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Major Soils of Bella Unión Area in Northwestern Uruguay[1]

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ABSTRACT

The soils of the area of Bella Unión are deep, of high inherent fertility, and can hold and supply sufficient amounts of water to a growing crop. They are mostly sandy clay loams and clay loams. Soil pH varies between 5.2 and 6.4. Some 38% of the soils have drainage problems mostly because of underlying impervious layers dominated by montmorillonitic clays. Irrigation and drainage are essential to guarantee high levels of crop production. Erosion can be a problem in some of the soils if they are not adequately protected. The use of open drains of suitable depth and spacing will help to maintain an optimum environment for the crops and, if well designed, can also help to minimize soil erosion.

INTRODUCTION

The area around Bella Unión, in northwestern Uruguay, offers exceptional opportunities for crop production and livestock raising under adequate management. Bella Unión is located at lat. 30°19' S and long. 57°34' W at the frontiers with Brazil and Argentina. Bella Unión is 640 km from Montevideo and 140 km from both Artigas, capital city of the Department, and Salto, the nearest towns with airports. There are railroad connections between Bella Unión and Montevideo. However, the network of rural roads is poor and transportation costs of sugarcane, livestock, other produce and fertilizer are high. In the Bella Unión area, there are around 10,000 inhabitants; about one-half of them in rural areas. During the sugarcane harvesting season, many workers immigrate from Brazil. Nearly 9/10 of the population depend directly for their living on the operations of the sugar industry.

Considerable effort is underway to increase sugarcane production as a source of both sugar and energy. The needs of Uraguay for total fermentable solids as sources of fuel and chemical feedstocks are becoming urgent. There is also a growing need of molasses as a source of ethanol for motor fuel. Marked interest is also evident in fostering the production of horticultural crops for the large Montevideo market.

This paper reports on soil studies conducted at the Bella Unión area in an effort to evaluate the situation and provide basic data to strengthen agricultural development.

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PROCEDURE

All available information from the area was studied and critically evaluated, including a reconnaissance soil survey report of an area of 18,621 ha (1) and a more detailed survey report of 4,970 ha of land in the Calagua area (3).

Soil profiles were examined and described throughout the area. Data were obtained from selected soils on bulk density, and water retained at 1/10, 1/3, 1 and 15 atmospheres of tension (6). Laboratory determinations were made on pH, organic matter, cation exchange capacity and exchangeable Ca, Mg, K and Na (2).

CLIMATE

The climate of Bella Unión is subhumid, subtropical. Mean monthly rainfall is 105 mm.[3] The driest months are from May through September. The lowest rainfall occurs in July: 73 mm; the highest in March: 132 mm. In some years, there are severe dry spells that can subject crops to undue moisture stress. From December 8, 1975 to October 2, 1976, there were four dry spells: 35 mm (Dec. 8 to Jan. 2); 2.8 mm (March 12 to April 3); 26 mm, (June 4 to July 31) and 9.5 mm (Aug. 7 to Oct. 2). From May 26 to July 4, 1977, rainfall was only 34.2 mm. These data show the erratic rainfall distribution and highlights the need for irrigation in order to provide sufficient moisture for crop growth. The months of more rainfall are also those of more sunlight hours. The monthly average is 224 sunlight hours. Mean minimum and mean maximum temperatures follow the same trend: May through September are the cooler months. Mean minimum temperatures range from 8° C in June, July and August to 18°C in November, December and January. Mean maximum temperatures range from 19.2° C in August and September to 32° C in December, January and February. In some years, frost can cause considerable damage to crops. Marked production dips attributable to frosts were recorded in 1966, 1967 and 1976. Again, on July 15, 1980, there was a severe frost. Mean monthly evaporation ranges from 70 mm in July to 280 in December. Maximum daily evaporation occurs in January. Mean monthly relative humidity ranges from 56% in December to 80% in June; wind velocity, from 203 km/day in January to 275 km/day in June. Agroclimatologically, the area is characterized by an ustic soil moisture regime and a mesic soil temperature regime.

SOILS

Descriptions of typical profiles of major soils of the Bella Unión area are presented in table 1 (see also figures 1 to 4). The following tabulation

[3] Mean of 36 recorded years.

TABLE 1.—*Descriptions of key pedons of the major soils of the Bella Unión area*

Great group	Soil series	Horizon	Depth	Profile description
			cm	
Pelluderts[1]	LB2	A^1	0–20	Black (10YR 2/1) clay loam; strong medium and coarse granular structure; friable to firm, sticky, plastic; gradual boundary.
		A^3–B_1	20–40	Black (10YR 2/1) clay loam to clay; strong, coarse granular structure; sticky, very plastic; common pebbles; diffuse boundary.
		B_2	40–60	Very dark gray to black (10YR 2.5/1) clay; medium subangular blocky structure parting to strong fine and medium granular; sticky, very plastic; some slickensides; common pebbles; gradual boundary.
		B_3	60–70 (90)	Dark gray to dark grayish brown (10YR 4/1.5) with black (10YR 2/1) nodules; clay; moderate medium and coarse subangular blocky structure; sticky, very plastic; common slickensides; clear irregular boundary.
		$C_{1\ ca}$	70 (90)–110	Brown to dark (7.5YR 4/2–4/4) clay; sticky, very plastic; common medium $CaCO_3$ concretions; clear boundary.
		C_2	110–120	Light yellowish brown (2.5Y 6/4) with brown (7.5YR 4/4) nodules; loam; abrupt boundary.
		R	120–129	Unweathered basalt.
Hapludalfs[2]	S2	A_1	0–20	Very dark grayish brown (10YR 3/2) moist, grayish brown (10YR 4.5/2) dry; sandy loam; weak medium subangular blocky structure; very friable; gradual boundary.
		A_3	20–35	Very dark brown (10YR 2/2) moist dark grayish brown (10YR 4/2) dry; gravelly sandy clay loam to gravelly sandy loam; weak to moderate fine and medium subangular blocky structure; clear boundary.
		B_{21t}	35–50	Very dark gray to black (10YR 2.5/1) with common medium prominent yellowish red (5YR 5/8) mottles; gravelly heavy sandy clay loam; strong medium prismatic structure; sticky, plastic; medium continuous clay films; common fine hard iron and manganese concretions; clear boundary.

