Forestry Bulletin No. 8: Soil Moisture and Soil Temperature Under a Post Oak-Shortleaf Pine Stand

G. Schneider
Stephen F. Austin State College

J. J. Stransky
Stephen F. Austin State College

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G. Schneider and J. J. Stransky

Stephen F. Austin State College
SCHOOL OF FORESTRY
Nacogdoches, Texas
STEPHEN F. AUSTIN STATE COLLEGE

SCHOOL OF FORESTRY FACULTY

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                                      Professor of Forestry

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                                       Game Management

HENRY L. SHORT, Ph.D. .................. Part-Time Instructor,
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SOIL MOISTURE AND SOIL TEMPERATURE UNDER A POST OAK-SHORTLEAF PINE STAND

G. Schneider and J. J. Stransky

This paper reports moisture and temperature observations in the surface 18 inches of soil under an east Texas post oak (Quercus stellata Wangenh.)—shortleaf pine (Pinus echinata Mill.) stand throughout a 4-year period (1957 to 1960). Such information is fundamental to determining the influence of climate upon stand regeneration and site productivity, especially important in east Texas where southern pines reach the western limit of their range. Here, rainfall is often deficient during the growing season and frequent summer droughts cause extensive pine seedling mortality. Furthermore, temperature fluctuations in the soil and air may alter numerous physiological processes vital to the survival of pine seedlings (22). The extremely high and low temperatures recorded in east Texas may also contribute to seedling mortality (1). To illustrate the problem's magnitude, almost one-sixth of the area's 11 million acres of commercial pine forest lands are in need of pine regeneration (7, 32).

Soil moisture under forest stands in other regions has been reported by many investigators (9, 11, 14, 15, 19, 23, 24, 34, 35, 36). Others have reported on forest soil temperatures (10, 12, 13, 17, 18, 30, 35). The limited information on soil moisture-temperature regimes for this area deals primarily with relatively short-term observations under field-planted pine seedlings (7, 8, 20, 31).

STUDY AREA AND PROCEDURES

The study was conducted on the Stephen F. Austin Experimental Forest, 15 miles southwest of Nacogdoches, Texas.

The vegetation consisted mainly of mixed second-growth hardwoods and pine, growing in closed stands with little natural pine reproduction beneath. Predominant trees were post oak and shortleaf pine, with scattered sweetgum (Liquidambar styraciflua L.), red oak (Quercus falcata Michx.), red maple (Acer rubrum L.), white ash (Fraxinus americana L.), and some redbud (Cercis canadensis L.) and dogwood (Cornus florida L.). The ratio of average stocking density for pine and hardwood was 1:2. Basal area varied from 60 to 130 square feet per acre among selected stands.

Average annual precipitation is about 48 inches, of which 22 inches fall during the growing season (April through September). Though this amount of rain is adequate to maintain established trees, pine reproduction often suffers from inadequate soil moisture due to erratic summer rainfall distribution. Over a 25-year period (1929 to 1953), growing season droughts of more than 22 days have occurred every year at four east Texas locations (8).
Soils are loams and sandy loams of the Boswell series; red podzolic types developed over acid clay sediments. Site index for shortleaf is approximately 80. The A horizon is from 3 to 7 inches thick and the B horizon from 24 to 62 inches. Soil texture below 30 inches is primarily clay. Drainage is moderate, with infiltration rapid and subsoil percolation low. The upper 18 inches of soil are capable of storing about 3 inches of water that is available to plants.

Nine 1/10-acre circular plots were selected on relatively homogeneous sites with respect to soil, aspect, topography, and vegetative composition.

Colman fiberglass units with thermisters were used to measure soil moisture and temperature (6). Their installation followed standard procedures (27). The units were placed in tiers of two, at 5-foot intervals from the plot center, along randomly selected radii. The upper unit was placed in the A horizon (representing the 0- to 9-inch depth), while the lower unit was installed midway in the first foot of the B horizon (measuring the 9- to 18-inch depth). Above ground terminals of the electrical wiring were protected by wooden switch shelters (26).

