Chapter 7.28

Soil Temperature Signatures for Two Zones on St. John Island, Virgin Islands*

ABSTRACT

Though soils on St. John Island have an isohyperthermic temperature regime, the differences in temperatures between the north and south sides of the island were not known. Consequently, several studies were designed during the ‘90s to determine these differences. The soils at sites with similar solar radiation interruption in Lameshur Bay (south side) and Caneel Hill (north side) have the most similar mean annual soil temperature at 20 cm (26.8°C and 25.7°C respectively). Results of this study did not quantify the interrelationship among vegetative canopy cover, slope aspect, mean annual soil temperature, and the isotivity values (difference in mean summer and mean winter soil temperatures). The Lam 1 site is on a west aspect in Lameshur Bay has the highest mean annual soil temperature (28.6°C) and the highest isotivity value at 20 cm (5.3°C). Conversely, the Caneel Hill site has the lowest mean annual soil temperature (25.7°C) but also has a high isotivity value at 20 cm (5.1°C). The south-facing soils at the Lam 2 and 3 sites in Lameshur Bay have intermediate mean annual soil temperatures (26.8°C and 27.7°C) and have the lowest isotivity values at 20 cm (3.9°C and 2.5°C respectively). The reasons for high isotivity values for the northern zone at the Caneel Hill site are related to its air temperature signature. At 18° north of the Equator, the location of the Caneel Hill site is enough for the sunlight to create a microclimate environment during the summer and winter months. Though the incoming solar radiation is intercepted by the canopy cover, the thermodynamics of air-soil heat exchange are maximized throughout the summer. In winter, mountain peaks shade the Caneel Hill site from the sun, resulting in a cooler environment. Data from this study show that the mean annual soil temperature on the north zone of St. John Island is less than the mean annual soil temperature on the south zone and suggests that the temperature signatures of soils in the tropics are site-specific. The St. John Island study shows that these signatures must be measured, then analyzed for precise differences. Soil temperature modeling cannot approach real distinctions for any useful application basis.

1. Background

Soil temperature regimes, as used in Soil Taxonomy, have precise criteria for seasonal and annual fluctuations (Soil Survey Staff, 1999). Knowledge of the soil temperature regimes in the tropics is important for three primary reasons: first, to understand the development and formation of specific soils; second, to consistently classify and accurately map soils; and third, to apply that knowledge to the use and management of soil-plant-water systems. Measured soil temperature data greatly enhance the understanding and management of soils and land use planning (Mount, *et al*., 1992).

The soil temperature monitoring stations in the Lameshur Bay Watershed and Caneel Hill on St. John Island have been a cooperative effort between the Natural Resources Conservation Service (NRCS) and the National Biological Survey (NBS) since December 1990. Major funding for this study has been provided by NRCS Global Change funding provided by the National Soil Survey Center in Lincoln, Nebraska and the National Biological Survey on St. John Island.

The purpose of this study is to quantify the difference in air and soil temperature signatures between sites on the south side of St. John Island (Lameshur Bay Zone) and a site on the north side of the island (Caneel Hill Zone). This comparison was initiated from observations during many visits to St. John that the biomass is more enhanced on the northern zones than on the southern zones. It is hypothesized that

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the air and soil temperature on the northern zone of St. John Island plays a role in this difference in biomass enhancement.

2. Study Area

St. John Island is part of the United States Virgin Islands (USVI), which also include St. Croix, St. Thomas, and about 50 smaller islands that range in size from a cluster of small rocks to about 240 hectares (ha) (Rivera, et al., 1970). St. John Island is about 1,770 kilometers (km) southeast of Miami, Florida. It is in the tropics has a latitude of 18° north and a longitude of 64° west. St. John Island is 3.2 km east of St. Thomas Island and about 65 km north of St. Croix Island. The land area of the island is 4,920.9 ha.

The Lameshur Bay zone is on the south side of the island in the Virgin Islands National Park. For this report, three sites on Lameshur Bay were chosen to compare air and soil temperatures with those on Caneel Hill. The latitude of the three sites ranges from 18°19'16" to 18°19'36" north and longitude ranges from 64°43'22" to 64°43'25" west. The slope, aspect, elevation, and canopy cover are displayed in Table 7.28.1.

