Site Preparation

and Reforestation

of Droughty, Acid Sands

U.S. Department of Agriculture—Forest Service

SITE PREPARATION

and REFORESTATION

of DROUGHTY, ACID SANDS

by

Russell M. Burns, Silviculturist

and

Edwin A. Hebb, Associate Silviculturist

Southeastern Forest Experiment Station

Library of Congress Catalog Card Number: 72-600002

Forest Service

United States Department of Agriculture

October 1972

i

ABSTRACT

BURNS, R. M. and HEBB, E. A.

Unmerchantable scrub oaks and wiregrass dominate millions of acres of
sandhills land in the Southeast. Conversion to pine requires reduction of
competition for moisture and nutrients and selection of species suited to
the soil and climate. Procedures based on 45 years of research are recom-
mended for land managers and owners of small woodlands.

Keywords: site preparation, dry acid sands, southern pines, sand pine,
reforestation, pulpwood, land use.

CONTENTS

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Environmental Protection Agency, consult your county agricultural agent or State Extension specialist to be sure the intended use is still registered.

SITE PREPARATION AND REFORESTATION OF

DROUGHTY, ACID SANDS

INTRODUCTION

Competition for moisture, light, and nutrients makes the introduction of pine seed or seedlings into an established plant community a risky undertaking; on hard-to-manage sites the task borders on the impossible. Chances for success are increased when the site is made receptive to new pine by reducing or destroying vegetation already established there. Application of treatments to increase the land's suitability for seed or seedlings is called site preparation, and it is most often accomplished by using machines, chemicals, fire, or combinations of these.

Droughty, acid sands requiring such treatments are found in the Atlantic and Gulf coastal plains from the barrens of New Jersey southward to Florida and westward to Texas. Typifying much of this area are millions of acres of sandhills in the Carolinas and Georgia and in peninsular and western Florida (fig. 1).

In south and central peninsular Florida droughty, acid sands are used primarily for citrus production. Because of cold climate, citrus gives way to scrub hardwoods and wiregrass north of Ocala in the central highlands and north of St. Augustine on the Atlantic coast. Scattered longleaf pines (*Pinus palustris* Mill.), remnants of stands harvested around the turn of the century, merely dot the landscape; almost complete occupation of the site by scrub vegetation has precluded their re-establishment (fig. 2).

Economic returns from this vegetative type are few. Scrub hardwoods and wiregrass are useful to wildlife, and they do provide some forage for livestock (table 1). Although hardwoods are seasonally rich in seed, they can support only widely foraging game animals on a year-round basis.

Increasing pressure on available land makes utilization of sandhills land more and more an economic necessity. Low potential for production of wood may be overridden by proximity to processing plants, the possibility of developing a stable base of raw material, and bringing all holdings to the same

1
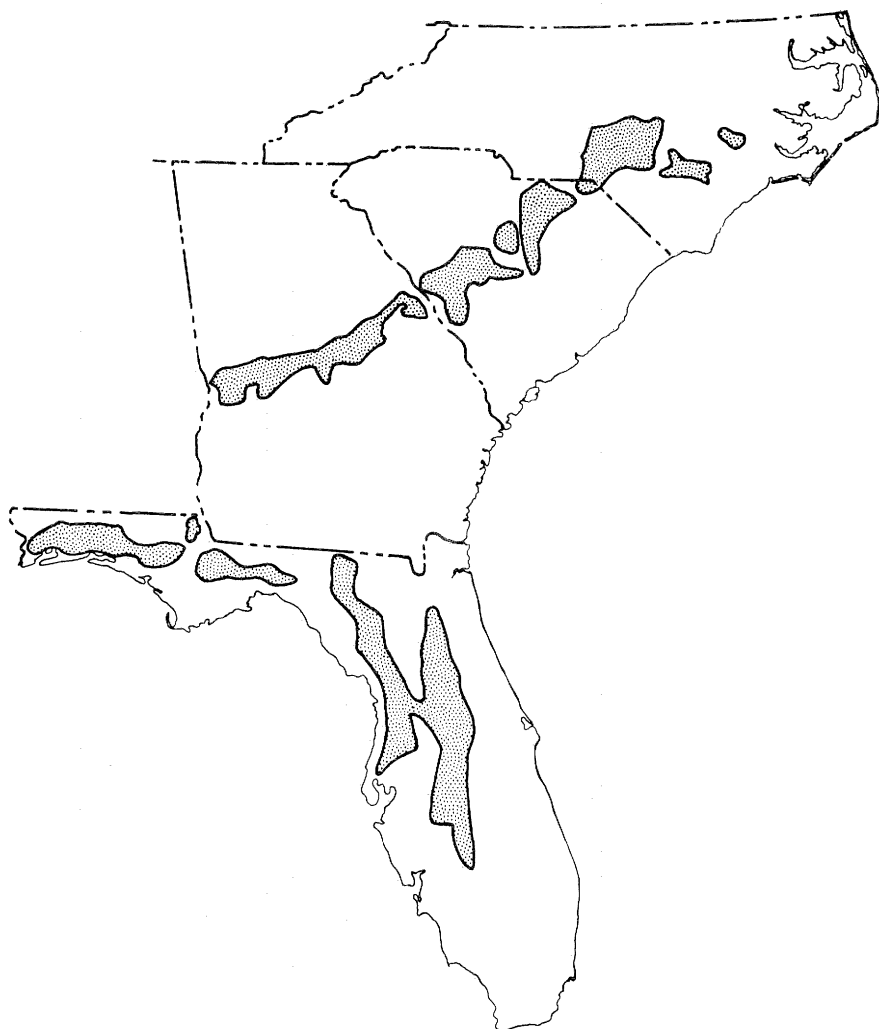
Figure 1.—Sandhills soils from North Carolina to Florida.

intensity of management. Moreover, a United States population estimated to grow by more than 65 million in the next 50 years (U.S. Bureau of the Census 1970) places ever-increasing demands on land available for production of food and fiber.

Pine trees are a relatively low maintenance crop that can be grown in droughty, acid sands. Though growth to sawtimber size is questionable because of the low inherent fertility of sands, pulpwood can be produced in a short enough period of time to be profitable. Future markets seem assured as the per capita demand for pulpwood increases annually. The most recent USDA Forest Service analysis, for example, shows that "demand in 1985 will be about 1.7 times the current level of consumption" (Hair and Ulrich 1970).

2

Figure 2.—Roots of turkey and bluejack oaks and wiregrass seriously threaten this volunteer longleaf seedling; planted pines would fare no better.

Table 1.—*Maximum amounts of crude protein and minerals in wiregrass from west Florida sandhills (from Woods 1959b)*

Nutrient	Minimum estimated beef-cattle requirements	Amount in forage	
		Burned area :	Unburned area
	.... Percent		
Crude protein	8–9	7.9	3.6
Phosphorus	0.18–0.21	.08	.03
Calcium	.20– .25	.91	.25
Magnesium	.04– .07	.07	.06
Potassium	.15– .20	.22	.22
Sodium	.02	.10	.02

3

This booklet was written to bring together information that will be useful to land managers and owners of small woodlands who produce pulpwood for such future markets. This comprehensive work summarizes 45 years of research and provides an up-to-date compilation of the latest practical, proven methods of site preparation and reforestation of sandhills lands.

THE SANDHILLS OF THE SOUTHEAST

Intensive preparation is the requisite treatment before planting or seeding a sandhills site to pine. It is the means whereby pines can be established and grown under adverse conditions. Conventional methods of plantation establishment have not been successful in the sandhills; if native woody and herbaceous weed plants are left intact they exclude any introduced plants. Most of the site preparation work summarized in this report was done in the sandhills of west Florida, principally on the Chipola Experimental Forest, but it has widespread application in similar soils, scrub vegetation, and climate.

CHARACTERISTICS OF THE AREA

Soil

In the Southern United States droughty, acid sands are interspersed with other soils throughout the coastal plain from Virginia to Florida and westward to Texas. They form an important physiographic feature in western and peninsular Florida and in a narrow band extending through Georgia, South Carolina, and into North Carolina (Austin 1965; Hodgkins 1965; Southern and Southeastern Forest Experiment Stations 1969). At their lower elevations these soils developed on marine terraces formed during interglacial stages of the Pleistocene.

Sandhills soils are droughty alluvial and marine deposits of comparatively recent geologic origin. In the current soil classification system (U.S. Department of Agriculture, Soil Conservation Service 1970) they fall into either of two groups: Entisols or Ultisols. Entisols have a weakly developed illuvial horizon or, more commonly, lack one entirely. Finer textured materials and soluble elements were dissolved and washed away prior to and during deposition leaving mostly quartz sands (quartzipsamments) in deposits ranging from a few feet to more than 20 feet (6.1 meters) in depth. Permeability and internal drainage are rapid, and moisture retention for plant use is low—water retention after 1 day of drainage ranges from 5 to 8 percent on an ovendry weight basis. Seasonal water tables occasionally are found at depths of 60 inches (152.4 cm.), but depths in excess of 120 inches (304.8 cm.) are more prevalent. In contrast, Ultisols of similar age developed from parent materials that were highly weathered before deposition contain a horizon in which some clay has accumulated. These soils are well drained to somewhat excessively drained and permeability is moderate to rapid.

The two soil orders typifying most soils in the sandhills of the Southeast may be distinguished by soil texture and the presence or absence of a clearly discernible B horizon. Excessively drained Entisols—represented by the Astatula, Alaga, Gainesville, Kershaw, Lake, and Lakeland series—are characterized by a gray or grayish-brown sandy surface soil, absence of a B

4

horizon, and a yellowish-brown to a brownish-yellow or brown sandy subsoil. Soils of the Paola and St. Lucie series have a gray to grayish-brown sandy surface horizon over light gray to white or light yellowish-brown sand. Ultisols—represented by the Eustis, Troup, and Wagram series—are characterized by a gray to yellowish-brown fine or loamy sand in surface layers, grading into a yellowish-brown, reddish-yellow, or brown loamy sand, sandy loam, or sandy clay loam B horizon which is underlain by varicolored sand or sandy clay loam.

Sandhills soils are acid in reaction and infertile (table 2). Most Entisols contain less than 10 percent silt and clay. The surface layer of organic debris oxidizes quickly because of high soil temperatures, and released nutrients are rapidly leached by rain. Soils are low in cation exchange surfaces provided by clay and organic colloids and, therefore, cannot retain many nutrients for plant use. Ultisols contain more fine-textured materials, especially in the argillic horizon, which gives them a higher potential for retention of nutrients and moisture. Nevertheless, they are droughty and infertile because this horizon is below the depth at which most feeder roots are found (Wells and Shunk 1931; Pessin 1935; Woods 1957; Hough, Woods, and McCormack 1965). Figure 2 illustrates the shallow depth at which most feeder roots occur in a typical scrub oak stand.

Table 2.—*Characteristics of sandhills soils (Brendemuehl 1967b)*

	Horizon	
Soil property	A	C
pH	4.8 –5.6	4.2 –5.0
Organic matter (%)	1.0 –2.0	.05 – .15
Total N (%) (Kjeldahl)	.02 – .03	.005– .015
Extractable P, p.p.m.	.5 –2.0	.025– .075
Ca (meq./100 g.)	.25 – .75	.05 – .15
K (meq./100 g.)	.025– .075	.005– .015
Mg (meq./100 g.)	.10 – .20	.025– .075
Base exchange capacity (meq./100 g.)	2.5 –5.5	.3 – .7

Topography

The most striking feature of the sandhills landscape is its apparent uniformity. Slopes of 30 percent do occur, but they seldom exceed 5 percent (Hopkins and Hebb 1954); elevation ranges between 30 to 50 feet (9.1 to 15.2 m.). The lowest elevations are along creeks and at springs. In the Carolina sandhills, topographic differences are much greater.

"Steepheads" that form around springs are characteristic of the Florida sandhills. These are small amphitheaters caused by slumping of sands overlying less pervious soils. Interspersed in the sandhills are flat areas of poor drainage described by Vernon[1] as adjustment of the surface to the solution of underlying marine marls.

---

[1] Vernon, R. Characteristics of the subsurface at the Chipola Experimental Forest. 1956. (Unpublished report on file, Southeast. Forest Exp. Stn., USDA Forest Serv., Marianna, Fla.).

Climate

Climatic conditions in the sandhills of the Southeast vary considerably from south to north because of their range in latitude and proximity to the Atlantic and Gulf coasts (table 3). In peninsular Florida, where the Gulf Stream influences climate, the growing season averages 312 days, summertime temperatures above 95° F. (35° C.) are common, and more than half of the 52-inch (132.1 cm.) annual rainfall occurs during June, July, August, and September. Sandhills in northwest Florida are close to the coast, and their climate is affected by prevailing winds from the south that moderate temperatures and promote convection storms. The growing season averages 269 days and storms deposit about 25 of the 58 inches (63.5 of the 147.3 cm.) of average annual rainfall from mid-June through mid-September. During the growing season temperature in the nineties is common but it seldom reaches 100° F. (37.8° C.). Summertime temperatures in Carolina and Georgia sandhills are comparable to those in northern Florida, but extremes between winter and summer are more pronounced. These inland sandhills are favored, nonetheless, by a growing season of 210 to 240 days and evenly distributed rainfall that averages about 47 inches (119.4 cm.) annually.

Despite apparently favorable climate, conditions in the sandhills are antagonistic to tree establishment and growth. Summertime air temperature combined with heat reflected from exposed sands cause temperatures at the soil surface to exceed 140° F. (60.0° C.) (Shipman 1955b). Rainfall is abundant, but moisture retention by sandy soils is low, and drought conditions may exist within 2 weeks after a heavy rain.

Vegetation

The same general spectrum of woody and herbaceous vegetation is native to sandhills throughout the Southeast. Dominant woody species are turkey oak (*Quercus laevis* Walt.), bluejack oak (*Q. incana* Bartr.), sand post oak (*Q. stellata* var. *margaretta* (Ashe) Sarg.), sand live oak (*Q. virginiana* var. *maritima* (Michx.) Sarg.), live oak [2] (*Q. minima* (Sarg.) Small), persimmon (*Diospyros virginiana* L.), sumac (*Rhus* spp.), hawthorn (*Crataegus* spp.), palmetto (*Sabal* spp.), and blueberry (*Vaccinium* spp.). Turkey oak and bluejack oak are most numerous.[3] In the Carolinas, blackjack oak (*Q. marilandica* Muenchh.) is common. Among the grasses and forbs, pineland three-awn (*Aristida stricta* Michx.), commonly called wiregrass; bluestem (*Andropogon* spp.); panicum (*Panicum malacon* Nash); and milkpea (*Galactia* spp.) are found in greatest abundance (Cushwa and Jones 1969; Hebb 1971b).

Longleaf pines that once dominated the overstory of the "high pine land" (Nash 1895) now exist in small patches and as isolated individuals. The "cut out and get out" philosophy of the early 1900's made no provision for regenerating the pines. The understory scrub oaks and wiregrass assumed dominance because they adapted well to droughty, acid sands. They continue to prevent natural and artificial establishment of most pines.

---

[2] This species is known locally as runner oak, running oak, or dwarf live oak (Kurz, Herman, and Godfrey, R. K. Trees of northern Florida. P. 89–91. Univ. Fla. Press, Gainesville. 1962).

[3] Burns, R. M., and McReynolds, R. D. Scheduling and intensity of site preparation for west Florida sandhills. 1972. (Manuscript in press, *J. For.*)

Table 3.—*Long-term temperature and rainfall averages for selected sandhills regions (U.S. Department of Commerce, Environmental Science Services Administration 1968, 1969a, 1969b, 1970a, 1970b, 1970c; U.S. Department of Agriculture 1941)*

Region [1]	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann. avg.
TEMPERATURE (degrees F.) [2]													
Peninsular Florida (312)	59.7	60.9	64.4	70.8	76.1	80.8	81.8	81.8	80.0	73.9	65.1	60.2	71.3
	(15.4)	(16.1)	(18.0)	(21.6)	(24.5)	(27.1)	(27.7)	(27.7)	(26.7)	(23.3)	(18.4)	(15.7)	(21.8)
Northwest Florida (269)	53.7	54.9	59.0	68.0	74.5	80.5	81.7	80.8	77.5	69.5	58.7	53.9	67.6
	(12.1)	(12.7)	(15.0)	(20.0)	(23.6)	(26.9)	(27.6)	(27.1)	(25.3)	(20.8)	(14.8)	(12.2)	(19.8)
Georgia (235)	47.6	49.2	54.3	63.9	71.8	78.9	80.7	79.6	75.0	65.2	54.1	46.5	63.8
	(8.7)	(9.6)	(12.4)	(17.7)	(22.1)	(26.1)	(27.1)	(26.4)	(23.9)	(18.4)	(12.3)	(8.1)	(17.7)
South Carolina (238)	47.3	48.8	55.1	63.5	71.8	78.8	80.7	79.9	74.9	64.7	53.7	46.8	63.8
	(8.5)	(9.3)	(12.8)	(17.5)	(22.1)	(26.0)	(27.1)	(26.6)	(23.8)	(18.2)	(12.1)	(8.2)	(17.7)
North Carolina (211)	44.1	45.6	51.8	61.7	70.0	77.2	79.2	78.2	72.7	62.4	51.9	43.9	61.6
	(6.7)	(7.6)	(11.0)	(16.5)	(21.1)	(25.1)	(26.2)	(25.7)	(22.6)	(16.9)	(11.1)	(6.6)	(16.4)
RAINFALL (inches) [3]													
Peninsular Florida (312)	2.53	2.91	3.11	2.65	4.10	7.04	7.97	7.15	6.34	3.63	1.94	2.41	51.77
	(6.4)	(7.4)	(7.9)	(6.7)	(10.4)	(17.9)	(20.2)	(18.2)	(16.1)	(9.2)	(4.9)	(6.1)	(131.5)
Northwest Florida (269)	4.29	4.66	4.40	4.38	3.95	5.25	7.46	6.98	5.51	3.26	3.03	4.60	57.78
	(10.9)	(11.8)	(11.2)	(11.1)	(10.0)	(13.3)	(18.9)	(17.7)	(14.0)	(8.3)	(7.7)	(11.7)	(146.8)
Georgia (235)	3.89	4.79	4.65	3.84	3.28	4.25	5.29	4.60	3.25	2.74	2.52	3.98	47.10
	(9.9)	(12.2)	(11.8)	(9.8)	(8.3)	(10.8)	(13.4)	(11.7)	(8.3)	(7.0)	(6.4)	(10.1)	(119.6)
South Carolina (238)	3.38	4.13	3.43	3.41	3.28	5.07	5.26	5.24	4.04	2.79	2.12	3.46	45.60
	(8.6)	(10.5)	(8.7)	(8.7)	(8.3)	(12.9)	(13.4)	(13.3)	(10.3)	(7.1)	(5.4)	(8.8)	(115.8)
North Carolina (211)	3.28	3.90	3.64	3.35	3.72	5.19	5.91	5.60	4.09	2.75	2.21	3.75	47.43
	(8.3)	(9.9)	(9.2)	(8.5)	(9.4)	(13.2)	(15.0)	(14.2)	(10.4)	(7.0)	(5.6)	(9.5)	(120.5)

[1] Numbers in parentheses indicate days in growing season.
[2] Numbers in parentheses indicate temperature in degrees Centigrade.
[3] Numbers in parentheses indicate rainfall in centimeters.

