Validation of an Aridic Soil Moisture Regime in Puerto Rico

By
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Background & Purpose

Soils of southwest Puerto Rico have historically been considered to have ustic moisture regimes bordering on aridic. Although soils in the area of Ensenada were thought to be aridic, their distribution was considered too to affect classification changes (Mount et al., 1992). This assumption was based on modeling using the Newhall Simulation Model, which showed only a small area of soils near Ensenada with an aridic soil moisture regime (Wambeke et al., 1991). In a quest to measure moisture content to determine the moisture regimes of southwest Puerto Rico, two climate stations were installed during February 2001. In addition to soil moisture, these stations measure soil temperature, air temperature, relative humidity, solar radiation, precipitation, wind speed, and wind direction. This report summarizes results for the first year of data capture.

Study Area

The study area is in southwest Puerto Rico (Figure 1). Soils at Guánica and Combaté were monitored for soil moisture and soil temperature and weather data including precipitation, relative humidity, solar radiation, wind speed, and wind direction were collected.

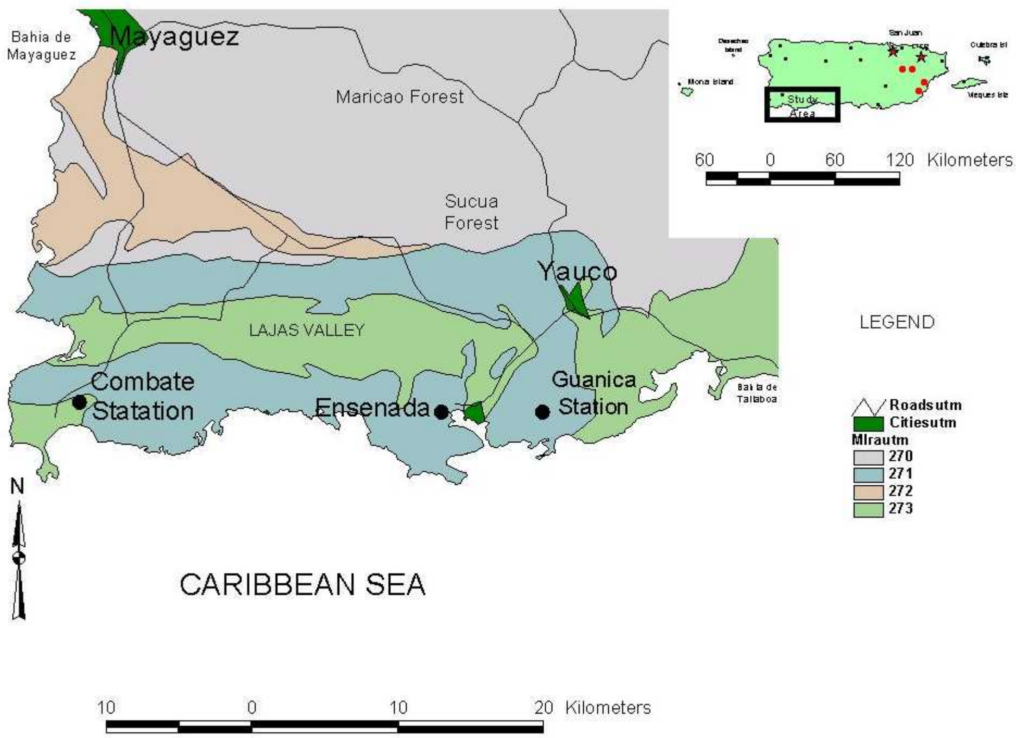

Figure 1. Location of the soils at Guánica and Combaté in Puerto Rico.

The soil at Guánica was sampled in 1992 (NSSL Project 93P26, CP93PR037 Guánica). The Guánica Dry Forest of Puerto Rico lies in Major Land Resource Area 271 – Semiarid Mountains and Valleys (SCS Staff, 1981). When sampled, the soil was classified as a member of the clayey-skeletal, mixed,

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isohyperthermic Lithic Ustropepts (Soil Survey Staff, 1975). The shallow soil at Guánica was sampled in 1992 and is located about 30 meters east of the Guánica Dry Forest Headquarters Office. The latitude is North 17°58'20.6" and the longitude is West 66°52'05.8". Soil has a 30-cm ochric epipedon that is clayey-skeletal and underlain by limestone bedrock. The stone and cobble cover is about 10 percent and rock outcrops constitute about 1 percent of the area. Elevation is about 100 meters, the soil aspect is south and the slope is about 7 percent. Vegetation consists of *Guayacán* (L), an endangered and native species of Puerto Rico. A few *Genip* (L) trees are near the site but they have been introduced. There is a sparse ground cover. About 20 percent of the soil surface receives solar radiation.