Table 7.28.1 - Slope, Aspect, Elevation, and Canopy Cover for Sites on Lameshur Bay.

Station (Name)	Slope (%)	Aspect (°)	Elevation (m)	Canopy Cover (%)
LAM 1	70	270	43	50
LAM 2	3	180	2	95
LAM 3	25	120	104	50

The Caneel Hill zone temperature site is on the north side of the island, has a north aspect, and is at an elevation of 107 m. Its latitude is 18°21'0" north and its longitude is 64°47'24" west. It is on a 45 percent slope to the north (downhill) and has a 36 percent slope to the South (uphill). Stone cover is estimated to be 25 percent. *Maytenus* is the dominant tree genus, and guavaberry shrubs are also present. The canopy cover shades the soil surface throughout the day, making it most similar to the Lam 2 site in Lameshur Bay for soil temperature comparison purposes. The distance between the Lameshur Bay zone and the Caneel Hill zone is about 15 km.

Weather data recorded on the Lameshur Bay Watershed from 1972 to 1989 indicated the total mean annual precipitation is about 1,140 mm with two seasonal peaks. Minor peaks in precipitation occur in April and May. The most significant peak in precipitation occurs from September through November. The highest mean monthly precipitation is 189 mm in November, and the lowest is 50 mm in March. Evaporative demand is high on St. John Island and exceeds the precipitation in every month of the year. The lack of rainfall, coupled with the mean annual relative humidity of 85 percent, makes for a semiarid island (Rivera, *et al*., 1970). This semiarid condition is most pronounced on the small eastern and southern peninsulas of St. John Island, where abundant cacti flourish.

All the woody vegetation on St. John Island is a secondary forest. It has been classified as dominantly a Subtropical Moist Forest with Dry Evergreen Woodland and Semi-Evergreen Seasonal Forest (Weaver, 1987). About 70 tree species have been documented in the Cinnamon Bay Watershed on the north side of St. John Island, which receives about 114 cm of annual rainfall. The dominant trees on the Lameshur Bay Watershed include species of the *Pimenta, Rondia, Lantana, Rauvolfia, Leuceama, Capparis, Ginoria, Bucida, Acacia,* and *Genip* genera.

Soils at the sites are tropical Inceptisols and Mollisols. The Cramer clay loam (S91VI-020-003) field classifies as a member of the clayey, mixed, active, isohyperthermic, shallow Typic Haplustolls family and is the dominant soil on St. John Island and on Caneel Hill (Rivera, *et al*., 1970, and Davis and Vick, 1995). This soil has about one percent cobbles and stones on the surface and is 6 m upslope (NW) from the long-term vegetative plot studies being monitored by the NBS. The soil profile horizon sequence is Oi, A, Bt1, Bt2, and Crt. The high amount of wormcasts and tubular pores in the soil suggests a high soil infiltration rate and little accelerated soil erosion (Mount, *et al*., 1991).

3. Methods

Soil temperature sensors were installed at the 10-cm and 20-cm soil depths at all of the sites on Lameshur Bay during 1991. At Lam 1 and Lam 2, soil temperature sensors are also placed at the 50-cm soil depth. Since Lam 3 is shallow to bedrock, a soil temperature sensor is not placed at the 50-cm soil depth (Mount, *et al*., 1991). The soil on Caneel Hill is also shallow to bedrock, and soil temperature sensors were placed at the 10-cm and 20-cm soil depths during November 1996. A steel rebar was driven into the ground and then extracted to place the soil temperature sensors at the 10 cm and 20 cm depth at all of the sites on Lameshur Bay. A sharpshooter spade was used to excavate the Cramer soil on Caneel Hill to place the soil temperature sensors.

