MORPHOLOGICAL AND PHYSICOCHEMICAL PROPERTIES OF VARIOUS TROPICAL SOILS FROM EAST-CENTRAL PUERTO RICO

M. A. Lugo-López, M. B. Martínez, and A. R. Riera[1]

Introduction

The mineral soils of east-central Puerto Rico are derived mainly from upper cretaceous rocks such as massive andesitic tuffs, and volcanic and igneous rocks including coarse quartz diorites and granites. Temperature is more or less equal throughout the year as in the rest of the Island and the area as a whole receives as much rainfall as the northern and eastern humid sections. The topography varies from level or nearly level as in the Caguas, Humacao, Yabucoa, and other lowlands through undulating, as in the vicinity of Las Piedras, Juncos, and San Lorenzo, to steep in the surrounding hills and mountains. Large-scale sugarcane farming predominates in the region, but upland rice, corn, root crops, and vegetables are grown on a subsistence basis. Soiling and pasture grasses are also grown extensively throughout the section. In the lowlands adequate drainage is of primary importance to obtain profitable crop yields.

This paper reports the results of a preliminary study of the morphological and some physicochemical properties of selected soil profiles from the region. The objective of the work was to gather some basic knowledge on the characteristics of the most important soils of the area which may lead to a better understanding of their behavior.

Materials and Methods

For the morphological studies pits 4 feet wide, 3 feet long, and 6 feet deep were dug at various selected scattered and distant places in east-central Puerto Rico. Information was then secured on number of horizons, thickness, color, and apparent texture and structure. Tests for the pH of each soil layer were made in the field by using a soil teskit. Observations

[1] Associate Soil Scientist, Research Assistant in Agricultural Engineering, and Associate Chemist, respectively, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R. The writers wish to express their appreciation to Dr. R. M. Smith, formerly Supervisor of the Cooperative Bureau of Plant Industry, Soils, and Agricultural Engineering—Soil Conservation Service Research Project, now Director of the Blackland Experiment Station, Texas; and to Dr. J. A. Bonnet, Head of the Department of Soils of this Station, for their help in describing the soil profiles. Mr. S. Silva cooperated in taking the soil cores and in the physical measurements conducted at the laboratory. Appreciation is also expressed to O. L. Heyn and R. McConnie, of the Eastern Sugar Associates, for their cooperation in selecting the fields, and providing all labor and transportation when required.

were made also on root development throughout the profile. Samples were taken from each profile for chemical analysis in the laboratory.

Undisturbed soil cores were taken from several places to a depth of 72 inches by using a Kelley soil sampling machine (2).[2] Permeability measurements were made in these cores by recording the rate at which water moved through a column of saturated soil at a known head. In this measurement special equipment was used as described by Smith, Furhiman, and Silva (11). Quick drainage was determined by taking the saturated core to a Buchner funnel, setting up a 60-cm. tension, and measuring the water drained out at the end of 15 minutes. The water removed and retained at pF 1.78 was measured by bringing the soil cores to equilibrium with a 60-cm. tension and determining the variation in weight of the core. Water remaining at pF 2.7 and pF 4.2 was determined by submitting saturated soil samples to pressures of 1/2 and 15 atmospheres, respectively. The maximum saturation was calculated from the above data.

The soil core was finally dried in the oven at 110°C. As the samples used had a definite known volume, the bulk density of the soil was calculated by dividing the net dry weight of soil by its original volume. The pore space was then calculated by assuming a specific gravity of 2.65 which can be used advantageously for Puerto Rican soils (4).

The pH was determined electrometrically by means of a Macbeth pH meter. Conductivity measurements were made by using a standard solubridge. Total nitrogen was determined by the standard Kjeldhal method and the organic matter by the simple colorimetric Schollenberger technique. The exchange capacity was determined by the ammonium acetate method (10).