Table 1—Continued

Great group	Soil series	Horizon	Depth	Profile description
		B_{22t}	50–65	Dark gray (10YR 4/1) with many medium and coarse prominent strong brown (7.5YR 5/8) and yellowish brown (10YR 5/6) mottles; sandy clay loam to clay; strong, medium and coarse prismatic structure; sticky, plastic; continuous clayfilms; common fine iron and manganese concretions; gradual boundary.
		B_{23t}	65–90	Gray (5Y 5/1) with common coarse prominent strong brown (7.5YR 5/8) mottles; gravelly sandy clay loam; coarse prismatic parting to strong medium angular blocky structure; sticky, plastic; continuous clay films; common, coarse, very friable iron and manganese concretions; gradual boundary.
		B_3	90–105	Gray (5Y 5/1) and reddish brown (5YR 4/4); gravelly sandy clay loam; moderate medium angular and subangular blocky structure; sticky, plastic; discontinuous clay films; common fine iron and manganese concretions; gradual boundary.
		C	105–110	Brown (7.5YR 5/3) and grayish brown (10YR 5/2) gravelly sandy clay loam.
Argiudolls[3]	F2	A_1	0–15	Black (10YR 2/1) clay loam; strong medium granular structure; gradual boundary.
		A_3	15–30	Black (10YR 2/1) gravelly clay loam; moderate to strong fine granular and subangular blocky structure; gradual boundary.
		B_{2t}	30–40	Black (10YR 2/1) clay; strong medium and fine subangular blocky structure; thin discontinuous clay films; clear boundary.
		B_3	40–50	Dark gray (7.5YR 3/2) and brown (7.5YR 4/4) with very dark gray (10YR 3/1) and black (10YR 2/1) coatings; clay; clear and abrupt boundary.
		C_{1ca}	50–65	Dark brown (7.5YR 3/2) and light brown (7.5YR 6/4) with pinkish white (7.5YR 8/2) and strong brown (7.5YR 5/6) nodules; clay; clear boundary.
		C_{2ca}	65–70	Fray Bentos pink tuff.

Table 1—*Continued*

Great group	Soil series	Horizon	Depth	Profile description
Argiudolls[4]	L1	A_1	0–25	Very dark grayish brown (10YR 3/2) sandy clay loam; weak medium subangular blocky structure; friable; gradual boundary.
		A_3	25–35	Very dark brown (10YR 2/2) sandy clay loam; weak to moderate medium and fine subangular blocky structure; clear boundary.
		B_{21t}	35–45	Very dark gray (10YR 3/1) sandy clay loam; strong coarse angular blocky structure; sticky, plastic; continuous clay films; gradual boundary.
		B_{22t}	45–55	Very dark gray (10YR 3/1) sandy clay loam; with many cobbles; sticky, plastic; gradual boundary.
		B_{23t}	55–65	Dark gray (10YR 4/1) with few fine faint yellowish brown (10YR 5/6) mottles; sandy clay loam and sandy clay; strong coarse angular blocky structure; sticky, very plastic; clear and abrupt boundary.
		C_{ca}	65–75	Brown (7.5YR 5/4) clay loam; few medium $CaCO_3$ concretions.
Argiudolls	L2	A_1	0–20	Very dark gray to black (10YR 2.5/1) fine sandy clay loam; moderate to strong fine subangular blocky structure; friable, slightly sticky, slightly plastic; gradual boundary.
		B_{21t}	20–45	Black (10YR 2/1) clay with some cobbles; moderate to strong medium subangular blocky structure; sticky, plastic; discontinuous clay films; gradual boundary.
		B_{22t}	45–70	Very dark gray (10YR 3/1) clay with common cobbles; moderate medium and coarse subangular blocky structure; sticky, plastic; discontinuous clay films; gradual boundary.
		B_3	70–80	Dark grayish brown (10YR 4/2) with common coarse faint brown (7.5YR 4/4) mottles; clay with many cobbles; sticky, plastic; clear boundary.
		C_{ca}	80–90	Brown (7.5YR 5/4) clay loam to clay; with gravel; medium and coarse common $CaCO_3$ friable splotches.

***Table 1**—Continued*

Great group	Soil series	Horizon	Depth	Profile description
Argiudolls	LF2	A_p	0–20	Very dark brown to black (10YR 2/1.5); clay loam with some cobbles; moderate to strong medium and fine subangular blocky structure; friable, slightly sticky, plastic; gradual boundary.
		A_3	20–37	Black (10YR 2/1) clay loam; strong coarse granular and strong fine subangular blocky structures; friable to firm, slightly sticky, plastic; gradual boundary.
		B_{21t}	37–50	Black (10YR 2/1) clay; strong medium subangular blocky structure; firm, sticky, plastic; thin discontinuous clay films; gradual boundary.
		B_{22t}	50–60	Black to very dark gray (10YR 2.5/1) clay with common cobbles; strong medium subangular blocky structure; sticky, plastic; thin discontinuous clay films; gradual boundary.
		B_3	60–70	Very dark grayish brown (10YR 3/2) clay with common cobbles; moderate medium subangular blocky structure; sticky, very plastic; clear boundary.
		C_{ca}	70–80	Brown (7.5YR 5/4) and strong brown (7.5YR 5/6) with common medium faint very dark gray (10YR 3/1) mottles; light clay; few medium $CaCO_3$ concretions; abrupt irregular boundary.
	L4	R	80–90	Fray Bentos tuff.
Argiudolls		A_1	0–22	Very dark grayish brown (10YR 3/2) with few fine faint dark yellowship brown (10YR 3/4) mottles; loam to silt loam; weak fine and medium subangular blocky structure; friable; gradual boundary.
		A_2[5]	22–32	Very dark gray (10YR 3/1) with common fine faint dark yellowship brown (10YR 3/4) mottles; weak medium subangular blocky structure; friable; abrupt boundary.
		B_{21t}	32–40	Very dark gray to black (10YR 2.5/1) clay; strong coarse prismatic structure; very hard, sticky, plastic; continuous clay films; gradual boundary.
		B_{22t}	40–76	Very dark gray (10YR 3/1) clay; strong coarse prismatic structure; very firm, sticky, plastic; continuous clay films; gradual boundary.

