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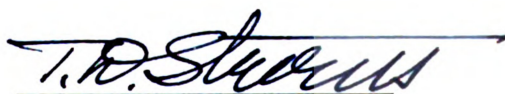
Some Effects of Stand Density on Soil Moisture in a
Red Pine (Pinus resinosa Ait.) Plantation on
Grayling Sand, Gravelly Phase, in
Crawford County, Michigan

presented by

Lino Della-Bianca

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Major professor

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SOME EFFECTS OF STAND DENSITY ON SOIL MOISTURE IN A RED PINE
(PINUS RESINOSA AIT.) PLANTATION ON GRAYLING SAND,
GRAVELLY PHASE, IN CRAWFORD COUNTY, MICHIGAN

By

LINO DELLA-BIANCA

A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
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(PINUS RESINOSA AIT.) PLANTATION ON GRAYLING SAND,

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AN ABSTRACT

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T.D. Stevens

Thinning dense stands of red pine (Pinus resinosa Ait.) results in an increased rate of growth for the remaining trees in the stand. The nutrient supply from the area is made available in greater quantities for the remaining trees; hence, they are able to grow at an increased rate. One of the growth factors which is at a critically low level during some part of the growing season for red pine growing on Grayling sand, gravelly phase, in Crawford County, Michigan is the soil moisture supply.

The purpose of this study was to determine whether thinning a dense plantation of red pine, spaced 5x5, and 44 years old, into stands of varying levels of stocking would produce a difference between stands in the moisture content of the soil present in the stands.

Research was also conducted with nylon electrical resistance units to determine whether or not they were suitable for use in Grayling sand, gravelly phase, for determining the in situ soil moisture content of the stands.

Related measurements were taken of the cumulative weekly rainfall, weekly radial growth, and soil temperatures.

The study was conducted in a red pine plantation growing on Grayling sand, gravelly phase, on the Higgins Lake State Forest in Michigan. The plantation had been thinned so as to produce stands of varying density. The stands selected for the study contained basal areas of 190, 120, and 80 square feet per acre, respectively. Additional measurements were taken from an adjacent open field.

1. Introduction

The purpose of this study is to investigate the effects of the independent variable on the dependent variable.

The study was conducted in a laboratory setting with a sample size of 30 participants. The data was collected over a period of 12 weeks.

The results of the study indicate that there is a significant positive correlation between the independent variable and the dependent variable.

The findings suggest that the independent variable has a positive impact on the dependent variable, which is consistent with the hypothesis.

The study also found that the effect of the independent variable on the dependent variable is moderated by the third variable.

The results of the study have important implications for the field of research, as they provide evidence for the role of the independent variable.

The study was limited by the sample size and the laboratory setting, which may have affected the generalizability of the findings.

Future research should investigate the effects of the independent variable on the dependent variable in a more naturalistic setting.

Some of the most significant results of the study show that:

1. Plot 80, containing 80 square feet of basal area, had the highest soil moisture content at the six inch depth 82.4 percent of the weeks during the growing season.
2. After June 20, 1953, the open field had the most soil moisture at the 36 inch depth. Soil moisture fluctuations were greatest in the open field.
3. Soil moisture fluctuations and differences between the plots were greatest from July 18 to August 22, 1953. They occurred at the six inch depth.
4. There was a gradual decrease in soil moisture at all three depths from April 1 to August 29, 1953. On August 29 the soil moisture supply was extremely low at all three depths.
5. Empirical field-calibration curves have been developed for Grayling sand, gravelly phase.
6. A separate empirical field-calibrated curve is needed for each depth to which units are interred.
7. The nylon electrical resistance units should be interred dry, preferably in the fall when Grayling sand tends to be dry.
8. Perhaps the best use of the nylon electrical resistance unit in a sand soil is as an indicator of broad relative soil moisture conditions rather than an actual moisture content.
9. Soil temperatures at all three depths in the open field were decidedly higher than the temperatures in any of the red pine plots.

10. The following are the main points of the report:

- The first point is that the data shows a clear trend of increasing sales over the last five years.
- The second point is that the market is becoming increasingly competitive, with new entrants appearing in the sector.
- The third point is that the company's current strategy is still valid, but it needs to be updated to reflect the changing market conditions.
- The fourth point is that the company's financial performance is strong, but it needs to be monitored closely to ensure it remains on track.
- The fifth point is that the company's customer base is growing, but it needs to be targeted more effectively.
- The sixth point is that the company's product range is expanding, but it needs to be managed carefully to avoid overextension.
- The seventh point is that the company's management team is experienced, but it needs to be supported by a strong infrastructure.
- The eighth point is that the company's marketing efforts are effective, but they need to be more targeted.
- The ninth point is that the company's research and development efforts are promising, but they need to be accelerated.
- The tenth point is that the company's overall outlook is positive, but it needs to be supported by a strong financial base.

10. The general trend in order of decreasing soil temperatures at all three depths was plot 80, 120, and 190, containing 80, 120, and 190 square feet of basal area per plot, respectively.
11. Radial growth began when the plots were at an approximate minimum temperature of 47.5 °F. at the six inch depth; and minimum temperature of 43°F. at the 36 inch depth.
12. Plot 80 produced the best radial growth; plot 120 followed; and plot 190 showed the least radial growth.
13. Radial growth practically ceased in plot 190 by July 25.
14. The growth rate for dominant trees increases only slightly when thinnings are made.

• $\mathcal{F}_t$ is the σ -algebra generated by $\{B_s, 0 \leq s \leq t\}$. •

– $\mathcal{F}_t$ is a filtration: $\mathcal{F}_s \subset \mathcal{F}_t$ for $s < t$.

• $\mathcal{F}_\infty = \sigma(\mathcal{F}_t, t \geq 0)$ is the σ -algebra generated by the whole process B . •

• $\mathcal{F}_t$ is a right continuous filtration: $\mathcal{F}_t = \mathcal{F}_{t+}$. •

• $\mathcal{F}_t$ is a complete filtration: $\mathcal{F}_t = \mathcal{F}_t \vee \mathcal{N}$. •

• $\mathcal{F}_t$ is a Brownian filtration: $\mathcal{F}_t = \mathcal{F}_t^B \vee \mathcal{N}$. •

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INTRODUCTION

A fact well known to foresters is that by thinning a dense stand of timber the yield expected from the stand will not be increased. Increased growth rates for the remaining trees contained in the stand merely indicate that the nutrient supply from the area has been available in greater amounts for the growth needs of the remaining trees. For any set period of time, the soil of an area can supply only a limited amount of nutrients for plant growth. The supply available varies with time and depends upon the highly complex and interrelated chemical, physical, and biological factors which are in a state of perpetual activity in the soil. Thinning a dense stand of timber results in a redistribution of the nutrient supply so that the total available quantity is shared with fewer individuals; consequently, the remaining individuals show an increase in growth. For the stand the yield remains the same, but it occurs on fewer trees.

Many advantages are gained when stands are properly thinned. Some advantages are: (1) Growth occurs on fewer stems; (2) the rotation can be shortened; (3) higher quality trees can be grown; (4) some soil conditions might be improved and result in an increased nutrient supply; (5) fewer stems per acre with increased diameters can result in a reduction of logging costs; (6) insect damage can be reduced; and (7) healthier, stronger trees will result in improved stand condition.

Forest research conducted in a thinned red pine plantation growing on Grayling sand on the Huron National Forest in Michigan has revealed that the greater the spacing between trees on a 35-year-old red pine plantation the greater the height growth (Ralston, 1953). The reason behind the increase in height growth after thinning was not specifically known. The water table underlying the area occurs at such a depth that not even overlying water from the capillary fringe is available for tree growth. Since drainage is so rapid through Grayling sand and it was known that the general soil moisture content of the soil decreased to critically low levels, it was thought that perhaps thinning dense stands of red pine produced an increase in the moisture content of the soil for those stands which were thinned. Consequently, this study was devised to determine whether or not thinning a dense stand, planted 5x5, of 44-year-old red pine to various levels of basal area would produce a difference in the moisture content of the soil between the various stands.

Concurrently, research would be conducted with nylon electrical resistance units to determine if they are adaptable for use in Grayling sand for the purpose of determining soil moisture conditions in the various stands.

Additional measurements would be taken to determine cumulative weekly rainfall, weekly radial growth, and soil temperatures.

The study was conducted in a red pine plantation growing on Grayling sand, gravelly phase, on the Higgins Lake State Forest in Michigan. The plantation had been thinned so as to produce stands of varying densities. The stands selected for the study contained basal areas of 190, 120, and 80 square feet per acre, respectively. Additional measurements were taken from an adjacent open field.

SOME INFLUENCES ON SOIL MOISTURE

The soil is dependent on its water supply for many of the characteristics found within the realm of its biological, chemical, and physical properties. Soil water, in addition to influencing the development of the particular soil in which it occurs, is directly responsible for supplying the needs of the vegetative cover growing on that soil. Trees will not grow except in the presence of at least a minimum quantity of water, depending upon the species; and, next to temperature, no factor plays so important a role in determining the distribution of tree species over the land surface of the earth (Raber 1937). The soil water with its accumulated nutrients is directly responsible for supplying the needs of existing vegetation. It functions as a link between the vegetation and the soil which, if broken, would have disastrous effects on the vegetation. Soils rich in nutrients could not support plant life without the necessary soil water. Soil water when available in adequate quantities can serve as a major supporter of vegetative growth on even the poorest of soils. The soil water supply functions as life-giving blood in the role of its support of vegetation. Wherever man concerns himself with growing plants, his attention must sooner or later focus itself upon the soil water supply. In many instances, maintaining an adequate supply of soil moisture for his crops becomes a matter of major concern to him.

The water of the earth can be divided into three parts -- atmospheric water, water resting on the surface of the solid part of the earth, and water which occurs below the surface of the earth.

The water occurring below the surface of the earth can be further subdivided into water existing above the zone of saturation, water in the zone of saturation, and water in the interior of the earth (Meinzer, 1923).

This study concerns itself with water which is below the surface of the earth, but above the zone of saturation and within the reach of plants. Specifically, it is a study of the moisture supply present in a sand soil at chosen depths. The dominant vegetative cover is red pine. This soil receives additional water from two principal sources -- rainfall and snow. Sleet, hail, and fog are relatively insignificant in being able to furnish additional water to the soil moisture supply.

A characteristic common to all soils is that they contain pores of varying size and configuration. In sand soils these pores may consist largely of the interstices between the solid soil grains, or they may consist of the spaces between and within aggregates of soil particles. Relatively large pores existing as passageways of soil animals, or brought about by the decay of roots, are rather common in forest soils and have an important effect on the soil-water relationship. The pores form an exceedingly complex system which is normally occupied jointly by air and water (Lutz and Chandler, 1946).

The large pore spaces of a sand contain considerable water and, as the soil dries out, this water will be the first to disappear. Since the large capillary tubes form a relatively large part of the pore space available for water, they will hold a considerable percentage of the water when the soil is saturated. In sands, large single intergranular spaces exist because of the relatively large

[illegible]

size of the soil particles. The withdrawal of water from the larger pore spaces will cause a large decrease in the moisture content of the soil. When the moisture content of the soil is about six percent, the critical point is reached and a change in soil volume begins (Cameron and Gallagher, 1908).

Water is retained in the soil by two forces: adhesion and cohesion. Adhesion involved the attractive force of molecules in the surface of the soil particles for water molecules. Cohesion is the force attracting water molecules to other water molecules. Through the action of adhesive forces tightly held films of water are built up on the surfaces of the soil particles. As more water molecules are attracted by the forces of cohesion, these films increase in thickness and finally fill the capillary pores unless entrapped air prevents them. The attractive force of the water molecules for each other is very apparent at the liquid-air interfaces; this phenomenon is referred to as surface tension (Lutz and Chandler, 1946).

Briggs (1897) recognized three forms of soil water. Hygroscopic water is that portion of the soil water which is retained as a thin film by the soil particles after capillary water has been removed. Neither gravitational nor surface tension forces can move it. Another form of soil water is capillary water. It is that portion of the soil water retained around the soil particles and in the capillary pores after the gravitational water has moved out. The last form of soil water, and usually the first to pass out of a saturated soil, is gravitational water. The soil is incapable of retaining gravitational water under conditions of free drainage. Gravitational water is

• The first step in the process of creating a new product is to identify a market need. This is often done through market research, which involves gathering information about the target market and its needs. Once a market need has been identified, the next step is to develop a concept for a product that meets that need.

• The second step in the process is to develop a business plan. This involves determining the costs of production, the pricing strategy, and the marketing strategy. The business plan also includes a financial forecast, which shows the expected revenue and profits over a period of time. Once the business plan has been developed, the next step is to secure financing for the project.

• The third step in the process is to develop a prototype of the product. This involves creating a small-scale version of the product that can be used to test the design and to gather feedback from potential customers. Once the prototype has been developed, the next step is to conduct a pilot production run. This involves producing a small quantity of the product to test the manufacturing process and to gather feedback from customers.

• The fourth step in the process is to launch the product into the market. This involves developing a marketing campaign to promote the product and to attract customers. Once the product has been launched, the next step is to monitor sales and customer feedback. This allows the company to make adjustments to the product and the marketing strategy as needed. Finally, the company should continue to develop new products to meet the needs of the market.

• The fifth step in the process is to evaluate the success of the product. This involves comparing the actual sales and profits to the targets set in the business plan. If the product is successful, the company can consider expanding its production and marketing efforts. If the product is not successful, the company can consider making adjustments to the product or the marketing strategy. Finally, the company should continue to monitor the market for new opportunities to develop new products.

• The sixth step in the process is to develop a long-term strategy for the company. This involves determining the company's goals and objectives for the future and developing a plan to achieve them. The long-term strategy should take into account the company's current position in the market and the needs of its customers. Once the long-term strategy has been developed, the company can begin to implement it and to work towards achieving its goals.

• The seventh step in the process is to review the company's performance. This involves evaluating the company's progress towards its goals and objectives and identifying areas for improvement. The review should be conducted regularly to ensure that the company is on track to achieve its long-term goals.

drained away under the influence of gravity.

Capillary water is most important from an ecological standpoint because this is that part of the soil water which is most available to plant roots. In soils, such as sand, gravitational water is not very significant to plants because of its leaching effect on the soil nutrient supply and because it moves so rapidly through the soil that plants have little time to utilize it. Hygroscopic water has no effect in sustaining plant life because plant roots are incapable of overcoming the forces which bind it to the soil. Parker (1922) made a study of various new classifications of soil moisture which had been proposed. He concluded that the old classification of dividing soil moisture into hygroscopic, capillary, and gravitational water was still best.

Capillary water is also referred to as water held in retention storage. Water in retention storage is available for use by vegetation and for evaporation. Detention storage is a common term used for water which is only temporarily detained in its passage through the soil; the term corresponds to gravitational water (Lassen, Lull, and Frank, 1952).

Water moves through the soil in either the liquid or the vapor form. The forces produced by gravity and capillary tension are responsible for moving soil water in the liquid phase. In the vapor phase, movement of the soil water is brought about by differences in vapor pressure. Unequal tensions developed under different degrees of curvature of the surface film of water over soil particles produces capillary movement. In sand soils the space between the soil particles

is too large and the cohesive forces of the water molecules will be insufficient to raise the water to any appreciable height. Soils containing appreciable quantities of soil moisture have a relative humidity of about 100 percent. The pressure of the water vapor in the soil atmosphere increases with temperature. If there is a considerable difference in the temperature of the soil at different depths, water vapor may move from a warm layer of soil to the colder depths where it will condense as moisture (Millar and Turk, 1943).

Lateral movements of ground water under the influence of gravity are slow. Movement on slopes is greater than in flat areas. Ground water can move very rapidly through gravel and sands (Hubbert, 1940). Capillary movements from a moist to a dry soil are too slow to be beneficial to plants (Veihmeyer and Hendrickson, 1927). If plants are to utilize the moisture in a soil mass they must extend their roots into that soil. Capillary movement from the zone of saturation to the capillary fringe is fairly rapid.

Other terms used when dealing with soil moisture are:

(1) hygroscopic coefficient; (2) moisture equivalent; (3) wilting coefficient; (4) field capacity; and (5) sticky point. All of these terms represent constants or equilibrium points.

The hygroscopic coefficient is supposed to mark the upper limit of the hygroscopic moisture range (approximately $pF\ 4.5$). The method employed in determining this value has been to expose a thin layer of dry soil to an atmosphere saturated with water vapor for a period of 24 hours (Lutz and Chandler, 1946).

• 1975-1976: The first year of the "Great Depression" in the Soviet Union, characterized by a severe economic crisis and a sharp decline in living standards.

[The following text is a transcription of a handwritten document, likely a letter or a report, discussing the economic situation in the Soviet Union during the 1970s. The text is written in Russian and is somewhat blurry and difficult to read. It appears to be a personal or official communication, possibly related to the author's work or research.]

• The author discusses the economic situation in the Soviet Union, mentioning the impact of the "Great Depression" and the subsequent recovery.

• The author mentions the role of the government in the economy, particularly in the context of the "Great Depression" and the subsequent recovery.

• The author discusses the impact of the "Great Depression" on the Soviet Union, particularly in the context of the economic crisis and the subsequent recovery.

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The term moisture equivalent has been used to designate the percentage of water retained by a soil when subjected to a constant centrifugal force equal to 1,000 times gravity (Briggs and Shantz, 1912). Bouyoucos (1929) introduced a method utilizing a vacuum pressure force for determining the moisture equivalent.

The wilting coefficient of a soil is the moisture content of the soil (expressed as a percentage of the oven-dry weight) at the time when the leaves of the plant growing in that soil first undergo a permanent reduction in their moisture content as the result of a deficiency in the soil-moisture supply. By permanent reduction is meant a condition from which the leaves can not recover in an approximately saturated atmosphere without the addition of water to the soil (Briggs and Shantz, 1912).

The non-available water in a soil is the soil moisture content when in equilibrium with the moisture of the air. It is important to recognize that the moisture in a soil is not non-available until it has been reduced to the moisture content of air-dry soil (Briggs and Shantz, 1912).

The field capacity of a soil indicates the amount of water held in a soil after excess gravitational water has drained away and after the rate of downward movement of water has materially decreased (Viehmeier and Hendrickson, 1931).

The first investigations of the sticky point were made by Keen and Coutts (1928). The sticky point is the moisture content at which the attractive power of the soil for water is satisfied (Baver, 1948).

Rainfall, snowfall, or any other form of precipitation must first enter into the soil before it can add to the moisture content of the soil. The litter layer of the forest floor is important in that it tends to keep frozen soil loose, porous, and permeable when bare soil becomes solid and impermeable (Kittredge, 1948). The organic material comprising the litter layer can absorb several times its own weight of water and quite often precipitation must first satisfy this high absorbent capacity before it can infiltrate into the soil. The infiltration capacity of a forest soil is usually decreased as a result of excessive grazing and repeated burning. Sand soils, due to their single grain structure, are less affected by such occurrences than heavy-textured soils. Arend (1942) found that annual burning reduced infiltration an average of 38 percent in comparison with that in soils protected for approximately 5-6 years.

Non-capillary pores facilitate the avenues of free water movement in the soil; in short, they are responsible for conducting subsurface and base flow to streams. The effects of plant cover conditions and treatment on these pores determines to a large extent how water moves to the stream. Water movement in the soil can be separated into two rather independent processes. The first of these -- infiltration -- refers to the entry of water into the surface half inch of soil. The other process is percolation and it refers to the rate of flow at any lower level. The maximum rate at which water can enter the soil surface is defined as the infiltration capacity of the soil. The rate at which water can flow through the subsurface layer is the percolation capacity of the soil. The usability of storage

space in a soil depends on infiltration and percolation values in relation to rainfall intensities (Lassen, Lull, and Frank, 1952).

Much of the water which enters a forest soil is moved downward by gravitational force and though it eventually contributes to sub-surface and base flow, it is usually of no value to the vegetation on the area on which it fell. In addition to the loss due to gravitational forces, some soil water is lost by evaporation. According to Lutz and Chandler (1946), the most noteworthy factors which influence loss of soil water by evaporation are: (1) the moisture content of the atmosphere; (2) wind velocity; (3) soil cover, both living and non-living; and (4) the nature of the soil, including moisture content and temperature.

MEASUREMENTS OF SOIL MOISTURE IN SITU

There has long been a necessity for developing some technique whereby the soil moisture changes in a soil could be measured in situ. Scientists have long recognized the fact that there is an increase in the electrical resistance offered to the passage of an electric current through the soil as the soil becomes drier. This knowledge led to the development of an electrical method for determining the moisture content of arable soils (Whitney, Gardner, Briggs, 1897); they wrote the following descriptions:

For the measurement of the electrical resistance of the soil the Wheatstone bridge method is used with the alternating current and a telephone to indicate when a balance has been obtained. For the measurement of resistances in the field it is necessary to have an instrument sufficiently accurate and yet with a very wide range.

The bridge consists of a rheostat, comparison coils, induction coil, and a watch receiver telephone with suitable electrical connections. One arm of the bridge contains a 1,000-ohm comparison coil, a second arm contains a 900-ohm coil, and a 100-ohm coil connected in series, while the third arm contains the rheostat.

The electrodes finally adopted for field work consist of carbon plates each three inches long, three-eighths of an inch wide, and three-sixteenths of an inch thick. Each electrode is copper plated on one end, and an insulated No. 20 copper wire soldered to the planting of a length sufficient to reach above the surface of the ground to the measuring instrument.

Recently a comparison of four types of electrical resistance instruments developed in recent years was made by Palpant and Lull (1953). One of the instruments compared, the portable soil moisture bridge (Bouyoucos and Mick, 1940), was used for taking the in situ moisture measurements of this study. The nylon electrical resistance unit first described by Bouyoucos (1949) was the type of electrode selected.

The most recent development for the measurement of soil moisture is a method which employs radioactive probes, the use of which permits soil moisture and density measurements (Carlton, Belcher, Cuykendall, and Sack, 1953). At the present time the size, cost, and stage of development of this equipment greatly restrict its use.

One obstacle which has presented itself in the use of electrical resistance methods for determining the moisture content of soils is the fact that for some soils suitable laboratory calibration curves which will accurately reflect field conditions have not been developed (Reinhart, 1953).

• The first step in the process of the development of the new system is the identification of the requirements. This is done by the user and the system analyst. The requirements are then used to design the system. The design is then implemented and the system is tested. The system is then deployed and the user is trained. The system is then maintained and the user is supported.

• The second step in the process of the development of the new system is the design. This is done by the system analyst. The design is then implemented and the system is tested. The system is then deployed and the user is trained. The system is then maintained and the user is supported.

• The third step in the process of the development of the new system is the implementation. This is done by the system analyst. The implementation is then tested and the system is deployed. The user is then trained and the system is maintained. The user is then supported.

• The fourth step in the process of the development of the new system is the testing. This is done by the system analyst. The testing is then implemented and the system is tested. The system is then deployed and the user is trained. The system is then maintained and the user is supported.

• The fifth step in the process of the development of the new system is the deployment. This is done by the system analyst. The deployment is then implemented and the system is tested. The system is then deployed and the user is trained. The system is then maintained and the user is supported.

To develop a suitable field calibration curve, Reinhart (1953) described a method used at the Vicksburg Infiltration Project, U. S. Forest Service:

Under the area concept the unit is installed in or adjacent to the area it is to represent -- at Vicksburg usually a plot 6 by 6 feet square. It is calibrated by drawing soil samples at random from this area and plotting the moisture content of the samples against the resistance determined at the time the samples are taken. The resistance is an index of average soil moisture at a particular soil depth over the entire sample plot. This is a distinct advantage, because the marked deviations in soil moisture that occur even within a small area give the value for a single point little significance.

REVIEW OF LITERATURE

Some Effects of Stand Density on Soil Moisture

Ebermayer (1889) investigated the relative soil moisture quantities found during the course of a year under stands of pine, varying from 25-120 years in age, and in open fields. The soil samples were taken at depths ranging down to 80 centimeters. The moisture content of the soil was expressed as a percent of the oven-dry weight. His results show that the forested areas selected for his study contained considerably less soil moisture than the open areas for all four seasons of the year. Differences were greatest in late summer and early autumn. An investigation conducted in beech stands gave similar results.

Some of the conclusions arrived at by Craib (1929) concerning soil moisture and its relative abundance in the open and under forest cover after two years of investigation at Keene, New Hampshire, are:

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1. Both in the open and in the forest there was considerably more moisture present during the growing season in the upper soil layers than in the lower. The amount of soil moisture consistently decreased with increase in depth, at least to 100 cm.

2. Both in the open and in the forest there was a rapid falling off in the amount of water present in the soil layers down to a depth of about 40 cm., below which there was much less change.

7. The soil became progressively drier in the forest with increase in depth, despite the fact that the tree roots were largely concentrated in the surface soil layers. Little moisture was lost by direct evaporation, due to the thick covering of needle litter.

8. The open soils contained considerably more moisture during dry periods than the forest soils. The difference was greatest in the upper soil layers and became progressively less with increase in depth.

Albert (1915) conducted a study on stand density and its effect on the water content of the soil. The study was conducted at Eberswalde, Germany, in three pine stands which were growing on a sand soil. Originally the 25-30 year old trees were all at the same degree of stocking. Two of the stands were thinned to equal densities of stocking. One of the two thinned stands had been cleared of all slash; in the other thinned stand the slash was left lying on the ground. The third, unthinned, stand was used as a control. The graphs for the years 1912 and 1913 show that the thinned stand on which the slash was left had a consistently higher soil water content at both the 20 and 40 centimeter depths. The thinned stand which had the slash removed contained less soil water for the two-year period than the stand in which the slash had been left. The unthinned stand contained the least amount of soil water for the two-year period. There were periods when the differences were

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large and other periods when the plots were at nearly the same moisture content. The moisture content of each plot was determined from 100-150 gram soil samples collected at weekly intervals from the first week in May until the second week in September in 1912, and until the third week in October in 1913. The study showed that thinning a stand of pine on a sand soil does increase the moisture content of the soil. The maximum moisture percentage (in terms of oven-dry weight) recorded at the 20 centimeter depth was 12.3 percent and the minimum 1.8 percent. At the 40 centimeter depth the maximum and minimum amounts of soil moisture were 8.1 percent and 1.6 percent respectively. In 1913 there was a general decline in soil moisture content from May to October.

Albert (1925) also investigated various sand types, ranging from alluvial to dune sands, and of the various types of vegetation each would support. He concluded that further research on a larger scale was justified in order to learn how to best use the various sand types to produce hardwood in addition to pine timber, and to build up the soil. Such a study might be justified for a system of intensive forest management, or for the purpose of increasing our knowledge of the potential capabilities the various sand soil types of Michigan possess. Eventually better ways of utilizing our sand soils might evolve from such a study.

of the total number of *Phragmites* stems per square meter. For each of the 100 quadrats, the number of *Phragmites* stems was counted and the number of *Phragmites* stems per square meter was calculated. The mean number of *Phragmites* stems per square meter was calculated for each of the 100 quadrats. The mean number of *Phragmites* stems per square meter was then compared to the mean number of *Phragmites* stems per square meter in the control quadrats. The mean number of *Phragmites* stems per square meter in the control quadrats was 1.5. The mean number of *Phragmites* stems per square meter in the treatment quadrats was 1.5. The mean number of *Phragmites* stems per square meter in the control quadrats was 1.5. The mean number of *Phragmites* stems per square meter in the treatment quadrats was 1.5.

DESCRIPTION OF THE AREA

The red pine plantation selected for this study is located in Crawford County, Michigan, approximately one mile north of Higgins Lake and one quarter mile east of U. S. Highway 27. The plantation is known as the Bosom Field Plantation and is in the Higgins Lake State Forest.

This part of the county is characterized by several separate ridges, irregular in outline, but having an east-west trend. In general, the relief is gently rolling or moderately hilly. South of the plantation area a very prominent ridge separates the Higgins Lake plain from the outwash plain on which the plantation is located. Approximately half of the county is covered by dry sand plains. The maximum and minimum elevations for the county are 1,480 and 1,006 feet respectively.

Climate

The main climatic features of Crawford County are: an annual average of 30 inches of precipitation, this includes the melted snowfall; an annual average of 78 inches of snow; a mean annual temperature of about 42°F., short mild summers, fairly high humidity, a large number of cloudy days, a small percentage of possible sunshine, and a low evaporation of moisture (Veatch, 1927).