EARLY RESEARCH INTO SANDHILLS PROBLEMS

The earliest work in conversion of sandhills scrub hardwoods to productive pine stands was begun on the Choctawhatchee National Forest (now Eglin Air Force Base) in northwest Florida. From the first, securing of reproduction on this forest was a problem. Longleaf pine reproduction had been scanty since the 1880's.

Trials of artificial reforestation were conducted just prior to World War I. Native pines were tried, as was a species of eucalyptus, some cork oak of uncertain source, and other exotic species in small numbers; much of the area was sowed with maritime pine (*Pinus maritima* R. Br.). Some of the sites were burned or plowed before seeding, but all efforts failed.[4]

Formal research on sandhills regeneration problems in the Southeast began in the early 1920's and expanded after 1927. Rainfall and temperature records were kept and rates of evaporation were measured to pinpoint factors limiting seedling establishment. Root systems of large trees and small plants were excavated and found to be close to the surface of the soil and to form a dense network within the upper few inches. These studies[5] provided the basis for Gemmer's conclusion: "vegetation is the principal factor in the removal of moisture even in this porous soil." Grass roots, found to occupy the same soil strata as pine roots, were considered their principal competitors because "during periods of drought the grasses . . . consume considerable quantities of soil moisture which might otherwise be taken up by the pine seedlings" (Pessin 1939).

Studies conducted in the 1930's on the Choctawhatchee National Forest were crowned in 1936 by an experiment including all conceivable land preparation techniques. Site treatments included scalping, plowing, disking, and minor variants of these. Planting was done on the ridges or in the furrows of a plowed site, in slits or dug holes, with wet moss or nitrate of soda, or with the seedlings protected by piles of brush or logs on either side. Most of the treatments were of no avail, and the experiment was abandoned in 1939. In a later re-examination four of these plots were found to be supporting pole-sized stands of pine (Fassnacht 1954). The secret was they had been double disked with an ordinary bush and bog harrow that removed oak and grass roots which otherwise would have competed with roots of the planted pines. This re-examination was undertaken in 1953 when the Southern Forest Experiment Station, in cooperation with the Florida Board of Forestry, established a branch in west Florida to search for the best means of converting scrub oak-wiregrass sandhills to forests of maximum productivity. Site preparation problems were among the first attacked.

METHODS OF SITE PREPARATION

Successful conversion of scrub hardwoods to pine in the sandhills requires control over plants that utilize available moisture and nutrients and requires conservation of the small amount of organic matter present in the topsoil.

---

[4] Gross, L. S., and Gemmer, E. W. 1929. (Memorandum on file at Southeast. Forest Exp. Stn., USDA Forest Serv., Marianna, Fla.)

[5] Gemmer, E. W. Relationship of forest cover to soil temperatures and soil moisture. 1932. (Unpublished report filed at Southeast. Forest Exp. Stn., USDA Forest Serv., Marianna, Fla.)

Site preparation can exert such control by reducing the number and vigor of existing plants until seeded or planted pines can establish themselves as the dominant species. Scrub oaks and wiregrass are the principal woody and herbaceous competitors; control of either enables the remaining competitor to maintain dominance over introduced pines. Scheer and Woods (1959) observed this phenomenon and reported that "where oaks alone were killed, wiregrass multiplied and produced a level of competition at least equivalent to that existing before the treatment." Similar effects of grass competition have been noted in other vegetative types (Carmean 1971; Stransky 1961; Stransky and Wilson 1966).

On droughty sandhills soils, survival of planted pines reflects increased moisture availability brought about by the intensity of site preparation. Probably the most intensive treatment tried on the Chipola Experimental Forest was done with a bulldozer, followed by leveling with a road grader or disk harrow, and hoeing once each summer for 3 consecutive years. Second-year survival of planted slash pines (*Pinus elliottii* Engelm.) averaged 87 percent; it was lower on other areas prepared with less drastic measures. Only on the bulldozed area was moisture in the 3- to 9-inch (7.6- to 22.9-cm.) soil layer, measured in May after 14 rainless days, sufficiently above the estimated wilting point for survival and growth of slash pine seedlings.

Growth of slash pine seedlings planted in the sandhills is directly related to the amount of topsoil present (Brendemuehl 1967a). Methods of site preparation that do not conserve topsoil or that promote excessive oxidation of organic matter lower the infertile sands' productive capacity by reducing virtually the only source of nutrients and cation exchange surfaces. A comparison of slash pine growth after various amounts of topsoil were removed illustrates the importance of the soil's organic fraction:

Site preparation	Amount of topsoil removed	Height of pines after 10 years	
		(Feet)	(meters)
Bulldozed	all	10.8	(3.29)
Rootraked	some	13.9	(4.24)
Chopped	none	15.9	(4.85)

These data are from three site preparation studies conducted in the sandhills of Calhoun and Liberty counties, Florida, between 1952 and 1960.

Clearly, an effective method of site preparation must reduce competition but must not remove or cause a loss of topsoil and organic matter.

MECHANICAL METHODS

Machines have proved to be effective for preparing sandhills sites by providing the best means whereby native vegetation can be destroyed, removed, or rendered less competitive to planted or seeded pines. Their advantages include control over the intensity of site preparation ultimately obtained; control of the physical sculpturing of surface soils, as is done in bedding; the close control over work in progress; the relatively short time the site is adversely affected (Sampson and Schultz 1957). Principal disadvantages are disturbance and possible removal of topsoil, resulting in erosion, and the relatively high cost of using heavy equipment in complete site preparation. Fortunately, most sandhills sites are level to gently rolling

and soils are highly permeable, so erosion is not a serious problem, and machinery that minimizes loss of topsoil is available.

In contrast, the action of prescribed fires and chemicals is difficult to control once started, and some herbicides and silvicides have long-lasting, undesirable aftereffects. Chemicals do have advantages, but if high dosages are required to achieve complete site preparation, the cost may exceed that of using machinery.

Repeated testing has shown double chopping with a heavy chopper to be about the most effective means of reducing hardwood competition and encouraging pine survival and growth (table 4). For this reason, results of double chopping are used in this report as the standard against which other methods of site preparation are judged.

Table 4.—*Fifteen-year survival and growth of planted slash pine on sites prepared with fire and machines*

Site preparation	Survival	Height		D.b.h.	
	Percent	Feet	(meters)	Inches	(cm.)
Burn followed by:					
Double chop	71	29.7	(9.1)	4.3	(10.9)
Single chop	71	25.7	(7.8)	3.9	(9.9)
Rootrake and disk	70	22.1	(6.7)	3.5	(8.9)
BSW [1] once	66	21.5	(6.6)	3.3	(8.4)
BSW twice	73	19.1	(5.8)	2.9	(7.4)
Rootrake	61	15.1	(4.6)	2.5	(6.4)
Only one burn	54	13.6	(4.1)	2.0	(5.1)
No site preparation	52	12.8	(3.9)	1.8	(4.6)

[1] A land-clearing machine with a razorlike blade, mounted like a bulldozer blade, that shears off protruding stems.

The eight types of machines used most commonly in preparation of sandhills sites are discussed in the following pages.

Chopper

Choppers resemble agricultural stalk cutters and serve a similar purpose. They cut scrub hardwoods into small chunks and incorporate the woody debris into the soil. Several makes and models are available and range from huge, single-drum choppers to multiple-drum choppers pulled in tandem. All are capable of cutting into pieces small hardwoods, such as those found on the majority of sandhills sites, but only one chopper has been designed to kill grasses also.

Marden duplex brush cutters,[6] because of a patented feature, best meet the objectives of controlling woody and herbaceous plants and minimizing loss of topsoil. Hereafter, the term chopper will be used interchangeably with duplex brush cutter.

We tested three models of choppers—all similar in action and appearance but differing in diameter and weight of the drums, drawbar horsepower necessary to pull them, and size of hardwoods that each is capable of process-

[6] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

ing. When the two drums are filled with water and ready for use, the light model weighs 4¼ tons (3,856 kg.), requires a tractor with 35 to 60 drawbar horsepower (2,661 to 4,562 kg.-m./sec.), and can chop trees up to about 2 inches (5.1 cm.) in diameter. The medium model weighs 8 tons (7,257 kg.), may be pulled by a tractor of 50 to 75 drawbar horsepower (3,802 to 5,703 kg.-m./sec.), and can chop trees up to 3 inches (7.6 cm.) in diameter. The heavy model weighs 11 tons (9,979 kg.) when filled, must be pulled by a tractor with 70 to 125 drawbar horsepower (5,323 to 9,505 kg.-m./sec.), and can chop hardwoods almost 4 inches (10.2 cm.) in diameter.

A 10-foot-wide (3-meter) chopper also is manufactured but it was not tested. Empty it weighs 16 tons (14,515 kg.) and has approximately the same weight distribution per lineal foot of cutting blade as the water-filled, 11-ton model. About 250 drawbar horsepower (19,010 kg.-m./sec.) is needed to pull it.

An 11-ton duplex brush cutter is illustrated in figure 3. Drums are 7 feet (2.1 m.) long and have alternate 6- and 8-inch (15.2- and 20.3-cm.) blades affixed lengthwise around their circumference. The drums are offset at angles of approximately 75 and 105 degrees to the direction of travel. This patented feature causes the drums to slide as well as roll and bounce slightly as they are pulled along. Wiregrass roots are sheared by the sliding of the blades, and chopping of woody stems is facilitated by slicing action of the bouncing drums. The long-term enhancement of the soil's organic matter content through incorporation of organic debris is a bonus.

The size of chopper needed for a particular job is determined to a large measure by the number, size, and distribution of hardwoods to be processed. Despite its higher cost, the 11-ton model is popular because it can effectively chop most trees normally encountered on all but a few sandhills sites. The few trees too large to chop can be girdled or poisoned where they stand. If an area with many large hardwood trees is encountered, other means must be employed to root them out.

A single chopping treatment does not provide sufficient hardwood control regardless of the size of equipment employed. Sprouts develop at the collar of hardwood stumps and must be processed a second time. Profuse sprouting follows even the second treatment, but these sprouts are comparatively weak and pose less of a competitive threat to pines seeded or planted later.

The 11-ton chopper does a better job of preparation than a smaller one, regardless of the age and size of the original hardwood stand. We tested[7] the effectiveness of two treatments with an 8-ton chopper and two treatments with an 11-ton chopper in a small, young hardwood stand and in an older and larger stand. The heavy chopper killed more hardwoods of all sizes, retarded development of sprout growth, and resulted in higher survival and growth of planted pines than did the lighter chopper (table 5).

Rootrake

The rootrake, a land-clearing machine that has been used successfully in the sandhills, resembles a bulldozer but has a comb-like rather than solid blade. The "Settlemire scalper" described by Woods (1953) was an improved

---

[7] Burns, R. M., and McReynolds, R. D. Heavy vs. medium choppers for preparing sandhills sites. (Manuscript in preparation.)

Figure 3.—Chopping with a duplex brush cutter greatly reduces competition when hardwoods are not too large.

Table 5.—*The effect of chopper size on the number and size of hardwood sprouts and on the survival and growth of planted slash pines*

Standard treatment	Before site preparation			15 months after treatment			4-year-old planted pines		
	Stems per acre	Maximum diameter		Sprouts per acre	Average diameter		Survival	Height	
	Number	Inches	(cm.)	Number	Inches	(cm.)	Percent	Feet	(m.)
Young hardwoods	5,737	3.5	(8.9)						
8-ton chopper				2,327	0.99	(2.5)	83	4.7	(1.4)
11-ton chopper				976	.82	(2.1)	90	5.0	(1.5)
Old hardwoods	5,158	6.0	(15.2)						
8-ton chopper				4,140	1.14	(2.9)	65	3.7	(1.1)
11-ton chopper				1,629	.98	(2.5)	73	4.0	(1.2)

rootrake having a solid cutting bar across the tines near their tips to facilitate cutting and rooting out of underground stems (fig. 4).

The rootrake does a thorough job by rooting out trees and shrubs and raking them into windrows spaced at convenient intervals along both sides of the cleared area. Land occupied by the windrows is lost from production, but once rotted down and graded these rows provide easy access for subsequent management of plantations. Sprouting occurs in the cleared area so some followup treatment is necessary, and usually it is done with a heavy disk. The combination of rootraking and disking is as effective in promoting pine survival as double chopping, but it costs more.

Rootraking has a number of disadvantages, not least of which is the windrow itself. Approximately 10 percent of the area is taken out of production, and the piled debris remains an obstacle to fire crews and equipment for a number of years. Much of the topsoil and organic matter that is supposed to sift between the tines is swept along with the woody material and deposited in and near the windrows. Growth of pines planted later reflects differences in depth of topsoil. The pine stand develops a saucer-shaped profile because trees grow taller near windrows where more topsoil was deposited, and where more room, moisture, and nutrients are available. Finally, rootraking is inefficient because almost half the machine time is lost to backing away from the windrow to prepare for another push. Rootrake operators also command a high salary because they need special skill to operate the "blade."

F-521416

Figure 4.—The rootrake resembles a bulldozer, but has a comb-like blade designed to leave the topsoil behind. Actually much of the topsoil is moved to the windrow with the debris.

14

Bulldozer

Shortcomings of the rootrake are exaggerated by bulldozing (fig. 5). Trees and organic debris are effectively removed, but most of the topsoil is lost to the windrow. Supplementary treatment to reduce sprout vigor usually is required. Survival of pines planted on sites prepared by bulldozing often is quite high owing to the lack of competition, but growth suffers from the lack of topsoil and nutrients.

BSW Blade

The BSW is a type of land-clearing machine that, like a straight razor, simply shears off all stems protruding from the earth. It is an aboveground brush and scrub hardwood cutter that looks like a snowplow and fits the front of a crawler tractor (fig. 6). It has been used to prepare sandy scrub hardwood ridges for seeding with longleaf pine (Croker 1957, 1959) and sandhills sites for planted pines. The flared framework of pipe along the BSW's upper edge bends the trees over and a crenate blade along the bottom edge cuts them. As the machine moves along, trees as large as 10 inches d.b.h. (25.4 cm. at 1.4 m.) are severed at groundline, leaving a smooth, clear site. With each subsequent swath, however, severed material is pushed into the previously cleared area. During winter planting this need not be a problem because a planting machine can be hitched in tandem with the

F-521417

Figure 5.—Bulldozing is thorough, but it removes topsoil as well as roots and stems of competing trees.

Figure 6.—The BSW is mounted like a bulldozer blade. Here the blade is raised above normal operating height to demonstrate how it can cut large trees with the crenate cutting edge along the bottom.

tractor-BSW combination. Although the combined treatment is tempting, it is not recommended because winter is a poor season in which to prepare sandhills sites even though pines show their best survival when planted in winter. Although no time is lost in backing up, as with the rootrake and bulldozer, disposal of organic debris and wiregrass remains a problem.

In one comparative test in the sandhills, the cutting edge of the BSW was set to scalp the surface of the soil and remove wiregrass. Survival of planted pine averaged 67 percent and height averaged 13.5 feet (4.1 m.) at plantation age 10 years. This was far better than the performance of pines on untreated areas, but not nearly as good as that of trees on double chopped areas (table 4).

Disk Harrow

Heavy-duty disk harrows (fig. 7) have been used successfully in the South (Ferguson and Stransky 1962) for preparing old fields, pastures, and wooded areas for seeding and planting pine. Repeated testing on the Chipola Experimental Forest indicates that they are not rugged enough for sustained use in riding down and cutting oaks.

The disk harrow is sometimes used in combination with a bulldozer when preparing scrub hardwood sites in the sandhills. Theoretically, the bulldozer knocks the scrub hardwoods down so the disks can cut them up and mix the debris into the soil. In practice, however, the disks tend to ride over small logs and aggregations of small stems without cutting them, and this leaves

16

Figure 7.—The heavy-duty disk harrow is used for site preparation, but is not rugged enough for sustained use against oaks.

patches of undisturbed wiregrass next to the uncut stems. Woody stems occasionally become lodged between the serrated disks, and clearing the accumulated debris wastes a considerable amount of operating time. At best, a disk harrow provides only partial control of the scrub vegetation.

Effectiveness of the disk harrow can be measured by comparing height and survival of planted pines. When one pass with a disk harrow resulted in partial control of scrub vegetation, the survival and growth of planted pines at age 10 years was roughly the same as with those on a site prepared with a hot fire in summer and only slightly better than those planted with no previous site preparation. A more complete vegetative control was obtained with repeated treatments. Sequential treatments with a disk harrow in July and August, following a prescribed burn in May, produced slash pine plantations at age 10 years that were of comparable size and stocking to those produced by a prescribed burn in May followed by a single treatment with a heavy double drum chopper in July and slightly better than those planted in a furrow made by a fireplow. None of the treatments were entirely satisfactory, however.

Treatment	Survival	Height		D.b.h.	
	Percent	Feet	(m.)	Inches	(cm.)
Furrow	50	9.3	(2.8)	1.5	(3.8)
Chop once	58	12.9	(3.9)	2.3	(5.8)
Burn, then harrow twice	59	13.9	(4.2)	2.3	(5.8)

The heavy-duty disk harrow is admirably suited for a followup operation to control oak sprouts. As such it is a useful and economical adjunct to heavy choppers or the rootrake.

17

Heavy Plow

Equipment designed for other purposes—agricultural machinery, for example—often is adapted for site preparation. Modification usually involves strengthening structural components, but for the most part results are disappointing because the equipment seldom is sturdy enough to withstand use in scrub hardwood control. An exception is the double-disk fireplow (fig. 8) pulled by a crawler tractor. Built to withstand rugged use, the heavy plow has the advantages of commercial availability with no need for modification and alternative use during fire season. Because of these advantages, furrowing with a heavy plow was considered by Brewster[8] to be one of the cheapest and most effective ways to prepare land for pine in northwest Florida. He may have had only the flatwoods in mind, for he acknowledged that special methods of site preparation would be necessary where the brush was dense and competition for light and soil moisture was great.

In the coastal plain of Texas, the heavy plow has been used with some success in the woods and to control sod and grasses in old fields and pastures preparatory for planting and seeding pine (Ferguson 1959; Ferguson and Stransky 1962; Stransky 1962). Furrowing with a heavy plow as site preparation for direct seeding pines in the South is recommended only on relatively flat, well-drained sandy soils because of the possibility of washing on sloping ground and flooding on poorly drained sites (Mann and Derr 1961, 1964; Derr and Mann 1971).