The very deep Sosa soil at Combaté was sampled in 1981 (NSSL Project 81P75, CP81PR160 Lajas Valley). The location of this soil lies in Major Land Resource Area 273 – Semiarid Coastal Plains (SCS Staff, 1981) (Figure 1). When sampled, the soil was classified as a member of the clayey, oxidic, isohyperthermic Plinthic Haplustults (Soil Survey Staff, 1975). Location of the Combaté station is about 40 meters southwest of the De Vida Silvestre de Cabo Rojo National Wildlife Refuge Headquarters Building in Puerto Rico. The latitude is North 17°58'45.7" and the longitude is West 67°10'08.2". The surface pebble cover is about 1 percent. Elevation is about 50 meters, the soil aspect is neutral and the slope is flat. Vegetation consists of hurricane grass and Kleberg bluestem grass with no trees. Figure 2 shows the Combaté station and associated vegetation at the site.

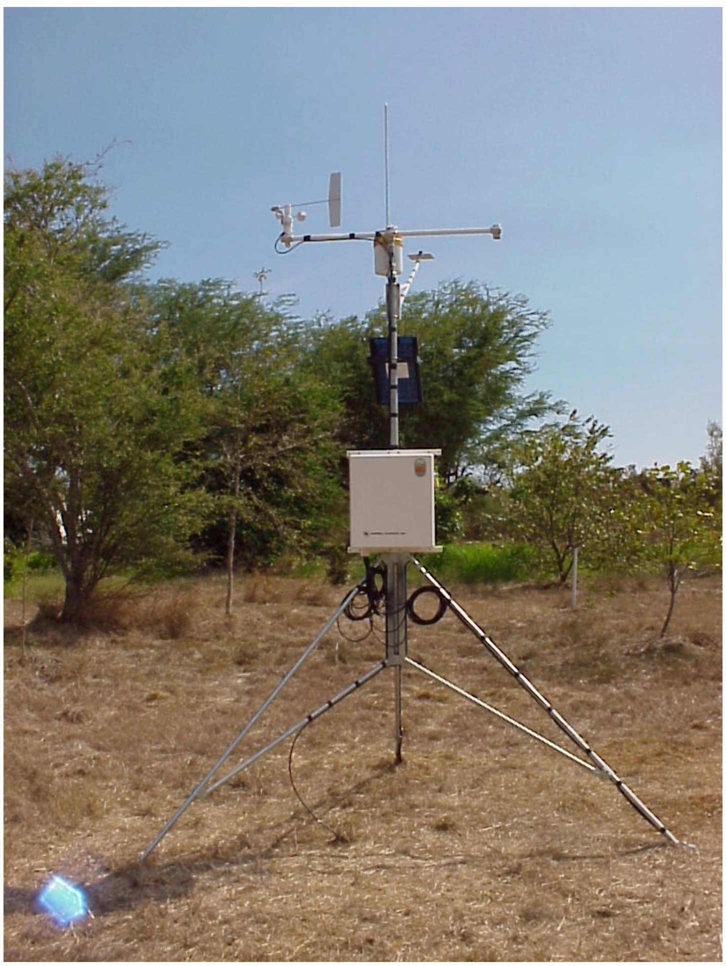

Figure 2. Soil scientists from Puerto Rico and Nebraska installed the NRCS climate station at Combaté.

Geology

The geology of southwest Puerto Rico is well documented. The oldest rocks – the serpentinites in part of the island – are thought to be slivers of late Jurassic oceanic crust torn off the North American plate subducted under the pre-Caribbean plate. In mid to late Cretaceous time and early Tertiary times, andesitic volcanics vented underwater above the subduction zone. Some of the extruded volcanics formed pillow lava, but most disintegrated upon contact with the water to form loose volcaniclastics. In late Cretaceous time, about 80 m.y. ago by potassium-argon dating (Burke et al, 1984), granodiorite magma intruded the volcaniclastics but failed to breach the surface. In early Tertiary time the Caribbean plate advanced eastward relative to the North American and South American plate to its present position. The North and South American plates divided and were overridden by the Caribbean plate to form the Caribbean Sea. The Gulf of Mexico had opened earlier. The Caribbean plate never quite reached Puerto Rico; it subducted into the Muertos trough south of Puerto Rico and under the bit of oceanic crust known as the Puerto Rico-Virgin Islands platform (Lynn, 1990).

