Effect of the density of Red Pine stands on moisture supply in sandy soils[1]

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Summary

The content of moisture was determined periodically from April till November by the neutron scattering probe in non-podzolic outwash sand supporting a 17-year-old fully-stocked red pine plantation and parts of the same plantation reduced 50 % by thinning. The current diameter increment of average trees was recorded by means of ring band dendrometers.
The supply of water in the 4-foot root zone of the thinned plantations during the entire growing season averaged nearly 10 per cent or 500 tons per acre. This soil gained some moisture from rainfall during the critical mid-summer period. The soil of the fully-stocked stand in the beginning of the growing season exhibited a high content of moisture because of a delayed thaw. Early in July a decrease of water content below the field capacity of 7 per cent coincided with a retarded diameter growth of trees, probably because of the restricted capillary transfer and depletion of moisture in the immediate vicinity of absorbing roots.
The results of the study indicate that 50 % thinning reduced the growing stock beyond the permissible limit: it failed to fully utilize the available supply of water and thus provided conditions favorable for invasion of weed vegetation; it led to a loss of current growth, expressed by the difference between 2300 trees with diameter increment of 0,17 inches and 1150 trees with diameter increment of 0,31 inches.

1. Introduction

The central part of Wisconsin is comprised of coarse sandy deposits which at one time formed the bottom of pre-existent Lake Wisconsin. Neither the low water-holding capacity, nor the limited supply of nutrients of these largely siliceous soils has permitted a sustained production of farm crops. At present most of this 1.000 square-mile plain is occupied by naturally or artificially established forests of pine species, including *Pinus banksiana, P. resinosa* and *P. strobus.*
Because of the natural infertility of soils and their depletion by repeated fires and cultivation, the average annual increment of pine stands seldom exceeds 0,3 cords per acre. Yet, under silvicultural management these forests serve as an important source of pulpwood, largely because of the proximity of paper mills located along the Wisconsin River.

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One of the important problems affecting timber production in this area is the regulation of density of stands permitting the maximum utilization of available soil water. Analyses of tree growth have indicated that the increment of plantations established at a spacing of 4 by 4 feet undergoes a drastic decrease soon after the closing of the canopy. On the other hand, the partly-open volunteer stands also appear to be depressed in their growth by a dense cover of grasses and heath plants.
Our reconnaissance investigations (HABERLAND and WILDE, 1961; KELLER and WATTERSTON, 1962) have indicated that the proper intensity of partial cuttings could be best established on the basis of systematic determinations of the soil water supply. This paper presents the results of the moisture determinations accomplished by the use of the neutron scattering method in sandy soils of a fully-stocked red pine plantation, adjacent heavily thinned plantations, and a recently deforested land.

2. Method of Study

The study was conducted in a 40-acre, seventeen year old red pine (*Pinus resinosa* AIT.) plantation located in the Nepco Industrial Forest, Adams County, Wisconsin, on non-podzolic Plainfield sand of glacial outwash. In the spring of 1958, the homogeneity of the plantation was checked by two parallel transects (LEAF and KELLER, 1956). One third acre plots were established in a fully stocked part of the plantation having basal area of 156 sq. ft per acre, in a part thinned to 50 % of basal area, and on adjacent cleared land. For the purposes of this study, partial cuttings were made in a uniform checker board pattern without regard to the growth potential of individual trees.
The content of soil moisture was periodically determined from March 29 to November 8 by the use of the Nuclear-Chicago scaler with decade counters and the p-19 depth moisture probe including a slow-neutron detector of boron trifluoride and a fast-neutron source of berillium and radium-226 (FIG. 1).
Prior to analyses and during the course of study the results obtained by the neutron scattering method were checked against gravimetric and immersion determinations (MAIBORODA, 1957; WILDE and SPYRIDAKIS, 1962). The maximum deviation observed within the range of soil moisture from 4 to 18 per cent by volume did not exceed 2 per cent. Consequently, there was only a slight alteration of the master calibration curve.
The access channels were made of 5-foot lengths of 20 gauge, type MT 1015 cold-drawn seamless steel tubing, 1,2 inch in diameter. The installation was accomplished by boring with an auger through the access tubes, removing 6-inch cores at a time and pushing the tube into the soil with a driving head. Three tubes were installed in each plot and 2 minute readings were taken at 1 foot intervals to a depth of 4 feet. This provided a record of the supply of soil moisture at least 8 inches below the maximum penetration of root systems.
The diameter growth was periodically recorded on 12 average trees in each plot by means of tree ring bands. Records of precipitation were obtained from the Griffith State Nursery, located 14 miles north of the study area.