According to "Climate and Man" (1941), weather records maintained for 40 years show that the mean annual growing season is 115 days long. The last killing frost in the spring and the first killing frost in

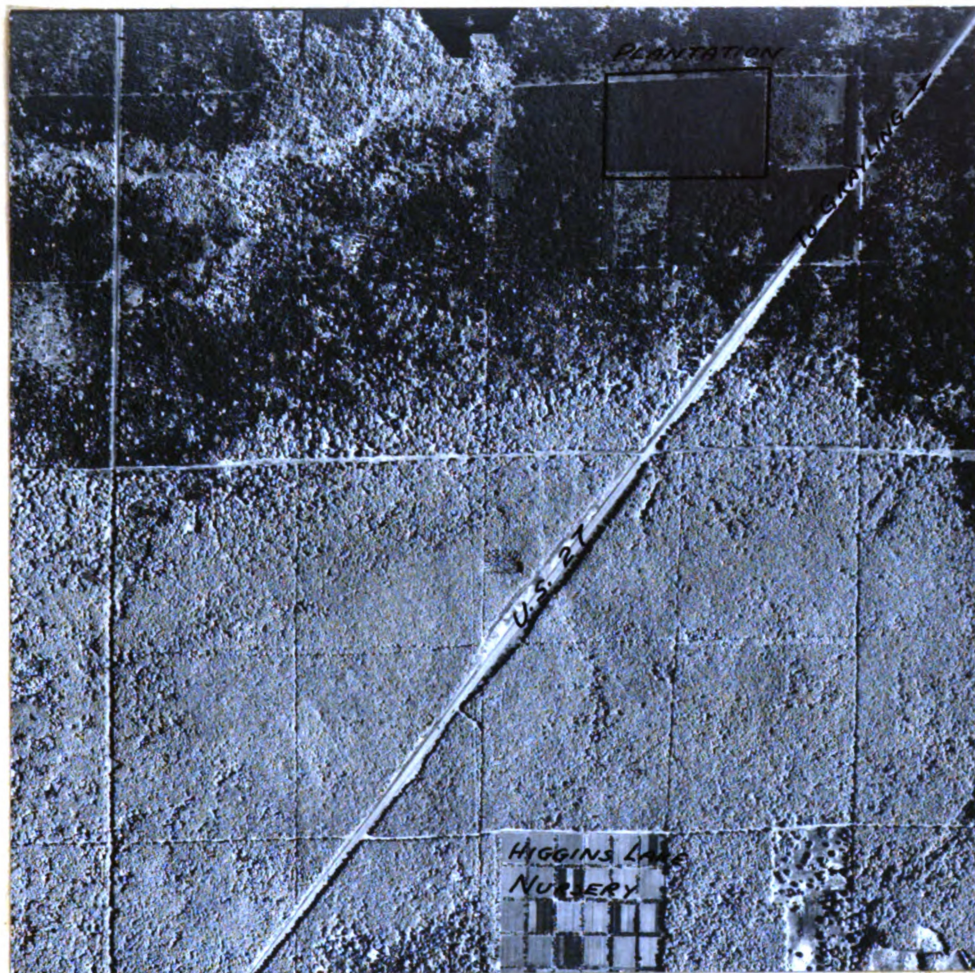


Figure 1. Aerial photograph showing location of the red pine plantation.

the fall, expressed as average dates, occur on May 27 and September 19 respectively. The maximum and minimum temperatures recorded were 106 and -41°F., respectively. The precipitation is well distributed throughout the year; the rainfall may occur as prolonged rains or as frequent showers.

Agricultural History

According to Veatch (1927):

The history of the settlement of the county and of the agriculture are closely connected with lumbering, which began on a large scale in the decade 1870-1880. The first land to be logged over was that covered by pine forests, and most of these trees were removed by 1890. The lumbering of hardwoods and swamp timber followed but was of less importance because of the comparatively small areas. The farming population did not increase so rapidly as in counties which had a greater proportion of hardwood timber. The early population, excluding trappers, came primarily to operate the logging camps and lumber mills, and only a small amount of farming was carried on. The census of 1880 and 1890 show, respectively, 175 and 202 farms in the county, but the amount of land actually in cultivation probably did not exceed 3,000 acres. A small income was realized by the farmers through supplying the camps and mills with necessary agricultural products, particularly hay and other feed for work animals. At the same time the farmer could work in the logging camps in the winter and thus add to his income. Probably the greater number of the earlier established farms have been abandoned, particularly those on sandy lands.

The past history of the Bosom Field Plantation closely compares with the above description. Originally the area was under forest cover. The former owners cut off the timber and attempted farming. The poor quality of the logged off land soon made farming unprofitable and the farm was abandoned. The abandoned land was acquired by the state and the plantation was established in 1912.



Figure 2. Plot 190, showing the dense stocking of the stand; except for some bracken fern in a few openings, only fungi grew on the forest floor.



Figure 3. Plot 120 in August, 1953, showing bracken fern growing in the openings. Annual woods plants were plentiful in this plot.



Figure 4. Plot 80 in August, 1953. The openings were quickly invaded by grasses.



Figure 5. Vegetative cover on the open field consisted mostly of prairie grasses and sweet-fern.

Plot Description

Three red pine plots were selected for this study. Each plot was designated with a number corresponding to the basal area which the stand contained. Plot 190 contained a basal area of approximately 190 square feet. This plot was unthinned and represented the original stocking of the stand as it was planted in 1912 with 3-0 stock. The trees were planted in horse-plowed furrows with a spacing of 5x5 feet. This spacing resulted in a stand of 1,740 trees per acre (Engle and Smith, 1952).

In 1951 plots 120 and 80 were thinned to basal areas of approximately 120 and 80 square feet respectively. Plot 120 averaged 696 stems per acre and plot 80 averaged 603 stems per acre. Practically all of the trees in these two stands are rated as dominants or codominants. Plot 190 contains some intermediate and suppressed trees.

Soil Description

The entire area contained within the red pine plots consisted of Grayling sand, gravelly phase. This soil type is a rather common occurrence throughout Crawford County, and usually occurs between areas of Grayling sand and Roselawn sand, gravelly phase. Roselawn sand occurs on low swells and on rather smooth rounded ridges and hills. Broad dry swales and valleys intervene. Grayling sand, gravelly phase, tends to occur at the base of the hills and ridges which have Roselawn sand, gravelly phase, as the principal soil type. Beyond the gravelly phase of Grayling sand are the relatively level

THE FIRST

The first of the three parts of the book is a history of the development of the theory of the structure of the atom. It begins with the discovery of the electron by Cathode ray experiments, and continues through the discovery of the nucleus by Rutherford, and the discovery of the neutron by Chadwick. The second part of the book is a history of the development of the theory of the structure of the nucleus. It begins with the discovery of the nucleus by Rutherford, and continues through the discovery of the neutron by Chadwick, and the discovery of the proton by Rutherford. The third part of the book is a history of the development of the theory of the structure of the nucleus. It begins with the discovery of the nucleus by Rutherford, and continues through the discovery of the neutron by Chadwick, and the discovery of the proton by Rutherford.

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sand plains with Grayling sand occurring as the dominant soil type.

A typical profile of Grayling sand, gravelly phase, has the following characteristics: The litter layer is approximately one inch thick and usually consists of dead conifer needles; the layer of fermentation is approximately one half to three fourth inch thick and, according to the Munsell color chart, is light gray in color, its pH is 4; the A_0 horizon is black and is approximately one fourth to one half inch thick, it is strongly acid with a pH of 4.5; the A_2 horizon is a gray sand from two to eight inches thick, its pH is 4; the B_2 horizon of sand ranges from a strong brown to a reddish yellow in color, it has a pH of 4, and is from 10 to 15 inches thick, at the approximate 18 inch depth, measured from the surface, there is a layer of gravel composed of angular, smooth, or rounded pieces of gravel which is made up of chert, granites, sandstones, and some calcareous rocks; the C horizon, or parent material, is a pale yellow usually large grained sand with a pH of 5.

The trees obtain some nutrients from the gravelly layer because many of the stones examined had characteristic depressions etched over the entire surface, which were produced by the action of solvents surrounding the tiny rootlets found in the depression.

According to Veatch (1927):

Except for the higher proportion of gravel, which consists of smooth or rounded fragments of many kinds of rock, the gravelly phase is similar throughout to typical Grayling sand. There is a suggestion of a little higher natural fertility in areas of the gravelly phase, indicated by a somewhat more thrifty tree growth, and owing, perhaps, to a higher proportion of minerals other than quartz in the parent materials or to a somewhat higher moisture holding capacity.

1. The first step is to identify the problem.

- The second step is to define the problem.
- The third step is to identify the causes of the problem.
- The fourth step is to identify the effects of the problem.
- The fifth step is to identify the stakeholders involved in the problem.
- The sixth step is to identify the resources available to solve the problem.
- The seventh step is to identify the constraints on the solution.
- The eighth step is to identify the potential solutions.
- The ninth step is to evaluate the potential solutions.
- The tenth step is to select the best solution.

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Referring to Graylingsand Veatch (1927) wrote:

Grayling sand including its gravelly phase is the most extensive soil in Crawford County, occurring in large uniform bodies in the eastern, central, and southern parts.

Areas of this soil are level, plainlike, or very slightly uneven, owing to shallow dry depressions and hummocks of wind-blown sand. The land is excessively drained and dry, owing to the perviousness of the soil and the underlying geologic formation. The water table or permanently wet sand probably lies at a depth of more than 15 feet.

The original tree growth probably consisted mainly of jack pine and red pine; there were probably a few white pine, scarlet oak, white oak, and the jack or northern pin oak. The present growth consists mainly of jack pine, either in thickets or scattered in association with small oaks, and a scrubby growth of aspen. In the more open areas the characteristic and more common shrubs and herbs are blueberries, low willow, sweetfern, bracken, a sedge, a species of bluegrass, oatgrass, and bunch grass. The pasturage value of the land is low.

The most logical use of the greater part of the land at present seems to be for forestry and recreational purposes, at least until some more economic use for it is discovered. In places the jack pines are of sufficient size and density to have some value, and wild blueberries produce profitable yields.

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METHODS OF PROCEDURE

Installing the Nylon Electrical Resistance Units

On November 8 and 9, 1952, the nylon electrical resistance units were installed. The initial work consisted of establishing the plot centers for the purpose of being able to locate the buried units whenever measurements would be taken.

It was then necessary to determine the depths to which the units would be buried. A nearby red pine was selected which approximated the dominant plantation trees in size, then a trench was dug two feet away from the tree to a depth of five feet. The riser roots and 2-1/2 inch lateral roots were concentrated at the six inch depth. Smaller lateral roots were approximately one half to one inch in diameter/at the 18 inch depth and sinker roots were found descending to the 36 inch depth. At the same time the soil profile was examined in detail and the appropriate notes taken for purposes of later describing the soil profile. A pH kit, yardstick, and a Munsell color chart proved valuable for this work.

The locations of the unit installations were chosen at random throughout the plots. Each installation was carefully mapped, using the center stake at each plot center as a reference point from which to determine the azimuth and distance to each unit stack. Then a diagram was made showing the direction and distance from each tree, designated by d.b.h., surrounding the unit stack to the stack.

For the actual unit installation, a large piece of heavy cardboard, a yardstick, a flashlight, a two-inch barrel auger (hollow

THEORY OF THE EARTH AND ITS HISTORY

The theory of the earth and its history is a branch of geology which deals with the origin and development of the earth and its various parts. It is a science which seeks to explain the processes which have shaped the earth and its features, and to determine the sequence of events which have taken place since the earth was first formed. The theory of the earth and its history is based on the study of the earth's rocks and fossils, and on the principles of geology. It is a science which is constantly developing, as new discoveries are made and new theories are proposed. The theory of the earth and its history is a branch of geology which deals with the origin and development of the earth and its various parts. It is a science which seeks to explain the processes which have shaped the earth and its features, and to determine the sequence of events which have taken place since the earth was first formed. The theory of the earth and its history is based on the study of the earth's rocks and fossils, and on the principles of geology. It is a science which is constantly developing, as new discoveries are made and new theories are proposed.

cylinder type with two projecting cutting edges), and three nylon units were used. As the auger boring was progressively deepened the soil was carefully laid out, in the sequence with which it was removed, on the heavy cardboard. The soil was very dry and seemed as dry as the soil collected on August 29, 1953, 10 months later. The flashlight was very useful in placing the block properly at the 36 and 18 inch depths. The two-inch barrel auger was selected because it minimized disturbance of the soil. Occasionally, in very dry sand, it is necessary to tamp the soil in the auger cylinder from above with a suitable rod before the soil can be lifted from the boring. If this is not done the sand will fall out of the bottom of the cylinder as the auger is being extracted. The nylon units were installed dry because it was thought that doing so would better permit their stabilization at the depth to which they were buried.

If readings are taken from the units during the winter, when a deep snow cover is probable, it is necessary to map the location of the stacks very carefully. To prevent freezing of the wires, which lead to the buried electrodes, to the duff, or to crusted bottom layers of a snow mantle from which they can be removed only with great difficulty, it is necessary to suspend them above the location from perhaps a stiff upright wire placed in the ground. A straightened wire clothes hanger would probably prove satisfactory. If very permanent installations are to be used and vandalism is not expected, then permanent switch shelters as described by Palpant, Thames, and Helmers (1953) may be built. In taking the resistance readings with the portable soil moisture bridge, it was found necessary to insulate the bridge from the ground. A dry



Figure 6. Field equipment used during the installation of the nylon electrical resistance units.

• 1. The first step is to identify the problem.
• 2. The second step is to define the problem.
• 3. The third step is to analyze the problem.
• 4. The fourth step is to develop a solution.
• 5. The fifth step is to implement the solution.
• 6. The sixth step is to evaluate the solution.

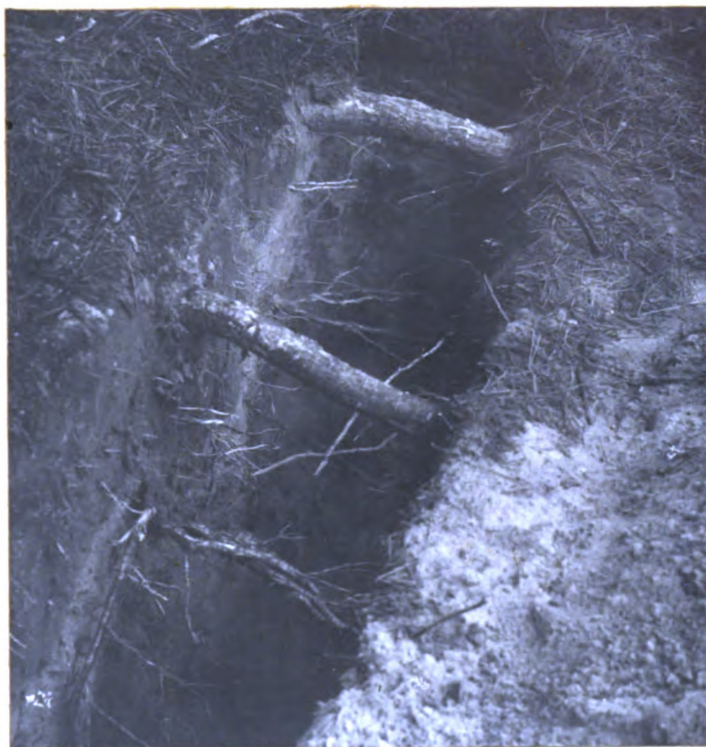


Figure 7. Slit trench dug to determine depth of root concentrations.



Figure 8. Installing the nylon units necessitated the use of a piece of cardboard to keep the soil in the order in which it was removed.



Figure 9. Taking nylon electrical resistance unit readings under frigid winter conditions. February 28, 1953.

potato sack proved satisfactory as it was carried without difficulty.

Collecting Soil Samples When a Deep Snow Mantle is Present

The soil cans used during this study were numbered both on the lid and on the side of the can proper. This is necessary because each can must be accurately identified during the course of the weighings. The soil samples collected weighed approximately 685 grams. The cans, each of which must be independently weighed, averaged approximately 85 grams. The oven-dry weight of each soil sample was about 600 grams. In working with sands, large samples are necessary, especially when the soil moisture content is low.

For collecting soil samples a three-inch barrel auger is to be preferred to a two-inch auger. Samples can be collected very quickly, especially if the sand soil is above four percent moisture content, and no large pieces of gravel are encountered. A rather moist sand extracts readily from an auger boring, but relatively dry sands can only be extracted after tamping. A very important advantage in using the three-inch barrel auger is that the boring is large enough to permit reaching down into it to remove any stones which may be hindering the penetration of the barrel auger cylinder. The handle of the barrel auger should be marked so that one only needs to bore down to the mark indicated to collect a sample from the depth desired. Care must be taken so that when the cylinder is at the indicated depth the sample will be so centered in the cylinder. Allowance must be made at the top of the cylinder to permit removal of any soil from an upper level which may have fallen to the bottom of the boring as the barrel auger

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is reinserted subsequent to removing a cylinder full of soil. If these precautions are followed, samples which are representative of the depth sampled can be accurately and easily collected. The soil cans must be sealed immediately and the plot designation and depth sampled must be marked on the sealing tape. "Scotch" brand masking tape No. 202 worked very satisfactorily at air temperatures above approximately 32°F. At the lower temperatures it should be carried in an inner pocket to facilitate its adhering to the soil cans. At the lower temperatures it tends to become brittle; hence, it must be protected by keeping it warm. It provides good protection as a moisture seal. If samples are collected on very warm, muggy days from a deep soil level, pronounced moisture condensation will occur on the outside of the can. The samples must be quickly sealed after extracting them from the soil. To do this, a soil collecting crew of two people is a necessity; in fact, if many samples are to be collected, it is necessary to have a permanent crew of two so that the samples may be collected efficiently. During this study six samples were collected from each ^{weekly} plot at each depth. This necessitated using a crew of two.

If soil samples are collected when a heavy cover of snow is on the ground, the use of snowshoes is a necessity. It is extremely difficult to walk any great distance without them. On February 28 it was necessary to collect soil samples, with snowshoes being used to provide mobility. On this occasion it was learned that a ^a ruck sack, or/potato sack, is extremely desirable for carrying the soil cans because of ~~their~~ light weight and ease of carrying. Two sacks are very useful to carry the full soil cans. Speed is essential when working

under frigid conditions and one should not have to waste time handling a sack full of mixed full and empty cans to secure an empty can. A shovel is an absolute necessity for clearing away the snow at the locations at which the samples are to be collected.

On arriving at the selected location the man who is to turn the auger removes his snowshoes and with the shovel clears an area large enough to collect the sample without having snow fall into the boring. The shovel is then placed upright into the soil at a sufficient distance from the boring to permit an accumulation of discarded soil without danger of it falling back into the boring. The man who is to seal the cans should stand to the left-front of the auger man, facing him, so that the sample may be readily placed into the soil can with efficiency. The man handling the cans should ~~trample~~ trample down a small area so that by tapping his snowshoes together the webbing presents a clean surface upon which the opened cans may be placed upside down to prevent snow flakes, or falling snow from the crowns, from adulterating the sample. Cans are sealed and marked immediately on the masking tape as soon as the sample is collected. The can number is only used to identify the can after the seal is removed. All the cans should be opened at once as this is an important time-saving procedure when working under frigid conditions. The sack containing the full soil cans can be readily carried slung over one shoulder. If the terrain is such that freedom of both hands is a necessity, then an aluminum frame mountain-type rucksack is best, because of the ease with which heavy loads may be carried and its large capacity.

• The first step in the process of creating a new product is to identify a market need. This can be done through market research, which involves gathering information about the target market and its needs. Once a market need has been identified, the next step is to develop a product concept. This involves creating a detailed description of the product, including its features, benefits, and target market. The product concept is then used to develop a business plan, which outlines the company's strategy for producing and marketing the product. The business plan is then used to secure financing for the product development process. Once financing has been secured, the next step is to develop a prototype of the product. This involves creating a small-scale version of the product that can be used to test the product concept and gather feedback from potential customers. The prototype is then used to develop a final product, which is then marketed to the target market. The final step in the process is to evaluate the product's performance in the market. This involves gathering data on sales, customer satisfaction, and other factors that can be used to assess the product's success. Once the product's performance has been evaluated, the company can decide whether to continue producing and marketing the product or to discontinue it.

In the laboratory the samples should always be systematically grouped by plots and then stratified by depth to facilitate recording the can numbers and to avoid confusion. Mimeographed forms are very useful, and ^{should be used} wherever possible if determinations of soil moisture content are to be carried on for a long period of time. They are fine time-savers and their use should be stressed. Field forms should be mimeographed too; they are especially useful for recording resistance temperature and dendrometer measurements when a set procedure is followed week after week.

The laboratory technique consists of weighing the samples after the tape is removed; oven drying them at 110°C. until a constant weight is reached. They can be permitted to cool in the oven and then they ^{re} are weighed. The loss in weight represents the moisture previously contained in the sample. The can weight must be subtracted from the dried samples plus can weight so that the oven-dry weight of the soil can be determined. The moisture content is divided by the oven-dry weight of the soil and the result multiplied by 100 to arrive at the moisture percent in terms of oven-dry weight. The computations are tedious and require considerable time. A calculator is a very useful tool in performing the type of computations required.

All the electrical resistances recorded have to be standardized to some chosen temperature. The standard temperature chosen for this study was 60°F. Figure 7A in the publication by Bouyoucos and Mick (1940) was used to standardize the ohms resistances recorded in the field.



Figure 10. Collecting soil samples from Plot 80 in July.

The soil temperatures were taken with two soil thermometers being used as a check on the recorded temperatures.

A standard rain gauge was used in an adjacent open field to record accumulated rainfall. It was placed in a pit so that the cool soil would minimize evaporation.

Dendrometer Installations

To efficiently put in dendrometer installations, two men are required. For equipment they need a brace and bit, or a drill and bit, round-headed brass screws 1-1/2 inches long (for red pine), two screw drivers, and a metal template. The metal template permits placing all the wood screws in an even pattern and thus saves time. Drilling a small hole into the tree prior to driving the screws into the wood considerably reduces compressive forces and still gives a secure base. For greatest efficiency, one man should hold the template at the desired location while the other drills the holes. After all holes are drilled, both men are free to drive the screws.

Above each setting of three screws a small 1/2 by 1/2 inch aluminum pressure plate was fastened to the bark by using ferrule cement. The pressure plate was placed so that the actuating rod on the dendrometer pressed on its center. With a relatively smooth barked species, such as red pine, a pressure plate of the type described is probably not necessary. The brass screws are driven into the wood only to the point where the dendrometer will record measurements somewhere within the first 0.100 of an inch; this permits considerable expansion of the bark before a readjustment



Figure 11. Taking radial growth measurements with a dial gauge dendrometer. August 1953.

of the screws is necessary, and is ample enough to record one season's radial growth. All the screws were placed 4-1/2 feet off the ground and on the south side of the trees.

Laboratory Calibration Experiments

To be able to convert resistance readings in ohms to a soil moisture percentage, expressed in terms of oven-dry weight, a calibration curve must be developed for the particular soil type being used. It was soon apparent that no such curve already developed would fit the field conditions which existed at the red pine plantation. Consequently, it was decided to investigate some other approaches to the problem. It was first decided to increase the mass of sand involved and to determine how drying proceeded within the container. A number 10 can was used and within it six nylon units were stratified at one inch intervals (Figure 12). The resulting data show that drying proceeded from the top, open end of the can down to the bottom. The sand in the can was saturated at the beginning of the experiment and at the end it was almost thoroughly dry. The data for the experiment are presented in Table VII. At the conclusion of the experiment, when the resistance readings from the top, upper surface of the can to the bottoms were 1,800,000, 1,400,000, 22,500, 1,350, 575, and 525 ohms, the sand immediately surrounding each block was weighed, oven-dried, and weighed again. The weighings were done with an analytical balance and the resulting moisture percentages in terms of oven-dry weight were from top to bottom — 0.0738, 0.1390, 0.5999, 1.5910,

1.8170, and 1.795 percent. Thus, for a range of from 525 to 1,800,000 ohms, the moisture percentage varied by only 1.74 percent of oven-dry weight. From Table VII it can be seen that the blocks were very slow to respond to changes in the moisture content of the can.

A new approach was attempted to see if a more rapid response could be secured from the nylon units (Figure 13). A number 10 can was perforated at the bottom and placed on three legs so that drying could proceed from the top and bottom of the can simultaneously, and thus more closely simulate field conditions. The six units which had been stratified from the top to the bottom of the can responded immediately to moisture changes (See Table VIII). At the conclusion of the experiment the blocks from the top to the bottom of the can had the following resistance readings: 940,000; 44,000; 7,200; 4,750; 30,500; and 780,000 ohms. The corresponding moisture percentages determined by oven drying and using the analytical balance were: 0.2810; 1.0082; 1.4223; 1.3812; 1.2010; and 0.5468 percent. Again, for a resistance range from 4,750 to 940,000 ohms, the moisture percentage varied only 1.1413 percent.

The last attempt at developing a laboratory calibration curve resulted in the data given in Table IX. Soil sample cans were perforated and the nylon units inserted vertically in the center of the can so that drying of the sand would immediately register as a change in the resistance reading of the nylon unit (Figure 13). These represent the best results obtained, but still they do not approach field conditions. A field calibration curve seems to be the only proper approach.

When saturated, the soil samples of Grayling sand, gravelly phase, had soil moisture contents of 25.3, 22.4, and 18.9 percent of oven-dry weight at the 6, 18, and 36 inch depths, respectively.



Figure 12. Setup using number 10 cans used in laboratory calibration of the nylon units. Cans had solid bottoms.



Figure 13. Setup showing the perforated number 10 can on supports, and the soil cans with perforated bottoms used in the laboratory calibration experiments.

RESULTS

The Soil Moisture and Snow Supply During Late Winter And Early Spring

During the month of February, 1953, the total amount of rain and snowfall recorded by the U. S. Weather Bureau's cooperative observer at Higgins Lake was 3.54 and 26.3 inches respectively. Even as early as February 28, the first day that soil samples were collected, it was evident that the existing snow cover and the rainfall, which had fallen previously, were going to furnish a large share of the soil moisture for the weeks ahead.

When the Bouyoucos nylon units were interred during the first week of November 1952, the soil moisture supply appeared very low. The sand grains would not adhere to each other even slightly. On February 28, however, a very different situation existed -- the sand throughout the soil profile was very moist and on being moulded would retain its shape. The soil moisture supply, as determined from the soil samples, varied from 4.6-8.6 percent of oven-dry weight. The moisture supply at the six inch depth tended to be larger than that at the 18 and 36 inch depths. Plot 190 had more moisture than plots 80 and 120, which were approximately at the same moisture level. The precipitation which had fallen during the winter months had obviously been effective in restoring water to the soil.

In spite of the 23°F. air temperature prevailing at the plantation on February 28, and the 21 inch snow depth, only the pine needle litter was frozen. The frozen litter condition probably resulted from a

thaw period during which much crown drip combined with the water from the melting snow to saturate the needle litter, or perhaps a period of precipitation in the form of rain followed by colder temperatures and snow. Possibly before the snow began to deepen appreciably low temperatures froze the saturated needle mass into a sheath of solid ice above which the snow began to accumulate. Below this sheath of ice-cemented needles, which averaged one inch in thickness, the soil in all the plots was moist; nowhere was there any evidence of frozen soil. This was a good example of the insulating effect of needle litter and snow cover as protection against soil freezing.

In an adjacent open field covered with grasses and low shrubs, the frozen sheath described as being present in the conifer plots was nowhere in evidence. In fact, the mat of dead grasses was very moist. The soil as in the conifer plots was not frozen. In case of a sudden thaw the water formed by the melting of the snow cover could have readily infiltrated into the soil of those areas where the grass cover existed. There would have been considerable runoff from the conifer plots because of the ice sheath.

During the month of March, precipitation was again in the form of rain and snow. A total of 1.53 inches of rain and 10 inches of snow produced an increase in the soil moisture content of the three red pine plots. Plot 190 continued to have the highest soil moisture percentage at all levels, ranging from 9.8 percent at six inches to 7.5 percent at 36 inches. The most uniform rise occurred in plot 80 where all three depths showed an approximate increase of 1.5 percent. By March 26 plot 120, which on February 28 had been below plot 80 in soil moisture

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content, now was slightly higher. Melting of the snow cover in addition to regular precipitation was producing a noticeable effect by raising the moisture content of the soil.

Differences in both depth and distribution of the snow cover throughout the three plots were very noticeable throughout the winter and early spring seasons. The snow cover was deepest on plot 80 on February 28. By March 26 the remaining snow on plot 80 was confined to the large openings between the trees, see Figure 17. Approximately 60 percent of the stand was covered by snow, which averaged six inches in depth. Slash beneath the crown canopy and that which protruded above the snow was entirely free of snow. Evidently heat absorption by the bark and dead needles of the slash had greatly accelerated the melting rate of the snow around it.

Plot 120 was visibly different from plot 80 on March 26 in that the remaining snow cover was only 3-4 inches deep. It was not confined to openings as in plot 80. Of the total area, about 90 percent remained covered with snow. Bare spots averaged about five feet in diameter and often radiated out from some particular tree. Heat absorption by the bark at the base of the tree had probably initiated the melting process and as the needle litter became free of snow it too absorbed considerable heat to further the melting process at an increased rate.

On plot 190 the snow had averaged only seven inches in depth on February 28; by March 26 the snow mantle was reduced to an average depth of three inches. Circular bare areas about 18 inches in diameter surrounded the base of every tree.

The pine plantation had served as a snow fence for the field north of it. On March 26 a belt of snow paralleled the plantation and extended out into the field 60 feet. The two thirds of the snow belt nearest to the plantation averaged nine inches in depth. The remaining one third tapered gradually down to the exposed grass cover which began along a line 60 feet north and parallel to the plantation.

In the surrounding jack pine forest no snow remained on the ground. This was in contrast to the red pine stands because the jack pine stands are also rather dense. The thinner crowns of the jack pine undoubtedly permitted larger amounts of light to penetrate to the ground, thus greatly accelerating the rate of melting. This was substantiated by the grasses and herbaceous shrubs growing in the jack pine stands. This type of ground cover appears to favor rapid melting of snow, and, in combination with the relatively large amount of light which can penetrate the jack pine stands, conditions were favorable for the rapid disappearance of the snow cover from those stands.