Methods

Hourly soil moisture data from 2001 to 2002 were measured in the soil using the Vitel Hydroprobe® at five depths. The output of this sensor is percent of volumetric water content (VWC). Using NSSC laboratory characterization data from each site, the volumetric water content at 1500 kPa tension was determined for each horizon by multiplying the 1500-kPa water content by the moist (33 kPa) bulk density. The upper and lower soil moisture control sections were then calculated using the water retention difference between 10 or 33 and 1500 kPa (Soil Survey Staff, 1999).

Data for soil moisture and other parameters were averaged for each month and annually. In some cases (i.e., soil temperature), the summer and winter temperatures (MST & MWT) were derived as well as isotivity values, the difference between summer and winter temperature. This was needed to determine if the soils in the study area met the criteria for iso temperature regimes.

Weather Summaries

Air Temperature: Mean annual air temperature (MAAT) values were nearly the same at both sites (25.8°C vs. 26.0°C) (Table 1). Monthly values were the same for April. May and June was the only months where averages differed by more than 0.5°C. August was the warmest month at both sites and February was the coldest month. The difference between summer and winter air temperature averages is 2.2°C at Guánica and 2.8°C at Combaté.

Table 1. Air Temperature Averages for the Study Area

Analysis	Guánica Air (°C)	Combaté Air (°C)
Jan	25.1	24.9
Feb	24.1	23.8
Mar	24.6	25.1
Apr	24.8	24.8
May	25.5	26.5
Jun	26.5	27.1
Jul	27.0	27.3
Aug	27.4	27.5
Sep	27.1	27.0
Oct	26.7	27.0
Nov	25.1	25.5
Dec	25.3	24.9
Annual Mean	25.8	26.0
MST	27.0	27.3
MWT	24.8	24.5
MS-MW	2.2	2.8

Relative Humidity: The annual relative humidity average was slightly higher at Combaté than Guánica (Table 2). Values are highest during May when most of the rain fell at these sites. The high relative humidity values at Guánica likely accounts for the woody shrubs and xerophytes being able to survive this arid environment.

Table 2. Relative Humidity Averages

Month	Guánica RH (%)	Combaté RH (%)
Jan	67.9	71.5
Feb	67.1	72.8
Mar	73.6	73.0
Apr	71.6	75.4
May	80.0	77.2
Jun	74.0	73.7
Jul	72.3	73.1
Aug	72.8	75.4
Sep	72.8	76.9
Oct	74.1	75.3
Nov	74.1	76.5
Dec	73.4	78.6
Annual Mean	72.8	75.0
Summer	73.0	74.1
Winter	69.5	74.3
MS-MW	3.6	-0.2

Solar Radiation: Solar radiation averages were slightly higher at Combaté than Guánica (Table 3). Values are lower during the winter months than during the summer months. Soil radiation is highest during June, followed by March. Solar radiation is lowest at both sites during December.

Table 3. Solar Radiation Averages

Month	Guánica SR (w/m^2)	Combaté SR (w/m^2)
Jan	188.3	203.8
Feb	223.1	236.5
Mar	244.0	270.1
Apr	241.2	255.3
May	222.5	249.3
Jun	261.6	274.2
Jul	240.4	249.9
Aug	222.6	252.4
Sep	214.7	251.4
Oct	198.9	217.5
Nov	171.9	179.9
Dec	164.6	169.3
Annual Mean	216.1	234.1
Summer	241.5	258.8
Winter	192.0	203.2
MS-MW	49.5	55.6

Wind Speed and Direction: The anemometer and wind direction sensors at Guánica were inoperable during March and April of 2001. Consequently, those months are not shown in Table 3. Averages for the remaining months indicate the wind is about twice as strong at Combaté than at Guánica. This suggests that the evapotranspiration will also be higher at Combaté. Wind direction (degrees azimuth) during the summer and winter vary more at Combaté than at Guánica (21.9 vs. –6.8).