3. Effect of stand stocking on the content of soil moisture and diameter growth of trees

The average contents of moisture, recorded in soils of the fully-stocked plantation, the thinned plots, and the adjacent cut-over area, are incorporated in TABLE 1.

FIG. 1. Determination of the shield count of the neutron-scattering probe. The 1960 clear-cut plot bounded by fully-stocked plantation; Dyracuse study area in Nepco Industrial Forest

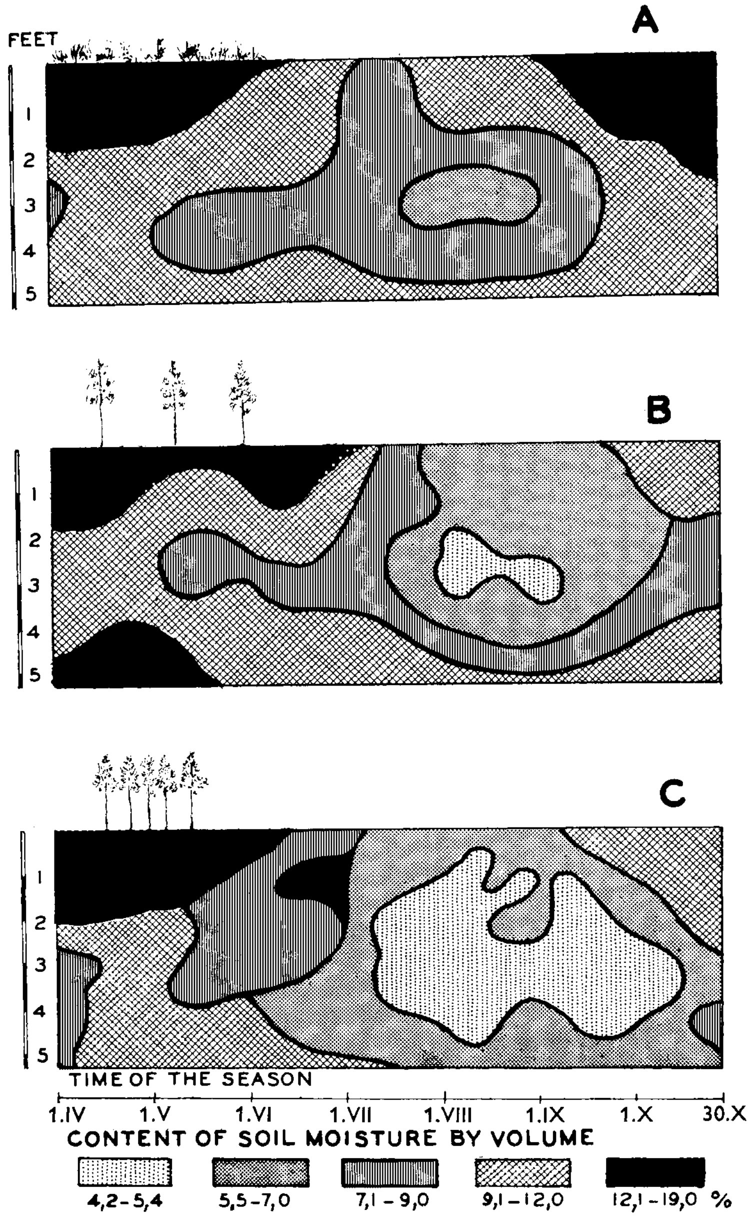

FIG. 2. Content of moisture in non-podzolic Plainfield sand during the growing season of 1961: A- Clear cut area; B- Plantation thinned to 50 % of basal area; C- Fully stocked plantation. Light colored regions show a possible shortage of water for the optimum growth of trees

TABLE 1. Average contents of moisture in Plainfield sand of the Dyracuse red pine study area