---

[8] Brewster, Donald R. Pine plantations on private lands in northwest Florida, an appraisal of results to date. 1937. (Unpublished report filed at Southeast. Forest Exp. Stn., USDA Forest Serv., Marianna, Fla.)

F-521420

Figure 8.—The heavy disk plow has o secondary use for site preparotion when not needed for fire control.

18

Theoretically, pines should grow well on the ridges between furrows because it is here that topsoil is piled. And, survival should be excellent within the furrow because improved soil moisture conditions result from complete removal of all competing vegetation. Yet, previously reported results and work by Shipman (1958) show that slash pine survival and growth were extremely poor whether seedlings were bar planted in the furrow or machine planted to the side of the furrow on the ridge (the packing wheels prevented planting directly in the bottom of the furrow). However, in old fields dominated by wiregrass and broomsedge, planting in the furrow proved quite beneficial—first-year survival of longleaf pines averaged 92 percent, compared to 59 percent on an adjacent, untreated old field. Comparison at a depth of 9 inches (22.9 cm.) showed that soil moisture was available for plant use for a greater part of the growing season in furrows than in the untreated old field (Shipman 1956, 1958). In the scrub oak rough, however, furrowing with a heavy plow proved to be one of the poorer methods.

Rotary Tiller

A heavy-duty rotary tiller was another piece of unmodified agricultural equipment tested. Pulled by a wheeled farm tractor and driven by the power takeoff, it efficiently shredded all herbaceous vegetation and hardwoods as large as 1½ inches (3.8 cm.) in diameter and mixed the debris with the soil to a depth of about 4½ inches (11.4 cm.).

The tractor and the tiller were not capable of processing the size and number of hardwoods normally encountered in the first treatment. Trees larger than 1½ inches (3.8 cm.) in diameter had to be avoided because the tiller could not cut them, and dense clumps of small trees were skirted because the tractor could not push through them. Rigidly mounted tiller tines did not break but showed effects of abuse from large, undecayed stumps and abrasive sandy soil.

Despite disadvantages, the heavy-duty rotary tiller may have some use in strip tilling to convert scrub oak-dominated stands to pine.[9] Preliminary results show that survival and growth on tilled strips 40 inches (101.6 cm.) wide and 4 inches (10.2 cm.) deep were best of those tested and comparable to results obtained on an area prepared with a rootrake and disk harrow.

Tillage	Survival (Percent)	Height	
		(Feet)	(meters)
Depth			
0 inches	88	4.6	(1.4)
2 inches	84	5.2	(1.6)
4 inches	89	5.6	(1.7)
Width			
0 inches	88	4.2	(1.3)
20 inches	83	5.1	(1.6)
40 inches	88	5.3	(1.6)
60 inches	89	5.2	(1.6)

Main advantages of the rotary tiller are that no second treatment is required to complete a job, and the machine is small enough to be manipulated through the woods to avoid obstacles beyond its capabilities. Rows will be

---

[9] Burns, R. M. Preparing sandhills sites for sand pine with a rotary tiller. (Manuscript in preparation.)

crooked but can be made reasonably parallel, and the prepared soil can be row seeded immediately (even in the same operation) or planted after the soil has settled. An interval of at least 6 months is essential between tillage and planting to allow the drastically disturbed soil to stabilize or planting survival can be expected to drop. Longer periods are recommended unless unusually heavy rains settle the soil or it is compacted mechanically.

The versatility of the rotary tiller makes it particularly well suited for year-round use by farmers who plan to convert their sandhills scrub hardwoods to pines. Depth, width, and speed of tillage can be adjusted for use in woods or field.

Root Plow

A root plow (fig. 9) is a horizontally positioned blade suspended from a rigid frame attached to a crawler tractor and drawn beneath the surface of the soil to sever roots. The tractor is usually equipped with a bulldozer blade or rootrake to knock down the larger stems.

The subsurface method of attacking the roots is a good one. Woods and Cassady (1961) found that oak sprouts originated at or above the root collar, so the root plow severing roots below this point is effective. Efficiency of the operation improves when cut roots are turned up at the soil surface and then chopped by disking.

This method of killing woody vegetation is sometimes called "webbing" and has been used in various forms in the Western United States. An adaptation of it—the blade mounted beneath a road grader—has been used in peninsular Florida to control saw-palmetto.

CHEMICAL METHODS

Chemical methods of site preparation refer to the use of herbicides to kill unwanted plants. Herbicides, which include silvicides (tree killers) and phytocides (plant killers), have had a place in forestry for many years. At first they were used on a tree-to-tree basis to release individual seedlings from undesired woody competition. Now, when complete preparation of a sandhills site is needed, application may be made over the entire area.

Figure 9.—When pulled through the soil below the surface, the root plow blade severs roots below the point where they sprout. (Photo courtesy FLECO Corporation, Jacksonville, Fla.)

20

Herbicides have the allure of scientifically bringing unruly nature into order. They lend themselves to simple, mechanized application, thereby eliminating the need for much costly labor. Extensive areas can be treated from the air (fig. 10) by plane or helicopter (Grelen 1956) or from the ground with machine- or hand-operated distributors. Soil structure is preserved and litter is not destroyed when chemical methods are used.

There are disadvantages: cost of chemicals is high and misuse can endanger nearby crops and livestock and expose man to toxic substances. With

F-521421

Figure 10.—Liquid formulations and pelleted herbicides can be applied with light equipment to extensive areas.

21

the awakened concern for quality of the environment, and the possibility of serious side effects of chemicals on human physiology, their use has come under close scrutiny.

Herbicides are used as liquid sprays, mists, dry crystals, or pellets. For large areas, broadcast applications by spraying or scattering pellets are most economical, particularly when done by airplane. Contamination of crops and livestock can be avoided by the use of recommended formulations and procedures.

The sandhills environment poses a special problem: it is difficult to find a chemical that will kill both oaks and grasses. In other regions foresters successfully use chemicals, mainly against a mixture of several species or genera of trees. On sandhills sites the trees and grasses differ enough in physiology that one chemical will not attack them both with the same efficiency.

Although he tested many chemicals, Woods (1959a) failed to find a herbicide that would kill both scrub oaks and wiregrass economically. The closest thing to success was achieved with the soil sterilant monuron (CMU). It killed all the oaks, but a satisfactory wiregrass kill was obtained only at prohibitively high dosages; disadvantages were the high cost per acre and the residual effect. When as little as 20 lb. active ingredient (a.i.) per acre (22.4 kg./ha.) of CMU were applied, pines planted 9 months later suffered 85-percent mortality (Woods 1955).

Fenuron (3-phenyl-1,1-dimethylurea), a compound related to CMU, does not have so great a residual effect and therefore has shown promise for sandhills site preparation. In an informal test [10] it was found to be effective against oaks—12 lb. of 25-percent fenuron per acre (13.4 kg./ha.) killed 96 percent of the undesirable hardwoods larger than 1 inch d.b.h. (2.5 cm. at 1.4 m.) and 81 percent of smaller hardwoods within 1 year. To account for geographical differences in climate, soil, and plants, about 20 lb. per acre of 25-percent fenuron pellets have been recommended (Peevy 1960; Rice 1966; Shipman and Scott 1963). In the Florida sandhills 30 pounds per acre (33.6 kg./ha.) of the same formulation were more effective than 20 and appeared to allow faster growth of sand pine. On similar soils in South Carolina, Shipman (1963a) compared areas treated with 30, 40, and 60 pounds of fenuron pellets per acre (33.6, 44.8, and 67.2 kg. per ha.) and found no differences in number of oaks killed.

Fenuron has the same limitation as compounds tried earlier (it does not kill both oaks and wiregrass with equal success), but when sand pine is planted it may not be essential to eliminate wiregrass. In one test where the oaks alone were killed by fenuron, sand pines grew twice as tall in 3 years as those planted amid oaks and wiregrass.

Where both hardwoods and grasses must be eliminated, some combination of chemicals may be effective. Fenuron was tried against oaks and in combination with paraquat (1,1'-dimethyl-4,4'-bipyridylium dichloride) was tried against oaks and grasses, but consistent mortality was obtained only in

---

[10] DeRolf, Bill. Fenuron—how good is it? (Unpublished report, Fla. Forest Serv., Tallahassee.)

the oaks. Some wiregrass died, but results were not well correlated with treatment:

Treatment		Turkey oak	Wiregrass
Lb./acre	(kg./ha.)	Percent mortality	
Fenuron alone			
0	(0)	0	4
10	(11.2)	17	0
20	(22.4)	63	4
30	(33.6)	93	7
Fenuron with paraquat			
0	(0)	0	7
10	(11.2)	13	0
20	(22.4)	70	41
30	(33.6)	83	23

Differences in the proportion of oaks killed were significant for fenuron with or without paraquat. Possibly the application rate of paraquat was too low—1 quart per acre of a concentrate containing 2 pounds of the paraquat cation per gallon (0.91 kg./3.8 1.)—or the fenuron may have curtailed action of the paraquat (Mees 1960).

The interest in chemicals has been reawakened by the growing scarcity of large tracts of land suitable for mechanical site preparation. On small tracts the expense and bother of treating a site mechanically—transporting and servicing the equipment—cannot be justified. Most companies feel that mechanical methods give "the best overall site preparation on 65 to 70% of their lands" (Campbell 1966), but the remaining sites are unsuited because of rough terrain or small size. In customary mechanical preparation these sites are either ignored or prepared by costly hand methods, but chemical methods of site preparation would seem most convenient because simple, inexpensive equipment may be used. For example, pelleted herbicides can be scattered by one man using a hand seeder; the work can be stopped and begun again whenever appropriate to take full advantage of seasonal differences in a plant's physiological condition.

Fenuron is no longer being marketed, but the manufacturer, E. I. du Pont de Nemours & Co., considers bromacil (5-bromo-3-sec-butyl-6-methyluracil) to be a good substitute (Edward L. Foland, personal communication, 1971). Tests on sandhills sites and species have not yet been made, but Peevy [11] has found bromacil pellets more effective than fenuron against blackjack oak (*Quercus marilandica* Muenchh.) and post oak (*Q. stellata* Wangenh.).

PRESCRIBED FIRE

Although fire is sometimes used in sandhills site preparation, it serves little useful purpose as a primary tool for converting scrub oak-wiregrass dominated sites to pine. Used alone it reduces the competitive influence of surface vegetation, but kills few roots; the beneficial effects are short-lived because most burned plants sprout and may even thrive for a short time on nutrients leached from ashes. The overall effect of fire is to reduce the number of comparatively large hardwood trees and to greatly increase the number of small hardwood sprouts.

---

[11] Peevy, F. A. Application date and dosage influence kill of hardwoods by soil application of bromacil, fenuron and picloram. (Paper presented at 1971 meeting of South. Weed Sci. Soc.)

One of the first site preparation prescriptions for Florida sandhills (Woods et al. 1958) recommended burning prior to use of machines. It now appears that mechanical methods alone are as effective, and they are more easily introduced and controlled.

An examination of long-term effects of prescribed burning on the Chipola Experimental Forest showed that survival of seedlings planted on sand-hills sites prepared by fire was extremely low, lower even than that of pines planted in the scrub oak-wiregrass rough. Growth of surviving pines was slightly better on fire-prepared areas than in the rough, but the difference could not compensate for lower survival.

Use of fire is attractive because it is cheap and relatively safe. It leaves an undisturbed seedbed or planting site, extensive areas can be treated within a relatively short time, and with judicious planning and timing experienced personnel can control intensity of the fire with a reasonable degree of precision.

In the sandhills lack of fuel places serious limitations on burning. Leaves of predominant scrub hardwoods are easily windblown and tend to drift into piles rather than forming the thatch-like litter that makes so consistent a fire in pine stands. Bare patches of exposed sand and drifted hardwood leaves characterize the forest floor (fig. 11), and result in fires of uneven intensity and duration (Shipman 1958).

Moreover, hardwood leaves burn best soon after they are shed; after weathering they form compact layers that remain moist for long periods of time. But, scrub hardwoods are susceptible to burning later in the year. Burning in spring and summer when ambient air temperatures are most conducive to a hot fire affords the possibility of interrupting development

F-521422

Figure 11.—Bare patches left by drifted hardwood leaves make it difficult to obtain a uniform burn.

of hardwoods at a time when much of their stored foods has been expended by flushes of growth.

Fire converts much of the litter and vegetation to ashes and charcoal. Volatile substances are lost to the atmosphere, and soluble constituents are leached into the soil or washed away. Temperatures during prescribed fire are seldom high enough to significantly alter physical properties of the soil or to reduce incorporated organic matter. Soil fertility, however, and the survival and growth of introduced pines, is affected by residues from fire. Water leaches calcium, potassium, and sometimes phosphorus from the ashes into the soil. Acid soils become less acid and therefore some nutrients become more available for plants. Nitrogen levels in the soil may also increase, not necessarily via the leachate, but because of biotic factors that increase nitrogen-fixing activity.

Fire does not always make more nutrients available. Recent work by DeBell and Ralston (1970) indicates that most nitrogen released in burning is gaseous, not returnable to the soil in rainfall, and so is not available for tree growth. For more details concerning the effects of fire on various ecological aspects of the forest community, the reader is referred to the excellent reviews by Ahlgren and Ahlgren (1960) and Hare (1961) and to the work by Burns (1952).

The only beneficial effects realized from using fire for site preparation involve subsequent treatment by mechanical means. Brittle, burned hardwood stems are processed more effectively by machine than are supple green stems. Roots of heavy sod can be eliminated more readily with a harrow when the grass has been removed by fire (Derr 1957).

We must conclude that burning for site preparation rarely justifies the expenditure of time and labor. Forty years ago, a bulletin describing methods for planting forest trees in Florida warned against use of fire for site preparation. Scorched areas were deemed unsuitable because they exposed young seedlings unnecessarily to damage by drought, sunscald, livestock, and rabbits (Coulter 1931). Moreover, a number of different investigators (including Cushwa et al. 1970) have determined that chances of altering species composition with single burns are very poor.

Recent emphasis on the abatement of environmental pollutants points to still another shortcoming of prescribed burning—considerable amounts of smoke and heat are produced and add to the general pollution. The principal disadvantage of this, however, may be in impaired public relations. The tentative conclusion of Cooper (1971) is that the contribution of prescribed burning to atmospheric pollution is not great enough to warrant restriction of the practice.

SCHEDULING OF TREATMENTS AND PLANTING

SITE PREPARATION

In any program of site preparation the work must be done when native vegetation is most vulnerable to treatment, and it must be done sufficiently in advance of the planting season to enable disturbed soil to settle. Competition from existing vegetation must be reduced to the point where planted or seeded pines can become dominant.

Turkey and bluejack oaks and wiregrass are susceptible to treatment when site preparation is tied in with cyclic fluctuations in their food reserves. Plants are most vulnerable when reserves are at an ebb. For turkey and bluejack oaks in the Southeast this occurs at the time of full leaf development following the first annual growth flush late in April or early May. Thereafter follows a period of about 2 months in which foods accumulate rapidly before a slight decline occurs. Removal of aerial portions of the trees in early May, however, prevents accumulation and causes the level of root carbohydrate to remain low for at least 12 weeks. During this period sprouts develop and synthesis of carbohydrates resumes. Differences between carbohydrate root reserves in live, standing scrub oaks and in those cut during May are most pronounced after 8 weeks (Woods, Harris, and Caldwell 1959). Even though its root reserves are lowest during midsummer, wiregrass can be chopped along with oaks in late April or early May because sprouting after such treatment is not a problem (the entire plant is displaced).

Stumps of scrub oaks cut in May begin to sprout within 2 weeks. Sprouts develop from dormant buds at or above the root collar and increase rapidly in number and size for the next 6 to 8 weeks. Thereafter the rate of increase declines, indicating that food reserves stored in the roots have been further depleted. In an experiment reported by Woods and Cassady (1961) turkey and bluejack oaks were cut in May and sprouts were removed at prescribed intervals thereafter. Those sprouts removed 4 weeks after oaks were cut resprouted from adventitious buds; 4 weeks later they were of a number and size equivalent to those allowed to develop undisturbed for 8 weeks. Sprout removal at intervals of 6, 7, and 8 weeks reduced subsequent sprout development much more than removal at 4-week intervals (fig. 12).
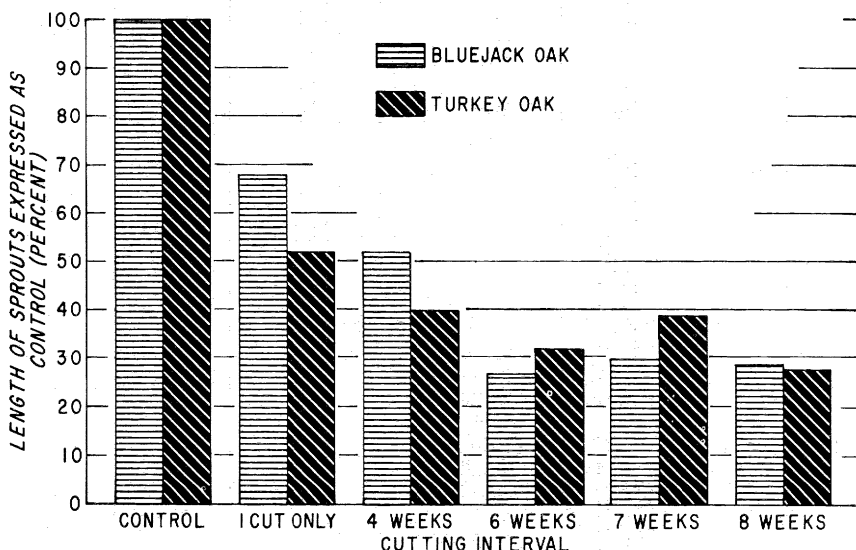

F-521423

Figure 12.—Relative total length of sprouts per stump in the second season following different cutting regimes (Woods and Cassady 1961).

26

The site preparation prescription developed from experiments (Woods et al. 1958) involves multiple treatments: prescribed burning in April or May followed by two chopping treatments with duplex brush cutters at intervals of 6 to 10 weeks. But a large investment in heavy equipment and restrictions in scheduling make this recommendation impractical. In practice, chopping continues almost year-round, and the second treatment usually is applied whenever it is convenient—sometimes immediately upon completion of the first chopping treatment and sometimes after months intervene. Results of current research in west Florida sandhills show that site preparation with duplex brush cutters can be done during 9 months of the year. But to do this, the time of applying the first of two treatments and the interval between successive treatments must be considered. The following chopping prescription, which is recommended for west Florida, can be modified for use in areas with differing climate: [12]

When the first of two chopping treatments is started during the period:	*The recommended interval between treatments is:* Weeks
Mid-February to mid-April	18
Mid-April through June	6, 12, or 18
July and until mid-August	6 or 12
Mid-August through September	6
October	18
November through mid-February	Start no new work

A serious disadvantage of burning is that it tends to conflict with the scheduling of mechanical treatments. Mechanical site preparation destroys fuel, so fire must precede chopping. Hardwood leaves, the principal fuel on scrub oak-dominated sites, burn best when dry soon after they fall; but burning is most effective against hardwoods when they are in full leaf during spring and summer. Chopping is most effective during the same period or slightly before, so fire would have to immediately precede the first mechanical treatment. If this is done without an interval to enable sprouts to develop, the fire merely eliminates trash; chopping alone is as effective. Accumulated litter and grass sod are not problems in the sandhills.