Table 4. Wind Speed and Wind Direction Averages

Month	Guánica Wind (mph)	Guánica WDIR	Combaté Wind (mph)	Combaté WDIR
Jan	5.7	95.7	13.1	76.5
Feb	6.4	115.4	13.0	30.7
Mar	6.5	107.8	--	--
Apr	7.0	105.4	--	--
May	7.2	103.1	12.0	61.3
Jun	6.4	94.5	13.1	82.2
Jul	6.2	100.1	12.4	81.7
Aug	5.9	95.4	13.0	83.0
Sep	6.2	105.9	11.3	75.6
Oct	5.5	89.5	11.7	77.7
Nov	6.8	174.5	10.7	92.3
Dec	5.5	99.3	11.1	74.0
Annual Mean	6.3	107.2	--	--
Summer	6.2	96.6	12.8	82.3
Winter	5.9	103.5	12.4	60.4
MS-MW	0.3	-6.8	0.4	21.9

Precipitation and Normal Months**:** Thirty-year precipitation data were reviewed for a long-term climate station in Ensenada, Puerto Rico (Table 5). Ensenada lies 7 km to the west of the Guánica site and 25 km east of the Combaté site (Figure 1). Its annual precipitation total is 31.2 inches with a standard deviation of 9.7 inches. In theory, the annual total could range between 21.6 and 40.9 inches and still be within one standard deviation of the mean. The minimum and maximum rainfall amounts for each month are also shown in table 5.

Table 5. Standard Deviations for Precipitation at Ensenada

Month	Ensenada Station (In.)	Standard Deviation (In.)	Rain plus 1 St. Dev. (In.)	Rain minus 1 St. Dev. (In.)
Jan	1.0	1.0	2.0	0.0
Feb	0.8	0.7	1.5	0.0
Mar	1.2	1.1	2.3	0.2
Apr	1.7	1.5	3.1	0.2
May	2.8	2.3	5.1	0.5
Jun	1.9	2.5	4.4	-0.7
Jul	1.9	1.4	3.3	0.4
Aug	3.7	3.0	6.7	0.6
Sep	5.5	4.2	9.7	1.2
Oct	5.5	4.1	9.6	1.3
Nov	3.9	2.8	6.7	1.2
Dec	1.6	1.7	3.2	-0.1
Annual Mean	31.2	9.7	40.9	21.6

The precipitation totals for Guánica and Combaté were compared to data from nearby Ensenada to determine if the monthly and annual precipitation totals were within one standard deviation of their means (Table 6).

Table 6. Normal Precipitation Months at Guánica and Combaté

Month	Guánica 2001-2002 (In.)	Normal Month/Year (<+ 1 StDev)	Combaté 2001-2002 (In.)	Normal Month/Year (<+ 1 StDev)
Jan	0.1	Yes	0.0	Yes
Feb	0.6	Yes	2.8	No
Mar	1.0	Yes	0.1	No
Apr	1.7	Yes	1.3	Yes
May	10.8	No	11.9	No
Jun	0.7	Yes	1.1	Yes
Jul	0.3	No	1.8	Yes
Aug	3.8	Yes	2.9	Yes
Sep	0.5	No	2.8	Yes
Oct	2.8	Yes	1.7	Yes
Nov	2.9	Yes	2.2	Yes
Dec	1.6	Yes	1.8	Yes
Annual Mean	26.7	Yes	30.4	Yes

Soil Taxonomy defines a normal precipitation year as one where eight or more months are within one standard deviation of the 30-year mean and the annual total is within one standard deviation of the 30-year mean (Soil Survey Staff, 1999). The monthly totals at both sites are within one standard deviation of the mean for nine months and the annual total is also within one standard deviation of the mean. These precipitation amounts in the study area are considered '**normal'** for classification purposes.

Soil Climate Summaries

Soil Temperature at Guánica: Since the soil at Guánica is shallow, soil temperature was measured at the 5-, 10-, 20-, 25-, and the 30-cm soil depths. Monthly, seasonal, and annual summaries are shown in table 7.