All units were laboratory calibrated to minimize soil disturbance on the plots, as laboratory estimates of field moisture can be used with an accuracy of about 3 percent (5). Soil moisture and temperature were recorded tri-weekly from May, 1957, through October, 1959, and from April through September, 1960.

From undisturbed soil cores and bulk soil samples collected from both depths at each plot, soil texture, bulk density, capillary and non-capillary porosity, and the amount of available water in the surface 18 inches of soil were determined (4, 16, 28). Although it is still controversial as to just what constitutes available water (3, 21, 22, 33), here it is the amount of water between field capacity (.06 atm tension) and wilting point (15 atm tension). Soil physical properties are shown in table 1.

Two standard rain gauges collected precipitation in open areas near the study plots. Air temperature maxima and minima were recorded daily.
<table>
<thead>
<tr>
<th>Depth</th>
<th>Mechanical Analysis</th>
<th>Bulk Density</th>
<th>Porosity</th>
<th>Water</th>
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<td>Sand</td>
<td>Silt</td>
<td>Clay</td>
<td>g/m/cc.</td>
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<tr>
<td>0 to 9</td>
<td>53</td>
<td>36</td>
<td>11</td>
<td>1.44</td>
</tr>
<tr>
<td>9 to 18</td>
<td>40</td>
<td>23</td>
<td>37</td>
<td>1.47</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
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</tbody>
</table>

Table 1.—Soil physical properties
RESULTS AND DISCUSSION

Soil Moisture

Soil moisture trends at both depths for the entire observation period are shown in figures 1 to 4. Because no appreciable differences in soil moisture were observed between plots and within plots, the daily values were averaged by depths.

In evaluating soil moisture fluctuations, one should note that the years immediately preceding the study (1950 to 1956) were extremely dry throughout the area. In 1956, rainfall was 20 inches below normal. Although in 1957 it was 9 inches above average, rainfall was unevenly distributed and monthly deficits occurred over half of the year (Table 2). In 1958, precipitation exceeded the normal by more than 4 inches, but little of it fell during the growing season. Rainfall in 1959 and 1960 was below average by more than 4 and 5 inches, respectively. Its distribution was also unfavorable during these years, and there was little opportunity for soil moisture recharge.
Fig. 1.—Rainfall, soil moisture, and soil and air temperature fluctuations in 1957.
Fig. 2.—Rainfall, soil moisture, and soil and air temperature fluctuations in 1958.
Fig. 3.—Rainfall, soil moisture, and soil and air temperature fluctuations in 1959.
Fig. 4.—Rainfall, soil moisture, and soil and air temperature fluctuations in 1960.
Table 2.—Normal monthly rainfall for Nacogdoches, Texas, and deviations from normal recorded at Stephen F. Austin Experimental Forest.

<table>
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<td></td>
<td>Inches</td>
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<td></td>
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<td>-3.61</td>
<td>-1.12</td>
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<td>-2.11</td>
<td>+0.47</td>
<td>+0.93</td>
<td></td>
</tr>
<tr>
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<td>-2.01</td>
<td>-2.40</td>
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</tr>
<tr>
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<td>+1.02</td>
<td>-2.11</td>
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<tr>
<td>May</td>
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<td>-2.40</td>
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<tr>
<td>June</td>
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<td>+0.53</td>
<td>+2.65</td>
<td>-0.50</td>
<td>+3.99</td>
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<td>-1.08</td>
<td>-2.17</td>
<td>+1.81</td>
<td>-1.77</td>
</tr>
<tr>
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<td>-1.87</td>
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<td>+2.47</td>
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<td>-0.53</td>
<td>-1.54</td>
</tr>
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<td>+0.44</td>
<td></td>
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<tr>
<td>Nov.</td>
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<td>-1.00</td>
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<tr>
<td>Dec.</td>
<td>5.25</td>
<td>-2.68</td>
<td>-4.37</td>
<td>-0.46</td>
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<tr>
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<td>+4.66</td>
<td>-5.58</td>
<td>-4.56</td>
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</table>