Infiltration tests were run in the field by using the buffer compartment method as outlined by Nelson and Muckenhirn (8). The procedure is briefly as follows:

> Three concentric iron rings, each 5 inches in height, and 9, 18 and 27 inches in diameter, are driven into the ground 2 or 3-inch surface. The soil inside the two outside rings is kept saturated with water while the test is running. The infiltration test is run in the soil within the inner 9-inch ring, over which hangs a calibrated 2,000 ml. burette, the water reservoir. A volume of 1,043 ml. in this burette is equivalent approximately to one inch of water added to the 9-inch soil core. A pinchcock serves as a valve at the rubber hose that connects the tip of this burette to a small glass tube. The burette is filled with water to the 2,000 ml. mark and stoppered. The stopcock is opened and the starting time is recorded. Water infiltrates rapidly at first, into the soil, until the thin film of water that collects on the top soil touches the end of the small tube. This film serves as a regulator for the water to run from the burette as fast as the soil requires it. The time is recorded every time the burette is emptied to the zero mark. At this time the pinchcock is closed rapidly and the burette is refilled with water. The outfit is kept covered with a canvas.

[2] Numerals in parentheses refer to Literature Cited, p. 178.

The tests were run for eight consecutive hours. The amount of water used every hour was recorded. Each test was run in quadruplicate.

Morphological Characteristics of the Soils

A soil profile was studied in a pasture field of about 10 acres, at Colonia Preston, near road 28, (Juncos-Naguabo) Km. 12 H. 9. The soil was previously mapped in the Soil Survey of Puerto Rico (9) as Vía silty clay, but field examinations indicated that it approached more a Caguas silt loam. The soil was in native pasture, mostly carpet grass mixed with some native legumes and many weeds. The root development was rather weak all the way down, thinning out considerably with depth, being practically none below the 16-inch layer. The slope of the field ranged from about 4 to 10 percent.

A soil profile examined on September 26, 1950 was as follows:

- 0–7″ Light grayish-brown silt loam with some admixture of yellowish subsoil. Many large, dark concretions, some ½″in diameter, mostly about ⅛″. Not definite and rather fine granular structure. pH 6.6.
- 7–16″ Highly mottled, predominantly yellow clay. Well-developed fragmental-blocky structure. pH 6.0. Transition layer.
- 16–26″ Highly mottled clay, gray color predominant. Fragmental-blocky structure coarser than above. Cut like putty. Concretions in the upper 16–22″ section. pH 5.0.
- 26–30″ + Gray, mottled brown and reddish-brown silty clay. Material resembling colloidal films along the cleavage planes. Prismatic structure, coarse, with tendency to vertical cleavage. pH 5.0.

On September 26, 1950 another profile was studied in a field at Colonia Sabana, road Las Piedras to San Lorenzo, Km. 17 H. 7. The sod had been recently turned under and the soil was being prepared for sugarcane planting. The soil was mapped as Las Piedras loam. It is derived from granite and occurs in gently rolling or undulating areas. The soil was covered with unimproved native pasture plants, but the root development was better than that observed in the profile previously described.

The profile examined was as follows:

- 0–7″ Light gray-brown loam or silt loam. Weak, crumb structure. Friable. pH 5.7.
- 7–19″ Highly varied color, but not true mottling, probably inherited from the parent material. Red, reddish-brown, and yellow clay loam. Blocky structure. pH 5.2.

19–26″	More rock color, loses reddish color. More sand, less clay. Some black streaks. pH 5.4. A transition zone to parent material.
26–50″ +	Fractures inherited from rock. Granular, light-yellow fine sand with block concretionary material. pH 6.4.

On October 26, 1950 a profile of Vía silty clay was examined at Colonia Buena Vista, on the outskirsts of Gurabo bordering the road to Trujillo Alto. The slope of the field was about 2 or 3 percent. The vegetation consisted mostly of sourgrass (Paspalum conjugatum) and weeds of the Calopogonium, Sesbania, Cyperus, Mimosa, and Eurena genera. All roots were concentrated above the gravel layer.

0–8″	Very dark gray to dark grayish-brown silty clay containing some gravel. Fragmental-blocky structure, medium size. pH 6.2.
8–11″	Transition zone.
11–21″	Gravelly clay, more gravel in the lower part. Some brown, gray, and yellowish mottling, the last predominating. Blocky structure. pH 7.0.
21–30″	Gravel layer. Very weak structure.
30–65″	Clay loam. Yellowish-brown with dark gray. Prismatic structure. From 32–38″ is more gravelly than below. From 40–48″ more uniform with some almost black mottlings. From 48–60″ contains more sand.
65–72″ +	Second gravel layer.