Table 1—*Continued*

Great group	Soil series	Horizon	Depth	Profile description
		B_3	76–94	Dark gray (10YR 4/1) with few coarse faint grayish brown (10YR 5/2) mottles; clay loam to clay; moderate coarse subangular blocky structure; sticky, plastic; common medium iron and manganese concretions; gradual boundary.
		C_{ca}	94–100	Grayish brown (10YR 5/2) and light brownish gray (2.5Y 6/2); clay; common medium and coarse $CaCO_3$ concretions.
Argiudolls	L41	A_{11}	0–15	Very dark grayish brown (10YR 3/2) loam to silt loam; weak medium subangular blocky structure; friable; gradual boundary.
		A_{12}	15–28	Very dark gray to very dark grayish brown (10YR 3/1.5); loam to silt loam; weak medium and fine angular and subangular blocky structure; friable; clear boundary.
		A_2	28–40	Dark gray to very dark gray (10YR 3.5/1) loam; very weak medium subangular blocky structure to massive; friable; few common iron and manganese concretions; clear boundary.
		B_{21t}	40–65	Very dark gray to black (10YR 2.5/1) heavy clay loam; strong coarse prismatic parting to strong coarse subangular blocky structure; sticky and plastic; continuous clay films; common fine iron and manganese concretions; gradual boundary.
		B_{22t}	65–80	Very dark gray (10YR 3/1) clay; strong coarse subangular blocky structure; sticky and plastic; continuous clay films; gradual boundary.
		B_{3ca}	80–90	Very dark grayish brown (10YR 3/2) clay; moderate coarse subangular blocky structure; sticky and plastic; discontinuous clay films; few medium $CaCO_3$ concretions; gradual boundary.
		C_{ca}	90–100	Grayish brown (10YR 5/2) clay to silty clay; sticky and plastic; common medium $CaCO_3$ concretions.
Hapludalfs[6]	L42	A_1	0–22	Dark grayish brown (10YR 4/2) moist and light brownish gray (10YR 6/2) dry; loam; massive; friable; gradual boundary.

***Table 1**—Continued*

Great group	Soil series	Horizon	Depth	Profile description
		A_2	22–25	Dark gray to dark grayish brown (10YR 4/1.5) moist and light gray (10YR 7/1.5) dry; loam; weak medium platy structure to massive; friable; abrupt irregular boundary.
		B_{21t}	25–40	Very dark gray (10YR 3/1) clay; moderate coarse prismatic structure; sticky, very plastic; discontinuous clay films; coatings of silt and sand, gradual boundary.
		B_{22t}	40–60	Dark gray (10YR 4/1) clay; moderate coarse prismatic structure; sticky, very plastic; continuous clay films; gradual boundary.
		B_{3ca}	60–90	Very dark grayish brown to dark grayish brown (10YR 3.5/2) with common coarse faint dark brown (7.5YR 3/2) mottles; clay loam to clay; weak to moderate coarse subangular blocky structure; sticky, very plastic; few medium and coarse $CaCO_3$ concretions; gradual boundary.
		C_{ca}	90–100	Grayish brown (10YR 5/2) clay loam and clay; common medium and coarse $CaCO_3$ concretions.

[1] Depth of the solum varies from 70 to 110 centimeters within short distances and in places goes directly to the unweathered basalt. Within the soil mass and at variable depths there are concentrations of pebbles in pockets.

[2] Depth of the A horizon frequently gets to 50 cm. There are discontinuous strata of cobbles in the B_{23}, B_3 and C horizons.

[3] There are cobbles throughout all the soil mass. Depth of the solum varies from 40 to 60 cm.

[4] Depth of solum varies from 60 to 80 cm, and sometimes there is a discontinuous stratum of cobbles in the base of the profile.

[5] The A_2 horizon is discontinuous. The thickness of the A horizon varies between 25 to 35 cm.

[6] In places the C_{ca} horizon is inexistent and the B_{22} or B_3 horizon lies directly on the unweathered rock (basalt).

shows that nearly 60% of the soils are Mollisols, which are deep soils that have a thick dark surface horizon, are relatively rich in organic matter, have a high base saturation throughout, and no deep, wide cracks in most years. Inceptisols occupy over 25% of the area. They lack horizons of clay accumulation and include the wet soils where gleying is dominant and others where the impact of the soil forming process is yet too weak. Almost 7% of the soils have been classified as Vertisols. They are dark