0- to 9-inch depth.—In 1957, initial soil moisture recorded in May for this portion of the profile was 3.5 inches, well above the field capacity of 2.8 inches. During the growing season, 6 major periods of soil moisture accretion and depletion took place (Fig. 1). Several minor fluctuations also occurred as the result of light showers. Between July 10 and 20, the wilting point was reached. Following a recharge period between July 21 and 27, when over 2 inches of rain fell, the soil again dried to the wilting point by August 15, and remained dry until September 10. Thus, for 35 days, soil moisture values were at or below wilting point. Sufficient rain fell during October to saturate the soil until the following growing season.

From January to early May, 1958, soil moisture was well above field capacity. This was the result of abundant rainfall during the last few months of 1957, and the reduced evapo-transpiration demands from vegetation and soil surface. During the growing season, seven distinct periods of soil moisture depletion and accretion occurred. For the first two weeks in June, soil moisture nearly approached the wilting point. Following two alternating recharge and depletion periods, 18 days of near-wilting point stress occurred between July and August. Four more alternating depletion and accretion periods took place between August 15 and November; after that time soil moisture recharge began.

During the winter and early spring of 1959, soil moisture recharge was not as great as for the same period in 1958 (Fig. 3). Still, soil moisture remained above field capacity during this time. As in the previous year, seven alternating depletion and accretion periods can be observed. Though at no time did soil moisture drop below the wilting point, it was approached during July and September.
In 1960, soil moisture depletion and accretion took place alternately on six occasions during the 6-month period of observation (Fig. 4). Soil moisture was depleted almost to the wilting point during May, July, August, and September.

9- to 18-inch depth.—During 1957, this portion of the profile behaved in much the same manner as the 0- to 9-inch depth. Following the initial observation in May and small fluctuations until June 10, moisture decreased gradually until July 24. For the last eight days of that period, soil moisture was below the wilting point. Following 2 inches of rain, soil moisture was almost continuously depleted until September 20. A total of 51 days had moisture content below the wilting point—one-third more than the number of days below the wilting point at the 0- to 9-inch depth for the same period of time. Between October 1957, through May 1958, nearly 6 inches of soil water were stored.

Three prominent soil moisture depletion periods occurred during 1958. Moisture steadily declined from May 12 to June 16, from June 17 to August 20, and from August 22 to September 5. These periods were interrupted by rain which fully recharged soil moisture. By mid-September, depletion diminished greatly. Because of little rain during the fall of 1958 and the winter and early spring of 1959, recharge was much slower than in 1957. During the growing season, soil moisture was below the wilting point only on one day (July 28), but was near it during most of July and August.

In 1959, as in 1958, three major soil moisture depletion and accretion periods were observed. A long but gradual decrease occurred from April 27 to July 29. During August and September, two additional depletion periods were recorded, each followed by sufficient rain to increase the soil moisture supply appreciably. Throughout the nine months of observation in 1959, soil moisture content did not fall below the wilting point. However, soil moisture stresses close to it were reached during most of July and the latter part of September.

During 1960, four alternating periods of soil moisture depletion and accretion were observed. Each ended by heavy rainfall that recharged the soil. The wilting point was not reached at any time during 1960, but was approached during August and September.

The main difference between the lower and upper soil layer was that smaller and less frequent soil moisture fluctuations occurred at the lower depth. A steady moisture decrease was often observed in this zone despite small intermittent rains.

Generally, during the period from April through September, soil moisture was depleted by near-continuous evapo-transpiration losses. Winter and early spring were periods of soil moisture recharge, resulting from more rain, reduced transpiration demands by the vegetative cover, and lower evaporation losses from the soil surface.
Soil and Air Temperature

Seasonal soil temperature trends at both depths closely followed air temperature. This dependence decreased slightly with increasing depth. As no appreciable soil temperature differences were found between and within plots, the daily temperatures were averaged by depths (Fig. 1 to 4). Average monthly soil and air temperatures are shown in tables 3 and 4, respectively.