A profile of Mabí silty clay was studied on November 8, 1950, at the Buonomo farm near the Gurabo-Caguas road. The slope of the field was about 3 percent. The vegetation consisted mostly of carpet and Bermuda grasses.

0–10″	Dark reddish-brown silty clay with some small stone fragments. Fairly well-developed medium fine fragmental-blocky structure.
10–20″	Dark reddish-brown, silty clay with very little mottling. Fairly dense, distinct fragmental-blocky structure.
20–30″	Structure coarser than above, became more massive with depth.
30–38″	Sandy clay layer, rather loose.
36–48″	Clay layer, tight.
48–60″ +	Very dense clay layer.

A profile of Mabí clay loam, poorly drained phase, was examined near the road from Las Torres to Las Piedras. The slope of the field was about 2 percent. The field had a dense stand of malojillo.

0–9″ Dark-brown mottled clay loam with dark iron and manganese concretions.

9–21″ Sandy clay loam. Mottled from almost white to almost black, predominantly white, pale color. Also grayish brown. Lower part began to change to reddish yellow. Structure almost massive except for old root holes.

TABLE 1.—*Mean pH, organic matter, nitrogen, and exchange capacity of some selected soils from east-central Puerto Rico*

Soil type	Location	Depth	pH	Organic matter	Nitrogen	Total exchange capacity
		Inches		*Percent*	*Percent*	*M.e./100 gm. dry soil*
Caguas silt loam.......	Colonia Preston	0–7	6.6	1.0	0.15	9.5
		7–16	6.0	(1)	.02	10.0
		16–26	4.9	(1)	.05	11.4
		26+	5.0	(1)	(1)	12.5
Las Piedras loam.......	Colonia Sabana	0–7	4.8	.5	.11	10.6
		7–19	5.8	.3	.03	17.1
		19–26	5.5	(1)	.01	25.1
		26+	6.3	(1)	.01	21.6
Vía silty clay..........	Colonia Buena Vista	0–8	6.4	2.0	.15	18.7
		11–21	6.8	.2	.06	24.4
		21–30	7.0	(1)	.04	22.9
		30–50	7.0	(1)	.03	22.2
		50+	6.9	(1)	.03	16.9

[1] Trace.

21–36″ Sandy clay loam. Highly mottled white, yellowish brown, and black. Structure almost massive. May be tightest layer of profile.

36″ + Water-bearing sandy layer.

CHEMICAL PROPERTIES

The results of the chemical analyses of three profiles sampled in east-central Puerto Rico are shown in table 1. The pH values for Caguas silt loam indicate considerable variability throughout the profile. They range from very strongly acid in the lower two layers to slightly acid or nearly neutral in the surface layer. On the other hand, in the profile of Las Piedras loam the surface soil is very strongly acid while the acidity is only slight after the 2-foot layer. The least fluctuations are observed in the profile of Vía silty clay.

The soils of east-central Puerto Rico are very low in organic matter. The surface layer of Las Piedras loam has the lowest content, only 0.5 percent of organic matter, and Vía silty clay the highest, but only 2.0 percent. The decrease in organic matter from the surface layer to the lower layers in the profile is highly significant. In the Vía silty clay the organic-matter content at the second horizon of the profile is only one-tenth that of the upper 8-inch layer. The nitrogen content of the plow layer in all three profiles is medium low. When going downward in the profile the variations in nitrogen content follow the same pattern as the organic-matter content, decreasing markedly to a very low limit.

The alluvial Vía soil has a total exchange capacity that can be considered moderately high, and high just beneath the plow layer. The values for Caguas silt loam range from moderage to moderately low. In the Las Piedras profile the changes are more radical ranging from moderately low in the upper layers, to moderately high in the lower subsoil.