Table 7. Soil Temperature Averages for the Shallow Soil at Guánica

Month	5 cm (°C)	10 cm (°C)	20 cm (°C)	25 cm (°C)	30 cm (°C)
Jan	26.4	26.4	26.4	26.4	27.1
Feb	26.4	26.4	26.4	26.4	27.0
Mar	27.3	27.2	27.1	27.0	27.7
Apr	28.3	28.1	28.0	27.8	28.2
May	27.5	27.4	27.4	27.4	27.5
Jun	29.3	29.1	29.0	28.9	28.6
Jul	29.9	29.8	29.7	29.7	29.4
Aug	30.2	30.0	30.0	30.0	30.2
Sep	29.5	29.5	29.5	29.5	30.6
Oct	27.4	27.5	27.6	27.5	28.8
Nov	26.2	26.4	26.5	26.5	27.4
Dec	25.7	25.8	25.8	25.8	26.6
MAST	27.8	27.8	27.8	27.7	28.3
MST	29.8	29.6	29.6	29.5	29.4
MWT	26.1	26.2	26.2	26.2	26.9
Isotivity	3.6	3.4	3.3	3.3	2.5

The MAST is similar for the first four depths. The 30-cm depth is slightly warmer suggesting exothermic activity near the lithic contact. The difference between MAST at 25 cm and MAAT is 2.5°C (4.5°F). The isotivity values for each depth are less than the 6°C required for iso temperature regimes. In other words, soils that are shallow as 5 cm will qualify for an isohyperthermic temperature regime in this part of Puerto Rico. The 5-cm depth at this site had the single lowest temperature reading of 22.1°C.

Soil Temperature at Combaté: Since the soil at Combaté is very deep, soil temperature was measured at the 5-, 10-, 20-, 50-, and the 100-cm soil depths. Monthly, seasonal, and annual summaries are presented in table 8. In contrast to the Guánica station, the MAST for Combaté decreases slightly with each depth. The difference between MAST at 50 cm and MAAT is 3.4°C (6.1°F). This difference is attributed to the lack of canopy cover at the Combaté station. The isotivity values for each depth at Combaté are also less than the 6°C required for iso temperature regimes. In other words, soils that are shallow as 5 cm will qualify for an isohyperthermic temperature regime in this part of Puerto Rico.

Table 8. Soil Temperature Averages for the Combaté Station in Puerto Rico.

Month	5 cm (°C)	10 cm (C)	20 cm (°C)	50 cm (°C)	100 cm (°C)
Jan	27.0	26.9	27.0	27.1	27.2
Feb	27.6	27.4	27.5	27.6	27.6
Mar	30.7	30.5	30.3	29.5	28.8
Apr	30.1	30.0	30.0	29.6	29.5
May	31.2	30.8	30.6	30.0	29.8
Jun	32.6	32.2	32.0	31.2	30.7
Jul	32.4	32.1	31.9	31.2	30.7
Aug	31.3	31.1	31.0	30.6	30.4
Sep	30.9	30.8	30.6	30.3	30.1
Oct	30.2	30.1	30.1	29.9	29.9
Nov	28.1	28.0	28.2	28.7	29.1
Dec	26.5	26.5	26.6	27.1	27.6
MAST	29.9	29.7	29.6	29.4	29.3
MST	32.1	31.8	31.6	31.0	30.6
MWT	27.0	27.0	27.0	27.2	27.4
Isotivity	5.1	4.8	4.6	3.8	3.2

Soil Moisture at Guánica: Soil moisture averages at the 5-, 10-, 20-, 25-, and the 30-cm soil depths are shown in table 9.

Table 9. Soil Moisture Averages and their Moisture State at Guánica

Month	5 cm VWC (%)	Moist. State	10 cm VWC (%)	Moist. State	20 cm VWC (%)	Moist. State	25 cm VWC (%)	Moist. State	30 cm VWC (%)	Moist. State
Jan	0.0	Dry	2.8	Dry	0.0	Dry	0.0	Dry	0.0	Dry
Feb	0.1	Dry	1.6	Dry	0.0	Dry	0.0	Dry	0.0	Dry
Mar	1.8	Dry	2.3	Dry	0.1	Dry	0.0	Dry	0.5	Dry
Apr	2.6	Dry	10.0	Dry	2.8	Dry	4.1	Dry	5.1	Dry
May	8.2	Dry	15.6	Dry	7.7	Dry	8.2	Dry	11.4	Dry
Jun	2.1	Dry	6.6	Dry	3.6	Dry	4.7	Dry	8.6	Dry
Jul	0.5	Dry	3.8	Dry	1.2	Dry	1.0	Dry	2.9	Dry
Aug	1.5	Dry	5.1	Dry	2.6	Dry	2.0	Dry	3.9	Dry
Sep	0.0	Dry	3.5	Dry	0.9	Dry	1.0	Dry	3.2	Dry
Oct	4.2	Dry	9.2	Dry	1.3	Dry	0.3	Dry	1.1	Dry
Nov	3.9	Dry	9.7	Dry	2.9	Dry	2.9	Dry	3.3	Dry
Dec	0.9	Dry	5.6	Dry	0.6	Dry	0.0	Dry	0.1	Dry
Mean	2.2	Dry	6.3	Dry	2.0	Dry	2.0	Dry	3.4	Dry