Observations of the snow cover on April 1 revealed that considerable melting had occurred in the six-day period lapsing since March 26. The snow belt adjacent to and north of the plantation had receded from 60 to 30 feet in width. It now tapered from an average depth at the center of eight inches to exposed ground cover at each side. In plot 80 no frozen duff remained. The remaining snow mantle was limited to the crown openings and covered only 10-15 percent of the total area. The average depth of the snow was approximately four inches. Sunlight can readily penetrate to all portions of this stand, consequently only previous heavy accumulations of snow in the crown openings remained.

Considerably less sunlight penetrated into plot 120; scattered patches of snow covered 20-30 percent of the area to a depth of four inches. In this plot the duff was still frozen and averaged $1\text{--}1\frac{1}{4}$ inches in thickness.

The most dense stand, plot 190, remained covered with snow, averaging $2\text{--}1\frac{1}{2}$ inches in thickness over 70-90 percent of the total area. In addition to the one-inch frozen layer of duff, the soil was frozen to a depth of one inch. On the southern and eastern edges of this plot, oblique penetration by the sun's rays had resulted in a very rapid disappearance of the snow cover.

On April 1, the soil samples for plots 190 and 120 showed that at the six inch depth the two plots had moisture percentages of 10.8 and 10.6 respectively. These percentages represent the highest amount of moisture recorded for the two plots. Plot 80 on the same date showed no increase in moisture over the recording for the previous week. The disappearance of practically all of the snow cover on this plot by April 1 was probably the reason for the lack of increase in soil moisture. At 18 inches all plots showed an increase in soil moisture. At this soil depth all three plots attained the maximum moisture content recorded for the study. At 36 inches plot 190 attained its maximum moisture content of 7.7 percent. From February 28 to April 1, plot 190 maintained an almost constant moisture supply at the 36 inch depth, averaging 7.5 percent. The beneficial effect of snow cover in building up the soil moisture supply had reached its optimum by April 1.

Yhteenveto ja johtopäätökset

Ennen kuin aloitamme, on tärkeää muistaa, että tämä on vain ohjeellinen teksti, jota ei pidä ottaa kirjainmukaisesti. Sen tarkoituksena on antaa yleisellä tasolla tietoa aiheesta, jota käsitellään. Tässä osassa keskitymme siihen, miten voimme hyödyntää saamiamme tietoja ja miten voimme välttää mahdolliset virheet. Tämä on tärkeää, jotta voimme varmistaa, että kaikki tiedot ovat oikein ja ajantasalla.

Ensimmäinen asia, jota on syytä muistaa, on se, että kaikki tiedot eivät ole yhtä tärkeitä. Jotkut asiat voivat olla enemmän keskeisiä kuin toiset, ja on tärkeää tunnistaa ne, jotka ovat olennaisia. Tämä auttaa meitä keskittymään oikeisiin asioihin ja välttämään turhaa hätkähtelyä. Toiseksi, on tärkeää olla valmiita muutoksiin. Tiedot voivat muuttua nopeasti, ja on tärkeää seurata muutoksia ja olla valmiita sopeutumaan niihin. Tämä tarkoittaa sitä, että meidän on oltava joustavia ja valmiita ottamaan vastaan uusia tietoja.

Sitten, on tärkeää muistaa, että kaikki tiedot eivät ole aina oikein. On tärkeää tarkistaa tiedot ja varmistaa, että ne ovat luotettavia. Tämä voidaan tehdä esimerkiksi vertailemalla eri lähteitä tai kysymällä asiantuntijalta. Tämä auttaa meitä välttämään virheitä ja varmistamaan, että meillä on oikeat tiedot. Lisäksi, on tärkeää muistaa, että kaikki tiedot eivät ole aina ajantasalla. On tärkeää seurata uutuuksia ja varmistaa, että meillä on viimeisin tiedo.

Viikkokokoukset ovat erittäin tärkeitä, ja on tärkeää osallistua niihin. Ne tarjoavat mahdollisuuden keskustella toisten kanssa, jakaa kokemuksia ja saada uusia ideoja. On tärkeää valmistautua kokouksiin etukäteen ja olla valmiita osallistumaan aktiivisesti. Tämä auttaa meitä saamaan enemmän irti kokouksista ja varmistamaan, että kaikki asiat on käsitelty.

Viikkokokoukset ovat myös erinomainen tilaisuus saada palautetta. On tärkeää kysyä toisilta, miten meidän toimintamme näkyy heille, ja saada heidän kommenttinsa. Tämä auttaa meitä parantamaan toimintaamme ja varmistamaan, että meillä on kaikki tarvittavat työkalut ja tiedot. Lisäksi, on tärkeää muistaa, että kaikki tiedot eivät ole aina oikein. On tärkeää tarkistaa tiedot ja varmistaa, että ne ovat luotettavia.

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Considerably less sunlight penetrated into plot 120; scattered patches of snow covered 20-30 percent of the area to a depth of four inches. In this plot the duff was still frozen and averaged $1\frac{1}{4}$ inches in thickness.

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On April 1, the soil samples for plots 190 and 120 showed that at the six inch depth the two plots had moisture percentages of 10.8 and 10.6 respectively. These percentages represent the highest amount of moisture recorded for the two plots. Plot 80 on the same date showed no increase in moisture over the recording for the previous week. The disappearance of practically all of the snow cover on this plot by April 1 was probably the reason for the lack of increase in soil moisture. At 18 inches all plots showed an increase in soil moisture. At this soil depth all three plots attained the maximum moisture content recorded for the study. At 36 inches plot 190 attained its maximum moisture content of 7.7 percent. From February 28 to April 1, plot 190 maintained an almost constant moisture supply at the 36 inch depth, averaging 7.5 percent. The beneficial effect of snow cover in building up the soil moisture supply had reached its optimum by April 1.

1. The first part of the paper is devoted to the study of the
 properties of the function $f(x)$ defined by the formula

$$f(x) = \sum_{n=0}^{\infty} \frac{a_n}{n!} x^n$$
 where a_n are the coefficients of the power series. It is shown that
 the function $f(x)$ is analytic in the whole plane and that it
 satisfies the differential equation

$$f'(x) = f(x) + x f''(x)$$
 The second part of the paper is devoted to the study of the
 properties of the function $g(x)$ defined by the formula

$$g(x) = \sum_{n=0}^{\infty} \frac{b_n}{n!} x^n$$
 where b_n are the coefficients of the power series. It is shown that
 the function $g(x)$ is analytic in the whole plane and that it
 satisfies the differential equation

$$g'(x) = g(x) + x g''(x)$$
 The third part of the paper is devoted to the study of the
 properties of the function $h(x)$ defined by the formula

$$h(x) = \sum_{n=0}^{\infty} \frac{c_n}{n!} x^n$$
 where c_n are the coefficients of the power series. It is shown that
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 satisfies the differential equation

$$h'(x) = h(x) + x h''(x)$$
 The fourth part of the paper is devoted to the study of the
 properties of the function $k(x)$ defined by the formula

$$k(x) = \sum_{n=0}^{\infty} \frac{d_n}{n!} x^n$$
 where d_n are the coefficients of the power series. It is shown that
 the function $k(x)$ is analytic in the whole plane and that it
 satisfies the differential equation

$$k'(x) = k(x) + x k''(x)$$
 The fifth part of the paper is devoted to the study of the
 properties of the function $l(x)$ defined by the formula

$$l(x) = \sum_{n=0}^{\infty} \frac{e_n}{n!} x^n$$
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 satisfies the differential equation

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 The sixth part of the paper is devoted to the study of the
 properties of the function $m(x)$ defined by the formula

$$m(x) = \sum_{n=0}^{\infty} \frac{f_n}{n!} x^n$$
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 satisfies the differential equation

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 The seventh part of the paper is devoted to the study of the
 properties of the function $n(x)$ defined by the formula

$$n(x) = \sum_{n=0}^{\infty} \frac{g_n}{n!} x^n$$
 where g_n are the coefficients of the power series. It is shown that
 the function $n(x)$ is analytic in the whole plane and that it
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$$n'(x) = n(x) + x n''(x)$$
 The eighth part of the paper is devoted to the study of the
 properties of the function $o(x)$ defined by the formula

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 The ninth part of the paper is devoted to the study of the
 properties of the function $p(x)$ defined by the formula

$$p(x) = \sum_{n=0}^{\infty} \frac{i_n}{n!} x^n$$
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 the function $p(x)$ is analytic in the whole plane and that it
 satisfies the differential equation

$$p'(x) = p(x) + x p''(x)$$
 The tenth part of the paper is devoted to the study of the
 properties of the function $q(x)$ defined by the formula

$$q(x) = \sum_{n=0}^{\infty} \frac{j_n}{n!} x^n$$
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4. The fourth part of the document discusses the implications of the findings and provides recommendations for future research. It suggests that further studies should be conducted to explore the underlying mechanisms of the observed phenomena.

5. The fifth part of the document concludes the study and summarizes the key findings. It reiterates the importance of the research and the need for continued investigation in this field.

Total precipitation for April amounted to 3.49 inches of rainfall and 0.4 inch of snow. By April 18 all of the winter snow cover had melted. However, it had snowed the day before and it was still evident in plot 80 as there was a trace in patches averaging approximately 10 inches in diameter over about 10 percent of the area. In plot 120 a trace remained over 40 percent of the area. In plot 190, one eighth inch of snow covered 90 percent of the area. No snow was evident either in the open field or under the jack pine stands. By this date all the duff had thawed out and the last vestiges of winter were practically gone. At the six inch depth all plots were at an approximate equal moisture content of 9.5 percent. All plots, except plot 80, had descended from their optimum level attained on April 1. The field samples revealed a gain in moisture content for the open field.

At the 18 inch depth, on April 18, all plots receded uniformly in moisture content. At 36 inches, plot 190 showed a sharp drop of 2.5 percent. Plot 80 decreased slightly and plot 120 increased to a moisture content of 6.1 percent (Figure 21).

From February 28 until April 1 the melting snow cover in combination with additional precipitation in the form of rain or snow had recharged the soil moisture supply to its maximum level in plots 190 and 120. Plot 80 did not reach its peak at the six inch depth until May 2. On that date the soil had a moisture content of 10.8 percent of oven-dry weight.



Figure 14. Plot 190 on February 28, 1953.



Figure 15. Plot 190 showing the snow cover existing at the end of March. March 31, 1953.



Figure 16. Plot 120 showing the snow cover on March 31, 1953.



Figure 17. Plot 80 showing snow cover on March 31, 1953.



Figure 18. The snow belt concentrated on the north edge of the plantation.
March 31, 1953.

1. The first part of the document is a list of the names of the persons who were present at the meeting. The names are listed in alphabetical order.

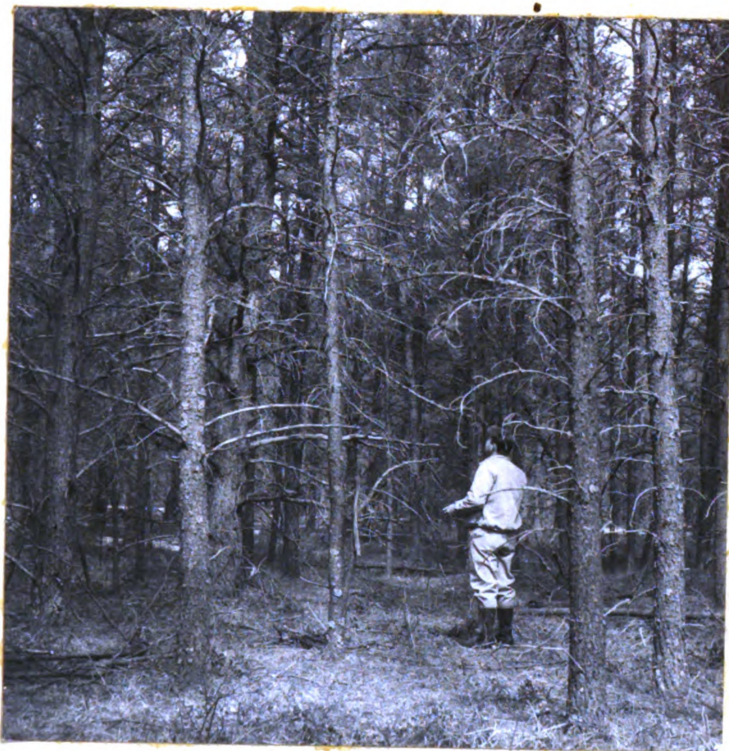


Figure 19. Jack pine stand on March 31, 1953,
showing dense mat of grasses.

Variations in Soil Moisture Supply During the Growing Season

The growing season began gradually. Most noticeable was the increase in air temperatures. On May 1 the recorded air temperature was 39°F., but by May 9 it had risen to a very warm 79°F. On May 9 the jack pine buds were beginning to open up; the red pine buds were noticeably swollen, but they did not begin to open until about May 16.

The first three days of May had a total rainfall of 0.51 inch and the soil moisture supply in all three plots was at a high level at the 6, 18, and 36 inch depths.

On May 2 the soil samples collected showed that at the six inch depth plot 80 contained 10.8 percent moisture, plot 120 10.3 percent, and plot 190 8.9 percent, as compared to 10.9 percent in the open field. At the 18 inch depth the order was open field 8.3 percent, plot 190 7.5 percent, plot 120 7.2 percent, and plot 80 6.7 percent. This pattern of moisture distribution had been evident in all three red pine plots since February 28 at this depth. The same order of moisture abundance occurred between plots at the 36 inch depth. Plot 80 had noticeably declined in moisture content at the 36 inch depth since March 26. The rapid disappearance of the snow cover in that plot had evidently adversely affected its moisture supply at the 36 inch depth.

Except for a rainfall of 0.23 inch on May 12, the period from May 4 to May 16, inclusive, was devoid of any precipitation. This lack of rainfall was reflected in the soil moisture content for the period. At all three depths there was a noticeable drop in soil moisture. It was during this period that growth had started, but

transpiration from the crowns must not have influenced the soil moisture content to any great extent because the moisture drop in the plots and open field was almost uniform in all cases. During this period the open field and plot 80 differed but slightly in their moisture content (Figure 21).

At the 18 and 36 inch depths all the plots were at nearly the same moisture content by May 16. During this period, fluctuations in soil moisture occurred among the plots. At the 36 inch depth plot 190 had a higher moisture content for the period than the other plots.

From May 16 through June 6 precipitation was abundant and well distributed as indicated in Figure 20. The total rainfall for the period amounted to 4.63 inches. The response in soil moisture was evident immediately in all the plots as the soil content started to increase.

The open field had a higher soil moisture content at 6 and 36 inches during this period than any of the pine plots except for plot 80. On May 30 plot 80 had a higher moisture for the period at the 6 inch depth than either plot 120 or 190. The latter two plots fluctuated among themselves in moisture abundance. Plot 190 showed the sharpest rise of the two plots for the period -- 5.6-9 percent.

For the period, the three red pine plots maintained the same order of moisture content at the 18 inch depth. Plot 120 had the highest moisture content, followed by plots 190 and 80. The open field curve shows a marked drop for the period.

There was a sharp drop in precipitation from June 6-13. After June 13 the rainfall occurred at rather regular intervals. The total

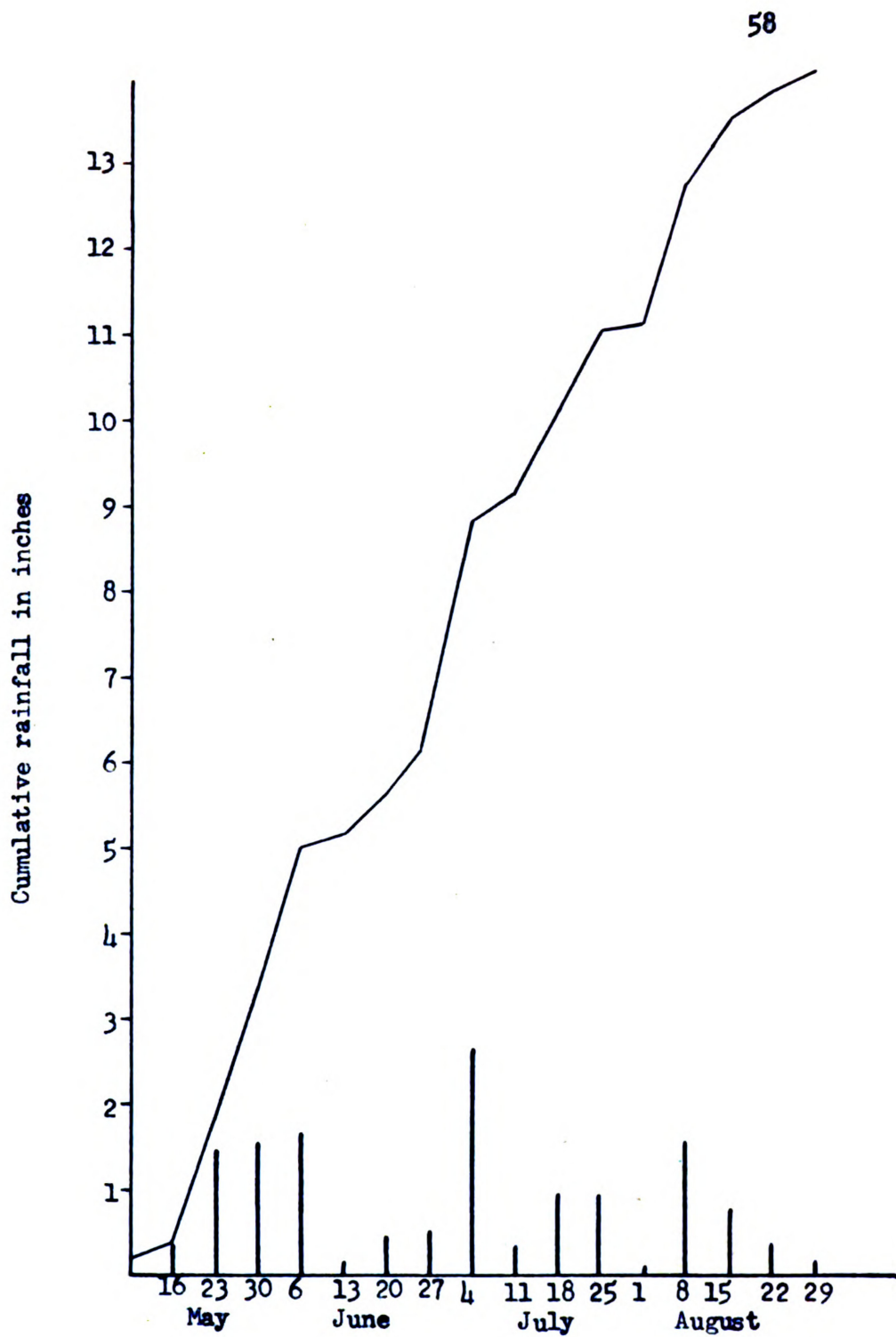


Figure 20. Cumulative weekly rainfall.

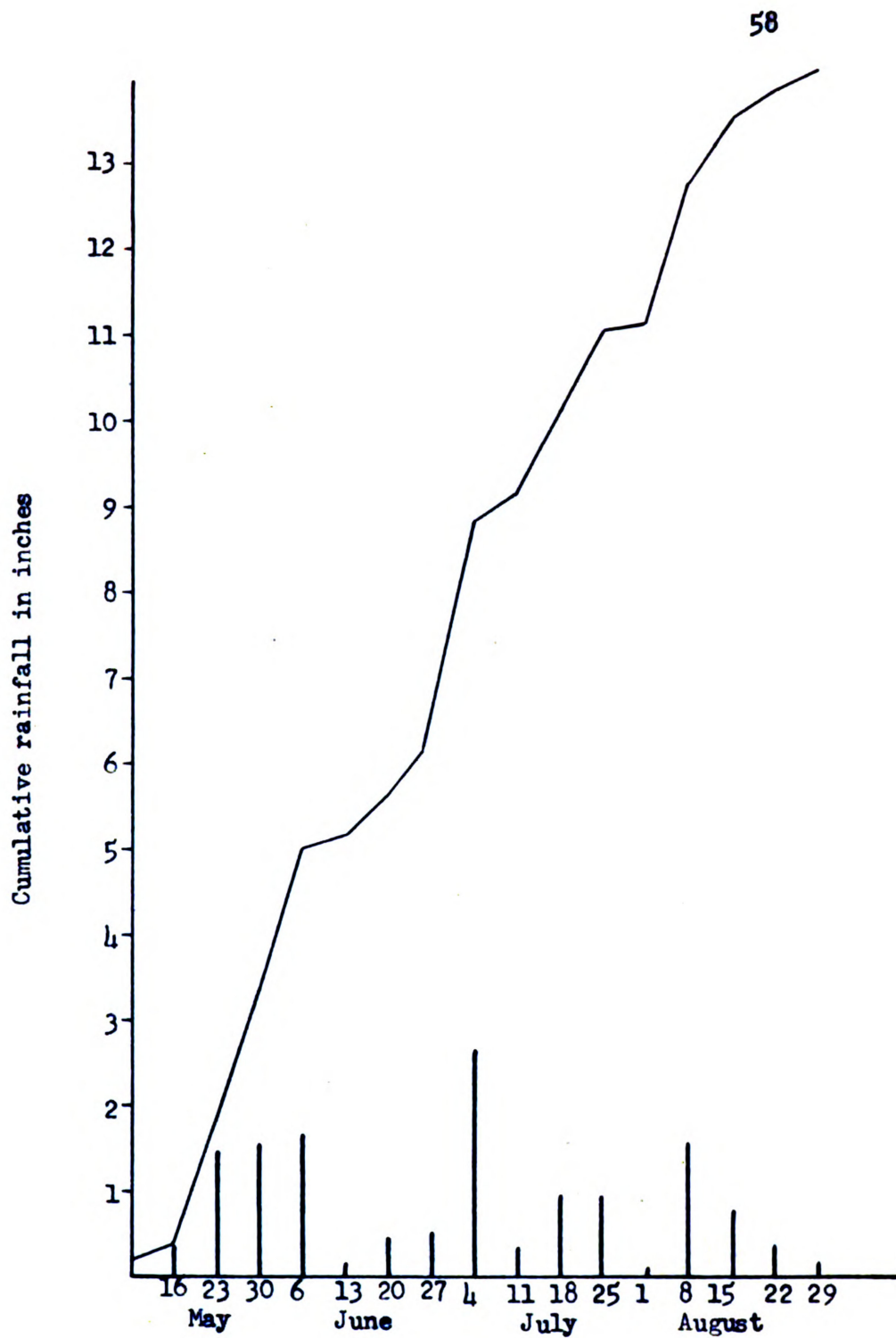


Figure 20. Cumulative weekly rainfall.

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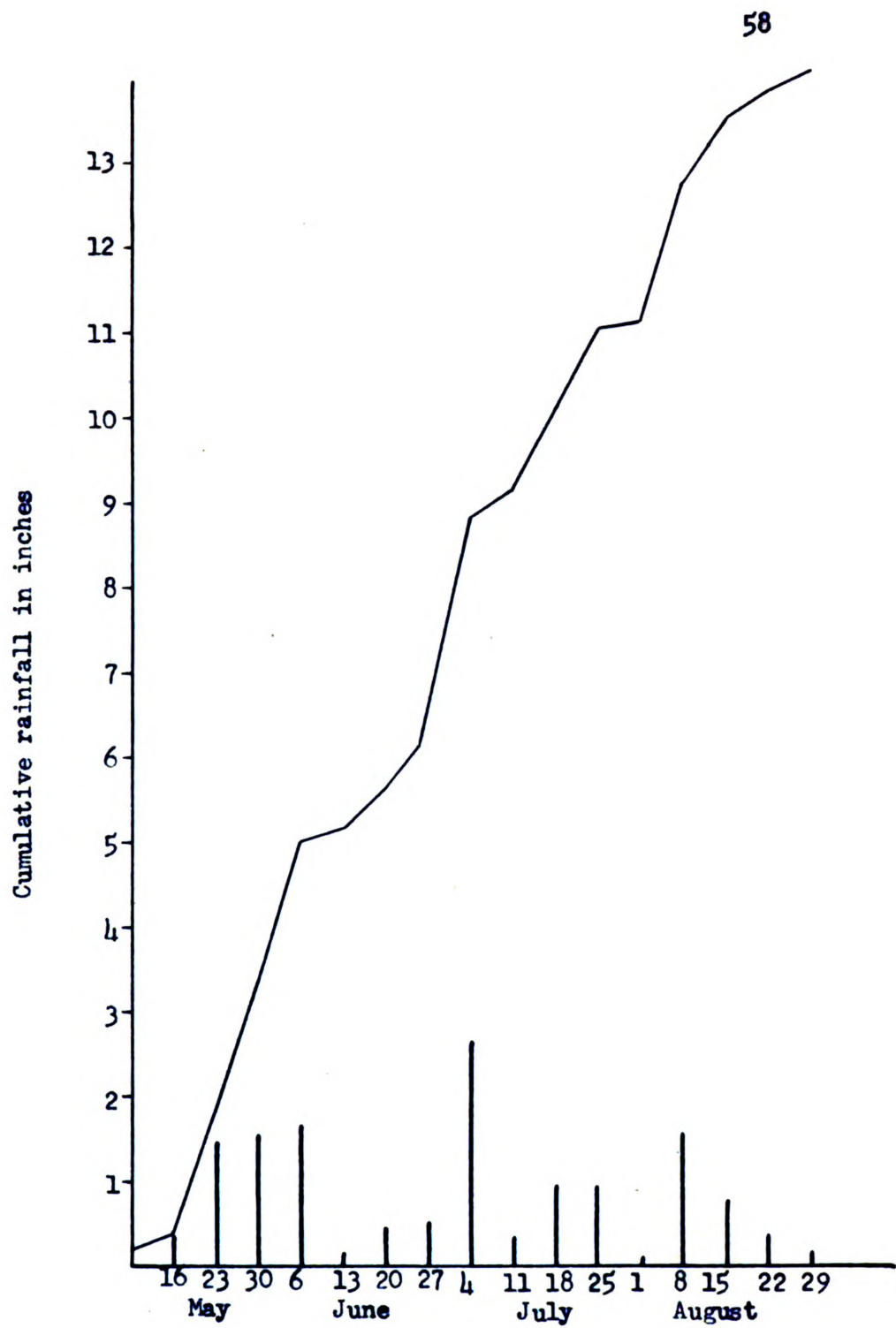


Figure 20. Cumulative weekly rainfall.

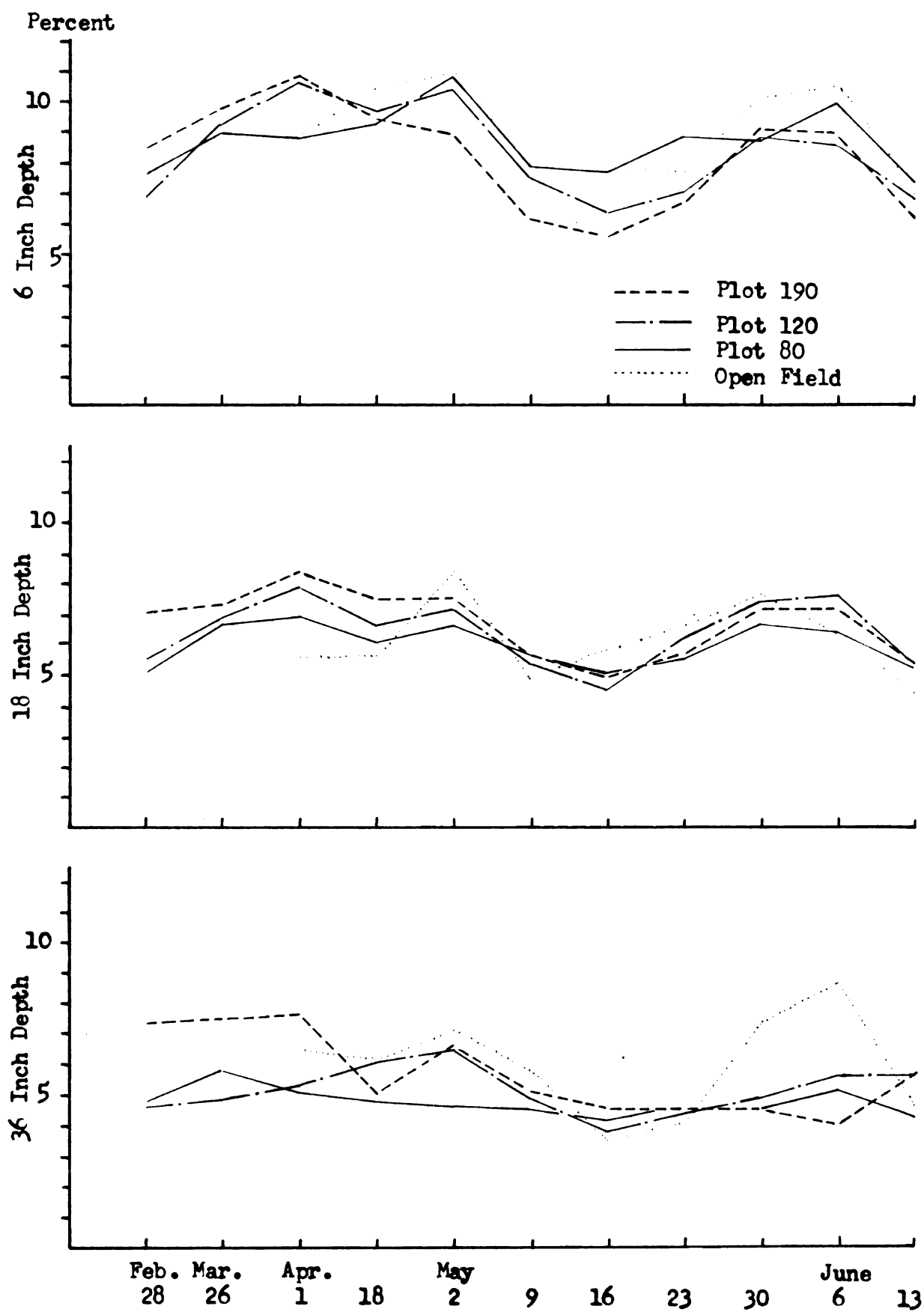


Figure 21. Soil moisture expressed as percent of oven-dry weight.