Physical Properties

Table 2 gives the results of permeability tests and other soil-moisture studies conducted on a number of undisturbed soil cores collected in the area. The permeability measurements made on undisturbed cores of a Caguas silt loam gave very slow and slow rates of percolation for all layers after the upper two feet. The 16–22-inch layer had a moderate rate of percolation of 3.90 inches per hour and the permeability of the surface layer was only 1.31 inches per hour. The "quick-drainage" values follow more or less the same pattern as did permeability measurements. Values for maximum saturation do not differ much for the various layers sampled. Permanent wilting percentage values (water remaining at pF 4.2) are high, ranging from 23.9 percent at the plow layer to 46.2 percent towards the bottom of the 6-ft. profile.

If the available water for crops is regarded as the difference between water remaining in the soil when tensions equivalent to pF 1.78 are applied and that remaining when permanent wilting occurs (pF 4.2) the upper 3 feet of Caguas silt loam will be able to hold about 6.46 acre-inches of water available for crops. A soil with a capacity to store that quantity of available water in the crop root zone can be rated as one having a moderately high water-supplying power.

The permeability measurements on cores of Vía silty clay indicate a rather rapid rate of percolation in the upper 15 inches with a sharp decrease when hitting the 18–24-inch layer. Permanent wilting percentage values range from 16.2 to 26.2 percent, considerably lower than in the first profile. Similar calculations as those made previously in regard to the available water supply indicate a maximum value of 7.76 acre-inches in the crop root zone (upper 38 inches). By comparison with standards which have been established (12) this Vía silty clay profile would rank as having a moderately high available water-holding capacity.

TABLE 2.—*Permeability and other soil-moisture data on soil cores from east-central Puerto Rico*

Soil type	Depth	Permeability	Water drained at 60 cms. in 15 minutes	Maximum saturation	Water remaining at pF—			Available water (water at pF 1.78–water at pF 4.2)
					1.78	2.7	4.2	
	Inches	*Inches/hour*	*Percent*	*Percent-water*	*Percent*	*Percent*	*Percent*	*Percent*
Caguas silt loam......	0–6	1.31	2.5	51.7	46.4	37.0	23.9	22.5
	7–14	1.44	1.9	46.6	42.3	39.9	26.8	15.5
	16–22	3.90	2.0	54.1	50.1	43.3	32.8	17.3
	23–30	.19	1.0	54.8	51.6	46.9	34.9	16.7
	32–38	.22	.9	56.1	54.1	51.0	37.6	16.5
	40–46	—	.8	55.5	53.8	51.0	35.2	18.6
	46–52	.02	.8	54.1	52.6	49.6	34.9	17.7
	53–60	.004	.7	53.1	51.3	50.5	34.9	16.4
	66–72	.001	.3	49.7	48.7	50.5	46.2	2.5
Vía silty clay..........	0–7	4.80	2.8	52.1	45.6	34.5	19.5	26.1
	8–15	2.10	1.1	47.8	45.1	42.2	25.0	20.1
	18–24	.74	2.1	47.3	42.8	43.2	26.2	16.6
	24–31	.86	3.2	44.3	38.1	28.7	16.2	21.9
	32–38	.86	1.6	45.4	40.2	35.9	22.5	17.7
	40–48	3.25	1.5	45.7	42.0	43.3	24.3	17.7
	48–55	1.20	2.1	44.1	40.4	42.7	25.0	15.4
	55–62	.60	1.9	45.9	38.4	35.5	20.9	17.5
Mabí silty clay........	0–8	27.5	3.5	43.1	35.7	36.6	25.4	10.3
	8–16	2.70	2.9	50.5	44.0	42.2	28.4	15.6
	20–26	.028	.6	47.7	46.0	44.0	30.4	15.6
Mabí clay loam........	0–9	7.61	3.0	45.7	39.4	35.0	17.4	22.0
	9–14	8.82	3.9	41.0	31.9	27.7	14.3	17.6
	14–21	1.80	2.6	40.0	31.4	27.8	12.7	18.7
	21–28	2.93	1.6	39.1	34.8	32.8	17.1	17.7
	28–36	1.75	1.5	40.0	35.8	19.5	11.4	24.4
	36–42	8.64	3.5	37.4	26.1	10.4	7.0	19.1

The very rapid percolation rate measured in the upper 8-inch layer of Mabí silty clay probably results from the many channels and root holes observed while sampling. It falls sharply to moderately rapid in the next layer and to very slow when the 20–26-inch layer is reached. Permanent wilting occurs when the soil still retains a relatively large amount of water, thus reducing its available water supply. The measurements made indicate a reliable storage reservoir of 3.65 inches of water in the upper 2 feet of the