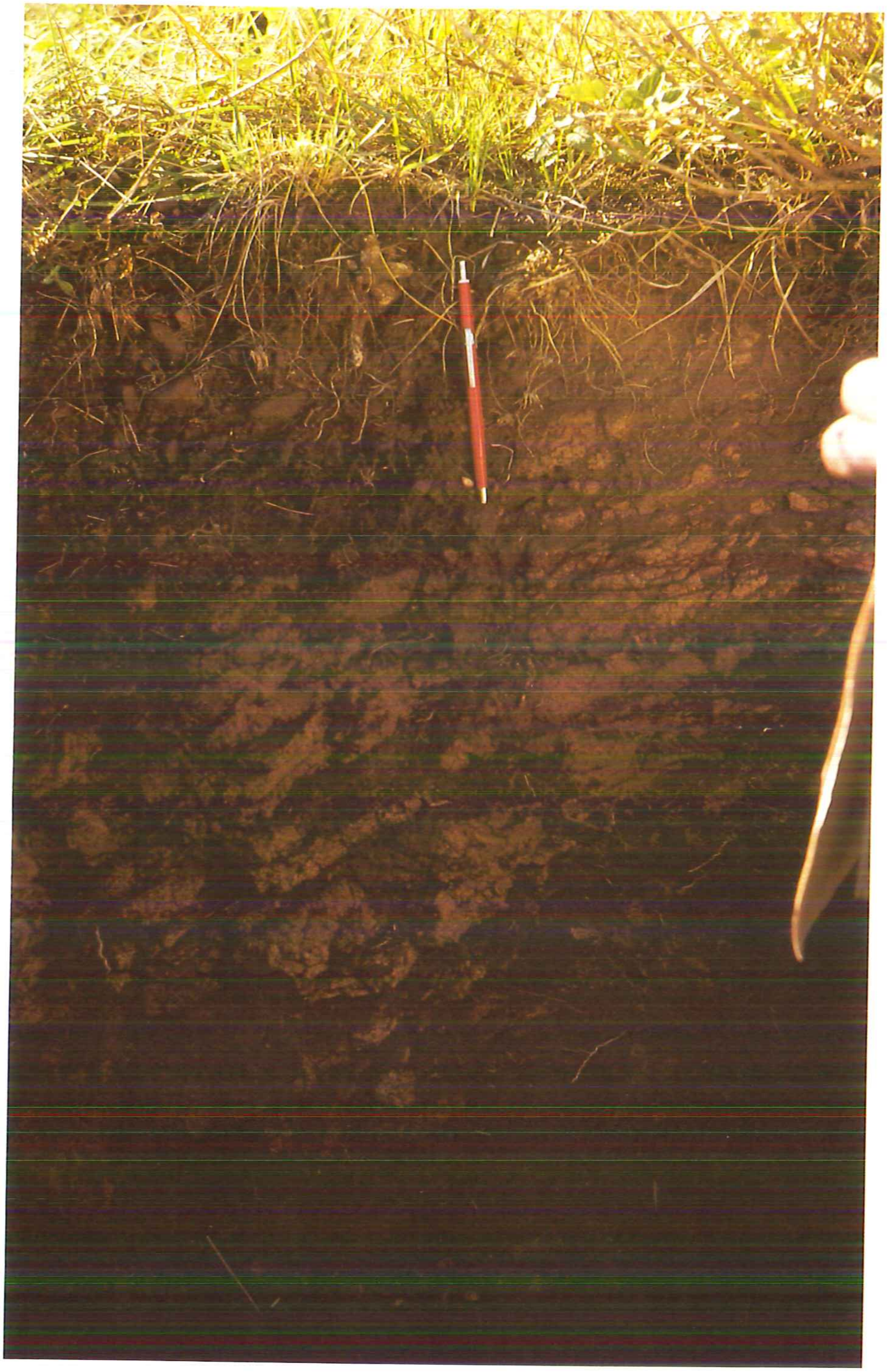

FIG. 1.—Inceptisol over basalt.

FIG. 2.—Weakly developed soil with some horizonation. Mollic epipedon in A; Argillic in B_t.

