THE SOIL CLIMATE REGIMES OF PUERTO RICO - REASSESSMENT AND IMPLICATIONS

By

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Abstract

The soil climate regimes of Puerto Rico were evaluated and their implications discussed. The main objective of this project was to evaluate soil moisture and temperature regimes in Puerto Rico. Knowledge of the soil climate is important for three major reasons: (1) to understand the development and formation of specific soils; (2) to consistently classify and map soils accurately; and (3) to apply that knowledge to the use and management of soil-plant-water systems (Mount et al., 1992, 1994). Average monthly precipitation and temperature data from 90 weather stations of the U.S. Weather Service were used to compute the soil moisture and temperature regimes using the Newhall Simulation Model program version 1.0 (Van Wambeke et al., 1991). The results of the model were evaluated with soil moisture and temperature data of five weather stations of the USDA-Natural Resources Conservation Service.

The study confirms the existence of soils with an aridic moisture regime in the island. The Newhall Simulation Model identified an area of 25,450 ha with an aridic moisture regime along the south coast and on Mona Island. This is the first recognition of the aridic moisture regime in Puerto Rico. An area with ustic soil moisture regime in the northwest corner of the island was also identified. This area is currently recognized as having a udic moisture regime.

The isomesic temperature regime previously identified at the Caribbean National Forest was not confirmed by the Newhall Simulation Model. The isothermic temperature regime previously identified in areas above 600 m above sea level was identified by the model in areas above 900 m. As a result of these changes in the soil climate regimes, approximately 100 soil series need to be reclassified and new soil series will have to be proposed.

Resumen

En este trabajo se evalúan los regímenes de clima de suelo de Puerto Rico y se discuten sus implicaciones. El propósito principal de este trabajo fue evaluar los regímenes de humedad y temperatura de suelo en Puerto Rico. El conocimiento de clima de suelo es importante por tres razones principales: (1) para entender el desarrollo y formación de suelos; (2) para clasificar y cartografiar suelos de manera más precisa; y (3) para aplicar este conocimiento al uso y manejo de las relaciones agua-planta-suelo (Mount et al., 1992, 1994). Se utilizó el simulador Newhall versión 1.0 (Van Wambeke et al., 1991) para procesar los promedios mensuales de precipitación y temperatura de 90 estaciones del Servicio Nacional de Meteorología de los Estados Unidos de América y calcular los regímenes de humedad y temperatura del suelo. Los resultados obtenidos por el simulador fueron evaluados con datos de humedad y temperatura de suelo de cinco estaciones meteorológicas del Servicio de Conservación de Recursos Naturales del Departamento de Agricultura de los Estados Unidos de América.

Este estudio confirma la existencia de suelos con régimen de humedad arídico en Puerto Rico. El simulador Newhall identificó un área de 25,450 ha con régimen de humedad arídico a lo largo de la costa sur y en la isla de Mona. Este es el primer reconocimiento del régimen de humedad arídico en Puerto Rico. Es probable que en otras islas del Caribe occuran suelos con régimen de humedad arídico en áreas de precipitación limitada. En adición, el simulador identificó un área con el régimen de humedad ústico en el noroeste de la isla, donde actualmente se reconoce un régimen de humedad údico.

El régimen de temperatura isomésico, el cual se reconoce en el Bosque Nacional del Caribe no fue identificado por el simulador Newhall. El régimen de temperatura isotérmico, el cual se reconoce en áreas con una elevación mayor de 600 m sobre el nivel del mar fue identificado por el simulador a elevaciones de 900 m. Como resultado de estos cambios en los regímenes de clima de suelo, aproximadamente 100 series de suelo deben ser reclasificadas y nuevas series de suelo serán propuestas.

Dedication

I dedicate this thesis to two Soil Scientists that I consider as the "Fathers of the Soil Science in Puerto Rico". For their excellent contribution and dedication to this profession, this work is dedicated to Dr. Miguel A. Lugo-López, Emeritus Professor of the University of Puerto Rico at Mayagüez, and Agronomist Roberto E. Gierbolini-Cruz, a former USDA-Soil Conservation Service Soil Scientist Project Leader, whom I consider as the best "soil mapper" of Puerto Rico.

To my spouse Alba Z. Madera and my son Leonardo who have been my support throughout my graduate studies. To my family and friends, for their support and comfort during hard times.

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1. Introduction

A reevaluation of the soil climate regimes of Puerto Rico was suggested by the USDA-NRCS Soil Survey Staff in February 2001, and more recently in the update of the taxonomic classification of the soils of Puerto Rico (Beinroth et al., 2003). Soil climate must be known for accurate interpretations of soil surveys (Smith, 1981). Soil surveys may be interpreted for many uses, but mainly for growing plants and supporting objects (Smith, 1981). Without soil climate as a criterion in the taxonomic system, Entisols from humid conditions could not be differentiated from Entisols with drier conditions (Van Wambeke et al., 1991). Mount et al. (1994, 1995) suggested that the knowledge of soil climate is important to understand the development and formation of specific soils; to consistently classify and accurately map soils; and to apply that knowledge to the use and management of soil-plant-water systems. The correlation that exists between plants and rainfall is in reality the relationship between plants and soil moisture (Roberts, 1942). A soil climate map provides valuable information for crop production, and soil moisture and temperature data greatly enhance the understanding and management of soils and land use planning (Mount et al., 1992, 1994). As a classification criterion, one would expect soil temperature to have implications on soil genesis as well as on the use and management of the soils with different crops (Comerma and Sánchez, 1981).

Soil temperature influences biological, chemical and physical processes in the soil as well as the establishment and adaptation of vegetative species; therefore, they should be well tested, documented, identified and delineated in Puerto Rico. Mount et al. (1992) suggested that the boundary of the isomesic soil temperature regime is not clearly delineated and needs to be evaluated under field conditions. Also in need of reevaluation is the lower elevation separation of the isothermic soil temperature regime.

The general purpose of this work was to reevaluate and delineate the soil moisture and temperature regimes of Puerto Rico and to assess the performance of the Newhall Simulation Model by comparing the model output to the observed data in order to accomplish the following specific objectives:

1. Document the aridic soil moisture regime and establish the Aridisols order in Puerto Rico as has been suggested by Castro-López (1987), Mount et al. (1992), and Beinroth et al. (2003).
2. Update the soil climate regions map of Puerto Rico.
3. Change the taxonomic classification of the soil series according to the results of this study.

2. Literature Review

Soil moisture and soil temperature regimes in Soil Taxonomy are referred to as soil climate (Soil Survey Staff, 1999). If we consider a soil as a natural body that exists outdoors and that has properties that change with the seasons, the soil climate must be considered as a soil property (Smith, 1981). Climate shapes the development of soils through temperature and precipitation and it influences the type of vegetation and animal life it can support (Smith and Smith, 1998). Soil climate is a particularly well suited diagnostic criterion for soil classification because it is a genetic factor that controls biological processes, the rate and type of weathering of primary minerals, the removal or accumulation of weathering products, and translocations through the soil profile (Smith, 1981).

Puerto Rico is located in a tropical zone without extreme temperature limitations and this allows agricultural production all year around (Picó, 1975). The topography of the island, rather than meteorological factors, causes the great diversification of climates within a relatively small area (Howarth, 1934). In Puerto Rico, due to the high mean temperatures and constant air movement, effective rainfall is considerably less that it would be in cooler climates (Thorp, 1941). According to Roberts (1942) a rainfall of 762 mm in Puerto Rico is as effective as 381 mm in the semiarid areas of the United States. He also suggests that high evaporation, combined with high temperatures, low relative humidity, and constant winds tend to cause subhumid or semiarid conditions even where the average annual rainfall is 1,143 mm. In the tropics, moisture and latent heat flux cycles are generally more critical than temperature (sensible heat flux), contrary to what is observed at middle and higher latitudes (Capiel and Cavelsbert, 1976). According to Picó (1974, 1975), there are several important factors which influence the climate in Puerto Rico. The first one is the latitude. The island lies between 17°52' and 18°30' north of the equator. The second one is insularity. The island is relatively small and the ocean exerts a large influence over its climate. The third one is its location with respect to the great masses of earth and water, placing the island within the influence of the Great Northern Equatorial Current and the trade winds, which leaves moisture the places they pass. The trade winds, when forced to rise, cool off and drop part of their moisture as rainfall. The climate of Puerto Rico is also influenced by the easterly waves, fronts, hurricanes and topography.

Thorp (1941) recognized nine climatic zones in Puerto Rico according to Thornwaite's classification system (Table 2.1). This classification system is designed to recognize that more rain is needed in warm countries to support a given type of vegetation than in cool countries (Thorp, 1941). The quantity of rain is the limiting factor for the geographical distribution of many plant species (Roberts, 1942) and the present climate is a property of the soil that determines their use and management (Soil Survey Staff, 1999). In Puerto Rico the moisture cycle, rather than the temperature cycle, is the controlling seasonal factor; and the concept of dry and rainy seasons replaces the four season temperature cycle of middle latitudes (Capiel and Cavelsbert, 1976). The USDA-NRCS recognizes three soil moisture regimes in Puerto Rico: ustic, udic, and perudic as well as three soil temperature regimes: isomesic, isothermic, and isohyperthermic. However, Castro-López (1987) and Mount et al. (1992) suggested an additional soil moisture regime (aridic), and six soil climate zones, as shown in Table 2.1.

Table 2.1. Climatic zones in Puerto Rico recognized by Thorp (1941) and soil moisture and temperature regimes recognized by USDA-NRCS (Mount et al., 1992).

Thorp Climate Zones (Thorp, 1941)	**USDA-NRCS Climate Zones (Mount et al., 1992)**
Wet Tropical	Isothermic Udic
Wet-Mesothermal	Isomesic Udic, Isomesic Perudic
Humid Tropical	Isohyperthermic Udic
Humid Tropical, winter dry	Isohyperthermic Udic
Humid-Mesothermal	Isohyperthermic Udic
Moist Subhumid Tropical	Isohyperthermic Typic Ustic
Dry Subhumid Tropical	Isohyperthermic Typic Ustic
Semiarid Tropical	Isohyperthermic Aridic Ustic
Arid Tropical	Isohyperthermic Ustic Aridic

The soil moisture regime refers to the presence or absence of ground water or water held at a tension less than 1,500 kPa in the soil or in specific horizons during periods of years (Soil Survey Staff, 1975, 1998, 1999, 2003). Water held at a tension of 1,500 kPa or more is not available to most plants (Soil Survey Staff, 1975, 1998, 1999, 2003). The soil moisture regime of most soils is inferred from the present climate (Mount et al., 1992) and small-scale maps can be interpreted in terms of accessory characteristics that are common to most of the soils that have a common climate (Soil Survey Staff, 1999). These characteristics include the amount, nature and distribution of organic matter, the base status of the soil, and the presence or absence of salts (Soil Survey Staff, 1999). Soil moisture is measured in the soil moisture control section and it is defined as a layer having an upper boundary at a depth to which a dry (tension of more than 1,500 kPa) but not air-dry soil will be moistened by 25 mm of water moving downward from the surface within 24 hours (Soil Survey Staff, 1999). The lower boundary is the depth to which a dry soil will be moistened by 75 mm of water moving downward from the surface within 48 hours. The range depth of the soil moisture control section depends on the particle-size class of the soil. Soil Taxonomy (1999) provides approximate ranges for the soil moisture control section as shown in Table 2.2.

Table 2.2. Soil Moisture Control Sections according to Soil Taxonomy (Soil Survey Staff, 1999).

Particle-size classes	Depth
Fine-loamy, fine or very-fine; coarse-silty; fine-silty or clayey	10 to 30 cm
Coarse-loamy	20 to 60 cm
Sandy	30 to 90 cm

Soil Taxonomy recognizes five major classes of soil moisture regimes: aridic, ustic, xeric, udic and perudic, and they are delineated based on meteorological data and supplemented on the ground by visual observation of the landscape (Smith, 1981). In the aridic (or torric) soil moisture regime, the control section is dry in all parts for more than half of the cumulative days per year, when the soil temperature at a depth of 50 cm from the soil surface is above biologic zero (in Puerto Rico, this is 186 days or more per year) and it is 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. Soils that have an aridic moisture regime normally occur in areas of arid climates but they are also recognized in areas of semiarid climates where physical properties or steep slopes promote dryness (Soil Survey Staff, 1999). There is little or no leaching in this moisture regime, potential evapotranspiration greatly exceeds precipitation during most of the year and in most years no water percolates through the soil (Buol et al., 1997). These conditions promote the accumulation of carbonates and soluble salts in the soil (Soil Survey Staff, 1999). Aridic soils do not have enough moisture to grow and mature a crop without irrigation (Buol et al., 1997).

A soil with an aquic moisture regime is saturated long enough so that it is virtually free of dissolved oxygen (Soil Survey Staff, 1999). This regime is not considered as a soil moisture regime class because is influenced by water fluctuations or is saturated permanently. It is implicit that the soil temperature is above biologic zero (5° C) for some time while the soil is saturated. Soils with an aquic soil moisture regime usually require artificial drainage before they are suitable for most cropping practices (Buol et al., 1997). The monthly net water is calculated as the difference between precipitation and potential evapotranspiration for each month (Buol et al., 1997).

The soil moisture control section of soils with an udic moisture regime is not dry in any part for as long as 90 cumulative days in normal years. The Soil Survey Staff (1999) defines a normal year as a year that is plus or minus 1 standard deviation of the long-term mean annual precipitation (30 years or more) or is plus or minus 1 standard deviation of the long term monthly precipitation for 8 of the 12 months. The amount of stored moisture plus rainfall is approximately equal to, or exceeds the amount of evapotranspiration (Soil Survey Staff, 1999). These moisture conditions are adequate for growing crops anytime the soil temperature is satisfactory for the crop (Buol et al., 1997). In the ustic soil moisture regime, the soil moisture control section is dry in some or all parts for 90 or more cumulative days in normal years. It is moist, however, in some part either for more than 180 cumulative days per year or for 90 or more consecutive days. Soils with this regime can grow one or two crops per year, but the lack of soil moisture stops plant growth parts of the year, when soil temperature is favorable for crop growth (Buol et al., 1997). The xeric soil moisture regime is typical in areas of Mediterranean climates, where winters are moist and cool and summers are warm and dry.

As stated above, in Puerto Rico, the USDA-NRCS recognizes three major classes of soil moisture regimes; however, Mount et al. (1992) suggested four major classes and four subgroups resulting in seven subclasses of soil moisture regimes (Table 2.1). The peraquic and aquic soil moisture regimes are too small to be delineated at a scale of 1:500,000. The perudic soil moisture regime is delineated in areas where the mean annual precipitation exceeds 3,800 mm. It covers an area of 1,140 ha that occurs in the Luquillo Division of the Caribbean National Forest. In this area, precipitation exceeds evapotranspiration every month of the year. According to Castro-López (1987), the data from the climatic station Pico del Este at Ceiba municipality, support the perudic soil moisture regime due to the orographic effect. The udic soil moisture regime is delineated in areas where the mean annual precipitation ranges from 1,350 to 3,800 mm and covers an area of 688,142 ha. Some areas in the udic soil moisture regime have typic ustic evapotranspiration rates. Castro-López (1987) reported an area from Manatí to Aguadilla municipalities, (recognized as udic by USDA-NRCS) to have an ustic soil moisture regime. Roberts (1942) also reported that the northwestern corner of the island is drier than the interior because this area is to the north of the winds that have been cooled by the mountain ranges. Capiel and Calvesbert (1976) reported that the north coast receives less than 100 mm of rainfall per month only in February and March. However, in the tropics much more water is needed to keep the fields moist than in middle latitudes (Capiel and Calvesbert, 1976). This is especially true for vegetable crops (Capiel and Calvesbert, 1976). The water storage capacity of most soils in this area is limited by a shallow root zone and by frequent erosion caused by intense showers on sloping landscapes (Capiel and Calvesbert, 1976).

The ustic soil moisture regime occurs in areas where the mean annual precipitation ranges from 890 to 1,350 mm and covers an area of 211,770 ha. The aridic ustic subgroup of the ustic soil moisture regime is delineated in areas where the mean annual precipitation ranges from 760 to 890 mm. This soil moisture regime occurs in the south of the island, where average rainfall is less than 100 mm per month during 6 months of the year (Capiel and Calvesbert, 1976). Rainfall deficiency becomes most critical in June and July due to higher temperatures and longer days (Capiel and Calvesbert, 1976). An area at the Rincón municipality may also have soils with an ustic moisture regime (Mount in personal communication with Beinroth). These areas need to be tested and could be reclassified as typic ustic or udic ustic in future updates of the soil climate map. The aridic subgroups of the ustic soil moisture regime may be as dry as soils with an aridic regime (Mount et al., 1992; Beinroth and Eswaran, 2003). The ustic aridic subgroup of the aridic soil moisture regime occurs in areas where the mean annual precipitation is less than 760 mm. This condition has been reported in Ensenada Ward at Guánica municipality. Data collected at this site indicate that the soil is moist for 52 consecutive days in the soil moisture control section (Mount et al., 1992, 1994). Other municipalities where an aridic soil moisture regime may occur are Guayanilla, Ponce and Santa Isabel (Castro-López, 1987).

Soil temperature influences biological, chemical, and physical processes in the soil and the adaptation of vegetative species. The soil temperature regime can be described by the mean annual soil temperature, the average seasonal deviation from the mean, and the mean warm or cold seasonal soil temperature gradient within the main root zone, which is the zone from a depth of 5 to 100 cm (Soil Survey Staff, 1999). The mean annual soil temperature is affected to some extent by the amount and distribution of rain, the protection provided by shade and by organic horizons in forests, the slope aspect and gradient, and irrigation (Soil Survey Division Staff, 1993; Soil Survey Staff, 1999). Soil temperature can vary appreciably depending on the direction of the slope, the type of vegetation and the kind of soil (Smith, 1981). Soil temperature is more subjected to fluctuations near the surface (Soil Survey Staff, 1999); however, fluctuations decrease with increasing depth, reaching ultimately a value similar to the mean annual soil temperature (Soil Survey Staff, 1999). Daily changes in air temperature have a significant effect on the temperature of soil horizons to a depth of about 50 cm (Smith et al., 1964; Comerma and Sánchez, 1981; Pickul and Allmaras, 1984; Soil Survey Staff, 1975, 1999). Daily fluctuations are affected by cloud cover, vegetation, length of day, soil color, slope, soil moisture, air circulation near the ground, and the temperature of rainfall (Capiel and Calvesbert, 1976; Soil Survey Staff, 1999).

Soil temperature can be estimated from air temperature (Soil Survey Staff, 1999) and from the average of four readings at about 50 cm or greater depth, equally spaced throughout the year (Soil Survey Staff, 1998, 2004). Mean annual soil temperature can be estimated from mean annual air temperature by adding 2 or 3°C. Soil temperature in tropical regions can be estimated by adding 2 to 4°C to air temperature (Comerma and Sánchez, 1981; Van Wambeke, 1981, 1982, and 1985; Murtha and Williams, 1986; Nullet et al., 1990). Ustic moisture regimes will require a higher correction factor than udic moisture regime (Comerma and Sánchez, 1981; Murtha and Williams, 1986) because in drier climates, the loss of moisture is higher with temperature increases. In most of the United States, 1°C is added to the mean annual air temperature to estimate the mean annual soil temperature (Buol et al., 1997).

Soil Taxonomy recognizes five major classes of soil temperature regimes: cryic, frigid, mesic, thermic and hyperthermic. If the mean summer and mean winter soil temperatures differ by less than 6°C at a depth of 50 cm or at densic, lithic, or paralithic contact, whichever is shallower, the prefix *iso* is attached to the major class (Soil Survey Staff, 1999). There are four subclasses of *iso* soil temperature regimes recognized by Soil Taxonomy since 1975 (Soil Survey Staff, 1975): the isofrigid soil temperature regime, where the mean annual soil temperature is lower than 8°C; the isomesic soil temperature regime, where the mean annual soil temperature is 8°C or higher but lower than 15°C; the isothermic soil temperature regime, where the mean annual soil temperature is 15°C or higher but lower than 22°C, and the isohyperthermic soil temperature regime, where the mean annual soil temperature is 22°C or higher. Murtha and Williams (1986) suggested that a difference of less than 5°C between the mean annual temperature of the summer and winter months is a better representation of the isotivity concept. Comerma and Sánchez (1981) reported an average isotivity value of 2.3°C. They reported a range of variation from 0.7 to 4.2°C. Data for 55 stations in Hawaii and Puerto Rico indicate that the difference between mean summer and winter air temperatures ranges from 1.7 to 4.0°C (Beinroth and Eswaran, 2003). At three sites in the southwest corner of Puerto Rico, the isotivity was well below 5°C (Mount, unpublished data). Mount et al. (1992) reported an isotivity of 2°C for two sites in the United States Virgin Islands and 4.3°C for one station during 1994 (Mount et al., 1995).

In Puerto Rico, the USDA-NRCS recognizes three *iso* subclasses of the soil temperature regimes: isomesic, isothermic and isohyperthermic. The isomesic soil temperature regime is delineated at elevations over 1,067 m (Mount et al., 1992). This regime has been officially recognized in an area of 1,140 ha surrounding El Toro and El Yunque Peaks in the Luquillo Division of the Caribbean National Forest (Huffaker, 2002). Mount et al. (1992) suggested that an area of 1,943 ha at the Toro Negro Division of the Caribbean National Forest should be isomesic. Primary data was used to assist in the separation of this temperature regime, but further evaluation is necessary (Mount et al., 1992). The only soil series in the isomesic soil temperature regime officially recognized in Puerto Rico is the Dwarf series which classifies as a *very-fine, mixed, subactive, isomesic Humic Haplaquox* (Beinroth et al., 2003). The isothermic soil temperature regime occurs at elevations from 610 to 1,067 m (Mount et al., 1992). It has been suggested that the isothermic soil temperature regime in Puerto Rico covers an area of 100,197 ha (Mount et al., 1992). Castro-López (1987) reported that at the Cerro Maravilla weather station (1,200 m) at Utuado municipality, the soil temperature regime is isothermic, with a mean annual air temperature of 21.2°C, interpolating with the Maricao municipality weather station (863 m) with a mean annual air temperature of 24.4°C. Castro-López (1987) also reported that the mean elevation of the isothermic soil temperature regime in Puerto Rico is 1,000 m. According to Nullet et al. (1990) on Maui, Hawaii, the isothermic regime is recognized at elevations from 500 to 1,650 m above sea level. The elevation range from the isothermic to the isohyperthermic regime is from 500 to 700 m above sea level (Nullet et al., 1990). They reported that in wetter areas the elevation of the isothermic regime was closer to the lower end of the range. The isohyperthermic soil temperature regime in Puerto Rico is delineated in areas where the elevation is lower than 610 m but this boundary needs further evaluation (Mount et al., 1992).

The Newhall Simulation Model is a tool used to predict soil climate regimes in lieu of measured data (Van Wambeke et al., 1991; Mount et al., 1992). This program, written in *BASIC* uses monthly data of only one year (either one individual year, monthly averages of a number of years, or average of normal years), latitude and longitude information, and computes potential evapotranspiration according to Thornthwaite (Van Wambeke, 2000). The model assumes that the potential evapotranspiration is uniformly distributed during each month (Van Wambeke, 2000). Results of the model should be applied judiciously because the calculated climate regimes are estimates derived from climatic data, not soil data (Newhall and Berdanier, 1996). The model does not consider: (1) ground water influence; (2) lateral inflows or outflows of water in the soil; (3) soils with restricted infiltration; (4) the effect of freezing and snowmelt into the water balance; (5) soil texture; and (6) surface air flow.

Most Aridisols are soils with an aridic soil moisture regime having an ochric or anthropic epipedon (Soil Survey Staff, 1999). Their unique properties are a combination of a lack of available water to mesophytic plants for extended periods, one or more pedogenic horizons, a surface horizon or horizons not significantly darkened by humus, an absence of deep, wide cracks, and andic soil properties (Soil Survey Staff, 1999).

Soil Taxonomy recognizes seven suborders of Aridisols; Cryids, Salids, Durids, Gypsids, Argids, Calcids and Cambids. The occurrence of Aridisols in Puerto Rico has been suggested by Castro-López (1987), Mount et al. (1992) and Beinroth et al. (2003). With the exception of Cryids and Durids, all suborders of Aridisols could potentially occur in Puerto Rico. According to these authors, Aridisols are likely to occur along the south and southwestern coast of Puerto Rico. Soils currently classified under the aridic subgroup of the ustic moisture regime may fit the criteria for the ustic subgroup of the aridic soil moisture regime. However, additional data on soil moisture are needed to support or discard this claim.

3. Methodology

3.1 Reevaluation and Delineation of the Soil Moisture and Temperature Regimes of Puerto Rico

3.1.1 Sources of Information

Precipitation and air temperature for 90 weather stations (Figure 3.1) (See Appendix A) were obtained from the U.S. Weather Service Cooperative Network of the National Oceanographic and Atmospheric Administration, Southeast Regional Climate Center. Forty nine (49) weather stations provided precipitation and air temperature data for 21 to 55 years. The remaining 41 stations provided only precipitation data for 20 to 48 years. Temperatures for these stations were estimated using data from stations at similar elevations.

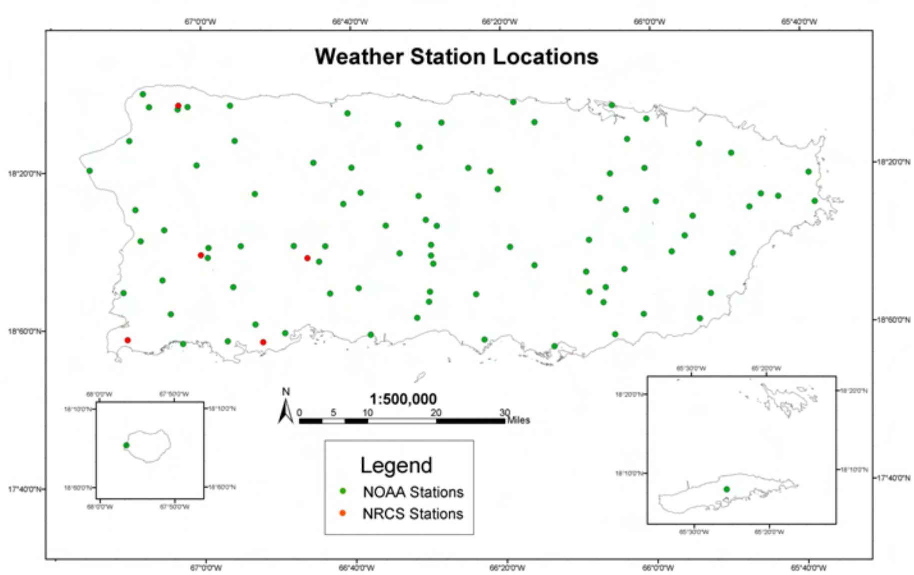

Figure 3.1. NOAA and NRCS Weather Stations in Puerto Rico.

3.1.2 Newhall Simulation Model

The monthly precipitation and temperature average were used to compute the soil moisture and temperature regimes using the Newhall Simulation Model program version 1.0 (Van Wambeke et al., 1991). The entries needed to run the program are the location of each station (coordinates in latitude and longitude), elevation (ft), monthly averages of precipitation (in) and temperature (°F) for a number of years, and the years of climate records. The model is run on a time-sequence of monthly climate data. The daily moisture status in the control section and temperature status (at the defined depth) are recorded, and the time-series of moisture and temperature status are summarized according to the rules of the soil moisture and temperature regimes. This model corrects soil temperature gradient between the winter and summer seasons (isotivity). One sixth of the difference between the temperature averages is added to the winter average and subtracted from the summer average.

As a result of these data compilation the output of the Newhall Simulation Model was obtained and is discussed in more detail on section 4.

3.1.3 Statistical Analysis

The results obtained from the Newhall Simulation Model were statistically analyzed using cluster methods (multivariable statistical analysis) using InfoStat version 2004 (InfoStat, 2004a). The seven hierarchical clustering algorithms that InfoStat provides were used. The produced dendrographs[1] of each algorithm were analyzed to decide the amount of clusters appropriate for the available data.

Multivariable statistical analysis is used to describe and analyze multidimensional observations, thus provides information about several variables for a particular study area (InfoStat, 2004b). The continuous variables of this study were air temperature, elevation, and precipitation. This makes this study a three dimensional variable analysis. In order to group multivariable data it is necessary to use classification techniques based on the association of classes (InfoStat, 2004b). This allows each class (cluster) to have common similarities by any criteria (InfoStat, 2004b). In order to group objects it is necessary to use an algorithm (InfoStat, 2004b). The algorithms used in InfoStat are hierarchical agglomerative, non divisive, and the results are shown in dendrographs (InfoStat, 2004b). The dendrographs point out the way the clusters group (InfoStat, 2004b).

The agglomerative algorithms proceed in the following order. Initially, each object belongs to an individual cluster (InfoStat, 2004b). The next step combines the two closest objects in order to form the first cluster (InfoStat, 2004b). In the next step a new object joins the cluster from the initial step or a second cluster is formed when two objects combine each other which ultimately, all the clusters generated are grouped in hierarchies under a parent cluster (InfoStat, 2004b).

The seven hierarchical algorithms available in InfoStat are (InfoStat 2004b):

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[1] Dendrographs are tree diagrams in two dimensions (InfoStat, 2004b).

1. Single linkage or nearest neighbor- The groups get combined based on the distance between the two closest members.
2. Complete linkage or farthest neighbor- The groups get combined based on the distance between the two farthest members.
3. Average linkage- In this algorithm the distance method between two clusters is obtained by averaging all the distances between pairs of objects, where one member of that group belongs to one cluster and the other member belongs to the second cluster. This method is one of the simplest and the most successful on several applications.
4. Weighted average linkage- Is a generalized averaged linkage algorithm and uses the number of objects in each cluster as weighted.
5. Unweighted centroid- This algorithm uses the average of all the objects in one cluster in order to represent the cluster and measure the distance between objects or clusters from them.
6. Weighted centroid- This algorithm is a generalized unweighted centroid, weighing the distance by the number of objects in each cluster.
7. Ward- This algorithm combines clusters by weighing them by their cluster size. This algorithm is recommended for data with normal distribution and tends to produce groups with the same amount of observations being affected by extreme values.

3.1.4 Update of Soil Climate Regions Map of Puerto Rico

Digital soil climate maps were prepared using Arc Info 8.3 platform. Tools such as Arc Map, Arc Tool Box and Arc Catalogue were used to support the geographic information system (GIS) procedure. A digital version of the soil map units was obtained from the Soil Survey Geographic Database (USDA-NRCS, 2001), whose boundaries have been delineated as polygons within the GIS base map.