TABLE 3.—*Bulk density, pore space, and air capacity of selected soil profiles from east-central Puerto Rico*

Soil type	Depth	Bulk density	Total porosity	Air porosity (total porosity-water retained at pF 1.78)
	Inches	*Gm./c.c.*	*Percent*	*Percent*
Caguas silt loam	0–6	1.26	52.4	6.0
	7–14	1.45	45.3	3.0
	16–22	1.19	55.1	5.0
	23–30	1.21	54.8	3.2
	32–38	1.20	56.1	2.0
	40–46	1.23	55.5	1.7
	46–52	1.30	54.1	1.5
	53–60	1.36	53.1	1.8
	66–72	1.43	49.7	1.0
Vía silty clay	0–7	1.24	53.2	8.6
	8–15	1.39	47.5	2.4
	18–24	1.44	45.7	2.9
	24–31	1.45	45.3	7.2
	32–38	1.48	44.1	3.9
	40–48	1.49	44.5	2.5
	48–55	1.50	43.4	3.0
	55–62	1.53	42.3	3.9
Mabí silty clay	0–8	1.27	52.1	16.4
	8–16	1.31	50.6	6.6
	20–26	1.39	47.5	1.5
Mabí clay loam	0–9	1.43	46.0	6.6
	9–14	1.49	43.8	11.9
	14–21	1.53	42.3	10.9
	21–28	1.57	40.1	5.3
	28–36	1.56	41.1	5.3
	36–42	1.46	44.9	18.8

profile. Assuming the same storage capacity for the next 10 inches, the crop root zone will have 5.21 inches of water available for crops. Similar calculations for the Mabí clay loam profiles show that this soil can store in readily available form approximately 7.36 acre-inches of water in the upper 3 feet where the bulk of the roots of crops plants are generally found.

Table 3 presents data on bulk density, total porosity, and air porosity of four profiles sampled in east-central Puerto Rico. Bulk-density values for the uppermost layers are around 1.25 gm./c.c. for all the profiles, except that of Mabí clay loam where it is 1.43 gm./c.c. As a rule bulk density increases with depth. In general, total-porosity values are larger where bulk-density values are smaller. They range from approximately 40 to 56 percent by volume. The soil solids occupy the remaining soil volume. By far the largest proportion of pores is filled with water at pF 1.78. The air porosity is in inverse relationship to the water porosity.

TABLE 4.—*Mean infiltration capacity of selected soils from east-central Puerto Rico*

Soil type	Location	Infiltration rate in inches of water per hour given—							
		1	2	3	4	5	6	7	8
Caguas silt loam	Colonia Preston	2.21	1.60	1.55	1.60	1.73	1.70	1.00	0.46
Vía silty clay	Colonia Buena Vista	2.06	.60	.67	.75	.77	.92	1.16	1.06
Vía clay loam	Colonia Río Grande	1.29	.17	.17	.16	.13	.17	.23	.19
Vía clay loam	Colonia Miraflores	6.63	4.12	4.08	2.95	2.23	2.15	1.59	1.43
Las Piedras loam	Colonia Sabana	1.70	.73	.69	.76	1.29	1.41	1.49	1.36
Las Piedras loam	Colonia Sabana	3.13	1.83	1.92	1.74	2.14	2.01	2.04	2.09
Las Piedras clay loam	Colonia Doctores	3.81	1.36	1.75	1.65	1.60	1.68	2.02	1.82
Las Piedras clay loam	Colonia Doctores	1.27	1.35	1.11	.97	.75	.69	.99	.29
Mabí clay	Colonia Río Grande	20.19	10.41	4.36	3.56	3.34	2.41	1.64	1.89
Mabí clay	Colonia Preston	.57	.26	.15	.23	.28	.43	.42	.19

INFILTRATION CAPACITY

The Caguas soil had a slow infiltration rate after it had been thoroughly soaked. The rate of infiltration of the Vía soils at the eighth-hour ranges from slow to moderate. Considerable variation can be observed in the Las Piedras soils which range from 0.29 inches per hour, a slow rate, to 2.09 inches per hour, a moderately rapid rate. The Mabí soils range from slow to moderate in their infiltration capacity at the eighth-hour run. In general, the minimum infiltration capacity of the soils of the east-central area is rather slow. (See table 4.)