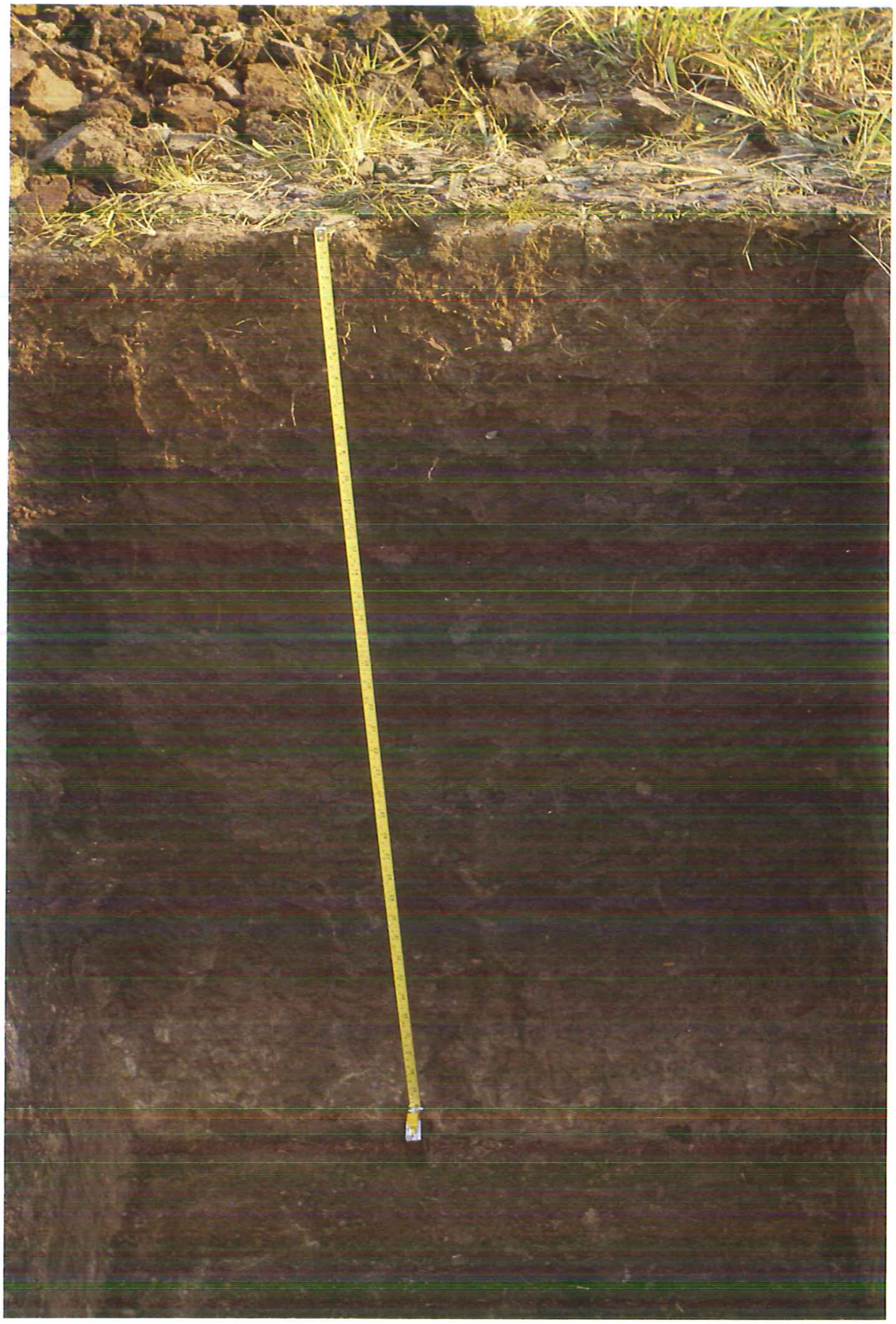

FIG. 3.—Mollisol showing clear textural differentiation between A and B_t. The A-horizon is a sandy clay loam while the B_t is clay with very slow hydraulic conductivity.

FIG. 4.—Typical Vertisol formed over silty clay alluvium with sand and gravel underlain by weathered basalt.

clayey soils that exhibit cracks at some time in most years. Slightly over 1% of the soils are Alfisols which are relatively low in organic matter, have a relatively high base saturation and an illuvial clay horizon. The rest of the area (6 to 7%) includes complexes of various soils that could not be mapped. They are mostly Mollisols-Inceptisols, Mollisols-Alfisols, Vertisols-Inceptisols and Vertisols-Mollisols associations.

Soil	*Major properties*	*Total area, ha*
Mollisols	Deep, dark, medium texture, well-developed B horizon, moderately well-drained, high fertility	11,175
Inceptisols		
Deep	Clayey, poorly drained, high fertility	2,500
Shallow	Medium to heavy texture, well-drained, high fertility	2,156
Vertisols	Very deep, dark, clayey, restricted drainage, very high fertility	1,300
Alfisols	Deep, light texture, imperfect drainage, medium fertility	1,113

A soil survey of 18,621 ha reveals that more than 90% of the soils are deep and moderately deep. They are mostly sandy clay loams (over 60%) and clay loams, derived from alluvium and basalt. There is a large variability in soils over relatively small areas. In general, the inherent fertility is rather high, but the soils need fertilizers, particularly nitrogen and potassium, for successful crop production on a continuous basis. Many of the soils have been subjected to leaching over the years by intense rainfall and poorly managed irrigation. Soil survey data indicate that in 14.6% of the soils erosion is likely to occur. This can be aggravated by inadequate management. In 38% of the soils there are drainage problems, mostly attributable to impervious underlying clay layers at 30 cm which extend to 1 m depths, dominated by montmorillonite. Unfortunately, there are no data available on infiltration and hydraulic conductivity of subsoils.

Table 2 shows land uses, capabilities and limitations of the soils. The total net area available for cropping amounts to 14,673 ha, i.e., nearly 80% of the total land area mapped. There are no apparent limitations to continuous cropping in 1/3 of the net area. In slightly over 1/4 of the land there is risk of compaction and crusting, whereas in slightly more than 1/10 of the land there is a very high erosion risk mainly attributable to poor management on 6–12% slopes. Drainage problems are limiting factors in 1/4 of the net area. Approximately 3,735 ha out of 7,029 in class V are subject to flooding at least once in 7 years.

The following tabulation gives information on slopes.

Slope	*Total area, ha*	*Percent of total area*
0–1	8,996	48.3
1–6	7,584	40.7
6–12	2,041	11.0

Nearly one-half of the land falls in the 0–1% slope range, i.e., they are nearly flat and comprise the soils with restricted drainage. The other one-half of the land is in the 1–12% slope range and presents varying risks of erosion. On 11% of the land, soil erosion is a serious problem mainly due to slope. In nearly 41% of the soils, erosion damage can be serious if the soils are not well managed. The most important factors are field layout, and irrigation and drainage designs.

TABLE 2.—*Land use capability classes in the Bella Unión area*

Capability class	Use capability and limitations	Total area, ha	Net area, ha[1]	Percent of net area	Percent of total area
I	Continuous cropping; no apparent limitations	4722	4593	31.3	25.4
II	Continuous cropping; risk of compaction and crusting	4278	4123	28.1	22.9
III	Continuous cropping, relatively low fertility	551	532	3.6	2.9
IV	Continuous cropping, slope, high erosion risk	2041	1689	11.5	10.9
V	Continuous cropping, imperfect to poor drainage; some soils subject to flooding	7029[2]	3735	25.5	37.7

[1] Excluding urban ureas, roads and lands subject to flooding.

[2] Of the 7,029 ha 44% (3,127) were exluded because they are subjected to flooding. Of these, 500 ha are probably in sugar cane.