Mean annual soil temperature on St. John Island has nearly the same average value no matter the depth at which it is measured (Mount, *et al*., 1994). Fifty centimeters was chosen as a point of measurement by Soil Taxonomy simply because the diurnal fluctuation is nil and the seasonal fluctuation is much less than at 10 cm or 20 cm. Since two of the sites in this study are less than 50-cm deep to bedrock, the 20-cm soil depth is used as a means of comparison among the sites for this report.

The period of record for the Lameshur Bay data is calendar year 1994, while the Caneel Hill data represents annual data from November 1996 to November 1997. Over 42,000 hourly temperature readings are available for Lameshur Bay and 3,600 readings (5 times per day) are available for Caneel Hill. The Virgin Islands have the most equable climate in the world, and comparisons of temperature data from one year to the next are not a concern for temperature summaries (Mount, *et al*., 1991). Monthly analyses of the air and temperature data from Lameshur Bay were previously presented in 1993 and 1994 (Mount, *et al*., 1993 & 1994).

Air and soil temperature data from the Caneel Hill site were off-loaded onto Excel software on St. John Island during November 1997, then graphed (Figure 7.28.1). In addition to calculating monthly and annual means for air temperature (MAAT) and soil temperature (MAST), a mean summer temperature (MST) and a mean winter temperature (MWT) were calculated to access the extreme seasonal variation at each of the sites. The MST is the average soil temperature for June, July, and August and the MWT is the average soil temperature for December, January, and February (Soil Survey Staff, 1999). An isotivity value, or the difference between MST and MWT, was determined at each of the sites to assess the extreme seasonal variation.

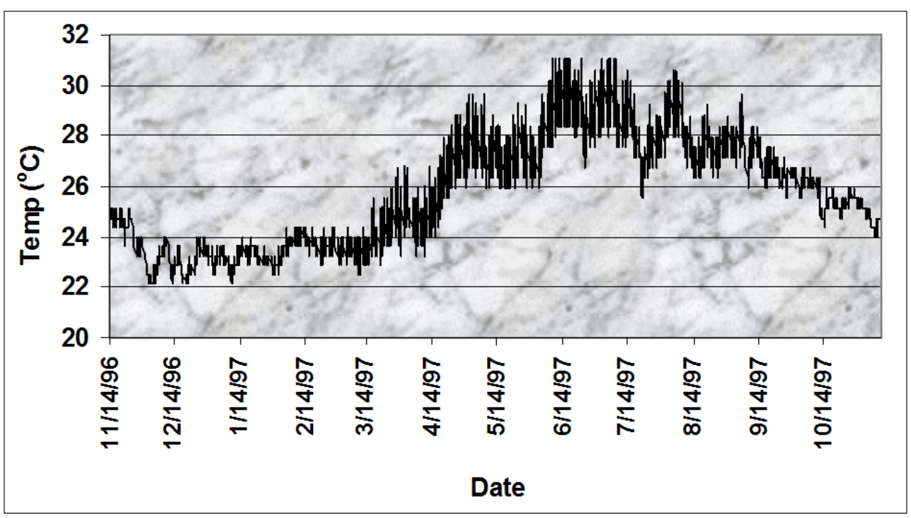


Figure 7.28.1. Soil temperature signature for the 20-cm soil depth at Caneel Hill.

4. Results

Air Temperature. Monthly and annual MAAT summaries are shown in Table 7.28.2 and graphically displayed in Fig. 7.28.2. The MAAT was highest at the Lam 3 site on Lameshur Bay (26.6°C) and was coolest at the Caneel Hill site(25.7°C). The MAAT at Caneel Hill is 0.7°C cooler than the average for the three sites in Lameshur Bay. On average, Caneel Hill is warmer from May through August but much cooler during the rest of the year. In December, the air temperature differs the most at 2.7°C (22.7°C at Caneel Hill versus an average of 25.4°C at Lameshur Bay). The air temperature during December on the north aspect at the Caneel Hill site is much cooler than on all of the individual sites on Lameshur Bay.

Table 7.28.2 - Monthly Air Temperatures (°C) for Lameshur Bay and Caneel Hill.