1957—Soil and air temperature gradually increased following the initial measurement on May 20, when temperature at the 0- to 9-inch depth was 21.9 °C and 20.7 °C at the 9- to 18-inch depth. Air temperature at the 4-foot level was 23.6 °C. Highest daily soil and air temperatures were reached on July 29, with 28.2 °C at the 0- to 9-inch, 27.8 °C at the 9- to 18-inch depth, and 29.7 °C air temperature. During August these temperatures remained fairly constant, but from September on they gradually decreased, reaching their lowest values in 1957 on December 13; 11.3 °C at the 0- to 9-inch, and 13.4 °C at the 9- to 18-inch depth. Lowest air temperature for the year (2.5 °C) also occurred on this date.

Soil temperature differences between the two depths seldom exceeded 1 °C, particularly during the months of May through September. This difference increased to 2 °C during the winter of 1957-1958.
Table 3.—Mean monthly soil temperatures for the 0-to 9-inch and 9- to 18-inch depths.

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
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<tr>
<td>Jan.</td>
<td>10.7</td>
<td>12.8</td>
<td>10.5</td>
<td>12.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Feb.</td>
<td>10.9</td>
<td>12.4</td>
<td>11.7</td>
<td>12.8</td>
<td></td>
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<tr>
<td>Mar.</td>
<td>13.8</td>
<td>15.0</td>
<td>13.5</td>
<td>14.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Apr.</td>
<td>17.7</td>
<td>17.9</td>
<td>16.4</td>
<td>16.8</td>
<td>17.5</td>
<td>17.3</td>
<td></td>
<td></td>
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<tr>
<td>May</td>
<td>23.2</td>
<td>22.8</td>
<td>21.7</td>
<td>21.3</td>
<td>20.9</td>
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<tr>
<td>June</td>
<td>24.8</td>
<td>24.3</td>
<td>25.5</td>
<td>24.8</td>
<td>22.9</td>
<td>22.5</td>
<td>22.3</td>
<td>21.9</td>
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<tr>
<td>July</td>
<td>27.5</td>
<td>27.1</td>
<td>25.8</td>
<td>25.4</td>
<td>23.5</td>
<td>23.2</td>
<td>23.0</td>
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<td>Aug.</td>
<td>26.6</td>
<td>26.8</td>
<td>26.8</td>
<td>26.8</td>
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<tr>
<td>Sept.</td>
<td>24.4</td>
<td>25.3</td>
<td>25.4</td>
<td>25.7</td>
<td>22.7</td>
<td>23.1</td>
<td>22.0</td>
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<tr>
<td>Oct.</td>
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<td>20.1</td>
<td>21.3</td>
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<tr>
<td>Nov.</td>
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<td>Dec.</td>
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<td>11.6</td>
<td>13.6</td>
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Table 4.—Mean monthly air temperatures at 4-foot level.

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<th>MONTH</th>
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<td>30.5</td>
<td>34.4</td>
<td>35.0</td>
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<td>24.4</td>
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<td>18.3</td>
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<tr>
<td></td>
<td>Min.</td>
<td>17.8</td>
<td>20.5</td>
<td>21.6</td>
<td>20.5</td>
<td>16.7</td>
<td>11.1</td>
<td>7.8</td>
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<tr>
<td></td>
<td>Mean</td>
<td>23.9</td>
<td>25.6</td>
<td>27.7</td>
<td>27.2</td>
<td>22.8</td>
<td>17.8</td>
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<td>11.1</td>
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<tr>
<td></td>
<td>Dep. a</td>
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<td>-0.9</td>
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<td>-1.0</td>
<td>-1.3</td>
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<td>+ 1.4</td>
<td>+ 0.2</td>
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<td>1958</td>
<td>Max.</td>
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<td>12.8</td>
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<tr>
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<td>+ 0.5</td>
<td>-1.2</td>
<td>-1.1</td>
<td>-1.5</td>
<td>-1.3</td>
<td>-0.9</td>
<td></td>
<td></td>
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</table>