All layers were georeferenced in the State Plane, Datum NAD-83, (1997) revision coordinate system. Geoprocessing was performed using the interpolation function in the Arc GIS Spatial Analyst. The interpolation[2] performed was the Inverse Distance Weighted because estimated cell values are the averages values of the data points in the vicinity of each cell. The closer a point is to the center of the cell being estimated, the more influence it has in the averaging process (ESRI, 2002). This method assumes that the variable being mapped (soil climate regimes and elevation) decreases in influence with distance from its sampled location (ESRI, 2002). In areas with few or no data the Digital Elevation Model was used to estimate the interpolation. The final output layers contain all the attributes from the input layers. For example, an area classified as a perudic isothermic soil climate regime within the map is associated with a unique

[2] The interpolation function predicts values for cells in a raster image from a limited number of sample data points (ESRI, 2002). It can be used to predict unknown values for any geographic point data as elevation, rainfall and others (ESRI, 2002).

combination of soil moisture regime, soil temperature regime and elevation. A total of six potential classes for soil climate regimes were found for Puerto Rico.

3.2 Evaluation of the Performance of the Newhall Simulation Model by Comparing the Model Output and Observed Data

In order to evaluated the Newhall Simulation Model in Puerto Rico, climatic data from five weather stations capable of providing hourly data on soil moisture and temperature (Figure 3.1) were included. Location and elevation data of the selected stations are shown in Table 3.1.

Table 3.1. Puerto Rico Soil Climate Analysis Network.

Station	Municipality	Coordinates	Elevation (m)
Guánica State Forest	Guánica	17º58'20" N; 66º52'05" W	164
Combate	Cabo Rojo	17º58'45" N; 67º10'08" W	10
Maricao State Forest	Maricao	18º09'26" N; 67º00'14" W	746
Guilarte State Forest	Adjuntas	18º08'54" N; 66º46'04" W	1019
Isabela	Isabela	18º28'24" N; 67º03'03" W	120

The Combate (Figure 3.2) and Guánica stations provided detailed data on soil moisture. The Guilarte and Maricao stations provided detailed data on the effect of elevation on soil temperature to evaluate the boundary between the isohyperthermic and the isothermic regimes. The station's configuration is summarized in Table 3.2.

Figure 3.2. USDA-NRCS Combate Station.

Table 3.2. Puerto Rico Soil Climate Analysis Network site configuration.

Parameter	Description
Precipitation (inches)	TE 525 Tipping bucket precipitation gage at 3 meters above the ground.
Air Temperature (ºC) / Relative Humidity (%)	Vaisala HMP45C sensor at 1.6 meters above the ground.
Wind Speed (mph) and Direction	Met One sensor (propeller-type anemometer) at 3 meters above the ground.
Solar Radiation (W/m²)	LI-COR pyranometer at 3 meters above the ground.
Soil Moisture (Volts)/ Soil Temperature (Volts)	Vitel Dielectric constant soil moisture sensors at 5, 10, 20, 50 and 100 cm with the exception of Guánica station where the sensors are at 5, 10, 20, 25 and 30 cm.
Soil Temperature	Campbell 107 soil temperature sensors at 5, 10, 20, 50 and 100 cm with the exception of the Guánica station where the sensors are at 5, 10, 20, 25 and 30 cm.
Data Transmission	MCC 545 RF modem.

3.3 Reevaluation of the Classification of Selected Soil Series of Puerto Rico Based on the Revised Soil Climatic Data

Soil Taxonomy (1999), Keys to Soil Taxonomy (2004), characterized soil series data (Soil Survey Staff, 2004) and results from the Newhall Simulation Model were used to discuss the implications for the soil series classification. Considering that estimates of soil moisture and temperature regimes were derived from climatic data, the results of the model were adjusted in the field to better represent the division between climatic regions. Soil data was used to support this process. After revising the soil series classification, updates of the soil series descriptions were prepared and new soil series will be proposed.

4. Results and Discussion

4.1 Reevaluation and Delineation of the Soil Moisture and Temperature Regimes of Puerto Rico using the Newhall Simulation Model

The computation of the soil moisture and temperature regimes by the Newhall Simulation Model is summarized on Table 4.1.

Table 4.1. Soil Moisture and Temperature Regimes of Puerto Rico according to the Newhall Simulation Model computation.

NOAA Climatologic Station	Elevation (m)	Soil Moisture Regime
Aridic/Isohyperthermic Regime		
Magueyes Island	6	Aridic
Mona Island 2	3	Aridic
Ensenada	3	Ustic Aridic
Ponce City	3	Ustic Aridic
Ustic/Isohyperthermic Regime		
Aguirre Central	6	Aridic Ustic
Central San Francisco	9	Aridic Ustic
Coamo	73	Aridic Ustic
Juana Díaz Camp	61	Aridic Ustic
Ponce 4E	21	Aridic Ustic
Santa Isabel 2ENE	9	Aridic Ustic
Santa Rita	21	Aridic Ustic
Borinquen Airport	70	Ustic
Guayabal	113	Ustic
Guayama	55	Ustic
Roosevelt Roads	12	Ustic
San Juan WSFO	3	Ustic
Vieques Island	15	Ustic

Ustic/Isohyperthermic Regime (Continuation)		
Lajas Substation	27	Udic Ustic
Peñuelas 1NE	98	Udic Ustic
Rincón Power Plant	24	Udic Ustic
Udic/Isohyperthermic Regime		
Corral Viejo	122	Ustic Udic
Aceituna	652	Udic
Adjuntas 1NW	457	Udic
Aibonito	640	Udic
Arecibo 3ESE	3	Udic
Barceloneta 2	3	Udic
Barranquitas	628	Udic
Cacaos	555	Udic
Calero Camp	76	Udic
Caguas 1W	79	Udic
Canovanas	12	Udic
Caonillas	259	Udic
Carite Plant 1	296	Udic
Cataño	6	Udic
Cayey 1E	418	Udic
Cerro Gordo, Ciales	293	Udic
Cidra 1E	427	Udic
Coloso	12	Udic
Corozal Substation	198	Udic
Dorado 2WNW	18	Udic
Dos Bocas	61	Udic
Fajardo	9	Udic
Guajataca Dam	207	Udic
Gurabo Substation	49	Udic
Hacienda Constanza	146	Udic
Humacao 2SSE	27	Udic

Udic/Isohyperthermic Regime (Continuation)		
Indiera Alta	792	Udic
Isabela Substation	128	Udic
Jayuya	469	Udic
Juncos 1NNE	55	Udic
La Muda	88	Udic
Lares 2SE	463	Udic
Manatí 3E	76	Udic
Maunabo	12	Udic
Mayagüez City	18	Udic
Mayagüez Airport	12	Udic
Monte Bello, Manatí	195	Udic
Mora Camp	125	Udic
Morovis 1N	183	Udic
Negro-Corozal	521	Udic
Patillas Dam	73	Udic
Puerto Real	9	Udic
Quebradillas	113	Udic
Río Piedras Exp. Sta.	27	Udic
Sabana Grande 2ENE	259	Udic
San Germán 4W	27	Udic
San Juan City	6	Udic
San Lorenzo Farm 2NW	73	Udic
San Sebastían	52	Udic
Toa Baja	6	Udic
Trujillo Alto	40	Udic
Utuado	158	Udic
Villalba	168	Udic
Yabucoa	9	Udic
Perudic Isohyperthermic		
Adjuntas Substation	558	Perudic

Perudic Isohyperthermic (Continuation)		
Arecibo Observatory	323	Perudic
Carite Dam	552	Perudic
Garzas	719	Perudic
Guavate Camp	780	Perudic
Jajome Alto	728	Perudic
Maricao 2SSW	863	Perudic
Maricao Fish Hatchery	457	Perudic
Matrullas Dam	747	Perudic
Paraíso, Fajardo	101	Perudic
Río Blanco Lower	40	Perudic
Río Grande El Verde	183	Perudic
San Lorenzo 3S	155	Perudic
Toro Negro Plant 2	686	Perudic
Perudic Isothermic		
Cerro Maravilla	1219	Perudic
Pico del Este	1052	Perudic

4.1.1 Soil Moisture Regimes

The Newhall Simulation Model identifies four soil moisture regimes: aridic, ustic, udic and perudic. In addition it suggests eight subdivisions: typic aridic, ustic aridic, aridic ustic, typic ustic, udic ustic, ustic udic, typic udic and perudic. The udic ustic and ustic udic regimes are not currently recognized as classes of the soil moisture regime by Soil Taxonomy.

The simulation model identified the aridic soil moisture regime along the southern coast of Puerto Rico (from Cabo Rojo to Juana Díaz municipalities) and on Mona Island.

Of the 90 NOAA stations the ones identified by the simulation model under this moisture regime were: Ensenada, Magueyes Island, Ponce City and Mona Island. These areas are currently recognized as an ustic moisture regime.

The ustic soil moisture regime was identified along the southern coast of the island (from Cabo Rojo to Arroyo municipalities), on Culebra and Vieques Islands, along the northwestern corner (from Rincón to Aguadilla municipalities), along the northeastern coast (from San Juan to Carolina municipalities) and along the eastern (from Ceiba to Naguabo municipalities). Of the 90 NOAA stations the ones identified by the simulation model under this moisture regime were: Aguirre Central, Borinquen Airport, Central San Francisco, Coamo, Guayabal, Guayama, Juana Díaz Camp, Lajas Substation, Peñuelas 1NE, Ponce 4E, Rincón Power Plant, Roosevelt Roads, San Juan WSFO, Santa Isabel 2ENE, Santa Rita and Vieques Island. Except for the area along the southern coast, these areas are currently recognized as udic moisture regimes.

The most extensive soil moisture regime found on the island of Puerto Rico was the udic soil moisture regime. The Newhall Simulation Model identified 54 of the 90 NOAA stations with this moisture regime along the central portion of the island, the northern coast and the western coast.

The perudic soil moisture regime is currently recognized at the Caribbean National Forest but the Newhall Simulation Model identified four additional areas. Three of these areas are located at the Central Mountain Range and the other at the Sierra de Cayey Mountain Range. Of the 90 NOAA stations the ones identified by the simulation model under this moisture regime were: Adjuntas Substation, Arecibo

Observatory, Carite Dam, Cerro Maravilla, Garzas, Guavate Camp, Jajome Alto, Maricao 2SSW, Maricao Fish Hatchery, Matrullas Dam, Paraíso, Pico del Este, Río Blanco Lower, Río Grande El Verde, San Lorenzo 3S and Toro Negro Plant 2. These results have to be taken cautionisly. The model considers a standard available water holding capacity of 200 mm. This amount of water is representative of deep, fine textured soils but it is not the case for Oxisols and Rendolls. Consecuently, the Newhall Simulation Model may have overestimated the area under the perudic moisture regime. Running the model considering the 100 mm available water holding capacity will reduce the area included in the perudic moisture regime and will provide a more realistic value in accordance with field observations.

4.1.2 Soil Temperature Regimes

The Newhall Simulation Model identified two soil temperature regimes: isothermic and isohyperthermic. The isomesic regime currently recognized at the Caribbean National Forest was not found.

The isothermic temperature regime was identified by the simulation model only in areas over 900 m above the sea level. Of the 90 NOAA stations the ones identified by the simulation model under this temperature regime were: Cerro Maravilla and Pico del Este. Currently, this regime is recognized in areas above 600 m above sea level.

The isohyperthermic temperature regime was identified by the simulation model in areas below 900 m above the sea level. A total of 88 of the 90 NOAA stations were identified with this temperature regime. Currently this regime is recognized only in areas below 600 m above sea level.

4.1.3 Soil Climate Regimes

The Newhall Simulation Model identifies nine soil climate regimes: perudic isothermic, perudic isohyperthermic, udic isohyperthermic, ustic udic isohyperthermic, udic ustic isohyperthermic, ustic isohyperthermic, aridic ustic isohyperthermic, ustic aridic isohyperthermic and aridic isohyperthermic (Table 4.1). Soil Taxonomy does not recognize the udic ustic and the ustic udic soil moisture regimes as such. As stated above, the simulation model used in this project identifies the existence of these subdivisions. Unfortunately, because the above soil moisture regimes are not recognized in the current Soil Taxonomy, the soil climate regimes that include them can not be described.

Figure 4.1 summarizes the mean annual precipitation versus the elevation of the 90 NOAA stations partitioned by the mean annual air temperature. Figure 4.2 compares the mean annual air temperature versus the elevation both partitioned by the mean annual precipitation.

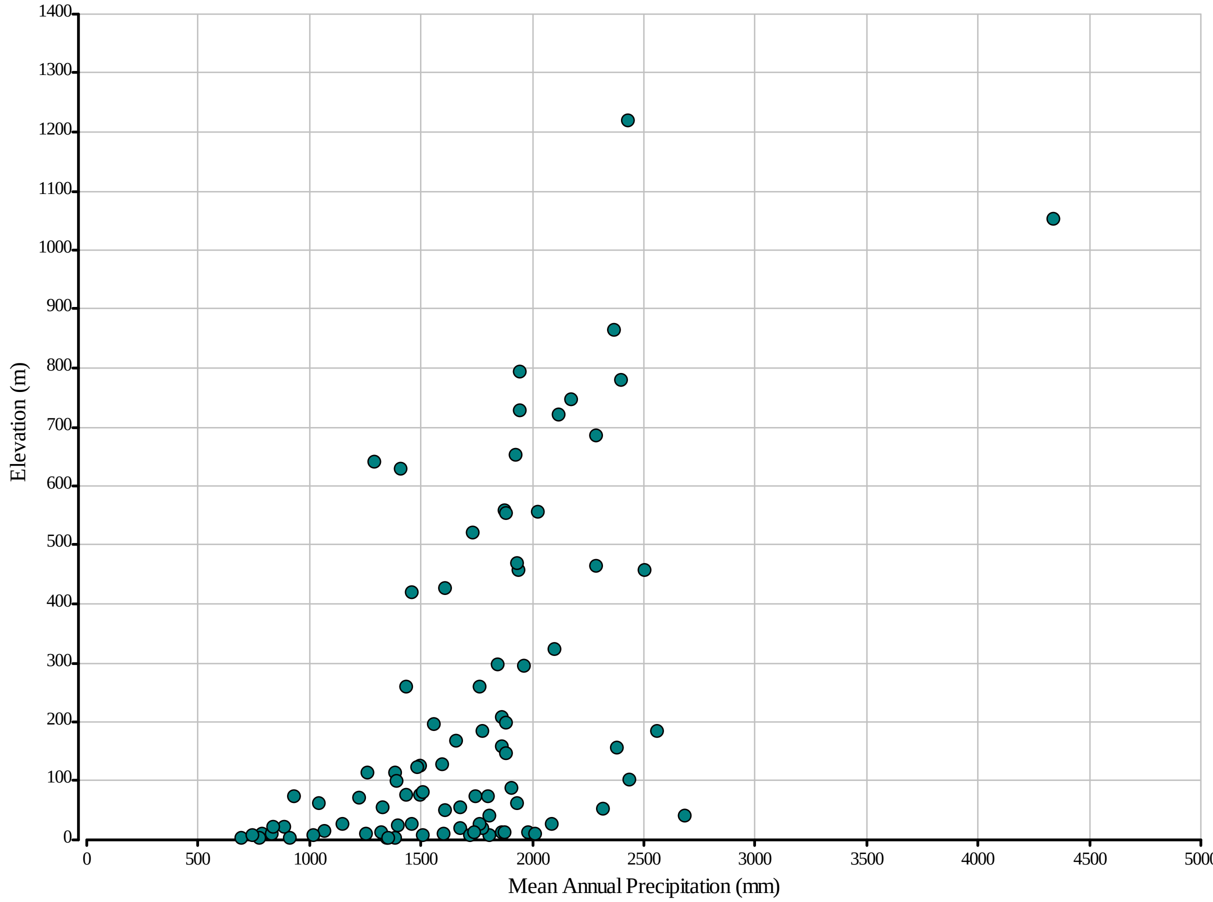

Figure 4.1. Mean annual precipitation vs. elevation of the NOAA stations.

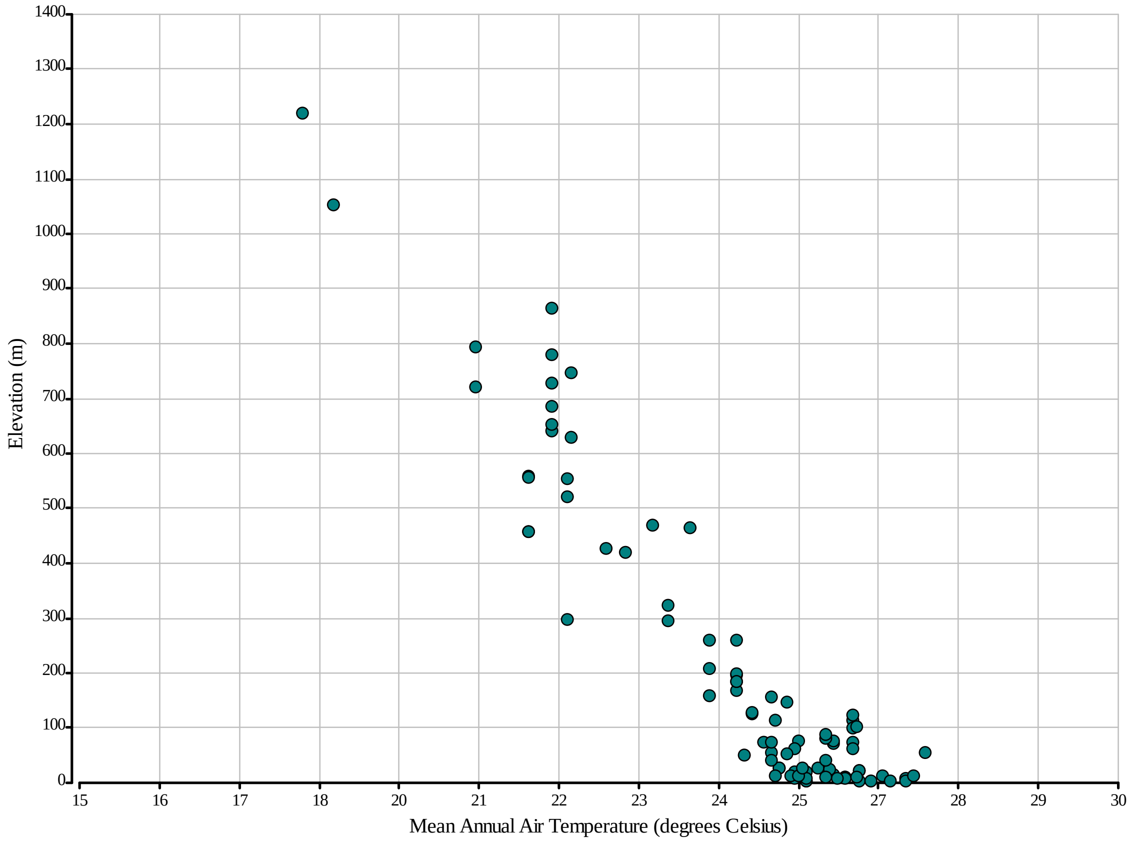

Figure 4.2. Mean annual air temperature vs. elevation of the NOAA stations.

Figure 4.3 and Figure 4.4 summarize the soil climate regimes according to the Newhall Simulation Model by the mean annual rainfall and the mean annual air temperature versus the elevations of the 90 NOAA stations respectively. The Figure 4.5 and Figure 4.6 summarize the soil climate regimes according Soil Taxonomy by the mean annual rainfall and the mean annual air temperature versus the elevations of the 90 NOAA stations, respectively. All figures including Figure 4.2 and Figure 4.3 clearly demonstrate 900 m above sea level elevation as the threshold point between the isothermic and the isohyperthermic soil temperature regimes.

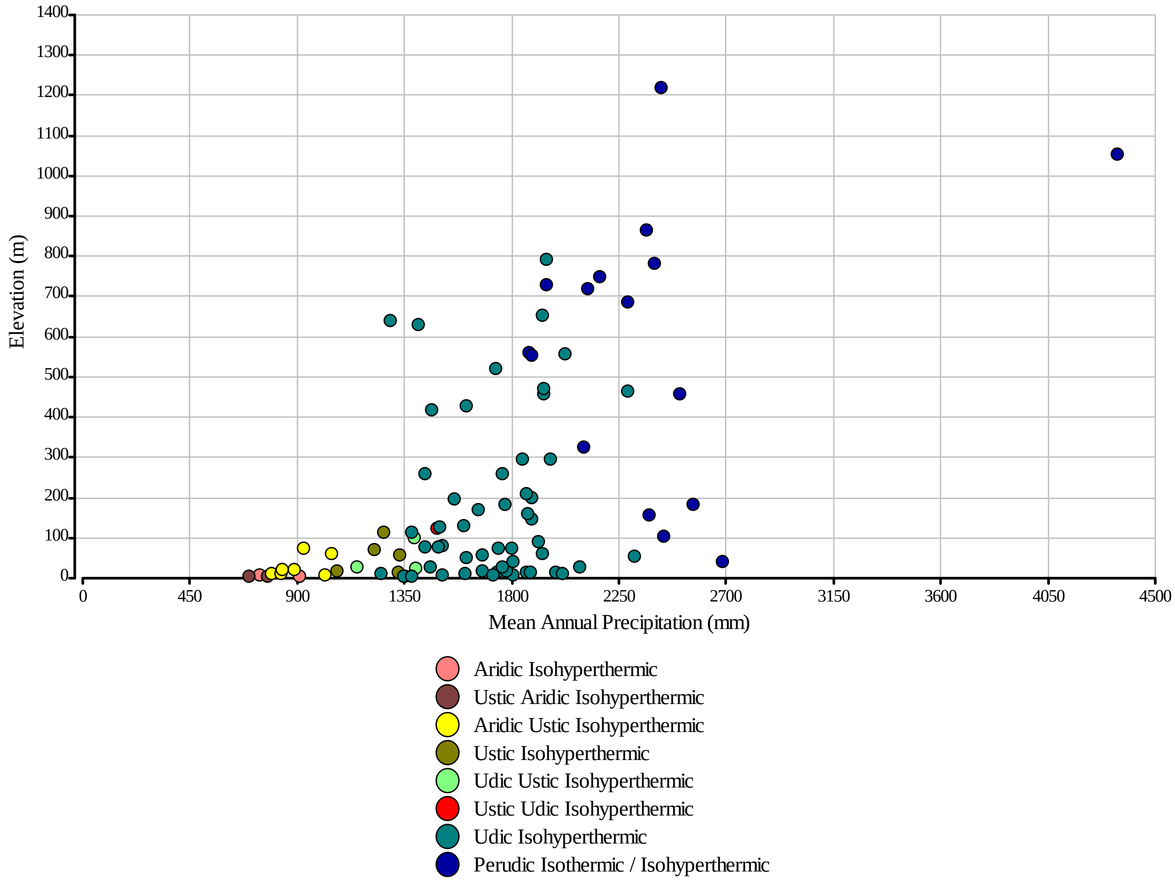

Figure 4.3. Soil Climate Regimes according to the Newhall Simulation Model by the mean annual precipitation and elevation.

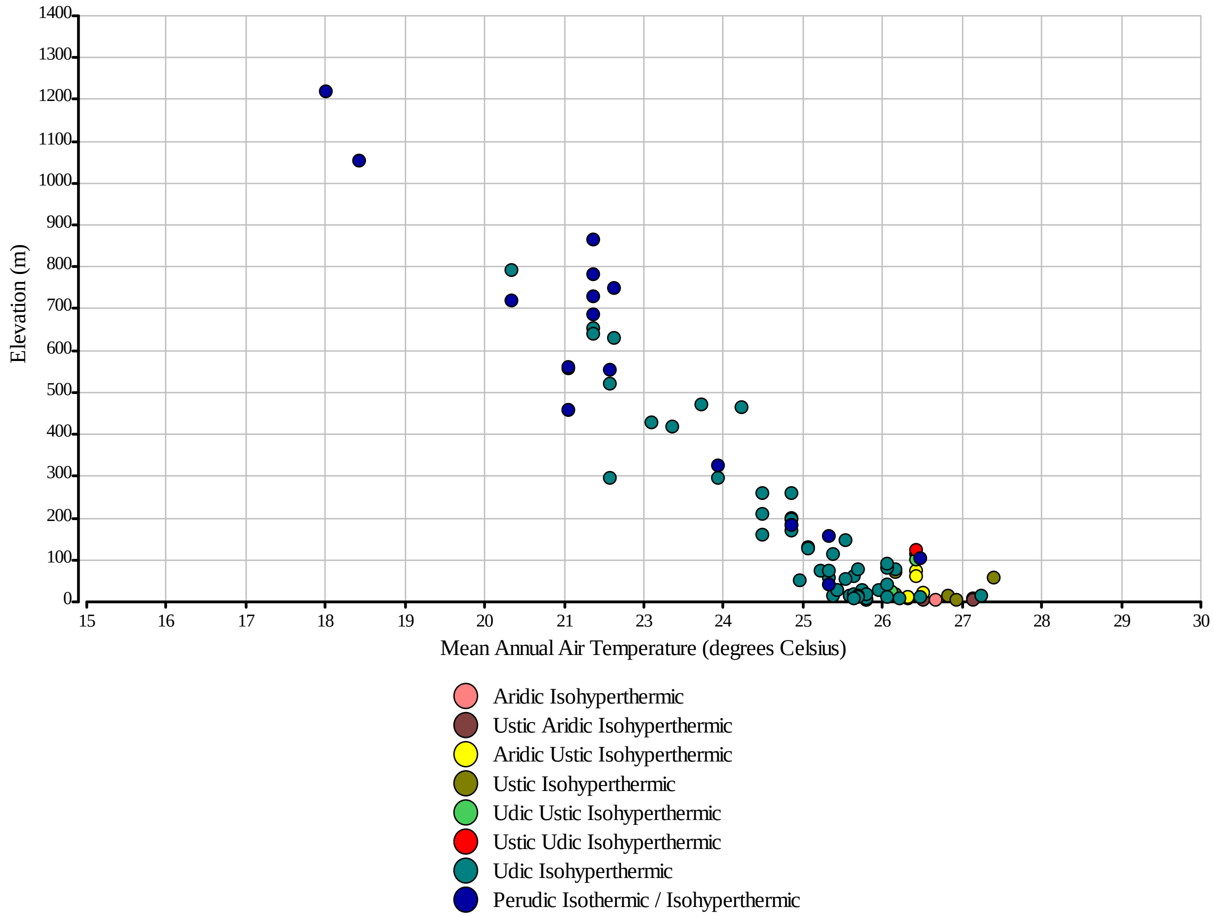

Figure 4.4. Soil Climate Regimes according to the Newhall Simulation Model by the mean annual air temperature and elevation.

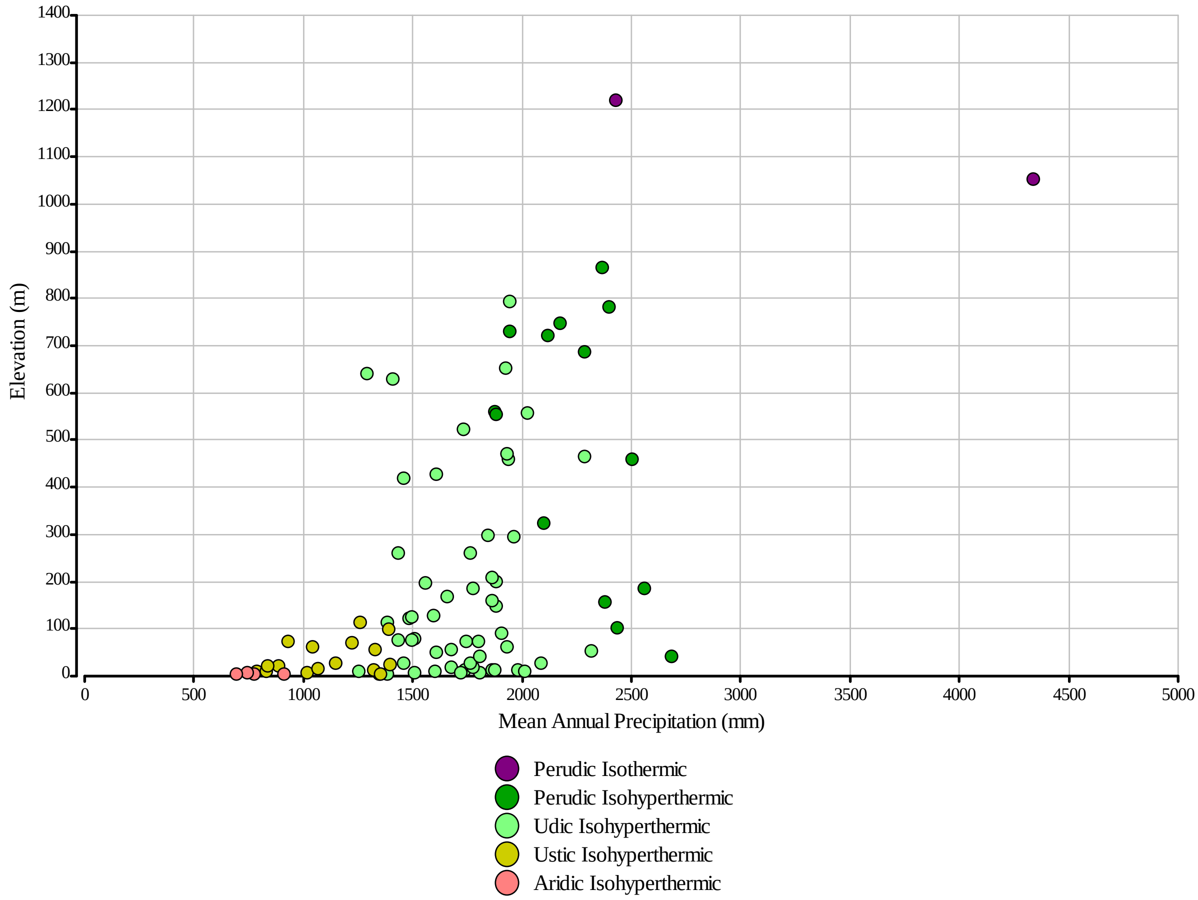

Figure 4.5. Soil Climate Regimes according to Soil Taxonomy by the mean annual precipitation and elevation.