The soil moisture control section for the soil at Guánica is 10 to 30 cm. At 5 cm, the VWC has to be greater than 12.9 percent to be moist, at 10 cm the VWC has to be greater than 17.6 percent to be moist, at 20 cm the VWC has to be greater than 21.1 percent to be moist, and at 25 cm and 30 cm the VWC must be greater than 29.7 percent to be moist. The soil at Guánica was dry for each month at every depth for the period of record.

Soil Moisture at Combaté: Soil moisture averages at the 5-, 10-, 20-, 50-, and the 100-cm soil depths are shown in table 10.

Table 10. Soil Moisture Averages and their Moisture States at Combaté

Month	5 cm VWC (%)	Moist. State	10 cm VWC (%)	Moist. State	20 cm VWC (%)	Moist. State	50 cm VWC (%)	Moist State	100 cm VWC (%)	Moist. State
Jan	1.0	Dry	1.3	Dry	6.2	Dry	0.0	Dry	4.3	Dry
Feb	3.0	Dry	3.9	Dry	8.6	Dry	0.0	Dry	2.8	Dry
Mar	0.2	Dry	0.8	Dry	7.4	Dry	0.0	Dry	2.0	Dry
Apr	0.7	Dry	0.0	Dry	4.1	Dry	0.0	Dry	2.2	Dry
May	3.0	Dry	3.5	Dry	13.0	Moist	11.8	Dry	22.7	Moist
Jun	0.6	Dry	0.7	Dry	6.5	Dry	1.7	Dry	10.9	Dry
Jul	1.3	Dry	1.2	Dry	6.2	Dry	0.3	Dry	5.6	Dry
Aug	3.3	Dry	3.9	Dry	10.0	Dry	3.6	Dry	7.8	Dry
Sep	3.7	Dry	4.6	Dry	10.7	Moist	4.2	Dry	7.0	Dry
Oct	1.8	Dry	1.7	Dry	5.2	Dry	0.1	Dry	5.4	Dry
Nov	4.6	Dry	4.8	Dry	10.4	Moist	0.0	Dry	4.5	Dry
Dec	4.2	Dry	3.9	Dry	8.5	Dry	0.0	Dry	4.3	Dry
Annual Mean	2.3	Dry	2.5	Dry	8.1	Dry	1.8	Dry	6.6	Dry

The soil moisture control section for the soil at Combaté is 14 to 32 cm. At 5 cm and 10 cm, the VWC has to be greater than 7.6 percent to be moist, at 20 cm the VWC has to be greater than 10.3 percent to be moist, at 50 cm the VWC has to be greater than 24.0 percent to be moist, and at 100 cm the VWC must be greater than 19.5 percent to be moist. The soil at Combaté was dry for each month at the 5-, 10-, and 50-cm depths. The soil was dry at 20 cm for nine months but the annual VWC was interpreted as being dry. The soil was dry at 100 cm for eleven months but the annual VWC was also interpreted as being dry.

Days Dry and Moist: By examining hourly data, total days dry and moist were determined for the soils in the study area (Table 11). The soil at Guánica was dry for more days than at Combaté.

Table 11. Days Moist and Dry for the Study Area

Site	Depth (cm)	Days Dry	Days Moist
Guánica	5	355	10
Guánica	10	345	20
Guánica	20	365	0
Guánica	25	365	0
Guánica	30	365	0
Combaté	5	325	40
Combaté	10	316	49
Combaté	20	272	93
Combaté	50	362	3
Combaté	100	342	23

Verification of Aridic Moisture Regime

Soil Taxonomy requires that an aridic moisture regime have a moisture control section (in normal years) that is dry in all parts for more than half of the cumulative days per year when the soil temperature at 50 cm from the soil surface is above 5°C and moist in some or all parts for less than 90 consecutive days when the soil temperature at a depth of 50 cm is above 8°C (Soil Survey Staff, 1999). Since the soil temperatures in the study area are always above 22°C, this part of the definition means that a full year (365 days) are used in determining whether soils have an aridic moisture regime.