Analysis	LAM 1	LAM 2	LAM 3	LAM AVE	Caneel Hill
Jan	22.1	24.2	24.8	23.7	22.4
Feb	23.9	24.8	25.0	24.6	22.7
Mar	25.4	25.1	25.4	25.3	23.7
Apr	26.1	26.0	25.7	25.9	25.9
May	27.6	27.6	27.0	27.4	27.7
Jun	27.9	28.0	27.3	27.8	29.2
Jul	28.1	28.2	27.6	28.0	28.8
Aug	28.4	28.5	28.1	28.3	28.6
Sep	26.9	27.7	27.6	27.4	27.4
Oct	27.0	26.9	27.6	27.2	25.8
Nov	25.3	26.0	26.6	25.9	24.0
Dec	24.5	25.1	26.6	25.4	22.7
Mean	26.1	26.5	26.6	26.4	25.7

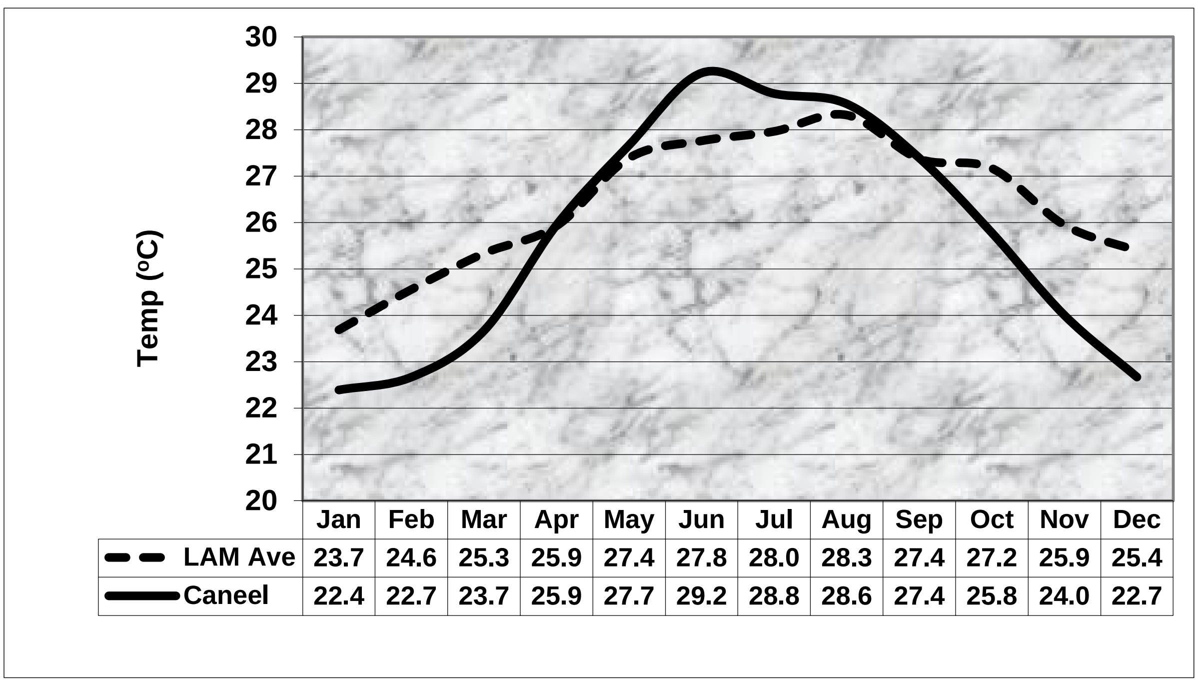


Figure 7.28.2. Monthly air temperature values for the average of the Lameshur Bay sites and Caneel Hill.

Soil temperature at 20 cm. Monthly, seasonal, and annual temperature summaries are shown in Table 7.28.3. Fig. 7.28.3 graphically shows the comparison of monthly soil temperature averages from the three Lameshur Bay sites to that at Caneel Hill.

Table 7.28.3 – Monthly and Annual Soil Temperatures (°C) at 20 cm for Lameshur Bay and Caneel Hill.