DISCUSSION

The morphological studies point to the presence of tight subsoil layers at variable depths beneath the surface soil in large areas of east-central Puerto Rico. It is very fortunate that many other areas in the same section do not have this undesirable feature. The presence of this compact subsoil considerably reduces the permeability of the profile and thus is a direct cause of imperfect and even poor drainage in many lowlands of the region. Ordinary plowing operations considerably increase the rate of infiltration of water through the upper profile layers. However, subsurface tillage practices can cause still a larger increase (7). In an area of heavy rainfall, like the one under consideration, where large volumes of water must be disposed of quickly so as not to impair crop growth, the loosening of the tight subsoil layers, where present, with the consequent increase in water infiltration is of fundamental importance. Improvement in the internal drainage of many soils of this area will probably result in more efficient land utilization, reduced farm expenses, and more effective soil and moisture conservation.

Field observations indicate that crop plants fail to develop extensive and deep root systems when grown in the compact soils of the area. The possibility of developing larger root systems through shattering and increasing the fertility level of subsoils deserves careful consideration (6). Liming is not a generalized practice in east-central Puerto Rico. However, the extreme acidity of many of the soils of the area must be properly corrected in order to obtain better yields and to maintain soil productivity over a longer period of time. Sugarcane, the crop which is grown on a large commercial basis in the region, is generally fertilized quite heavily. In order to reduce leaching loses to a minimum, careful attention must be given to the moderate exchange capacity of the main soils of the region, so as not to apply nutrients much in excess of what the soil colloids can hold at a given time.

Efforts should be made to maintain a reasonable level of organic matter in the soils of the area, though no definite figure can be given. In sugarcane fields the problem is not too difficult considering the large amount of trash, roots, and other crop residues present. The increase in the level of organic matter through the proper handling of trash has proved very beneficial for crop yields through its effect on soil properties (3, 5). Moreover, mulching with trash can be very beneficial to the hilly soils of the area from the standpoint of soil and water conservation. Experience with four crops of sugarcane (1944–1948) grown in a lateritic soil with a 40-percent slope in western Puerto Rico indicates that unmulched plots lose about 11 times as much soil as the mulched ones (1). Efforts to build up and maintain a very high level of organic matter would be rather expensive, and they may fail to produce the expected benefits. The objective should be to maintain the lowest level compatible with adequate energy release for microorganisms, adequate nutrient availability, and profitable crop yields.

The soil-moisture studies indicate that the soils of the area generally have a moderately high capacity to store available water for crop growth. Field observations over a long period of time have shown that the soils of the area are generally able to supply sufficient moisture for crop growth throughout the year, except during periods of very prolonged drought. The laboratory results have confirmed this fact on a basis of the capacity of the soil to store water at tensions which are low enough for plants to use it efficiently.

It might be helpful to have some more additional fertility and soil-moisture measurements covering a larger number of samples. However, the results so far available provide important reference points for estimates of what to expect from most of the soils of the area.

Summary

This report presents the results of a preliminary soil reconnaissance in east-central Puerto Rico. It contains soil-profile observations made on several deep pits dug for the purpose. It also includes the results of various infiltration tests conducted in the major soil types of the area. The laboratory data reported include organic matter, pH, nitrogen, and total exchange capacity, and also the following measurements conducted on undisturbed soil cores dug with a Kelley (Utah) soil sampling machine: Permeability, quick drainage, water retained at pF 1.78, maximum saturation, and bulk density. Additional data are presented on water retained at pF 2.7 and pF 4.2, available water, total porosity, and air porosity.

The soils of east-central Puerto Rico are rather deep, medium- or heavy-textured, acid, and of medium to low fertility. They are not generally well supplied with organic matter and nitrogen. In many cases they have compact, tight subsoil layers near the surface which considerably reduce the permeability of the profile and induce poor drainage. Laboratory soil-moisture studies confirmed field observations indicating that the majority of the soils of this region have a moderately high capacity to store water available for crop growth.