Date of analysis	Clear cut				Thinned area				Fully stocked			
	12''	24''	36''	48''	12''	24''	36''	48''	12''	24''	36''	48''
March 29	14,9	10,1	8,1	11,1	14,9	11,4	7,6	10,6	17,1	11,9	8,4	8,1
April 4	15,0	10,2	8,4	10,3	14,9	9,1	7,8	10,6	16,1	10,5	7,8	8,8
April 13	12,2	11,3	9,3	10,8	16,1	11,3	9,5	10,8	16,4	10,1	8,3	9,1
April 26	12,2	10,0	9,6	11,4	11,7	11,1	10,3	13,1	19,0	10,4	9,7	10,9
May 18	13,4	10,0	6,7	8,5	12,0	8,3	7,1	9,4	12,8	9,8	9,0	9,2
June 2	11,7	9,2	9,0	9,5	11,1	10,8	9,4	10,9	8,7	8,5	7,9	10,3
June 14	12,0	10,6	8,3	9,8	12,2	10,1	8,7	10,8	11,1	8,2	9,0	10,6
June 26	11,6	10,1	7,9	8,9	10,7	9,9	8,3	9,4	9,8	9,0	6,2	7,0
July 5	8,7	8,8	7,3	8,5	6,8	7,1	7,6	9,5	6,2	6,3	6,2	6,9
July 17	7,4	8,0	6,3	8,0	7,2	6,5	7,2	9,4	6,4	6,2	6,1	6,7
July 26	11,1	7,9	6,5	7,6	9,3	5,6	5,6	7,5	7,4	4,9	4,7	5,6
August 8	9,5	7,7	5,8	7,1	6,2	4,7	5,0	6,9	5,3	4,8	4,4	5,2
August 18	10,1	8,5	6,7	8,2	7,0	5,9	5,8	7,3	6,2	5,7	5,3	5,9
August 25	8,9	7,6	7,0	8,1	6,1	5,5	5,5	6,9	5,4	5,7	4,8	6,1
September 2	9,7	8,1	6,4	8,4	6,1	5,7	5,4	6,3	6,0	5,7	4,9	5,8
September 11	10,1	8,6	7,1	7,6	6,8	6,3	5,5	6,9	5,0	5,0	4,2	4,4
September 19	12,2	10,1	9,5	9,9	6,7	6,2	5,7	6,8	7,2	5,2	4,5	5,4
October 7	11,3	8,4	7,0	9,8	9,5	7,7	7,2	9,6	9,7	6,8	5,0	5,7
October 26	15,2	13,4	10,1	10,1	11,2	8,6	8,0	10,1	9,6	7,3	6,2	8,3
November 8	12,5	10,8	9,4	10,1	13,3	10,7	10,0	12,8	11,5	10,6	9,4	10,0

FIGURE 2 presents graphically the supply of water in soils of the clear-cut, recently thinned and fully-stocked plots. Increases in the circumference of average trees are reported in TABLE 2. FIGURE 3 presents diagramatically the relationships among precipitation, total supply of soil water in the 4-foot zone and circumferential increments of the fully stocked and thinned plantations. Both the record of precipitation and the content of soil moisture testify to a very favorable growing season with abundant and well distributed rainfall.

TABLE 2. Average rate of circumference growth of fully stocked and thinned red pine plantations during the growing season of 1961

Period of	Increment in inches of		
	fully-stocked plantation	thinned plantation A	thinned plantation B
26.IV—27.V	0,07	0,14	0,11
28.V—14.VI	0,22	0,33	0,30
15—26.VI	0,09	0,15	0,13
27.VI—26.VII	0,15	0,24	0,24
27.VII—8.VIII	0,03	0,05	0,05
9—18.VIII	0,02	0,04	0,04
19.VIII—19.IX	0,02	0,06	0,06
Total increase in circumference	0,60	1,01	0,93
Increase in DBH	0,19	0,32	0,30

At the beginning of the growing season the soil of the dense stand had a somewhat higher supply of moisture resulting from the delayed thawing. During the first