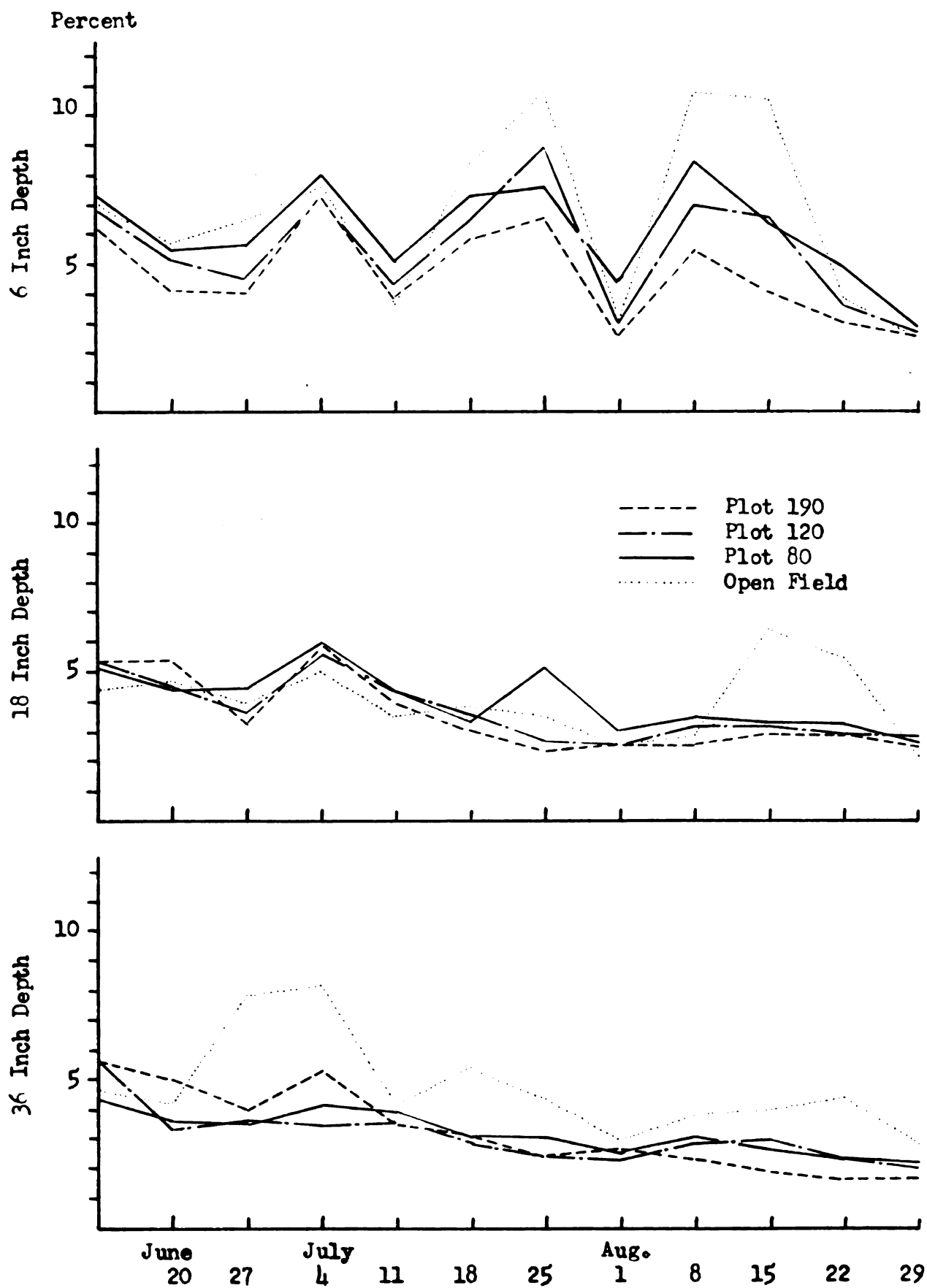


Figure 22. Soil moisture expressed as percent of oven-dry weight.

for the period June 6 to July 4 amounted to 4.10 inches. Most of this rainfall occurred on July 1 when a total of 2.35 inches of rain fell.

There was a noticeable decrease in soil moisture from June 6 to 27 in all three plots at all three levels. At the six inch depth, plot 80 had the highest moisture content for the period followed by plots 120 and 190 in that order. The drop in soil moisture for the three plots at the six inch depth was approximately 4.3 percent of the oven-dry weight.

At the 18 inch depth the approximate drop in soil moisture was from 7 to 4 percent. The 4 percent moisture content of June 27 represented a new low for this depth, as did the 5 percent moisture content at the six inch depth.

At 36 inches the plots were at a new low of approximately 4 percent moisture content. Plot 190 had a higher moisture content than the other two plots. On June 27 the open field had a moisture content of 7.8 percent. This was considerably higher than the moisture content of any of the three plots. This trend at the 36 inch depth continued until the conclusion of the study on August 29. Apparently a cover of grasses and low shrubs is very favorable for increasing the soil moisture supply at the 36 inch level.

A heavy rainfall of 2.35 inches on July 1 brought the soil moisture content up in all plots and at all soil depths, except for plot 120 which decreased by 0.2 percent in moisture content at the 36 inch depth. On July 4 plot 80 showed a moisture content of 8.0 percent at the six inch depth. Plots 190 and 120 were at 7.3 and 7.2 percent respectively. At 18 inches, the order of soil moisture content was;

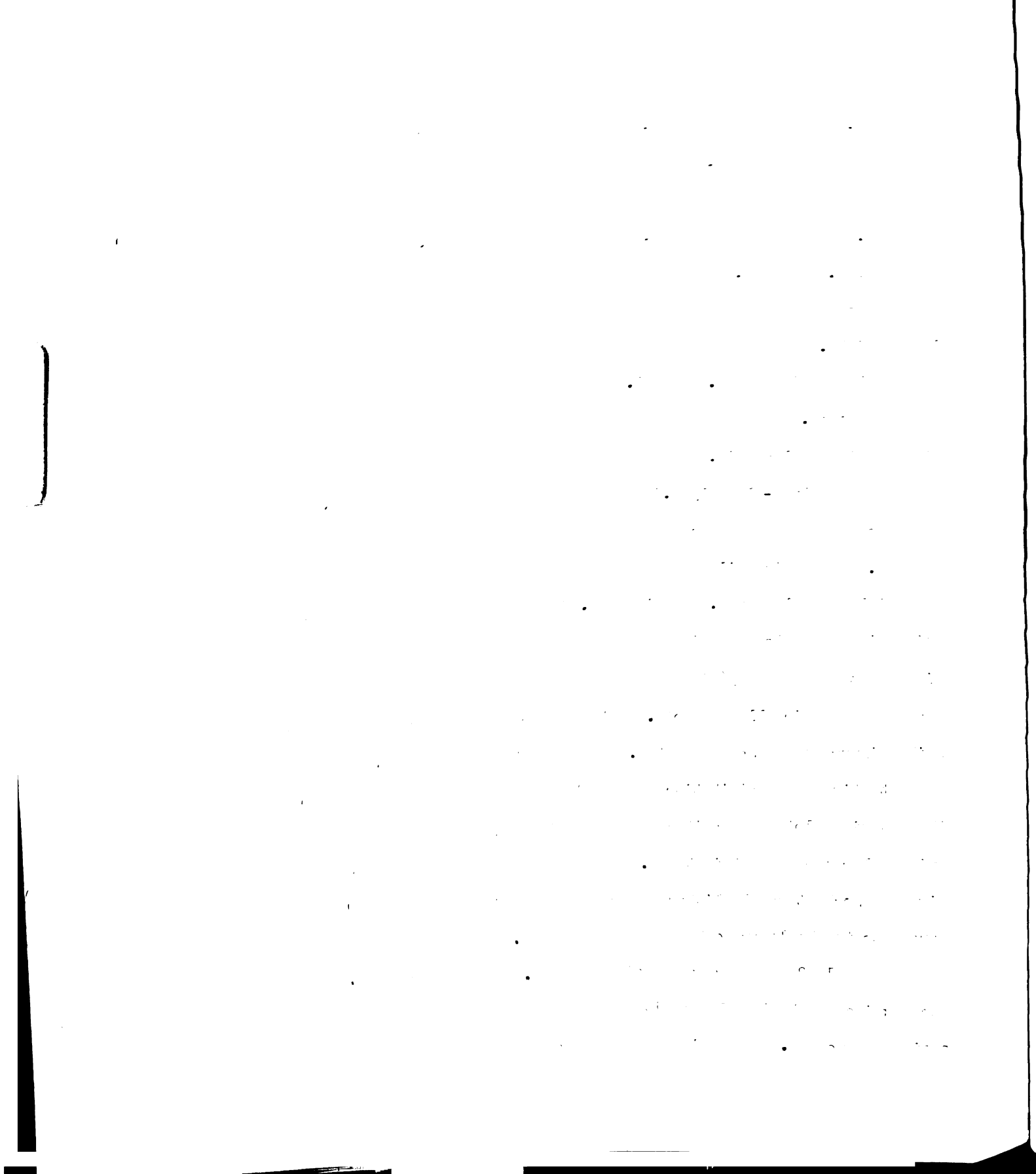
1. Introduction
 The purpose of this report is to provide a comprehensive overview of the current state of the project and to outline the key findings and recommendations. The report is structured as follows:
 2. Background
 The project was initiated in response to the need for a more efficient and effective way of managing the company's resources. The initial goals were to improve communication, streamline processes, and reduce costs.
 3. Methodology
 The data for this report was collected through a series of interviews, surveys, and focus groups. The information was then analyzed using a combination of qualitative and quantitative methods.
 4. Findings
 The findings of the study indicate that there are several areas where the current system is inefficient. These include the lack of a central database, the use of multiple software applications, and the absence of a clear communication protocol.
 5. Recommendations
 Based on the findings, the following recommendations are made:
 a. Implement a central database to store all project-related information.
 b. Consolidate software applications to reduce costs and improve efficiency.
 c. Establish a clear communication protocol to ensure that all team members are kept up-to-date.
 6. Conclusion
 The project has identified several key areas for improvement and has provided a clear roadmap for the future. It is recommended that the company take immediate action on the recommendations provided in this report.

plot, 80 6.0 percent; plot 190, 5.8 percent; plot 120, 5.6 percent; and the open field, 5 percent. Differences in soil moisture between plots were more apparent at the 36 inch depth where the order was: open field, 8.2 percent; plot 190, 5.3 percent; plot 80, 4.2 percent; and plot 120, 3.5 percent.

The period from July 5 to August 1 was characterized by a very low rainfall. The precipitation which occurred was practically limited to July 18 and 25 when 0.82 and 1.03 inches of rain fell on the respective dates. The air temperatures for the period were mostly in the middle 70's and low 80's.

From July 4-11, only 0.24 inches of rainfall had occurred. This shortage of rain was reflected in the soil moisture determinations for July 11. A drop in soil moisture occurred in all the plots and the open field at all depths. A rain of 0.82 inch on July 18 raised the soil moisture content at six inches in all the plots and in the open field. At the 18 and 36 inch depths the soil moisture continued its downward trend in all the plots. Only the open field showed a rise in soil moisture at these two depths. Undoubtedly interception, absorption, and retention of precipitation by the plantation canopy and litter in the red pine plots before it could get past the six inch depth were the principal reasons for this trend. In the open field there is no highly absorbent needle litter; consequently, rainfall can quickly percolate to the lower depths of the sand soil.

On July 25 another heavy rainfall of 1.03 inches occurred. At the six inch depth in all the plots the soil moisture content rose again (Figure 22). The soil samples collected in the open field showed



a very high soil moisture content of 10.8 percent. Plot 120 surpassed plot 80 with a 9.0 percent vs. 7.6 percent moisture content. Plot 190 remained relatively low with a moisture content of 6.5 percent. At the 18 inch depth plot 80 rose to 5.2 percent. Plots 120, 2.7 percent, and 190, 2.3 percent, continued their downward trend which began shortly after July 4. At the 36 inch depth all the plots continued their downward trend or remained the same as on July 18.

From July 25 to August 1 only 0.06 inch of rainfall was recorded. All the plots showed a considerable drop in soil moisture. The most noticeable decline occurred in the open field where the soil moisture dropped from 10.8 percent to 3.2 percent. At the 18 inch depth the open field, plot 120, and plot 190 showed the same moisture content of 2.5 percent. Plot 80 was slightly higher with 3.1 percent soil moisture. At 36 inches all the plots were at a moisture content of 2.5 percent of oven-dry weight. Low as this moisture percentage was, it was to drop even lower before the conclusion of the study.

The total rainfall for the month of August was 2.93 inches. Actually, more rain fell than in June, but the water content of the soil at the lower depths was at a more critical level. The most prominent precipitation periods occurred as follows: August 2, 0.22 inch; August 4, 0.72 inch; August 8, 0.67 inch; August 12, 0.63 inch; August 21, 0.20 inch; and August 25, 0.28 inch (Figure 20).

The combined rainfall of August 4 and 8 raised the soil moisture content at six inches to favorable levels. In the open field on August 8 the moisture content was at 10.8 percent. In the red pine plantations the soil moisture distribution was as follows: Plot 80,

[illegible]

8.5 percent; plot 120, 7.2 percent; and plot 190, 5.4 percent. Except on August 15, plot 80 remained above the other plots in soil moisture content at the six inch depth. On August 29 the plots were all at an approximate moisture content of 2.7 percent.

At the 18 inch depth throughout the month of August, the plots varied between moisture contents of 2.5-3.5 percent. Even though the variation was small, the order of decreasing soil moisture in the plots was plot 80, 120, and 190. During this period the open field had moisture contents on August 15 and 22 of 6.5 percent and 5.5 percent. These percentages were approximately double those which were recorded for the plots. On August 29, however, the open field had the lowest soil moisture average recorded during the entire study for the 18 inch depth (2.2 percent of oven-dry weight).

For the period August 8-29, soil moisture differences at the 36 inch depth were more noticeable. For this entire period, plot 190 constantly had the lowest soil moisture content (Figure 22). The lowest recorded averages for this depth, 1.7 percent on August 22 and 29, occurred in plot 190. Of the three red pine plots, plot 190 on August 1 had the lowest recorded soil moisture content at the six inch depth (2.6 percent); on July 25 it had the lowest average recorded at the 18 inch depth (2.3 percent).

Thus, plot 190, with a basal area of 190 square feet, exhibits the most pronounced soil moisture fluctuations when compared with the other two red pine plots. In March and during the first week in April when the snow cover in plot 190 was melting at a slower rate than in plots 120 and 80, it had the highest soil moisture content at all three

8.5 percent; plot 120, 7.2 percent; and plot 190, 5.4 percent. Except on August 15, plot 80 remained above the other plots in soil moisture content at the six inch depth. On August 29 the plots were all at an approximate moisture content of 2.7 percent.

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Thus, plot 190, with a basal area of 190 square feet, exhibits the most pronounced soil moisture fluctuations when compared with the other two red pine plots. In March and during the first week in April when the snow cover in plot 190 was melting at a slower rate than in plots 120 and 80, it had the highest soil moisture content at all three

8.5 percent; plot 120, 7.2 percent; and plot 190, 5.4 percent. Except on August 15, plot 80 remained above the other plots in soil moisture content at the six inch depth. On August 29 the plots were all at an approximate moisture content of 2.7 percent.

At the 18 inch depth throughout the month of August, the plots varied between moisture contents of 2.5-3.5 percent. Even though the variation was small, the order of decreasing soil moisture in the plots was plot 80, 120, and 190. During this period the open field had moisture contents on August 15 and 22 of 6.5 percent and 5.5 percent. These percentages were approximately double those which were recorded for the plots. On August 29, however, the open field had the lowest soil moisture average recorded during the entire study for the 18 inch depth (2.2 percent of oven-dry weight).

For the period August 8-29, soil moisture differences at the 36 inch depth were more noticeable. For this entire period, plot 190 constantly had the lowest soil moisture content (Figure 22). The lowest recorded averages for this depth, 1.7 percent on August 22 and 29, occurred in plot 190. Of the three red pine plots, plot 190 on August 1 had the lowest recorded soil moisture content at the six inch depth (2.6 percent); on July 25 it had the lowest average recorded at the 18 inch depth (2.3 percent).

Thus, plot 190, with a basal area of 190 square feet, exhibits the most pronounced soil moisture fluctuations when compared with the other two red pine plots. In March and during the first week in April when the snow cover in plot 190 was melting at a slower rate than in plots 120 and 80, it had the highest soil moisture content at all three

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depths. Late in the growing season when the heavy tree population of the stand exerted a tremendous moisture demand from the soil through its very dense root system, the situation was completely reversed and plot 190 exhibited the lowest soil moisture percentages.

Statistical analysis did not disclose a significant difference between plots for the season as a whole.

Analysis of Variance

Source	Degrees of Freedom	Sums of Squares	Mean Square	F	F Book
Total	65	330			
Between	2	13	6.5	1.30	3.15
Within	63	317	5.0		

However, close inspection of Figures^{21 and 22} will disclose that during the growing season 82.4 percent of the time plot 80 had the highest moisture content at the six inch depth; plot 120, 11.8 percent; and plot 190, 5.8 percent of the time.

The only time during the growing season that plot 190 surpassed the other two plots in moisture content at the six inch depth was on May 30. During the week of May 23-30, 1.62 inches of rain had fallen and the maximum moisture variation between the plots at that level was only 0.4 percent. It is quite conceivable that with such a small amount of variation and for the number of samples collected that the usual order of moisture abundance between plots could have differed



Figure 23. Partial soil profile in Plot 190 showing dense mass of roots.



Figure 24. Partial soil profile in Plot 80.



Figure 25. Partial soil profile in the open field showing the grass roots.

• *Phragmites australis* (Common reed)
• *Scirpus americanus* (Common reed)
• *Phragmites australis* (Common reed)

from the customary. The same situation occurred between plots 80 and 120 on August 15.

The moisture trend as shown in Figure 22 strongly indicates that at the critical six inch level, where the feeder roots are located, plot 80 had the highest soil moisture content 82 percent of the time. When abundant rainfall tends to create a high level of soil moisture throughout the plots, then perhaps if there are insufficient samples the usual tendency will not resolve itself.

At the 18 and 36 inch depths the usual trend, early in the growing season, is a variation among the plots as to which contains the most moisture. Differences are not nearly as large as are found at the six inch depth. From July until September the usual trend was as for the six inch depth in that the order of decreasing soil moisture at the 18 inch depth between plots was plot 80, 120, and 190.

At the 36 inch depth, from August until September, plots 80 and 120 had practically the same moisture content. Plot 190 had markedly less soil moisture than either of the other two plots.

Soil Moisture Trends as Indicated by the Nylon

Electrical Resistance Unit

Originally the plan of study had called for the determination of the soil moisture variation between the red pine plots by using nylon electrical resistance units. The units were carefully installed at random throughout the three plots and the open field on November 8, 1952. The blocks were dry when installed because it was thought that they would thus be better able to stabilize to the soil moisture

conditions surrounding them. In December, approximately one month later, ohms reading were taken at all the stations. Analysis of the data resulted in the decision to collect soil samples to determine the soil moisture trend for the plots. Initially the readings were rather erratic, but by February 28, 1953, on which date the readings were taken again, the data were such as to indicate that the resistance units had stabilized themselves to their surroundings during the winter months.

It should be pointed out that by the very nature of the unit installation many resistance units need to be placed in the soil area for a reliable measure of soil moisture. Once a nylon resistance unit is installed its location is fixed. If the location is too wet or too dry and does not properly represent the soil moisture conditions for the plot in which it is located, nothing can be done to remedy the situation. Unless there are drastic changes in the soil moisture regimen for the plot so that the soil situation for the plot is then properly reflected by the readings taken from the unit, then all readings taken from the unit will not properly reflect the soil moisture conditions as they exist in the plot. Even in plantations where the litter and humus layers have not been disturbed for many years, important differences exist throughout the litter layer as to its perviousness to rainfall and crown drip.

An important objective to be attained while installing the block is a minimum of soil and litter disturbance. Consequently, if the block is placed in a location where penetration by rainfall is made difficult by a relatively impervious litter layer, high resistance readings will be encountered. If the location selected has

a litter layer which permits rainfall to enter the mineral soil quickly, lower resistance readings will be given by the block. The only remedy for this situation is to install many resistance units systematically at random on the plot which is to be tested. An important consideration encountered with the installation of many resistance units is the high initial cost. It is difficult to appraise the perviousness of the needle litter in the small area surrounding the block installation. If this could be judged, locations might be chosen which are comparable.

Another very important factor which will indirectly affect the readings taken from the unit is the overhead crown cover. The more variation in the overhead canopy the more are the number of units that should be installed. Here, again, the cost per unit may easily become prohibitive. Even under a crown canopy that is as uniform as the one over plot 190, the spacing is 4x5, considerable variations existed in the readings within the plot on any particular day. It became obvious after the study was under way that the only possible approach would be to use the average of the units on each plot for any particular day as a working item with which to construct a graph of the soil moisture trend.

As was previously pointed out, once the unit is placed in the ground it becomes fixed and is subject only to the particular micro-climatic conditions surrounding it. The moisture trend it indicates is only for one location throughout the period of the study. In sampling a quantity which is as variable as soil moisture, it is obvious that many units need to be installed. A distinct advantage which soil samples taken at random possess is that of variability of location.

Each sample taken is from a different location. This is advantageous in that the effect of any one particular location is minimized and the average of all samples for any particular day can thus more nearly represent the general soil moisture condition present on that day. For the entire period of this study, any one resistance unit represented the soil moisture conditions existing at only one location within the plot in which it was buried. In contrast to this, each soil sample collected on a comparable basis represented the soil moisture found in 22 locations within the same plot.

Other disadvantages present themselves when one decides to use the resistance units to determine the moisture content of the soil. First and foremost is the task of successfully developing an ohm-soil moisture curve. The curve is necessary for determining the quantity of soil moisture present in the soil for any given reading in ohms. For some soils this is a relatively easy task, for others, and sand is one, it is extremely difficult to obtain a curve which approximates field conditions. Reinhart (1953) had a very good approach to the problem in that he described a field technique for constructing a calibration curve. Each time a reading is taken it is necessary to measure the soil temperature at the depth of the unit. The ohms reading then must be corrected to the temperature at which the calibration curve is standardized. This is a time consuming procedure which must be considered when many resistance readings are taken.

For the actual relationship between soil moisture abundance and the density of stocking complete reliance has been placed on the soil moisture values obtained from the soil samples. The graphs of the

ohm-date trend, constructed from the data collected from the resistance block readings, is presented to show that it is possible to follow the moisture trend of a sand soil using electrical resistance units if a suitable field calibrated curve can be constructed, and if a sufficient number of resistance units are installed (Figures 27, 28, and 29).

The ohm-date graph for the six inch depth distinctly shows that the fluctuations in soil moisture correspond to the periods of light and heavy rainfall as they occurred during the summer months (Figures 20 and 27). On July 25 the resistance readings were recorded for all the units between 8:30-10:00 A.M. With but one exception, 75,000 ohms, all the readings at the six inch depth were between 200,000-460,000 ohms. At 10:00 A.M. it commenced to rain and between 10:00 A.M. and 3:00 P.M. a total of 0.86 of an inch of rainfall was recorded by the area rain gauge. The cumulative rainfall for the week of July 18-25 was only 0.07 inch; hence, high readings were given by all the resistance units. At 3:00 P.M., when the rain ceased, all the unit resistances were measured again. Some of the resistances recorded showed resistances as low as 9,500 ohms. Most of the recordings were in the vicinity of 30,000 ohms; several showed only a small drop when compared to the reading recorded before the rain. This indicated that the units could respond quickly to soil moisture changes. Close inspection of the unit location where high resistances were recorded showed that rapid drainage from the location before the rain water had penetrated to the six inch depth was responsible for the high readings. At the end of the season an inspection of the locations showed that the A_0 horizon was very indurated and evidently rather

[illegible]



Figure 26. Electrical resistance measurements can be easily taken during the summer months. Note the sack used as insulation for the portable soil moisture bridge.

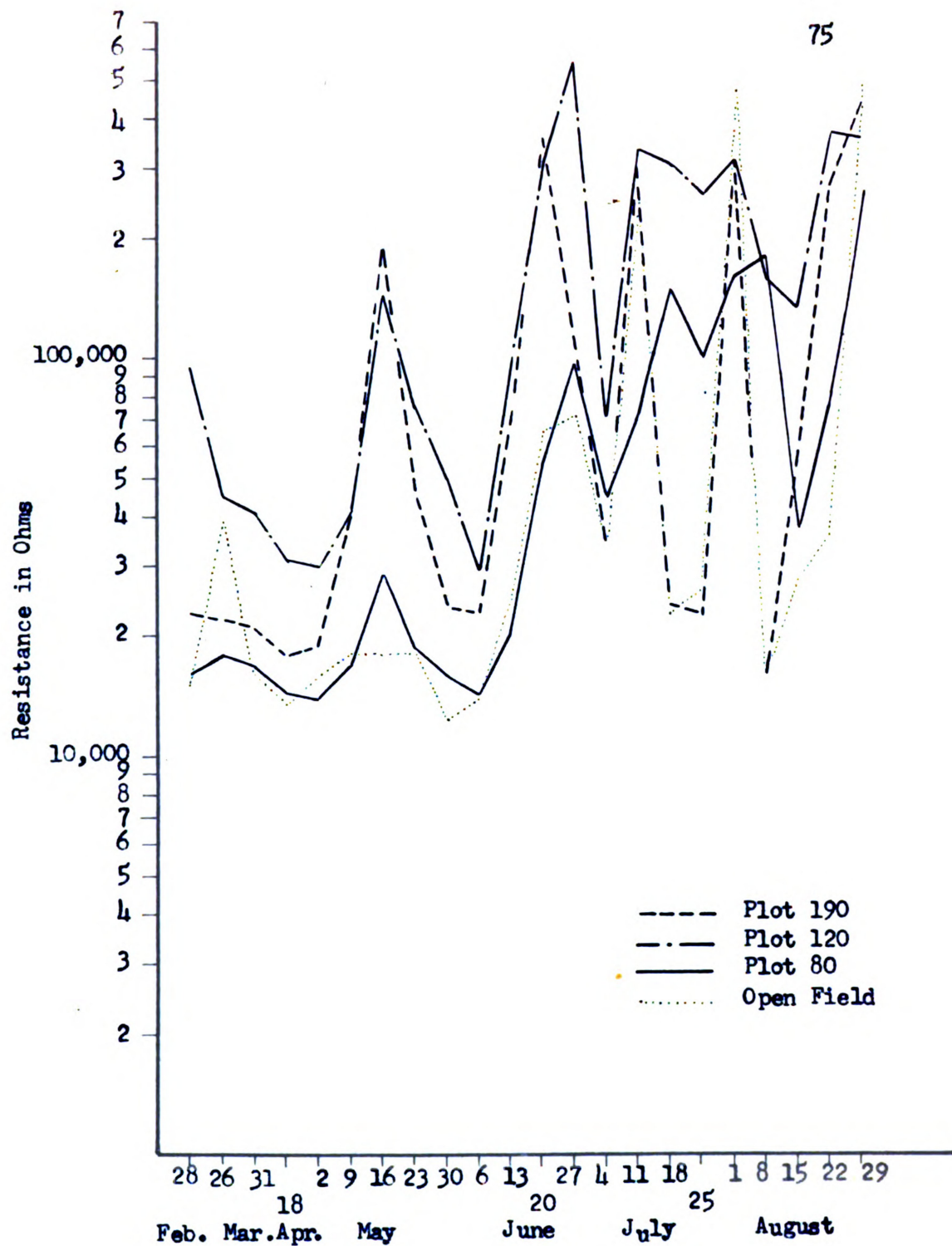


Figure 27. Ohms resistance at the 6 inch depth at 60°F.