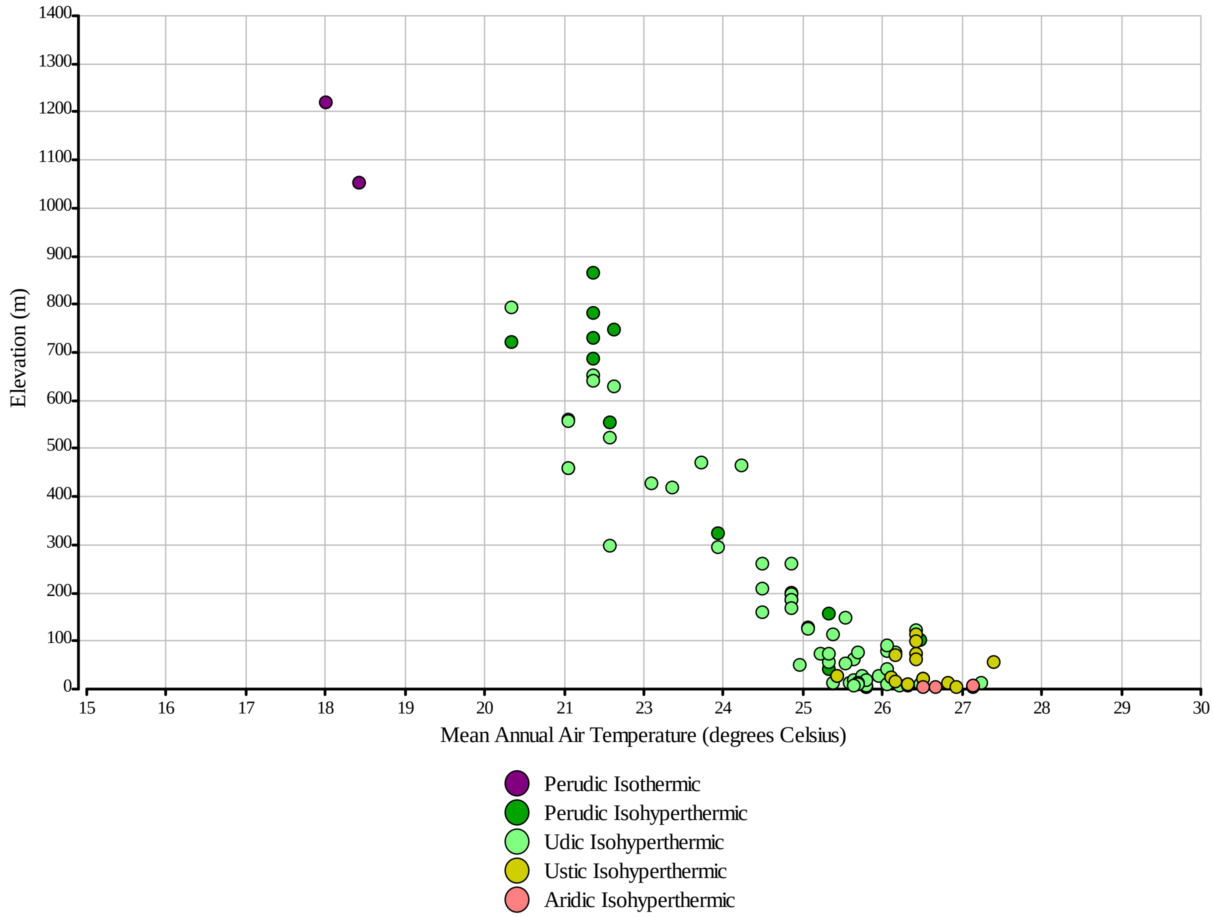

Figure 4.6. Soil Climate Regimes according to Soil Taxonomy by the mean annual air temperature and elevation.

4.1.4 Statistical Analysis

Table 4.2 summarizes the parameters that were used in the cluster analysis. The unweighted centroid and the average linkage algorithms were the appropriate cluster generators for the data of this study as shown in Figure 4.7 and Figure 4.8. The unweighted centroid and the average linkage algorithms had the highest cophenetic correlation coefficients, 0.663 and 0.652, respectively (Table 4.3). This coefficient indicates the correlation of the defined distances for the binary tree matrix with the original distances between objects (InfoStat, 2004b). The higher the coefficient the better is the description of the natural grouping of the data (InfoStat, 2004b). The weighted centroid, the single linkage, the weighted average linkage and the completed linkage algorithms had reasonable cophenetic correlation coefficients (0.651, 0.648, 0.635 and 0.615 respectively) and grouped the clusters very similar to the unweighted centroid and the average linkage algorithms. The ward algorithm had the lowest cophenetic correlation coefficient (0.250) because tends toproduce groups with the same amount of observations being affected by extreme values. Figure 4.7 and Figure 4.8 are the dendrographs generated by InfoStat (InfoStat, 2004a) using the unweighted centroid and the average linkage algorithms. The cutting line on the dendrograph on Figure 4.7 can be placed between the distance of 0.5975 and 0.6575; therefore the mean value of the range was used (0.6275). The cutting line on the dendrograph on Figure 4.8 can be placed between the distance of 0.6250 and 0.8750; therefore the mean value of the range was used (0.7500). Both algorithms grouped the weather stations parameters (precipitation, air temperature and elevation) in eight clusters as shown on Table 4.4. Graphically, the average linkage algorithm was the best cluster generator because the separation of the groups is more evident as shown on Figure 4.8. Finally, the distance matrix in Appendix B and Appendix C shows how close the clusters are against each other.

Table 4.2. Cluster Analysis parameters.

Soil Temperature Regime	**Soil Moisture Regime**	**Elevation (m)**
1-Isohyperthermic	1-Aridic	1- 0 to 99
2-Isothermic	2-Ustic Aridic	2- 100 to 499
	3-Aridic Ustic	3- 500 to 999
	4-Ustic	4- 1000 plus
	5-Udic Ustic	
	6-Ustic Udic	
	7-Udic	
	8-Perudic	

Table 4.3. Cophenetic correlation coefficients for the seven hierarchical algorithms provided by InfoStat (InfoStat, 2004a).

Hierarchical Algorithms	**Cophenetic correlation coefficient**
Single linkage	0.648
Complete linkage	0.615
Average linkage	0.652
Weighted average linkage	0.635
Unweighted centroid	0.663
Weighted centroid	0.651
Ward	0.250

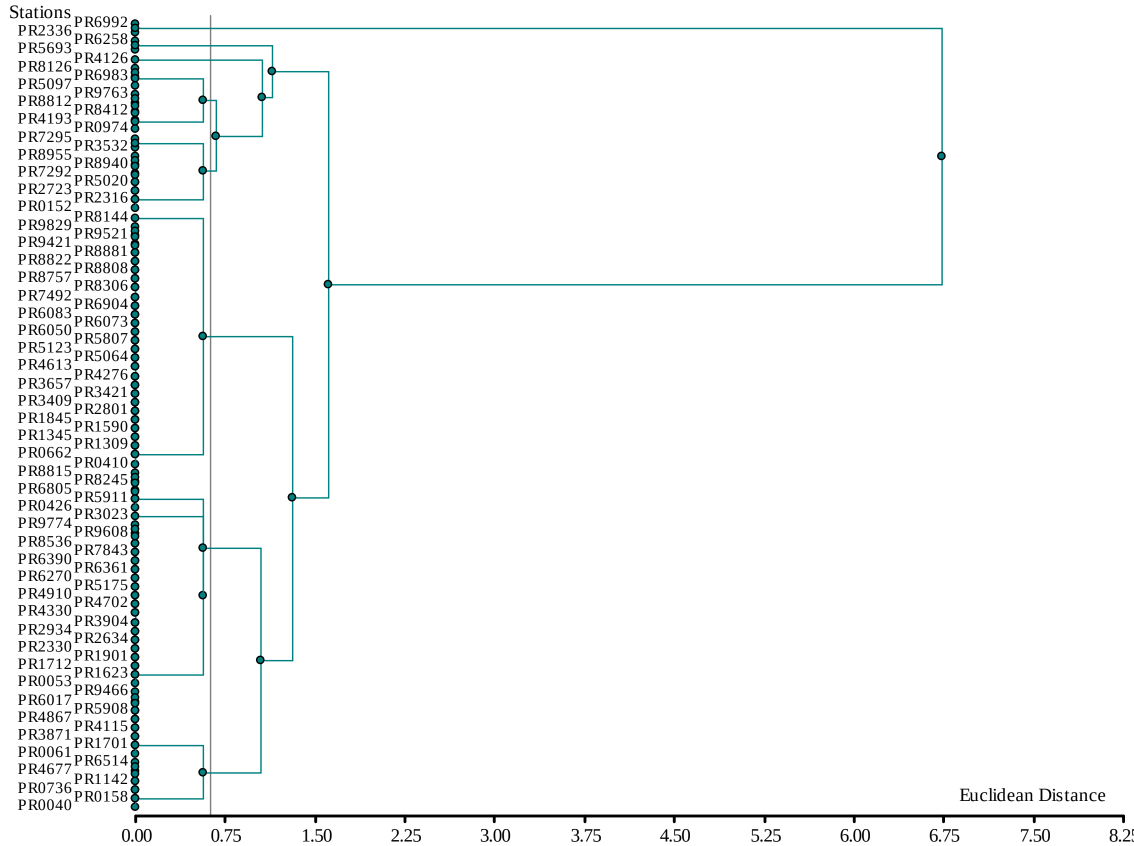

Figure 4.7. Unweighted centroid dendrograph generated from the data of the study.

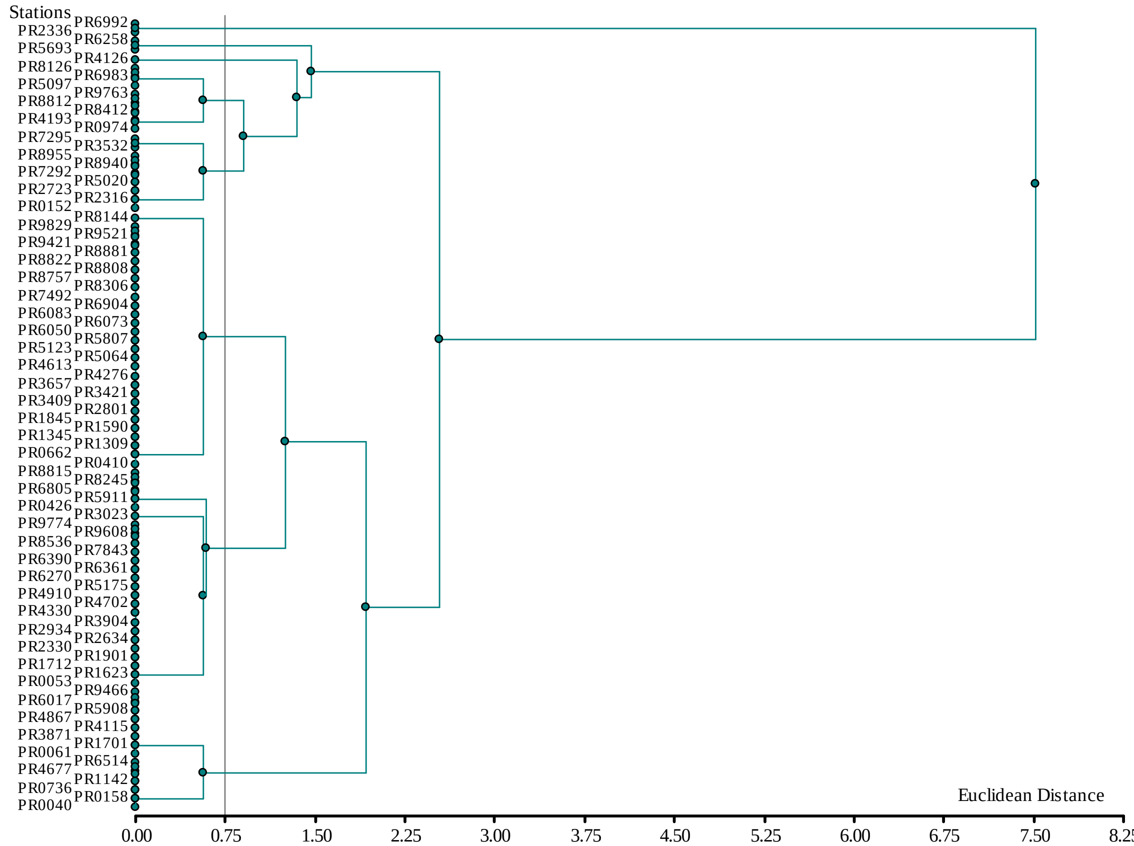

Figure 4.8. Average linkage dendrograph generated from the data of the study.

Table 4.4. Grouped clusters by the Average linkage and the Unweighted centroid algorithms by InfoStat (InfoStat, 2004a).

Clusters	NOAA Stations
Cluster1 (Perudic and Udic Isohyperthermic- 500 to 999 m asl)	Aceituna, Adjuntas Substation, Aibonito, Barranquitas, Cacaos, Orocovis, Carite Dam, Garzas, Guavate Camp, Indiera Alta, Jajome Alto, Maricao 2SSW, Matrullas Dam, Negro-Corozal and Toro Negro Plant 2
Cluster 2 (Perudic and Udic Isohyperthermic-100 to 499 m asl)	Adjuntas 1NW, Arecibo Observatory, Caonillas, Carite Plant, Cayey 1E, Cerro Gordo-Ciales, Cidra 1 E, Corozal Substation, Corral Viejo, Guajataca Dam, Hacienda Constanza, Isabela Substation, Jayuya, Lares 2SE, Maricao Fish Hatchery, Monte Bello, Mora Camp, Morovis 1N, Paraíso-Fajardo, Quebradillas, Río Grande El Verde, Sabana Grande 2ENE, San Lorenzo 3S, Utuado and Villalba 1E
Cluster 3 (Perudic Isothermic - 1,000 m asl)	Cerro Maravilla and Pico del Este
Cluster 4 (Ustic Isohyperthermic-100 to 499 m asl)	Guayabal
Cluster 5 (Ustic Aridic and Aridic Ustic Isohyperthermic- 0 to 99 m asl)	Aguirre Central, Central San Francisco, Coamo, Ensenada, Juana Díaz Camp, Ponce 4E, Ponce City, Santa Isabel 2ENE and Santa Rita
Cluster 6 (Aridic Isohyperthermic- 0 to 99 m asl)	Magueyes Island and Mona Island
Cluster 7 (Perudic and Udic Isohyperthermic- 0 to 99 m asl)	Arecibo 3ESE, Barceloneta 2, Calero Camp, Caguas 1W, Canóvanas, Cataño, Coloso, Dorado 2WNW, Dos Bocas, Fajardo, Gurabo Substation, Humacao 2SSE, Juncos 1NNE, La Muda, Manatí 3E, Maunabo, Mayagüez City, Mayagüez Airport, Patillas Dam, Puerto Real, Río Blanco Lower, Río Piedras Exp. Sta., San Germán 4W, San Juan City, San Lorenzo Farm 2NW, San Sebastían 2WNW, Toa Baja 1SSW, Trujillo Alto 2SSW and Yabucoa 1NNE
Cluster 8 (Ustic and Udic Ustic Isohyperthermic- 0 to 99 m asl)	Borinquén Airport, Guayama, Lajas Substation, Peñuelas 1NE, Rincón Power Plant, Roosevelt Roads, San Juan WSFO and Vieques Island

Figure 4.9 and Figure 4.10 summarizes the soil climate regimes after cluster segregation by the average linkage algorithm according to Soil Taxonomy by the mean annual precipitation and the mean annual air temperature versus elevation respectively. The Figure 4.9 and Figure 4.10 are identical to Figure 4.5 and Figure 4.6 demonstrating that a graphic or tabular method appropriately separated the clusters. Therefore the descriptive statistical analysis supports the results obtained by graphic and tabular methods.

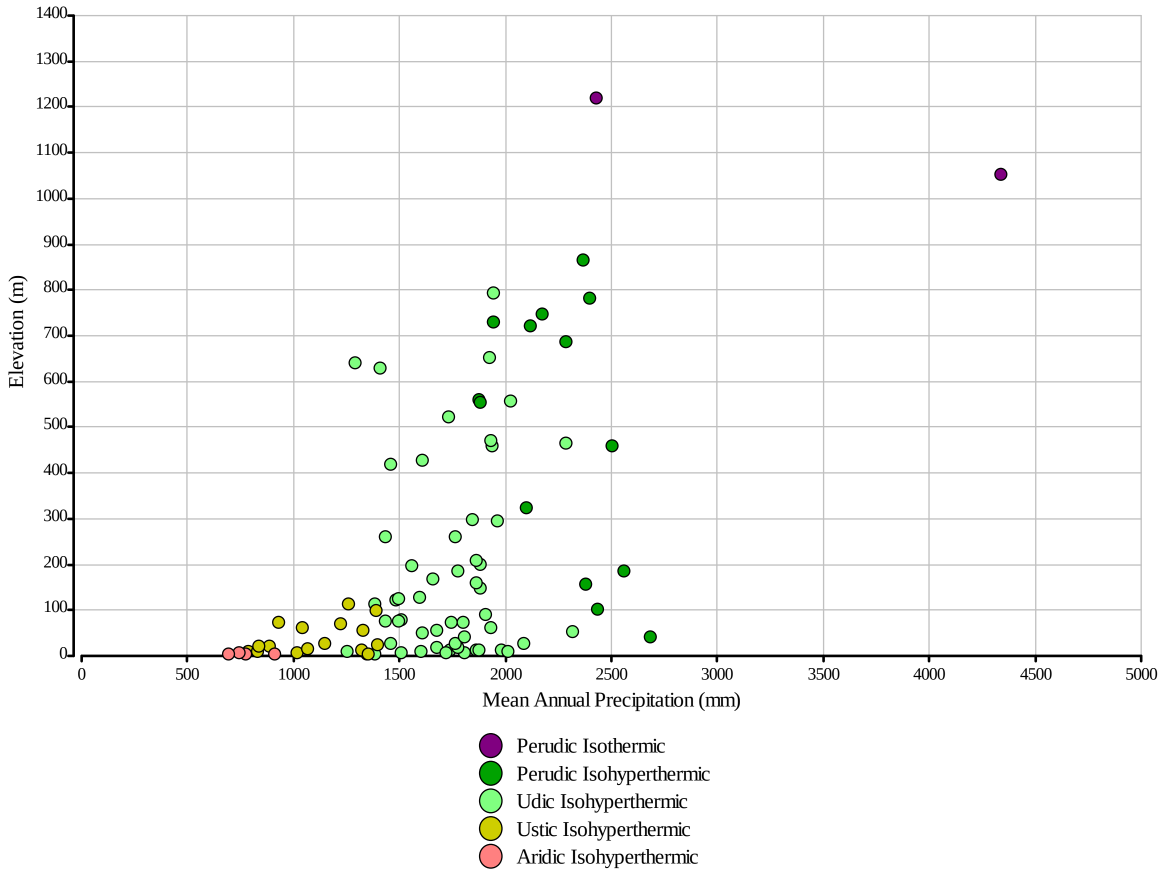

Figure 4.9. Soil Climate Regimes according to Soil Taxonomy by the mean annual precipitation after clusters segregation.

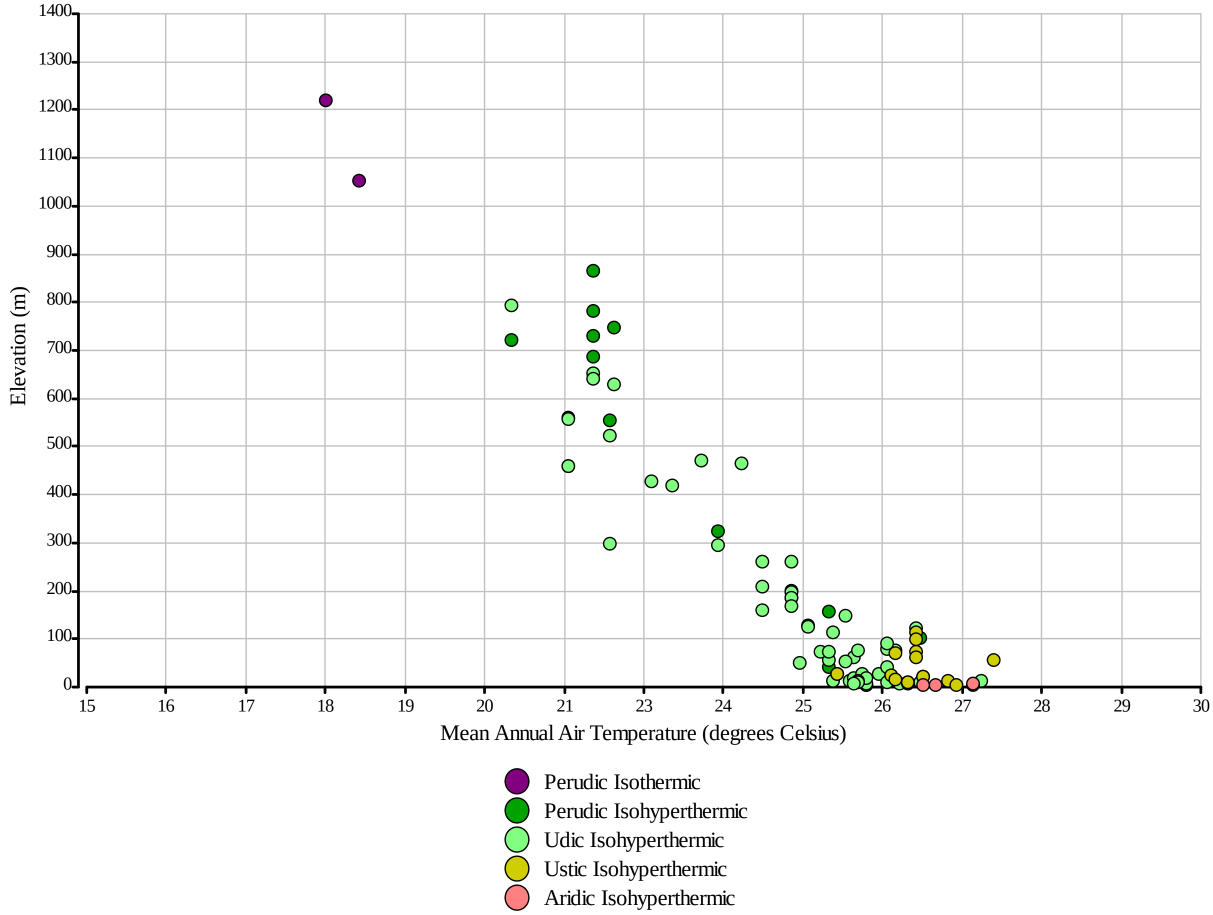

Figure 4.10. Soil Climate Regimes according to Soil Taxonomy by the mean annual air temperature after clusters segregation.

4.1.5 Update of Soil Climate Regions Map of Puerto Rico

4.1.5.1 Update of the Soil Moisture Regimes Map

The soil moisture regime map of Puerto Rico created from a geographic information system contains the eight classes identified by the Newhall Simulation Model (Figure 4.11). The eight classes are: aridic, ustic aridic, aridic ustic, ustic, udic ustic, ustic udic, udic and perudic. The eight classes are summarized in Table 4.5 .

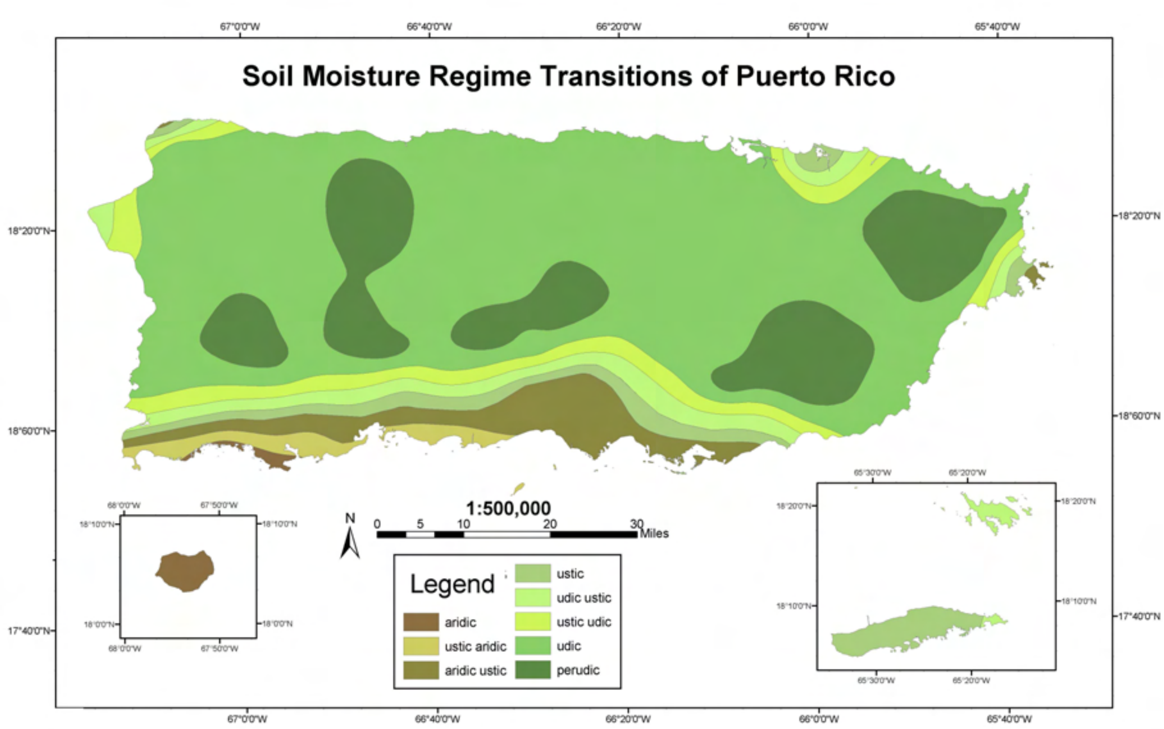

Figure 4.11. Soil Moisture Regimes of Puerto Rico according to the Newhall Simulation Model.

Table 4.5. Soil Moisture Regimes identified by the Newhall Simulation Model in Puerto Rico.

Class	Area (hectares)	Percentage
Aridic	8,000	0.89
Ustic Aridic	17,450	1.94
Aridic Ustic	51,312	5.71
Ustic	44,736	4.98
Udic Ustic	45,887	5.10
Ustic Udic	55,719	6.20
Udic	517,975	57.62
Perudic	157,943	17.57
	899,022	100

The aridic soil moisture regime covers an area of 8,000 ha along the southern coast of Puerto Rico and on Mona Island, equivalent of the 0.89 per cent total land area of the island. This soil moisture regime is not currently recognized in Puerto Rico and is the least extensive.

The ustic aridic soil moisture regime covers an area of 17,450 ha along the southern coast of Puerto Rico to be equivalent of the 1.94 per cent total land area of the island. This soil moisture regime is not currently recognized in Puerto Rico.

The aridic ustic soil moisture regime covers an area of 51,312 ha along the southern coast and two small portions, one in the east coast and the other in the northwestern corner of Puerto Rico. This area is equivalent to the 5.71 per cent total land area of the island. This soil moisture regime is currently recognized in Puerto Rico mainly along the area that was found by the Newhall Simulation Model to be an aridic and ustic aridic soil moisture regimes on this study.

The ustic soil moisture regime covers an area of 44,736 ha along the southern and on small portions on the northern, eastern and western Puerto Rico and in Culebra and Vieques Islands. This area is equivalent of the 4.98 per cent total land area of the island. This soil moisture regime is currently recognized in Puerto Rico.

The udic ustic soil moisture regime covers an area of 45,887 ha along the southern and on small portions along the northern, eastern and western Puerto Rico. This area is equivalent of the 5.10 per cent total land area of the island. This soil moisture regime is not currently recognized by Soil Taxonomy.

The ustic udic soil moisture regime covers an area of 55,719 ha next to the areas covered by the udic ustic soil moisture regime. This area is equivalent of the 6.20 per cent total land area of the island. This soil moisture regime is not currently recognized by Soil Taxonomy.

The udic soil moisture regime is the most extensive one in Puerto Rico. This soil moisture regime covers an area of 517,975 ha, equivalent to 57.62 per cent total land area of the island. This soil moisture regime is currently recognized in Puerto Rico.

The perudic soil moisture regime is the second most extensive in Puerto Rico. This soil moisture regime covers an area of 157,943 ha, equivalent to 17.57 per cent total land area of the island. This soil moisture regime is not currently recognized in Puerto Rico. This soil moisture regime was found on this study in the Sierra de Cayey and Sierra de Luquillo Mountain Ranges and in the Central Mountain Range.

As stated on section 4.1.1 the udic ustic and the ustic udic soil moisture regimes are not currently recognized as classes of the soil moisture regimes by Soil Taxonomy.

The soil moisture regimes map obtained from a geographic information system containing the four classes recognized by Soil Taxonomy is shown on Figure 4.12. The four classes are: aridic, ustic, udic and perudic. The four classes are summarized in Table 4.6.

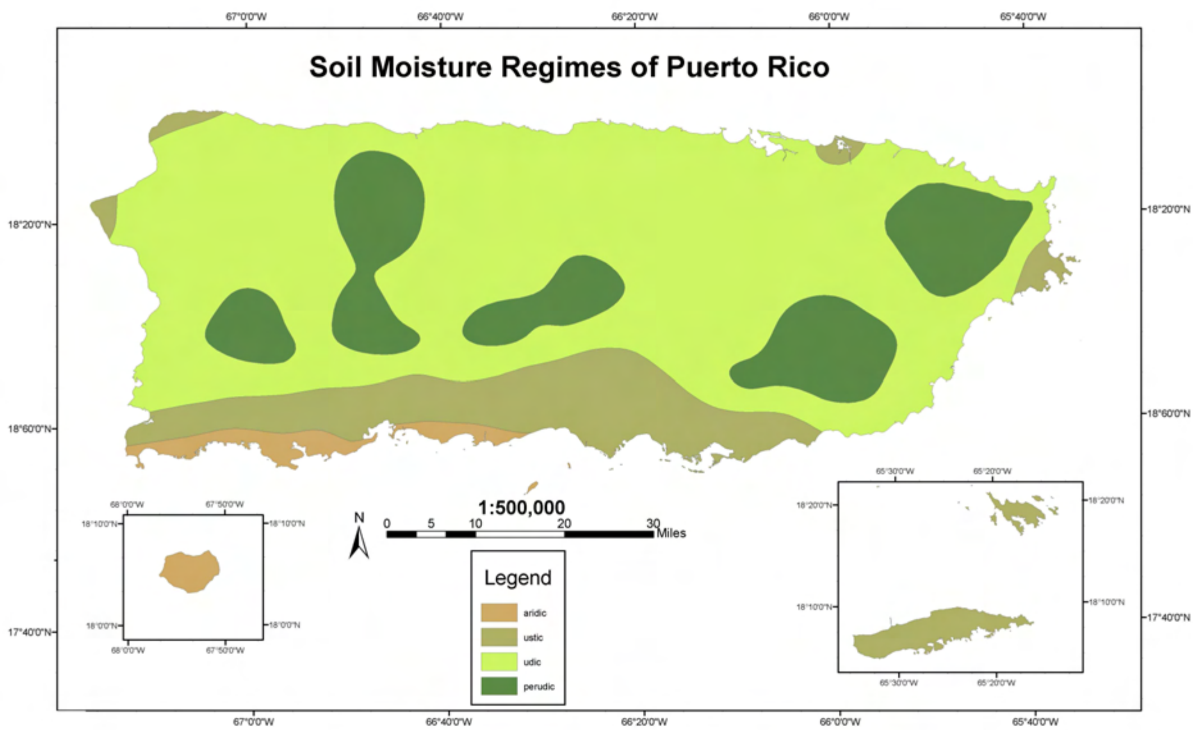

Figure 4.12. Soil Moisture Regimes of Puerto Rico according to Soil Taxonomy.