*Difference between measurements taken at S.F.A. Experimental Forest and the 30-year average at Nacogdoches, Texas.*
Soil and air temperatures were closely related. Air temperature fluctuations were often large; corresponding soil temperature changes were much smaller. The relationship between mean monthly soil and air temperatures is shown in Fig. 5. Little difference exists between the temperatures of the two soil depths for the whole period of study. Mean monthly soil and air temperatures from 1957 to 1960 are shown in Fig. 6. Soil temperature inversion (when temperature curves of the upper soil layer cross those of the lower one) occurred in August; the corresponding air temperature inversion occurred in September. The 4-year average of the mean monthly soil and air temperatures is shown in Fig 7.

1958.—The mean monthly air temperature for January and February was 7.5 C. Soil temperature was 11.5 C in the upper and 12.5 C in the lower soil depth. Soil and air temperature then began to rise. Highest air temperature was recorded on August 1, while highest soil temperatures occurred on August 6, with 27.9 C at the 0- to 9-inch depth and 27.8 C at the 9- to 18-inch depth.

From May to December, soil temperatures were similar to those recorded for the same period in 1957. Soil and air temperature inversion occurred in late April and then again in August for soil and in September for air temperatures. Again, only small differences in temperature between the two depths were observed; usually only 1 C or 2 C.
Fig. 5.—Relationship between mean monthly soil temperature at 0- to 9-inch and 9- to 18-inch depth, and mean monthly air temperature at 4-foot levels, 1957-1960.
Fig. 6.—Mean monthly soil temperature at 0- to 9-inch and 9- to 18-inch depth, and mean monthly air temperature at 4-foot level, 1957-1960.
Fig. 7.—Four year (1957-1960) average of the mean monthly soil temperature at 0- to 9-inch and 9- to 18-inch depth, and the mean monthly air temperature at 4-foot level.
Some temperature differences between depths can probably be attributed to texture. Sandy soils have a lower specific heat, by volume, than clay soils; and as they dry, soil temperatures increase more rapidly. There was a textural difference between the two depths, with the 9- to 18-inch layer having considerably more clay.

1959-60.—Soil and air temperature trends in 1959 and 1960 were similar, but differed from those in 1957 and 1958. In general, soil temperatures between June and September were consistently 1-2 C lower than during the same period in 1957-1958. It appears that soil moisture may have had a decided effect on this, because air temperatures for the entire study period were similar.

The soil was generally much drier during 1957-1958 than in 1959-1960. Wilting point stresses were often approached for extended periods of time during the first two years, while this was not so apparent during the second half of the study.

The soil's thermal properties change with changes in soil moisture. Both heat conductivity and specific heat decrease with decreasing moisture. With less soil moisture in 1957-1958, soil temperatures were higher than in 1959-1960.

Soil temperature has an important influence on root growth. Numerous studies report growth for tree species at soil temperatures as low as 4.4 C and as high as 35 C (2, 22, 27). As soil temperatures did not go below 6.1 C or above 28.3 C in this study, it is probable that root growth was not limited by extremes of heat or cold.

CONCLUSIONS

In east Texas, soil moisture and soil temperatures were measured from 1957 to 1960 at depths of 0-9 and 9-18 inches under a post oak-shortleaf pine stand.

The soil moisture measurements in the 0- to 18-inch profile suggest that:

(1) The general soil moisture pattern showed depletions during the period of April through September as a result of continuous evapo-transpirational losses. Late fall, winter, and spring were periods of soil moisture recharge; because of more rain, reduced transpiration, and lower evaporation.