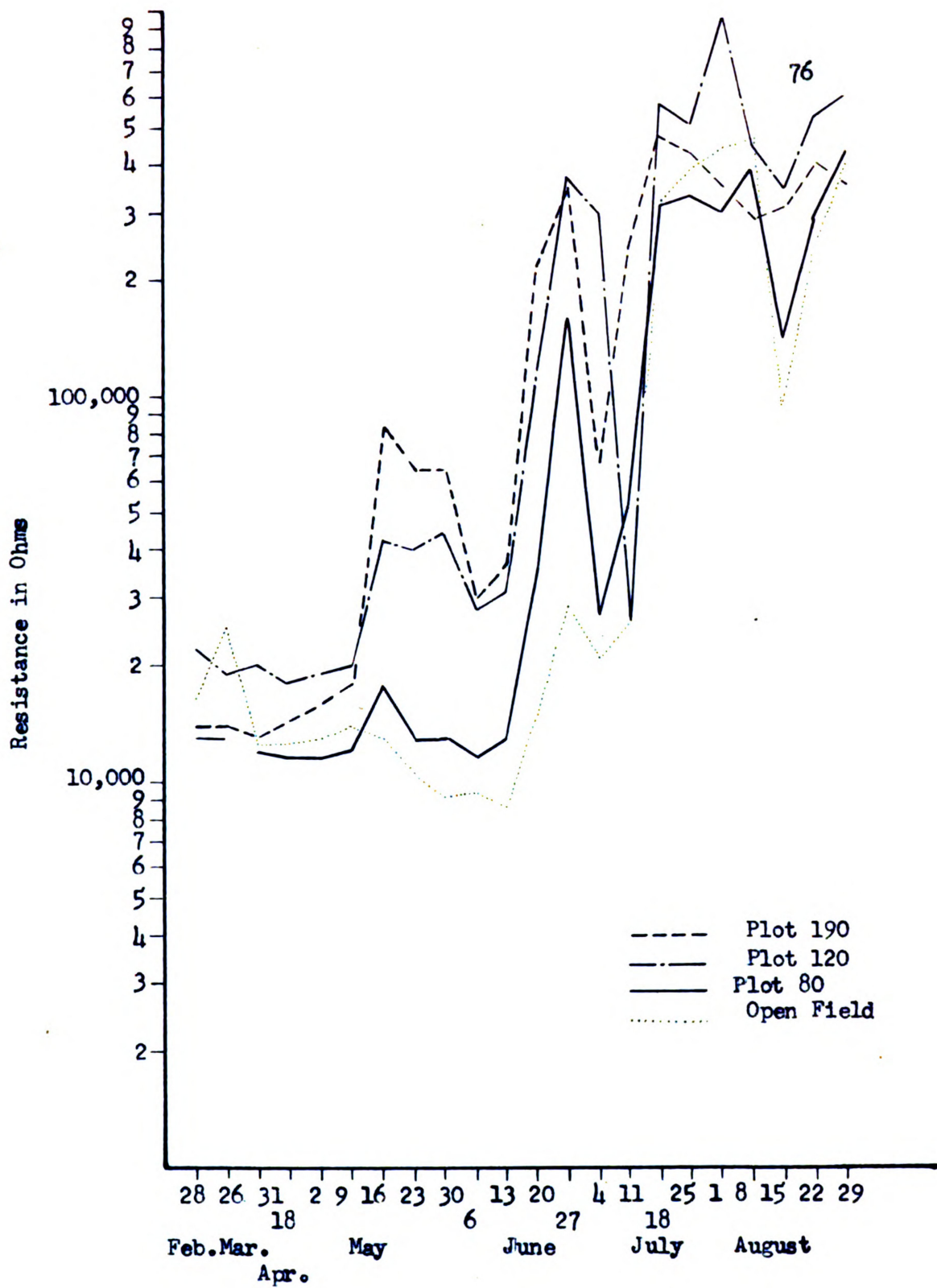


Figure 28. Ohms resistance at the 18 inch depth at 60°F.

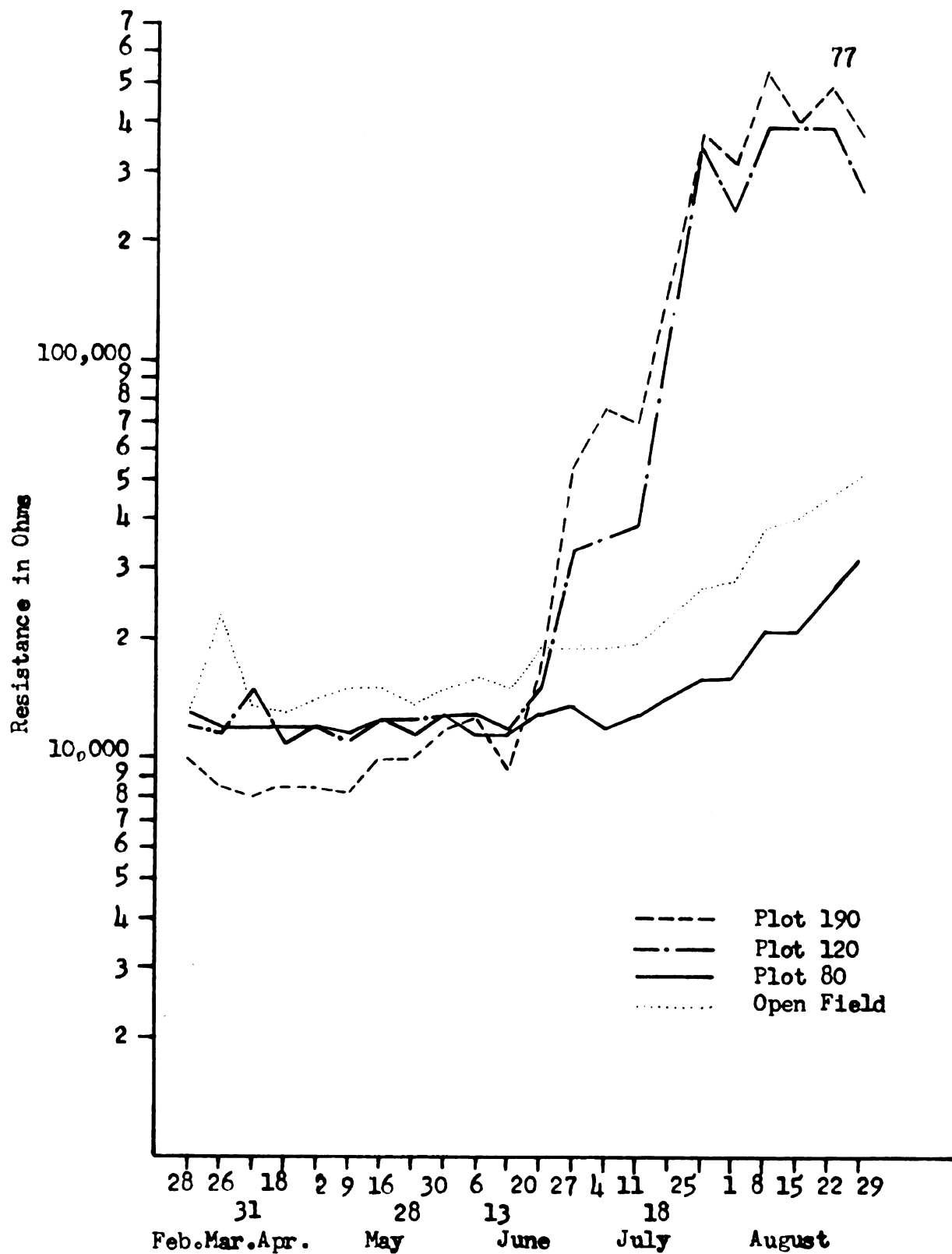


Figure 29. Ohms resistance at the 36 inch depth at 60°F.

resistant to penetration by rainfall. Inspection of the graph will show that distinctions between the various plots are obvious, but no reliance can be placed on their significance because of the insufficient number of resistance units used during the study. The high per unit cost prevented using any additional units. Early recognition of this deficient resulted in the decision to collect soil samples at weekly intervals in order to obtain more specific information on soil moisture.

The graph plotted for the 18 inch depth has variations corresponding to the high and low precipitation periods as did the graph for the six inch depth. Differences between the plots are even more clearly shown than they were at the six inch depth. At this depth the indicated trends more closely follow those obtained from the soil samples.

Several things are very obvious when one examines the graph for the 36 inch depth (Figure 29). The curve no longer corresponds to rainfall fluctuations as did those at the six and 18 inch depths. Relatively dry periods and the dessicated conditions they produce at the soil surface are not reflected on the graph until near the end of the period. The curves are in rather close agreement with the soil moisture trend indicated by the soil samples. For the purpose of illustration, they tend to show moisture trends more distinctly at the 36 inch depth than soil samples do because the relatively high sensitivity of the resistance scale under low soil moisture conditions produces more marked variance on the graph when the scale of the graph remains unchanged. The graphs indicate that the deeper the resistance units are placed in the soil the fewer are the number required to obtain valid results.

Field Resistance-Moisture Calibration Curves Developed
For the Nylon Electrical Resistance Unit for Use in
Grayling Sand, Gravelly Phase

At the beginning of the study laboratory experiments were conducted in an attempt to construct an ohm-soil moisture curve which would permit conversion of the ohms resistance values recorded during the course of the study into equivalent soil moisture values. No workable curve which would adequately represent the soil moisture values existing in the field was developed. It became obvious as the experimental work progressed that the effect of the microclimate surrounding each unit on the unit at the depth at which it was interred was so intricate that it probably could never be satisfactorily reproduced in the laboratory. For some soils, satisfactory laboratory curves have been produced, but for Grayling sand, gravelly phase, no such curve had been developed. With the data available, it seemed logical that an approximation to a satisfactory curve could be developed by plotting the average of the resistance values and soil moisture values for each plot for each day the data was collected. Furthermore, the data indicated that it would be necessary to plot the data for each depth separately. The resulting curves are shown in Figures 30, 31, and 32). Each plotted point represents the average of three resistance readings, in ohms, and the soil moisture content of six soil samples expressed as percent of oven-dry weight. A similar procedure was attempted by Reinhart (1953), but on a more limited scale.

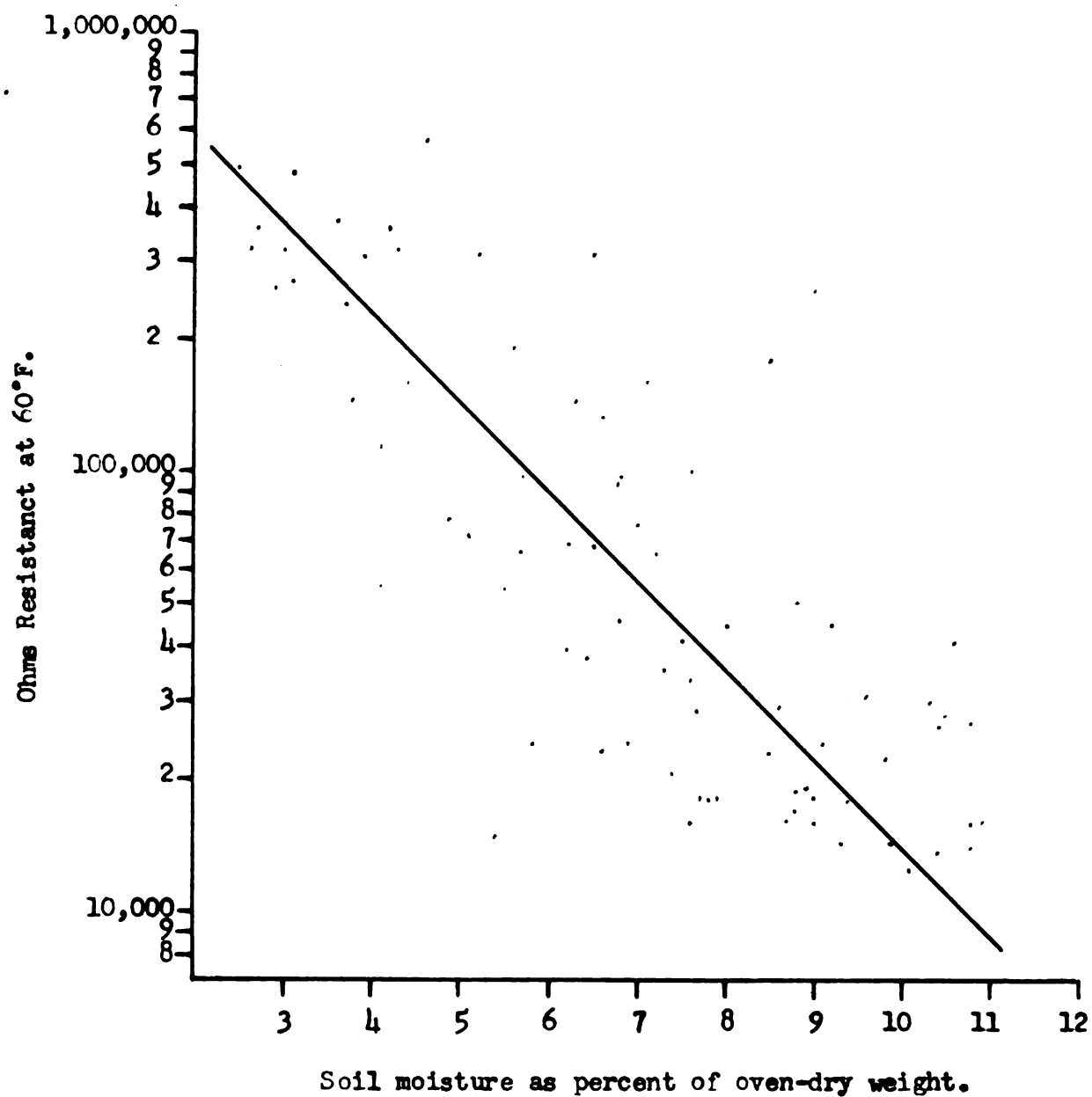


Figure 30. Field calibration curve for Grayling sand, gravelly phase, at the 6 inch depth.

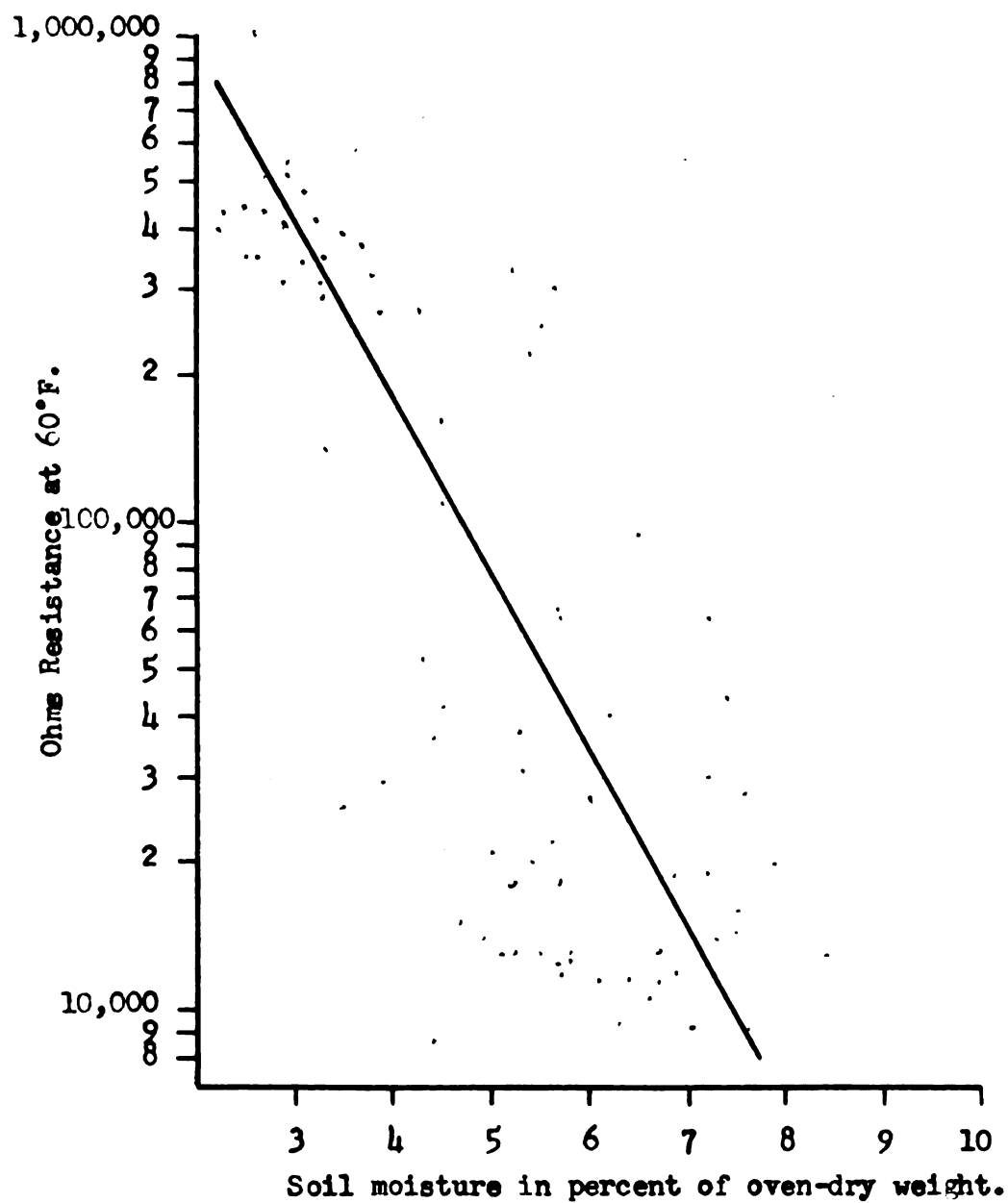


Figure 31. Field calibration curve for Grayling sand, gravelly phase, at the 18 inch depth.

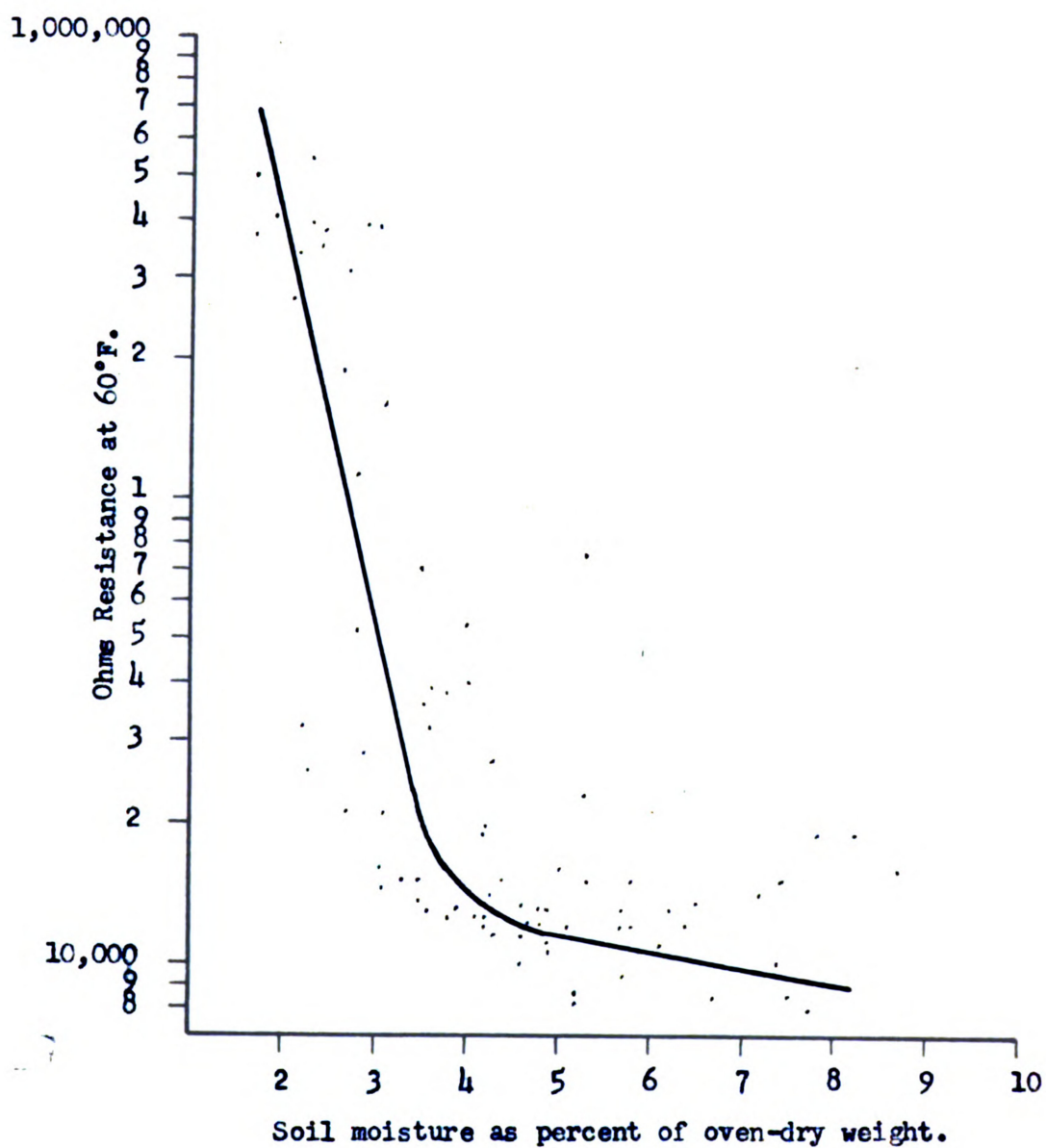


Figure 32. Field calibration curve for Grayling sand, gravelly phase, at the 36 inch depth.

The graphs indicate that it is probably necessary to develop a calibration curve for each depth being tested. The curve for the six inch depth has an approximate 45 degree slope. At the 18 inch depth the curve is noticeably steeper but still maintains a linear trend. At the 36 inch depth the curve assumes a reversed "J" shape.

The wide latitude between plotted values for both soil moisture and ohm resistance suggests that perhaps the best use of the resistance unit in a sand soil is as an indicator of broad relative soil moisture conditions rather than an actual moisture content.

Soil Temperature Trends

During the course of this study it was necessary to record soil temperatures weekly for the purpose of converting all the resistance unit measurements to a standard temperature of 60 degrees Fahrenheit. It was soon apparent that the soil temperatures at the 6, 18, and 36 inch depths usually differed from week to week among all the plots and the open field (Figure 33).

In the open field the soil temperatures recorded at the three depths were decidedly higher than the temperatures recorded for the same date in the red pine plots. The maximum variation occurred on May 9 when at the six inch level the open field was 14.5 degrees higher than plot 80. The red pine plots varied most at the six inch depth. Plot 190 usually had the lowest temperatures at all three depths. Plot 120 often had soil temperatures which were intermediate between the temperatures of plot 80 and 190 at all three levels. Usually the soil temperatures in plot 120 tended to be more nearly

1. *Journal of the American Medical Association*, 1990; 263: 1025-1028.

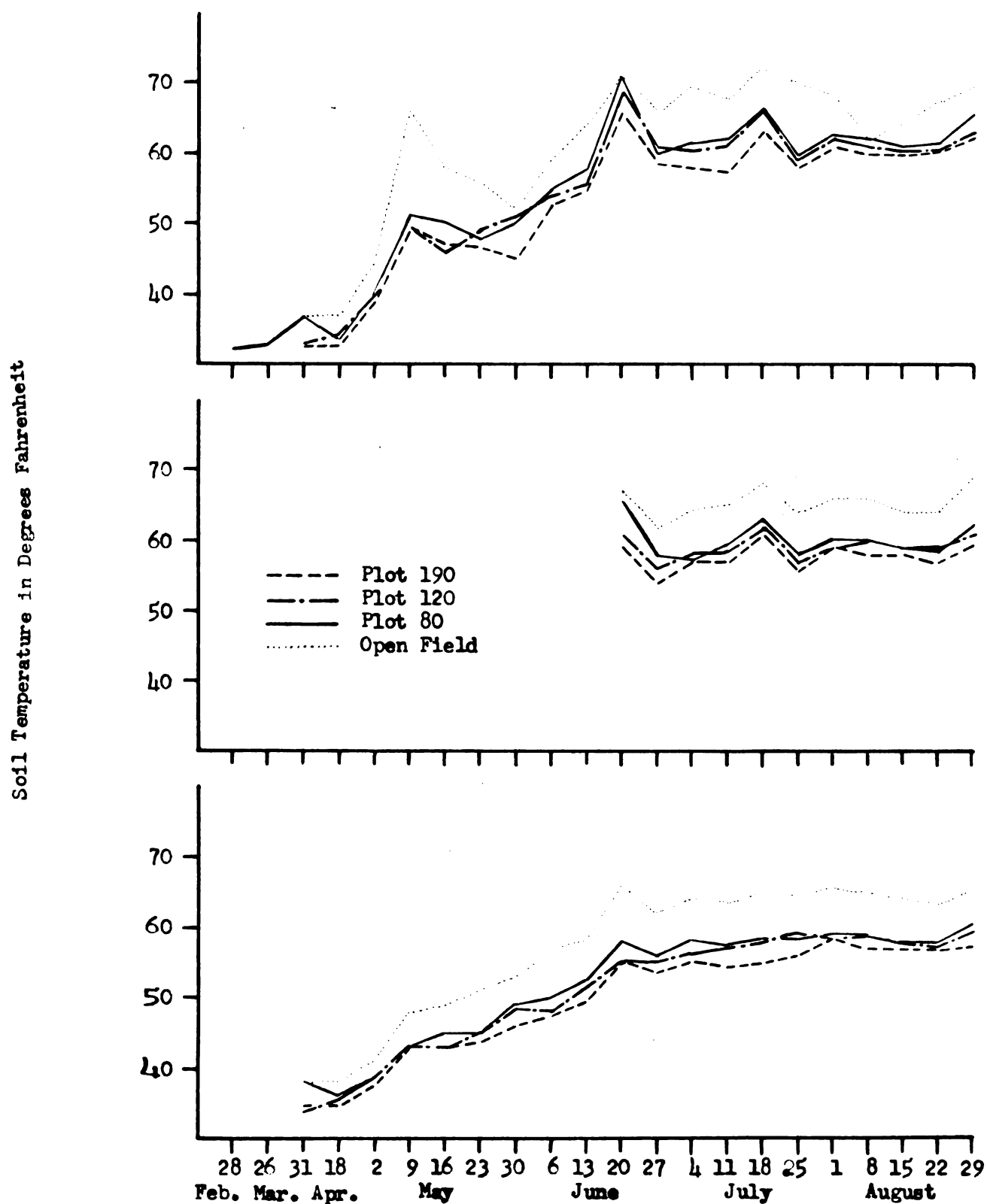


Figure 33. Soil temperatures in the red pine plots and in the open field.

similar to those in plot 80 than those in plot 190.

At the six inch depth, from April 18 to May 9, the three red pine plots had temperatures which differed but slightly. From May 9 to July 18 the soil temperature differences were especially large. On May 30 the differences between the curves for the red pine plots were most obvious. On that date plot 120 had a temperature six degrees higher than that for plot 190. At this depth prolonged dry spells were occasioned by a rise in soil temperature. Conversely, periods of heavy rainfall caused the soil temperatures to decrease. At the six inch depth the recorded temperatures never went below 32°F. For the red pine plots the temperature recorded on June 20 was the maximum attained, 71°F in plot 80. On that date plot 80 and the open field were at the same temperature at the six inch depth. From June 27 to August 29 the temperatures recorded for the red pine plots tended to vary around 62°F. at the six inch depth. Referring to Figure 33, a straight line connecting April 18 to June 20 would indicate a rise of approximately four degrees per week for the period.

The curves for the 18 inch depth have very nearly the same trend as those for the six inch depth. From August 8 to August 29, plots 120 and 80 tended to be at nearly the same temperature at this depth. However, for this period, at the six inch depth plot 120 tended to have temperatures more nearly like those of plot 190. From June 20 until August 29 the open field maintained its trend of having higher temperatures at the 18 and 36 inch depths; however, the 0.67 inch rainfall on August 8 caused a very noticeable drop in the field temperature at the six inch depth where the recorded temperature of 62°F. was the same

as for plot 80. The soil moisture content of the field for that date was raised to a high level, 3.2 percent recorded on August 1 to 10.8 percent on August 8. In general, periods of heavy precipitation produced more noticeable declines of soil temperature in the open field than in the red pine plots. After July 4 the trend indicated for all plots at all three depths was a general leveling of the temperature curves. The period preceding July 4, except for two occasions, is characterized by weekly temperature increases. The temperature curves for the 36 inch depth show the same trend. However, temperature fluctuations at this depth are less noticeable for similar periods when compared with the six and 18 inch depths. An approximation of the mean temperature for the period July 25 to August 29 at the 6, 18, and 36 inch depths would be 62, 59, and 58°F. respectively.

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Effects of Soil Moisture and Stand Density

On Radial Growth

As nearly as could be determined from examination of the bud development and radial increases measured by the dendrometer, growth in the red pine stands started during the week of May 9-16. By May 16 all the plots had shown an increase in radial growth (Figure 34). During the period May 16-23, plots 80 and 190 showed a larger increase in radial growth than plot 120. By May 30, however, a radial growth trend developed that was to remain the same throughout the course of the observations. Plot 80 constantly showed the most growth. Plot 120 was next highest in total growth; plot 190 showed the least total growth.

Except for the month of June, the total monthly rainfall during the growing season of 1953 was above the monthly means for Crawford County, Michigan, as given in "Climate and Man" (1941). The year 1953 was a good year for tree growth in Crawford County because a greater supply of rainfall was available during the growing season than normally occurred. This in turn undoubtedly raised the level of available moisture in the soil.

During the period of growth, four periods occurred during which the growth rates in plots 120 and 190 noticeably decreased. The first of these occurred during the week of June 6-13. Reference to Figures 20 and 21 will show that there was a marked decrease in rainfall for the period with a subsequent drop in soil moisture. Some low temperatures also prevailed during this period.