Very limited data have been obtained on retention at 1/3 bar, water storage at various tensions and water availability at the Calagua, Cainsa-Calpica and Franquía sites (tables 3 and 4). Assuming that the water held at tensions approaching 1/10 atmosphere can be used by plants before it drains away, and considering the 15-atmosphere percentage as the upper limit, the available water that the soils at Calagua can supply to growing plants ranges from 8.6% in a Mollisol to 19.7% in the A horizon of an Alfisol. This is acceptable in view of the fact that the supply is gradually replenished with rainfall and irrigation water. The available water sharply drops to 12% in the B horizon of this soil. In all

TABLE 3.—*Bulk density, porosity and water retained at various tensions of selected soils at Calagua*

Great group	Series	Horizon	Depth	Bulk density	Porosity	Water retained at indicated bars, %				Available water
						1/10	1/3	1	15	
			Cm	*g/cm³*	*%*					*%*
Argiudolls	L2	A_1	0–20	1.40	44.2	32.6	29.3	27.3	20.9	11.7
		B_2	20–45	1.58	38.0	36.9	34.4	32.7	25.0	11.9
Argiudolls	L1	A_1	0–25	1.48	42.0	29.2	25.2	23.3	16.1	13.1
		A_3	25–35	1.43	44.1	31.8	28.2	26.6	20.0	11.8
		B_2	35–55	1.64	36.4	32.2	29.9	28.7	23.0	9.2
Argiudolls	F2	A_1	0–15	1.24	50.5	34.6	32.3	30.7	21.5	13.1
		B	15–50	1.30	49.0	40.1	37.4	35.8	26.0	14.1
Pelluderts	LB2	A_1	0–20	1.20	52.0	33.6	31.6	30.2	25.0	8.6
		A_3	20–40	1.33	47.0	32.3	29.2	25.9	—	—
		B	40–70	1.30	48.6	40.7	39.0	37.9	32.0	8.7
Hapludalfs	S2	A_1	0–20	1.55	40.6	19.9	16.5	15.7	10.6	9.4
		A_3	20–35	1.60	38.7	21.4	18.5	17.0	—	—
		B	35–50	1.65	37.0	36.8	34.8	33.7	26.6	10.3
Argiudolls	L41	A	0–28	1.30	48.8	37.1	34.1	31.4	17.3	19.8
		B	40–80	1.35	47.1	42.0	39.9	38.9	30.0	12.0
Hapludalfs	L42	A	0–22	1.50	41.0	28.2	24.7	21.9	14.0	14.2
		B	25–40	1.45	44.1	42.7	40.2	38.0	26.0	16.8

Mollisols, the lower A_2 and B horizons can store as much available water as the topsoil. In general, the available water supplying capacity of the soils is rather good. This is further confirmed by the data on available water on the root zone of selected soils from Calagua as shown in table 5. Effective root zone ranges from 5 to 60 cm. These values were estimated based on soil morphology, bulk density and proportion of macro to micropores. Available water ranges from 6 to 60 mm. The following

TABLE 4.—*Bulk density and water retention at 1/3 and 15 bars at Cainsa-Calpica and Franquía Alta*

Location	Depth, cm	Bulk density g/cm³	Water retained at indicated bars, %		Available water, %
			1/3	15	
Cainsa-Calpica	0–20	1.19	37.4	22.9	14.8
	20–40	1.33	42.0	29.6	12.4
	40–60	1.35	42.2	29.3	18.9
	60–80	1.48	41.6	25.2	16.4
Franquía	0–20	1.45	21.1	8.3	12.8
Alta	20–40	1.67	24.4	10.8	13.6
	40–60	1.57	35.7	20.6	15.1
	60–80	1.64	32.8	20.4	12.4
	80–100	1.67	32.2	18.7	13.5

TABLE 5.—*Effective root zone and available water of the soils at Calagua*

Soil series	Area		Effective root zone, cm	Available water, mm
	Total, ha	%		
L1	408.3	8.20	35	45
L2	278.5	5.59	30	31
L3	36.5	0.73	20	28
L4	182.1	3.65	25	50
L5	220.3	4.42	40	54
L41	91.1	1.83	30	60
L42	72.3	1.45	25	37
L15	60.9	1.22	40	41
LB2	1,130.3	22.7	60	52
LB3	99.2	1.99	30	33
LF2	258.1	5.18	40	45
L51	125.2	2.51	30	30
F2	206.6	4.15	50	67
S2	106.0	2.13	40	37
B1	44.5	0.89	20	24
B11	100.9	2.02	5	6
B12	249.5	5.01	30	24
B13	150.7	3.03	20	20
B2	286.0	5.74	45	40
SB1	4.5	0.09	30	30

tabulation shows the distribution in hectares of the soils classified according to available water intervals.

Range of available water, mm	*Distribution*	
	Ha	%[4]
Less than 12	100.9	2.02
13–24	941.8	18.90
25–36	992.1	19.90
37–48	929.9	18.70
49+	1269.9	25.51

Twenty-five percent of the soils have good available water supplying power; 57%, satisfactory; and only 2%, very low. In general, most of the soils at Calagua can retain sufficient moisture readily available to plants.

Bulk density values at the topsoil at Cainsa-Calpica are much more favorable than equivalent values at Calagua (table 4) and at Franquía Alta. The higher bulk density values at Calagua can be probably attributed to compaction. The most extensive soils have more macropores, a condition conducive to good internal drainage and no impedance to root penetration. This probably indicates a more favorable soil structure and better water movement throughout the profile. However, water retention and supply values are similar in the Cainsa-Calpica and Franquía Alta as in the Calagua soils.

Chemical data on selected soils of Calagua are given in table 6. Organic matter levels range from 1.69 to 5.31% in the A1 horizon and decrease gradually with depth. Cation exchange capacity (CEC) values are high and increase from the A to the B horizons. Total bases are approximately 60 to 75% or more of the CEC. Exchangeable calcium (Ca) is usually from 50 to 75% of the total bases. These data are reliable indices of the high fertility of the soils. In general, the soils at the Bella Unión area are somewhat acid (pH 5.2 to 6.4) in the A horizon.

POTENTIAL

The soils of Bella Unión appear to have a great potential for sugarcane, rice, sweet sorghum, grain sorghum, forage and horticultural crops such as tomatoes, squash, melons, cabbage and others. Any program for the improvement of crop production in the area must provide for efficient irrigation at critical periods. The main sources of irrigation water are the Uruguay and Cuareim rivers. There are some streams like the Itacumbú which supply water to nearby fields. Existing irrigation systems are obsolete. Drainage is also an essential component of the water management system. The use of open drains at suitable depths and spacings will

[4] Percentage of total area (approx. 4,978.7 ha).