Analysis	LAM 1	LAM 2	LAM 3	LAM AVE	Caneel Hill
Jan	26.1	24.3	25.7	25.3	23.1
Feb	25.7	24.5	26.0	25.4	23.7
Mar	27.4	25.6	27.2	26.7	23.9
Apr	28.2	26.1	27.3	27.2	25.8
May	30.6	27.6	28.1	28.7	27.2
Jun	31.3	28.5	28.4	29.4	28.7
Jul	31.0	28.5	28.5	29.3	28.3
Aug	31.5	28.9	29.1	29.8	27.9
Sep	29.8	28.4	28.7	28.9	27.0
Oct	28.7	27.3	29.1	28.4	25.6
Nov	27.3	26.2	27.8	27.1	24.4
Dec	26.1	25.6	26.9	26.2	23.0
Mean	28.6	26.8	27.7	27.7	25.7
MST	31.3	28.6	28.7	29.5	28.3
MWT	25.9	24.8	26.2	25.6	23.3
Isotivity	5.3	3.9	2.5	3.9	5.1

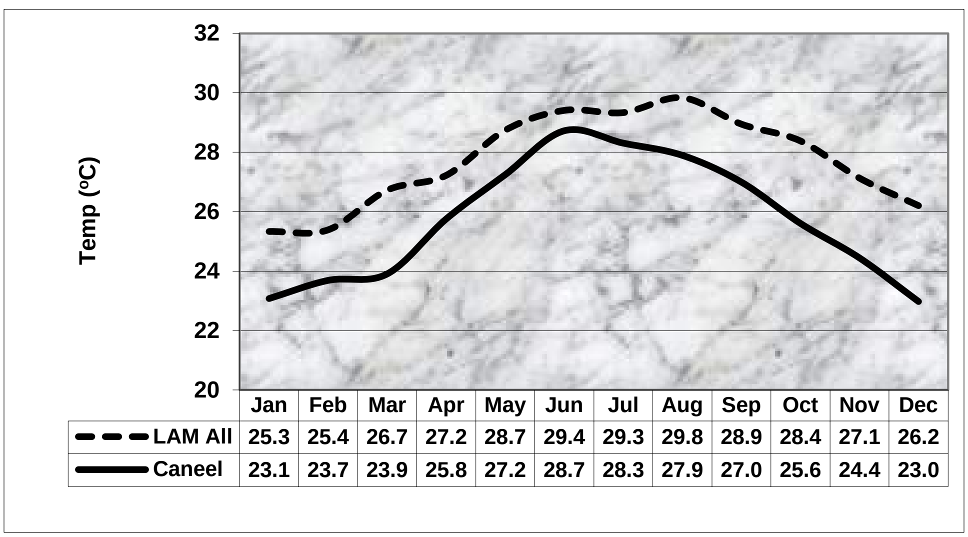
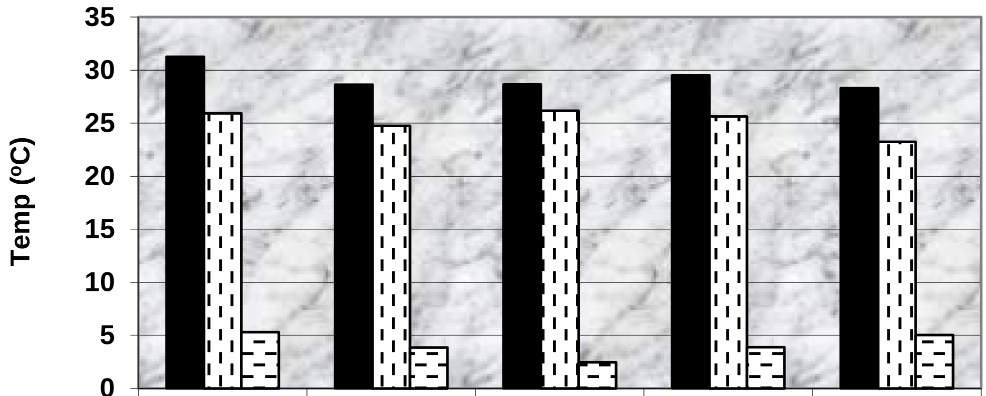


Figure 7.28.3. Monthly soil temperature averages at 20-cm for the Lameshur Bay sites and Caneel Hill.