The soil at Guánica was moist for fewer days than at Combaté (Table 11). The 10-cm depth at Guánica was moist for only 20 days and the other depths were moist for even fewer days (Figure 3). Therefore, the soil at Guánica has an aridic moisture regime, irregardless of its moisture control section, which happens to be 10 to 30 cm.

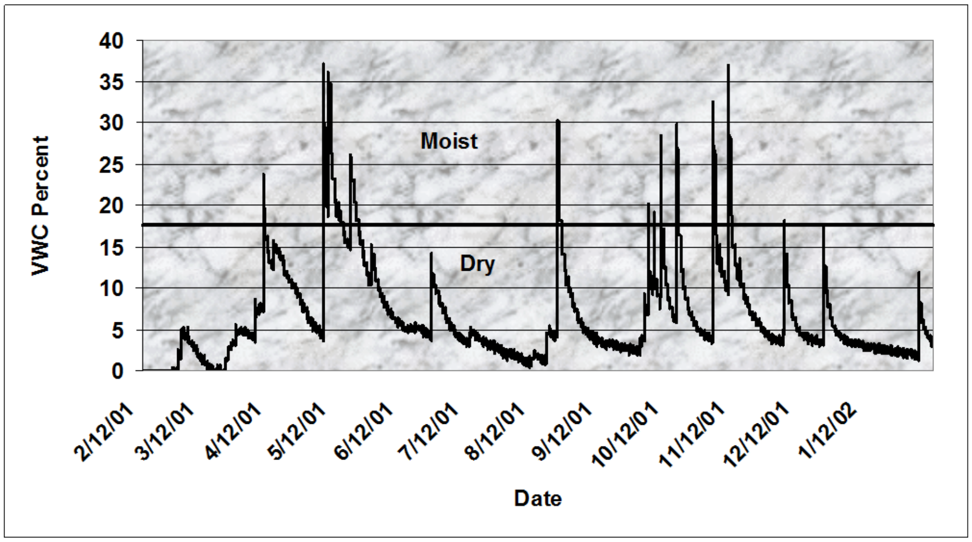

Figure 3. Soil moisture signature for the 10-cm depth at Guánica

The soil at Combaté was moist for 93 days or less at all five depths (Table 11). The moisture control section at Combaté is at 14 cm for the upper part and at 32 cm for the lower part. Consequently, the 20-cm depth is within the moisture control section and used to verify the aridic soil moisture regime. Since the soil is moist for 93 cumulative days, an examination as to whether there is a sequence of 90 consecutive days was initiated (Figure 4).

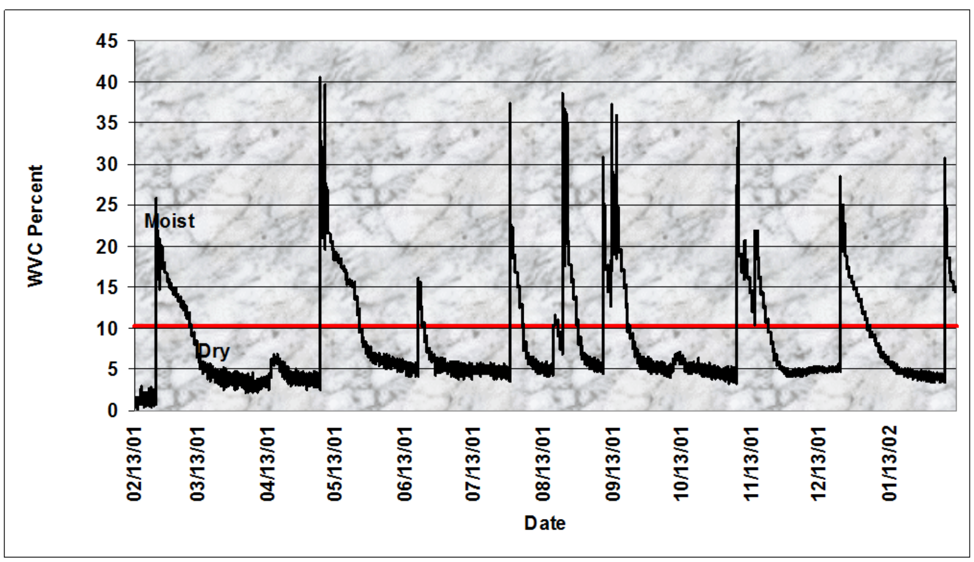

Figure 4. Soil moisture signature for the 20-cm depth at Combaté.