Prescribed burning alone or in combination with mechanical methods of site preparation contributes little to the growth of planted pines. No longer is it recommended as a prerequisite for mechanical site preparation.

Soil must be allowed to settle following mechanical site preparation (Stransky 1960). The length of time needed depends to some measure on the equipment used, the degree to which the soil has been disturbed, the type and amount of vegetation present, and the amount and intensity of rainfall received. Rotary tilling, for example, physically reorients the entire surface layer of the soil and incorporates all existing herbaceous and woody vegetation. So thorough is the preparation that months later the surface retains a structure which may be likened to crusted snow; when soil is tilled to a depth of 4 or more inches (10.2 cm.), these effects may be apparent for more than a year.

Although such disturbance is extreme, all mechanical methods of site preparation alter the structure of surface soils to some degree. Soils with

---

[12] Burns, R. M., and McReynolds, R. D. Scheduling and intensity of site preparation for west Florida sandhills. 1972. (Manuscript in press, *J. For.*)

large air pockets and concentrations of undecomposed plant debris will not sustain plant life. Roots of newly planted seedlings dry out, are mechanically injured during planting, or suffer from early products of decomposition. Another problem is that disturbed soil on freshly prepared sites washes and buries newly planted seedlings.

Settling of the soil may be hastened with equipment that levels the surface and destroys air pockets by compaction. Roadgraders have been used following preparation with rootrakes or choppers; simple drags made of iron bars or logs and pulled behind a wheeled tractor serve a similar function (Shipman 1958) and are cheaper to operate. Cultipackers press broadcast seeds of pines into the soil to cover them, thereby increasing germination and seedling establishment in droughty sand. On newly prepared sites compaction of the soil to destroy pockets of air, as done by the cultipacker, may be equally as important as covering the seeds.

When supplementary packing treatments are not used, stabilization or settling of the soil requisite for planting longleaf pines may require as long as 12 months. The interval may be reduced by half if the prepared site is graded or dragged. First-year survival of longleaf pine seedlings was increased almost 20 percent when soils on sites prepared by disking were dragged and allowed to settle for 6 months before planting (Shipman 1958). With slash and sand pines there is no danger of soil washing in over the terminal bud unless seedlings are planted exceptionally deep, so areas prepared by mechanical means other than rotary tilling generally are not given a supplementary compaction treatment. Although longer periods are recommended, weathering for 2 to 6 months usually stabilizes the soil sufficiently for planting seedlings. Length of the settling period depends more on intensity and frequency of rainfall than any other factor.

DIRECT SEEDING

Sandy soils on cleared sites contain enough moisture to support newly germinated seeds provided they are planted under good conditions and at the correct depth. The crust that forms on many sandhills soils following a rain prevents the rapid penetration of radicles needed to insure establishment in dry, sandy soil; they wither and die when exposed to high surface temperatures. A covering of soil greatly increases the likelihood of establishment, but the depth to which seeds are covered is critical because seed of pines vary in their tolerance to this depth. Although tolerant of slightly greater depths of soil covering, seed of longleaf should be planted at ¼ inch (6 mm.) and seed of slash and sand pines should be planted at ½ inch (12 mm.) (Hodges and Scheer 1962). Shipman's studies in South Carolina (1963b) showed "optimum sowing depths for slash pine were ½ to ¾ inches [19 mm.] and for longleaf pine were ¼ to ¾ inches."

One satisfactory method of direct seeding prepared sites is pressing broadcast seed into the soil with a cultipacker. Row seeding with a machine also has been successful—in limited trials it has resulted in more economical use of seeds and in higher stocking than cultipacking broadcast seeds. Regardless of what method is used, there is no substitute for placing an adequate number of sound, repellent-coated seeds of an adapted species in intimate contact with a well-prepared seedbed (Burns 1966a).

Soil moisture, temperature, and the prevalence of seed-eating predators dictate the time of year for seeding. Beneath the surface, soil moisture usually is adequate for germination and establishment of pine seeds except during prolonged drought. In the sandhills of west Florida detrimental droughts are most likely to occur during the spring and fall. When soil moisture is not limiting, establishment depends upon temperature extremes, particularly during the 10-week period following planting.[13] Although the response of different pine species varies somewhat, germination and establishment are generally highest when the daily maximum averages less than 75° F. (24° C.) and the average daily minimum exceeds 40° F. (4° C.).

Rodents, insects, and birds are year-round threats to pine establishment by direct seeding throughout the sandhills (Shipman 1955b). Predation lessens, however, with the advent of cold weather in late fall and winter when soil moisture and temperature are most conducive to germination and seedling establishment. The following tabulation summarizes the possibilities and recommendations for planting unstratified, repellent-coated seed in west Florida:

Pine	Range	Recommended
Longleaf	Sept. 15-Feb. 28	Oct. 1-Jan. 31
Slash	Sept. 15-Feb. 15	Nov. 1-Jan. 31
Ocala sand	Nov. 1-Feb. 28	Nov. 1-Jan. 31
Choctawhatchee sand	Oct. 15-Feb. 28	Nov. 1-Jan. 15

Stratified seed might germinate faster and thus escape predation by seed-eating insects and animals. In the test from which these data were derived we noted no losses in germination attributable to storage.

PLANTING

The combination of comparatively short winters and the tremendous amount of land in need of planting often pressures land managers into lifting and transplanting before seedlings are in best physiological condition for transfer from the nursery to the field. Ten years of survival measurements on the Yazoo-Little Tallahatchie Flood Prevention Project in northern Mississippi show conclusively that planting during late fall results in lower survival and poorer growth than planting during the winter (Ursic, Williston, and Burns 1966). Wakeley (1954) reported that southern pines planted in the latter half of the season survived better.

Delaying planting exposes seedlings to a longer period of cold in the nursery bed and enables them to "harden off"—to become dormant rather than quiescent. Lack of dormancy is a greater problem in the more southern nurseries. Some species of pine become dormant earlier and remain dormant longer than others. For example, Ocala seedlings are more apt to break dormancy following a few days of warm weather than are Choctawhatchee seedlings.[14] For best planting survival the season of transplanting should coincide with seedling dormancy, which is more likely as winter progresses

---

[13] Burns, R. M., and McReynolds, R. D. Season for planting pine seed in the sandhills. (Manuscript in preparation.)

[14] Zelawski, W., and Strickland, R. K. Temperature effects on growth, net assimilation rate and bud development of two races of sand pine (*Pinus clausa* Engelm.). (Unpublished report on file at Forest Physiol. and Genet. Lab., Univ. Fla., Gainesville.)

and the probability of unseasonable warm weather diminishes. For this reason, sand pines in Florida should not be lifted before January 1, and then they should be planted within 3 to 5 days; those lifted later may be stored in bales for progressively longer periods but rarely more than 1 week. Farther north, lifting and planting of dormant seedlings might start 1 or 2 weeks earlier.

The pressure to plant pines, coupled with a limited season in Georgia and Florida, has led to experimentation with summer planting (McGregor 1965; Schultz and Wilhite 1967; Wilhite and Schultz 1969). Though the work appears promising, it has not been consistently successful. Refrigerated storage of dormant, baled seedlings and delayed planting has proved to be a practical alternative elsewhere and one worth considering along the gulf coast. The secret of success apparently lies in baling only completely dormant seedlings and storing them under refrigeration to prevent breaking of dormancy by heat generated within the bales. Dormant seedlings may be planted well into the spring without loss of vigor. In Virginia, Dierauf and Marler (1971) found that storage up to 5 weeks did not harm survival or growth of loblolly pine.

Seedlings should be of good quality. They should be dormant, free from disease and insects, undamaged, and possess a good balance between roots and foliage. Although size alone is no guarantee of superiority, seedlings should be large enough to plant easily at the proper depth.

Attempts to plant seedlings without forming roots into "J" or "U" shapes and the admonition to "plant at root collar depth" often result in shallow planting. Roots of a pine seedling proliferate immediately below the root collar, and if a fraction of an inch of soil washes or blows away, these roots will be exposed to the elements. Another consideration in planting depth is the hypocotyl—that portion of the stem between the root collar and the lowest needles. This is the weak spot of a newly planted pine because no sprouts can arise in the hypocotyl if it should be severed by rabbits or rodents or if the top should die. Planting seedlings (except longleaf pine) deep enough to cover the lower needles with soil protects the hypocotyl, reduces transpirational surfaces, insures against exposure of roots, and increases the likelihood of survival by sprout formation should damage befall the seedling top. In extremely droughty sands on the Chipola Experimental Forest, sand pine seedlings have often been planted with only 1 to 3 inches (2.5 to 7.6 cm.) of stem protruding, and survival and growth have been excellent. In the South Carolina sandhills, Shipman and Hatcher (1957) found that deep planting was beneficial to all classes of slash pine seedlings and that survival of the smallest and poorest class was doubled.

EFFECTS OF MECHANICAL SITE PREPARATION

The sudden and drastic physical alteration of the plant-soil community that is common to all methods of mechanical site preparation has both immediate and long-lasting effects on the ecosystem. The relatively stable community is disrupted when native vegetation is removed, destroyed, or relegated to a minor role; plant succession starts anew as soon as the machinery leaves. Invading species may assume temporary dominance of the area, but all vegetation is forced ultimately to compete with planted pines. The

soil itself is modified somewhat in structure, fertility, and chemistry, and these modifications affect survival, growth, and development of the native plants and introduced pines alike. Animals and birds forced to seek food, shelter, and breeding grounds elsewhere return as a new environment develops. Understanding these and other effects of mechanical site preparation provides the basis for justifying the expenditure of time, labor, and money for conversion of scrub hardwood- and wiregrass-dominated sandhills to pine.

EFFECTS ON SOIL

Mechanical site preparation influences fertility of the soil through the processing of humus, litter, and standing vegetation. Among all methods of mechanical site preparation and among the particular localities where they are practiced, there is variation in the amount and type of disturbance and the degree of change in some physical and chemical properties of the soil.

One extreme is represented by the rotary tiller that thoroughly mixes existing vegetation and litter into the topsoil without removing the topsoil and causes a temporary increase in the proportion of large pores; the process "fluffs" the soil but leaves it in place. A bulldozer represents the other extreme, wherein vegetation and topsoil are removed and deposited in windrows, leaving soils compacted and devoid of topsoil and organic matter. Between these extremes are such machines as rootrakes that transport vegetation and some topsoil to windrows; heavy choppers that incorporate all herbaceous and woody vegetation into the soil without removing topsoil; disk harrows that do a similar but less thorough job of eliminating vegetation than choppers, but incorporate more of the organic matter with mineral soil; plows and BSW blades that simulate on a small scale the action of bulldozers.

Important changes in chemical and physical properties of the soil occur most rapidly in places where the mixture of organic matter and topsoil is deposited. Changes follow a general sequence which is governed to a large measure by climate; warm, moist conditions are quite conducive to rapid change. "In the virgin state in Florida, exchangeable Ca, Mg, and K decrease as the organic matter content decreases in the profile . . ." (Southern Regional Soil Research Committee 1959). Humus and partially decomposed organic matter oxidize rapidly in the topsoil exposed to air during the preparation process. An increase in released plant nutrients accompanies reduction in the amount of humus. As green, newly mixed organic material begins to decompose, the population of soil flora and fauna multiplies and utilizes almost all nitrogen and many other nutrients formerly available to higher plants. This stage persists until the population of microscopic plants and animals exceeds its food supply and their death begins to surpass reproduction. From their remains, nitrogenous elements and other nutrient compounds are released in forms suitable for use by higher plants. By this time the huge mass of organic debris has been reduced to a relatively minute amount of amorphous materials, or humus.

Humus is an important constituent of any soil; its value to infertile, excessively drained sands cannot be overemphasized. Humus serves as the energy source for bacteria, fungi, and actinomycetes, but its most important single function is providing the great surface area of its colloidal particles. In sandhills soils, many of which are lacking in silt and clay, organic colloids

provide the principal source of exchange surfaces for charged nutrient elements. Without exchange surfaces all nutrients are quickly leached from the root zone and lost to ground water.

If the amount of plant tissue added to soil during mechanical site preparation were the sole factor governing the quantity of humus produced, improvement of soil fertility and structure would be relatively simple. Humification is a complex process that includes enzymic digestion of organic matter by living organisms. Nitrogen is one element needed to sustain these microorganisms and, because it is extremely scarce in droughty sands, the nitrogen supply becomes the second factor limiting production of humus.

The ratio of carbon to nitrogen in soil organic matter is a measure of potential humus production. In the uppermost 6 inches (15.2 cm.) of arable soil, ratios of 10:1 or 12:1 are common (Buckman and Brady 1960); in forested coastal plains or sandhills soils they average about 30:1 (Heyward and Barnette 1934, 1936; Brendemuehl 1967b), indicating a much lower potential for humus production on unfertilized forested sites. On mechanically prepared sites, the situation is not entirely bleak, however, because nitrogen formerly lost through leaching, volatilization, and mineralization is immediately tied up, and thereby conserved by organisms humifying incorporated organic matter. Ultimately this nitrogen may be made available to plants.

Probably conservation of soil moisture is the most significant contribution of mechanical site preparation to improvement of soil-plant relations. Elimination of standing vegetation increases exposure of the soil to sun and wind, and disturbance of the soil increases the surface area exposed. Rates of evaporation and transpiration are affected and moisture is lost. The loss does not extend to any appreciable depth, however, because a sand and organic matter mulch forms a temporary impediment to evaporation after weak soil aggregates and capillaries at the surface have been destroyed. Following the first soil-settling rain, a crust several millimeters thick characteristically forms at the surface, probably as the result of biological action. This crust and the still fluffy soil beneath it appear to serve as effective barriers to evaporation; therefore, losses are of no great consequence on prepared sandhills soils.

Reduction of the transpirational drain on soil moisture by vegetation contributes most to soil water conservation and more than offsets increased evaporative losses resulting from exposure of the soil. The amount of moisture made available relates directly to the thoroughness with which standing vegetation has been eradicated (Shipman 1956; Woods 1956) and the rate of reinvasion by herbaceous vegetation and sprouts. Figure 13 shows soil moisture conditions as measured on sites prepared during the previous November.

Differences in soil moisture are most pronounced during spring and diminish as moisture requirements of plants increase. By midsummer, differences in available soil moisture are negligible on sites completely and partially released from oaks and herbaceous vegetation and on those left unprepared, suggesting that re-establishment of hardwood sprouts and herbaceous vegetation is virtually complete.

Water-holding capacity of the soil is also increased by the organic matter incorporated during mechanical site preparation. Instead of being rapidly lost
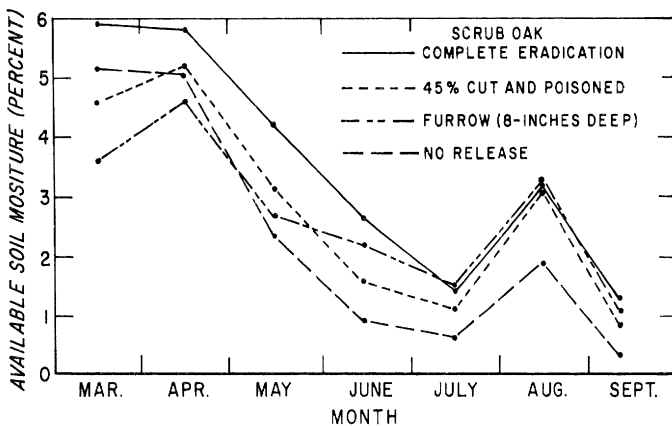
32

Figure 13.—Effect of scrub oak removal on soil moisture in South Carolina
sandhills, 1954 growing season (Shipman 1955a).

to ground water, some moisture is absorbed by this plant tissue and the
organisms involved in its decomposition. The water-holding effect of organic
matter .is not lost when the tissue has been digested. Completely humified
plant and animal remains are hygroscopic and according to Buckman and
Brady (1960) ". . . will absorb from a saturated atmosphere perhaps 80 or
90 percent of water." Although some of this moisture may be tightly bound,
most is available for plant use.

All mechanical methods of site preparation aim at facilitating the planting
operation and improving survival and growth of planted trees. Fortunately,
methods having the greatest beneficial impact upon soil structure and fer-
tility also conserve topsoil, enhance its organic content, and improve its
water-holding capacity.

EFFECTS ON THE PINE STAND

Early growth and subsequent development of a new pine stand are in-
fluenced by the method, scheduling, and intensity of mechanical site prepara-
tion and by their interrelationship with the environment into which seed
and seedlings are introduced. Essential to understanding the part site
preparation plays in this interrelationship is knowledge of the contribution
made by the other factors involved—species selection, spacing of trees, and
nutrient supplements.

Objectives of the landowner also have an important bearing on plantation
establishment and growth. Pulpwood production over a comparatively short
rotation and with minimal interim maintenance is a logical and practical
choice. It is an objective that can be achieved by selecting pines well suited
to a particular site, by proper spacing of seedlings, and by using other eco-
nomical techniques to stimulate growth and yield.

Species Selection

Extensive testing of native and exotic pines in west Florida shows the
following have some degree of suitability to sandhills soils: Choctawhatchee

33

and Ocala sand pines[15] (*Pinus clausa* (Chapm.) Vasey), longleaf pine, slash pine, and loblolly pine (*P. taeda* L.). These pines have been exposed to the rigors of sandhills life for 15 years in west Florida and for 5 years in Georgia and South Carolina (table 6). As a further measure of suitability, the 5-year-old planting in South Carolina was subjected to a devastating ice storm during which damage was catastrophic in a wide band that included the county where the comparative test was located. The following paragraphs describe how these species responded to testing throughout the sandhills.

Table 6.—*Performance, at plantation age 5 years, of the principal species of pine planted in the sandhills* [*(Hebb 1971b) and Burns* [1]]

| Pine | West Florida | | Georgia | | South Carolina | | |
	Survival	Height	Survival	Height	Survival	Height	Ice damage
	Percent	Feet (cm.)	Percent	Feet (cm.)	Percent	Feet (cm.)	Percent
Slash	91	7.2 (219)	84	5.1 (155)	92	8.8 (268)	27
Loblolly	88	4.8 (146)	88	5.4 (165)	96	10.0 (305)	13
Longleaf	31	2.1 (64)	16	1.5 (46)	59	5.8 (177)	23
Ocala sand	61	9.3 (283)	34	7.8 (238)	60	9.7 (296)	37
Choctawhatchee sand	87	8.4 (256)	75	8.3 (253)	81	10.6 (323)	25

[1] Burns, R. M. Economical site preparation prescriptions for the sandhills. (Manuscript in preparation.)