TABLE 6.—*Chemical data on selected soils at Calagua*

Series	Horizon	Depth	pH	Organic matter	Exchangeable					CEC	Total bases
					Ca	Mg	K	Na	H		
					Meq.						
		Cm		%							
S2	A_1	0–20	5.2	1.69	3.7	2.1	0.33	0.16	1.8	8.1	6.3
	A_3	20–35	5.8	1.35	5.5	2.6	0.16	0.15	1.7	10.1	8.4
	B_{21}	35–50	6.0	0.96	11.0	4.2	0.18	0.23	1.6	17.2	15.6
	B_{22}	50–65	6.3	0.74	12.1	5.8	0.18	0.23	0.9	19.2	18.3
	B_{23}	65–90	6.6	0.20	14.5	3.8	0.16	0.24	0.8	19.5	18.7
	B_3	90–105	6.6	0.17	13.2	3.7	0.22	0.24	0.3	17.7	17.4
	C	105–110	6.6	0.09	13.8	2.9	0.21	0.24	0.2	17.4	17.2
L1	A_1	0–25	5.8	2.89	7.9	2.3	0.14	0.20	3.2	13.7	10.5
	A_3	25–35	6.0	2.51	9.1	2.5	0.10	0.28	3.0	15.0	12.0
	B_{23}	35–55	6.1	1.55	13.8	3.8	0.19	0.53	2.2	20.5	18.3
	B_3	55–65	6.3	0.93	18.2	2.9	0.17	0.55	1.6	23.4	21.8
	C	65–75	7.9	0.48	30.6	4.1	0.25	0.91	—	35.9	35.9
L2	A_1	0–20	6.0	4.42	12.6	3.8	0.23	0.21	2.8	19.6	16.8
	B_2	20–70	6.4	1.77	20.8	5.6	0.22	0.69	1.3	27.3	26.0
	B_3	70–80	7.1	0.93	25.7	2.2	0.28	0.76	—	28.9	28.9
LF2	A_1	0–20	6.2	4.28	14.2	3.8	0.34	0.27	2.9	21.5	18.6
	A_3/B_1	20–37	6.3	3.32	16.0	3.2	0.18	0.34	2.9	23.2	20.3
	B_{21}	37–50	6.9	1.66	25.0	6.2	0.22	0.50	0.4	32.3	31.9
	B_{22}	50–60	7.2	0.93	25.9	7.2	0.30	0.61	—	34.0	34.0
LB2	A_1	0–20	6.1	5.31	17.8	7.2	0.28	0.22	3.5	29.0	25.5
	B_2	40–60	6.3	2.76	19.8	6.2	0.21	0.34	3.1	29.7	26.6
	B_3	60–70	7.1	0.84	31.7	10.6	0.33	0.42	—	43.0	43.0

L42	A_1	0–22	6.0	1.35	4.0	3.1	0.09	0.47	1.50	9.2	7.7
	A_2	22–25	6.0	1.11	5.1	2.6	0.11	0.54	1.70	10.0	8.3
	B_{21}	25–40	6.2	1.45	15.4	3.7	0.17	1.50	1.90	22.7	20.8
	B_{22}	40–60	7.5	0.93	22.0	5.5	0.28	1.75	—	29.5	29.5
	B_3	60–90	8.2	0.35	26.2	3.1	0.27	1.60	—	31.2	31.2
F2	A_1	0–15	6.4	3.72	18.1	2.9	0.43	0.22	2.3	24.0	21.7
	B_1	15–30	6.5	3.35	20.6	2.4	0.24	0.25	2.2	25.7	23.7
	B_2	30–40	6.6	2.45	22.0	3.8	0.19	0.31	0.9	27.2	26.3
	B_3	40–50	6.7	1.98	26.4	3.9	0.34	0.36	0.6	31.6	31.0
	C	50–70	7.6	0.93	30.3	4.9	0.35	0.50	—	36.0	36.0
L41	A_1	0–28	5.9	2.85	7.0	4.9	0.10	0.54	2.40	14.9	12.5
	A_2	28–40	6.5	1.25	6.9	3.1	0.09	0.51	1.30	11.9	13.2
	B_2	40–80	6.8	1.53	12.7	5.1	0.14	0.94	0.30	19.2	18.9
	B_3	80–90	7.9	0.61	21.2	5.7	0.24	1.40	—	28.5	28.5

be practical. Well designed multipurpose projects involving irrigation, drainage, erosion control and production observed at the Calpica site should be followed by other groups of farmers. Land preparation should include smoothing and levelling where feasible. Farmers appear to be using more fertilizer than needed, particularly phosphorus. There is evidence of phosphorus accumulation in the soil arising from relatively large applications to previous crops. Under good management, sugarcane offers a distinct potential (4). The 8,000 ha now under sugarcane cultivation could be extended by an additional 1,500 or 2,000 ha which will help to extend the milling season and to conform to the capacity of the existing mill. Rice production with irrigation could be increased. The possibilities of sweet sorghum as an energy crop appear good, but need further investigation (5). Rainfed grain sorghum can probably be produced successfully. Short cycle horticultural crops could take advantage of the seasons and the produce could be marketed advantageously in Montevideo. Cattle and sheep will continue to be major sources of income in the area, but production could be improved through more adequate management systems.

RESUMEN

Los suelos del área de Bella Unión, en el noroeste del Uruguay, son profundos, de alta fertilidad y capaces de suministrar suficiente agua para las cosechas. Son suelos principalmente de textura franco-arcillo-arenosa y franco-arcillosa. El pH varía de 5.2 a 6.4. El 38% de los suelos tiene problemas de desagüe, mayormente atribuibles a capas pesadas subyacentes de arcillas montmorilloníticas. Tanto el riego como el desagüe son esenciales para que las cosechas produzcan altos rendimientos. La erosión puede convertirse en un serio problema si los suelos no se protegen adecuadamente. Las zanjas, a profundidades y distancias adecuadas, pueden ayudar a proveer un ambiente óptimo en la zona de raíces de las cosechas. Si estas zanjas se diseñan bien, pueden ayudar a minimizar los daños que causa la erosión.

