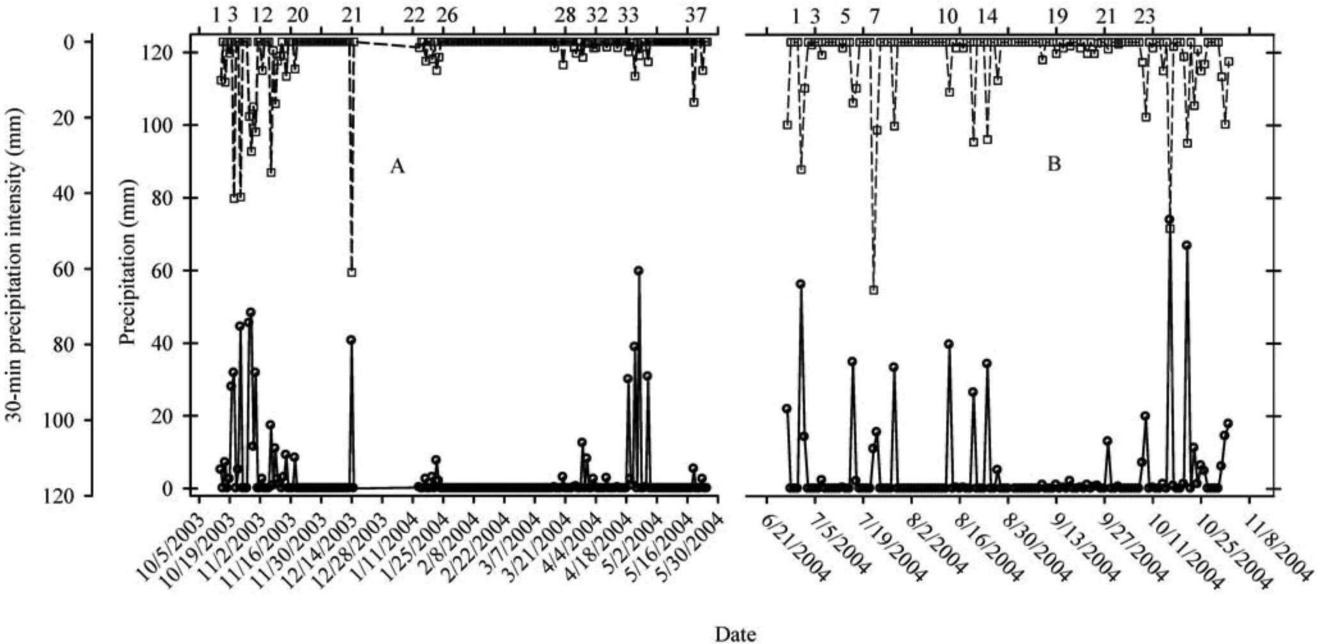

FIGURE 2. Daily instantaneous precipitation (open circles) and 30-min precipitation intensity (open squares) in Las Marías during Phase 1(A) and Phase 2 (B) of the experiments. Runoff event numbers corresponding to the dates are listed on the top abscissa. Some numbers have been omitted for clarity in the presentation.

TABLE 2.—*Summary of water-quality parameters associated with runoff in "Media Luna" and conventional planting systems for coffee in Phase 1.*

Parameter	Conventional	"Media Luna"
Suspended sediments (g/L)	0.489	0.431
Total P (mg/L)	0.113	0.108
Total N (mg/L)	4.31	4.04
Mean eroded sediment loss (kg/ha)	56.5	83.1
Mean extractable P in eroded sediment (mg/kg)	10.71	9.97
Mean extractable P in eroded sediment (g/ha)	0.388	0.538
P enrichment	1.37	1.36

in the conventional and "Media Luna" planting systems, respectively, and TKN concentrations were 13.9 (3.47) and 7.0 (2.63) mg N/L, respectively. Although our statistical design did not permit us to statistically compare between treatments for a particular event, it is noteworthy that numerical nutrient values were lower for the "Media Luna" treatment. Observation of trends in TP demonstrates that except for event 27, concentrations in runoff decreased to near median values of 0.08 mg P/L immediately following fertilizer application, from runoff event 21 until event 34. The TP concentration increase for event 35 occurred after a second fertilization.