Table 4.6. Soil Moisture Regimes of Soil Taxonomy in Puerto Rico.

Class	Area (hectares)	Percentage
Aridic	25,450	2.83
Ustic	141,935	15.79
Udic	573,694	63.81
Perudic	157,943	17.57
	899,022	100

The aridic regime is the least extensive soil moisture regime in Puerto Rico. It covers and area of 25,450 ha along the southwestern coast of Puerto Rico and on Mona Island. This area is equivalent to the 2.83 per cent total land area of the island. As stated above this soil moisture regime is not currently recognized in Puerto Rico.

The ustic soil moisture regime covers an area of 141,935 ha along the southern and on portions along the northern, eastern and western Puerto Rico and on the Culebra and Vieques Islands. This area is equivalent to the 15.79 per cent total land area of Puerto Rico and is currently recognized.

The udic soil moisture regime is the most extensive one in Puerto Rico. This soil moisture regime covers an area of 573,694 ha or 63.81 per cent of the total land area of the island. This soil moisture regime is currently recognized in Puerto Rico.

The perudic soil moisture regime covers an estimated area of 157,943 ha, equivalent to 17.57 per cent total land area of the island. This soil moisture regime is not currently recognized in Puerto Rico. This soil moisture regime was found on this study in the Sierra de Cayey and Sierra de Luquillo Mountain Ranges and in portions of the Central Mountain Range.

The area designated by the geographic information system as perudic nearby the Arecibo Observatory was based on data from only one weather station. This area may have been overestimated because the limited amount of data and the irregular topography of the zone. These two conditions limit the capability of Arc Info to delineate clearly the geographical boundaries.

4.1.5.2 Update of the Soil Temperature Regimes Map

The soil temperature regimes map of Puerto Rico obtained from the geographic information system contains two classes as shown on Figure 4.13. These classes are the isothermic and the isohyperthermic soil temperature regimes. The two classes are summarized on Table 4.7.

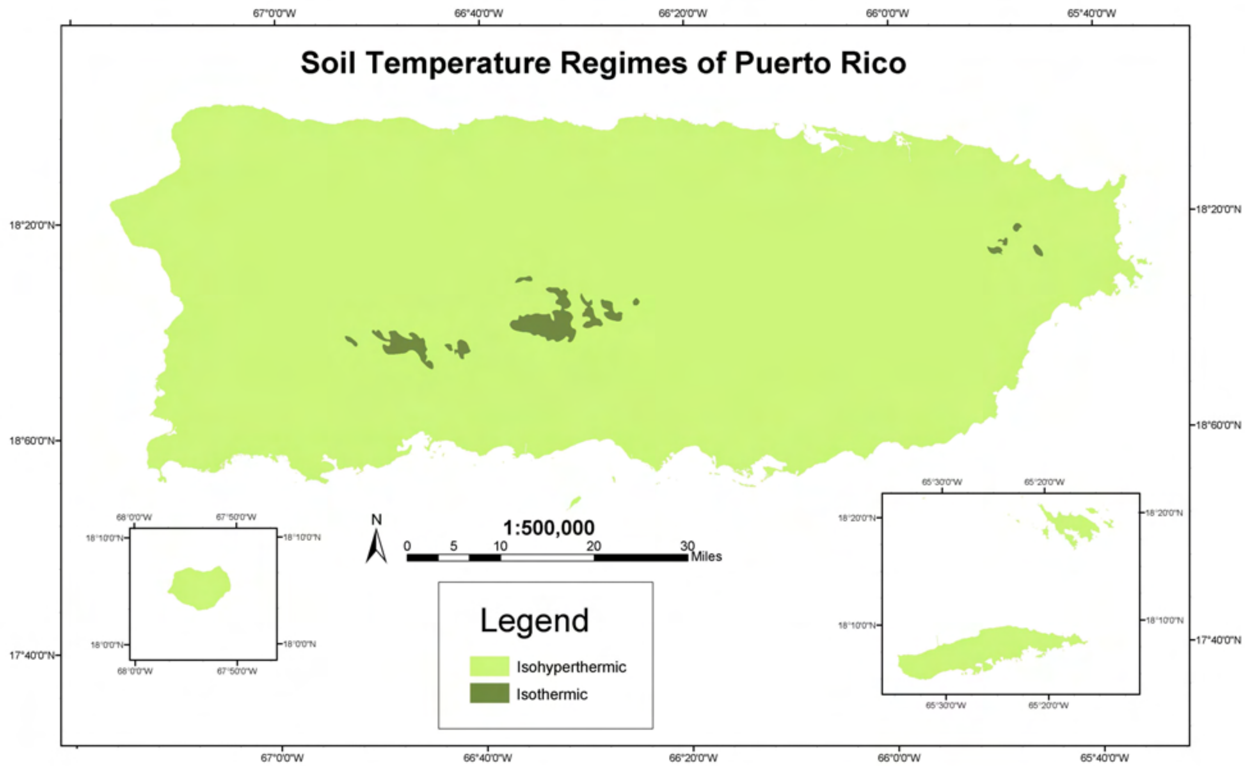

Figure 4.13. Soil Temperature Regimes of Puerto Rico.

Table 4.7. Soil Temperature Regimes of Puerto Rico.

Class	Area (hectares)	Percentage
Isothermic	10,938	1.22
Isohyperthermic	888,084	98.78
	899,022	100

The isohyperthermic soil temperature regime covers an area of 888,084 ha, equivalent to 98.78 per cent the total land area of Puerto Rico. This soil temperature regime is currently recognized in Puerto Rico. According to the Newhall Simulation

Model the isohyperthermic soil temperature regime is identified in areas below 900 m above sea level. This soil temperature regime is currently recognized in areas below the elevation of 600 m above sea level.

The isothermic soil temperature regime covers an area of 10,938 ha, equivalent of 1.22 per cent total land area of Puerto Rico. This soil temperature regime is currently recognized in the island. According to the Newhall Simulation Model this soil temperature regime is identified in areas above 900 m above sea level, not in areas above 600 m like it is currently recognized.

The isomesic soil temperature regime previously identified at the Sierra de Luquillo Mountain Range was not found by the Newhall Simulation Model. Therefore in Puerto Rico the mean annual soil temperature never is cooler than 15ºC at any elevation.

4.1.5.3 Update of the Soil Climate Regimes Map

The soil climate regimes map of Puerto Rico obtained from the geographic information system contains six classes as shown on Figure 4.14. These classes are: aridic isohyperthermic, ustic isohyperthermic, udic isohyperthermic, udic isothermic, perudic isohyperthermic and perudic isothermic. The six classes are summarized on Table 4.8. These six classes are recognized by Soil Taxonomy.

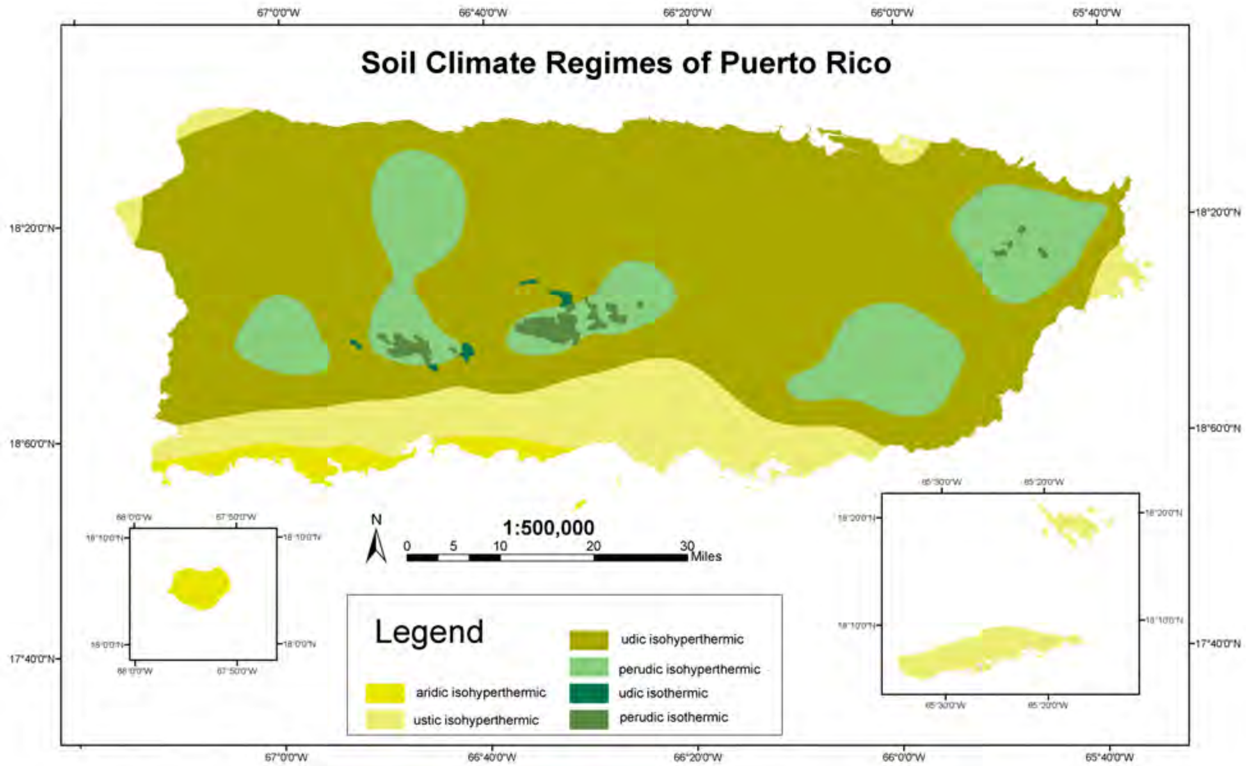

Figure 4.14. Soil Climate Regimes of Puerto Rico.

Table 4.8. Soil Climate Regimes of Puerto Rico.

Class	Area (hectares)	Percentage
Aridic Isohyperthermic	25,450	2.83
Ustic Isohyperthermic	141,935	15.79
Udic Isohyperthermic	569,906	63.39
Udic Isothermic	1,649	0.18
Perudic Isohyperthermic	150,790	17.07
Perudic Isothermic	9,292	1.04
	899,022	100

The aridic isohyperthermic climate regime covers an area of 25,450 ha along the southern coast of Puerto Rico and on Mona Island, representing 2.83 per cent total land area of the island. This soil climate regime is not currently recognized in Puerto Rico. The ustic isohyperthermic regime covers an area of 141,935 ha equivalent to 15.79 per cent land area of Puerto Rico. This soil climate regime is currently recognized on the island. The udic isohyperthermic regime is the most extensive one in Puerto Rico. This soil climate regime covers an area of 569,906 ha or 63.39 per cent of the total land area of the island. This soil climate regime is currently recognized. The udic isothermic regime is the least extensive, covering an area of 1,649 ha or a 0.18 per cent of the total land area. This soil climate regime is currently recognized on the island. The perudic isohyperthermic regime is not currently recognized in Puerto Rico. This soil climate regime covers an area of 150,790 ha equivalent to 17.07 per cent land area of the island. Finally, the perudic isothermic regime was found in the Sierra de Luquillo Mountain Range and in the Central Mountain Range. This soil climate regime covers an area of 9,292 ha equivalent to 1.04 per cent of the total land area of the island. This soil climate regime is not currently recognized in Puerto Rico.

4.2 Evaluation of the performance of the Newhall Simulation Model by Comparing the Model Output and Observed Data

4.2.1 Soil Moisture at the Guánica State Forest Station

The soil moisture was measured as volumetric water content from March 2001 through September 2004. Table 4.9 summarizes the mean monthly volumetric water content at the central portion of the soil moisture control section (20 cm). The soil series at this site is the Tuque series (*clayey-skeletal, carbonatic, isohyperthermic Lithic Petrocalcic Calciustolls*) (Beinroth et al., 2003), which has not been characterized. In order to calculate available water in the control section, a characterization from a similar soil was used. The San Germán series (*clayey-skeletal, mixed, superactive, isohyperthermic, shallow Typic Ustorthents*) (Beinroth et al., 2003) has a 21.10 per cent water held (volumetric content) at 1,500 kPa (Soil Survey Staff, 2004).

Table 4.9. Mean Monthly Soil Moisture at 20 cm at the Guánica State Forest Station.

Month	Mean Monthly Soil Moisture (%) at 20 cm	Water held at 1,500 kPa (20 cm)	Soil Moisture Control Section Status
January	1.70	21.10	Dry
February	1.93	21.10	Dry
March	1.65	21.10	Dry
April	6.78	21.10	Dry
May	4.81	21.10	Dry
June	4.13	21.10	Dry
July	1.55	21.10	Dry
August	2.15	21.10	Dry
September	2.72	21.10	Dry
October	2.87	21.10	Dry
November	5.23	21.10	Dry
December	3.20	21.10	Dry

The mean monthly soil moisture content for the study period was 3.23 per cent. As shown on Table 4.9 in average the soil moisture control section was dry every month of the year therefore this site meets the definition for an aridic soil moisture regime.

4.2.2 Soil Temperature at the Guánica State Forest Station

The soil temperature was measured at a 50 cm depth from March 2001 through August 2004. Table 4.10 summarizes the mean monthly soil temperature and the mean monthly air temperature for the study period.

Table 4.10. Mean Monthly Soil Temperature at 50 cm at the Guánica State Forest Station.

Month	Mean Monthly Soil Temperature (ºC) at 50 cm	Mean Monthly Air Temperature (ºC)	Temperature Difference (ºC)
January	26.42	24.72	1.70
February	26.74	24.63	2.11
March	27.05	24.95	2.10
April	27.16	25.33	1.83
May	27.61	26.42	1.19
June	28.15	27.32	0.83
July	29.23	27.70	1.53
August	29.83	28.00	1.83
September	29.70	27.50	2.20
October	28.60	27.37	1.23
November	27.40	26.24	1.16
December	26.71	25.86	0.85

The mean monthly soil temperature for the study period was 27.88 ºC. The mean summer and mean winter soil temperatures at this site differ by 2.85 ºC at 50 cm depth meeting the definition for the isotivity concept. The results of this site demonstrate that the soil temperature can be estimated by adding 1.55 ºC to the air temperature. This estimation is close to the values reported by Comerma and Sánchez (1981), Van Wambeke (1981, 1982 and 1985) and Murtha and Williams (1986).

4.2.3 Soil Moisture at the Combate Station

The soil moisture was measured as volumetric water content from March 2001 through August 2004. Table 4.11 summarizes the mean monthly volumetric water content at the central portion of the soil moisture control section (20 cm). The soil series at this site is the Melones series (*fine, smectitic, isohyperthermic Vertic Paleustalfs*) (Beinroth et al., 2003) which has a 23.50 per cent water held (volumetric content) at 1,500 kPa (Soil Survey Staff, 2004).

Table 4.11. Mean Monthly Soil Moisture at 20 cm at the Combate Station.

Month	Mean Monthly Soil Moisture (%) at 20 cm	Water held at 1,500 kPa (20 cm)	Soil Moisture Control Section Status
January	5.53	23.50	Dry
February	7.71	23.50	Dry
March	7.53	23.50	Dry
April	9.94	23.50	Dry
May	14.33	23.50	Dry
June	8.64	23.50	Dry
July	10.91	23.50	Dry
August	13.26	23.50	Dry
September	9.52	23.50	Dry
October	7.43	23.50	Dry
November	8.56	23.50	Dry
December	6.70	23.50	Dry

The mean monthly soil moisture content for the study period was 9.17 per cent. As shown on Table 4.11 in average the soil moisture control section was dry every month, meeting the definition for an aridic soil moisture regime.

4.2.4 Soil Temperature at the Combate Station

The soil temperature was measured at a 50 cm depth from March 2001 through July 2004. Table 4.12 summarizes the mean monthly soil temperature and the mean monthly air temperature for the study period.

Table 4.12. Mean Monthly Soil Temperature at 50 cm at Combate Station.

Month	Mean Monthly Soil Temperature (ºC) at 50 cm	Mean Monthly Air Temperature (ºC)	Temperature Difference (ºC)
January	26.43	25.20	1.23
February	26.17	24.93	1.24
March	27.60	25.24	2.36
April	28.16	25.42	2.74
May	28.45	26.55	1.90
June	29.39	27.95	1.44
July	29.49	27.82	1.67
August	29.71	27.90	1.81
September	29.77	27.76	2.01
October	28.94	27.31	1.63
November	28.02	26.23	1.79
December	26.72	25.37	1.35

The mean monthly soil temperature for the study period was 28.24 ºC. The mean summer and mean winter soil temperatures at this site differ by 2.93 ºC at 50 cm depth meeting the definition for the isotivity concept. The results of this site demonstrate that the soil temperature can be estimated by adding 1.76 ºC to the air temperature. This estimation is close to the values reported by Comerma and Sánchez (1981), Van Wambeke (1981, 1982 and 1985) and Murtha and Williams (1986).

4.2.5 Soil Moisture at the Maricao State Forest Station

The soil moisture was measured as volumetric water content from May 2001 through October 2004. Table 4.13 summarizes the mean monthly volumetric water content at the central portion of the soil moisture control section (20 cm). The soil series at this site is the Rosario series (*clayey, ferruginous, isohyperthermic, shallow Typic Hapludox*) (Beinroth et al., 2003). This soil has a 29.20 per cent water held (volumetric content) at 1,500 kPa (Soil Survey Staff, 2004).

Table 4.13. Mean Monthly Soil Moisture at 20 cm at the Maricao State Forest Station.

Month	Mean Monthly Soil Moisture (%) at 20 cm	Water held at 1,500 kPa (20 cm)	Soil Moisture Control Section Status
January	32.97	29.20	Moist
February	30.70	29.20	Moist
March	30.52	29.20	Moist
April	36.74	29.20	Moist
May	36.73	29.20	Moist
June	33.96	29.20	Moist
July	34.65	29.20	Moist
August	35.19	29.20	Moist
September	36.82	29.20	Moist
October	37.44	29.20	Moist
November	37.24	29.20	Moist
December	35.61	29.20	Moist

The mean monthly soil moisture content for the study period was 34.88 per cent. As shown on Table 4.13 in average the soil moisture control section was moist every month of the year. In fact only one month (March, 2003) was dry during the study period. Therefore this site meets the definition for the udic soil moisture regime. At this point is not possible to decide if this site meets the definition for a perudic soil moisture regime. This will be discussed in more detail on section 4.2.13.1.

4.2.6 Soil Temperature at the Maricao State Forest Station

The soil temperature was measured at a 50 cm depth from May 2001 through October 2004. Table 4.14 summarizes the mean monthly soil temperature and the mean monthly air temperature for the study period.

Table 4.14. Mean Monthly Soil Temperature at 50 cm at the Maricao State Forest Station.

Month	Mean Monthly Soil Temperature (ºC) at 50 cm	Mean Monthly Air Temperature (ºC)	Temperature Difference (ºC)
January	21.25	19.86	1.39
February	21.52	20.29	1.23
March	21.25	20.23	1.02
April	21.49	20.49	1.00
May	21.63	21.34	0.29
June	22.17	22.17	0
July	22.40	22.27	0.13
August	22.78	22.54	0.24
September	22.80	22.51	0.29
October	22.64	21.98	0.66
November	22.18	21.20	0.98
December	21.62	20.60	1.02

The mean monthly soil temperature for the study period was 21.98 ºC (~ 22 ºC) which lays in the borderline of the isothermic and isohyperthermic soil temperature regimes at the elevation of 746 m above sea level. The implication of this finding will be discussed in more detail on section 4.2.13.2. The mean summer and mean winter soil temperatures at this site differ by 1.32 ºC at 50 cm depth meeting the definition for the isotivity concept. The results of this site demonstrate that the soil temperature can be estimated by adding 0.69 ºC to the air temperature. This estimation is lower than the values reported by Comerma and Sánchez (1981), Van Wambeke (1981, 1982 and 1985) and Murtha and Williams (1986).

4.2.7 Soil Moisture at the Guilarte State Forest Station

The soil moisture was measured as volumetric water content from May 2001 through August 2004. Table 4.15 summarizes the mean monthly volumetric water content at the central portion of the soil moisture control section (20 cm). The soil series at this site is the Maricao series (*fine, mixed, subactive, isohyperthermic Inceptic Hapludults*) (Beinroth et al., 2003). This soil has a 32.90 per cent water held (volumetric content) at 1,500 kPa (Soil Survey Staff, 2004).

Table 4.15. Mean Monthly Soil Moisture at 20 cm at the Guilarte State Forest Station.

Month	Mean Monthly Soil Moisture (%) at 20 cm	Water held at 1,500 kPa (20 cm)	Soil Moisture Control Section Status
January	40.34	32.90	Moist
February	40.29	32.90	Moist
March	39.56	32.90	Moist
April	41.04	32.90	Moist
May	41.22	32.90	Moist
June	40.89	32.90	Moist
July	38.61	32.90	Moist
August	40.35	32.90	Moist
September	42.16	32.90	Moist
October	41.12	32.90	Moist
November	40.77	32.90	Moist
December	39.74	32.90	Moist

The mean monthly soil moisture content for the study period was 40.51 per cent. As shown on Table 4.15, in average the soil moisture control section was moist every month of the year therefore this site meets the definition for the udic soil moisture regime. At this point is not possible to decide if this site meets the definition for a perudic soil moisture regime. This will be discussed in more detail on section 4.2.13.1.

4.2.8 Soil Temperature at the Guilarte State Forest Station

The soil temperature was measured at a 50 cm depth from May 2001 through August 2004. Table 4.16 summarizes the mean monthly soil temperature and the mean monthly air temperature for the study period.

Table 4.16. Mean Monthly Soil Temperature at 50 cm at the Guilarte State Forest Station.

Month	Mean Monthly Soil Temperature (ºC) at 50 cm	Mean Monthly Air Temperature (ºC)	Temperature Difference (ºC)
January	19.38	17.42	1.96
February	19.61	17.51	2.10
March	19.86	17.58	2.28
April	20.08	18.21	1.87
May	20.67	19.16	1.51
June	21.62	20.04	1.58
July	22.02	20.19	1.83
August	22.13	20.33	1.80
September	21.74	20.41	1.33
October	21.41	20.06	1.35
November	20.52	19.07	1.45
December	19.93	18.37	1.56

The mean monthly soil temperature for the study period was 20.74 ºC meeting the definition for an isothermic soil temperature regime. The mean summer and mean winter soil temperatures at this site differ by 2.34 ºC at 50 cm depth meeting the definition for the isotivity concept. The results of this site demonstrate that the soil temperature can be estimated by adding 1.72 ºC to the air temperature. This estimation is close to the values reported by Comerma and Sánchez (1981), Van Wambeke (1981, 1982 and 1985) and Murtha and Williams (1986).

4.2.9 Soil Moisture at the Isabela Station

The data of the Isabela station is incomplete. In order to provide more reliable interpretations further data collection is needed. The soil moisture was measured as volumetric water content from August 2003 through September 2004. Table 4.17 summarizes the mean monthly volumetric water content at the central portion of the soil moisture control section (20 cm). The soil series at this site is the Coto series (*very-fine, kaolinitic, isohyperthermic Typic Eutrustox*) (Beinroth et al., 2003). This soil has a 19.20 per cent water held (volumetric content) at 1,500 kPa (Soil Survey Staff, 2004).

Table 4.17. Mean Monthly Soil Moisture at 20 cm at the Isabela Station.

Month	Mean Monthly Soil Moisture (%) at 20 cm	Water held at 1,500 kPa (20 cm)	Soil Moisture Control Section Status
August 2003	27.49	19.2	Moist
September 2003	28.74	19.2	Moist
October 2003	29.13	19.2	Moist
November 2003	30.34	19.2	Moist
December 2003	28.99	19.2	Moist
January 2004	29.91	19.2	Moist
February 2004	No data	19.2	No data
March 2004	29.62	19.2	Moist
April 2004	25.59	19.2	Moist
May 2004	26.36	19.2	Moist
June 2004	20.89	19.2	Moist
July 2004	27.33	19.2	Moist
August 2004	27.68	19.2	Moist
September 2004	29.78	19.2	Moist

As shown on Table 4.17 in average the soil moisture control section was moist every month of the study period. This result shows a tendency to meet the definition for an udic soil moisture regime.

4.2.10 Soil Temperature at the Isabela Station

The data of the Isabela station is incomplete. In order to provide more reliable interpretations further data collection is needed. The soil temperature was measured from August 2003 to October 2004. Table 4.18 summarizes the mean monthly soil temperature and the mean monthly air temperature for the study period.

Table 4.18. Mean Monthly Soil Temperature at 50 cm at the Isabela Station.

Month	**Mean Monthly Soil Temperature (ºC) at 50 cm**	**Mean Monthly Air Temperature (ºC)**	**Temperature Difference (ºC)**
August 2003	27.61	25.16	2.45
September 2003	28.00	24.33	3.67
October 2003	27.79	23.76	4.03
November 2003	26.09	23.28	2.81
December 2003	24.88	22.79	2.09
January 2004	24.00	21.89	2.11
February 2004	No data	No data	No data
March 2004	25.27	23.31	1.96
April 2004	26.37	24.16	2.21
May 2004	26.52	24.55	1.97
June 2004	27.65	25.75	1.90
July 2004	27.93	25.49	2.44
August 2004	28.62	26.11	2.51
September 2004	26.89	25.55	1.34
October 2004	27.22	25.73	1.49

The mean monthly soil temperature for the study period was 26.77 ºC showing the tendency to meet the definition for an isohyperthermic soil temperature regime. There is insufficient data to calculate the isotivity for this site. The results of this site suggest that the soil temperature can be estimated by adding 2.36 ºC to the air temperature. This estimation concurs with the values reported by Comerma and Sánchez (1981), Van Wambeke (1981, 1982 and 1985) and Murtha and Williams (1986).

4.2.11 Soil Temperature Estimation

Table 4.19 summarizes the degrees that need to be added to the mean monthly air temperature in order to estimate the soil temperature. The data indicate that mean monthly soil temperature in Puerto Rico can be estimated by adding 1.62 ˚C to the mean monthly air temperature. This value is close to the values reported by Comerma and Sánchez (1981), Van Wambeke (1981, 1982 and 1985) and Murtha and Williams (1986).

Table 4.19. Soil temperature estimation from air temperature.

NRCS station	Degrees to be added (˚C)
Guánica State Forest Station	1.55
Combate Station	1.76
Maricao State Forest Station	0.69
Guilarte State Forest Station	1.72
Isabela Station	2.36

4.2.12 Isotivity Concept

Table 4.20 summarizes the isotivity values obtained from the data of the NRCS stations. These values demonstrate that the 5 ˚C difference between the mean summer and mean winter soil temperatures is a better representation of the isotivity concept as suggest by Murtha and Williams (1996) than the 6 ˚C established by the Soil Survey Staff (1999).

Table 4.20. Isotivity values for the NRCS stations.

NRCS station	Isotivity value (˚C)
Guánica State Forest Station	2.85
Combate Station	2.93
Maricao State Forest Station	1.32
Guilarte State Forest Station	2.34
Isabela Station	No data available

4.2.13 Newhall Simulation Model

The computation of the soil moisture and temperature regimes by the Newhall Simulation Model of the NRCS stations is summarized on Table 4.21. The Isabela station is not included because we did not have sufficient data to compute the soil climate regime by the simulation model.

Table 4.21. Soil Moisture and Temperature Regimes of the NRCS stations according to the Newhall Simulation Model.

NRCS station	Elevation (m)	Soil Moisture Regime	Soil Temperature Regime
Guánica State Forest Station	164	Aridic	Isohyperthermic
Combate Station	10	Aridic	Isohyperthermic
Maricao State Forest Station	746	Udic	Isohyperthermic
Guilarte State Forest Station	1019	Udic	Isothermic

4.2.13.1 Estimation of the Soil Moisture Regimes with the Newhall Simulation Model

The Newhall Simulation Model identified the aridic soil moisture regime at the Guánica State Forest and Combate Stations. These results supported the ones obtained from the soil moisture sensors of these stations discussed on sections 4.2.1 and 4.2.3. In addition Table 4.22 and Figure 4.15 shows that during the study period on average monthly precipitation only exceeded evapotranspiration during November at the Guánica State Forest Station.

Table 4.22. Guánica State Forest Station data (2001-2004).