The MAST at 20 cm was highest at the Lam 1 site on Lameshur Bay and was coolest on the Caneel Hill site. This difference is 2.9°C. The difference between the Lam 2 site and the Caneel Hill site that has similar enclosed canopy cover is much closer at 1.1°C. The MAST at 20 cm at Caneel Hill is 2.0°C cooler than the MAST at 20 cm for the three sites in Lameshur Bay. Moreover, the MAST at 20 cm on Caneel Hill is cooler than the MAST at 20-cm on Lameshur Bay for every month of the year. In December, the soil temperature differences at 20 cm are the most pronounced at 3.2°C (23.0°C at Caneel Hill versus an average of 26.2°C on Lameshur Bay). During December, the 20-cm soil temperature on the north aspect at the Caneel Hill site is much cooler than the 20-cm soil temperature at all of the individual sites on Lameshur Bay.

Soils in the tropics have higher isotivity values at 20 and 50 cm than had been originally thought

(Mount, *et al*., 1991). This maximum difference has historically been set at 5°C (Soil Survey Staff, 1975). A change in *Soil Taxonomy* now allows for a soil to have isotivity value up to 6°C and still be iso (Soil Survey Staff, 1999). This changes is the result of recent temperature findings in the Hawaiian Islands. Studies on the island of Maui show isotivity values greater than 5°C on savanna soils (Nullet, *et al*., 1990). Fig. 7.28.4 shows seasonal changes in soil temperature at 20 cm for the study area.



	Lam 1	Lam 2	Lam 3	LAM All	Caneel
MST	31.3	28.6	28.7	29.5	28.3
MWT	25.9	24.8	26.2	25.6	23.3
MS-MW	5.3	3.9	2.5	3.9	5.1

Figure 7.28.4. MST, MWT, and isotivity values at Lameshur Bay and Caneel Hill.

The isotivity value of 5.1°C at the Caneel Hill zone is larger than the average at the Lameshur Bay zone (3.9°C) but less than the maximum difference that occurred at Lam 1 (5.3°C). However, the 50-cm soil depth at Lam 1 has an isotivity value of 4.8°C, which substantiates the depth paradigm of decreasing seasonal fluctuation with depth.

5. Discussion

Data from this study show the MAST on the north zone of St. John Island is cooler than the MAST on the south zone. The soils at the sites with similar solar radiation interruption resulting from canopy cover (Lam 2 and Caneel Hill) have the most similar annual temperatures at 20 cm (26.8°C and 25.7°C respectively).

The interrelationship among vegetative canopy cover, slope aspect, MAST, and isotivity value are complicated. Lam 1 is on a west aspect and has the highest MAST (28.6°C) and has the highest isotivity value (5.3°C). Conversely, the Caneel Hill site has the lowest MAST (25.7°C) but also has a high isotivity value (5.1°C). The south-facing soils at Lam 2 and Lam 3 have an intermediate MAST (26.8°C and 27.7°C) and have the lowest isotivity values (3.9°C and 2.5°C).

Reasons for the high isotivity values at Caneel Hill are closely tied to its air temperature signature. The location of the Caneel Hill site 18° north of the Equator is enough for the sunlight to create a microclimate environment during the summer and winter months. Though the incoming solar radiation is intercepted by the canopy cover, air-soil heat exchange are maximized throughout the summer. In winter, mountain peaks shade the Caneel Hill site from the sun, resulting in a cooler soil climate.

This study confirms that the temperature signatures of soils are site-specific. The St. John Island study shows that these signatures must be measured, then analyzed for precise differences. Soil temperature modeling cannot approach real distinctions for any useful application basis.

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Mount H.R. and R.F. Paetzold. 2002. *The temperature regime for selected soils in the United States*. Soil Survey Investigation Report No. 48. USDA-NRCS. Lincoln, NE.