Choctawhatchee Sand Pine

The field performance of Choctawhatchee sand pine surpasses that of all other pines with which it has been compared on most sandhills soils. Choctawhatchee has open cones and is found along the gulf coast from Apalachicola to Mobile Bay, extending inland 30 or 40 miles (48.3 or 64.4 km.) at the center of this range. It appears immune to damage by diseases common to other pines, and though attacked by tip moths (*Rhyacionia frustrana* Comst.), suffered practically no loss of height (0.3 ft. or 0.09 m.) or diameter growth (0.1 in. or 2.5 mm.) in a 5-year study (Burns 1966b). Individual trees are found infected with gall rust (*Cronartium quercuum* (Berk.) Miy.) and witches' broom (cause unknown), but seldom are more than a few trees in one locality afflicted. Choctawhatchee pines remained healthy after 15 years even though they were planted within 25 feet (7.6 m.) of Ocala sand pine dead and dying from mushroom root rot (*Clitocybe tabescens* (Fr.) Bres.), suggesting either immunity or high resistance to the disease (Ross 1970). Choctawhatchee's tolerance to underplanting and ability to survive and eventually overtop competing scrub oaks matches that of Ocala. So successful has sand pine been in this respect that one land manager in west Florida underplants scrub oaks with Choctawhatchee pines during the winter and releases them later when labor is available. Table 7 [16] shows that

---

[15] Varietal names in current usage are *Pinus clausa* var. *immuginata* Ward for Choctawhatchee sand pine and *P. clausa* var. *clausa* Ward for Ocala sand pine (Ward, D. B. Contributions to the flora of Florida—2, *Pinus* (Pinaceae). Castanea 28: 1–10. 1963.).

[16] Burns, R. M. Choctawhatchee sand pine: a good prospect for planting in the Georgia-Carolina sandhills. (Manuscript in preparation.)

Table 7.—*Effects, after 5 years, of release on Choctawhatchee sand pine planted in the Georgia-Carolina sandhills*

Location	Released from sprouts				Not released from sprouts			
	Survival	Height	D.b.h.		Survival	Height	D.b.h.	
	Percent	Feet (m.)	Inches	(cm.)	Percent	Feet (m.)	Inches	(cm.)
Georgia	77	8.4 (2.56)	1.0	(2.5)	72	8.2 (2.5)	1.0	(2.5)
South Carolina	79	11.0 (3.35)	1.5	(3.8)	82	10.3 (3.14)	1.2	(3.0)

Choctawhatchee benefits from, but does not require, release from competing vegetation. Seedlings were planted on prepared sites, then half were released from hardwood sprouts that overtopped them (Harms 1969).

In the 5-year-old South Carolina test, Choctawhatchee planted 300 miles north of its natural range (Fowells 1965a) did not survive quite as well as loblolly and slash pines, but outgrew them both. The ice storm damaged one-fourth of the Choctawhatchee and about the same proportion of slash and longleaf, and this was fully twice the number of loblolly damaged.

Sand pines are known as worthless scrub trees and for their lack of resistance to fire. These beliefs are mostly false. Choctawhatchee sand pines, and many Ocala, grow straight and tall; taller than other pines growing on the same droughty site. Pulping qualities of both sand pines are good; Choctawhatchee compares favorably with longleaf (Martin 1962). Wildfire kills or seriously injures young sand pine, especially if crowns are scorched, but older trees can withstand a cool prescribed fire. In this respect Choctawhatchee is similar to slash (Cooper 1957; Fowells 1965b), but it will not withstand quite as hot a fire.

Seed orchards of superior selections of Choctawhatchee have been established by industry, and state and federal agencies in cooperative sand pine tree improvement. Because viable seed often are produced as early as age 5, a limited number of seedlings have already been produced.

On most sandhills sites, survival and growth are affected by the thoroughness with which native vegetation has been eliminated and the species of pine selected for each particular site. All pines respond to site preparation, but not to the same degree. On droughty, infertile sand, for example, sand pine planted amid scrub oaks and wiregrass will grow more rapidly than other pines will grow in the absence of such competition, but it will not grow as fast as when released from the oaks or when planted on a prepared site. There tends to be a direct relationship between field performance and intensity with which an area has been prepared for planting. The proper blend of species, soil, climate, and site preparation will result in survival and growth similar to that shown for Choctawhatchee sand pine in figure 14.

Choctawhatchee sand pine has attributes that qualify it as the most promising species for conversion planting on droughty, infertile soils in the sandhills: survival is high and growth is rapid; seedlings are tolerant of underplanting, possessing the ability to outgrow and ultimately suppress overtopping scrub oaks and yet respond to release; trees resist many common insects and diseases of the sandhills; saplings have displayed surprising adaptability to climate north of the species' natural range.
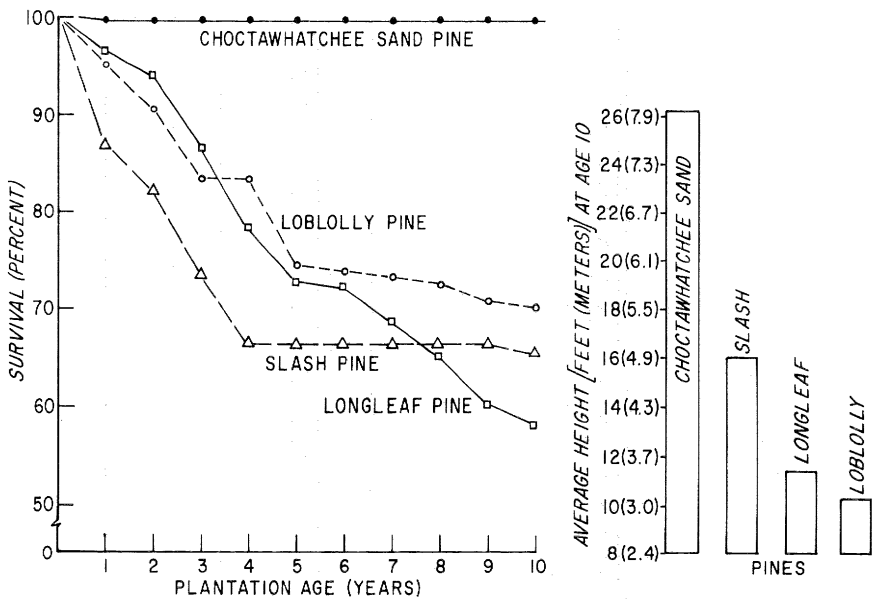
Figure 14.—Once established by seed or seedlings, Choctawhatchee sand pine survived and grew better in droughty, acid sands than other pines, especially longleaf which was sprayed for brown spot disease control.

Ocala Sand Pine

This pine is characterized by closed cones and is confined to peninsular Florida. Ocala outgrows other pines on deep, infertile sands, but it is susceptible to disease and damage by ice (Hebb 1971a) and plagued by comparatively low planting survival (Burns 1968a, 1968b). Mushroom root rot is contracted by Ocala from live, diseased oak roots or from chunks of diseased oak tissue cut into the soil during site preparation and then transmitted from pine to pine by root contact (Rhoads 1950). The disease emanates from infection centers and is credited with reducing planting survival and with causing mortality throughout the life of a plantation (Ross 1970). In an infected plantation in Florida, survival dropped from 53 percent 1 year after planting to 33 percent 14 years later—a mortality rate almost four times higher than normal (fig. 15).

Ocala sand pine is a fierce competitor and, once established, will outgrow and eventually suppress the oaks that overtop it. Comparisons of Ocala and slash pine growth when planted under scrub oaks and on prepared sites are illustrated in table 8.

Table 8.—*Comparative heights, at plantation age 12 years, of Ocala sand pine and slash pine planted under scrub oaks and on prepared sites in west Florida*

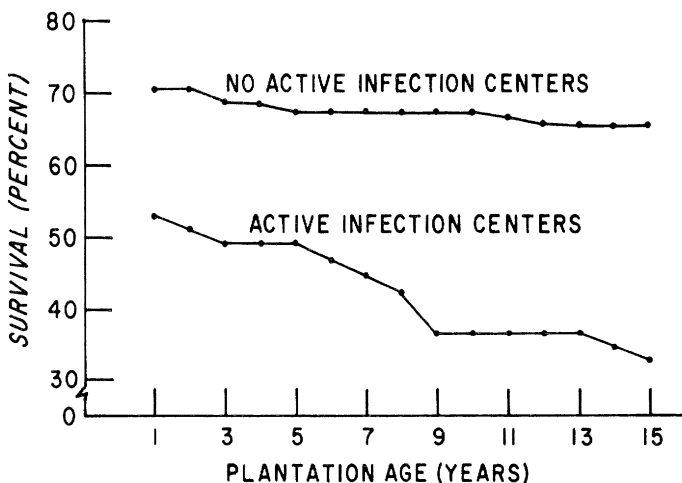| Pine	Unreleased	Released at time of planting	Planted on sites prepared with rootrake and harrow
		Feet (meters)	
Ocala sand	26.0 (7.9)	32.8 (10.0)	29.8 (9.1)
Slash	6.7 (2.0)	12.9 (4.0)	16.1 (4.9)

36

Figure 15.—Survival of Ocala sand pine on noninfected plots and on plots infected with mushroom root rot (Clitocybe tabescens).

Because mortality from root rot has been noted only on prepared sites, and because of sand pine's rapid growth when underplanted and released, landowners may be tempted to underplant Ocala sand pine when there is no danger of ice damage. They should be aware, however, that such plantings may result in low stocking levels because of Ocala's high planting mortality and susceptibility to disease. Choctawhatchee has none of these shortcomings —its first-year survival is 15 to 40 percent higher than survival of Ocala— and should be used instead.

Longleaf Pine

The nostalgia associated with longleaf pine, and the hope that a practical means of improving survival and stimulating early height growth is forth-coming, appear to justify its continued use in sandhills forestry. Low planting survival, mortality, and retardation of height growth by brown spot needle blight (*Scirrhia acicola* (Dearn.) Siggers) are the chief deterrents to its use. Brown spot can be controlled with chemical sprays and by fire on sites other than those intensively prepared as required for establishment of long-leaf pine in the sandhills. On such sites spraying planted seedlings for disease control is very costly, and insufficient fuel accumulates to allow burning.

Despite these handicaps many longleaf pines are planted, especially in the more northerly sandhills where saw log forestry has not been obscured entirely by demands for pulpwood. Problems of regeneration and disease control appear close to solution. Mann (1969) assembled evidence indicating that planting survival can be improved when adequate care is taken in growing and handling longleaf pine seedlings. Moreover, evidence that re-sistance to brown spot needle blight is heritable (Derr and Melder 1970) gives hope that plantings of the future will be disease-free. Brown spot-resistant strains are currently being developed from disease-free longleaf pines.

37

Until these problems are finally resolved and longleaf pine can again play an important role in conversion of sandhills scrub, other pines will have to serve.

Slash Pine

Slash pine is widely planted in the South. It grows best along pond margins and on incompletely drained soils (Fowells 1965b), but also exhibits good survival and juvenile growth on deep sands (Shipman 1958). Two diseases seriously impair survival and growth of slash pine in the sandhills: one is black root rot (*Sclerotium bataticola* Taub. [*Macrophomina phaseolina* (Tassi) Goid.] and *Fusarium oxysporum* Schlecht. var. *aurantiacum* (Lk.) Wr.), a disease complex found in many nursery soils (Foster 1961); the second is fusiform rust (*Cronartium fusiforme* Hedgc. & Hunt), characterized by spindle-shaped galls on the bole or branches of young seedlings. Trees with roots abbreviated by black root rot often succumb to periodic droughts (Smalley and Scheer 1963). Although survivors recuperate and many symptoms of the disease disappear, black root rot continues to sap tree vigor when moisture again becomes available. This disease contributes to a decline in growth rate that becomes noticeable about 10 years after planting. Fusiform rust usually is contracted on the bole or branches while the tree is a seedling or sapling. Branch cankers may spread to the bole or may die in natural pruning. Bole cankers continue to enlarge throughout the life of the tree, degrade the wood, and weaken the stem so that it may break.

Slash pine also is susceptible to damage by ice (Hebb 1971a). Planted slightly north of their natural range (Fowells 1965b), slash pine saplings, poles, and saw log-sized trees in a 5-year-old comparative planting in South Carolina were broken or seriously bent by ice, and 27 percent of the trees still showed damage 2 months after the storm (table 6). Because of comparatively slow growth and intolerance to ice, slash pine is recommended for planting only on sandhills soils with an adequate supply of available moisture within its natural range (roughly 100 miles inland, from Hammond, Louisiana, to Georgetown, South Carolina). It is not recommended for planting on infertile, droughty soil.

Loblolly Pine

Loblolly pine generally is associated with fertile, poorly drained soils, and survival and early growth on some of the better sandhills soils has been exceptionally good. On Troup loamy sand in South Carolina, for instance, almost every seedling planted on land previously cropped for watermelons survived the rigors of sandhills life plus a crippling ice storm and grew to an average height of 10 feet (3.0 m.) in 5 years. On more droughty, infertile soils in Georgia and Florida, survival has not been quite as good and trees average only about half as much height growth. Annual measurements of a 17-year-old loblolly planting in Florida sandhills show that both survival and growth decline after plantation age 10 years.

Loblolly pine also suffers from diseases and insects. Fusiform rust is about as serious a threat to loblolly as it is to slash pine. Fungi responsible for black

root rot have been found on loblolly roots, but seriousness of the disease has not been determined because of the limited extent to which this pine has been planted in the sandhills. Trees planted "off site," however, are usually more than normally susceptible to the ravages of insects and diseases, and loblolly is "off site" on droughty, acid sands.

Tip moths attack young loblolly pines and retard height growth. A comparative test of growth on plots treated with a systemic insecticide to control tip moths and on untreated plots showed that loss of height amounts to about 4 feet (1.2 m.) during the first 5 years of a loblolly pine plantation (Burns 1966b).

Loblolly pine is recommended for the less well drained sandhills soils and as a substitute for slash pine in northern Georgia and South Carolina where there is danger of severe damage by ice.

Tree Spacing

The future of a pine plantation is shaped by the number and distribution of seedlings that survive the first growing season afield. When pines are well suited to a particular environment, losses following the first year are usually minor (as illustrated in figure 16). No amount of supplementary planting will satisfactorily augment marginal stocking and growth of seedlings poorly suited to the planting site. Therefore, in order to decide on how many trees to plant per acre, landowners must first consider factors affecting survival and then those affecting growth.
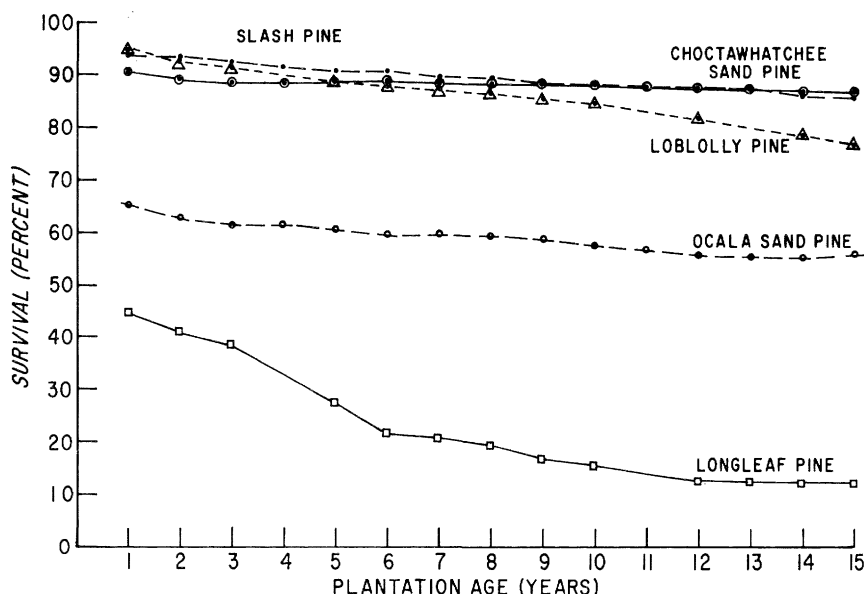

Figure 16.—Low planting survival, low first-year survival, and subsequent mortality are signs of poor suitability. On one sandy soil in Florida, longleaf was poorly suited and Ocala did moderately well. Choctawhatchee, slash, and loblolly pines were well suited, but elsewhere in the sandhills slash and loblolly have not survived and grown as well.

In species selection tests, Choctawhatchee sand pine performed best on droughty, infertile soils throughout the sandhills; slash pine did best on less droughty soils within its botanical range; loblolly pine grew well on less well drained soils, particularly on the more northerly sandhills sites subjected to severe ice storms.

Pine	Lakeland sand West Florida	Alaga loamy sand Georgia	Troup loamy sand South Carolina
	Average percentage first-year survival		
Choctawhatchee sand	95	84	82
Slash	91	90	92
Loblolly	95	92	97

Site potential and plantation management objectives must also be considered before deciding on how many trees to plant per acre. Site potential includes the nutrient- and moisture-supplying capabilities of the soil. Fertile soil with adequate moisture can support more trees than dry, sterile soil; however, most sandhills soils are droughty and infertile.

In the past, a thousand or more seedlings per acre were planted to compensate for expected high mortality, to obtain early crown closure, and to fully utilize the site as early as possible; but narrow spacing on droughty, infertile soil retards tree growth. Current practice favors wide spacing to stimulate growth, to eliminate or reduce the need for thinning by shortening the rotation, and to facilitate mechanical harvesting. Wide spacing comes closer to meeting the potential of most sandhills sites because low stocking levels do not overtax capabilities of the soil. Extremely wide spacing, however, wastes growing space and produces wolf-type trees and wood with a high proportion of knots with short fiber. This is especially true of sand pine, which tends toward limbiness and persistent branches.

Other considerations in plantation establishment should be orientation of and spacing between rows. In North Carolina, for example, trees are planted in rows paralleling the prevailing wind and spaced to enable ready entrance of fire equipment to flank a running fire (Henry S. Plotkin, N.C. Forest Service, personal communication, 1971).

Practical objectives of much sandhills management call for maximum cellulose production, minimum interim maintenance, and mechanical harvesting. Wide spacing is suggested, especially if no thinning is planned before harvest. Under these circumstances the aim might be to grow 400 trees per acre (988 per ha.) to large pulpwood size in a 30-year rotation on an intensively prepared site.