Concentrations of TKN in runoff following event 21 also decreased but were more variable relative to median values of 3.77 mg N/L than those of TP. Nitrogen fertilizer sources are more soluble than those of P (IFDC/UNIDO, 1998), and processes that remove N from solution are different from those of P. Soil solution N is utilized by roots and by soil microbial biomass and can eventually be incorporated within the various soil organic matter pools (Paul and Clark, 1996). Hence, mineralization-immobilization reactions control soil solution N. In contrast, when the concentrated P diffuses from the fertilizer granule into the surrounding soil solution, root uptake, adsorption and precipitation reactions, and to a minor extent, microbial reactions remove P from solution (Beauchemin et al., 1996; Morel et al., 2000). The Inceptisol used in our study has a relatively large proportion of its mineralogy of oxidic type, which is expected to rapidly fix P, thus reducing soil solution P (Fox, 1982). Concentrations of soil solution P in dissolved form will increase because of desorption of labile P when rainfall disrupts soil aggregates, and P in particulate form (associated with sediments) is most important at low sediment concentrations in runoff.

Phosphorus transport at the field scale has been associated with sediment characteristics such as clay content and organic carbon, and at the field scale higher sediment concentrations are associated with lower TP (Steegen et al., 2001). Phosphorus is found in organic form

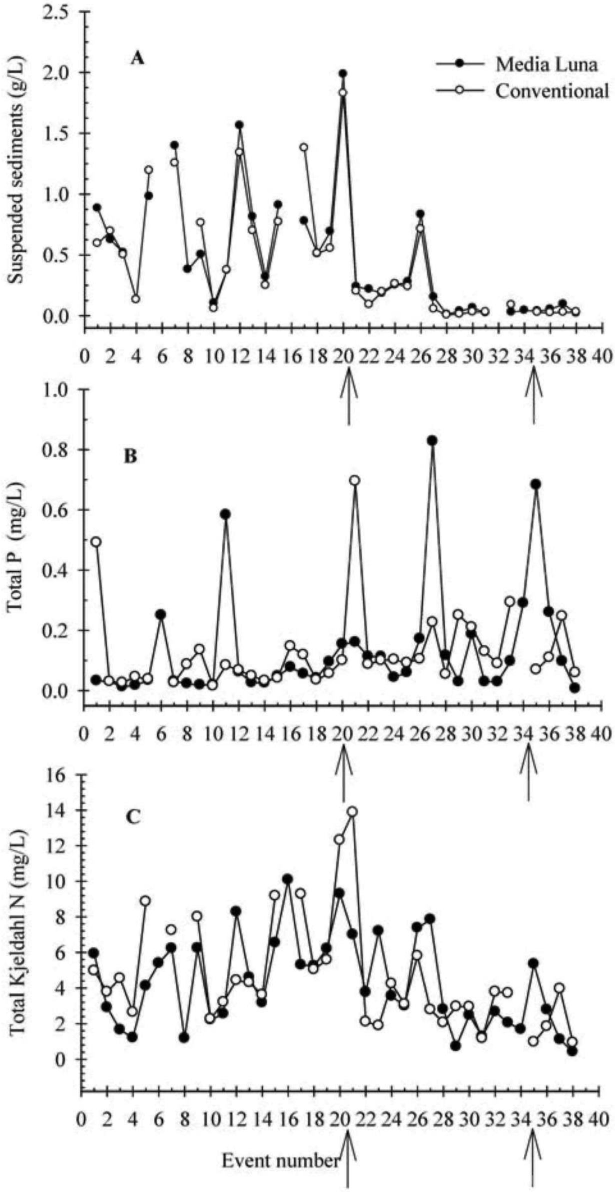

FIGURE 3. Suspended sediment (A), total P (B) and total Kjeldahl N (C) concentrations in runoff under "Media Luna" and conventional planting system during the establishment phase of coffee (Phase 1) in Las Marías, Puerto Rico. The arrow corresponds to the approximate time when fertilizer was applied.

and bound to Al and Fe complexes, the latter of which are important sediment components (Sparks, 1995). The concentrations of TP were not correlated to suspended sediments, but rather an inverse exponential relationship was observed between the ratio of total P to suspended sediment concentrations (TP/SS) and suspended sediments (Figure 4). This finding demonstrates that P is enriched in sediments when concentration of the latter is low in runoff water, and TP concentration decreases to near background levels at sediment concentrations in runoff near 0.1 g/L. This result contrasts with TKN concentrations which were positively correlated to suspended sediments ($r = 0.65$; $P < 0.01$; $n = 47$). Nitrogen in organic and NH_4+ form is quantified with the TKN procedure so that the potential quantification of NO_3- may have offset the observed TKN-sediment relationship.