- The first step in the process of identifying a problem is to define the problem. This involves identifying the symptoms of the problem and determining the scope of the problem.
- The second step is to identify the causes of the problem. This involves identifying the factors that are contributing to the problem and determining the underlying causes.
- The third step is to develop a plan of action. This involves identifying the steps that need to be taken to solve the problem and determining the resources that will be needed.
- The fourth step is to implement the plan. This involves putting the plan into action and monitoring the progress of the solution.
- The fifth step is to evaluate the results. This involves assessing the effectiveness of the solution and determining whether the problem has been solved.
- The sixth step is to document the results. This involves recording the steps that were taken and the results that were achieved.
- The seventh step is to communicate the results. This involves sharing the results with the relevant stakeholders and ensuring that they are understood.
- The eighth step is to review the process. This involves reflecting on the process and identifying areas for improvement.
- The ninth step is to implement the improvements. This involves putting the improvements into action and monitoring the progress of the solution.
- The tenth step is to evaluate the results. This involves assessing the effectiveness of the solution and determining whether the problem has been solved.
- The eleventh step is to document the results. This involves recording the steps that were taken and the results that were achieved.
- The twelfth step is to communicate the results. This involves sharing the results with the relevant stakeholders and ensuring that they are understood.
- The thirteenth step is to review the process. This involves reflecting on the process and identifying areas for improvement.
- The fourteenth step is to implement the improvements. This involves putting the improvements into action and monitoring the progress of the solution.
- The fifteenth step is to evaluate the results. This involves assessing the effectiveness of the solution and determining whether the problem has been solved.

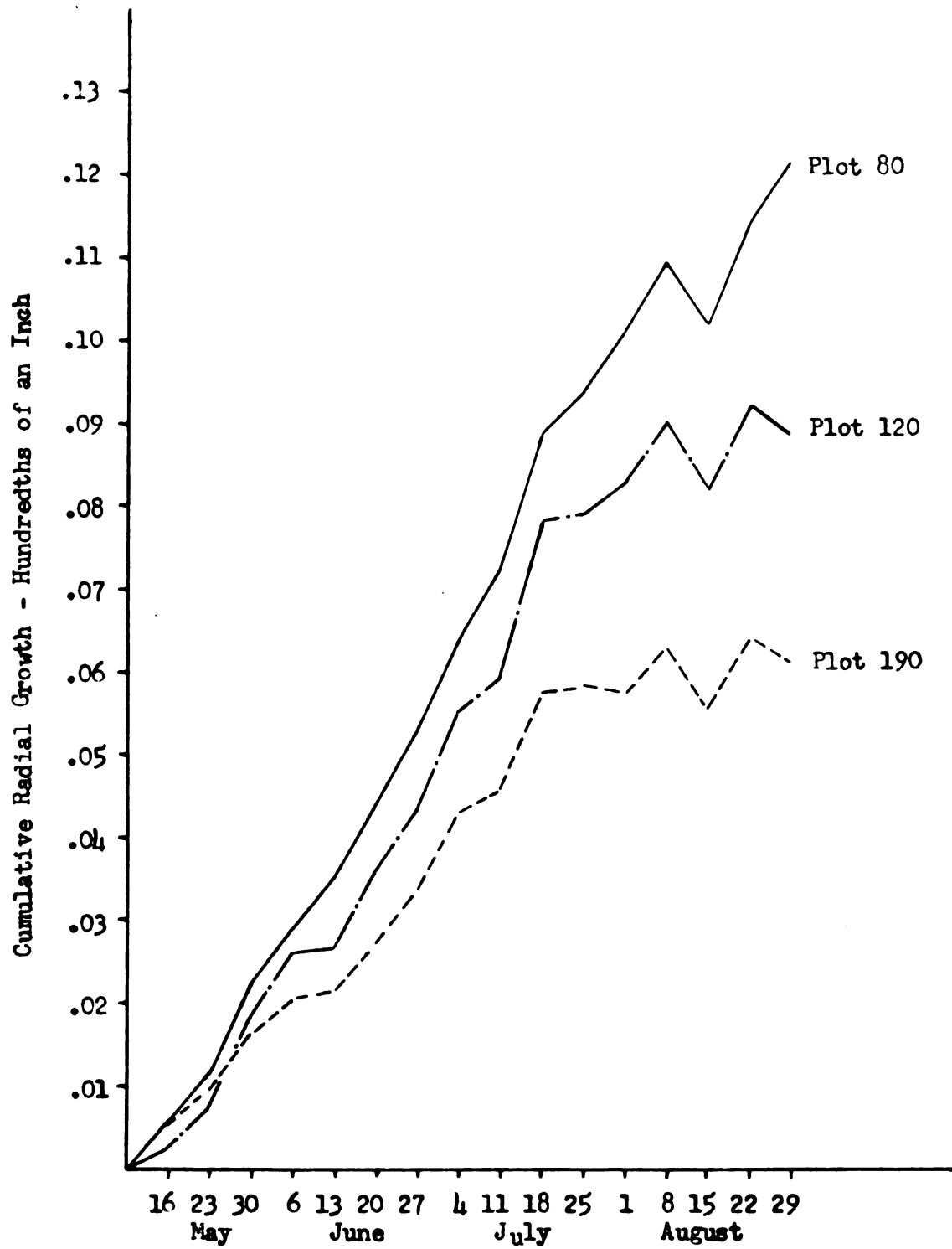


Figure 34. Cumulative Radial Growth Curves for 1953.

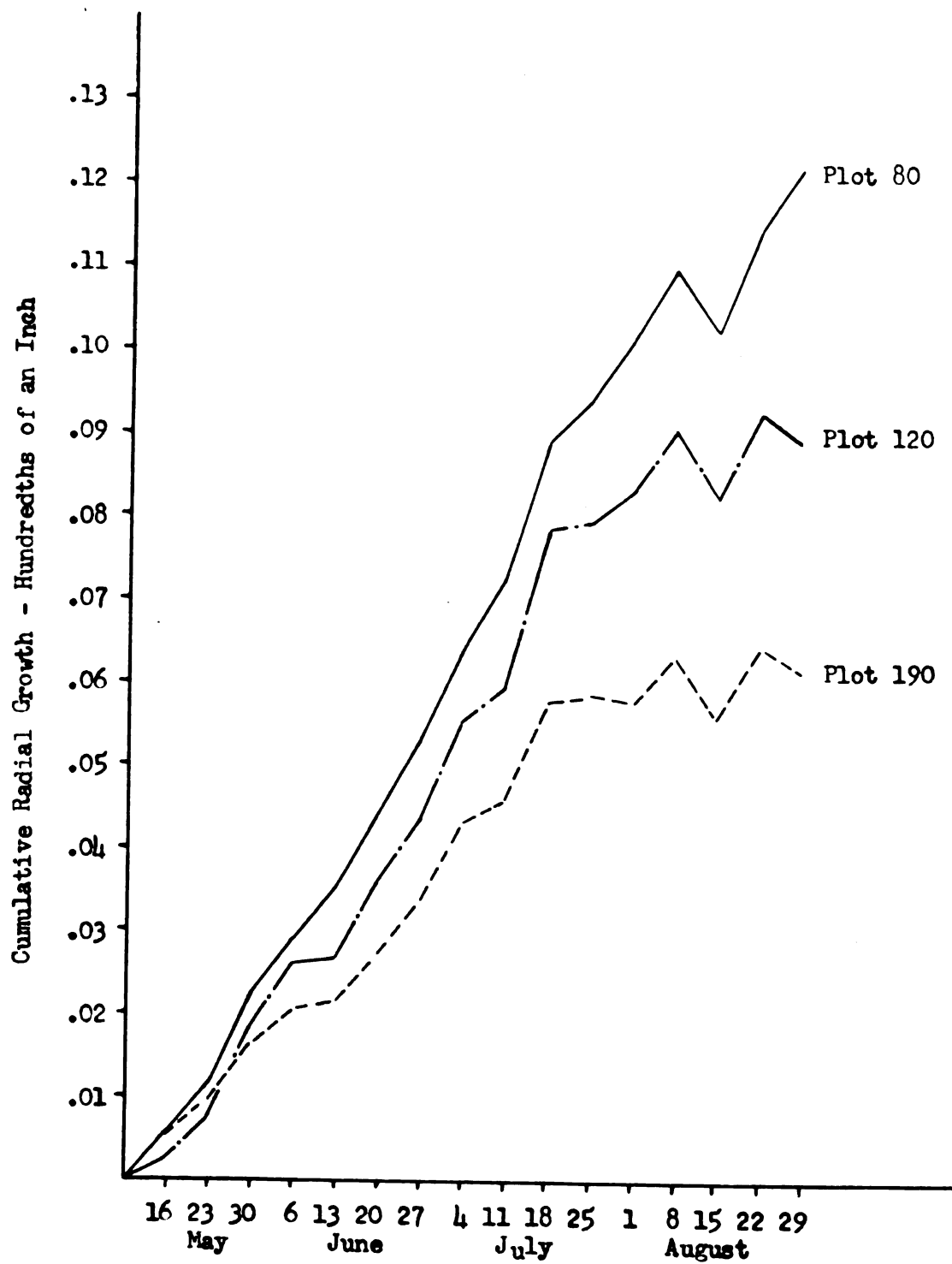


Figure 34. Cumulative Radial Growth Curves for 1953.

From July 4-11 another decrease in the growth rate occurred in plots 120 and 190. This, too, was a period of low rainfall and the moisture content of the soil showed a decrease.

A very marked decrease in growth occurred during the week of July 18-25 in plots 120 and 190. Plot 80 showed only a very slight decrease. The rainfall which fell for the period occurred only on the first and last days of the period. The soil moisture trend for the period at the six inch depth shows a general rise. However, since the soil samples were collected soon as the rain had ceased on July 25, the soil moisture curve would show a general increase for the period. The best trend for the period is shown by the moisture curves for the 18 and 36 inch depths because the heavy rainfall which fell on the area during the morning of July 25 had not changed the soil moisture situation at those depths. The soil moisture trend for the period can be considered as a general decrease. On July 25 the soil moisture curves show the lowest soil moisture percentage recorded at the 18 inch depth for both plot 120 and 190. Also, at the 36 inch depth very low moisture percentages were recorded for these two plots. A shortage of soil moisture for the period evidently caused the decrease in the growth rate for the two plots. Plot 80, in which only a slight decrease in the growth rate occurred, shows an increase in soil moisture for the 6 and 18 inch depths for the period. At 36 inches the moisture content remained unchanged for this plot.

From July 25 to August 1 only 0.06 of an inch of rain fell. The growth curve for the period shows that plots 120 and 80 increased

their growth rate. Plot 190 showed a recession. The moisture curves for the period show a general decrease in soil moisture. At the six inch depth, plot 190 on August 1 had the lowest soil moisture content recorded at that depth for the red pine plots during the entire course of the study. The rainfall on July 25 of 1.03 inches must have been in sufficient quantity to satisfy the growth requirements of the trees on plots 120 and 80 so as to cause the trees to show an increase in growth for the week. Evidently the dry condition of the soil at the 18 and 36 inch depths in plot 190, in addition to the large number of trees per acre on this plot, had created a growth moisture requirement which could not be adequately supplied by the rainfall of July 25.

On August 15 a recession occurred in all three plots. A similar recession was reported by Dils (1952). By August 22 all the plots showed a slight gain above the amount recorded for August 8. However, on August 29, plots 120 and 190 showed a recession of radial growth; plot 80 continued its trend of the previous week and showed additional radial growth. From August 8-29 there was a weekly decrease in rainfall until by August 29 the soil moisture content of all the plots was nearly the same at all three depths.

What caused the general growth recession in all plots on August 15 is not known. Neither is the reason known why plot 80 showed a radial growth increase at such a favorable rate on August 29, while plots 120 and 190 receded for a second and third time respectively. Possibly the recessions are associated with termination of growth.

At the six inch depth, plot 190 was at the same moisture content as on August 1, when it receded in radial growth for the first time. Plot 80 for the period of August 22-29 showed a higher soil moisture content at the six inch depth than either plots 120 or 190. Possibly this slight moisture advantage coupled with the light rainfall for the period may have provided enough moisture for the riser roots to supply the growth requirements for the plot. It is also probable that some compensating factor, such as soil temperature or the amount of light received by the plot, may have aided plot 80 to show additional growth. The soil temperature curves show a distinct decrease in the soil temperature on August 15, the date of the major recession, for all three plots. By August 29, plot 80 showed a distinct increase in soil temperature at all three levels and was obviously warmer at all three soil depths than plots 120 and 190.

Statistically, the radial growth for the entire season was not significant.

Analysis of Variance of Radial Growth

Source	Degrees of Freedom	Sum of Squares	Mean Square	F	F Book
Total	47	153,742			
Between	2	11,519	5,759.5	1.822	3.21
Within	45	142,223	3,160.5		

Examination of Table V will disclose the fact that the within error was so large as to make the analysis of variance insignificant.

TABLE V-A. Radial Growth per Diameter Class per Plot.

D.B.H. class	Plot 80	Plot 120	Plot 190
(Inches)		(Inches)	
6	0.117	0.062	0.041
7	0.122	0.088	0.072
8	0.134	0.100	0.125

The radial growth data showed that for trees with a six inch diameter the rate of growth was 2.8 times faster three years after thinning from 190 to 80 basal area. From a basal area of 190 to 120 the rate for six inch trees was 1.5 times faster. For seven inch trees the comparable rates were 1.7 and 1.2; for eight inch trees the rate in reducing the basal area from 190 to 80 was 1.1. For the small six inch trees, reducing the basal area of the stand from 190 to 80 square feet resulted in almost tripling the growth rate. The dominant eight inch trees showed practically no increase. Within the same plot the larger diameter trees showed the largest growth rates. The less basal area the plots contained the greater was the rate of growth.

On August 29, five increment cores were collected at random from dominant trees in each of the three plots. The analysis of variance for the 15 cores shows that there is a significant difference between the number of growth rings in the last inch for the cores collected.

1. The first part of the report is a general statement of the purpose of the study.

2. The second part of the report is a description of the methods used in the study.

3. The third part of the report is a description of the results of the study.

4. The fourth part of the report is a discussion of the results of the study.

5. The fifth part of the report is a conclusion of the study.

6. The sixth part of the report is a list of references.

7. The seventh part of the report is a list of appendices.

8. The eighth part of the report is a list of figures.

9. The ninth part of the report is a list of tables.

10. The tenth part of the report is a list of footnotes.

11. The eleventh part of the report is a list of abbreviations.

12. The twelfth part of the report is a list of symbols.

13. The thirteenth part of the report is a list of equations.

14. The fourteenth part of the report is a list of definitions.

15. The fifteenth part of the report is a list of acknowledgments.

16. The sixteenth part of the report is a list of references.

17. The seventeenth part of the report is a list of appendices.

18. The eighteenth part of the report is a list of figures.

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20. The twentieth part of the report is a list of footnotes.

21. The twenty-first part of the report is a list of abbreviations.

22. The twenty-second part of the report is a list of symbols.

23. The twenty-third part of the report is a list of equations.

24. The twenty-fourth part of the report is a list of definitions.

25. The twenty-fifth part of the report is a list of acknowledgments.

Analysis of Variance for Increment Cores

Source	Degrees of Freedom	Sum of Squares	Mean Square	F	F Book
Total	14	6,666			
Between	2	2,976	1,488.0	4.84*	3.88
Within	12	3,690	307.5		

The mean number of growth rings in the last inch for the cores collected from each of the three plots is as follows: Plot 80, 10.36 rings; plot 120, 12.78 rings; and plot 190, 13.70 rings. Growth was best in plot 80. Plot 190 showed the least growth; plot 120 had an intermediate growth rate, but tended toward the growth rate of plot 80 (Figure 34). By July 18 growth had practically ceased in plot 190. Growth continued in plot 80 until about August 8, thereafter no important growth gain was made. In plot 80, on August 29, was still progressing. A heavy density of stocking (large basal area) appears to reduce the length of the growing period for the stand. Forty-year old red pine stands at an average stocking of 80 square feet of basal area grow relatively satisfactorily on Grayling sand, gravelly phase.

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MEMORANDUM FOR THE DIRECTOR

Subject: [Illegible]

Reference is made to [Illegible]

On [Illegible]

[Illegible]

- 1. [Illegible]
- 2. [Illegible]
- 3. [Illegible]

It is recommended that [Illegible]

The [Illegible]

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SUMMARY AND CONCLUSIONS

A soil moisture study was made in a 44-year old red pine (Pinus resinosa Ait.) plantation during the winter, spring, and summer months of 1953. The plantation is located on the Higgins Lake State Forest in Crawford County, Michigan. The trees are growing on Grayling sand, gravelly phase; the area is relatively level and is geologically classed as an outwash plain. The soil moisture content was determined for the soil at the 6, 18, and 36 inch depths. The soil samples were collected at weekly intervals during the growing season from three red pine stands within the plantation which had basal areas of 190, 120, and 80 square feet, respectively, and from an adjacent open field.

The soil moisture content for the soil samples was computed as a percent of oven-dry weight. Weekly resistance readings were taken using the Bouyoucos portable soil moisture bridge with Bouyoucos nylon electrical resistance units. The units had been interred since November, 1952. Measurements were taken from February 28 until August 29, 1953. Previous to the month of May, measurements were taken at two-week intervals.

In addition to soil moisture determinations, measurements and observations were made to determine the depth of snow accumulation, rate of snow melting, precipitation, soil temperature, and radial growth of the red pine.

1. Snow accumulations were deeper in plot 80 than in plot 190; however, the rate of melting was greater in plot 80 than in plot 190. The snow cover had considerable influence on the supply of moisture

present in the plots; it remained longer in plot 190 than in the other two plots,

2. During the early spring months plot 190 had a consistantly higher soil moisture content at all three depths than did plots 120, 80, or the open field. This was due to the snow covere it contained and to the slow rate of melting. During the month of August, plot 190 had the lowest soil moisture content at all three depths.

3. The rapid loss of snow cover in plot 80 resulted in an early decrease in the rate of increase of its soil moisture supply at the six inch depth. At the same time it produced decreases in soil moisture content at the 18 and 36 inch depths. A gradual decrease in moisture content in plot 80 at the 36 inch depth was evident from March 26 until May 16; during this period and at this depth it had the lowest moisture content of any of the plots.

4. Plot 80 had the highest moisture content at the six inch depth 82.4 percent of the weeks during the growing season; plot 120, 11.8 percent; and plot 190, 5.8 percent. From July until September the usual trend among the plots at the 18 inch depth was a decrease in soil moisture with increasing basal area.

5. After June 20 the open field had the most soil moisture at the 36 inch depth. Soil moisture fluctuations were greatest in the open field.

6. Soil moisture fluctuations and differences between the plots were greatest from July 18 to August 22, they occurred at the six inch depth.

7. There was a gradual decrease in soil moisture at all three depths from April 1 to August 29. On August 29 the soil moisture supply was extremely low at all three depths; all the plots and the open field were at a moisture content of approximately 2.7 percent at the six and 18 inch depths. At the 36 inch depth the average moisture content for all plots was approximately 2.0 percent. Considering the area as a whole, on August 29 the soil was at its most critical moisture level and tended to be nearly uniform throughout all the plots, including the open field; in addition, it was nearly uniform in moisture content at all three depths.

8.

TABLE II-D. Maximum and Minimum Soil Moisture Percentages (Percent of Oven-dry Weight).

Plot	6 inch depth				18 inch depth				36 inch depth			
	Max.	Date	Min.	Date	Max.	Date	Min.	Date	Max.	Date	Min.	Date
190	10.80	3/31	2.57	8/29	7.46	4/18	2.35	7/25	7.70	3/31	1.66	8/29
120	10.65	3/31	2.69	8/29	7.89	5/2	2.58	8/1	6.35	5/2	2.10	8/29
80	10.84	5/2	2.92	8/29	6.91	3/31	2.73	8/29	5.83	3/26	2.22	8/29
Open	10.82	7/25	2.46	8/29	8.40	5/2	2.22	8/29	8.74	6/6	2.77	8/29

9. Laboratory calibration curves for the nylon electrical resistance unit which will properly represent field conditions have not been developed for Grayling sand, gravelly phase.

1. The first part of the document is a letter from the President of the United States to the Congress, dated January 3, 1862. It is a very important document, as it contains the President's annual message to Congress. The letter is written in a very formal and dignified style, and it is one of the most important documents in the history of the United States. It is a very long letter, and it covers a wide range of topics, including the state of the Union, the progress of the government, and the President's plans for the future. The letter is a very important document, as it contains the President's annual message to Congress. It is a very long letter, and it covers a wide range of topics, including the state of the Union, the progress of the government, and the President's plans for the future.

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10. Empirical field-calibration curves have been developed for Grayling sand, gravelly phase.

11. Many nylon resistance units are needed to adequately sample the moisture content of an area.

12. Fewer units are needed as the depth to which the units are interred is increased.

13. A separate empirical field-calibrated curve is needed for each depth to which units are interred.

14. The nylon electrical resistance units should be interred dry, preferably in the fall when Grayling sands are dry.

15. The nylon electrical resistance units require several months before they become stabilized to the soil conditions surrounding them.

16. Nylon electrical resistance units can respond quickly to sudden moisture changes under field conditions.

17. Perhaps the best use of the nylon electrical resistance unit in a sand soil is as an indicator of broad relative soil moisture conditions rather than an actual moisture content.

18. Temperatures at all three depths in the open field were decidedly higher than the temperatures in any of the red pine plots.

19. From April 18 to June 20 an approximate rise in soil temperature of four degrees Fahrenheit per week occurred.

20. The curves at the 18 inch depth have nearly the same trend as those at the six inch depth.

21. After July 4 the trend indicated for all the plots at all three depths was a general leveling of the temperature curves.

22. Temperature fluctuations at the 36 inch depth are notably less when compared to those at the six and 18 inch depths for similar periods.

23. The recorded soil temperatures for the red pine plots at the six inch depth were never below 32°F. nor above 71°F.; at the 36 inch depth they were never below 34°F. nor above 60.5°F.

24. In the open field the maximum and minimum temperatures were 72°F. and 36.5°F., respectively, for the 6 inch depth; at the 36 inch depth the maximum was 66°F. and the minimum 38°F.

25. An approximation of the mean temperature for the period July 25 to August 29 at the 6, 18, and 36 inch depths would be 62, 59, and 58°F., respectively.

26. The general trend in order of decreasing soil temperatures at all three depths was plot 80, 120, and 190.

27. Radial growth began when the plots were at an approximate minimum temperature of 47.5 °F. at the six inch depth; and a minimum temperature of 43°F. at the 36 inch depth.

28. During the first week radial growth occurred, plot 120 showed the least growth; this was not a characteristic trend for plot 120, and a consequent inspection of the temperature graphs revealed the fact that the plot showed the lowest soil temperatures recorded at the 6 and 36 inch depths for that week.

29. During the week growth began the maximum and minimum air temperatures were 79°F. and 50°F., respectively; the mean temperature for the week was 64.1°F. No precipitation occurred during the week so it is assumed that the maximum amount of sunlight occurring for that

week at that latitude was available for photosynthesis.

30. Plot 80 produced the best radial growth; plot 120 followed, and plot 190 showed the least radial growth.

31. There were three periods previous to August 15 when plots 120 and 190 showed greatly reduced growth rates. This was attributed to a lack of sufficient soil moisture in the plots.

32. Radial growth practically ceased in plot 190 by July 25.

33. A general radial growth recession occurred in all plots on August 15; there was a slight drop in soil temperature in the plots on that date.

34. On August 29 radial growth receded again in plots 120 and 190; plot 80 continued to add radial growth at a comparatively rapid rate. Plot 80 showed a definite increase in soil temperatures on that date, which were larger than the soil temperature increases shown for plots 120 and 190.

35. The radial growth data showed that thinning from a basal area of 190 square feet to 80 square feet the growth rate almost tripled for 6 inch d.b.h. trees; for 8 inch d.b.h. trees the increase was very slight.

36. The growth rate for dominant trees increases only slightly when thinnings are made.

37. Within the same plots, the dominant trees showed the best growth.

38. Reducing the density of the stand increased the total radial growth rate for the stand.

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■ 2007年10月1日起，凡在境内销售货物或提供应税劳务、服务、无形资产、不动产的单位和个人，均应按照《增值税暂行条例》和《营业税暂行条例》的有关规定，分别缴纳增值税和营业税。

1. The first group of variables, *demographic*, includes age, sex, and marital status. The second group, *education*, includes years of schooling and the highest level of education completed. The third group, *employment*, includes whether the respondent is employed, the type of employment, and the number of hours worked per week. The fourth group, *income*, includes the respondent's annual income and the number of people in the household. The fifth group, *health*, includes the respondent's self-rated health and whether the respondent has any chronic health conditions. The sixth group, *social capital*, includes the respondent's level of social capital and whether the respondent is a member of any social organizations. The seventh group, *subjective well-being*, includes the respondent's life satisfaction and whether the respondent is happy. The eighth group, *mental health*, includes the respondent's mental health status and whether the respondent has any mental health problems. The ninth group, *physical health*, includes the respondent's physical health status and whether the respondent has any physical health problems. The tenth group, *quality of life*, includes the respondent's quality of life and whether the respondent is satisfied with their life.

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1. The first part of the document is a title page. It contains the title "THE HISTORY OF THE UNITED STATES OF AMERICA" and the author "BY JAMES M. SMITH".

1. *Pharmaceutical industry*—United States—History. I. Title. II. Series.

Journal of Management Studies, 20(6), 791-806
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• How to use the book

[illegible][illegible]

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APPENDIX

- A. Data recorded within or collected from the red pine plantation designated for thinning studies by the U. S. Forest Service at Higgins Lake State Forest, Michigan.
- B. Data recorded at U. S. Weather Bureau cooperative weather station at Higgins Lake, Michigan.
- C. Data recorded for the laboratory calibration experiments with the Bouyoucos nylon electrical resistance unit.
- D. Plot diagrams.

APPENDIX A

TABLE I. Cumulative weekly rainfall, 1953.

Dates (inclusive)	Rainfall (Inches)
May 2-9	0.03
10-16	0.37
17-23	1.46
24-30	1.52
May 31-June 6	1.65
June 7-13	0.19
14-20	0.48
21-27	0.51
June 28-July 4	2.64
July 5-11	0.34
12-18	0.95
19-25	0.07
July 26-August 1	0.08
August 2-8	1.57
9-15	0.78
16-22	0.34
23-29	0.17
Total	13.15

TABLE II-A. Soil moisture averages from soil samples at the 6 inch depth expressed as percent of oven-dry weight.

Date Collected	Plot 80	Plot 120	Plot 190	Open Field
February 28	7.56	6.82	8.49	
March 26	8.99	9.24	9.77	
31	8.82	10.65	10.80	8.83
April 18	9.31	9.56	9.43	10.39
May 2	10.84	10.33	8.95	10.94
9	7.86	7.47	6.19	7.80
16	7.66	6.29	5.64	7.85
23	8.77	7.00	6.77	7.71
30	8.72	8.82	9.13	10.06
June 6	9.92	8.62	8.88	10.53
13	7.43	6.80	6.16	6.85
20	5.54	5.18	4.17	5.72
27	5.70	4.65	4.14	6.53
July 4	8.00	7.20	7.34	7.64
11	5.10	4.25	3.88	3.73
18	7.29	6.49	5.76	8.44
25	7.57	8.98	6.58	10.77
August 1	4.41	3.01	2.65	3.11
8	8.45	7.08	5.41	10.82
15	6.35	6.61	4.12	10.58
22	4.86	3.57	3.12	3.80
29	2.92	2.69	2.57	2.46
Total	162.07	151.31	139.95	154.56

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TABLE II-B. Soil moisture averages from soil samples at the 18 inch depth expressed as percent of oven-dry weight.

Date Collected	Plot 80	Plot 120	Plot 190	Open Field
February 28	5.09	5.57	7.10	
March 26	6.66	6.94	7.35	
31	6.91	7.89	8.37	5.79
April 18	6.12	6.70	7.46	5.70
May 2	6.67	7.19	7.46	8.40
9	5.68	5.37	5.70	4.92
16	5.17	4.53	4.91	5.76
23	5.55	6.23	5.69	6.61
30	6.75	7.44	7.17	7.55
June 6	6.40	7.62	7.15	6.27
13	5.22	5.27	5.33	4.43
20	4.44	4.54	5.36	4.74
27	4.47	3.71	3.31	3.90
July 4	5.97	5.64	5.75	4.99
11	4.35	4.25	3.95	3.55
18	3.32	3.62	3.15	3.76
25	5.19	2.72	2.35	3.54
August 1	3.05	2.58	2.57	2.52
8	3.46	3.24	2.62	2.90
15	3.33	3.22	2.86	6.48
22	3.30	2.90	2.91	5.49
29	2.73	2.85	2.48	2.22
Total	109.8	110.0	111.0	99.52

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TABLE II-C. Soil moisture averages from soil samples at the 36 inch depth expressed as percent of oven-dry weight.