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Research Note

EFFECTS OF ADDING MAGNESIUM NITRATE BEFORE DRY-ASHING ON PHOSPHORUS IN HONDURAS PINE FOLIAGE[1]

Several authors have recommended adding magnesium nitrate or magnesium acetate to dried plant material before ashing.[2,3,4] This pre-ashing treatment reportedly reduces P volatilization from pine foliage, seeds, or other vegetative material that is inherently low in bases. A disadvantage is that Ca and Mg cannot be determined in the same ashed sample because of added salts.

Unpublished data (C. G. Wells, personal communication)[5] suggest that pre-ashing is not needed for foliage of conifers found in the Southern United States. Eliminating any pre-ashing treatment would save considerable laboratory sample preparation and analysis time while allowing determination of bases in the same samples. This study involved examination of the effects of adding magnesium nitrate to P concentrations in Honduras pine (*Pinus caribaea* Mor. var. *hondurensis* Barr. and Golf.) foliage.

Thirteen foliage samples were collected from two different areas in Puerto Rico (table 1). Trees in the private planting were 3 to 4 years old and those at the Institute of Tropical Forestry grounds were almost 13 years old. All samples were oven-dried at 70° C, ground to pass a 1 mm sieve, and stored in screw-tight vials before being shipped to Analytical Services Laboratory (ASL), Soil Science Department, North Carolina State University, in Raleigh, North Carolina. For each sample, duplicate 2.5 g subsamples (A and B) were weighed and placed in porcelain crucibles. The A set was first wet with a 7.5% magnesium nitrate solution that was then evaporated by a steam bath; the B set was nontreated. Subsamples were ashed overnight in a muffle furnace at 500° C. After the furnace was opened, all subsamples were allowed to cool, were wet with distilled water, and 2 ml of concentrated HCl was added; crucible contents were then evaporated slowly to dryness on a hot plate. After dehydration, 2 ml of distilled water followed by 2 ml of concentrated HCl were added, the crucible residues being redissolved slowly over low heat. Contents from the crucibles were then transferred to 50 ml flasks in which the solutions were brought up to volume with distilled water.

[1] Manuscript submitted to Editorial Board July 5, 1982.

[2] Jackson, M. L., 1958. Soil chemical analysis, Prentice-Hall, Inc., Englewood Cliffs, N.J.

[3] Piper, C. S., 1944. Soil and plant analysis, Interscience Publishers, Inc., New York.

[4] Wilde, S. A., R. B. Corey, J. G. Iyer and C. K. Voight, 1979. Soil and plant analysis for tree culture, 5th ed, Oxford and IBH Publishing Co., New Delhi, India.

[5] Principal Soil Scientist, USDA Forestry Sciences Laboratory, Research Triangle Park, N.C.

Phosphorus was determined in phosphomolybdic acid by reading absorbance at 470 nm on a spectrophotometer.

No significant differences ($p \geq 0.10$) appeared between overall means of treated and nontreated samples (table 1). For individual trees growing on different soil types and representing different ages, little differences showed between treated and nontreated samples. Adding magnesium nitrate probably did not affect P concentrations because of the relatively low ashing temperature used in this study.

TABLE 1.—*Foliage P results from dry-ashing* Pinus caribaea *var.* hondurensis *needles with and without 7.5 % magnesium nitrate*

Sample number[1]	Tree height	Topography/soils	Dry-ashing; foliage P Nontreated	Treated
	m		%	
1	4	Slope, subsoil spoil	0.080	0.070
2	7	Slope, non-spoil	0.070	0.070
3	4	Slope, non-spoil	0.095	0.100
4[2]	8	Flat, topsoil removed	0.110	0.120
5	5	Flat, topsoil removed	0.088	0.085
6	8	Fat, topsoil removed	0.085	0.093
7	6	Flat, topsoil removed	0.138	0.134
8	4	Flat, topsoil removed	0.132	0.134
9	15	Flat, heavy clay	0.100	0.100
10	13	Flat, heavy clay	0.119	0.116
11	14	Flat, heavy clay	0.123	o.119
12	15	Flat, heavy clay	0.141	0.140
13	15	Flat, heavy clay	0.086	0.095
		$\bar{x}$	0.105	0.106
		Paired-t Test	NS[3]	

[1] Trees 1 to 8 located on a private farm near Carite State Forest, Puerto Rico; foliage samples taken from upper third of the crown. Trees 9 to 13 located at Institute of Tropical Forestry grounds, Río Piedras, P.R.; foliage samples taken from lower crown branches.

[2] Foxtail individual.

[3] Paired-t test nonsignificant ($P \geq 0.10$).

Low ashing temperatures are routinely used at the ASL in Raleigh as well as at the USDA Forest Service's Forestry Sciences Laboratory at Research Triangle Park, N.C. Ashing temperatures used by authors recommending pre-ashing treatment with magnesium salts were between 600° and 800° C. Other researchers have reported that ashing temperatures above 500° C will affect foliage concentrations for certain elements of citrus.[6] In future foliar analytical work with pine in Puerto Rico, low

[6] Labanauskas, C. K. and M. F. Handy, 1975. Dry-ashing temperature, time, and sample size as variables influencing concentrations in citrus leaf analysis, HortScience 10:386–88.

ashing temperatures should continue to be used and pre-ashing treatment with magnesium salt is not necessary.

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ERRATUM

Inadvertently the title of the article in page 446 of Vol. LXVII, No. 4 (October 1983) of the *Journal of Agriculture of the University* of Puerto Rico was edited and changed from the one that appears in the table of contents on the cover. The correct title is "Crop response to soil acidity factors in Ultisols and Oxisols in Puerto Rico. IX. Taniers."