First-year survival and subsequent mortality must be considered in determining the number of trees to plant to meet this 400-tree objective. Fully 85 percent of slash, loblolly, or Choctawhatchee sand pine seedlings properly planted on intensively prepared sites may be expected to survive the first year, depending upon suitability of the pine to a given set of conditions. Similarly, losses after the first year may vary widely among species, but the proper match of pine with environment will minimize these losses to about 5 percent. Using survival records and a procedure similar to that described by Hatcher (1957) in computing from the 400 established trees desired, the requisite number to absorb a 5-percent loss after the first year would be

$$\frac{400}{0.95} = 421 \text{ trees per acre } (1,040/\text{ha.}).$$

40

Assuming 85-percent survival during the first year, the number to plant to reach this figure would be

$$\frac{421}{0.85} = 495 \text{ trees per acre } (1,223/\text{ha.}).$$

Therefore, approximately 500 seedlings should be planted per acre (1,236/ha.) to obtain 400 trees (988/ha.) at rotation age 30 years. Any spacing of rows and seedlings within rows that allows 88 square feet (8.2 m.^{2}) per plant will meet this goal (8 by 11 feet (2.4 by 3.4 m.) for example). Extremely rectangular spacing, such as 4 by 22 feet (1.2 by 6.7 m.), should be avoided, however, because trees become crowded within rows and seldom fully occupy the vast area between rows. Measurements of the only existing Choctawhatchee sand pine plantation older than 25 years suggest that a yield of about 35–40 cords per acre (220–250 m.^{3}/ha.) might be expected at rotation age 30 (Burns and Brendemuehl 1969).

A greater number of seedlings may be planted if a thinning is anticipated, but the number is limited by the carrying capacity of the site. Thus it does not necessarily follow that, in considering alternatives of plantation management, many seedlings can be planted just because some of the trees will be removed at the time of thinning. The stand may stagnate in the interim. The vigor of Choctawhatchee sand pine planted 5 by 5 feet (1.5 by 1.5 m.), i.e., 1,742 per acre (4,304/ha.), on intensively prepared, droughty, infertile soil begins to decline between plantation ages 5 and 8 years, while those spaced 7 by 7 feet (2.1 by 2.1 m.), i.e., 889 per acre (2,197/ha.), maintain a fairly uniform growth rate until 12 or 15 years old. (A similar pattern may be expected for slash and loblolly pine on more fertile, moist sandhills sites.) Slightly wider spacing will enable them to grow, unaffected by crowding, to a more profitable pulpwood size by plantation age 17 to 20 years.

A droughty, infertile site probably should not be planted with more than 750 Choctawhatchee per acre (1,853/ha.) because it will carry no more than 600 (1,483/ha.) trees for 20 years before starting to stagnate. This means that only about 300 trees per acre (741/ha.) will remain for harvest at rotation age 30 years if every second row is removed:

(750x0.85)(0.95x0.50) =303 trees per acre (748/ha.).

If one in three rows is removed by thinning, the desired 400 trees (988/ha.) will be left:

(750x0.85)(0.95x0.67) =406 trees per acre (1,003/ha.).

Removal of one row in three plus a selective thinning to remove seriously suppressed and diseased trees in the remaining rows should leave approximately 60 percent of the stand, or 360 trees per acre (890/ha.), for the harvest:

(750x0.85)(0.95x0.60) =363 trees per acre (897/ha.).

Spacing Choctawhatchee at 7 by 8 feet (2.1 by 2.4 m.), i.e., 778 trees per acre (1,922/ha.) or 6 by 10 feet (1.8 by 3.0 m.), i.e., 726 trees per acre (1,794/ha.) provides for anticipated losses, circumvents crowding, leaves about 600 trees per acre (1,483/ha.) for thinning at age 20, and should not seriously restrict movement of mechanical harvesters.

Relatively flat, infertile sandhills land lends itself to use of mechanical harvesters. Row thinning is the cheapest and probably the quickest method

of making an intermediate cut because rows are clearly discernible and no marking is needed (Enghardt 1968). A most promising variation involves removal of every third row plus a selective sanitation and salvage cut of diseased and suppressed trees in the remaining two rows.

Nutrient Supplementation

Fertilization may provide an alternative to low plantation yields and long rotations. Research shows that phosphorus is deficient in most sandhills soils and that until the deficiency is satisfied slash, longleaf, and sand pines will not respond to fertilization with other elements. When properly placed in sandy soil, phosphorus remains available for several years (Humphreys and Pritchett 1971).

Nitrogen elicits marked growth when used in relatively small amounts; however, a response is forthcoming in sandhills soils only if phosphorus requirements have been met. Nitrogen leaches rapidly from the soil, and if applied during or shortly after planting, much of it is lost before the young pines are large enough to utilize it. In fact, application of nitrogen at planting time might be detrimental to the pines because it stimulates growth of herbaceous competition. Best results are obtained when nitrogen is applied after seedlings have become well established, usually during the third year after planting.

The level of potassium in most sandhills soils is low, yet it need not be increased unless high levels of phosphorus and nitrogen have been applied. Phosphorus and nitrogen appear to be the most deficient and the most needed macroelements to stimulate growth of pines in sandhills soils. The beneficial effects of fertilization are clearly illustrated in figure 17.

The interrelated roles of moisture, nutrients, and competition are intimately involved in forest fertilization. Adequate moisture is needed for survival and growth and to dissolve and transport nutrient elements. Unbelievably, plants that receive 45 to 60 inches (114.3 to 152.4 cm.) of rainfall annually (at least half during the growing season) often suffer from a water shortage because sandy soils do not retain much moisture. Intensive site preparation aimed at reducing demands for moisture and nutrients by plants other than introduced pines is, therefore, an essential prerequisite to fertilization of young pine plantations.

The relative importance of moisture, nutrients, and control of competition on growth of young slash pine has been measured.[17] Seedlings were planted in a well-prepared Lakeland sand, fertilized with phosphorus and nitrogen, and cultivated to eliminate invading plants. Plots were irrigated throughout five consecutive growing seasons to insure at least 1 acre-inch (25.4 mm./ha.) of water per week. All treatments, singly and in combinations, stimulated tree growth but not to the same extent. Trees in plots cultivated annually were 35 percent taller at age 5 years than untreated controls, and fertilized trees without supplementary irrigation were 60 percent taller than untreated trees. Similarly, combinations of treatments had greater beneficial influence on tree growth than single treatments, especially if fertiliza-

---

[17] Baker, J. B. Effect of fertilization, irrigation, and competition control on growth of slash pine. (Manuscript in preparation.)
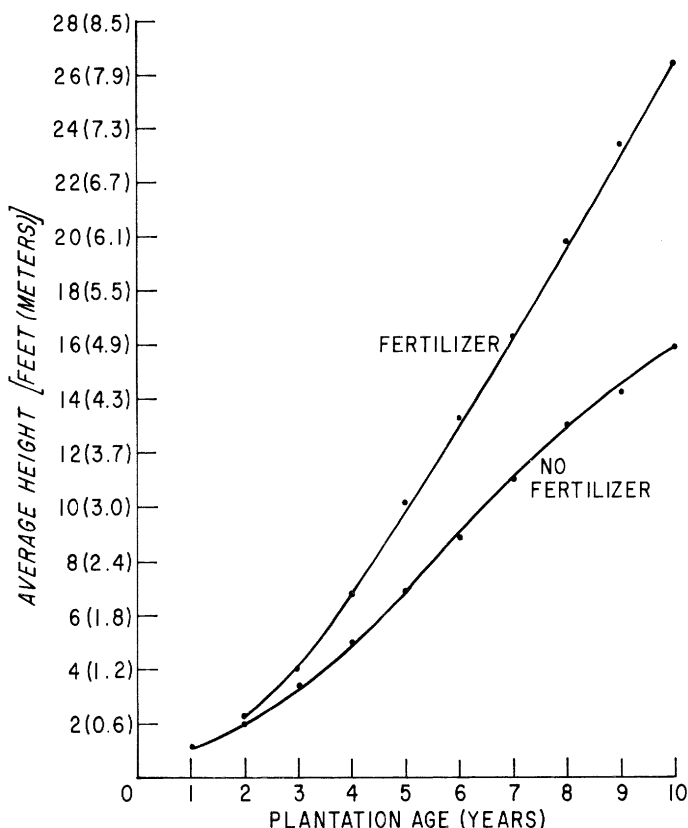
Figure 17.—Slash pine fertilized with 1,560 lb. per acre (1,748 kg./ha.) of 8-8-8 at 2 years outgrew unfertilized trees by 66 percent after 8 years on the same prepared sandhills site.

tion was included in the combination. These findings[18] suggest that periodic release from invading vegetation becomes less important and supplementary moisture and nutrients become progressively more important after pines completely utilize growing space allotted them and begin to compete among themselves. Results emphasize the lack of nutrients in sandhills soil and the need for adequate moisture to enable plants to utilize applied fertilizers.

Pines vary in their suitability to a site and in their ability to extract and utilize nutrients available to them. It is common to find, on identically prepared soils, unfertilized Choctawhatchee sand pine to be the same as fertilized slash pine of the same age (fig. 18). A comparison of figures 17 and 18 illustrates this advantage of suitability, even where slash pine benefited from both fertilizer and a slightly more fertile sandhills soil. Choctawhatchee consistently outgrew slash planted on the same site and fertilized identically with phosphorus and nitrogen, and at age 3 even unfertilized sand pines were a foot taller than the tallest fertilized slash pines. As evi-
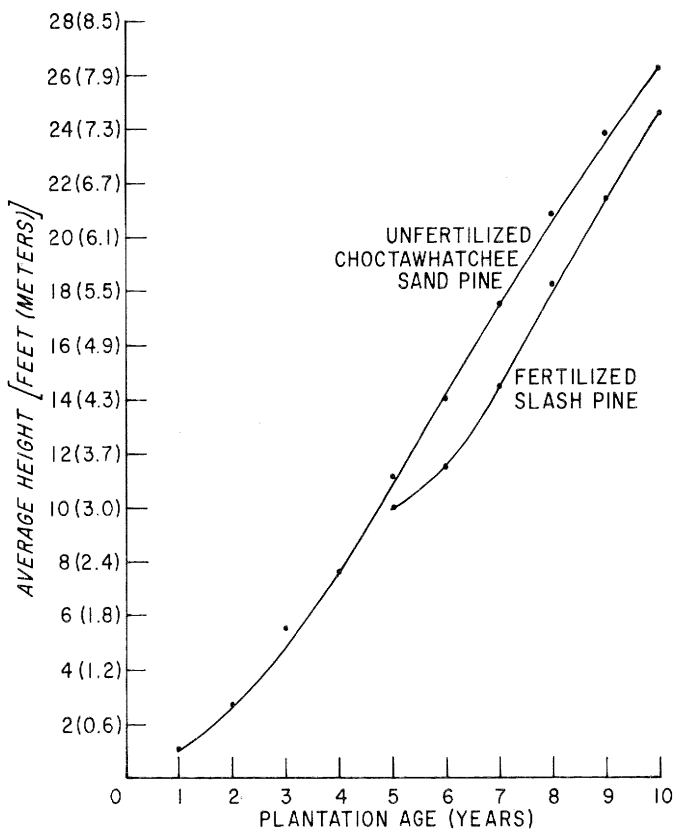
---

[18] *Ibid.*

Figure 18.—Choctawhatchee sand pine has grown better without nutrient supplements than slash pine fertilized with 3/4 ton per acre of 10-40-0 at age 6.

dence that sand pine also responds well to phosphorus and nitrogen, the tallest fertilized Choctawhatchee were 2 feet (0.6 m.) taller than unfertilized ones.

Long-term benefits often are overlooked when assessing or considering possibilities of fertilization, but they are as important as the improved growth rate in the current rotation. Trees in a plantation are a row crop, and as such they extract nutrients from the soil; when they are harvested nutrients are removed with the wood and bark and lost. Only about 10 percent of the nutrients in a tree are removed by harvest, but removal of any amount from a soil already deficient in most elements will limit growth of future plantations. In management of sandhills plantations, removal without replenishment may mean the difference between a successful economic venture or a failure. Phosphorus, an element deficient in many sandhills soils, exemplifies a nutrient with relatively long-term benefits. It moves through the soil at a comparatively slow rate. One application may influence tree growth throughout an entire rotation by recycling through herbaceous and woody litter and translocation from older tissue to meristematic tissue within

44

the tree itself. The addition of phosphorus to satisfy a deficiency may be economically feasible on many sandhills soils, especially if "the area to be fertilized is near the phosphate source" (Pritchett and Smith 1969). Depending upon the rate at which it and other nutrients are applied, and considering the relatively small proportion removed from the site when wood is harvested, a single application may more than compensate for the drain of harvest. Brendemuehl (1967b) has published specific information about tree nutrition on sandhills soils.

EFFECTS ON NATIVE VEGETATION

Vegetation present at the time of site preparation includes principally turkey oak, bluejack oak, and sand post oak, wiregrass, and several bluestem grasses (*Andropogon* spp.). Minor constituents are legumes, such as milkpea (*Galactia* spp.) and rhynchosia (*Rhynchosia* spp.).

The object of site preparation is to eliminate competition, so we expect it to reduce native vegetation drastically. The most obvious effect of chopping is the felling and mutilation of all standing woody vegetation. The oaks with their acorns, other trees and brush with their fruits, and browse are destroyed, and grass and herbaceous vegetation are eliminated by uprooting and displacement.

After the dust of mechanical site preparation has settled, the site appears nearly devoid of vegetation (fig. 19, top). Shortly thereafter follow the changes of early plant succession; the bare, prepared site is receptive to rapid colonization by herbaceous seedlings and hardwood sprouts.

Even on the most intensively prepared sandhills sites there are oak sprouts, although at first they are inconspicuous among the growth of abundant herbs. Many sprouts develop from each rootstock, but with time one or two become dominant and the others die. Numbers of oak sprouts vary greatly from site to site; differences can often be attributed to density of the original pine overstory, fire history of the area, or methods of inventory. Sprouts ranging in number from 1,300 to 13,000 per acre (3,212 to 32,123/ha.) have been counted at various times and in various areas of northwest Florida (Hebb 1971b). Where chopping is improperly scheduled or poorly done, the total number of sprouts can be immense.

Where sites are prepared by using pelleted herbicides there is a similar surge of low plant growth, but wiregrass is common among these plants. The growth is so luxuriant (Shipman 1963a) that it is often cited as the principal disadvantage of using pellets.

For 15 years the succession of invading plants on prepared sites has been followed by using marked quadrats on the Chipola Experimental Forest (fig. 19, bottom). The first prominent vegetation on the chopped areas were plants of the composite family (Hebb 1971b). During spring the foremost was *Balduina angustifolia* Pursh; the next year, dogfennel (*Eupatorium* spp.) became luxuriant, and later that same year fleabane (*Erigeron* spp.) was prominent. Among the grasses were fall witchgrass (*Leptoloma cognatum* (Schult.) Chase) and a panic grass (*Panicum malacon* Nash).

After several years, changes in vegetation became more gradual. The forbs were still present, but their numbers declined until only one or two domi-

Figure 19.—Plant succession on a small plot following double chopping: top—the bare site in April, 7 months after preparation; bottom—15 years later, broomsedge is prominent in the understory and oak sprouts, weakened by site preparation, offer little competition to the planted pines.

46

nated and these remained for a long period. The composition of the grasses also changed gradually until finally the principal grass was broomsedge (*Andropogon virginicus* L.).

As the pine stand develops, successional changes in vegetation lessen. Under a dense stand of pine the herbaceous and shrubby understory usually is sparse and the oaks are small and few.

EFFECTS ON GAME

Site preparation causes drastic, immediate changes in the availability of protective cover, acorns, and forage favored by animals. Mast alone contributes to the diet of many sandhills creatures, including deer (Harlow and Jones 1965), turkey (Schemnitz 1954; Hutt 1964), and ducks (Shaw 1957). Oak browse is not as important, but may complement the diet of deer in emergencies (Moore 1967). However, clearing and agitation of the soil by chopping exposes the site and makes seed available to birds; game birds in particular are attracted to such areas (Cushwa and Jones 1969).

The spectacular invasion by forbs following completion of chopping is important because of the abundance of seeds produced by these plants, especially for the first 4 or 5 years after chopping. The plants themselves provide much food, but it is different from that provided by oaks of the former vegetation and it attracts different kinds of game, such as doves and quail. Thus, chopping makes the area more attractive by increasing the seed-bearing forbs and the low cover they provide. But the variety of lush forbs is eventually replaced by one or two dominant species, and grasses become more important constituents of the ground cover.

It seems likely that prepared sites can be made hospitable by leaving some uncleared areas to provide cover. On large holdings in the sandhills, game occupancy is encouraged by leaving strips of undisturbed scrub vegetation both for food and cover and as avenues of access. Beckwith (1967) found that if one-quarter to one-half of an area was left in uncut strips it received twice as much use by deer as a mile-square clearing. He attributed this to the proximity of cleared and uncleared areas, each attractive to the deer in a different season.

In the sandhills, some uncleared strips could be provided by natural drainage courses which normally are not cleared in most site preparation operations. These courses provide strips of irregular width and orientation, and, because they are wetter than the sandhills, support a different flora and offer a different food supply.

For some years after chopping the vegetation on prepared sites changes continually and finally stabilizes when the pine stand fully dominates. The understory of the pine stand is not rich with a variety of plants—mast and browse of the oak have gone, and the profusion of forbs and grasses that enriched the site at first have given way to a simpler and sparser plant community. But a pine plantation of reasonably wide spacing is not entirely devoid of understory plants. Runner oak, for example, is an understory plant capable of producing abundant crops of large acorns. And the pines themselves are not barren of provender; scattered and suppressed scrub hardwoods, and small patches of grasses and forbs in fail-spots provide excellent cover and some food. Hunters frequently find deer bedded down or browsing in these thickets.

In sand pine plantations the habitat may be favorable because these trees have persistent branches which obscure animal movement, and they frequently start to produce seed within 5 or 6 years. Because of their seed-hoarding habit, Ocala sand pine in plantations are particularly attractive to fox squirrels.

OTHER EFFECTS

Certain advantages and disadvantages associated with each method of site preparation might influence a manager to adopt or reject a specific treatment. Most differences are relatively minor, but all should be considered when appraising alternative treatments.

Mechanical methods leave the surface of the site relatively clean and facilitate planting. There are many chunks of wood scattered over the site, however, and the longer ones sometimes lodge in the planting machine or protrude from the soil and are hazardous to the planter.

Pieces of the original scrub oak are buried in moist soil and support decay organisms, some of which may be harmful to introduced pines. Mushroom root rot is such a pathogen. Ross (1970) found it heavily infecting oak roots on prepared sites in Florida and Georgia sandhills. The fungus and its spores remain viable for years on infected oak roots and "serve as sources of infection to trees subsequently planted" (Rhoads 1950).

On sites prepared with chemicals, the soil surface or the stems of vegetation are not disturbed, and this can be a disadvantage. The standing dead hardwoods are aesthetically depressing, and their leafless twigs can cause eye or ear injuries or lacerations. Planting in a stand not prepared in any way, as is often done with sand pine, exposes planters to almost the same conditions. There are advantages, however, in planting without preparation—it is aesthetically pleasing and costs are lower (but growth is less). All site preparation treatments make the sites less attractive, but mechanical preparation by chopping leaves the area the least unsightly.