Extractable P (Bray 1) concentrations in eroded sediment from the two planting systems had mean values of 9.97 and 10.71 mg P/kg for the "Media Luna" and conventional systems, respectively (Table 2). Enrichment ratios (relationship between P concentration in eroded sediment and P in soil) were 1.36 and 1.37 for "Media Luna" and conven-

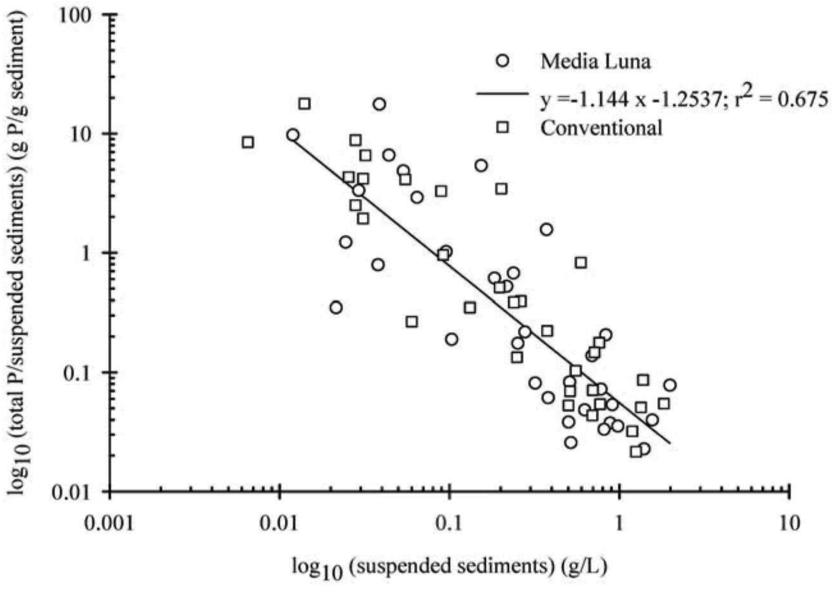

FIGURE 4. Relationship between suspended sediment concentrations and P enrichment of sediment in runoff samples collected under "Media Luna" and conventional planting systems during the establishment phase (Phase 1) of coffee in Las Marías, Puerto Rico.

tional systems, respectively (Table 2). This finding indicates that when sediment was exported from the plots, the amounts of P associated with the sediment were similar in the two planting systems. The mass of exported P from each plot is a function of P concentration in eroded sediments that accumulated in the runoff collectors (but did not reach the sampling buckets), which occurred primarily from October through November 2003. Mean extractable P losses associated with sediment were 0.538 and 0.388 g P/ha, for the "Media Luna" and conventional planting systems, respectively (Table 2).

The results indicate that there are no significant differences in terms of TP, TKN, and suspended sediment concentrations in runoff as affected by "Media Luna" and conventional planting systems. Mean eroded sediment mass losses and extractable P associated with eroded sediments were similar between the treatments, although there was a consistent trend for values to be higher in the "Media Luna" method. The runoff event occurring immediately following fertilization increased TP and TKN concentrations in both treatments. There were no significant increases in plant growth parameters associated with the treatments.

Phase 2: The amounts of runoff from plots were significantly lower in the "Media Luna" relative to the amounts from the conventional method. Soil organic matter values were similar in "Media Luna" and conventional planting systems, with values of 3.42 and 3.32%, respectively. Soil pH values were also similar in "Media Luna" and conventional planting systems, with values of 4.29 and 4.63, respectively. The soil particle size distribution was 62, 18, and 20%, for clay, silt and sand size separates, respectively, with no significant treatment differences. Twenty-three runoff events were collected from 19 June 2004 to 1 December 2004. For suspended solids, seventeen events were collected in the conventional system whereas four events were collected in the "Media Luna" system. This difference occurred because less runoff water entered the collectors in the "Media Luna" planting system. Mean sediment concentrations were 0.243 g/L for conventional planting and 0.016 g/L for "Media Luna" (Figure 5A; Table 3). Sediment concentrations were low during the collection period. Various factors apparently contribute to the observed low sediment concentrations found. The plots had mature coffee trees that had a large leaf area index and covered a large portion of the soil area, thus reducing rainfall impact to soil. The soil area was also covered by common volunteer grasses and weeds. Only when these are cleared by hand (machete) is the soil exposed. Finally, the collectors were placed in representative areas of the plots where sheet flow was hypothesized to occur. We opted for this method because it best serves to integrate rainfall-sediment detach-