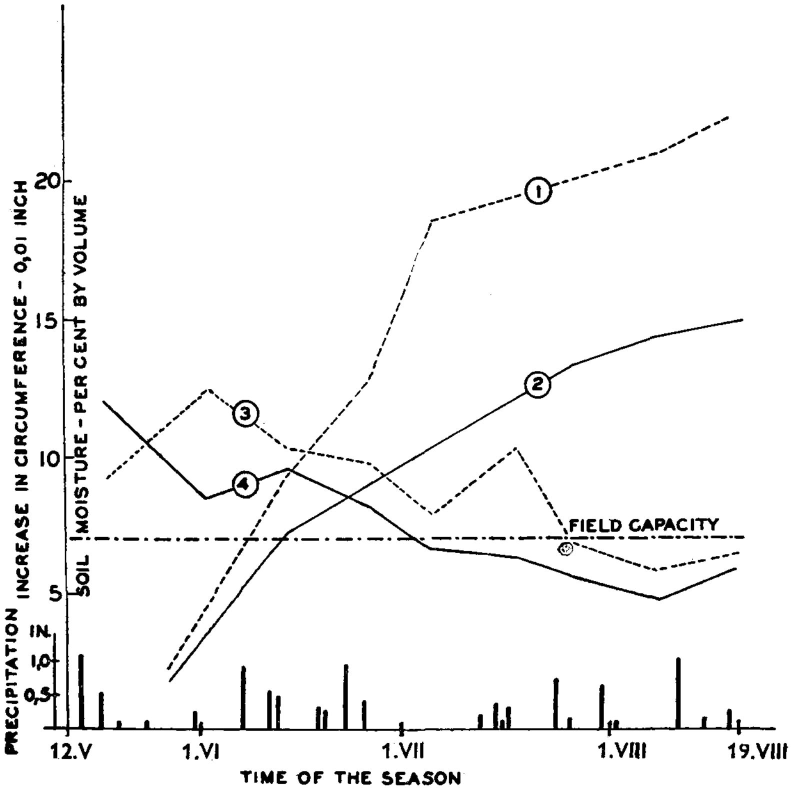

FIG. 3. Relation between the precipitation, current diameter increment of the thinned (1) and fully stocked plantations (2) and the content of moisture in corresponding soils (3 and 4)

four weeks the thinned and unthinned plantations exhibited similar trends of diameter growth. In the middle of June, however, the angle of the ascending increment line of the dense stand dropped to 30°, whereas that of the reduced stand continued to rise at an angle of nearly 60°. Early in July the content of moisture in the fully-stocked plot fell below field capacity and the total circumferential increment for the rest of the growing season amounted to less than 0,05 inches. On the other hand, the moisture content of the thinned plot remained above field capacity for another 3 weeks, and the increment of average trees exceeded 0,10 inches.
The shape of curves for treated and untreated stands shows that a decrease of soil moisture to field capacity retarded the growth of trees. It may be surmised that the average supply of soil moisture corresponding to field capacity coincided with a depletion of water in the immediate vicinity of adsorbing roots. A deficiency of this kind may well be expected in coarse sandy soils with their very limited capillary transfer of water. These observations are in disagreement with claims that trees continue their uniform growth even when soil moisture approaches the wilting point

(VEIHMEYER, 1927). It should be noted that an oversight of a single tree root drawing water from a deeper soil layer may lead to an erroneous conclusion about the water supplying capacity of the soil.

The diagram further shows that precipitation from the middle of June to the end of the growing season failed to contribute appreciably to the water supply of the soil supporting the fully stocked stand. This indicates that under conditions of a dense forest cover, the level of soil moisture during the growing season depends largely upon the water stored during period of dormant vegetation, that is water of fall rains, snowfall and early spring rains. On the other hand, the soil of the thinned plot gained some moisture from rainfall during the critical mid-summer period.

The polygons formed by the lines of soil moisture content of the dense stand form approximately equal areas above and below the line of field capacity. Therefore, the moisture content of the soil during the entire growing season averaged 7 per cent or 360 tons per acre of 4 foot root zone. Contrariwise, the supply of soil moisture in the thinned stand exceeded, on the average, the field capacity by at least 3 per cent, and hence amounted to nearly 500 tons per acre of 4 foot root zone.

These figures show that at this stage the thinning did not cause a depletion of soil moisture, but rather suggest that a removal of too many trees left a considerable fraction of water unused, and thus provided favorable conditions for the eventual invasion of weed vegetation. This assumption is supported by the record of the total current increment of stands of different densities (TABLE 2).

The product of 0,19 inches of the average diameter growth and 2300 trees per acre of the fully stocked plantation is appreciably higher than the product of 0,31 inches and 1150 trees of the thinned plantations. This indicates that a 50 per cent cut has reduced the growing stock beyond permissible limits. Under the given site conditions an elimination of 800 trees or 35 per cent of the stand population would have insured an increment at least equal to that of the fully stocked stand.

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