Month	**Mean Monthly Air Temperature (ºC)**	**Mean Monthly Precipitation (mm)**	**Mean Monthly Evapotranspiration (mm)**
January	24.72	14.99	100.40
February	24.63	22.86	92.90
March	24.95	54.36	110.30
April	25.33	117.22	117.70
May	26.42	101.60	146.60
June	27.32	29.97	150.70
July	27.70	23.88	160.90
August	28.00	46.99	159.60
September	27.50	51.82	146.60
October	27.37	72.90	140.90
November	26.24	215.39	122.30
December	25.86	56.13	118.40

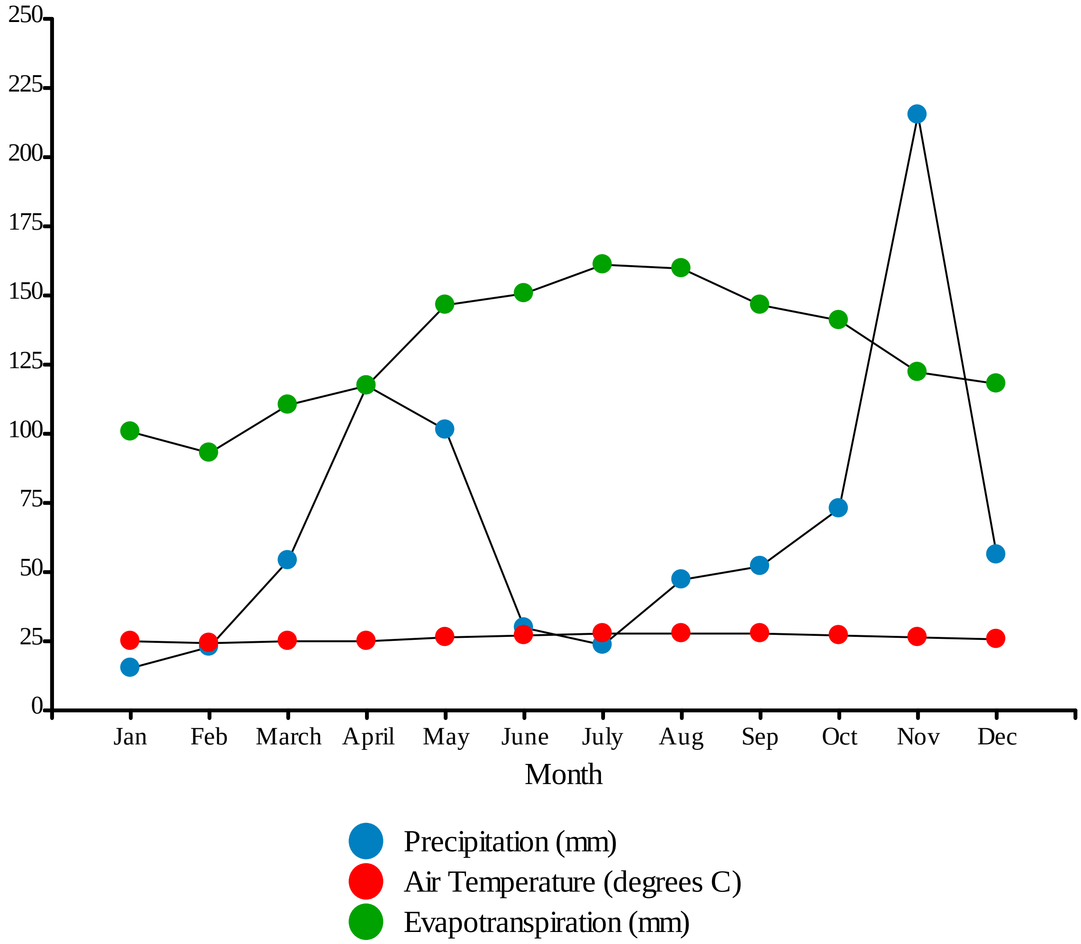

Figure 4.15. Guánica State Forest Station data (2001-2004).

Table 4.23 and Figure 4.16 show that during the study period on average monthly precipitation exceeded the evapotranspiration only on May and November at the Combate Station. The data from these weather stations clearly support the occurrence of the aridic soil moisture regime in Puerto Rico.

Table 4.23. Combate Station data (2001-2004).

Month	Mean Monthly Air Temperature (ºC)	Mean Monthly Precipitation (mm)	Mean Monthly Evapotranspiration (mm)
January	25.20	3.56	107.20
February	24.93	28.19	96.60
March	25.24	33.02	114.50
April	25.42	114.05	118.70
May	26.55	169.16	149.90
June	27.95	15.49	155.20
July	27.82	38.61	160.90
August	27.99	73.66	155.20
September	27.76	53.59	146.60
October	27.31	68.33	140.90
November	26.33	189.74	123.60
December	25.37	30.73	109.90

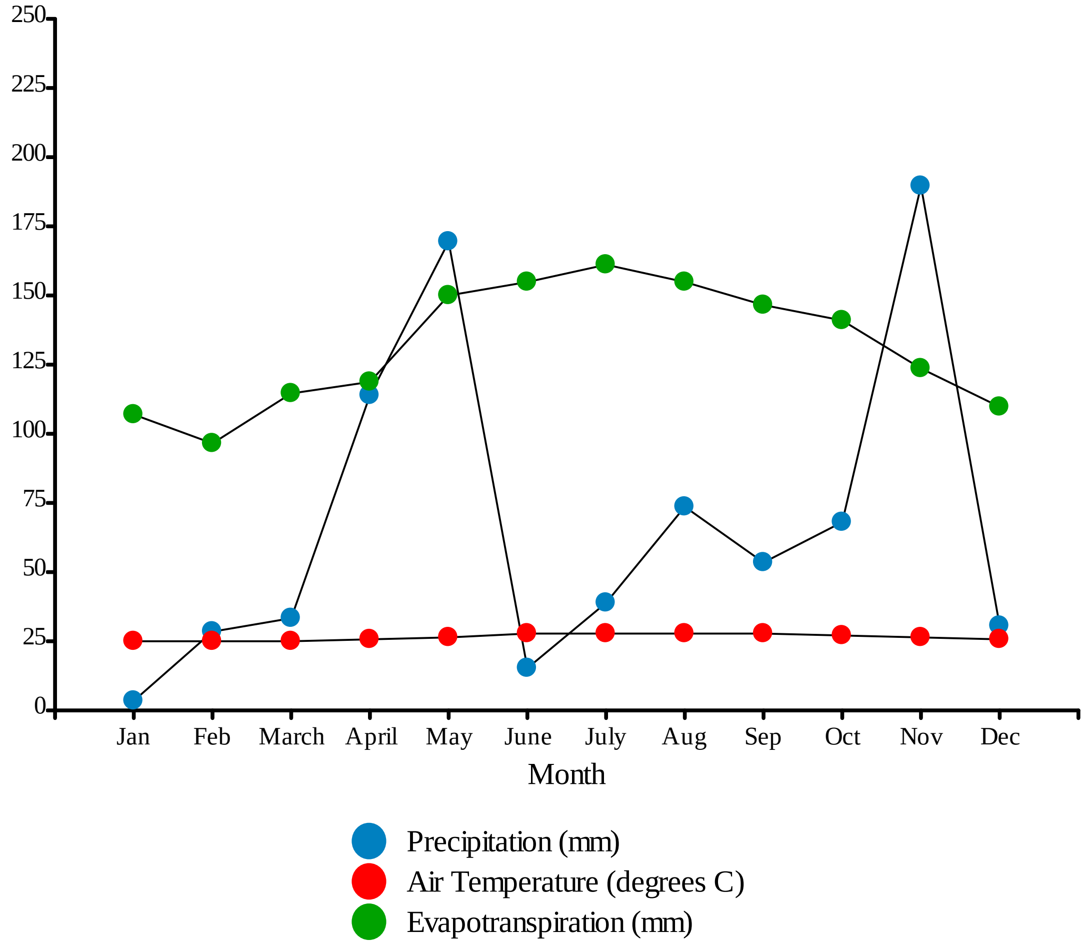

Figure 4.16. Combate Station data (2001-2004).

The Newhall Simulation Model identified the udic soil moisture regime at the Maricao and Guilarte State Forest Stations. These results disagreed with the ones obtained from the NOAA stations discussed in section 4.1.1. A possible explanation for the discrepancy is that only two years of data were collected instead of four during the months of January and February at the Maricao State Forest Station. The same reason applies to the Guilarte State Forest Station, where during the month of July only two years of data were collected instead of four. The Table 4.24 and Figure 4.17 show that during the study period in 10 out of 12 months the precipitation exceeded the evapotranspiration (March to December) at the Maricao State Forest Station.

Table 4.24. Maricao State Forest Station data (2001-2004).

Month	Mean Monthly Air Temperature (°C)	Mean Monthly Precipitation (mm)	Mean Monthly Evapotranspiration (mm)
January	19.86	28.19	66.20
February	20.29	30.99	65.40
March	20.23	94.49	73.50
April	20.49	336.30	76.50
May	21.34	231.90	89.90
June	22.17	128.27	95.70
July	22.27	175.77	100.40
August	22.54	326.39	99.60
September	22.51	248.16	93.70
October	21.98	282.45	87.70
November	21.20	205.49	75.70
December	20.60	179.32	72.20

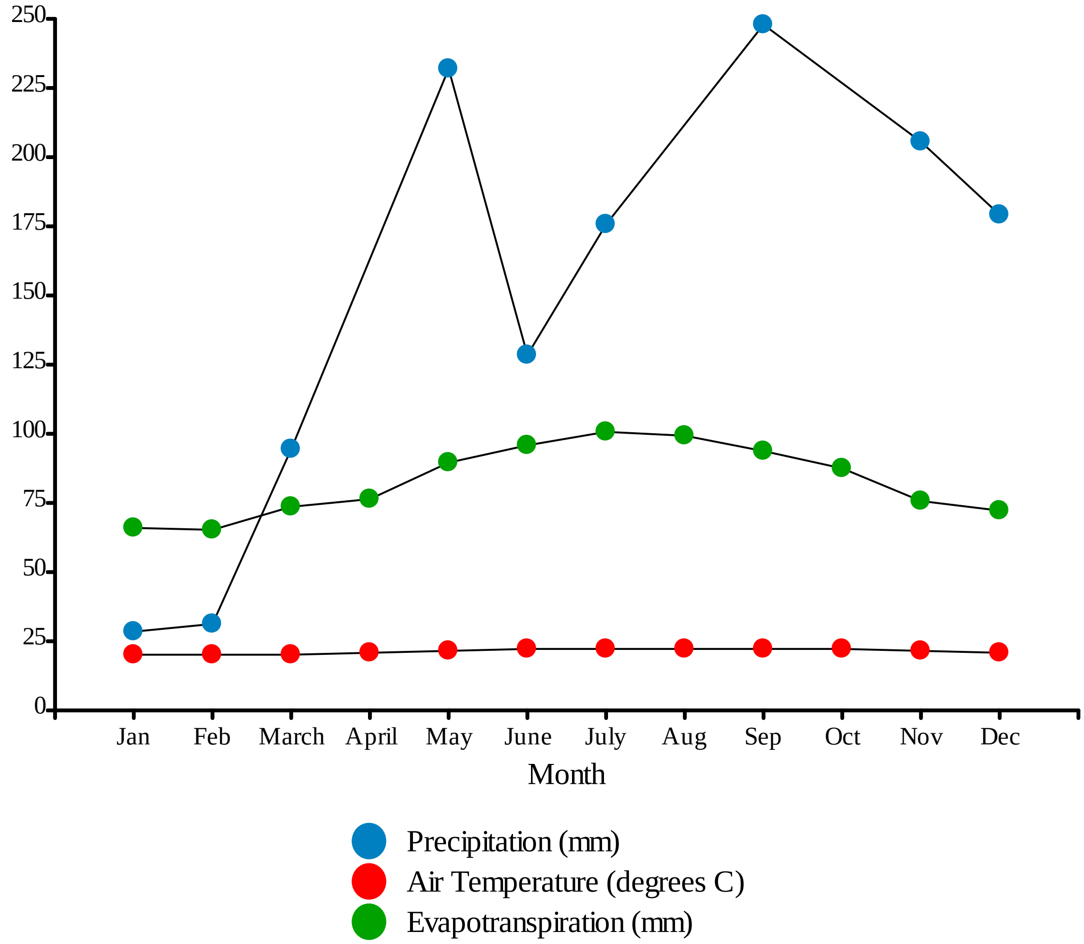

Figure 4.17. Maricao State Forest Station data (2001-2004).

The Table 4.25 and Figure 4.18 show that during the study period in 11 out of 12 months the precipitation exceeded the evapotranspiration at the Guilarte State Forest Station.

The author considers that at both stations the perudic soil moisture regime is more representative because data sets of 20 years or longer from nearby weather stations indicated the occurrence of perudic soil moisture regime. The Adjuntas Substation, Garzas, Maricao 2SSW and Maricao Fish Hatchery stations have the same rainfall pattern of the Maricao and Guilarte State Forest Stations.

Table 4.25. Guilarte State Forest Station data (2001-2004).

Month	**Mean Monthly Air Temperature (ºC)**	**Mean Monthly Precipitation (mm)**	**Mean Monthly Evapotranspiration (mm)**
January	17.42	130.56	56.70
February	17.51	71.37	53.70
March	17.58	123.44	61.30
April	18.21	289.81	66.40
May	19.16	236.47	78.40
June	20.04	96.27	83.40
July	20.19	68.83	87.80
August	20.33	167.39	85.80
September	20.41	259.84	81.70
October	20.06	238.76	78.20
November	19.07	216.66	66.50
December	18.37	100.33	63.00

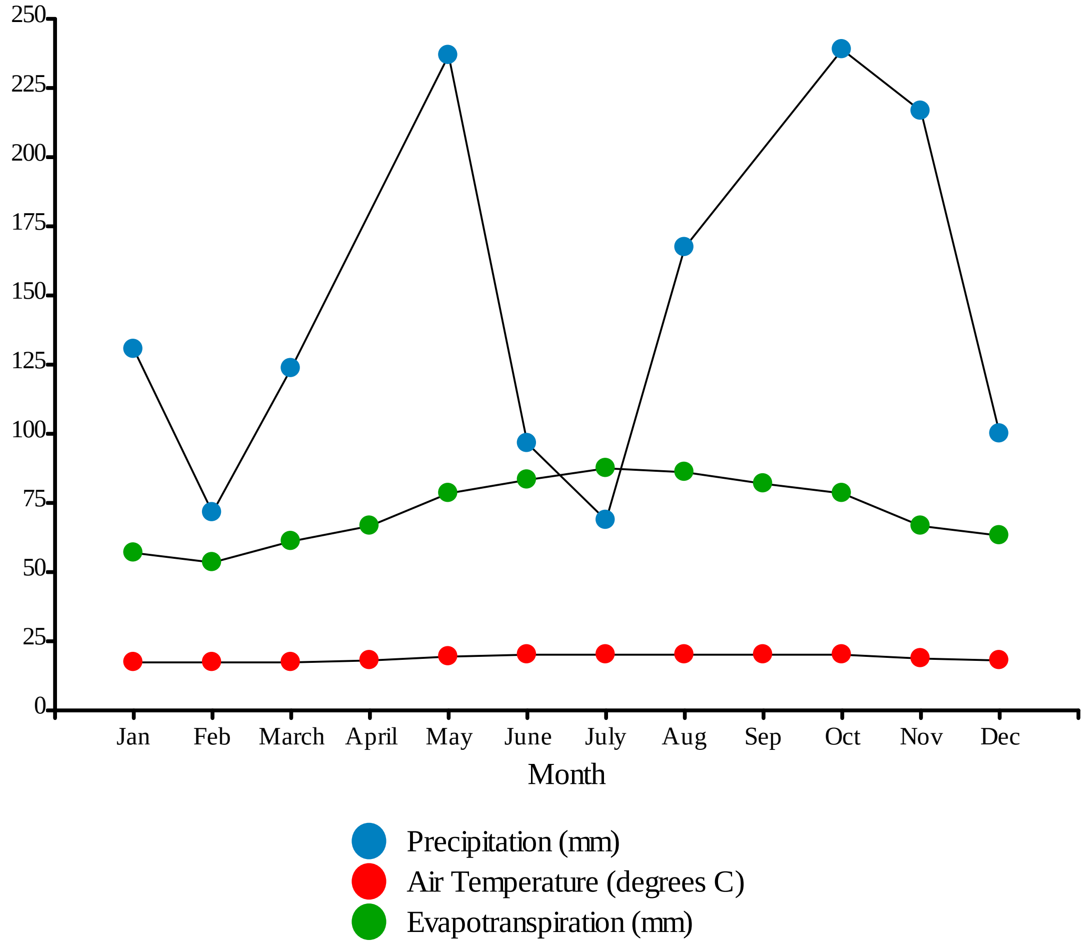

Figure 4.18. Guilarte State Forest Station data (2001-2004).

4.2.13.2 Estimation of the Soil Temperature Regimes with the Newhall Simulation Model

The Newhall Simulation Model identified the isohyperthermic soil temperature regime at the Guánica State Forest and Combate stations. These results concur with the ones obtained from the soil temperature sensors of these stations.

The isohyperthermic soil temperature regime at the Maricao State Forest Station was identified by the Newhall Simulation Model as well. This result concurs with the one obtained from the soil temperature sensor. This sensor obtained a mean monthly soil temperature of 21.98˚C (~ 22˚C) for the study period. As stated on section 4.2.6 the 22˚C is the limit temperature between the isohyperthermic and isothermic temperature regimes. This finding suggests that in a perudic soil moisture regime the elevation limit between the isohyperthermic and the isothermic soil temperature regimes is 750 m instead of 900 m as shown on Figure 4.1 through Figure 4.6 in section 4.1. This occurs because in wetter climates the temperature tends to be cooler (Nullet et al., 1990). On udic soil moisture regime this limit is 900 m because in drier climates the temperature tends to be warmer.

The Newhall Simulation Model identified the isothermic soil temperature regime at elevations 900 m above sea level or higher. This result concurs with the one obtained from the soil temperature sensor at the Guilarte State Forest Station (section 4.2.8). Therefore the isothermic and the isohyperthermic soil temperature regimes are well documented in Puerto Rico and these implications are summarized on Table 4.26 and Figure 4.19.

Table 4.26. Soil Temperature Regimes of Puerto Rico including the 750 m limit elevation of the perudic isothermic soil climate regime.

Class	Area (hectares)	Percentage
Isothermic (> 750 m to 900 m)	16,754	1.86
Isothermic (> 900 m)	9,292	1.04
Isohyperthermic	872,976	97.10
	899,022	100

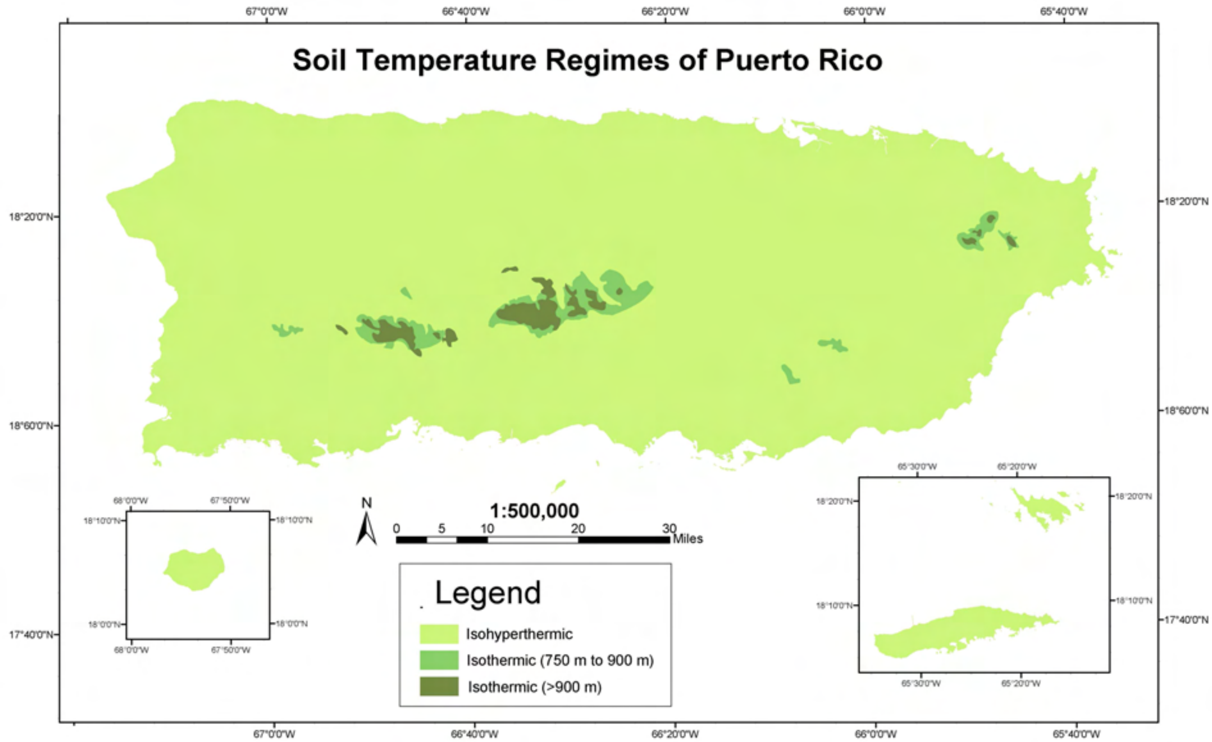

Figure 4.19. Soil Temperature Regimes of Puerto Rico including the 750 m limit elevation of the perudic isothermic soil climate regime.

The isohyperthermic soil temperature regime is the most extensive covering an area of 872,976 ha, equivalent to 97.10 per cent the total land area of Puerto Rico.

The isothermic soil temperature regime from 750 m to 900 m above sea level covers an area of 16,754 ha to be equivalent of the 1.86 per cent total land area of Puerto Rico.

The implications of the results discussed above on the soil climate regimes are summarized on Table 4.27 and Figure 4.20.

Table 4.27. Soil Climate Regimes of Puerto Rico including the 750 m limit elevation of the perudic isothermic soil climate regime.

Class	Area (hectares)	Percentage
Aridic Isohyperthermic	25,450	2.83
Ustic Isohyperthermic	141,935	15.79
Udic Isohyperthermic	569,906	63.39
Udic Isothermic	1,649	0.18
Perudic Isohyperthermic	134,036	14.91
Perudic Isothermic (> 750 m to 900 m)	16,754	1.86
Perudic Isothermic (> 900 m)	9,292	1.04
	899,022	100

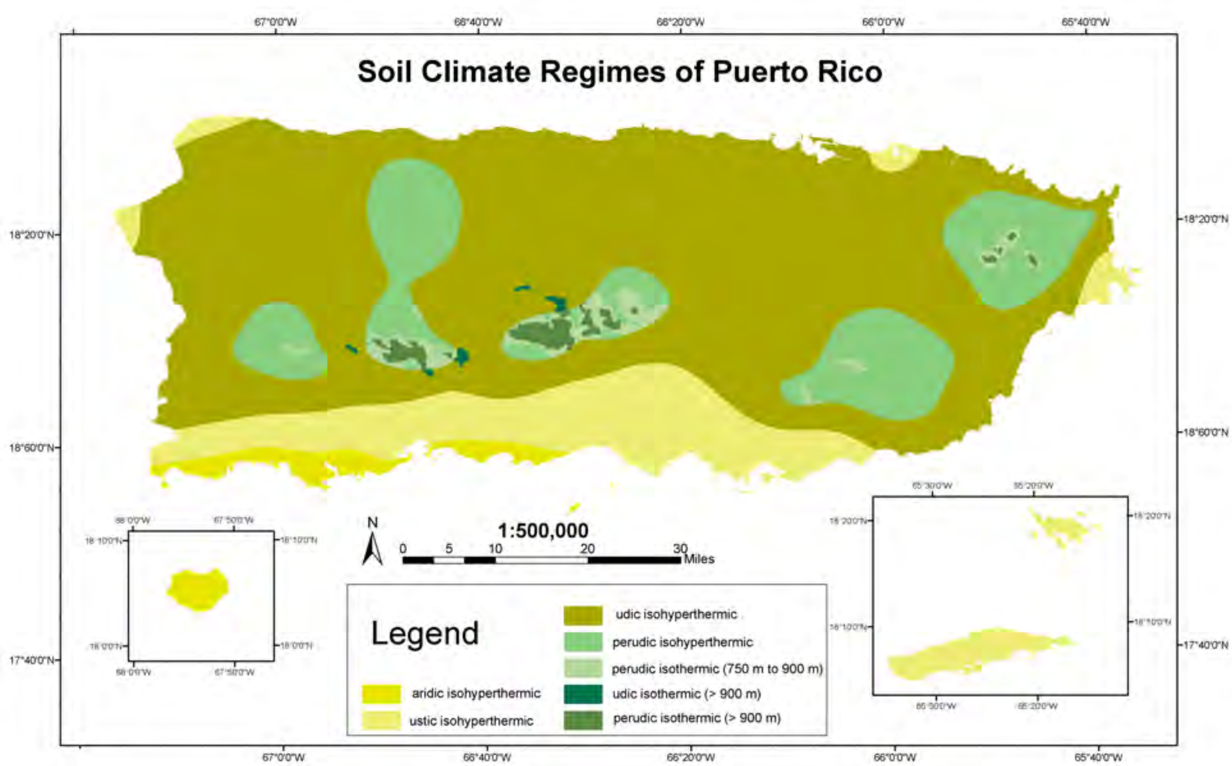

Figure 4.20. Soil Climate Regimes of Puerto Rico including the 750 m limit elevation of the perudic isothermic soil climate regime.

The aridic isohyperthermic, the ustic isohyperthermic, the udic isohyperthermic and the udic isothermic soil climate regimes were not affected. The perudic isohyperthermic regime covers and area of 134,036 ha equivalent to 14.91 per cent land area of Puerto Rico. The perudic isothermic (> 750 m to 900 m) regime covers an area of 16,754 ha equivalent to 1.86 per cent land area of the island. Finally, the perudic isothermic (> 900 m) regime covers an area of 9,292 ha equivalent to 1.04 per cent land area of Puerto Rico.

4.3 Reevaluate the Classification of Selected Soil Series of Puerto Rico Based on the Revised Soil Climatic Data

4.3.1 Aridic Isohyperthermic Soil Climate Regime

According to the soil climate regimes map obtained from the geographic information system (Figure 4.20), 15,680 ha of soils need to be reclassified because several series occurs in different regimes. Table 4.28 summarizes the area and percentages of the three soil orders found in the aridic isohyperthermic soil climate regime.

Table 4.28. Approximate area and distribution of the soil orders of the Aridic Isohyperthermic Soil Climate Regime.

Soil Order	Area (ha)	Percentage of soil area	Percentage of total regime area
Aridisols	11,342	70.30	44.57
Entisols	3,166	19.62	12.44
Vertisols	1,625	10.08	6.38
Other land	9,317	N/A	36.61

The Aridisols order covers an area of 11,342 ha, equivalent of 1.26 per cent of the total land area of Puerto Rico. Table 4.29 summarizes the proposed classification of the soil series in the aridic isohyperthermic soil climate regime.

The area designated as Aridisols by the Newhall Simulation Model needs further evaluation pertaining the inclusion of the Mollisols in the aridic moisture regime. The model considers soil moisture in the control section as defined in Soil Taxonomy. However, for the specific case of Mollisols we should consider the moisture content in the mollic epipedon. A soil with a mollic epipedon, moist for over 90 cummulative days should be classified as a Mollisol, otherwise should classify as Aridisol. Based on this criterion the land area classified as Aridisols by the model may be reduced.

Table 4.29. Classification of the Soil Series at the Aridic Isohyperthermic Soil Climate Regime.

Soil Series	**Current classification**	**Updated Classification**	**Area (ha)**
Aguilita	Coarse-loamy, carbonatic, isohyperthermic Aridic Calciustolls	Coarse-loamy, carbonatic, isohyperthermic Typic Haplocalcids	1,398
Amelia	Fine, mixed, semiactive, isohyperthermic Typic Haplustalfs	Fine, mixed, semiactive, isohyperthermic Typic Haplargids	381
Bahía	Mixed, isohyperthermic Psammentic Paleustalfs	Sandy, mixed, isohyperthermic Arenic Paleargids	186
Cartagena	Fine, mixed, superactive, isohyperthermic Sodic Haplusterts	Fine, mixed, superactive, isohyperthermic Chromic Haplotorrerts	9
Constancia	Fine, smectitic, isohyperthermic Aeric Calciaquolls	Fine, smectitic, isohyperthermic Aquic Haplocalcids	907

Soil Series	Current classification	Updated Classification	Area (ha)
Cortada	Fine, smectitic, isohyperthermic Cumulic Haplustolls	Fine, smectitic, isohyperthermic Typic Haplocambids	168
Descalabrado	Clayey, mixed, superactive, isohyperthermic, shallow Typic Haplustolls	Clayey, mixed, superactive, isohyperthermic, shallow Typic Haplocambids	892
Ensenada	Clayey-skeletal, mixed, superactive, isohyperthermic Calcidic Argiustolls	Clayey-skeletal, mixed, superactive, isohyperthermic Typic Haplargids	90
Fé	Fine, smectitic, isohyperthermic Sodic Haplusters	Fine, smectitic, isohyperthermic Typic Salitorrerts	14
Fraternidad	Fine, smectitic, isohyperthermic Typic Haplusters	Fine, smectitic, isohyperthermic Typic Haplotorrerts	1,030
Guayabo	Mixed, isohyperthermic Psammentic Paleustalfs	Sandy, mixed, isohyperthermic Arenic Paleargids	83
Guayama	Clayey, mixed, active, isohyperthermic, shallow Typic Haplustalfs	Clayey, mixed, active, isohyperthermic, shallow Typic Haplargids	74
Jácana	Fine, mixed, superactive, isohyperthermic Vertic Haplustolls	Fine, mixed, superactive, isohyperthermic Vertic Haplocambids	1,418
Juana Díaz	Loamy, mixed, superactive, isohyperthermic, shallow Typic Haplustepts	Loamy, mixed, superactive, isohyperthermic, shallow Ustic Haplocambids	2
Machuelo	Fine, mixed, superactive, calcareous, isohyperthermic Fluvaquentic Endoaquepts	Fine, mixed, superactive, calcareous, isohyperthermic Fluventic Aquicambids	376
Maguayo	Fine, smectitic, isohyperthermic Vertic Haplustalfs	Fine, smectitic, isohyperthermic Ustertic Haplargids	163
Meros	Mixed, isohyperthermic Typic Ustipsamments	Mixed, isohyperthermic Typic Torripsamments	367
Palmarejo	Fine, mixed, semiactive, isohyperthermic Typic Haplustults	Fine, mixed, semiactive, isohyperthermic Ustic Haplargids	1

Soil Series	Current classification	Updated Classification	Area (ha)
Pozo Blanco	Fine-loamy, mixed, superactive, isohyperthermic Aridic Calciustolls	Fine-loamy, mixed, superactive, isohyperthermic Typic Haplocalcids	1,444
San Antón	Fine-loamy, mixed, superactive, isohyperthermic Cumulic Haplustolls	Fine-loamy, mixed, superactive, isohyperthermic Ustic Haplocambids	774
San Germán	Clayey-skeletal, mixed, superactive, isohyperthermic, shallow Typic Ustorthents	Clayey-skeletal, mixed, superactive, isohyperthermic Typic Torriorthents	2,346
Sosa	Fine, kaolinitic, isohyperthermic Aridic Paleustalfs	Fine, kaolinitic, isohyperthermic Typic Paleargids	153
Teresa	Very-fine, smectitic, isohyperthermic Sodic Haplusters	Very-fine, smectitic, isohyperthermic Aquic Salitorrerts	572
Tuque	Clayey-skeletal, carbonatic, isohyperthermic Lithic Petrocalcic Calciustolls	Clayey-skeletal, carbonatic, isohyperthermic Calcic Lithic Petrocalcids	2,456
Vayas	Fine, smectitic, nonacid, isohyperthermic Vertic Endoaquolls	Fine, smectitic, nonacid, isohyperthermic Typic Aquicambids	267
Yauco	Fine-silty, carbonatic, isohyperthermic Typic Calciustolls	Fine-silty, carbonatic, isohyperthermic Typic Haplocalcids	109

4.3.2 Ustic Isohyperthermic Soil Climate Regime

According to the soil climate regimes map obtained from the geographic information system (Figure 4.20), 55,036 ha of soils need to be reclassified because several series occurs in different regimes. Table 4.30 summarizes the area and percentages of the seven soil orders found in the ustic isohyperthermic soil climate regime. Appendix D summarizes the proposed classification of the soil series at this soil climate regime.