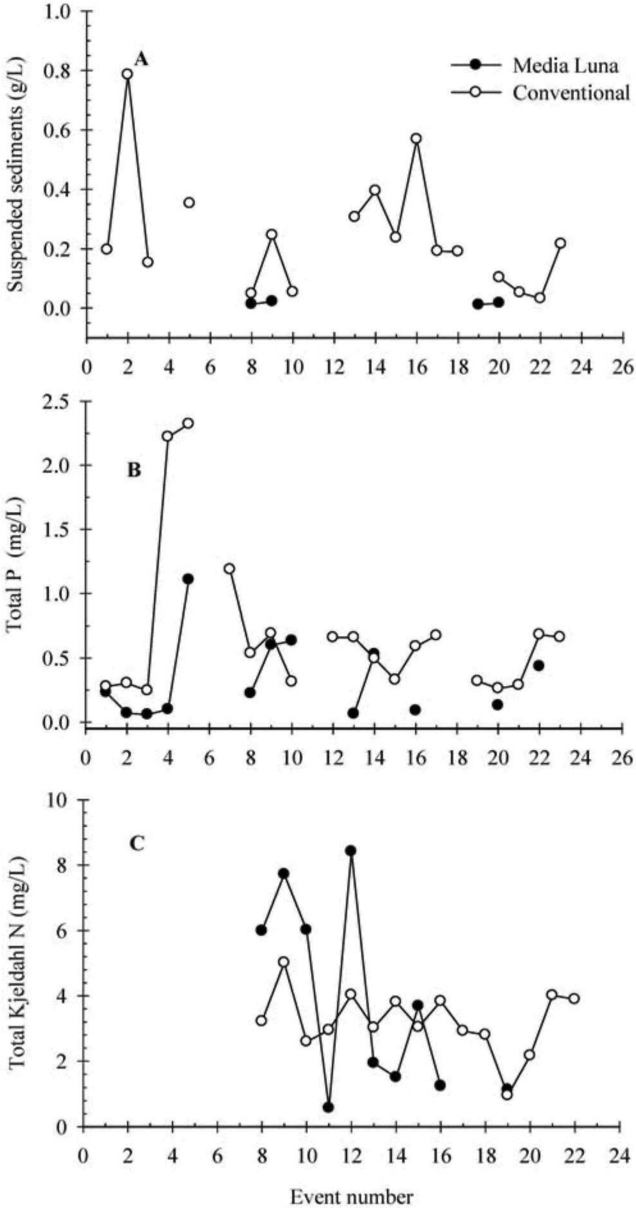

FIGURE 5. Suspended sediment (A), total P (B) and total Kjeldahl N (C) concentrations in runoff under "Media Luna" and conventional planting systems for mature coffee trees (Phase 2) in Las Marías, Puerto Rico.

TABLE 3.—*Summary of water-quality parameters in runoff during Phase 2 in "Media Luna" and conventional planting systems, respectively.*

	Conventional			"Media Luna"		
	n	mean	Standard deviation	n	mean	Standard deviation
		-----------mg/L---------			-----------mg/L---------	
Suspended sediments	17	243	198	4	15.7	5.0
Total P	20	0.555	0.372	13	0.282	0.372
Total Kjeldahl N	15	3.23	1.46	10	2.89	1.62

ment-erosion processes within the study plots, and reduces water input from surrounding areas, input that does not correspond to the plot areas. As opposed to Phase 1 of the project, the plots had no definite boundaries; therefore, the origin of runoff water may be from anywhere within the plot that contained the planting system.

Mean TP concentrations significantly differed between treatments and were 0.555 and 0.282 mg/L for conventional and "Media Luna" treatments, respectively (Figure 5B, Table 3). Mean TKN concentrations did not differ between treatments and were 3.23 and 2.89 mg/L for conventional and "Media Luna" planting systems, respectively (Figure 5C; Table 3). Mean extractable STP was 46.84 mg/kg in the conventional planting system and 80.74 mg/kg in the "Media Luna" planting system. The high STP value quantified in the "Media Luna" system was apparently associated with a small area (80 m^2) within the field. It is unclear why the pattern was observed, yet the contributing area was sufficiently small so that this did not lead to higher TP concentrations in runoff in the "Media Luna" treatment.

CONCLUSIONS

In Phase 1 of the project, no significant treatment effects on suspended sediments, TP and TKN concentrations were observed. Soils from Phase 1 tended to have a greater proportion of sand+silt and a lesser proportion of clay than those in Phase 2. In combination with the fact that the soils had recently been disturbed by the planting system, these factors may have resulted in no treatment effects during Phase 1. Soils with a coarser texture (less clay proportion) are more susceptible to erosion; thus may have caused the higher sediment concentrations quantified in Phase 1 than in Phase 2. Furthermore, recently loosened unconsolidated material may be more susceptible to losses. In Phase 2 of the project, lower suspended sediment and TP concentrations were quantified in the "Media Luna" planting system than in the conventional planting system. It is expected that by the time the experiment was conducted the soil had been stabilized by vegetation, with the high clay content of the soil leading to improved aggregation and soil structure. Soil organic matter, pH, and TKN concentrations did not differ between the two treatments. The lower TP concentrations measured during phase 2 of the project may warrant recommendation of "Media Luna" as a planting practice for coffee production in some areas of Puerto Rico.

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