Resumen

En este trabajo se informan los resultados de un reconocimiento preliminar de los suelos de la zona este-central de Puerto Rico. Incluye el informe observaciones hechas en varias trincheras preparadas para el estudio. Incluye, además, los resultados de varias pruebas de infiltración que se hicieron en los tipos de suelos más importantes del área. Se presentan datos de laboratorio, tales como determinaciones de materia orgánica, pH, nitrógeno y capacidad total de intercambio. También se presentan datos sobre las siguientes determinaciones hechas en columnas de suelo en su estado natural que se obtuvieron con una máquina especial del tipo desarrollado por Kelly en Utah: permeabilidad, agua removida en 15 minutos a una tensión de 60 centímetros, agua retenida a pF 1.78, saturación máxima

y peso por volumen. Se presenta también información sobre el agua retenida a pF 2.7 y a pF 4.2, el agua aprovechable, la porosidad total y la proporción de poros gruesos.

Los suelos de la región este-central de Puerto Rico son bastante profundos, de textura mediana o pesada, ácidos y de una fertilidad baja o mediana. Generalmente, no están bien provistos de materia orgánica y nitrógeno. En muchos casos, se encuentran relativamente cerca de la superficie subsuelos compactos y pesados que reducen considerablemente la permeabilidad del perfil, restringiendo el desagüe. Los estudios de laboratorio han confirmado las observaciones de campo de que la mayoría de los suelos de esta zona tienen una capacidad moderadamente alta para retener el agua a tensiones lo suficientemente bajas, de modo que las plantas la puedan utilizar eficientemente.

Literature Cited

1. Bonnet, J. A., Abruña, F., and Lugo López, M. A., Trash disposal and its relation to cane yield, soil and water losses, *Jour. Agric. Univ. of P. R.*, **34**(3) 1951.
2. Kelley, O. J., Hardman, J. A., and Jennings, D. J., A soil-sampling machine for obtaining two, three, and four inch diameter cores of undisturbed soil to a depth of six feet, *Soil Sc. Amer. Proc.* (1947) **12** 85–87, 1948.
3. Landrau, Jr., P., and Samuels, G., The handling of sugarcane trash: I, Yields and economic considerations; submitted for publication in *Jour. Agric. Univ. P. R.*, **36** (3) 1952
4. Lugo López, M. A., *Moisture Relationships of Puerto Rican Soils*, unpublished doctoral dissertation, Cornell University Library, Ithaca, N. Y., 1950.
5. Lugo López, M. A., Landrau, Jr., P., and Samuels, G., The handling of sugarcane trash: II, Effects of various practices upon soil properties, *Jour. Agric. Univ. P. R.*, **36**(3) 1952.
6. Martínez, M. B., and Lugo López, M. A., Plans for research on the effect of subsoiling and subsoil fertilization in sugarcane fields, *Sugar Jour.* **14** 36–43, 1951.
7. Martínez, M. B., and Lugo López, M. A., Tillage tests: I, Effect of subsoiling and mole drainage upon the minimum infiltration capacity of a heavy claypan soil of the tropics, *Jour. Agric. Univ. P. R.*, **36**(2) 1952.
8. Nelson, L. B., and Muckenhirn, R. J., Field percolation rates of four Wisconsin soils having different drainage characteristics, *Jour. Amer. Soc. Agron.* **33**(11) 1028–1036, 1941.
9. Roberts, R. C., *Soil Survey of Puerto Rico*, U.S.D.A. in cooperation with Agric. Exp. Sta. Univ. of Puerto Rico; Series 1936, No. 9, 1942.
10. Schollenberger, C. J., and Simon, R. H., Determination of exchange capacity and exchangeable bases in soil—ammonium acetate method, *Soil Sc.* **59** 13–24,
11. Smith, R. M., Furhiman, D., and Silva, S., Simple procedures for studying soil cores collected with the Kelly (Utah) sampling machine. BPI-SCS *Cooperative Research Project Report* No. 181, 5 mimeographed pages, March 1, 1950.
12. Soil Conservation Service (U.S.D.A.) *Guide for Soil Conservation Surveys*, 39 pp. May 1, 1948.