Table 4.30. Approximate area and distribution of the soil orders of the Ustic Isohyperthermic Soil Climate Regime.

Soil Order	Area (ha)	Percentage of soil area	Percentage of total regime area
Mollisols	51,228	40.90	36.09
Inceptisols	33,241	26.54	23.42
Vertisols	26,080	20.82	18.38
Alfisols	6,655	5.31	4.69
Entisols	4,742	3.79	3.34
Ultisols	3,080	2.46	2.17
Oxisols	232	0.18	0.16
Other land	16,677	N/A	11.75

4.3.3 Udic Isohyperthermic Soil Climate Regime

According to the soil climate regimes map obtained from the geographic information system (Figure 4.20), 35,986 ha of soils need to be reclassified because several series occurs in different regimes. Table 4.31 summarizes the area and percentages of the nine soil orders found in the udic isohyperthermic soil climate regime. Appendix E summarizes the proposed classification of the soil series at this soil climate regime.

Table 4.31. Approximate area and distribution of the soil orders of the Udic Isohyperthermic Soil Climate Regime.

Soil Order	Area (ha)	Percentage of soil area	Percentage of total regime area
Inceptisols	184,152	37.20	32.31
Ultisols	140,115	28.31	24.58
Mollisols	73,380	14.82	12.88
Oxisols	37,002	7.47	6.49
Alfisols	23,304	4.71	4.09
Entisols	21,648	4.37	3.80
Vertisols	10,367	2.10	1.82
Histosols	3,299	0.67	0.58
Spodosols	1,717	0.35	0.30
Other land	74,922	N/A	13.15

4.3.4 Udic Isothermic Soil Climate Regime

According to the soil climate regimes map obtained from the geographic information system (Figure 4.20), 941 ha of soils area need to be reclassified because several series occurs in different regimes. Table 4.32 summarizes the area and percentages of the three soil orders found in the udic isothermic soil climate regime. Appendix F summarizes the proposed classification of the soil series at this soil climate regime.

Table 4.32. Approximate area and distribution of the soil orders of the Udic Isothermic Soil Climate Regime.

Soil Order	Area (ha)	Percentage of soil area	Percentage of total regime area
Oxisols	629	38.16	37.33
Inceptisols	544	32.97	32.26
Ultisols	476	28.87	28.25
Other land	36	N/A	2.16

4.3.5 Perudic Isohyperthermic Soil Climate Regime

According to the soil climate regimes map obtained from the geographic information system (Figure 4.20), 123,186 ha of soils need to be reclassified because several series occurs in different regimes. Table 4.33 summarizes the area and percentages of the seven soil orders found in the perudic isohyperthermic soil climate regime. Appendix G summarizes the proposed classification of the soil series at this soil climate regime.

Table 4.33. Approximate area and distribution of the soil orders of the Perudic Isohyperthermic Soil Climate Regime.

Soil Order	Area (ha)	Percentage of soil area	Percentage of total regime area
Inceptisols	51,483	41.48	38.41
Ultisols	31,579	25.44	23.56
Oxisols	19,757	15.92	14.74
Mollisols	14,703	11.85	10.97
Alfisols	3,699	2.98	2.76
Vertisols	1,864	1.51	1.39
Entisols	1,019	0.82	0.76
Other land	9,932	N/A	7.41

Arc Info overestimated the perudic isohyperthermic soil climate regime with the inclusion of 1,864 ha of Vertisols. Pedogenetically, Vertisols and soils with calcic horizon can not be developed under a perudic moisture regime.

4.3.6 Perudic Isothermic Soil Climate Regime

According to the soil climate regimes map obtained from the geographic information system (Figure 4.20), 10,884 ha of soils need to be reclassified because several series occurs in different regimes. Table 4.34 summarizes the area and percentages of the four soil orders found in the perudic isothermic soil climate regime. Appendix H summarizes the proposed classification of the soil series at this soil climate regime.

Table 4.34. Approximate area and distribution of the soil orders of the Perudic Isothermic Soil Climate Regime.

Soil Order	Area (ha)	Percentage of soil area	Percentage of total regime area
Oxisols	11,572	47.90	44.43
Inceptisols	9,059	37.48	34.78
Ultisols	3,532	14.61	13.56
Entisols	1	0.01	0.01
Other land	1,533	N/A	7.22

In the perudic soil moisture regime areas field observations will be necessary to determine if the Oxisols will classified as Perox or Aquox.

4.3.7 Soil Orders of Puerto Rico

The results from this study indicate that 241,713 ha soils of Puerto Rico (26.89 per cent of the total soil area) needs to be reclassified. Table 4.35 summarizes the approximate area and distribution of the soil orders of Puerto Rico based on the results of this study (Appendix I). This area and distribution is based until the 1982 soil survey mapping of Puerto Rico. Areas with less than 50 ha will not be proposed as a new soil series. This areas willl be included as inclusions of other similar soil series previously established on soil surveys.

Table 4.35. Approximate area and distribution of the soil orders of Puerto Rico.

Soil Order	Area (ha)	Percentage of soil area	Percentage of total land area
Inceptisols	278,506	35.42	30.98
Ultisols	179,350	22.81	19.95
Mollisols	139,605	17.75	15.53
Oxisols	68,234	8.68	7.59
Vertisols	39,988	5.08	4.45
Alfisols	33,730	4.29	3.75
Entisols	30,593	3.89	3.40
Aridisols	11,342	1.44	1.26
Histosols	3,299	0.42	0.37
Spodosols	1,717	0.22	0.19
Other land	112,658	N/A	12.53
	899,022	100	100

5. Conclusions and Recomendations

1. The Newhall Simulation Model based on data from 95 weather stations identified 25,450 ha of an aridic soil moisture regime in Puerto Rico and 160,082 ha of a perudic soil moisture regime. This is the first recognition of the aridic soil moisture regime in Puerto Rico. The area recognized as aridic soil moisture regime needs further evaluation pertaining the inclusion of the Mollisols in this regime. For the specific case of Mollisols we should consider the moisture content in the mollic epipedon. A soil with a mollic epipedon that is moist for over 90 cummulative days should be classified as a Mollisol, otherwise it should classify as an Aridisol. Also, the area designated by the geographic information system as perudic nearby the Arecibo Observatory was based on data from only one weather station. This area may have been overestimated because the limited amount of data and the irregular topography of the zone. These two conditions limit the capability of Arc Info to delineate clearly the geographical boundaries.
2. The Newhall Simulation Model did not identify the isomesic soil temperature regime in Puerto Rico. Therefore, in Puerto Rico the mean annual soil temperature never is cooler than 15ºC at any elevation. However, soil temperature data will be necessary to support this estimate.
3. The cluster analysis corroborated the results of graphic and tabular methods of this study. The unweighted centroid algorithm was the best cluster generator for the data with a 0.663 cophenetic correlation coefficient.

4. The estimation obtained from the Newhall Simulation Model was evaluated with the USDA-Natural Resources Conservation Service weather stations in Puerto Rico. This model is a useful tool for simulating soil moisture and temperature regimes. However, these results have to be taken cautionisly. The model considers a standard available water holding capacity of 200 mm. This amount of water is representative of deep, fine textured soils but it is not the case for Oxisols and Rendolls. Consecuently, the Newhall Simulation Model may have overestimated the area under the perudic moisture regime. Running the model considering the 100 mm available water holding capacity will reduce the area included in the perudic moisture regime and will provide a more realistic value in accordance with field observations.
5. The soil climate regimes classes identified on this study are: aridic isohyperthermic, ustic isohyperthermic, udic isohyperthermic, udic isothermic, perudic isohyperthermic and perudic isothermic.
6. The elevation limit between the isohyperthermic and the isothermic soil temperature regimes in the perudic soil moisture regime is 750 m above sea level. The elevation limit between the isohyperthermic and the isothermic soil temperature regimes in the udic soil moisture regime is 900 m.
7. The mean monthly soil temperature in Puerto Rico can be estimated by adding 1.62˚C to the mean monthly air temperature. However, only data from 5 weather stations for 5 years are available. Additional stations and longer data are necessary to provide a more realistic value.

8. The mean isotivity value of the USDA-Natural Resources Conservation Service stations was 2.36 ˚C. This result demonstrates that Puerto Rico is well recognized as having an isotivity value of 6˚C or less as established by the Soil Survey Staff (1999).
9. In Puerto Rico 10 of the 12 soil orders established by Soil Taxonomy are well documented. The Aridisols is the new soil order identified by the Newhall Simulation Model and by the soil moisture sensors of the USDA-NRCS stations.
10. A soil area in Puerto Rico of 241,713 ha (26.89 per cent of the total soil area) was evaluated and its classification updated.

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7. Appendices

Appendix A. U.S. Weather Service Cooperative Network in Puerto Rico (U.S. Department of Commerce-NOAA-Southeast Regional Climate Center, 2004).

ID	Station	Municipality	Coordinates	Elevation (m)
North Coast				
PR0410	Arecibo 3 ESE	Arecibo	18°27’12” N; 66°41’29” W	3
PR0662	Barceloneta 2	Barceloneta	18°25’43” N; 66°33’45” W	3
PR0974	Borinquen Airport	Aguadilla	18°29’55” N; 67°07’46” W	70
PR1845	Cataño	Cataño	18°16’00” N; 66°07’00” W	6
PR3409	Dorado 2 WNW	Dorado	18°28’20” N; 66°18’21” W	18
PR7843	Quebradillas	Quebradillas	18°28’19” N; 66°56’09” W	113
PR8306	Rio Piedras Experiment Station	Rio Piedras	18°23’26” N; 66°03’15” W	27
PR8808	San Juan City	San Juan	18°27’45” N; 66°05’11” W	6
PR8812	San Juan WSFO	Carolina	18°25’57” N; 66°00’39” W	3
PR9421	Toa Baja 1 SSW	Toa Baja	18°25’45” N; 66°15’33” W	6
South Coast				
PR0152	Aguirre Central	Salinas	17º57’20” N; 66º13’20” W	6
PR2316	Central San Francisco	Guayanilla	17º59’26” N; 66º49’08” W	9
PR3532	Ensenada	Guánica	17º58’29” N; 66º56’48” W	3
PR5097	Lajas Substation	Lajas	18º01’59” N; 67º04’20” W	27
PR7292	Ponce 4E	Ponce	18º01’09” N; 66º31’32” W	21
PR7295	Ponce City	Ponce	17º59’06” N; 66º37’46” W	3
PR8940	Santa Isabel 2ENE	Santa Isabel	17º58’18” N; 66º22’38” W	9

Appendix A. (Continued)

ID	Station	Municipality	Coordinates	Elevation (m)
South Coast (Continued)				
PR8955	Santa Rita	Guánica	18º00’35”N; 66º53’05” W	21
Northern Hills				
PR0426	Arecibo Observatory	Arecibo	18º20’58” N; 66º45’07” W	323
PR1345	Calero Camp	Aguadilla	18º28’14” N; 67º06’57” W	76
PR1590	Canóvanas	Canóvanas	18º22’43” N; 65º53’39” W	12
PR3657	Fajardo	Fajardo	18º18’53” N; 65º39’08” W	9
PR4702	Isabela Substation	Isabela	18º27’55” N; 67º03’08” W	128
PR5807	Manatí 3E	Manatí	18º25’51” N; 66º27’58” W	76
PR6361	Mora Camp	Isabela	18º28’13” N; 67º01’49” W	125
PR8126	Rincón Power Plant	Rincón	18º20’16” N; 67º14’58” W	24
PR9521	Trujillo Alto 2SSW	Trujillo Alto	18º19’43” N; 66º00’59” W	39.6
Southern Hills				
PR2723	Coamo	Coamo	18º04’04” N; 66º23’39” W	73
PR3023	Corral Viejo	Ponce	18º05’01” N; 66º39’17” W	122
PR4126	Guayabal	Juana Díaz	18º04’27” N; 66º29’48” W	113
PR4193	Guayama	Guayama	17º58’43” N; 66º05’14” W	55
PR4613	Humacao 2SSE	Humacao	18º08’48” N; 65º49’25” W	27
PR5020	Juana Díaz Camp	Juana Díaz	18º03’11” N; 66º29’57” W	61
PR5693	Magueyes Island	Lajas	17º58’13” N; 67º02’44” W	6
PR6050	Maunabo	Maunabo	18º00’34” N; 65º53’56” W	12

Appendix A. (Continued)

ID	Station	Municipality	Coordinates	Elevation (m)
Southern Hills (Continued)				
PR6083	Mayagüez Airport	Mayagüez	18º15’14” N; 67º08’55” W	12
PR6073	Mayagüez City	Mayagüez	18º11’16” N; 67º08’16” W	18
PR6258	Mona Island 2	Mayagüez	18º05’21” N; 67º56’25” W	3
PR6904	Patillas Dam	Patillas	18º01’14” N; 66º01’24” W	73
PR6983	Peñuelas 1NE	Peñuelas	18º04’23” N; 66º43’07” W	98
PR7492	Puerto Real	Cabo Rojo	18º04’44” N; 67º10’37” W	9
PR8144	Rio Blanco Lower	Naguabo	18º14’37” N; 65º47’06” W	40
PR8412	Roosevelt Roads	Ceiba	18º15’10” N; 65º38’23” W	12
PR8536	Sabana Grande 2ENE	Sabana Grande	18º05’20” N; 66º56’00” W	259
PR8757	San Germán 4W	San Germán	18º06’17” N; 67º05’25” W	27
PR9763	Vieques Island	Vieques	18º07’46” N; 65º25’34” W	15.2
PR9829	Yabucoa 1NNE	Yabucoa	18º 03’46” N; 65º52’25” W	9.1
East Interior				
PR1309	Caguas 1NW	Caguas	18º14’30”N; 66º03’33” W	79
PR1701	Carite Dam	Guayama	18º04’42” N; 66º06’24” W	552
PR1712	Carite Plant	Guayama	18º02’49” N; 66º06’43” W	296
PR1901	Cayey 1E	Cayey	18º06’42” N; 66º08’58” W	418
PR2634	Cidra 1E	Cidra	18º10’44” N; 66º08’31” W	427
PR4115	Guavate Camp	Cayey	18º06’58” N; 66º03’52” W	780

Appendix A. (Continued)

ID	Station	Municipality	Coordinates	Elevation (m)
East Interior (Continued)				
PR4276	Gurabo Substation	Gurabo	18º15’30” N; 65º59’32” W	49
PR4867	Jajome Alto	Cayey	18º04’10” N; 66º08’35” W	728
PR5064	Juncos 1NNE	Juncos	18º13’35” N; 65º54’41” W	55
PR5123	La Muda	Caguas	18º19’05” N; 66º 05’37” W	88
PR6805	Paraíso	Fajardo	18º15’54” N; 65º43’15” W	101
PR6992	Pico del Este	Ceiba	18º16’15” N; 65º45’33” W	1052
PR8245	Rio Grande El Verde	Rio Grande	18º21’28” N; 65º49’25” W	183
PR8815	San Lorenzo 3S	San Lorenzo	18º09’06” N; 65º57’32” W	155
PR8822	San Lorenzo Farm 2NW	San Lorenzo	18º11’06” N; 65º55’46” W	73
West Interior				
PR0040	Aceituna	Villalba	18º09’02” N; 66º29’36” W	652
PR0053	Adjuntas 1NW	Adjuntas	18º10’23” N; 66º43’41” W	457
PR0061	Adjuntas Substation	Adjuntas	18º10’28” N; 66º47’52” W	558
PR0158	Aibonito	Aibonito	18º07’37” N; 66º15’51” W	640
PR0736	Barranquitas	Barranquitas	18º10’00” N; 66º19’04” W	628
PR1142	Cacaos	Orocovis	18º13’34” N; 66º30’14” W	555
PR1623	Caonillas	Utuado	18º17’07” N; 66º38’51” W	259
PR2330	Cerro Gordo	Ciales	18º16’35” N; 66º31’10” W	293
PR2336	Cerro Maravilla	Utuado	18º09’23” N; 66º33’46” W	1219

Appendix A. (Continued)

ID	Station	Municipality	Coordinates	Elevation (m)
West Interior (Continued)				
PR2801	Coloso	Aguada	18º23’59” N; 67º09’39” W	12
PR2934	Corozal Substation	Corozal	18º19’36” N; 66º21’33” W	198
PR3421	Dos Bocas	Arecibo	18º20’17” N; 66º40’03” W	61
PR3871	Garzas	Adjuntas	18º08’26” N; 66º44’31” W	719
PR3904	Guajataca Dam	Quebradillas	18º23’52” N; 66º55’36” W	207
PR4330	Hacienda Constanza	Mayagüez	18º12’38” N; 67º05’07” W	146
PR4677	Indiera Alta	Maricao	18º10’31” N; 66º54’56” W	792
PR4910	Jayuya	Jayuya	18º12’ 54”N; 66º35’35” W	469
PR5175	Lares 2SE	Lares	18º17’06” N; 66º52’59” W	463
PR5908	Maricao 2SSW	Maricao	18º09’04” N; 66º59’20” W	863
PR5911	Maricao Fish Hatchery	Maricao	18º10’21” N; 66º59’14” W	457
PR6017	Matrullas Dam	Orocovis	18º12’47” N; 66º28’47” W	747
PR6270	Monte Bello	Manatí	18º22’46” N; 66º30’55” W	195
PR6390	Morovis 1N	Morovis	18º20’04” N; 66º24’28” W	183
PR6514	Negro-Corozal	Corozal	18º17’19” N; 66º20’36” W	521
PR8881	San Sebastían 2WNW	San Sebastían	18º20’49” N; 67º00’43” W	52
PR9466	Toro Negro Plant 2	Ciales	18º10’23” N; 66º29’34” W	686
PR9608	Utuado	Utuado	18º15’42” N; 66º41’11” W	158
PR9774	Villalba 1E	Villalba	18º07’59” N; 66º29’19” W	168

Appendix B. Distance Matrix-Cluster Analysis (Unweighted centroid algorithm).

Euclidean Distance (Cophenetic correlation coefficient = 0.663)

	PR0040	PR0053	PR0061	PR0152	PR0158
	PR0410	PR0426	PR0662	PR0736	PR0974
	PR1142	PR1309	PR1345	PR1590	PR1623
	PR1701	PR1712	PR1845	PR1901	PR2316
	PR2330	PR2336	PR2634	PR2723	PR2801
	PR2934	PR3023	PR3409	PR3421	PR3532
	PR3657	PR3871	PR3904	PR4115	PR4126
	PR4193	PR4276	PR4330	PR4613	PR4677
	PR4702	PR4867	PR4910	PR5020	PR5064
	PR5097	PR5123	PR5175	PR5693	PR5807
	PR5908	PR5911	PR6017	PR6050	PR6073
	PR6083	PR6258	PR6270	PR6361	PR6390
	PR6514	PR6805	PR6904	PR6983	PR6992
	PR7292	PR7295	PR7492	PR7843	PR8126
	PR8144	PR8245	PR8306	PR8412	PR8536
	PR8757	PR8808	PR8812	PR8815	PR8822
	PR8881	PR8940	PR8955	PR9421	PR9466
	PR9521	PR9608	PR9763	PR9774	PR9829

Appendix B. (Continued)

PR0040	0.00											
PR0053	1.22	0.00										
PR0061	0.57	1.34	0.00									
PR0152	3.32	2.57	3.73	0.00								
PR0158	0.00	1.22	0.57	3.32	0.00							
PR0410	2.44	1.22	2.50	2.26	2.44	0.00						
PR0426	1.34	0.57	1.22	3.08	1.34	1.34	0.00					
PR0662	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00				
PR0736	0.00	1.22	0.57	3.32	0.00	2.44	1.34	2.44	0.00			
PR0974	2.97	2.09	3.32	0.57	2.97	1.70	2.57	1.70	2.97	0.00		
PR1142	0.00	1.22	0.57	3.32	0.00	2.44	1.34	2.44	0.00	2.97	0.00	
PR1309	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44	0.00

Appendix B. (Continued)

PR1345 2.44 1.22 2.50 2.26 2.44 0.00 1.34 0.00 2.44 1.70 2.44
0.00 0.00

PR1590 2.44 1.22 2.50 2.26 2.44 0.00 1.34 0.00 2.44 1.70 2.44
0.00 0.00 0.00

PR1623 1.22 0.00 1.34 2.57 1.22 1.22 0.57 1.22 1.22 2.09 1.22
1.22 1.22 1.22 0.00

PR1701 0.57 1.34 0.00 3.73 0.57 2.50 1.22 2.50 0.57 3.32 0.57
2.50 2.50 2.50 1.34 0.00

PR1712 1.22 0.00 1.34 2.57 1.22 1.22 0.57 1.22 1.22 2.09 1.22
1.22 1.22 1.22 0.00 1.34 0.00

PR1845 2.44 1.22 2.50 2.26 2.44 0.00 1.34 0.00 2.44 1.70 2.44
0.00 0.00 0.00 1.22 2.50 1.22 0.00

PR1901 1.22 0.00 1.34 2.57 1.22 1.22 0.57 1.22 1.22 2.09 1.22
1.22 1.22 1.22 0.00 1.34 0.00 1.22 0.00

PR2316 3.32 2.57 3.73 0.00 3.32 2.26 3.08 2.26 3.32 0.57 3.32
2.26 2.26 2.26 2.57 3.73 2.57 2.26 2.57 0.00

PR2330 1.22 0.00 1.34 2.57 1.22 1.22 0.57 1.22 1.22 2.09 1.22
1.22 1.22 1.22 0.00 1.34 0.00 1.22 0.00 2.57 0.00

PR2336 6.88 7.19 6.86 8.18 6.88 7.69 7.17 7.69 6.88 8.00 6.88
7.69 7.69 7.69 7.19 6.86 7.19 7.69 7.19 8.18 7.19 0.00

Appendix B. (Continued)

PR2634	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
PR2723	3.32	2.57	3.73	0.00	3.32	2.26	3.08	2.26	3.32	0.57	3.32
2.26	2.26	2.26	2.57	3.73	2.57	2.26	2.57	0.00	2.57	8.18	2.57
0.00											
PR2801	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00										
PR2934	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00									
PR3023	1.34	0.57	1.66	2.09	1.34	1.34	1.13	1.34	1.34	1.66	1.34
1.34	1.34	1.34	0.57	1.66	0.57	1.34	0.57	2.09	0.57	7.26	0.57
2.09	1.34	0.57	0.00								
PR3409	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00							
PR3421	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00						
PR3532	3.73	3.08	4.18	0.57	3.73	2.83	3.60	2.83	3.73	1.13	3.73
2.83	2.83	2.83	3.08	4.18	3.08	2.83	3.08	0.57	3.08	8.39	3.08

Appendix B. (Continued)

0.57	2.83	3.08	2.57	2.83	2.83	0.00					
PR3657	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00				
PR3871	0.57	1.34	0.00	3.73	0.57	2.50	1.22	2.50	0.57	3.32	0.57
2.50	2.50	2.50	1.34	0.00	1.34	2.50	1.34	3.73	1.34	6.86	1.34
3.73	2.50	1.34	1.66	2.50	2.50	4.18	2.50	0.00			
PR3904	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00		
PR4115	0.57	1.34	0.00	3.73	0.57	2.50	1.22	2.50	0.57	3.32	0.57
2.50	2.50	2.50	1.34	0.00	1.34	2.50	1.34	3.73	1.34	6.86	1.34
3.73	2.50	1.34	1.66	2.50	2.50	4.18	2.50	0.00	1.34	0.00	
PR4126	2.09	1.70	2.57	1.34	2.09	2.09	2.26	2.09	2.09	1.22	2.09
2.09	2.09	2.09	1.70	2.57	1.70	2.09	1.70	1.34	1.70	7.52	1.70
1.34	2.09	1.70	1.13	2.09	2.09	1.66	2.09	2.57	1.70	2.57	0.00
PR4193	2.97	2.09	3.32	0.57	2.97	1.70	2.57	1.70	2.97	0.00	2.97
1.70	1.70	1.70	2.09	3.32	2.09	1.70	2.09	0.57	2.09	8.00	2.09
0.57	1.70	2.09	1.66	1.70	1.70	1.13	1.70	3.32	2.09	3.32	1.22
0.00											
PR4276	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44

Appendix B. (Continued)

0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00										
PR4330	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00									
PR4613	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00								
PR4677	0.00	1.22	0.57	3.32	0.00	2.44	1.34	2.44	0.00	2.97	0.00
2.44	2.44	2.44	1.22	0.57	1.22	2.44	1.22	3.32	1.22	6.88	1.22
3.32	2.44	1.22	1.34	2.44	2.44	3.73	2.44	0.57	1.22	0.57	2.09
2.97	2.44	1.22	2.44	0.00							
PR4702	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00						
PR4867	0.57	1.34	0.00	3.73	0.57	2.50	1.22	2.50	0.57	3.32	0.57
2.50	2.50	2.50	1.34	0.00	1.34	2.50	1.34	3.73	1.34	6.86	1.34
3.73	2.50	1.34	1.66	2.50	2.50	4.18	2.50	0.00	1.34	0.00	2.57

Appendix B. (Continued)

3.32	2.50	1.34	2.50	0.57	1.34	0.00					

PR4910	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00				

PR5020	3.32	2.57	3.73	0.00	3.32	2.26	3.08	2.26	3.32	0.57	3.32
2.26	2.26	2.26	2.57	3.73	2.57	2.26	2.57	0.00	2.57	8.18	2.57
0.00	2.26	2.57	2.09	2.26	2.26	0.57	2.26	3.73	2.57	3.73	1.34
0.57	2.26	2.57	2.26	3.32	2.57	3.73	2.57	0.00			

PR5064	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00		

PR5097	2.69	1.66	2.97	1.13	2.69	1.13	2.09	1.13	2.69	0.57	2.69
1.13	1.13	1.13	1.66	2.97	1.66	1.13	1.66	1.13	1.66	7.86	1.66
1.13	1.13	1.66	1.34	1.13	1.13	1.70	1.13	2.97	1.66	2.97	1.34
0.57	1.13	1.66	1.13	2.69	1.66	2.97	1.66	1.13	1.13	0.00	

PR5123	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00

PR5175	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70

Appendix B. (Continued)

2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00	2.57	1.22	1.66	1.22
0.00											
PR5693	4.18	3.60	4.65	1.13	4.18	3.39	4.14	3.39	4.18	1.70	4.18
3.39	3.39	3.39	3.60	4.65	3.60	3.39	3.60	1.13	3.60	8.63	3.60
1.13	3.39	3.60	3.08	3.39	3.39	0.57	3.39	4.65	3.60	4.65	2.09
1.70	3.39	3.60	3.39	4.18	3.60	4.65	3.60	1.13	3.39	2.26	3.39
3.60	0.00										
PR5807	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00									
PR5908	0.57	1.34	0.00	3.73	0.57	2.50	1.22	2.50	0.57	3.32	0.57
2.50	2.50	2.50	1.34	0.00	1.34	2.50	1.34	3.73	1.34	6.86	1.34
3.73	2.50	1.34	1.66	2.50	2.50	4.18	2.50	0.00	1.34	0.00	2.57
3.32	2.50	1.34	2.50	0.57	1.34	0.00	1.34	3.73	2.50	2.97	2.50
1.34	4.65	2.50	0.00								
PR5911	1.34	0.57	1.22	3.08	1.34	1.34	0.00	1.34	1.34	2.57	1.34
1.34	1.34	1.34	0.57	1.22	0.57	1.34	0.57	3.08	0.57	7.17	0.57
3.08	1.34	0.57	1.13	1.34	1.34	3.60	1.34	1.22	0.57	1.22	2.26
2.57	1.34	0.57	1.34	1.34	0.57	1.22	0.57	3.08	1.34	2.09	1.34
0.57	4.14	1.34	1.22	0.00							
PR6017	0.57	1.34	0.00	3.73	0.57	2.50	1.22	2.50	0.57	3.32	0.57
2.50	2.50	2.50	1.34	0.00	1.34	2.50	1.34	3.73	1.34	6.86	1.34

Appendix B. (Continued)

3.73	2.50	1.34	1.66	2.50	2.50	4.18	2.50	0.00	1.34	0.00	2.57
3.32	2.50	1.34	2.50	0.57	1.34	0.00	1.34	3.73	2.50	2.97	2.50
1.34	4.65	2.50	0.00	1.22	0.00						

PR6050	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00					

PR6073	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00				

PR6083	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00			

PR6258	4.18	3.60	4.65	1.13	4.18	3.39	4.14	3.39	4.18	1.70	4.18
3.39	3.39	3.39	3.60	4.65	3.60	3.39	3.60	1.13	3.60	8.63	3.60
1.13	3.39	3.60	3.08	3.39	3.39	0.57	3.39	4.65	3.60	4.65	2.09
1.70	3.39	3.60	3.39	4.18	3.60	4.65	3.60	1.13	3.39	2.26	3.39
3.60	0.00	3.39	4.65	4.14	4.65	3.39	3.39	3.39	0.00		

Appendix B. (Continued)

PR6270	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00	2.57	1.22	1.66	1.22
0.00	3.60	1.22	1.34	0.57	1.34	1.22	1.22	1.22	3.60	0.00	

PR6361	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00	2.57	1.22	1.66	1.22
0.00	3.60	1.22	1.34	0.57	1.34	1.22	1.22	1.22	3.60	0.00	0.00

PR6390	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00	2.57	1.22	1.66	1.22
0.00	3.60	1.22	1.34	0.57	1.34	1.22	1.22	1.22	3.60	0.00	0.00
0.00											

PR6514	0.00	1.22	0.57	3.32	0.00	2.44	1.34	2.44	0.00	2.97	0.00
2.44	2.44	2.44	1.22	0.57	1.22	2.44	1.22	3.32	1.22	6.88	1.22
3.32	2.44	1.22	1.34	2.44	2.44	3.73	2.44	0.57	1.22	0.57	2.09
2.97	2.44	1.22	2.44	0.00	1.22	0.57	1.22	3.32	2.44	2.69	2.44
1.22	4.18	2.44	0.57	1.34	0.57	2.44	2.44	2.44	4.18	1.22	1.22
1.22	0.00										

PR6805	1.34	0.57	1.22	3.08	1.34	1.34	0.00	1.34	1.34	2.57	1.34
1.34	1.34	1.34	0.57	1.22	0.57	1.34	0.57	3.08	0.57	7.17	0.57
3.08	1.34	0.57	1.13	1.34	1.34	3.60	1.34	1.22	0.57	1.22	2.26