(2) Soil moisture depletion occurred at both depths, indicating that plant roots were readily removing moisture from throughout the entire measured profile.

(3) The 0- to 9-inch depth tended to dry more rapidly than the 9- to 18-inch depth. Except for short periods of time following high rainfall, the 0- to 9-inch depth contained less moisture than did the lower depth.

(4) The moisture content of the 9- to 18-inch depth fluctuated much less than that of the 0- to 9-inch depth. The primary reason for this is that the lower layers of the soil are influenced less by intermittent and light rains.
During the growing season, soil moisture at both depths was near or below wilting point on numerous occasions and for extended periods. Tree seedling survival is probably reduced, and growth curtailed, as the result of such unfavorable soil moisture conditions.

From the soil temperature records of the 0- to 18-inch profiles, these relationships are apparent:

1. Seasonal variations of soil temperature at the 0- to 9-inch and 9- to 18-inch depth are dependent upon air temperature. This dependence decreases slightly with increasing depth. Mean monthly soil temperature differences between the two depths seldom exceeded 1 C throughout the study.

2. Both soil and air temperature inversion occurred in late April and again in August for soil temperature and in September for air temperature.

3. Soil temperatures were generally lowest in January and highest in August. Heating in the upper 18-inch layer began in late February and early March and ended in late August or early September.

4. Soil temperature was influenced by soil moisture. Heat conductivity and specific heat decrease as soil moisture decreases, causing a rise in soil temperature.

5. Mean soil temperatures never were below 6.1 C nor above 28.3 C. Root growth probably was not seriously limited throughout the period of investigation by unfavorable soil temperatures.

LITERATURE CITED

1. Anonymous
   Climatological data—Texas. Published monthly by the Weather Bureau, U. S. Department of Commerce.

2. Barney, C. W.

3. Black, C. H.

4. Bouyoucos, G. J.

5. Carlson, C. A.

6. Colman, E. A.
7. Ferguson, E. R.  


9. Fraser, D. A.  

10. ———  

11. Gaiser, R. N.  

12. Geiger, R.  

13. Greene, G. E.  

14. Helvey, J. D., and J. D. Hewlett  

15. Hoover, M. D., D. F. Olson, and G. E. Greene  

16. ———, ———, and L. J. Metz  

17. Hursh, C. R.  

18. Jeffrey, W. W.  

19. Koshi, P. T.  
20. ———, and G. K. Stephenson
   1962. Shade and mulch as influences on loblolly pine seedlings and
   their immediate environment. For. Sci. 8: 191-204.

   1964. Water metabolism in plants. Harper & Row Biological Mon-

22. Kramer, P. J., and T. T. Kozlowski
   642 pp.

23. Lull, M. W., and J. H. Axley
   1958. Forest soil moisture relations in the coastal plain sands of

24. Metz, L. J., and J. E. Douglass
   1959. Soil moisture depletion under several piedmont cover types.

25. Moyle, R. C., and R. Zahner
   1954. Soil moisture as affected by stand conditions. U. S. Forest

   1953. Switch shelters for use with soil-moisture units. U. S. Forest

27. Reinhart, K. G.
   1953. Installation and field calibration of fiberglass soil-moisture

28. Richards, L. A.
   1949. Methods of measuring soil moisture tension. Soil Sci. 68:
   95-112.

29. Romberger, J. A.
   1963. Meristems, growth, and development in woody plants. U. S.

30. Smith, G. D., F. Newhall, L. H. Robinson, and D. Swanson
   1964. Soil-temperatures regimes—their characteristics and pre-
   Paper 144, 14 pp.

31. Stransky, J. J.
   1961. Weed control, soil moisture, and loblolly pine seedling be-

32. Texas Forest Service
   1963. The current and future status of forest resources of east
   Texas. Forest Products Dept., Cir. 81. 62 pp.
33. White, D. P.

34. ———, and R. S. Wood

35. Will, G. M.

36. Zahner, R.
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