Removal of all protective vegetation from sandy soil causes the surface to dry rapidly, and dry sand moves easily in wind. Damage to seedlings by abrasion sometimes occurs, and when sand is blown away from around the base of shallow-planted seedlings their roots are exposed to the desiccating sun and wind. Blown sand may also accumulate around newly planted longleaf seedlings and kill them by smothering the bud.

ECONOMIC CONSIDERATIONS

Even the most hard-to-manage sandhills site will grow some species of pine if the soil is properly prepared for planting. The rate of growth can be increased by carefully matching soil, climate, and method and intensity of site preparation with the species of pine planted; by selecting a density of stocking that will not overtax the nutrient- and moisture-supplying capabilities of the site; by supplementary treatments, the most alluring of which is fertilization. But can all this be done economically? Will pines harvested from droughty, impoverished soil yield a return sufficient to justify the investment of time, labor, machinery, and supplies?

The basic question is, "Can a profit be made?" The fact that land managers continue to prepare and plant large acreages of sandhills land year after

year provides part of the answer. The remainder is left to the judgment of the reader and to his interpretation and assessment of the information and data that follow. All the information was obtained from persons actively engaged in converting sandhills scrub to pine, and it represents several years and many thousands of acres.

Costs of double chopping planting sites on the Eglin Air Force Base are presented in the following tabulation, giving actual cost per acre based on extensive areas of treatment. Separate items included in the per-acre cost could not be obtained, so the data have mostly relative value. Expenditures are presented later in this section as acres prepared per machine hour to eliminate variability from place to place and year to year.

Year	Average cost per acre	Basis Number acres
1964	$23.74	2,024
1965	22.50	1,514
1966	20.75	2,035
1967	23.50	1,473
1968	26.94	2,286
1969	35.50	2,086

COSTS OF MECHANICAL METHODS

At least two treatments are needed to prepare a site intensively. The first is more time consuming, and requires the heaviest equipment, and therefore is the more costly. For the majority of sandhills sites the 11-ton (9,979 kg.), 7-foot-wide (2.1 m.) duplex brush cutter is the best and most popular piece of equipment used for the first treatment. The number of acres chopped depends upon topography and the number and size of scrub hardwoods. The 11-ton (9,970 kg.) chopper can prepare from 1¾ to 3½ acres (0.7 to 1.4 ha.) per hour when pulled by a crawler tractor of about 170 drawbar horsepower (12,927 kg.-m./sec.); more acres can be prepared per hour when a more powerful tractor is used. Chopping can be nearly doubled if two 11-ton (9,979 kg.) choppers in a "quad" coupling arrangement are pulled behind a crawler tractor of approximately 350 drawbar horsepower (26,614 kg.-m./sec.). Because of its greater width the relatively new, 10-foot-wide (3.0 m.), 16-ton (14,515 kg.) chopper pulled by a crawler tractor of 250 drawbar horsepower (19,010 kg.-m./sec.) can process approximately 50 percent more area per hour than the 7-foot-wide (2.1 m.), 11-ton (9,979 kg.) model.

The second treatment costs considerably less because relatively small hardwood sprouts are the only vegetation to contend with. If the same sized chopper is used in both the first and second treatments, the second treatment may be 15 to as much as 20 percent faster than the first.

Rootrakes are used where topography is broken or steep or where trees are too large to be processed by a chopper. Mounted on the front of a crawler tractor of about 80 drawbar horsepower (6,083 kg.-m./sec.), an 11-foot (3.4 m.) rootrake can clear 1 to 1¼ acres (0.51 ha.) per hour when the trees are large or the terrain rough and up to 2¼ acres (0.91 ha.) per hour in small hardwoods on level ground or with a more powerful tractor.

Yoho et al. (1971) presented data on the cost of total site preparation in 1967 by all mechanical methods. The largest component of the cost was equipment, which accounted for nearly two-thirds of the total. There was a

49

marked difference in cost, depending on difficulty of the site: sites less difficult than average had a mean per-acre cost of $17.36; cost on sites more difficult than average was $32.30.

Reducing Costs of Chopping

Cost of the second mechanical treatment can be reduced by substituting a lighter piece of equipment for the 11-ton chopper. Limited tests [19] have shown that either an 8-ton chopper requiring 80 horsepower (6,083 kg.-m./ sec.), or a 4¼-ton (3,856 kg.) chopper, or a heavy-duty disk harrow requiring at least 50 drawbar horsepower (3,802 kg.-m./sec.) is as effective as the 11-ton chopper for the second treatment. The disk harrow also is well suited to follow an initial treatment with a rootrake or chopper. Savings are realized because less power is needed for a shorter period than with heavier equipment, yet survival and growth are as good.

Recent success with a heavy bedding harrow in wetlands (Bethune 1963) has led to its use for the second treatment on droughty sites (fig. 20). Following initial preparation by a chopper or rootrake, 9-foot-wide beds have been prepared at the rate of 2 to 2½ acres (0.81 to 1.0 ha.) per hour with 55 drawbar horsepower (4,182 kg.-m./sec.) and 3 acres (1.2 ha.) per hour with 80 horsepower (6,083 kg.-m./sec.). The bedding harrow has one additional advantage—soil at the center of the bed is compacted by a drum, thereby reducing from at least 6 months to about 2 the time needed for soil to stabilize before planting.

[19] Burns, R. M. Economical site preparation prescriptions for the sandhills. (Manuscript in preparation.)

F-521425

Figure 20.—On a site previously prepared by chopping, a bedding harrow concentrates topsoil and compacts the planting surface.

COSTS OF CHEMICAL METHODS

The most important economic consideration in chemical site preparation is cost of materials. For example, if fenuron costs $1 per lb. in bulk and $1.50 per lb. in small quantities (bromacil is usually slightly cheaper), a treatment of 20 lb. per acre (22.4 kg./ha.) could cost from $20 to $30 for materials alone. If the price of material is high, or if heavy applications are required, total costs may be prohibitive. The heavy applications required to do an effective job are not only expensive, but chemical residues remain in the soil long enough to prevent successful planting (Woods 1955).

Cost of application must be added to the price of the chemicals, but it is not a major part of total expense. A study by the Florida Forest Service [20] mentions $14 for material and labor to apply 12 lb. (5.4 kg.) of fenuron with a cyclone seeder. This low rate probably would not be adequate on most sandhills sites, but increasing the application to 20 or 25 lb. (9.1 or 11.3 kg.) would suffice and should not greatly increase the cost—certainly not double it. And when the small landowner does the work himself, his only out-of-pocket expense will be for materials.

The use of pelletized herbicides offers certain economic advantages: the investment in equipment is small; highly trained labor is not necessary; complicated mixing or computing of rates is not required (Shipman 1963a). Because the danger of chemical drift and contamination of nearby crops is lessened with the use of pellets, aircraft may be used.

Application by helicopter is perfectly feasible, yet need not be expensive; small acreages can be treated economically if the work can be done in conjunction with a nearby larger operation. Application of 200 lb. (90.7 kg.) of fertilizer by helicopter may cost approximately $3 per acre ($7.41/ha.). At this rate, treating a site with 25 lb. of herbicide pellets at $1 per lb. would cost $28 per acre ($69.19/ha.). This would be competitive with the cost of double chopping.

Use of pelletized herbicides leads to further reduction of costs. One promising possibility is combining pellet distribution with direct seeding. The idea is not new; the two operations have been used together (Campbell 1966). If herbicide pellets can be scattered along with seed, without adversely affecting young seedlings, application costs may be greatly reduced.

Effective chemical site preparation need not cost much more than using machines. If a rate lower than 25 lb. per acre (11.3 kg./ha.) is adequate, as it is on some sandhills sites, then the cost of chemical site preparation is competitive; otherwise, cost may be slightly higher than mechanical methods. The ease and handiness of using chemicals will count toward their attractiveness, especially to land managers with small, scattered holdings and to owners who plan to do the work themselves.

COSTS OF USING FIRE

Prescribed burning can be either a cheap or an extremely expensive method of site preparation, depending upon the experience and skill of the users. If experienced, they take every precaution and burn only when the weather and fuel moisture conditions are right for the type and intensity of fire needed.

---

[20] DeRolf, *loc. cit.*

Over a large area costs amount to only cents per acre. Burning under the wrong conditions or without necessary safeguards, however, likely will result in an inefficient fire or in wildfire. The law states that any landowner is responsible for damage caused by his negligence, and damage by a fire that escapes falls in that category. Under the circumstances of burning at too high or too low an intensity for the job or causing wildfire, the per-acre cost may be many dollars.

When done properly, prescribed burning for site preparation in droughty sandhills dominated by scrub hardwoods may be inexpensive, but regardless of the cost, it appears to be a waste of time and money. The interval between burning and the first chopping would be more profitably used if burning were eliminated, scheduling of mechanical treatments advanced, and the soil allowed to stabilize for an additional 6 weeks before planting.

COSTS TO THE SMALL LANDOWNER

Owners of small tracts (100 acres (40.5 ha.) or fewer) often find themselves in a predicament when trying to convert sandhills land to pine. Their holdings are not extensive enough to justify an investment in the heavy, specialized equipment needed for site preparation, so the work must be contracted. Contractors usually charge a premium rate when equipment has to be moved to small jobs. Favoring larger jobs, contractors cannot be expected to schedule work on small areas to take best advantage of seasonal fluctuations in carbohydrate reserves in scrub hardwood roots. To save time, the second treatment usually follows on the heels of the first, thereby minimizing its effectiveness when measured in resulting survival and growth of planted pines. The small landowner determined to convert his scrub hardwoods to pine must either pay the premium because of the small acreage involved or try alternative methods of stand conversion.

One alternative is to plant a tolerant and tenacious species, such as Choctawhatchee sand pine, amid the scrub oaks and wiregrass. The landowner can either release the pines at a later date or accept a reduced rate of growth until the pines overtop and suppress the oaks.

A second alternative is planting an interim crop on prepared land to help defray the premium charged for site preparation. The most fertile sites will grow corn or soybeans and may be cropped or rented for several years. Watermelons are a popular crop on droughty sands, especially if water for irrigation is available. Because of a buildup of disease organisms, watermelons can be planted on the same site only 1 out of 7 years [21] unless costly sprays are used; for this reason the demand for newly cleared sandhills land is likely to remain high. Proponents of interim cropping maintain there is a distinct tax advantage in clearing land for agricultural rather than silvicultural purposes. They also claim that growth lost by waiting 1 or more years to plant pine is regained, in part, through the stimuli provided by residual fertilizers in the soil and the cultivation of previous years.

Programs such as one recently devised in Virginia (Harris 1970) should ease the burden on small landowners. Enacted in 1970, the Pine Reforestation Act

---

[21] Newcomb, L. S. Planting pine seedlings following watermelon planting on Ocala National Forest. 1954. (Report filed at Southeast. Forest Exp. Stn., USDA Forest Serv., Marianna, Fla.)

pays the landowner up to $20 per acre ($49.42/ha.) to cover half the costs or provides an interest-free loan of up to $30 per acre ($74.13/ha.) to cover three-fourths the costs of conversion. Loans may be made for as long as 30 years.

The small landowner is advised not to use fire or agricultural equipment for site preparation. Prescribed burning by inexperienced personnel is dangerous, and farm equipment seldom is rugged enough to withstand prolonged abuse.

Use of degradable silvicides has special significance for small landowners. Hardwoods may be treated in a relatively short time and when their food reserves are at an ebb; pines can be planted several months later when effects of the chemical have dissipated. The cost of these chemicals is comparable to that of intensive mechanical site preparation. Although herbaceous plants are not affected, limited testing with Choctawhatchee sand pine showed that this species was tolerant of the chemical residues and almost unaffected by competition from grasses and forbs.

FAILURES AND THEIR PROBABLE CAUSES

Attempts to convert scrub-dominated sandhills to pine occasionally meet with failure. Hardwoods sprout prolifically, wiregrass persists, and, consequently, planted pines survive and grow poorly. On rare occasions the climatic extremes of temperature and moisture cause a failure. More often, failures are caused by not following procedures and practices found to be successful; makeshift actions result in preparing sites inadequately, planting pines not well suited to a particular soil or site, and planting seeds and seedlings under conditions not favorable for establishment.

A poorly prepared site usually results from using equipment incapable of processing scrub vegetation adequately, applying the first mechanical treatment during the fall and winter instead of spring and early summer, failing to apply a second treatment, not allowing sufficient time for sprouts to develop between treatments, or not allowing disturbed soils to settle sufficiently prior to planting.

Pine species poorly suited to a particular soil and site may cause as many failures as inadequate site preparation. Choctawhatchee sand pine should be planted on the driest and most impoverished sandhills soils—it tolerates poorly prepared sand and excessively drained soil, but will not perform well on poorly drained sites. Slash and loblolly pines perform best on more fertile and less well drained soils, and loblolly is particularly well suited at the northern extremes of the sandhills where ice and snow storms are likely.

Seeding and planting failures are common if insufficient attention is paid to depth and time of planting. Seeds must be covered with at least 1/4 inch (6 mm.) of soil to improve the likelihood of satisfactory germination and establishment, but they must not be planted too deeply. The season during which seeds are planted is most dependent upon temperature; soil moisture is adequate on prepared sites throughout most of the year. The greatest likelihood of satisfactory germination occurs when the average daily temperature does not exceed 75° F. (23.9° C.) nor fall below 40° F. (4.4° C.) for 10 weeks following seeding.

Seedlings should be completely dormant before they are lifted at the nursery, if this is practical. Longleaf pine seedlings require planting at root-collar

depth; planting mortality rises rapidly if roots are exposed or if the terminal bud is covered with soil. All other southern pines should be planted so that at least the lowest whorl of green needles is below ground line after the soil has settled.

The majority of land managers experienced in sandhills work know the consequences of expedient action and innovate only within bounds of their experience. Newcomers to the field sometimes take imprudent actions and succeed, but not often. The following example emphasizes just how far astray some land managers may go without understanding reasons for failure in converting scrub hardwoods to pine:

Several years ago we were called upon to explain failure of a planting on a prepared sandhills site. "All recommendations were followed, yet the seedlings are dying for no apparent reason," we were told; investigation revealed otherwise.

The "prepared" site had been burned during late summer then chopped once a few weeks later, near the end of September. (Burning is not a recommended method of site preparation; only one mechanical treatment was applied, and it was done at the wrong season and with an insufficient interval between burning and chopping to allow sprouts to develop.)

Ocala sand pine seedlings lifted early in December were planted at root-collar depth throughout December and part of January. (Choctawhatchee sand pine should have been used because its planting survival averages 15- to 40-percent higher than Ocala; seedlings were lifted too early in the season and were not dormant when planted; seedlings stacked three high in the field had been stored for periods in excess of 3 days and some for longer than 3 weeks; seedlings were not planted deep enough to cover the hypocotyl.)

The planting site included several small, poorly drained areas, and rainfall and temperature were unseasonably high during and immediately following planting. (Sand pine survival is adversely affected in water-saturated soil.)

Following all recommended procedures and practices does not necessarily guarantee satisfactory results, but it greatly increases the probability of successful conversion from scrub hardwoods to pine. In preparing hard-to-manage sandhills sites, great care must be taken when modifying the treatments or materials used. Some adjustments can be made, but there are requirements that should not be changed. Apparently identical substitutions can differ enough to omit the essential ingredient, and this usually causes failures.

SUMMARY

Droughty, acid sandhills occupy millions of acres in the Atlantic and Gulf coastal plains. Most of them support worthless scrub hardwoods and wiregrass, but they have the capacity to produce pine pulpwood within a reasonable span of time and thereby contribute to demands of a rapidly growing population.

Before most pines can be established on hard-to-manage sandhills sites, competition from scrub vegetation must be reduced to lessen the drain on soil moisture and nutrients. The use of fire for this purpose is not recommended because it is followed by poor survival and slow growth of pine.

On small holdings or on rough terrain, early indications are that chemicals, such as fenuron, give adequate control of competing plants so that pines may be introduced.

Mechanical site preparation with heavy equipment designed for the job has been most successful. The 11-ton (9,979 kg.) duplex brush cutter or heavy chopper is one of the most popular pieces of equipment because it eliminates standing woody and herbaceous vegetation without removing topsoil.

Two successive mechanical treatments are needed, the first to eliminate standing vegetation and a second to reduce the number and vigor of hardwood sprouts. The treatments are most effective when scheduled to interrupt growth processes and reduce the store of carbohydrates in woody roots. Chopping during the spring, at the time of full leaf development, greatly depletes the store of foods. Developing sprouts further reduce reserves in roots so that a second treatment at least 6 weeks (preferably 12 or 18 weeks) later does much to deplete stored foods and weaken subsequent sprouts.

Soil disturbed by mechanical site preparation must stabilize before seedlings are planted, or survival will be reduced. The soil surface may be mechanically compacted or allowed to settle naturally. In either event, at least 3 months of normal rainfall are required; heavy, prolonged rainstorms are most beneficial. Seeds and seedlings must be planted properly if they are to survive and grow. Time and depth of planting are important. Only completely dormant seedlings should be lifted and these (except for longleaf) should be planted deep enough to cover at least the lower needles. Seeds must be covered with at least ¼ inch (6 mm.) of soil at a time when average temperatures do not exceed 75° F. (23.9° C.) or drop below 40° F. (4.4° C.).

Suitability determines the pine species to use on a particular site. Choctawhatchee sand pine should be planted on the driest, most infertile sands. Slash and loblolly pine are better suited to comparatively moist, fertile sites, and loblolly is particularly well suited for planting where there is danger of snow and ice damage. Longleaf pine grows well on a variety of soils and sites, but planting difficulties, brown spot needle blight, and a prolonged grass stage presently make it a poor choice for the sandhills. Susceptibility to mushroom root rot, lack of prolonged winter dormancy, and low planting survival determine that Ocala sand pine is at best a poor second choice to Choctawhatchee on prepared droughty sites. One big advantage of Ocala sand pine is its ability to survive and grow well when planted in the rough, amid scrub oaks and wiregrass; Choctawhatchee does as well.

Maximum pulpwood production, minimum interim maintenance, and machine harvesting seem most practical for pines planted on infertile soil. Comparatively wide spacings are suggested: the number to be planted depends upon estimated mortality and whether the plantation will be thinned. Plantings to yield 400 trees per acre (988/ha.) at plantation age 30 seem appropriate where no thinning is anticipated. When one thinning is planned, trees may be planted to produce about 600 trees per acre (1,483/ha.) at plantation age 20, and one mechanical thinning can remove designated rows plus suppressed and diseased trees within the remaining rows. Thinning can be done to leave from 300 to 400 trees per acre (741 to 988 per ha.) for the harvest cut at plantation age 30 years. A yield of about 35 to 40 cords per acre (220 to 250 m.³ per ha.) might be expected at plantation age 30 years if no thinning is planned.