Appendix B. (Continued)

2.57	1.34	0.57	1.34	1.34	0.57	1.22	0.57	3.08	1.34	2.09	1.34
0.57	4.14	1.34	1.22	0.00	1.22	1.34	1.34	1.34	4.14	0.57	0.57
0.57	1.34	0.00									
PR6904	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00								
PR6983	2.69	1.66	2.97	1.13	2.69	1.13	2.09	1.13	2.69	0.57	2.69
1.13	1.13	1.13	1.66	2.97	1.66	1.13	1.66	1.13	1.66	7.86	1.66
1.13	1.13	1.66	1.34	1.13	1.13	1.70	1.13	2.97	1.66	2.97	1.34
0.57	1.13	1.66	1.13	2.69	1.66	2.97	1.66	1.13	1.13	0.00	1.13
1.66	2.26	1.13	2.97	2.09	2.97	1.13	1.13	1.13	2.26	1.66	1.66
1.66	2.69	2.09	1.13	0.00							
PR6992	6.88	7.19	6.86	8.18	6.88	7.69	7.17	7.69	6.88	8.00	6.88
7.69	7.69	7.69	7.19	6.86	7.19	7.69	7.19	8.18	7.19	0.00	7.19
8.18	7.69	7.19	7.26	7.69	7.69	8.39	7.69	6.86	7.19	6.86	7.52
8.00	7.69	7.19	7.69	6.88	7.19	6.86	7.19	8.18	7.69	7.86	7.69
7.19	8.63	7.69	6.86	7.17	6.86	7.69	7.69	7.69	8.63	7.19	7.19
7.19	6.88	7.17	7.69	7.86	0.00						
PR7292	3.32	2.57	3.73	0.00	3.32	2.26	3.08	2.26	3.32	0.57	3.32
2.26	2.26	2.26	2.57	3.73	2.57	2.26	2.57	0.00	2.57	8.18	2.57
0.00	2.26	2.57	2.09	2.26	2.26	0.57	2.26	3.73	2.57	3.73	1.34
0.57	2.26	2.57	2.26	3.32	2.57	3.73	2.57	0.00	2.26	1.13	2.26
2.57	1.13	2.26	3.73	3.08	3.73	2.26	2.26	2.26	1.13	2.57	2.57

Appendix B. (Continued)

2.57	3.32	3.08	2.26	1.13	8.18	0.00					
PR7295	3.73	3.08	4.18	0.57	3.73	2.83	3.60	2.83	3.73	1.13	3.73
2.83	2.83	2.83	3.08	4.18	3.08	2.83	3.08	0.57	3.08	8.39	3.08
0.57	2.83	3.08	2.57	2.83	2.83	0.00	2.83	4.18	3.08	4.18	1.66
1.13	2.83	3.08	2.83	3.73	3.08	4.18	3.08	0.57	2.83	1.70	2.83
3.08	0.57	2.83	4.18	3.60	4.18	2.83	2.83	2.83	0.57	3.08	3.08
3.08	3.73	3.60	2.83	1.70	8.39	0.57	0.00				
PR7492	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00			
PR7843	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00	2.57	1.22	1.66	1.22
0.00	3.60	1.22	1.34	0.57	1.34	1.22	1.22	1.22	3.60	0.00	0.00
0.00	1.22	0.57	1.22	1.66	7.19	2.57	3.08	1.22	0.00		
PR8126	2.69	1.66	2.97	1.13	2.69	1.13	2.09	1.13	2.69	0.57	2.69
1.13	1.13	1.13	1.66	2.97	1.66	1.13	1.66	1.13	1.66	7.86	1.66
1.13	1.13	1.66	1.34	1.13	1.13	1.70	1.13	2.97	1.66	2.97	1.34
0.57	1.13	1.66	1.13	2.69	1.66	2.97	1.66	1.13	1.13	0.00	1.13
1.66	2.26	1.13	2.97	2.09	2.97	1.13	1.13	1.13	2.26	1.66	1.66
1.66	2.69	2.09	1.13	0.00	7.86	1.13	1.70	1.13	1.66	0.00	

Appendix B. (Continued)

PR8144	2.50	1.34	2.44	2.83	2.50	0.57	1.22	0.57	2.50	2.26	2.50
0.57	0.57	0.57	1.34	2.44	1.34	0.57	1.34	2.83	1.34	7.67	1.34
2.83	0.57	1.34	1.66	0.57	0.57	3.39	0.57	2.44	1.34	2.44	2.57
2.26	0.57	1.34	0.57	2.50	1.34	2.44	1.34	2.83	0.57	1.70	0.57
1.34	3.96	0.57	2.44	1.22	2.44	0.57	0.57	0.57	3.96	1.34	1.34
1.34	2.50	1.22	0.57	1.70	7.67	2.83	3.39	0.57	1.34	1.70	0.00

PR8245	1.34	0.57	1.22	3.08	1.34	1.34	0.00	1.34	1.34	2.57	1.34
1.34	1.34	1.34	0.57	1.22	0.57	1.34	0.57	3.08	0.57	7.17	0.57
3.08	1.34	0.57	1.13	1.34	1.34	3.60	1.34	1.22	0.57	1.22	2.26
2.57	1.34	0.57	1.34	1.34	0.57	1.22	0.57	3.08	1.34	2.09	1.34
0.57	4.14	1.34	1.22	0.00	1.22	1.34	1.34	1.34	4.14	0.57	0.57
0.57	1.34	0.00	1.34	2.09	7.17	3.08	3.60	1.34	0.57	2.09	1.22
0.00											

PR8306	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00	1.22	1.13	0.57
1.34	0.00										

PR8412	2.97	2.09	3.32	0.57	2.97	1.70	2.57	1.70	2.97	0.00	2.97
1.70	1.70	1.70	2.09	3.32	2.09	1.70	2.09	0.57	2.09	8.00	2.09
0.57	1.70	2.09	1.66	1.70	1.70	1.13	1.70	3.32	2.09	3.32	1.22
0.00	1.70	2.09	1.70	2.97	2.09	3.32	2.09	0.57	1.70	0.57	1.70
2.09	1.70	1.70	3.32	2.57	3.32	1.70	1.70	1.70	1.70	2.09	2.09
2.09	2.97	2.57	1.70	0.57	8.00	0.57	1.13	1.70	2.09	0.57	2.26

Appendix B. (Continued)

2.57	1.70	0.00									
PR8536	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00	2.57	1.22	1.66	1.22
0.00	3.60	1.22	1.34	0.57	1.34	1.22	1.22	1.22	3.60	0.00	0.00
0.00	1.22	0.57	1.22	1.66	7.19	2.57	3.08	1.22	0.00	1.66	1.34
0.57	1.22	2.09	0.00								
PR8757	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00	1.22	1.13	0.57
1.34	0.00	1.70	1.22	0.00							
PR8808	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00	1.22	1.13	0.57
1.34	0.00	1.70	1.22	0.00	0.00						
PR8812	2.97	2.09	3.32	0.57	2.97	1.70	2.57	1.70	2.97	0.00	2.97
1.70	1.70	1.70	2.09	3.32	2.09	1.70	2.09	0.57	2.09	8.00	2.09
0.57	1.70	2.09	1.66	1.70	1.70	1.13	1.70	3.32	2.09	3.32	1.22

Appendix B. (Continued)

0.00	1.70	2.09	1.70	2.97	2.09	3.32	2.09	0.57	1.70	0.57	1.70
2.09	1.70	1.70	3.32	2.57	3.32	1.70	1.70	1.70	1.70	2.09	2.09
2.09	2.97	2.57	1.70	0.57	8.00	0.57	1.13	1.70	2.09	0.57	2.26
2.57	1.70	0.00	2.09	1.70	1.70	0.00					

PR8815	1.34	0.57	1.22	3.08	1.34	1.34	0.00	1.34	1.34	2.57	1.34
1.34	1.34	1.34	0.57	1.22	0.57	1.34	0.57	3.08	0.57	7.17	0.57
3.08	1.34	0.57	1.13	1.34	1.34	3.60	1.34	1.22	0.57	1.22	2.26
2.57	1.34	0.57	1.34	1.34	0.57	1.22	0.57	3.08	1.34	2.09	1.34
0.57	4.14	1.34	1.22	0.00	1.22	1.34	1.34	1.34	4.14	0.57	0.57
0.57	1.34	0.00	1.34	2.09	7.17	3.08	3.60	1.34	0.57	2.09	1.22
0.00	1.34	2.57	0.57	1.34	1.34	2.57	0.00				

PR8822	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00	1.22	1.13	0.57
1.34	0.00	1.70	1.22	0.00	0.00	1.70	1.34	0.00			

PR8881	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00	1.22	1.13	0.57
1.34	0.00	1.70	1.22	0.00	0.00	1.70	1.34	0.00	0.00		

Appendix B. (Continued)

PR8940	3.32	2.57	3.73	0.00	3.32	2.26	3.08	2.26	3.32	0.57	3.32
2.26	2.26	2.26	2.57	3.73	2.57	2.26	2.57	0.00	2.57	8.18	2.57
0.00	2.26	2.57	2.09	2.26	2.26	0.57	2.26	3.73	2.57	3.73	1.34
0.57	2.26	2.57	2.26	3.32	2.57	3.73	2.57	0.00	2.26	1.13	2.26
2.57	1.13	2.26	3.73	3.08	3.73	2.26	2.26	2.26	1.13	2.57	2.57
2.57	3.32	3.08	2.26	1.13	8.18	0.00	0.57	2.26	2.57	1.13	2.83
3.08	2.26	0.57	2.57	2.26	2.26	0.57	3.08	2.26	2.26	0.00	
PR8955	3.32	2.57	3.73	0.00	3.32	2.26	3.08	2.26	3.32	0.57	3.32
2.26	2.26	2.26	2.57	3.73	2.57	2.26	2.57	0.00	2.57	8.18	2.57
0.00	2.26	2.57	2.09	2.26	2.26	0.57	2.26	3.73	2.57	3.73	1.34
0.57	2.26	2.57	2.26	3.32	2.57	3.73	2.57	0.00	2.26	1.13	2.26
2.57	1.13	2.26	3.73	3.08	3.73	2.26	2.26	2.26	1.13	2.57	2.57
2.57	3.32	3.08	2.26	1.13	8.18	0.00	0.57	2.26	2.57	1.13	2.83
3.08	2.26	0.57	2.57	2.26	2.26	0.57	3.08	2.26	2.26	0.00	0.00
PR9421	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00	1.22	1.13	0.57
1.34	0.00	1.70	1.22	0.00	0.00	1.70	1.34	0.00	0.00	2.26	2.26
0.00											
PR9466	0.57	1.34	0.00	3.73	0.57	2.50	1.22	2.50	0.57	3.32	0.57
2.50	2.50	2.50	1.34	0.00	1.34	2.50	1.34	3.73	1.34	6.86	1.34
3.73	2.50	1.34	1.66	2.50	2.50	4.18	2.50	0.00	1.34	0.00	2.57
3.32	2.50	1.34	2.50	0.57	1.34	0.00	1.34	3.73	2.50	2.97	2.50

Appendix B. (Continued)

1.34	4.65	2.50	0.00	1.22	0.00	2.50	2.50	2.50	4.65	1.34	1.34
1.34	0.57	1.22	2.50	2.97	6.86	3.73	4.18	2.50	1.34	2.97	2.44
1.22	2.50	3.32	1.34	2.50	2.50	3.32	1.22	2.50	2.50	3.73	3.73
2.50	0.00										
PR9521	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00	1.22	1.13	0.57
1.34	0.00	1.70	1.22	0.00	0.00	1.70	1.34	0.00	0.00	2.26	2.26
0.00	2.50	0.00									
PR9608	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00	2.57	1.22	1.66	1.22
0.00	3.60	1.22	1.34	0.57	1.34	1.22	1.22	1.22	3.60	0.00	0.00
0.00	1.22	0.57	1.22	1.66	7.19	2.57	3.08	1.22	0.00	1.66	1.34
0.57	1.22	2.09	0.00	1.22	1.22	2.09	0.57	1.22	1.22	2.57	2.57
1.22	1.34	1.22	0.00								
PR9763	2.97	2.09	3.32	0.57	2.97	1.70	2.57	1.70	2.97	0.00	2.97
1.70	1.70	1.70	2.09	3.32	2.09	1.70	2.09	0.57	2.09	8.00	2.09
0.57	1.70	2.09	1.66	1.70	1.70	1.13	1.70	3.32	2.09	3.32	1.22
0.00	1.70	2.09	1.70	2.97	2.09	3.32	2.09	0.57	1.70	0.57	1.70
2.09	1.70	1.70	3.32	2.57	3.32	1.70	1.70	1.70	1.70	2.09	2.09
2.09	2.97	2.57	1.70	0.57	8.00	0.57	1.13	1.70	2.09	0.57	2.26

Appendix B. (Continued)

2.57	1.70	0.00	2.09	1.70	1.70	0.00	2.57	1.70	1.70	0.57	0.57
1.70	3.32	1.70	2.09	0.00							
PR9774	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00	2.57	1.22	1.66	1.22
0.00	3.60	1.22	1.34	0.57	1.34	1.22	1.22	1.22	3.60	0.00	0.00
0.00	1.22	0.57	1.22	1.66	7.19	2.57	3.08	1.22	0.00	1.66	1.34
0.57	1.22	2.09	0.00	1.22	1.22	2.09	0.57	1.22	1.22	2.57	2.57
1.22	1.34	1.22	0.00	2.09	0.00						
PR9829	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00	1.22	1.13	0.57
1.34	0.00	1.70	1.22	0.00	0.00	1.70	1.34	0.00	0.00	2.26	2.26
0.00	2.50	0.00	1.22	1.70	1.22	0.00					

Appendix C. Distance Matrix-Cluster Analysis (Average linkage algorithm).

Euclidean Distance (Cophenetic correlation coefficient = 0.652)

PR0040	PR0053	PR0061	PR0152	PR0158
PR0410	PR0426	PR0662	PR0736	PR0974
PR1142	PR1309	PR1345	PR1590	PR1623
PR1701	PR1712	PR1845	PR1901	PR2316
PR2330	PR2336	PR2634	PR2723	PR2801
PR2934	PR3023	PR3409	PR3421	PR3532
PR3657	PR3871	PR3904	PR4115	PR4126
PR4193	PR4276	PR4330	PR4613	PR4677
PR4702	PR4867	PR4910	PR5020	PR5064
PR5097	PR5123	PR5175	PR5693	PR5807
PR5908	PR5911	PR6017	PR6050	PR6073
PR6083	PR6258	PR6270	PR6361	PR6390
PR6514	PR6805	PR6904	PR6983	PR6992
PR7292	PR7295	PR7492	PR7843	PR8126
PR8144	PR8245	PR8306	PR8412	PR8536
PR8757	PR8808	PR8812	PR8815	PR8822
PR8881	PR8940	PR8955	PR9421	PR9466
PR9521	PR9608	PR9763	PR9774	PR9829

Appendix C. (Continued)

PR0040	0.00												
PR0053	1.22	0.00											
PR0061	0.57	1.34	0.00										
PR0152	3.32	2.57	3.73	0.00									
PR0158	0.00	1.22	0.57	3.32	0.00								
PR0410	2.44	1.22	2.50	2.26	2.44	0.00							
PR0426	1.34	0.57	1.22	3.08	1.34	1.34	0.00						
PR0662	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00					
PR0736	0.00	1.22	0.57	3.32	0.00	2.44	1.34	2.44	0.00				
PR0974	2.97	2.09	3.32	0.57	2.97	1.70	2.57	1.70	2.97	0.00			
PR1142	0.00	1.22	0.57	3.32	0.00	2.44	1.34	2.44	0.00	2.97	0.00		
PR1309	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44	0.00	
PR1345	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44	0.00	0.00
PR1590	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44		

Appendix C. (Continued)

0.00	0.00	0.00									
PR1623	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00								
PR1701	0.57	1.34	0.00	3.73	0.57	2.50	1.22	2.50	0.57	3.32	0.57
2.50	2.50	2.50	1.34	0.00							
PR1712	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00						
PR1845	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00					
PR1901	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00				
PR2316	3.32	2.57	3.73	0.00	3.32	2.26	3.08	2.26	3.32	0.57	3.32
2.26	2.26	2.26	2.57	3.73	2.57	2.26	2.57	0.00			
PR2330	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00		
PR2336	6.88	7.19	6.86	8.18	6.88	7.69	7.17	7.69	6.88	8.00	6.88
7.69	7.69	7.69	7.19	6.86	7.19	7.69	7.19	8.18	7.19	0.00	
PR2634	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
PR2723	3.32	2.57	3.73	0.00	3.32	2.26	3.08	2.26	3.32	0.57	3.32

Appendix C. (Continued)

2.26	2.26	2.26	2.57	3.73	2.57	2.26	2.57	0.00	2.57	8.18	2.57
0.00											
PR2801	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00										
PR2934	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00									
PR3023	1.34	0.57	1.66	2.09	1.34	1.34	1.13	1.34	1.34	1.66	1.34
1.34	1.34	1.34	0.57	1.66	0.57	1.34	0.57	2.09	0.57	7.26	0.57
2.09	1.34	0.57	0.00								
PR3409	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00							
PR3421	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00						
PR3532	3.73	3.08	4.18	0.57	3.73	2.83	3.60	2.83	3.73	1.13	3.73
2.83	2.83	2.83	3.08	4.18	3.08	2.83	3.08	0.57	3.08	8.39	3.08
0.57	2.83	3.08	2.57	2.83	2.83	0.00					
PR3657	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22

Appendix C. (Continued)

2.26 0.00 1.22 1.34 0.00 0.00 2.83 0.00

PR3871 0.57 1.34 0.00 3.73 0.57 2.50 1.22 2.50 0.57 3.32 0.57
2.50 2.50 2.50 1.34 0.00 1.34 2.50 1.34 3.73 1.34 6.86 1.34
3.73 2.50 1.34 1.66 2.50 2.50 4.18 2.50 0.00

PR3904 1.22 0.00 1.34 2.57 1.22 1.22 0.57 1.22 1.22 2.09 1.22
1.22 1.22 1.22 0.00 1.34 0.00 1.22 0.00 2.57 0.00 7.19 0.00
2.57 1.22 0.00 0.57 1.22 1.22 3.08 1.22 1.34 0.00

PR4115 0.57 1.34 0.00 3.73 0.57 2.50 1.22 2.50 0.57 3.32 0.57
2.50 2.50 2.50 1.34 0.00 1.34 2.50 1.34 3.73 1.34 6.86 1.34
3.73 2.50 1.34 1.66 2.50 2.50 4.18 2.50 0.00 1.34 0.00

PR4126 2.09 1.70 2.57 1.34 2.09 2.09 2.26 2.09 2.09 1.22 2.09
2.09 2.09 2.09 1.70 2.57 1.70 2.09 1.70 1.34 1.70 7.52 1.70
1.34 2.09 1.70 1.13 2.09 2.09 1.66 2.09 2.57 1.70 2.57 0.00

PR4193 2.97 2.09 3.32 0.57 2.97 1.70 2.57 1.70 2.97 0.00 2.97
1.70 1.70 1.70 2.09 3.32 2.09 1.70 2.09 0.57 2.09 8.00 2.09
0.57 1.70 2.09 1.66 1.70 1.70 1.13 1.70 3.32 2.09 3.32 1.22
0.00

PR4276 2.44 1.22 2.50 2.26 2.44 0.00 1.34 0.00 2.44 1.70 2.44
0.00 0.00 0.00 1.22 2.50 1.22 0.00 1.22 2.26 1.22 7.69 1.22
2.26 0.00 1.22 1.34 0.00 0.00 2.83 0.00 2.50 1.22 2.50 2.09
1.70 0.00

Appendix C. (Continued)

PR4330	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00									
PR4613	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00								
PR4677	0.00	1.22	0.57	3.32	0.00	2.44	1.34	2.44	0.00	2.97	0.00
2.44	2.44	2.44	1.22	0.57	1.22	2.44	1.22	3.32	1.22	6.88	1.22
3.32	2.44	1.22	1.34	2.44	2.44	3.73	2.44	0.57	1.22	0.57	2.09
2.97	2.44	1.22	2.44	0.00							
PR4702	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00						
PR4867	0.57	1.34	0.00	3.73	0.57	2.50	1.22	2.50	0.57	3.32	0.57
2.50	2.50	2.50	1.34	0.00	1.34	2.50	1.34	3.73	1.34	6.86	1.34
3.73	2.50	1.34	1.66	2.50	2.50	4.18	2.50	0.00	1.34	0.00	2.57
3.32	2.50	1.34	2.50	0.57	1.34	0.00					
PR4910	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00

Appendix C. (Continued)

2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00				
PR5020	3.32	2.57	3.73	0.00	3.32	2.26	3.08	2.26	3.32	0.57	3.32
2.26	2.26	2.26	2.57	3.73	2.57	2.26	2.57	0.00	2.57	8.18	2.57
0.00	2.26	2.57	2.09	2.26	2.26	0.57	2.26	3.73	2.57	3.73	1.34
0.57	2.26	2.57	2.26	3.32	2.57	3.73	2.57	0.00			
PR5064	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00		
PR5097	2.69	1.66	2.97	1.13	2.69	1.13	2.09	1.13	2.69	0.57	2.69
1.13	1.13	1.13	1.66	2.97	1.66	1.13	1.66	1.13	1.66	7.86	1.66
1.13	1.13	1.66	1.34	1.13	1.13	1.70	1.13	2.97	1.66	2.97	1.34
0.57	1.13	1.66	1.13	2.69	1.66	2.97	1.66	1.13	1.13	0.00	
PR5123	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
PR5175	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00	2.57	1.22	1.66	1.22
0.00											

Appendix C. (Continued)

PR5693	4.18	3.60	4.65	1.13	4.18	3.39	4.14	3.39	4.18	1.70	4.18
3.39	3.39	3.39	3.60	4.65	3.60	3.39	3.60	1.13	3.60	8.63	3.60
1.13	3.39	3.60	3.08	3.39	3.39	0.57	3.39	4.65	3.60	4.65	2.09
1.70	3.39	3.60	3.39	4.18	3.60	4.65	3.60	1.13	3.39	2.26	3.39
3.60	0.00										
PR5807	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00									
PR5908	0.57	1.34	0.00	3.73	0.57	2.50	1.22	2.50	0.57	3.32	0.57
2.50	2.50	2.50	1.34	0.00	1.34	2.50	1.34	3.73	1.34	6.86	1.34
3.73	2.50	1.34	1.66	2.50	2.50	4.18	2.50	0.00	1.34	0.00	2.57
3.32	2.50	1.34	2.50	0.57	1.34	0.00	1.34	3.73	2.50	2.97	2.50
1.34	4.65	2.50	0.00								
PR5911	1.34	0.57	1.22	3.08	1.34	1.34	0.00	1.34	1.34	2.57	1.34
1.34	1.34	1.34	0.57	1.22	0.57	1.34	0.57	3.08	0.57	7.17	0.57
3.08	1.34	0.57	1.13	1.34	1.34	3.60	1.34	1.22	0.57	1.22	2.26
2.57	1.34	0.57	1.34	1.34	0.57	1.22	0.57	3.08	1.34	2.09	1.34
0.57	4.14	1.34	1.22	0.00							
PR6017	0.57	1.34	0.00	3.73	0.57	2.50	1.22	2.50	0.57	3.32	0.57
2.50	2.50	2.50	1.34	0.00	1.34	2.50	1.34	3.73	1.34	6.86	1.34
3.73	2.50	1.34	1.66	2.50	2.50	4.18	2.50	0.00	1.34	0.00	2.57
3.32	2.50	1.34	2.50	0.57	1.34	0.00	1.34	3.73	2.50	2.97	2.50

Appendix C. (Continued)

1.34	4.65	2.50	0.00	1.22	0.00						

PR6050	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00					

PR6073	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00				

PR6083	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00			

PR6258	4.18	3.60	4.65	1.13	4.18	3.39	4.14	3.39	4.18	1.70	4.18
3.39	3.39	3.39	3.60	4.65	3.60	3.39	3.60	1.13	3.60	8.63	3.60
1.13	3.39	3.60	3.08	3.39	3.39	0.57	3.39	4.65	3.60	4.65	2.09
1.70	3.39	3.60	3.39	4.18	3.60	4.65	3.60	1.13	3.39	2.26	3.39
3.60	0.00	3.39	4.65	4.14	4.65	3.39	3.39	3.39	0.00		

PR6270	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00	2.57	1.22	1.66	1.22

Appendix C. (Continued)

0.00	3.60	1.22	1.34	0.57	1.34	1.22	1.22	1.22	3.60	0.00	
PR6361	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00	2.57	1.22	1.66	1.22
0.00	3.60	1.22	1.34	0.57	1.34	1.22	1.22	1.22	3.60	0.00	0.00
PR6390	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00	2.57	1.22	1.66	1.22
0.00	3.60	1.22	1.34	0.57	1.34	1.22	1.22	1.22	3.60	0.00	0.00
0.00											
PR6514	0.00	1.22	0.57	3.32	0.00	2.44	1.34	2.44	0.00	2.97	0.00
2.44	2.44	2.44	1.22	0.57	1.22	2.44	1.22	3.32	1.22	6.88	1.22
3.32	2.44	1.22	1.34	2.44	2.44	3.73	2.44	0.57	1.22	0.57	2.09
2.97	2.44	1.22	2.44	0.00	1.22	0.57	1.22	3.32	2.44	2.69	2.44
1.22	4.18	2.44	0.57	1.34	0.57	2.44	2.44	2.44	4.18	1.22	1.22
1.22	0.00										
PR6805	1.34	0.57	1.22	3.08	1.34	1.34	0.00	1.34	1.34	2.57	1.34
1.34	1.34	1.34	0.57	1.22	0.57	1.34	0.57	3.08	0.57	7.17	0.57
3.08	1.34	0.57	1.13	1.34	1.34	3.60	1.34	1.22	0.57	1.22	2.26
2.57	1.34	0.57	1.34	1.34	0.57	1.22	0.57	3.08	1.34	2.09	1.34
0.57	4.14	1.34	1.22	0.00	1.22	1.34	1.34	1.34	4.14	0.57	0.57
0.57	1.34	0.00									

Appendix C. (Continued)

PR6904	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00								

PR6983	2.69	1.66	2.97	1.13	2.69	1.13	2.09	1.13	2.69	0.57	2.69
1.13	1.13	1.13	1.66	2.97	1.66	1.13	1.66	1.13	1.66	7.86	1.66
1.13	1.13	1.66	1.34	1.13	1.13	1.70	1.13	2.97	1.66	2.97	1.34
0.57	1.13	1.66	1.13	2.69	1.66	2.97	1.66	1.13	1.13	0.00	1.13
1.66	2.26	1.13	2.97	2.09	2.97	1.13	1.13	1.13	2.26	1.66	1.66
1.66	2.69	2.09	1.13	0.00							

PR6992	6.88	7.19	6.86	8.18	6.88	7.69	7.17	7.69	6.88	8.00	6.88
7.69	7.69	7.69	7.19	6.86	7.19	7.69	7.19	8.18	7.19	0.00	7.19
8.18	7.69	7.19	7.26	7.69	7.69	8.39	7.69	6.86	7.19	6.86	7.52
8.00	7.69	7.19	7.69	6.88	7.19	6.86	7.19	8.18	7.69	7.86	7.69
7.19	8.63	7.69	6.86	7.17	6.86	7.69	7.69	7.69	8.63	7.19	7.19
7.19	6.88	7.17	7.69	7.86	0.00						

PR7292	3.32	2.57	3.73	0.00	3.32	2.26	3.08	2.26	3.32	0.57	3.32
2.26	2.26	2.26	2.57	3.73	2.57	2.26	2.57	0.00	2.57	8.18	2.57
0.00	2.26	2.57	2.09	2.26	2.26	0.57	2.26	3.73	2.57	3.73	1.34
0.57	2.26	2.57	2.26	3.32	2.57	3.73	2.57	0.00	2.26	1.13	2.26
2.57	1.13	2.26	3.73	3.08	3.73	2.26	2.26	2.26	1.13	2.57	2.57
2.57	3.32	3.08	2.26	1.13	8.18	0.00					

PR7295	3.73	3.08	4.18	0.57	3.73	2.83	3.60	2.83	3.73	1.13	3.73
2.83	2.83	2.83	3.08	4.18	3.08	2.83	3.08	0.57	3.08	8.39	3.08
0.57	2.83	3.08	2.57	2.83	2.83	0.00	2.83	4.18	3.08	4.18	1.66

Appendix C. (Continued)

1.13	2.83	3.08	2.83	3.73	3.08	4.18	3.08	0.57	2.83	1.70	2.83
3.08	0.57	2.83	4.18	3.60	4.18	2.83	2.83	2.83	0.57	3.08	3.08
3.08	3.73	3.60	2.83	1.70	8.39	0.57	0.00				
PR7492	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00			
PR7843	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00	2.57	1.22	1.66	1.22
0.00	3.60	1.22	1.34	0.57	1.34	1.22	1.22	1.22	3.60	0.00	0.00
0.00	1.22	0.57	1.22	1.66	7.19	2.57	3.08	1.22	0.00		
PR8126	2.69	1.66	2.97	1.13	2.69	1.13	2.09	1.13	2.69	0.57	2.69
1.13	1.13	1.13	1.66	2.97	1.66	1.13	1.66	1.13	1.66	7.86	1.66
1.13	1.13	1.66	1.34	1.13	1.13	1.70	1.13	2.97	1.66	2.97	1.34
0.57	1.13	1.66	1.13	2.69	1.66	2.97	1.66	1.13	1.13	0.00	1.13
1.66	2.26	1.13	2.97	2.09	2.97	1.13	1.13	1.13	2.26	1.66	1.66
1.66	2.69	2.09	1.13	0.00	7.86	1.13	1.70	1.13	1.66	0.00	
PR8144	2.50	1.34	2.44	2.83	2.50	0.57	1.22	0.57	2.50	2.26	2.50
0.57	0.57	0.57	1.34	2.44	1.34	0.57	1.34	2.83	1.34	7.67	1.34
2.83	0.57	1.34	1.66	0.57	0.57	3.39	0.57	2.44	1.34	2.44	2.57
2.26	0.57	1.34	0.57	2.50	1.34	2.44	1.34	2.83	0.57	1.70	0.57
1.34	3.96	0.57	2.44	1.22	2.44	0.57	0.57	0.57	3.96	1.34	1.34

Appendix C. (Continued)