Date Collected	Plot 80	Plot 120	Plot 190	Open Field
February 28	4.81	4.71	7.39	
March 26	5.83	4.93	7.49	
31	5.08	5.28	7.70	6.47
April 18	4.79	6.12	5.19	6.24
May 2	4.74	6.35	6.67	7.19
9	4.64	4.87	5.23	5.77
16	4.17	3.84	4.59	3.54
23	4.69	4.40	4.57	4.15
30	4.57	4.87	4.61	7.42
June 6	5.18	5.68	4.13	8.74
13	4.31	5.68	5.70	4.65
20	3.64	3.30	4.99	4.17
27	3.49	3.56	3.97	7.84
July 4	4.20	3.49	5.35	8.20
11	3.94	3.57	3.54	4.24
18	3.09	2.85	3.15	5.38
25	3.13	2.45	2.39	4.30
August 1	2.61	2.31	2.72	2.90
8	3.09	2.90	2.27	3.84
15	2.73	3.00	1.88	4.02
22	2.30	2.25	1.69	4.44
29	2.22	2.10	1.66	2.77
Total	87.3	88.5	96.9	106.27

TABLE III-A. Bouyoucos nylon block resistance averages at the 6 inch depth.

Date Recorded	Plot 80	Plot 120	Plot 190	Open Field
(OHMS)				
February 28	16,000	90,500	23,000	15,000
March 26	18,000	45,000	22,000	39,000
31	17,000	41,000	21,000	16,000
April 18	14,500	31,000	18,000	13,500
May 2	14,000	30,000	19,000	16,000
9	17,000	41,000	40,000	18,000
16	29,000	145,000	190,000	18,000
23	19,000	76,000	46,000	18,000
30	16,000	50,000	24,000	12,500
June 6	14,500	29,000	23,000	14,000
13	20,500	98,000	69,000	24,000
20	54,000	310,000	360,000	66,000
27	98,000	570,000	115,000	72,000
July 4	45,000	66,000	35,000	34,000
11	72,000	340,000	310,000	240,000
18	150,000	310,000	24,000	23,000
25	100,000	260,000	23,000	26,500
August 1	160,000	320,000	320,000	480,000
8	180,000	160,000	15,000	16,000
15	38,000	134,000	55,000	28,000
22	78,000	370,000	270,000	36,000
29	260,000	360,000	440,000	490,000

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26	27	28	29	30
31	32	33	34	35
36	37	38	39	40
41	42	43	44	45
46	47	48	49	50
51	52	53	54	55
56	57	58	59	60
61	62	63	64	65
66	67	68	69	70
71	72	73	74	75
76	77	78	79	80
81	82	83	84	85
86	87	88	89	90
91	92	93	94	95
96	97	98	99	100

TABLE III-B. Bouyoucos nylon block resistance averages at the 18 inch depth.

Date Recorded	Plot 80	Plot 120	Plot 190	Open Field
(OHMS)				
February 28	13,000	22,000	14,000	16,000
March 26	13,000	19,000	14,000	25,000
31	12,000	20,000	13,000	12,500
April 18	11,500	18,000	14,500	12,500
May 2	11,500	19,000	16,000	13,000
9	12,000	20,000	18,000	14,000
16	18,000	42,000	84,000	13,000
23	13,000	40,000	64,000	10,500
30	13,000	44,000	64,000	9,200
June 6	11,500	28,000	30,000	9,400
13	13,000	31,000	37,000	8,600
20	36,000	110,000	220,000	15,000
27	160,000	370,000	350,000	29,000
July 4	27,000	300,000	66,000	21,000
11	52,000	26,000	240,000	26,000
18	310,000	580,000	480,000	320,000
25	330,000	510,000	430,000	390,000
August 1	300,000	1,000,000	350,000	440,000
8	390,000	440,000	290,000	460,000
15	141,000	344,000	310,000	94,000
22	290,000	540,000	400,000	250,000
29	430,000	610,000	350,000	400,000

TABLE III-B. Bouyoucos nylon block resistance averages at the 18 inch depth.

Date Recorded	Plot 80	Plot 120	Plot 190	Open Field
(OHMS)				
February 28	13,000	22,000	14,000	16,000
March 26	13,000	19,000	14,000	25,000
31	12,000	20,000	13,000	12,500
April 18	11,500	18,000	14,500	12,500
May 2	11,500	19,000	16,000	13,000
9	12,000	20,000	18,000	14,000
16	18,000	42,000	84,000	13,000
23	13,000	40,000	64,000	10,500
30	13,000	44,000	64,000	9,200
June 6	11,500	28,000	30,000	9,400
13	13,000	31,000	37,000	8,600
20	36,000	110,000	220,000	15,000
27	160,000	370,000	350,000	29,000
July 4	27,000	300,000	66,000	21,000
11	52,000	26,000	240,000	26,000
18	310,000	580,000	480,000	320,000
25	330,000	510,000	430,000	390,000
August 1	300,000	1,000,000	350,000	440,000
8	390,000	440,000	290,000	460,000
15	141,000	344,000	310,000	94,000
22	290,000	540,000	400,000	250,000
29	430,000	610,000	350,000	400,000

TABLE III-C. Bouyoucos nylon block resistance averages at the
36 inch depth.

Date Recorded	Plot 80	Plot 120	Plot 190	Open Field
(OHMS)				
February 28	13,000	12,000	10,000	13,000
March 26	12,000	10,500	8,500	23,000
31	12,000	15,000	8,000	13,500
April 18	12,000	11,000	8,500	13,000
May 2	12,000	12,000	8,500	14,000
9	11,500	11,000	8,200	15,000
16	12,500	12,500	10,000	15,000
23	11,500	12,500	10,000	13,500
30	13,000	13,000	12,000	15,000
June 6	11,500	13,000	12,500	16,000
13	11,500	12,000	9,400	15,000
20	13,000	15,000	16,000	19,000
27	13,500	34,000	54,000	19,000
July 4	12,000	36,000	76,000	19,000
11	13,000	39,000	70,000	19,500
18	14,500	110,500	160,000	23,000
25	16,000	350,000	380,000	27,000
August 1	16,000	240,000	310,000	28,000
8	21,000	390,000	540,000	38,000
15	21,000	390,000	400,000	40,000
22	26,000	390,000	490,000	46,000
29	32,000	270,000	370,000	52,000

TABLE IV-A. Soil temperature at the 6 inch depth.

Date Recorded	Plot 80	Plot 120	Plot 190	Open Field
(Degrees Fahrenheit)				
February 28	32			
March 26	32.5			
31	36.5	33.0	32.5	36.5
April 18	33.5	34.0	32.5	37.0
May 2	40.5	39.5	39.0	44.5
9	51.0	49.0	49.5	66.0
16	50.0	46.0	47.0	58.0
23	48.0	49.0	46.5	56.0
30	50.0	51.0	45.0	52.0
June 6	55.0	54.0	52.5	59.0
13	57.5	55.5	54.5	64.0
20	71.0	68.5	66.0	70.0
27	60.0	60.5	58.5	66.0
July 4	61.5	60.5	58.0	69.5
11	62.0	61.0	57.5	68.0
18	66.0	66.0	63.0	72.0
25	59.5	59.0	58.0	64.5
August 1	62.5	62.0	62.5	68.0
8	62.0	61.0	60.0	62.0
15	61.0	60.5	60.0	64.5
22	61.5	60.5	60.5	67.5
29	65.5	63.0	62.5	69.5

• *Journal of the American Medical Association*, 2000; 284: 1039-1044

1. The first step is to identify the problem. In this case, the problem is that the company is not meeting its sales targets.

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TABLE IV-B. Soil temperature at the 18 inch depth.

| Date Recorded | Plot 80 | Plot 120 | Plot 190 | Open Field |
|----------------------|---------|----------|----------|------------|
| (Degrees Fahrenheit) | | | | |
| June 20 | 66 | 61 | 59 | 67 |
| 27 | 58 | 56 | 54 | 62 |
| July 4 | 57.5 | 58 | 56 | 64 |
| 11 | 59 | 58.5 | 56 | 65 |
| 18 | 63 | 62 | 61 | 68 |
| 25 | 58 | 57 | 56 | 64 |
| August 1 | 60 | 59 | 59 | 66 |
| 8 | 60 | 60 | 58 | 66 |
| 15 | 59 | 59 | 58 | 64 |
| 22 | 58.5 | 59 | 57 | 64 |
| 29 | 62 | 61 | 59.5 | 69.5 |

TABLE IV-C. Soil temperature at the 36 inch depth.

| Date Recorded | Plot 80 | Plot 120 | Plot 190 | Open Field |
|----------------------|---------|----------|----------|------------|
| (Degrees Fahrenheit) | | | | |
| February 28 | 35 | .. | .. | .. |
| March 26 | 34.5 | .. | .. | .. |
| 31 | 38 | 34 | 34.5 | 38 |
| April 18 | 36 | 35.5 | 34.5 | 38 |
| May 2 | 38.5 | 38.5 | 37.5 | 41 |
| 9 | 43 | 43 | 43 | 48 |
| 16 | 45 | 43 | 43 | 49 |
| 23 | 45 | 45 | 44 | 51 |
| 30 | 49 | 48 | 46 | 53 |
| June 6 | 50 | 48 | 47.5 | 56.5 |
| 13 | 52.5 | 51.5 | 49.5 | 58 |
| 20 | 58 | 55 | 55 | 66 |
| 27 | 56 | 55 | 53.5 | 62 |
| July 4 | 58 | 56.5 | 55 | 64 |
| 11 | 57.5 | 57 | 54.5 | 63.5 |
| 18 | 58.5 | 58 | 55 | 65 |
| 25 | 58.5 | 59 | 56 | 64.5 |
| August 1 | 59 | 58.5 | 58.5 | 65.5 |
| 8 | 59 | 59 | 57 | 65 |
| 15 | 58 | 58 | 57 | 63.5 |
| 22 | 58 | 57.5 | 57 | 63.5 |
| 29 | 60.5 | 59.5 | 57.5 | 65.5 |

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TABLE V. Average radial growth gains and losses as computed from the dendrometer recordings.

| Date Recorded | Plot 80 | Plot 120 | Plot 190 |
|---------------------|----------|----------|----------|
| | (Inches) | | |
| May 16 | +0.0055 | +0.0025 | +0.0052 |
| 23 | +0.0058 | +0.0053 | +0.0043 |
| 30 | +0.0113 | +0.0104 | +0.0066 |
| June 6 | +0.0068 | +0.0064 | +0.0045 |
| 13 | +0.0064 | +0.0021 | +0.0011 |
| 20 | +0.0088 | +0.0097 | +0.0062 |
| 27 | +0.0093 | +0.0074 | +0.0060 |
| July 4 | +0.0106 | +0.0119 | +0.0093 |
| 11 | +0.0058 | +0.0040 | +0.0028 |
| 18 | +0.0193 | +0.0188 | +0.0119 |
| 25 | +0.0046 | +0.0007 | +0.0006 |
| August 1 | +0.0073 | +0.0038 | -0.0009 |
| 8 | +0.0085 | +0.0074 | +0.0054 |
| 15 | -0.0080 | -0.0083 | -0.0076 |
| 22 | +0.0128 | +0.0099 | +0.0089 |
| 29 | +0.0073 | -0.0034 | -0.0028 |
| Total radial growth | +0.1221 | +0.0886 | +0.0615 |

TABLE VI. Air temperatures and rainfall as recorded at the U. S. Weather Bureau Cooperative Station at Higgins Lake, Michigan. 1953.

| Date | May | | June | | July | | August | |
|-------|-----|--------------------|------|--------------------|------|--------------------|--------|--------------------|
| | °F | Rainfall
Inches | °F | Rainfall
Inches | °F | Rainfall
Inches | °F | Rainfall
Inches |
| 1 | 39 | 0.33 | 65 | 0.02 | 85 | 2.35 | 68 | T |
| 2 | 46 | 0.14 | 38 | 0 | 75 | 0 | 69 | 0.22 |
| 3 | 47 | 0.04 | 69 | 0 | 66 | 0 | 70 | 0 |
| 4 | 60 | | 70 | 0.82 | 76 | 0 | 65 | 0.72 |
| 5 | 70 | 0 | 71 | 0.12 | .. | 0.24 | 62 | T |
| 6 | 68 | 0 | 52 | 0.07 | .. | | 70 | 0 |
| 7 | 68 | 0 | 62 | 0.0 | .. | | 64 | 0 |
| 8 | 70 | T | 75 | 0.08 | .. | | 62 | 0.67 |
| 9 | 79 | 0 | 62 | T | .. | | 68 | 0 |
| 10 | 74 | 0 | 73 | 0 | 74 | 0 | 79 | 0 |
| 11 | 71 | 0 | 70 | 0 | 78 | 0 | 79 | 0 |
| 12 | 57 | 0.23 | 73 | | 82 | 0 | 72 | 0.63 |
| 13 | 50 | 0 | 72 | 0 | 82 | 0 | 67 | 0 |
| 14 | 54 | 0 | 73 | T | 77 | 0 | 83 | 0.06 |
| 15 | 64 | 0 | 61 | 0 | 79 | 0 | 71 | 0 |
| 16 | 62 | 0 | 65 | 0.36 | 78 | 0 | 68 | 0 |
| 17 | 53 | 0.15 | 72 | 0.04 | 81 | 0 | 71 | 0.01 |
| 18 | 63 | 1.28 | 71 | 0.04 | 78 | 0.82 | 75 | 0 |
| 19 | 61 | 0.06 | 78 | 0 | 78 | 0 | 75 | 0 |
| 20 | 61 | 0 | 82 | 0 | 78 | 0 | 80 | 0 |
| 21 | 53 | 0.07 | 79 | 0 | 80 | 0 | 63 | 0.20 |
| 22 | 51 | 0.02 | 75 | | 69 | 0.07 | 79 | 0 |
| 23 | 65 | 0 | 65 | 0 | 56 | 0 | 80 | 0 |
| 24 | 59 | 0 | 68 | 0 | 64 | 0 | 78 | 0 |
| 25 | 52 | 1.32 | 73 | 0.43 | 74 | 1.03 | 75 | 0.28 |
| 26 | 49 | 0.04 | 77 | 0 | 79 | T | 80 | 0 |
| 27 | 60 | 0 | 75 | 0 | 74 | 0 | 85 | 0 |
| 28 | 60 | 0 | 72 | 0.35 | 70 | 0.06 | 85 | 0 |
| 29 | 59 | 0.26 | 73 | 0 | 76 | 0 | 85 | 0 |
| 30 | 52 | 0.09 | 73 | 0.38 | 74 | 0 | 79 | T |
| 31 | 59 | 0.04 | .. | | 79 | 0 | 78 | 0.14 |
| Total | | 4.07 | | 2.71 | | 4.57 | | 2.93 |

[illegible]

APPENDIX C

Table VII. Laboratory Calibration -- Using Stratified Nylon Electrical Resistance Units in a Sand -- Container Open Only at the Top.

| Date | Depth From Top of Container - Inches | | | | | | Soil
Moisture
Percent |
|---------------|--------------------------------------|-----|-------|--------|-----------|-----------|-----------------------------|
| | 6 | 5 | 4 | 3 | 2 | 1 | |
| Ohms at 72°F. | | | | | | | |
| March 7 | 130 | 50 | 50 | 50 | 75 | 125 | 23.0 |
| 8 | 70 | 60 | 60 | 70 | 120 | 230 | 21.8 |
| 9 | 60 | 70 | 70 | 90 | 180 | 250 | 20.0 |
| 10 | 70 | 90 | 110 | 120 | 220 | 275 | 18.7 |
| 11 | 80 | 90 | 120 | 130 | 225 | 270 | 17.7 |
| 12 | 80 | 90 | 125 | 130 | 220 | 260 | 16.7 |
| 13 | 80 | 90 | 130 | 190 | 225 | 260 | 15.5 |
| 14 | 90 | 100 | 130 | 140 | 230 | 260 | 14.5 |
| 15 | 90 | 90 | 125 | 140 | 230 | 250 | 13.4 |
| 16 | 90 | 90 | 125 | 140 | 240 | 250 | 12.3 |
| 17 | 90 | 90 | 120 | 130 | 220 | 240 | 11.3 |
| 18 | 90 | 90 | 120 | 125 | 200 | 230 | 10.4 |
| 19 | 90 | 90 | 110 | 125 | 200 | 225 | 9.4 |
| 20 | 100 | 80 | 110 | 110 | 125 | 190 | 8.1 |
| 22 | 110 | 80 | 90 | 100 | 150 | 175 | 5.7 |
| 23 | 120 | 90 | 90 | 100 | 150 | 210 | 4.6 |
| 25 | 125 | 100 | 110 | 110 | 160 | 460 | 3.9 |
| 27 | 130 | 110 | 110 | 120 | 170 | 4,000 | 3.4 |
| 28 | 140 | 110 | 110 | 125 | 190 | 14,300 | 3.2 |
| 29 | 140 | 110 | 110 | 120 | 190 | 9,500 | 3.0 |
| 30 | 140 | 110 | 110 | 120 | 225 | 11,100 | 2.9 |
| April 1 | 140 | 110 | 120 | 125 | 230 | 21,500 | 2.6 |
| 2 | 150 | 110 | 120 | 130 | 360 | 46,000 | 2.5 |
| 3 | 150 | 110 | 125 | 140 | 500 | 130,000 | 2.3 |
| 4 | 150 | 120 | 130 | 160 | 1,050 | 350,000 | 2.2 |
| 5 | 160 | 125 | 140 | 175 | 1,950 | 660,000 | 2.1 |
| 6 | 160 | 125 | 140 | 180 | 4,500 | 720,000 | 2.0 |
| 7 | 160 | 125 | 150 | 200 | 12,000 | 800,000 | 1.9 |
| 8 | 160 | 125 | 150 | 230 | 23,000 | 1,400,000 | 1.8 |
| 10 | 175 | 150 | 175 | 375 | 130,000 | 1,800,000 | 1.7 |
| 12 | 200 | 175 | 220 | 775 | 400,000 | | 1.6 |
| 14 | 225 | 200 | 280 | 2,225 | 500,000 | | 1.4 |
| 15 | 260 | 220 | 340 | 4,350 | 1,400,000 | | 1.3 |
| 17 | 350 | 325 | 600 | 12,500 | | | 1.1 |
| 19 | 525 | 575 | 1,350 | 22,500 | | | 1.0 |

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TABLE VIII. Laboratory Calibration -- Using Stratified Nylon Electrical Resistance Units in a Sand -- Container Open at Top and With Perforated Bottom.

| Date | Depth From Top of Container - Inches | | | | | | Soil
Moisture
Percent |
|---------------|--------------------------------------|--------|-------|-------|--------|---------|-----------------------------|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| Ohms at 75°F. | | | | | | | |
| June 14 | 150 | 80 | 40 | 25 | 50 | 50 | 22.7 |
| 15 | 170 | 125 | 50 | 25 | 30 | 40 | 21.1 |
| 16 | 190 | 150 | 75 | 60 | 60 | 50 | 18.1 |
| 17 | 210 | 175 | 100 | 80 | 90 | 90 | 16.2 |
| 18 | 225 | 175 | 120 | 100 | 100 | 100 | 14.4 |
| 19 | 225 | 175 | 120 | 110 | 130 | 100 | 12.7 |
| 21 | 225 | 190 | 140 | 130 | 140 | 130 | 11.4 |
| 23 | 225 | 210 | 160 | 150 | 160 | 150 | 9.2 |
| 24 | 225 | 220 | 170 | 170 | 175 | 160 | 8.1 |
| 25 | 230 | 225 | 175 | 175 | 175 | 170 | 7.5 |
| 26 | 250 | 250 | 180 | 175 | 180 | 175 | 6.7 |
| 28 | 275 | 290 | 210 | 190 | 200 | 200 | 5.4 |
| 30 | 340 | 350 | 260 | 250 | 250 | 260 | 4.2 |
| July 2 | 550 | 470 | 320 | 310 | 320 | 330 | 3.0 |
| 3 | 1,110 | 580 | 360 | 350 | 375 | 475 | 2.3 |
| 5 | 6,300 | 1,050 | 480 | 475 | 580 | 1,650 | 1.7 |
| | 9,200 | 1,200 | 510 | 500 | 650 | 2,250 | 1.6 |
| 6 | 30,000 | 2,700 | 775 | 700 | 1,250 | 9,000 | 1.4 |
| 7 | 120,000 | 7,200 | 1,275 | 1,100 | 3,100 | 41,000 | 1.1 |
| 8 | 300,000 | 24,000 | 2,900 | 2,300 | 11,700 | 300,000 | 0.8 |
| 9 | 940,000 | 44,000 | 7,200 | 4,750 | 30,500 | 780,000 | 0.7 |

TABLE VIII. Laboratory Calibration -- Using Stratified Nylon Electrical Resistance Units in a Sand -- Container Open at Top and With Perforated Bottom.

| Date | Depth From Top of Container - Inches | | | | | | Soil
Moisture
Percent | |
|---------------|--------------------------------------|---------|--------|-------|-------|--------|-----------------------------|------|
| | 1 | 2 | 3 | 4 | 5 | 6 | | |
| Ohms at 75°F. | | | | | | | | |
| June | 14 | 150 | 80 | 40 | 25 | 50 | 50 | 22.7 |
| | 15 | 170 | 125 | 50 | 25 | 30 | 40 | 21.1 |
| | 16 | 190 | 150 | 75 | 60 | 60 | 50 | 18.1 |
| | 17 | 210 | 175 | 100 | 80 | 90 | 90 | 16.2 |
| | 18 | 225 | 175 | 120 | 100 | 100 | 100 | 14.4 |
| | 19 | 225 | 175 | 120 | 110 | 130 | 100 | 12.7 |
| | 21 | 225 | 190 | 140 | 130 | 140 | 130 | 11.4 |
| | 23 | 225 | 210 | 160 | 150 | 160 | 150 | 9.2 |
| | 24 | 225 | 220 | 170 | 170 | 175 | 160 | 8.1 |
| | 25 | 230 | 225 | 175 | 175 | 175 | 170 | 7.5 |
| | 26 | 250 | 250 | 180 | 175 | 180 | 175 | 6.7 |
| | 28 | 275 | 290 | 210 | 190 | 200 | 200 | 5.4 |
| July | 30 | 340 | 350 | 260 | 250 | 250 | 260 | 4.2 |
| | 2 | 550 | 470 | 320 | 310 | 320 | 330 | 3.0 |
| | 3 | 1,110 | 580 | 360 | 350 | 375 | 475 | 2.3 |
| | 5 | 6,300 | 1,050 | 480 | 475 | 580 | 1,650 | 1.7 |
| | | 9,200 | 1,200 | 510 | 500 | 650 | 2,250 | 1.6 |
| | 6 | 30,000 | 2,700 | 775 | 700 | 1,250 | 9,000 | 1.4 |
| | 7 | 120,000 | 7,200 | 1,275 | 1,100 | 3,100 | 41,000 | 1.1 |
| | 8 | 300,000 | 24,000 | 2,900 | 2,300 | 11,700 | 300,000 | 0.8 |
| | 9 | 940,000 | 44,000 | 7,200 | 4,750 | 30,500 | 780,000 | 0.7 |

1. The first part of the document is a list of names and their corresponding addresses. The names are listed in the left column, and the addresses are listed in the right column. The names are: John Doe, Jane Smith, and Bob Johnson. The addresses are: 123 Main St, 456 Elm St, and 789 Oak St.

2. The second part of the document is a table with two columns. The first column is labeled "Name" and the second column is labeled "Address". The table contains the following data:

| Name | Address |
|-------------|-------------|
| John Doe | 123 Main St |
| Jane Smith | 456 Elm St |
| Bob Johnson | 789 Oak St |

3. The third part of the document is a list of names and their corresponding addresses. The names are listed in the left column, and the addresses are listed in the right column. The names are: John Doe, Jane Smith, and Bob Johnson. The addresses are: 123 Main St, 456 Elm St, and 789 Oak St.

4. The fourth part of the document is a table with two columns. The first column is labeled "Name" and the second column is labeled "Address". The table contains the following data:

| Name | Address |
|-------------|-------------|
| John Doe | 123 Main St |
| Jane Smith | 456 Elm St |
| Bob Johnson | 789 Oak St |

5. The fifth part of the document is a list of names and their corresponding addresses. The names are listed in the left column, and the addresses are listed in the right column. The names are: John Doe, Jane Smith, and Bob Johnson. The addresses are: 123 Main St, 456 Elm St, and 789 Oak St.

6. The sixth part of the document is a table with two columns. The first column is labeled "Name" and the second column is labeled "Address". The table contains the following data:

| Name | Address |
|-------------|-------------|
| John Doe | 123 Main St |
| Jane Smith | 456 Elm St |
| Bob Johnson | 789 Oak St |

7. The seventh part of the document is a list of names and their corresponding addresses. The names are listed in the left column, and the addresses are listed in the right column. The names are: John Doe, Jane Smith, and Bob Johnson. The addresses are: 123 Main St, 456 Elm St, and 789 Oak St.

8. The eighth part of the document is a table with two columns. The first column is labeled "Name" and the second column is labeled "Address". The table contains the following data:

| Name | Address |
|-------------|-------------|
| John Doe | 123 Main St |
| Jane Smith | 456 Elm St |
| Bob Johnson | 789 Oak St |

9. The ninth part of the document is a list of names and their corresponding addresses. The names are listed in the left column, and the addresses are listed in the right column. The names are: John Doe, Jane Smith, and Bob Johnson. The addresses are: 123 Main St, 456 Elm St, and 789 Oak St.