Growth, and presumably yields, might be increased by satisfying major nutrient deficiencies of sandhill soils. In Florida sandhills phosphorus is the element most lacking; only when this deficiency has been remedied do pines respond to nitrogen.

Economy of operation dictates choice of machinery and intensity of site preparation. The 11-ton (9,979 kg.), 7-foot-wide (2.1 m.) chopper is widely used because it can process scrub oaks and wiregrass cheaply and well in the first treatment. Cost of the second treatment may be reduced by substituting lighter choppers or a heavy-duty disk harrow for the heavy chopper.

The small landowner has a special problem. Because of the impracticability of his buying heavy, specialized equipment, he must contract for mechnical site preparation, pay a premium to have heavy equipment moved in, and often accept an inferior job because of his limited acreage. To recoup some of these costs, he may rent his cleared land or plant an interim crop for a year or more before planting pines and then charge the lost time against the increased rate of pine growth resulting from added cultivation and residual fertilizer. He may also plant a tenacious and tolerant species, such as Choctawhatchee sand pine, without site preparation and then release survivors later or accept a slightly slower rate of growth. Newly developed biodegradable herbicides afford the small landowner yet another alternative. Hardwoods can be treated so to take best advantage of seasonal fluctuations in carbohydrate reserves in roots, then pines can be planted when chemical residues have dissipated. Unless the landowner does the work himself, however, his costs for chemical control of hardwoods are about the same as for intensive mechanical site preparation.

Droughty sandhills are extremely exacting in their demands, more so than many other physiographic regions. There is some latitude for improvisation during the various steps involved in converting sites dominated by scrub hardwoods to pine, but chances for success are greatest if recommended equipment is used and prescribed methods are followed.

LITERATURE CITED

Ahlgren, I. F., and Ahlgren, C.E.
   1960. Ecological effects of forest fires. Bot. Rev. 26: 483–533.

Austin, M. E.
   1965. Land resource regions and major land resource areas of the United States. USDA Soil Conserv. Serv. Agric. Handb. 296, 82 p.

Beckwith, S. L.
   1967. Effect of site preparation on wildlife and vegetation in the sandhills of central Florida. Eighteenth Annu. Conf. Southeast. Assoc. Game and Fish Comm. Proc. 1964: 39–48.

Bethune, J. E.
   1963. Ridging—low-cost technique for increasing growth on wet flatwoods sites. Forest Farmer 23(2): 6–7, 18.

Brendemuehl, R. H.
   1967a. Loss of topsoil slows slash pine seedling growth in Florida sandhills. South. Forest Exp. Stn., U.S. Forest Serv. Res. Note SO–53, 4 p.

   1967b. Research progress in the use of fertilizers to increase pine growth on the Florida sandhills, p. 191–196. In Forest fertilization . . . theory and practice symposium. Tenn. Val. Auth., Muscle Shoals, Ala.

Buckman, H. O., and Brady, N. C.
　1960. The nature and property of soils. Ed. 6, 567 p. New York: The MacMillan Co.

Burns, P. Y.
　1952. Effect of fire on forest soils in the Pine Barren Region of New Jersey. Yale Univ. Sch. For. Bull. 57, 50 p.

Burns, R. M.
　1966a. Machine seeding—row and broadcast. USDA Forest Serv. Reg. 8, Direct-Seeding Workshops Proc. 1965: 18–20.

———— 1966b. Tip moths in the sandhills. Forest Farmer 26(1): 12, 14.

———— 1968a. Sand pine: A tree for west Florida's sandhills. J. For. 66: 561–562.

———— 1968b. Sand pine: Florida's much maligned pioneer. South. Lumberman 217(2704): 170–181.

———— and Brendemuehl, R. H.
　1969. Yield of a Choctawhatchee sand pine plantation at age 28. Southeast. Forest Exp. Stn., USDA Forest Serv. Res. Note SE–103, 4 p.

Campbell, R. L.
　1966. Pelleted herbicides in forest management. South. Weed Conf. Proc. 19: 301–303.

Carmean, W. H.
　1971. Large, well-balanced stock and control of grass competition needed for red pine plantings on sandy soils. USDA Forest Serv. Tree Plant. Notes 22(1): 8–10.

Cooper, C. F.
　1971. Effects of prescribed burning on the ecosystem, p. 152–159. In Prescribed burning symposium proceedings. USDA Forest Serv. Southeast. Forest Exp. Stn.

Cooper, R. W.
　1957. Silvical characteristics of slash pine. USDA Forest Serv. Southeast. Forest Exp. Stn. Pap. 81, 13 p.

Coulter, C. H.
　1931. Planting forest trees in Florida. Fla. Forest Serv. Bull. 8, 29 p.

Croker, T. C., Jr.
　1957. Scalping aids longleaf seedling catch. USDA Forest Serv. South. Forest Exp. Stn. South. For. Notes 112, p. 2–3.

———— 1959. Scalping stimulates longleaf growth. USDA Forest Serv. South. Forest Exp. Stn. South. For. Notes 121, p. 3–4.

Cushwa, C. T., Hopkins, M., and McGinnes, B. S.
　1970. Response of legumes to prescribed burns in loblolly pine stands of the South Carolina Piedmont. Southeast. Forest Exp. Stn., USDA Forest Serv. Res. Note SE–140, 6 p.

———— and Jones, M. B.
　1969. Wildlife food plants on chopped areas in the Piedmont of South Carolina. Southeast. Forest Exp. Stn., USDA Forest Serv. Res. Note SE–119, 4 p.

DeBell, D. S., and Ralston, C. W.
　1970. Release of nitrogen by burning light forest fuels. Soil Sci. Soc. Am. Proc. 34: 936–938.

Derr, H. J.
　1957. Effects of site treatment, fertilization, and brownspot control on planted longleaf pine. J. For. 55: 364–367.

———— and Mann, W. F., Jr.
　1971. Direct-seeding pines in the South. USDA Forest Serv. Agric. Handb. 391, 68 p.

———— and Melder, T. W.
　1970. Brown-spot resistance in longleaf pine. Forest Sci. 16: 204–209.

Dierauf, T. A., and Marler, R. L.
　1971. Exposure, clay treatment, and storage of loblolly pine seedlings. Va. Div. For. Occas. Rep. 34, 10 p.

Enghardt, H. G.
    1968. Early thinnings—by individual trees or by rows?, p. 84–91. *In* Proceedings — symposium on planted southern pines, 1968. USDA Forest Serv. Southeast. Area, State and Priv. For.

Fassnacht, D. L.
    1954. An old bet pays off. South. Lumber J. 58(1): 24, 78.

Ferguson, E. R.
    1959. Furrowing increases first-year survival of planted pine in Texas. USDA Forest Serv. South. Forest Exp. Stn. South. For. Notes 124, p. 3.

——————— and Stransky, J. J.
    1962. Site preparation benefits pine seeding and planting in Texas. USDA Forest Serv. South. Forest Exp. Stn. South. For. Notes 138, p. 3–4.

Foster, A. A.
    1961. Control of black root rot of pine seedlings by soil fumigation in the nursery. Ga. Forest Res. Counc. Rep. 18, 5 p.

Fowells, H. A.
    1965a. Sand pine *(Pinus clausa* (Chapm.) Vasey)*, p. 447–450. *In* Silvics of forest trees of the United States. USDA Forest Serv. Agric. Handb. 271.

———————
    1965b. Slash pine *(Pinus elliottii* Engelm. var. *elliottii)*, p. 458–463. *In* Silvics of forest trees of the United States. USDA Forest Serv. Agric. Handb. 271.

Grelen, H. E.
    1956. How about helicopters for sandhill scrub oak? South. Lumberman 193(2417): 247–248.

Hair, D., and Ulrich, A. H.
    1970. The demand and price situation for forest products 1969-70. USDA Forest Serv. Misc. Publ. 1165, 79 p.

Hare, R. C.
    1961. Heat effects on living plants. USDA Forest Serv. South. Forest Exp. Stn. Occas. Pap. 183, 32 p.

Harlow, R. F., and Jones, F. K.
    1965. The white-tailed deer in Florida. Fla. Game and Fresh Water Fish Comm. Tech. Bull. 9, 240 p.

Harms, W. R.
    1969. Sand pine in the Georgia-Carolina sandhills: third-year performance. Southeast. Forest Exp. Stn., USDA Forest Serv. Res. Note SE-123, 3 p.

Harris, T. G.
    1970. The Virginia approach to site preparation and planting. Forest Farmer 30(2): 17, 30, 32.

Hatcher, J. B.
    1957. Prescription planting. Forest Farmer 16(5): 4-6.

Hebb, E. A.
    1971a. Resistance to ice damage—a consideration in reforestation. USDA Forest Serv. Tree Plant. Notes 22(2): 24-25.

———————
    1971b. Site preparation decreases game food plants in Florida sandhills. J. Wildl. Manage. 35: 155–162.

Heyward, F., and Barnette, R. M.
    1934. Effect of frequent fires on chemical composition of forest soils in the longleaf pine region. Univ. Fla. Agric. Exp. Stn. Tech. Bull. 265, 39 p.

——————— and Barnette, R. M.
    1936. Field characteristics and partial chemical analyses of the humus layer of longleaf pine forest soils. Univ. Fla. Agric. Exp. Stn. Tech. Bull. 302, 27 p.

Hodges, J. D., and Scheer, R. L.
    1962. Soil cover aids germination of pine seed on sandy sites. USDA Forest Serv. Tree Plant. Notes 54: 1-3.

Hodgkins, E. J. (ed.)
    1965. Southeastern forest habitat regions based on physiography. Auburn Univ. Agric. Exp. Stn., For. Dep. Ser. 2, 10 p.

Hopkins, W., and Hebb, E. A.
    1954. Guide to Chipola Experimental Forest. USDA Forest Serv. South. Forest Exp. Stn., 24 p.

Hough, W. A., Woods, F. W., and Mc-
    Cormack, M. L.
    1965. Root extensions of individual
        trees in surface soils of a natural
        longleaf pine-turkey oak stand.
        Forest Sci. 11: 223–242.

Humphreys, F. R., and Pritchett, W. L.
    1971. Phosphorus adsorption and
        movement in some sandy forest
        soils. Soil Sci. Soc. Am. Proc.
        35: 495–500.

Hutt, A.
    1964. The Florida wild turkey. Fla.
        Wildl. 17(10): 20–24, 30–31.

McGregor, W. H. D.
    1965. Successful summer planting of
        slash pine. J. For. 63: 208–209.

Mann, W. F., Jr.
    1969. At last—longleaf pine can be
        planted successfully. Forest Farm-
        er 28(6): 6–7, 18–19.
    _____ and Derr, H. J.
    1961. Guidelines for direct-seeding
        loblolly pine. USDA Forest Serv.
        South. Forest Exp. Stn. Occas.
        Pap. 188, 23 p.
    _____ and Derr, H. J.
    1964. Guides for direct-seeding slash
        pine. South. Forest Exp. Stn.,
        USDA Forest Serv. Res. Pap.
        SO–12, 27 p.

Martin, J. S.
    1962. Kraft pulping of west Florida
        sand pine and longleaf pine.
        USDA Forest Serv. Forest Prod.
        Rep. 2248, 12 p.

Mees, G. C.
    1960. Experiments in the herbicidal
        action of 1,1'-ethylene-2,2'-dipyri-
        dilium dibromide. Ann. Appl.
        Biol. 48: 601–612.

Moore, W. H.
    1967. Deer browse resources of the
        Atomic Energy Commission's Sa-
        vannah River Project Area. South-
        east. Forest Exp. Stn., U.S. For-
        est Serv. Resour. Bull. SE–6,
        28 p.

Nash, G. V.
    1895. Notes on some Florida plants.
        Torrey Bot. Club Bull. 22(4):
        141–161.

Peevy, F. A.
    1960. Controlling southern weed
        trees with herbicides. J. For.
        58: 708–710.

Pessin, L. J.
    1935. Root habits of longleaf pine
        seedlings. USDA Forest Serv.
        South. Forest Exp. Stn. Occas.
        Pap. 43, 7 p.
    _____
    1939. Root habits of longleaf pine
        and associated species. Ecology
        20: 47–56.

Pritchett, W. L., and Smith, W. H.
    1969. Sources of nutrients and their
        reactions in forest soils. Soil and
        Crop. Sci. Soc. Fla. Proc. 29:
        149–158.

Rhoads, A. S.
    1950. Clitocybe root rot of woody
        plants in southeastern United
        States. U.S. Dep. Agric. Circ. 853,
        25 p.

Rice, C.
    1966. The application of fenuron by
        helicopter in the control of scrub
        oak in the South Carolina sand-
        hills. South. Weed Conf. Proc.
        19: 295–300.

Ross, E. W.
    1970. Sand pine root rot—pathogen:
        Clitocybe tabescens. J. For. 68:
        156–158.

Sampson, A. W., and Schultz, A. M.
    1957. Control of brush and undesir-
        able trees. F.A.O., Rome, p. 1–49.

Scheer, R. L., and Woods, R. W.
    1959. Intensity of preplanting site
        preparation required for Florida's
        sandhills. USDA Forest Serv.
        South. Forest Exp. Stn. Occas.
        Pap. 168, 12 p.

Schemnitz, S. D.
    1954. Turkey foods in Florida. Fla.
        Wildl. 7(10): 27, 38.

Schultz, R. P., and Wilhite, L. P.
    1967. Operational summer planting
        of slash pine. Southeast. Forest
        Exp. Stn., U.S. Forest Serv. Res.
        Note SE–80, 3 p.

Shaw, M.
    1957. Best bet for ducks. Fla. Wildl.
        11(7): 16–17, 39.

Shipman, R. D.

1955a. Furrows improve longleaf survival in scrub oak. South. Lumberman 190(2381): 70–72.

1955b. Preliminary test of direct seeding of longleaf pine in the South Carolina sandhills. USDA Forest Serv. Southeast. Forest Exp. Stn. Res. Notes 72, 2 p.

1956. Furrow old fields to plant longleaf in the sandhills. USDA Forest Serv. Southeast. Forest Exp. Stn. Res. Notes 98, 2 p.

1958. Planting pine in the Carolina sandhills. USDA Forest Serv. Southeast. Forest Exp. Stn. Pap. 96, 43 p.

1963a. Pelleted silvicides—their use in controlling unwanted hardwoods in South Carolina. S.C. Agric. Exp. Stn. Forest Res. Ser. 11, 25 p.

1963b. Seeding depth—its influence on establishment of direct-seeded pine in the South Carolina sandhills. J. For. 61: 907–912.

———— and Hatcher, J. B.
1957. Planting small slash pine seedlings. Forest Farmer 16(5): 7, 18.

———— and Scott, H. R.
1963. Pelleted silvicides. Forest Farmer 22(12): 6–7, 13.

Smalley, G. W., and Scheer, R. L.
1963. Black root rot in Florida sandhills. U.S. Dep. Agric. Plant Dis. Rep. 47: 669–671.

Southern Regional Soil Research Committee
1959. Certain properties of selected southeastern United States soils and mineralogical procedures for their study. Va. Polytech. Inst., South. Coop. Serv. Bull. 61, 146 p.

Southern and Southeastern Forest Experiment Stations
1969. A forest atlas of the South. USDA Forest Serv. South. and Southeast. Forest Exp. Stn., 27 p.

Stransky, J. J.
1960. Let plowed ground settle before planting pines. USDA Forest Serv. South. Forest Exp. Stn. South. For. Notes 128, p. 4.

1961. Weed control, soil moisture, and loblolly pine seedling behavior. J. For. 59: 282–284, 289–290.

1962. Furrows aid pine survival during drought. USDA Forest Serv. Tree Plant. Notes 53: 23–24.

———— and Wilson, D. R.
1966. Pine seedling survival under simulated drought. South. Forest Exp. Stn., U.S. Forest Serv. Res. Note SO–30, 2 p.

U.S. Bureau of the Census
1970. Current population reports. Series P–25, No. 448, "Projection of the population of the United States, by age and sex (interim revisions): 1970 to 2020." U.S. Gov. Print. Off., Wash., D.C., 50 p.

U.S. Department of Agriculture
1941. Climate and man. Yearb. Agric. 1941, 1248 p.

U.S. Department of Agriculture, Soil Conservation Service
1970. Selected chapters from the unedited text of the Soil Taxonomy of the National Cooperative Soil Survey. 249 p.

U.S. Department of Commerce, Environmental Science Services Administration
1968. Florida, annual summary 1967. Climatol. Data 71: 163–172.

1969a. Florida, annual summary 1968. Climatol. Data 72:157–166.

1969b. South Carolina, annual summary 1968. Climatol. Data 71: 131–137.

U.S. Department of Commerce, Environmental Science Services Administration
1970a. Florida, annual summary 1969. Climatol. Data 73: 153–162.

———
1970b. Georgia, annual summary 1969. Climatol. Data 73: 157–166.

———
1970c. North Carolina, annual summary 1969. Climatol. Data 74: 189–199.

Ursic, S. J., Williston, H. L., and Burns, R. M.
1966. Late planting improves loblolly survival. South. Forest Exp. Stn., U.S. Forest Serv. Res. Pap. SO–24, 12 p.

Wakeley, P. C.
1954. Planting the southern pines. USDA Forest Serv. Agric. Monogr. 18, 233 p.

Wells, B. W., and Shunk, J. V.
1931. The vegetation and habitat factors of the coarser sands of the North Carolina coastal plain. Ecol. Monogr. 1: 465–520.

Wilhite, L. P., and Schultz, R. P.
1969. Summer plantings of sand and longleaf pines fail. USDA Forest Serv. Tree Plant. Notes 20(1): 7.

Woods, F. W.
1953. Operation sandhills. South. Lumberman 187(2345): 150–151.

———
1955. Tests of CMU for forestry. Forest Sci. 1: 240–243.

Woods, F. W.
1956. Relation of soil moisture and temperature to weed control. South. Weed Conf. Proc. 9: 161–165.

———
1957. Factors limiting root penetration in deep sands of the Southeastern Coastal Plain. Ecology 38: 357–359.

———
1959a. Converting scrub oak sandhills to pine forests in Florida. J. For. 57: 117–119.

———
1959b. Nutritional aspects of wiregrass from West Florida sandhills. J. Range Manage. 12: 141.

——— and Cassady, J. T.
1961. Sprouting of sandhills scrub oaks following cutting, p. 1–6. In Hardwood sprout development on cleared sites. USDA Forest Serv. South. Forest Exp. Stn. Occas. Pap. 186.

——— Cassady, J. T., and Rossoll, H.
1958. How to prepare Gulfcoast sandhills for planting pines. USDA Forest Serv. South. Forest Exp. Stn. Occas. Pap. 161, 9 p.

——— Harris, H. C., and Caldwell, R. E.
1959. Monthly variations of carbohydrates and nitrogen in roots of sandhill oaks and wiregrass. Ecology 40: 292–295.

Yoho, J. G., Dutrow, G. F., and Moak, J. S.
1971. What it costs to practice forestry. Forest Farmer 30(7): 42–50.