1.34	2.50	1.22	0.57	1.70	7.67	2.83	3.39	0.57	1.34	1.70	0.00
PR8245	1.34	0.57	1.22	3.08	1.34	1.34	0.00	1.34	1.34	2.57	1.34
1.34	1.34	1.34	0.57	1.22	0.57	1.34	0.57	3.08	0.57	7.17	0.57
3.08	1.34	0.57	1.13	1.34	1.34	3.60	1.34	1.22	0.57	1.22	2.26
2.57	1.34	0.57	1.34	1.34	0.57	1.22	0.57	3.08	1.34	2.09	1.34
0.57	4.14	1.34	1.22	0.00	1.22	1.34	1.34	1.34	4.14	0.57	0.57
0.57	1.34	0.00	1.34	2.09	7.17	3.08	3.60	1.34	0.57	2.09	1.22
0.00											
PR8306	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00	1.22	1.13	0.57
1.34	0.00										
PR8412	2.97	2.09	3.32	0.57	2.97	1.70	2.57	1.70	2.97	0.00	2.97
1.70	1.70	1.70	2.09	3.32	2.09	1.70	2.09	0.57	2.09	8.00	2.09
0.57	1.70	2.09	1.66	1.70	1.70	1.13	1.70	3.32	2.09	3.32	1.22
0.00	1.70	2.09	1.70	2.97	2.09	3.32	2.09	0.57	1.70	0.57	1.70
2.09	1.70	1.70	3.32	2.57	3.32	1.70	1.70	1.70	1.70	2.09	2.09
2.09	2.97	2.57	1.70	0.57	8.00	0.57	1.13	1.70	2.09	0.57	2.26
2.57	1.70	0.00									
PR8536	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00	2.57	1.22	1.66	1.22

Appendix C. (Continued)

0.00	3.60	1.22	1.34	0.57	1.34	1.22	1.22	1.22	3.60	0.00	0.00
0.00	1.22	0.57	1.22	1.66	7.19	2.57	3.08	1.22	0.00	1.66	1.34
0.57	1.22	2.09	0.00								
PR8757	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00	1.22	1.13	0.57
1.34	0.00	1.70	1.22	0.00							
PR8808	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00	1.22	1.13	0.57
1.34	0.00	1.70	1.22	0.00	0.00						
PR8812	2.97	2.09	3.32	0.57	2.97	1.70	2.57	1.70	2.97	0.00	2.97
1.70	1.70	1.70	2.09	3.32	2.09	1.70	2.09	0.57	2.09	8.00	2.09
0.57	1.70	2.09	1.66	1.70	1.70	1.13	1.70	3.32	2.09	3.32	1.22
0.00	1.70	2.09	1.70	2.97	2.09	3.32	2.09	0.57	1.70	0.57	1.70
2.09	1.70	1.70	3.32	2.57	3.32	1.70	1.70	1.70	1.70	2.09	2.09
2.09	2.97	2.57	1.70	0.57	8.00	0.57	1.13	1.70	2.09	0.57	2.26
2.57	1.70	0.00	2.09	1.70	1.70	0.00					
PR8815	1.34	0.57	1.22	3.08	1.34	1.34	0.00	1.34	1.34	2.57	1.34
1.34	1.34	1.34	0.57	1.22	0.57	1.34	0.57	3.08	0.57	7.17	0.57

Appendix C. (Continued)

3.08	1.34	0.57	1.13	1.34	1.34	3.60	1.34	1.22	0.57	1.22	2.26
2.57	1.34	0.57	1.34	1.34	0.57	1.22	0.57	3.08	1.34	2.09	1.34
0.57	4.14	1.34	1.22	0.00	1.22	1.34	1.34	1.34	4.14	0.57	0.57
0.57	1.34	0.00	1.34	2.09	7.17	3.08	3.60	1.34	0.57	2.09	1.22
0.00	1.34	2.57	0.57	1.34	1.34	2.57	0.00				
PR8822	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00	1.22	1.13	0.57
1.34	0.00	1.70	1.22	0.00	0.00	1.70	1.34	0.00			
PR8881	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00	1.22	1.13	0.57
1.34	0.00	1.70	1.22	0.00	0.00	1.70	1.34	0.00	0.00		
PR8940	3.32	2.57	3.73	0.00	3.32	2.26	3.08	2.26	3.32	0.57	3.32
2.26	2.26	2.26	2.57	3.73	2.57	2.26	2.57	0.00	2.57	8.18	2.57
0.00	2.26	2.57	2.09	2.26	2.26	0.57	2.26	3.73	2.57	3.73	1.34
0.57	2.26	2.57	2.26	3.32	2.57	3.73	2.57	0.00	2.26	1.13	2.26
2.57	1.13	2.26	3.73	3.08	3.73	2.26	2.26	2.26	1.13	2.57	2.57
2.57	3.32	3.08	2.26	1.13	8.18	0.00	0.57	2.26	2.57	1.13	2.83

Appendix C. (Continued)

3.08	2.26	0.57	2.57	2.26	2.26	0.57	3.08	2.26	2.26	0.00	
PR8955	3.32	2.57	3.73	0.00	3.32	2.26	3.08	2.26	3.32	0.57	3.32
2.26	2.26	2.26	2.57	3.73	2.57	2.26	2.57	0.00	2.57	8.18	2.57
0.00	2.26	2.57	2.09	2.26	2.26	0.57	2.26	3.73	2.57	3.73	1.34
0.57	2.26	2.57	2.26	3.32	2.57	3.73	2.57	0.00	2.26	1.13	2.26
2.57	1.13	2.26	3.73	3.08	3.73	2.26	2.26	2.26	1.13	2.57	2.57
2.57	3.32	3.08	2.26	1.13	8.18	0.00	0.57	2.26	2.57	1.13	2.83
3.08	2.26	0.57	2.57	2.26	2.26	0.57	3.08	2.26	2.26	0.00	0.00
PR9421	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00	1.22	1.13	0.57
1.34	0.00	1.70	1.22	0.00	0.00	1.70	1.34	0.00	0.00	2.26	2.26
0.00											
PR9466	0.57	1.34	0.00	3.73	0.57	2.50	1.22	2.50	0.57	3.32	0.57
2.50	2.50	2.50	1.34	0.00	1.34	2.50	1.34	3.73	1.34	6.86	1.34
3.73	2.50	1.34	1.66	2.50	2.50	4.18	2.50	0.00	1.34	0.00	2.57
3.32	2.50	1.34	2.50	0.57	1.34	0.00	1.34	3.73	2.50	2.97	2.50
1.34	4.65	2.50	0.00	1.22	0.00	2.50	2.50	2.50	4.65	1.34	1.34
1.34	0.57	1.22	2.50	2.97	6.86	3.73	4.18	2.50	1.34	2.97	2.44
1.22	2.50	3.32	1.34	2.50	2.50	3.32	1.22	2.50	2.50	3.73	3.73
2.50	0.00										

Appendix C. (Continued)

PR9521	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00	1.22	1.13	0.57
1.34	0.00	1.70	1.22	0.00	0.00	1.70	1.34	0.00	0.00	2.26	2.26
0.00	2.50	0.00									
PR9608	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00
2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00	2.57	1.22	1.66	1.22
0.00	3.60	1.22	1.34	0.57	1.34	1.22	1.22	1.22	3.60	0.00	0.00
0.00	1.22	0.57	1.22	1.66	7.19	2.57	3.08	1.22	0.00	1.66	1.34
0.57	1.22	2.09	0.00	1.22	1.22	2.09	0.57	1.22	1.22	2.57	2.57
1.22	1.34	1.22	0.00								
PR9763	2.97	2.09	3.32	0.57	2.97	1.70	2.57	1.70	2.97	0.00	2.97
1.70	1.70	1.70	2.09	3.32	2.09	1.70	2.09	0.57	2.09	8.00	2.09
0.57	1.70	2.09	1.66	1.70	1.70	1.13	1.70	3.32	2.09	3.32	1.22
0.00	1.70	2.09	1.70	2.97	2.09	3.32	2.09	0.57	1.70	0.57	1.70
2.09	1.70	1.70	3.32	2.57	3.32	1.70	1.70	1.70	1.70	2.09	2.09
2.09	2.97	2.57	1.70	0.57	8.00	0.57	1.13	1.70	2.09	0.57	2.26
2.57	1.70	0.00	2.09	1.70	1.70	0.00	2.57	1.70	1.70	0.57	0.57
1.70	3.32	1.70	2.09	0.00							
PR9774	1.22	0.00	1.34	2.57	1.22	1.22	0.57	1.22	1.22	2.09	1.22
1.22	1.22	1.22	0.00	1.34	0.00	1.22	0.00	2.57	0.00	7.19	0.00

Appendix C. (Continued)

2.57	1.22	0.00	0.57	1.22	1.22	3.08	1.22	1.34	0.00	1.34	1.70
2.09	1.22	0.00	1.22	1.22	0.00	1.34	0.00	2.57	1.22	1.66	1.22
0.00	3.60	1.22	1.34	0.57	1.34	1.22	1.22	1.22	3.60	0.00	0.00
0.00	1.22	0.57	1.22	1.66	7.19	2.57	3.08	1.22	0.00	1.66	1.34
0.57	1.22	2.09	0.00	1.22	1.22	2.09	0.57	1.22	1.22	2.57	2.57
1.22	1.34	1.22	0.00	2.09	0.00						
PR9829	2.44	1.22	2.50	2.26	2.44	0.00	1.34	0.00	2.44	1.70	2.44
0.00	0.00	0.00	1.22	2.50	1.22	0.00	1.22	2.26	1.22	7.69	1.22
2.26	0.00	1.22	1.34	0.00	0.00	2.83	0.00	2.50	1.22	2.50	2.09
1.70	0.00	1.22	0.00	2.44	1.22	2.50	1.22	2.26	0.00	1.13	0.00
1.22	3.39	0.00	2.50	1.34	2.50	0.00	0.00	0.00	3.39	1.22	1.22
1.22	2.44	1.34	0.00	1.13	7.69	2.26	2.83	0.00	1.22	1.13	0.57
1.34	0.00	1.70	1.22	0.00	0.00	1.70	1.34	0.00	0.00	2.26	2.26
0.00	2.50	0.00	1.22	1.70	1.22	0.00					

Appendix D. Classification of the Soil Series at the Ustic Isohyperthermic Soil Climate Regime.

Soil Series	Current classification	Updated Classification	Area (ha)
Aguadilla	Mixed, isohyperthermic Typic Udipsamments	Mixed, isohyperthermic Typic Ustipsamments	216
Bejucos	Fine-loamy, mixed, subactive, isohyperthermic Typic Hapludalfs	Fine-loamy, mixed, subactive, isohyperthermic Typic Haplustalfs	332
Caguabo	Loamy, mixed, active, isohyperthermic, shallow Typic Eutrudepts	Loamy, mixed, active, isohyperthermic, shallow Typic Eutrustepts	1,606
Callabo	Fine, mixed, superactive, isohyperthermic, shallow Typic Dystrudepts	Fine, mixed, superactive, isohyperthermic, shallow Typic Dystrustepts	14,833
Cataño	Carbonatic, isohyperthermic Typic Udipsamments	Carbonatic, isohyperthermic Typic Ustipsamments	1,387
Colinas	Coarse-loamy, carbonatic, isohyperthermic Typic Haprendolls	Coarse-loamy, carbonatic, isohyperthermic Typic Calciustolls	280
Consumo	Fine, mixed, semiactive, isohyperthermic Typic Haplohumults	Fine, mixed, semiactive, isohyperthermic Ustic Haplohumults	102
Daguao	Fine, mixed, semiactive, isohyperthermic Typic Haplohumults	Fine, mixed, semiactive, isohyperthermic Ustic Haplohumults	42
Espinal	Mixed, isohyperthermic Typic Udipsamments	Mixed, isohyperthermic Typic Ustipsamments	6
Guerrero	Clayey, kaolinitic, isohyperthermic Arenic Paleudalfs	Clayey, kaolinitic, isohyperthermic Arenic Paleustalfs	29
Humatas	Very-fine, parasesquic, isohyperthermic Typic Haplohumults	Very-fine, parasesquic, isohyperthermic Ustic Haplohumults	7
Jobos	Fine, kaolinitic, isohyperthermic Plinthaquic Paleudults	Fine, kaolinitic, isohyperthermic Plinthaquic Paleustults	249
Lares	Very-fine, mixed, semiactive, isohyperthermic Aquic Paleudults	Very-fine, mixed,semiactive, isohyperthermic Aquic Paleustults	72
Mabí	Very-fine, mixed, active, isohyperthermic Aquic Hapluderts	Very-fine, mixed, active, isohyperthermic Aquic Haplusterts	771
Malaya	Clayey, mixed, superactive, isohyperthermic, shallow Typic Eutrudepts	Clayey, mixed, superactive, isohyperthermic, shallow Typic Eutrustepts	1,029

Appendix D. (Continued)

Soil Series	Current classification	Updated Classification	Area (ha)
Maleza	Fine, parasesquic, isohyperthermic Typic Paleudults	Fine, parasesquic, isohyperthermic Typic Paleustults	228
Maragüez	Fine-loamy, mixed, superactive, isohyperthermic Typic Eutrudepts	Fine-loamy, mixed, superactive, isohyperthermic Typic Eutrustepts	69
Montegrande	Very-fine, mixed, superactive, isohyperthermic Chromic Hapluderts	Very-fine, mixed, superactive, isohyperthermic Chromic Haplusterts	958
Morado	Fine, mixed, superactive, isohyperthermic Dystric Eutrudepts	Fine, mixed, superactive, isohyperthermic Dystric Eutrustepts	691
Múcara	Fine-loamy, mixed, superactive, isohyperthermic Dystric Eutrudepts	Fine-loamy, mixed, superactive, isohyperthermic Dystric Eutrustepts	1,383
Naranjito	Fine, mixed, semiactive, isohyperthermic Typic Haplohumults	Fine, mixed, semiactive, isohyperthermic Ustic Haplohumults	238
Naranjo	Fine, carbonatic, isohyperthermic Inceptic Haprendolls	Fine, carbonatic, isohyperthermic Typic Calciustolls	19
Pandura	Coarse-loamy, mixed, active, isohyperthermic, shallow Dystric Eutrudepts	Coarse-loamy, mixed, active, isohyperthermic, shallow Dystric Eutrustepts	691
Parcelas	Fine, mixed, superactive, isohyperthermic Vertic Hapludalfs	Fine, mixed, superactive, isohyperthermic Vertic Haplustalfs	1
Quebrada	Fine-loamy, mixed, active, isohyperthermic Dystric Eutrudepts	Fine-loamy, mixed, active, isohyperthermic Dystric Eutrustepts	1,296
Reilly	Sandy-skeletal, mixed, isohyperthermic Mollic Udifluvents	Sandy-skeletal, mixed, isohyperthermic Mollic Ustifluvents	140

Appendix D. (Continued)

Soil Series	Current classification	Updated Classification	Area (ha)
Río Arriba	Fine, mixed, subactive, nonacid, isohyperthermic Vertic Paleudults	Fine, mixed, subactive, nonacid, isohyperthermic Vertic Paleustults	297
Río Lajas	Sandy-skeletal, mixed, isohyperthermic Psammentic Paleudalfs	Sandy-skeletal, mixed, isohyperthermic Psammentic Paleustalfs	96
Río Piedras	Fine, kaolinitic, isohyperthermic Typic Hapludults	Fine, kaolinitic, isohyperthermic Typic Haplustults	14
Sabana	Clayey, mixed, active, isohyperthermic Lithic Dystrudepts	Clayey, mixed, active, isohyperthermic Lithic Dystrustepts	308
Santa Clara	Fine, mixed, active, isohyperthermic Typic Eutrudepts	Fine, mixed, active, isohyperthermic Typic Eutrustepts	84
Santa Marta	Fine, magnesic, isohyperthermic Typic Kanhapludults	Fine, magnesic, isohyperthermic Typic Kanhaplustults	245
Soller	Clayey, mixed, active, isohyperthermic, shallow Typic Haprendolls	Clayey, mixed, active, isohyperthermic, shallow Typic Haplustolls	115
Tanamá	Clayey, mixed, active, isohyperthermic Lithic Hapludalfs	Clayey, mixed, active, isohyperthermic Lithic Haplustalfs	21
Toa	Fine, mixed, active, isohyperthermic Fluvaquentic Hapludolls	Fine, mixed, active, isohyperthermic Fluvaquentic Haplustolls	3,643
Vega Alta	Fine, kaolinitic, isohyperthermic Typic Hapludults	Fine, kaolinitic, isohyperthermic Typic Haplustults	70
Voladora	Very-fine, mixed, active, isohyperthermic Typic Palehumults	Very-fine, mixed, active, isohyperthermic Ustic Palehumults	2

Appendix E. Classification of the Soil Series at the Udic Isohyperthermic Soil Climate Regime.

Soil Series	Current classification	Updated Classification	Area (ha)
Aguilita	Coarse-loamy, carbonatic, isohyperthermic Aridic Calciustolls	Coarse-loamy, carbonatic, isohyperthermic Typic Calciudolls	212
Arenales	Mixed, isohyperthermic Aridic Ustipsamments	Mixed, isohyperthermic Typic Udipsamments	624
Caracoles	Loamy, mixed, superactive, isohyperthermic Lithic Haplustolls	Loamy, mixed, superactive, isohyperthermic Lithic Hapludolls	434
Cartagena	Fine, mixed, superactive, isohyperthermic Sodic Haplusterts	Fine, mixed, superactive, isohyperthermic Sodic Hapluderts	143
Coamo	Fine, mixed, superactive, isohyperthermic Typic Argiustolls	Fine, mixed, superactive, isohyperthermic Typic Argiudolls	79
Cotito	Clayey, kaolinitic, isohyperthermic Lithic Kandiustox	Clayey, kaolinitic, isohyperthermic Lithic Kandiudox	333
Coto	Very-fine, kaolinitic, isohyperthermic Typic Eutrustox	Very-fine, kaolinitic, isohyperthermic Typic Eutrudox	5,229
Cuchillas	Loamy, mixed, isothermic, shallow Typic Dystrudepts	Loamy, mixed, isohyperthermic, shallow Typic Dystrudepts	154
Cuyón	Sandy-skeletal, mixed, isohyperthermic Torrifluventic Haplustolls	Sandy-skeletal, mixed, isohyperthermic Fluventic Hapludolls	4
Descalabrado	Clayey, mixed, superactive, isohyperthermic, shallow Typic Haplustolls	Clayey, mixed, superactive, isohyperthermic, shallow Typic Hapludolls	13,233
Fraternidad	Fine, smectitic, isohyperthermic Typic Haplusters	Fine, smectitic, isohyperthermic Typic Hapluders	306
Guamaní	Fine-loamy over sandy or sandy-skeletal, mixed, superactive, isohyperthermic Torrifluventic Haplustepts	Fine-loamy over sandy or sandy-skeletal, mixed, superactive, isohyperthermic Fluventic Hapludepts	73
Guayama	Clayey, mixed, active, isohyperthermic, shallow Typic Haplustalfs	Clayey, mixed, active, isohyperthermic, shallow Typic Hapludalfs	392
Jacaguas	Loamy-skeletal, mixed, superactive, isohyperthermic Fluventic Haplustolls	Loamy-skeletal, mixed, superactive, isohyperthermic Fluventic Hapludolls	34

Appendix E. (Continued)

Soil Series	Current classification	Updated Classification	Area (ha)
Jácana	Fine, mixed, superactive, isohyperthermic Vertic Haplustolls	Fine, mixed, superactive, isohyperthermic Vertic Hapludolls	900
Llanos	Fine, smectitic, isohyperthermic Entic Haplusterts	Fine, smectitic, isohyperthermic Entic Hapluderts	78
Los Guineos	Very-fine, kaolinitic, isothermic Humic Hapludox	Very-fine, kaolinitic, isohyperthermic Humic Hapludox	5,978
Mabí	Very-fine, mixed, active, isohyperthermic Aquic Hapluderts	Very-fine, mixed, active, isohyperthermic Aquic Hapluderts	4,728
Machete	Very-fine, mixed, active, isohyperthermic Aridic Paleustalfs	Very-fine, mixed, active, isohyperthermic Typic Paleudalfs	14
Matanzas	Clayey, kaolinitic, isohyperthermic Lithic Kandiustox	Clayey, kaolinitic, isohyperthermic Lithic Kandiudox	1,668
Meros	Mixed, isohyperthermic Typic Ustipsamments	Mixed, isohyperthermic Typic Udipsamments	38
Paso Seco	Fine, mixed, superactive, isohyperthermic Entic Udic Haplusterts	Fine, mixed, superactive, isohyperthermic Entic Hapluderts	72
Ponceña	Fine, mixed, superactive, isohyperthermic Typic Calciusterts	Fine, mixed, superactive, isohyperthermic Typic Calciuderts	29
Pozo Blanco	Fine-loamy, mixed, superactive, isohyperthermic Aridic Calciustolls	Fine-loamy, mixed, superactive, isohyperthermic Typic Calciudolls	13
San Antón	Fine-loamy, mixed, superactive, isohyperthermic Cumulic Haplustolls	Fine-loamy, mixed, superactive, isohyperthermic Cumulic Hapludolls	65
San Germán	Clayey-skeletal, mixed, superactive, isohyperthermic, shallow Typic Ustorthents	Clayey-skeletal, mixed, superactive, isohyperthermic, shallow Typic Udorthents	4,875
Sosa	Fine, kaolinitic, isohyperthermic Aridic Paleustalfs	Fine, kaolinitic, isohyperthermic Typic Paleudalfs	28
Teresa	Very-fine, smectitic, isohyperthermic Sodic Haplusters	Very-fine, smectitic, isohyperthermic Sodic Hapluderts	11

Appendix E. (Continued)

Soil Series	Current classification	Updated Classification	Area (ha)
Vives	Fine-loamy, mixed, superactive, isohyperthermic Fluvaquentic Haplustepts	Fine-loamy, mixed, superactive, isohyperthermic Fluvaquentic Hapludepts	86

Appendix F. Classification of the Soil Series at the Udic Isothermic Soil Climate Regime.

Soil Series	Current classification	Updated Classification	Area (ha)
Adjuntas	Very-fine, kaolinitic, isohyperthermic Inceptic Hapludox	Very-fine, kaolinitic, isothermic Inceptic Hapludox	10
Alonso	Very-fine, parasesquic, isohyperthermic Oxic Dystrudepts	Very-fine, parasesquic, isothermic Oxic Dystrudepts	65
Anones	Fine, parasesquic, isohyperthermic Humic Dystrudepts	Fine, parasesquic, isothermic Humic Dystrudepts	1
Caguabo	Loamy, mixed, active, isohyperthermic, shallow Typic Eutrudepts	Loamy, mixed, active, isothermic, shallow Typic Eutrudepts	179
Consumo	Fine, mixed, semiactive, isohyperthermic Typic Haplohumults	Fine, mixed, semiactive, isothermic Typic Haplohumults	35
Cuchillas	Loamy, mixed, isothermic, shallow Typic Dystrudepts	Loamy, mixed, isothermic, shallow Typic Dystrudepts	20
Dagüey	Very-fine, kaolinitic, isohyperthermic Inceptic Hapludox	Very-fine, kaolinitic, isothermic Inceptic Hapludox	2
Humatas	Very-fine, parasesquic, isohyperthermic Typic Haplohumults	Very-fine, parasesquic, isothermic Typic Haplohumults	171
Lirios	Fine, mixed, subactive, isohyperthermic Typic Hapludults	Fine, mixed, subactive, isothermic Typic Hapludults	36
Los Guineos	Very-fine, kaolinitic, isothermic Humic Hapludox	Very-fine, kaolinitic, isothermic Humic Hapludox	627
Maragüez	Fine-loamy, mixed, superactive, isohyperthermic Typic Eutrudepts	Fine-loamy, mixed, superactive, isothermic Typic Eutrudepts	132
Maricao	Fine, mixed, subactive, isohyperthermic Inceptic Hapludults	Fine, mixed, subactive, isothermic Inceptic Hapludults	224
Morado	Fine, mixed, superactive, isohyperthermic Dystric Eutrudepts	Fine, mixed, superactive, isothermic Dystric Eutrudepts	53
Múcara	Fine-loamy, mixed, superactive, isohyperthermic Dystric Eutrudepts	Fine-loamy, mixed, superactive, isothermic Dystric Eutrudepts	57

Appendix F. (Continued)

Soil Series	Current classification	Updated Classification	Area (ha)
Pellejas	Fine-loamy over sandy or sandy-skeletal, mixed, subactive, isohyperthermic Typic Dystrudepts	Fine-loamy over sandy or sandy-skeletal, mixed, subactive, isothermic Typic Dystrudepts	37

Appendix G. Classification of the Soil Series at the Perudic Isohyperthermic Soil Climate Regime.

Soil Series	Current classification	Updated Classification	Area (ha)
Adjuntas	Very-fine, kaolinitic, isohyperthermic Inceptic Hapludox	Very-fine, kaolinitic, isohyperthermic Typic Haploperox	284
Almirante	Very-fine, kaolinitic, isohyperthermic Plinthic Hapludox	Very-fine, kaolinitic, isohyperthermic Plinthic Haploperox	951
Bayamón	Very-fine, kaolinitic, isohyperthermic Typic Hapludox	Very-fine, kaolinitic, isohyperthermic Typic Haploperox	1,822
Consejo	Fine, kaolinitic, isohyperthermic Xanthic Hapludox	Fine, kaolinitic, isohyperthermic Xanthic Haploperox	637
Cuchillas	Loamy, mixed, isothermic, shallow Typic Dystrudepts	Loamy, mixed, isohyperthermic, shallow Typic Dystrudepts	871
Dagüey	Very-fine, kaolinitic, isohyperthermic Inceptic Hapludox	Very-fine, kaolinitic, isohyperthermic Typic Haploperox	243
Guayama	Clayey, mixed, active, isohyperthermic, shallow Typic Haplustalfs	Clayey, mixed, active, isohyperthermic, shallow Typic Hapludalfs	104
Limones	Fine, kaolinitic, isohyperthermic Typic Kandiudox	Fine, kaolinitic, isohyperthermic Typic Kandiperox	846
Los Guineos	Very-fine, kaolinitic, isothermic Humic Hapludox	Very-fine, kaolinitic, isohyperthermic Humic Haploperox	13,030
Nipe	Very-fine, ferruginous, isohyperthermic Anionic Acrudox	Very-fine, ferruginous, isohyperthermic Anionic Acroperox	283
Picacho	Fine-loamy, kaolinitic, isothermic Aquic Dystrudepts	Fine-loamy, kaolinitic, isohyperthermic Aquic Dystrudepts	49
Rosario	Clayey, ferruginous, isohyperthermic, shallow Typic Hapludox	Clayey, ferruginous, isohyperthermic, shallow Typic Haploperox	353
San Germán	Clayey-skeletal, mixed, superactive, isohyperthermic, shallow Typic Ustorthents	Clayey-skeletal, mixed, superactive, isohyperthermic, shallow Typic Udorthents	129
Yunque	Very-fine, kaolinitic, isothermic Humic Hapludox	Very-fine, kaolinitic, isohyperthermic Humic Haploperox	1,308

Appendix H. Classification of the Soil Series at the Perudic Isothermic Soil Climate Regime.

Soil Series	Current classification	Updated Classification	Area (ha)
Alonso	Very-fine, parasesquic, isohyperthermic Oxic Dystrudepts	Very-fine, parasesquic, isothermic Oxic Dystrudepts	212
Anones	Fine, parasesquic, isohyperthermic Humic Dystrudepts	Fine, parasesquic, isothermic Humic Dystrudepts	23
Caguabo	Loamy, mixed, active, isohyperthermic, shallow Typic Eutrudepts	Loamy, mixed, active, isothermic, shallow Typic Eutrudepts	1,361
Callabo	Fine, mixed, superactive, isohyperthermic, shallow Typic Dystrudepts	Fine, mixed, superactive, isothermic, shallow Typic Dystrudepts	130
Consumo	Fine, mixed, semiactive, isohyperthermic Typic Haplohumults	Fine, mixed, semiactive, isothermic Typic Haplohumults	20
Humatas	Very-fine, parasesquic, isohyperthermic Typic Haplohumults	Very-fine, parasesquic, isothermic Typic Haplohumults	770
Limones	Fine, kaolinitic, isohyperthermic Typic Kandiudox	Fine, kaolinitic, isothermic Typic Kandiperox	1,541
Lirios	Fine, mixed, subactive, isohyperthermic Typic Hapludults	Fine, mixed, subactive, isothermic Typic Hapludults	368
Los Guineos	Very-fine, kaolinitic, isothermic Humic Hapludox	Very-fine, kaolinitic, isothermic Humic Haploperox	8,927
Maragüez	Fine-loamy, mixed, superactive, isohyperthermic Typic Eutrudepts	Fine-loamy, mixed, superactive, isothermic Typic Eutrudepts	1,543
Maricao	Fine, mixed, subactive, isohyperthermic Inceptic Hapludults	Fine, mixed, subactive, isothermic Inceptic Hapludults	2,374
Morado	Fine, mixed, superactive, isohyperthermic Dystric Eutrudepts	Fine, mixed, superactive, isothermic Dystric Eutrudepts	486
Múcara	Fine-loamy, mixed, superactive, isohyperthermic Dystric Eutrudepts	Fine-loamy, mixed, superactive, isothermic Dystric Eutrudepts	641
Pandura	Coarse-loamy, mixed, active, isohyperthermic, shallow Dystric Eutrudepts	Coarse-loamy, mixed, active, isothermic, shallow Dystric Eutrudepts	167

Appendix H. (Continued)

Soil Series	Current classification	Updated Classification	Area (ha)
Pellejas	Fine-loamy over sandy or sandy-skeletal, mixed, subactive, isohyperthermic Typic Dystrudepts	Fine-loamy over sandy or sandy-skeletal, mixed, subactive, isothermic Typic Dystrudepts	273
Picacho	Fine-loamy, kaolinitic, isothermic Aquic Dystrudepts	Fine-loamy, kaolinitic, isothermic Aquic Dystrudepts	1,237
Quebrada	Fine-loamy, mixed, active, isohyperthermic Dystric Eutrudepts	Fine-loamy, mixed, active, isothermic Dystric Eutrudepts	51
Reilly	Sandy-skeletal, mixed, isohyperthermic Mollic Udifluvents	Sandy-skeletal, mixed, isothermic Mollic Udifluvents	1
Viví	Coarse-loamy over sandy or sandy-skeletal, mixed, subactive, isohyperthermic Fluventic Dystrudepts	Coarse-loamy over sandy or sandy-skeletal, mixed, subactive, isothermic Fluventic Dystrudepts	4
Yunque	Very-fine, kaolinitic, isothermic Humic Hapludox	Very-fine, kaolinitic, isothermic Humic Haploperox	1,104

Appendix I. Updated Soil Orders Map of Puerto Rico.