10. The tenth part of the document is a table with two columns. The first column is labeled "Name" and the second column is labeled "Address". The table contains the following data:

| Name | Address |
|-------------|-------------|
| John Doe | 123 Main St |
| Jane Smith | 456 Elm St |
| Bob Johnson | 789 Oak St |

TABLE VIII. Laboratory Calibration -- Using Stratified Nylon Electrical Resistance Units in a Sand -- Container Open at Top and With Perforated Bottom.

| Date | Depth From Top of Container - Inches | | | | | | Soil
Moisture
Percent | |
|---------------|--------------------------------------|---------|--------|-------|-------|--------|-----------------------------|------|
| | 1 | 2 | 3 | 4 | 5 | 6 | | |
| Ohms at 75°F. | | | | | | | | |
| June | 14 | 150 | 80 | 40 | 25 | 50 | 50 | 22.7 |
| | 15 | 170 | 125 | 50 | 25 | 30 | 40 | 21.1 |
| | 16 | 190 | 150 | 75 | 60 | 60 | 50 | 18.1 |
| | 17 | 210 | 175 | 100 | 80 | 90 | 90 | 16.2 |
| | 18 | 225 | 175 | 120 | 100 | 100 | 100 | 14.4 |
| | 19 | 225 | 175 | 120 | 110 | 130 | 100 | 12.7 |
| | 21 | 225 | 190 | 140 | 130 | 140 | 130 | 11.4 |
| | 23 | 225 | 210 | 160 | 150 | 160 | 150 | 9.2 |
| | 24 | 225 | 220 | 170 | 170 | 175 | 160 | 8.1 |
| | 25 | 230 | 225 | 175 | 175 | 175 | 170 | 7.5 |
| | 26 | 250 | 250 | 180 | 175 | 180 | 175 | 6.7 |
| | 28 | 275 | 290 | 210 | 190 | 200 | 200 | 5.4 |
| July | 30 | 340 | 350 | 260 | 250 | 250 | 260 | 4.2 |
| | 2 | 550 | 470 | 320 | 310 | 320 | 330 | 3.0 |
| | 3 | 1,110 | 580 | 360 | 350 | 375 | 475 | 2.3 |
| | 5 | 6,300 | 1,050 | 480 | 475 | 580 | 1,650 | 1.7 |
| | | 9,200 | 1,200 | 510 | 500 | 650 | 2,250 | 1.6 |
| | 6 | 30,000 | 2,700 | 775 | 700 | 1,250 | 9,000 | 1.4 |
| | 7 | 120,000 | 7,200 | 1,275 | 1,100 | 3,100 | 41,000 | 1.1 |
| | 8 | 300,000 | 24,000 | 2,900 | 2,300 | 11,700 | 300,000 | 0.8 |
| | 9 | 940,000 | 44,000 | 7,200 | 4,750 | 30,500 | 780,000 | 0.7 |

TABLE IX. Laboratory Calibration - Using a Single Vertical Nylon Electrical Resistance Unit in a Soil Can With Perforated Bottom - Grayling Sand, Gravelly Phase.

| Date | Depth From Which Soil Was Taken | | | | | |
|-------------|---------------------------------|-----------------------------|------------------|-----------------------------|------------------|-----------------------------|
| | 6 Inch | | 18 Inch | | 36 Inch | |
| | Ohms at
60°F. | Soil
Moisture
Percent | Ohms at
60°F. | Soil
Moisture
Percent | Ohms at
60°F. | Soil
Moisture
Percent |
| August 30 | 220 | 25.3 | 250 | 22.4 | 220 | 18.9 |
| 31 | 170 | 23.8 | 280 | 20.9 | 240 | 17.4 |
| September 1 | 320 | 22.0 | 520 | 18.9 | 600 | 15.7 |
| 2 | 500 | 20.5 | 730 | 17.4 | 900 | 14.2 |
| 3 | 660 | 18.3 | 1,000 | 15.2 | 1,200 | 12.3 |
| 4 | 760 | 16.4 | 1,150 | 13.3 | 1,350 | 10.4 |
| 5 | 840 | 14.3 | 1,200 | 11.0 | 1,450 | 8.5 |
| 6 | 960 | 12.1 | 1,400 | 8.7 | 1,650 | 6.5 |
| 8 | 1,400 | 8.6 | 2,900 | 4.9 | 3,400 | 2.9 |
| 9 | 2,800 | 6.1 | 74,000 | 2.3 | 90,000 | 1.2 |
| 10 | 18,000 | 4.1 | 260,000 | 1.2 | 260,000 | 0.4 |
| 11 | 45,000 | 2.6 | 820,000 | 0.5 | 820,000 | 0.1 |
| 12 | 72,000 | 1.6 | | | | |
| 13 | 170,000 | 0.8 | | | | |

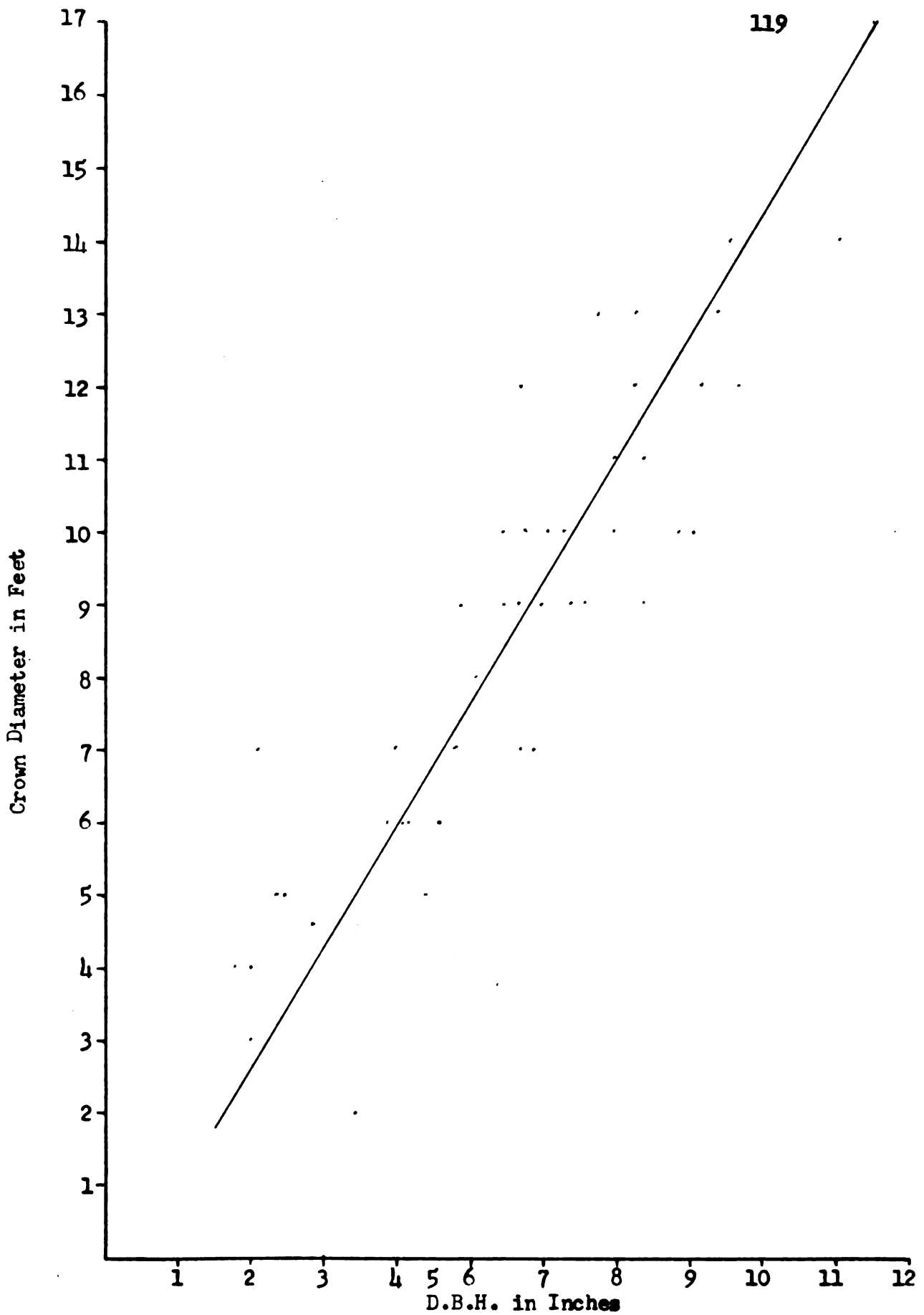


Figure 35. Crown-diameter graph used to plot crown area.

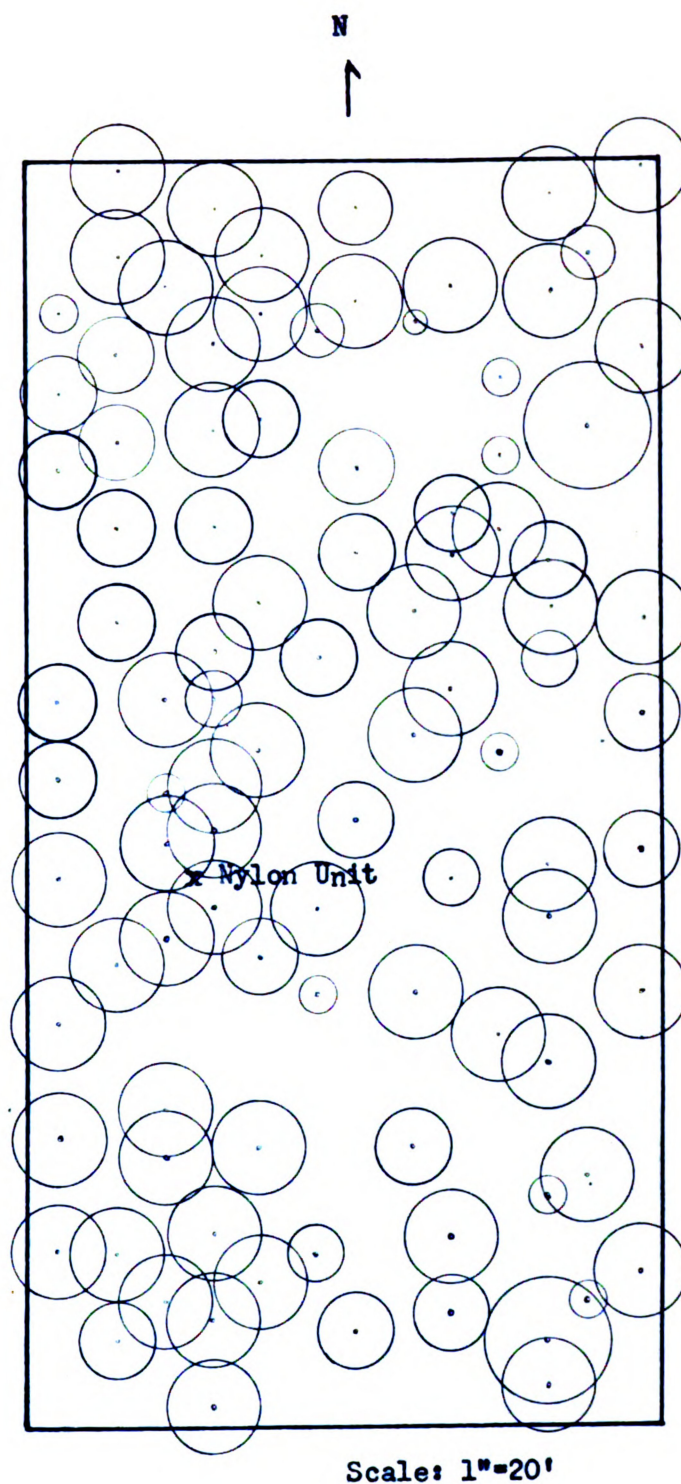


Figure 36. Subplot 80-A.

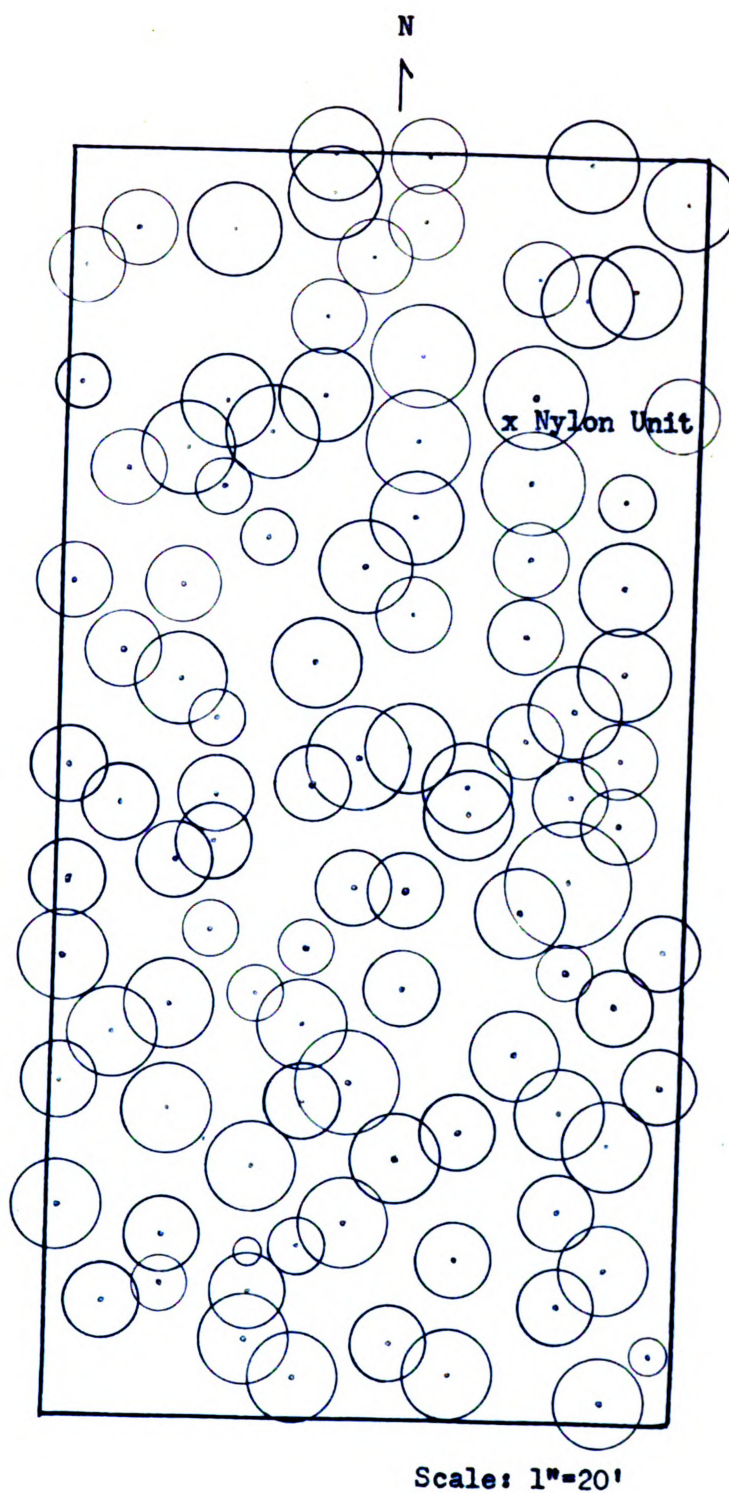


Figure 37. Subplot 80-B.

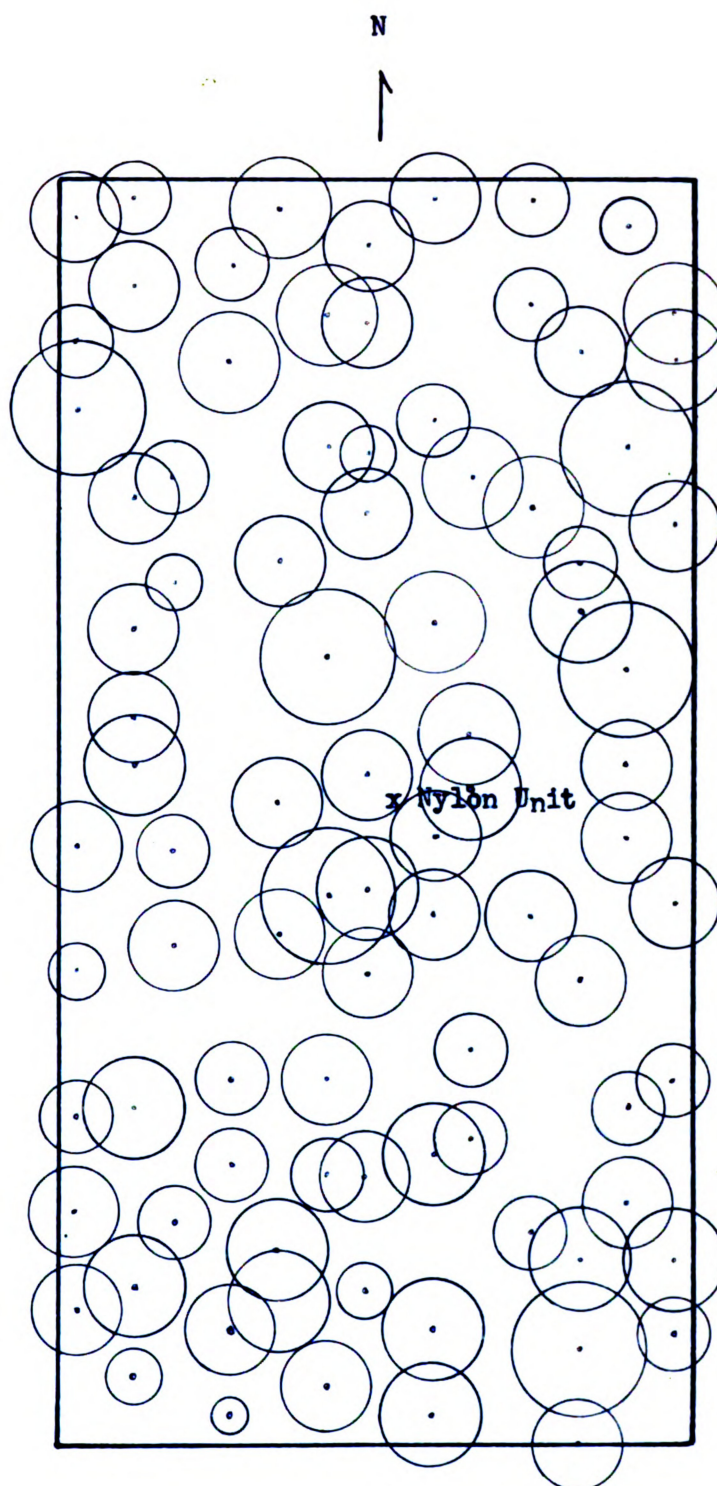


Figure 38. Subplot 80-C.

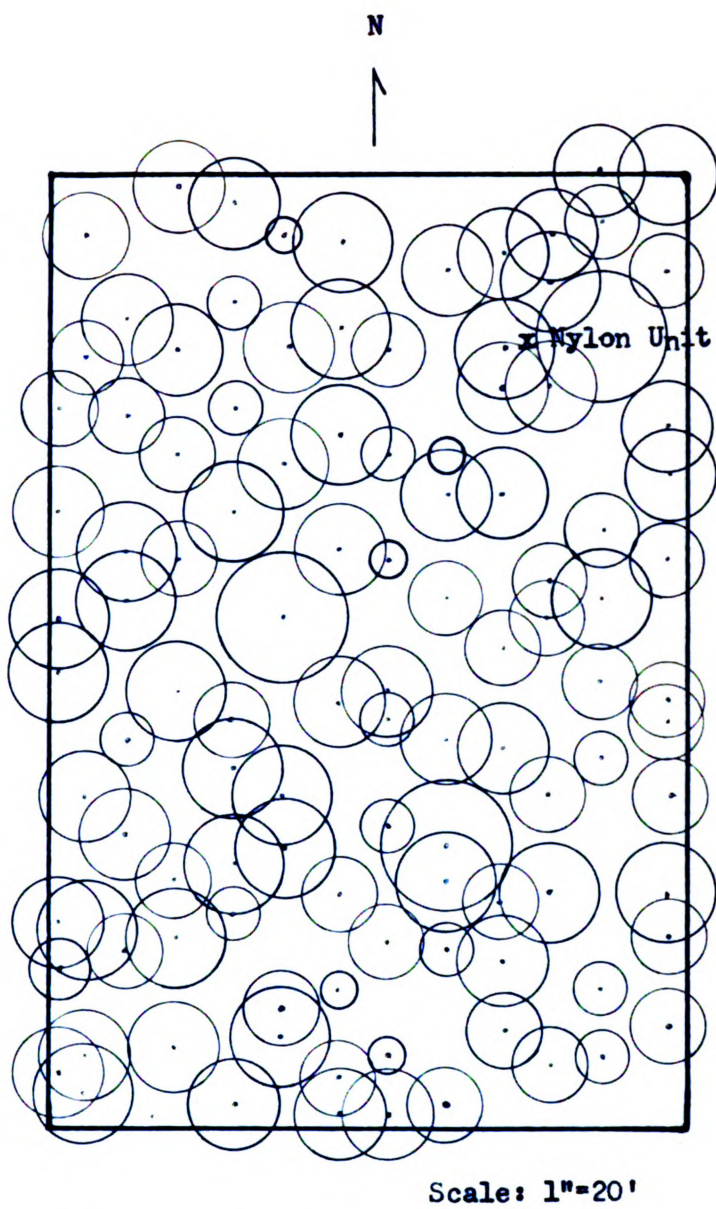


Figure 39. Subplot 120-A.

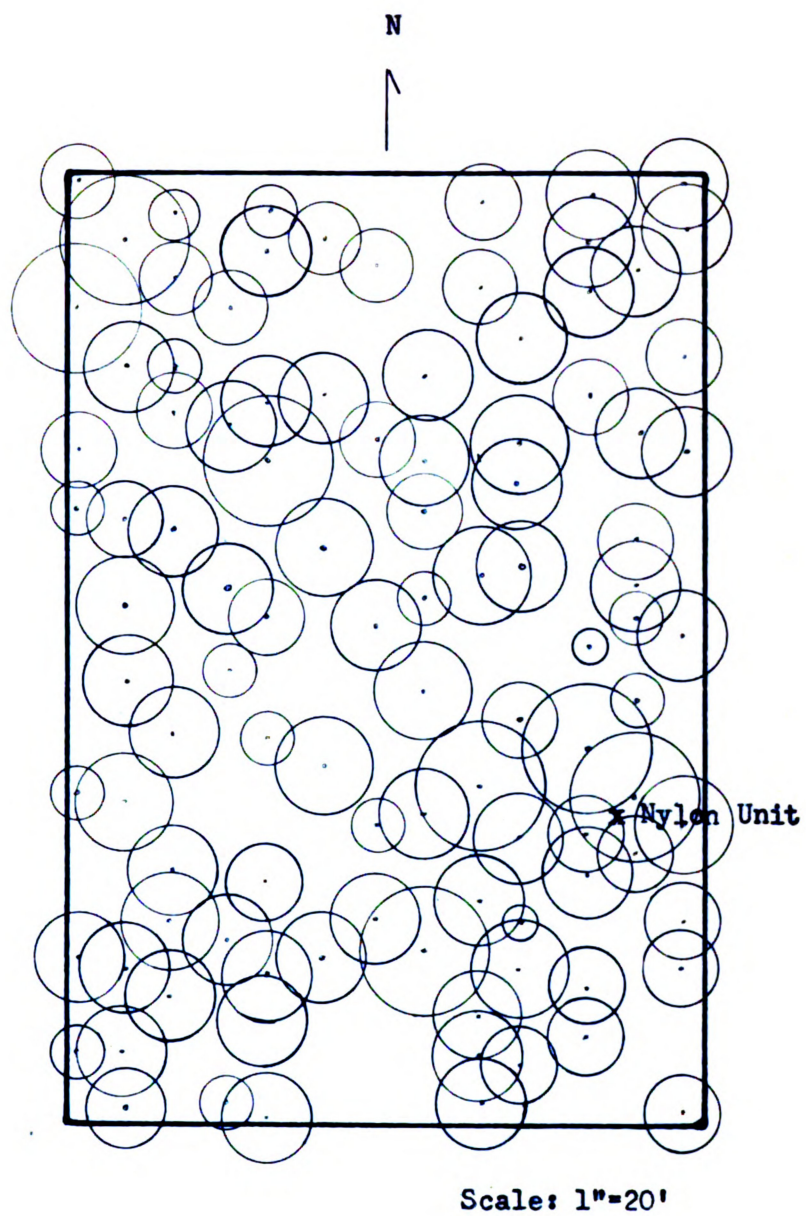


Figure 40. Subplot 120-B.

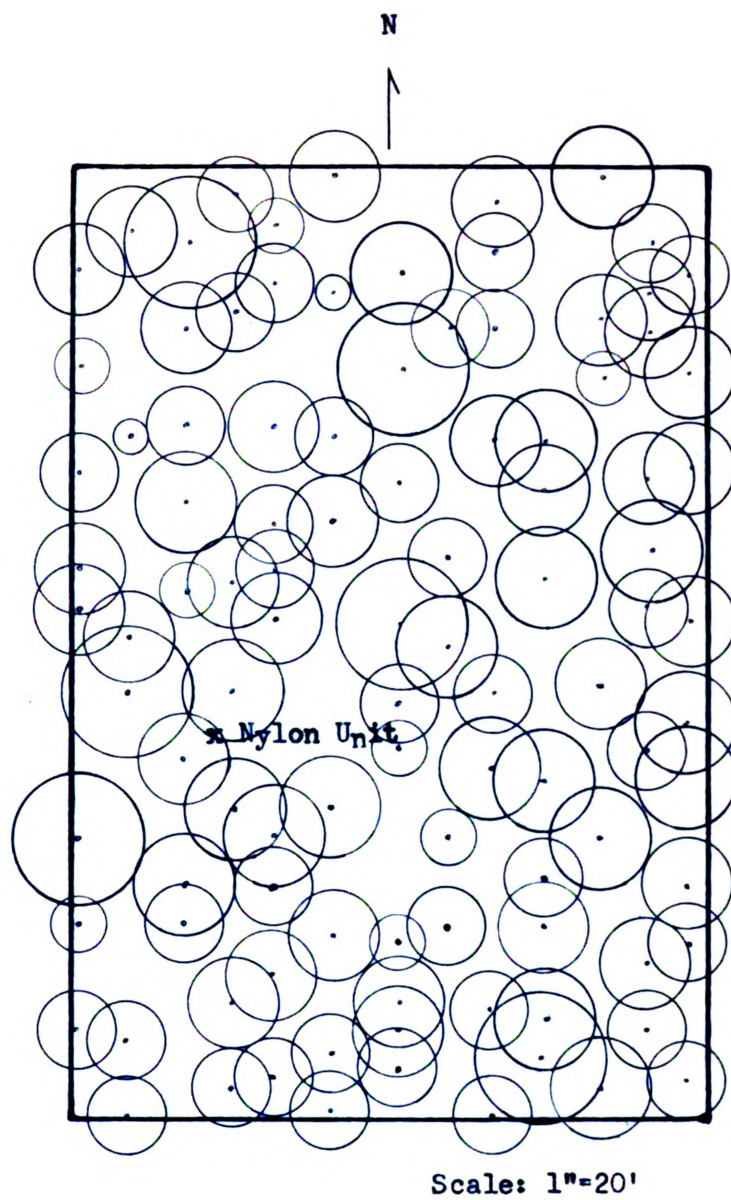


Figure 41. Subplot 120-C.

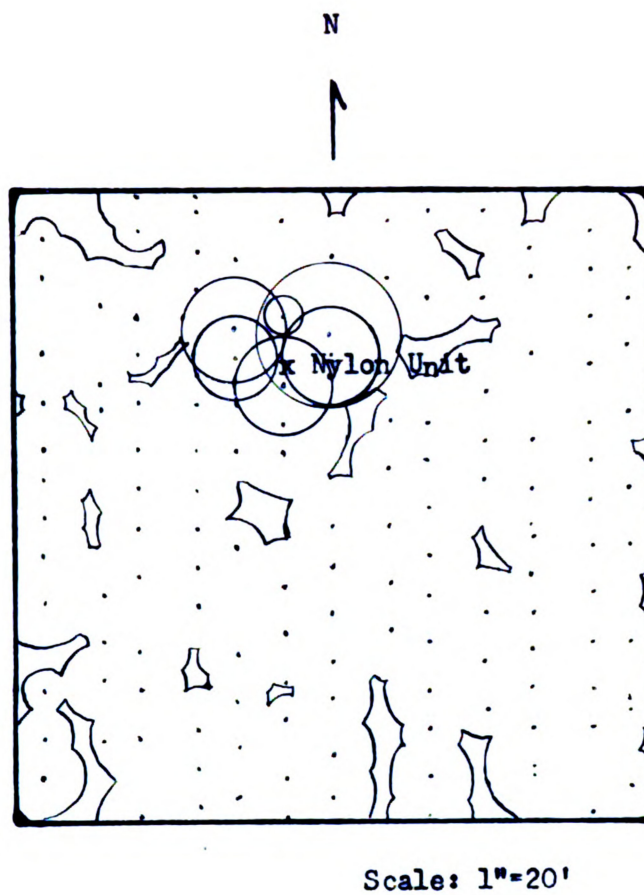


Figure 42. Subplot 190-A.
Enclosed areas show canopy
openings.

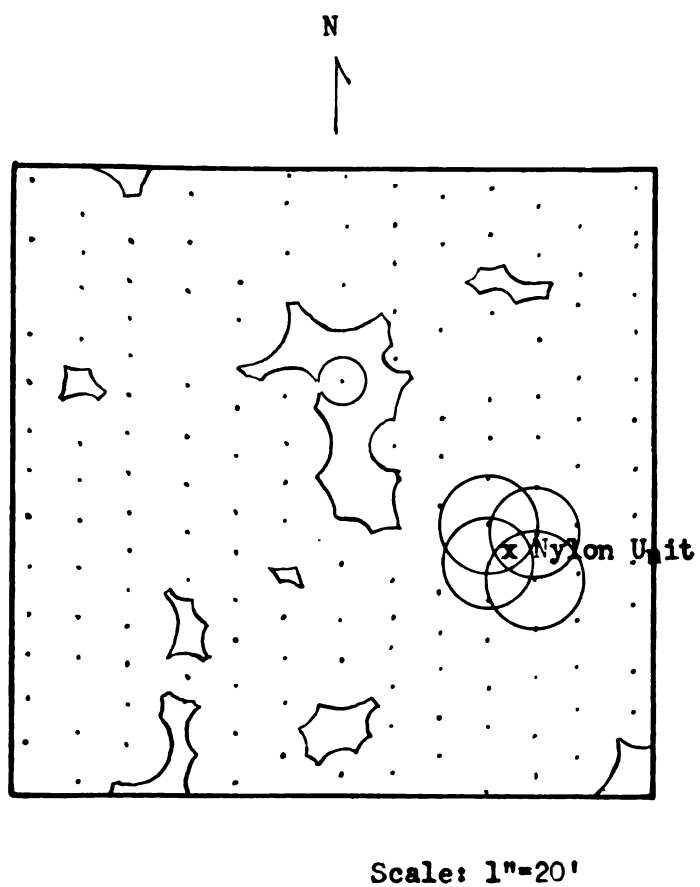


Figure 43. Subplot 190-B.
Enclosed areas show canopy
openings.

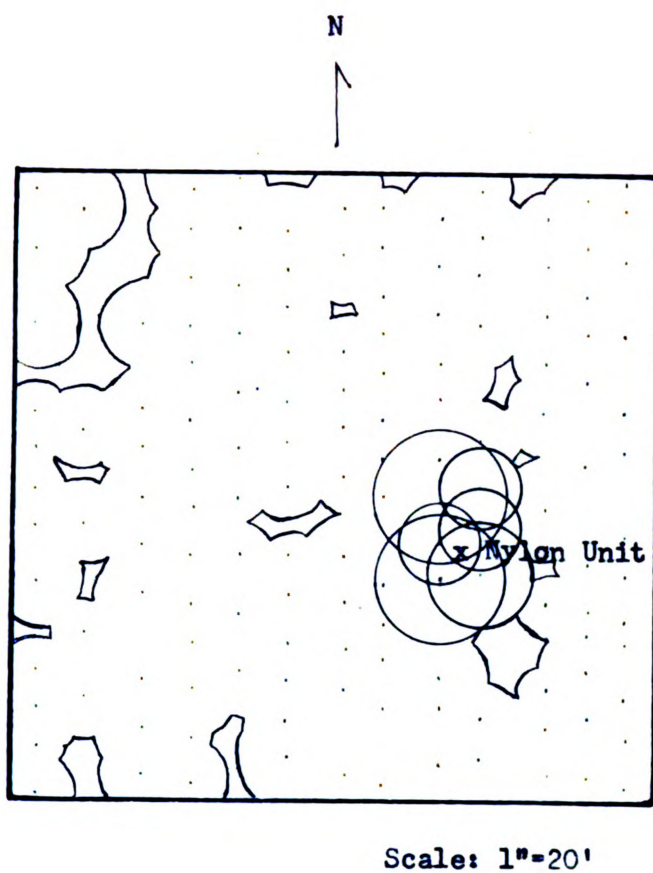


Figure 44. Subplot 190-C.
Enclosed areas show canopy
openings.

ROOM USE ONLY

AP 16 '54

ROOM USE ONLY

May 21 '54

~~WIN 1 1905 36~~