Figure 4 shows nine peaks above the 1500-kPa line (red) when the soil was moist. The time frame when the soil was moist does not approach 90 consecutive days. The longest period of moist soil was 17 consecutive days during May 2001. Therefore, the soil at the Combaté station has an aridic moisture regime that borders on an ustic moisture regime.

Unexpectedly, the soil at Combaté also has a mollic epipedon. To meet that criteria, some part of the epipedon has to be moist for 90 or more cumulative days in normal years (Soil Survey Staff, 1999). The Ap and A horizons from 0 to 30 cm meet all the criteria for a mollic epipedon and the A horizon is moist in some part for 93 days.

Classification of Aridisols

The shallow soil in the Guánica Dry Forest of Puerto Rico has more than 35 percent clay and rock fragments in the particle-size control section (clayey-skeletal) but montorillonite and other expandable clays are not dominant enough (mixed) for our soil to qualify as a Vertisol even though the activity class is quite active (superactive). The MAST is greater than 22.0°C and the isotivity value is less than 6°C (isohyperthermic). The soil is terminated by limestone bedrock within 50 cm (lithic) and is dry in the moisture control section for more than 180 days (aridic). The clay content decreases with depth and it has a cambic horizon with a lower depth of 25 cm or more (Cambids). Using the rules of *Soil Taxonomy*, the soil Guánica classifies as a member of the clayey-skeletal, mixed, superactive, isohyperthermic Lithic Haplocambids (Soil Survey Staff, 1999).[2]

The very deep soil at Combaté has a mollic epipedon and an argillic horizon with kaolinitic mineralogy. Therefore, it keys out in the Argids suborder and the Paleargids great group. It meets the criteria for an ustic subgroup of the Paleargids because the soil borders on an ustic moisture regime. Therefore, the soil at Combaté classifies as a member of the fine, kaolinitic, isohyperthermic Ustic Paleargids (Soil Survey Staff, 1999).

Discussion

This study is the first to verify soils with aridic moisture regimes in Puerto Rico. Data from this study suggests that soils with aridic moisture regimes likely occur on other Caribbean islands with low precipitation values. For instance, East Hill on St. Croix Island (17°46' North & 64°39' West) only receives 39.0 inches (990 mm) and Santo Domingo in the Dominican Republic only receives 39.4 inches (1000 mm). Perhaps the extent of the aridic moisture regime is more widespread for islands in the Caribbean that what was thought.

There are several other dry islands in the Caribbean. The Netherlands Antilles (Aruba, Bonaire, and Curaçao) receives 500 mm per year and their soils have aridic moisture regimes. The Guantánamo Naval Station receives only 430 mm per year of precipitation and is the driest area in Cuba (Bennett & Allison, 1928). Offshore islands of the Bahamas, Virgin Islands, Puerto Rico, and Cuba are also likely to have soils with aridic moisture regimes.

Another important revelation resulting from the summarized data in this study is the iso temperature regimes for islands in the Caribbean. It was thought that perhaps the soil at Combaté, Puerto Rico would have an isotivity value greater than 5°C at 50 cm – similar to Aridisols in Hawaii (Nullet et al., 1990). This was not the case. Isotivity values less than 5°C were recorded at all depths but the 5-cm depth at Combaté. This infers that shallow soils throughout southern Puerto Rico and perhaps other islands in the Caribbean will have an isohyperthermic temperature regime.

Acknowledgment

The author wishes to acknowledge Don Huffman, NRCS Hydrologist from the Water and Climate Center in Portland, Oregon for his assistance in help on this project.

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[2] There is some question as to whether the lithic contact is actually a petrocalcic horizon at the Guánica site. Arguments could be made both ways. If prevailing opinions side with a petrocalcic horizon, the soil would be a member of the Typic Petrocambids.

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Citation:

Mount H.R. and W.C. Lynn. 2004. ***Soil Survey Laboratory Data and Soil Descriptions for Puerto Rico and the U.S. Virgin Islands***. Soil Survey Investigation Report No. 49. USDA-NRCS. Lincoln, NE.