University of Rhode Island

DigitalCommons@URI

1979

FUELWOOD PRODUCTION OF MIXED HARDWOODS ON MESIC SITES IN SOUTHERN RHODE ISLAND

Jeffrey Alan Bridge
University of Rhode Island

Terms of Use

Recommended Citation

FUELWOOD PRODUCTION OF MIXED

HARDWOODS ON MESIC SITES IN

SOUTHERN RHODE ISLAND

BY

JEFFREY ALAN BRIDGE

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN

PLANT AND SOIL SCIENCE

UNIVERSITY OF RHODE ISLAND

1979

MASTER OF SCIENCE THESIS

OF

JEFFREY ALAN BRIDGE

Approved:

Thesis Committee

Major Professor

Dean of the Graduate School

UNIVERSITY OF RHODE ISLAND

1979

ABSTRACT

Fuelwood biomass production was determined for three coppice origin, even-aged, mixed-hardwood stands growing on moderately well-drained sites in Washington County, Rhode Island. A total of 93 trees including mixed-oaks and red maple, ranging from 7.6 to 30.5 cm in diameter were destructively sampled.

Sample trees were felled, sectioned and separated into two components: stemwood and branchwood. Total green weight by component was recorded for each tree in the field. Components were subsampled to permit oven-dry weight and specific gravity determinations. Although no relationship was found between specific gravity and rate of diameter growth, specific gravities for black oak species were found significantly different from white oak and red maple.

Values based upon component subsamples were used to project fuelwood production per unit area on a weight and volume basis. Average cordwood production for the study sites was approximately 73 cords per hectare (30 cords per acre), while mean annual increment was 1.6 cords per hectare (.65 cords per acre). Fuelwood estimates closely paralleled those of previous studies conducted for Appalachian hardwoods in southern New England.

Increased fuelwood utilization has created a demand for methods to quickly estimate tree and stand biomass. This paper presents equations and tables to estimate green and

oven-dry weights for individual trees and species, diameter classes and entire stands. Weight estimates were obtained through use of equations developed by regression analysis. Analyses indicated natural logarithm transformation on diameter and tree basal area multiplied by total tree height accounted for most of the variation in whole-tree weight. Estimates of total stand biomass were developed from equations including natural log transformation on basal area per unit area, and total stand basal area multiplied by the height of the tree of mean basal area. Coefficients of determination, R^2, calculated for stand biomass estimates were .88 using basal area and .91 using basal area times height.

An attempt was made to relate differences in site productivity to soil characteristics. It was established that soil texture, organic carbon content, available water and depth of solum are strongly correlated with tree-growth parameters. However, sample size was insufficient to permit the development of meaningful equations for determining site productivity. Also, results indicated that biotic competition may overshadow the importance of edaphic factors in influencing tree growth.

Tree height did not appear to work well in indexing site productivity. Site index was variable on soils considered similar in terms of their abilities to grow trees.

ii

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

I. INTRODUCTION

The current energy crisis has fostered a renewed inter-
est in the use of wood for fuel. In fact, the use of wood
as an energy source has increased dramatically in the last
several years. It appears that this trend will continue,
particularly in southern New England where forests occur in
close proximity to large population centers. Presently,
knowledge concerning the potential of this forest to fulfill
increasing demands is not known.

The quantity of fuelwood currently harvested in Rhode
Island, and the potential demand for fuelwood are also un-
known. Several studies in the Northeast have reported sub-
stantial use of firewood by homeowners either as a primary
or secondary source of heat (Dalton et al., 1977). A recent
survey by Stoddard (1979) in Washington County, Rhode Island,
indicates that fifty percent of homeowners are burning fuel-
wood with an average household consumption of two cords per
season.

Extensive and repeated clear-cuttings, forest fires,
severe weather phenomena, and disease and insect infesta-
tions have exerted cumulative effects resulting in a pre-
dominately even-aged, mixed-oak forest of sprout origin.
Little appears to be known of the present productivity of
the southern New England sprout forest in terms of biomass
production. Toumey and Korstian (1947) speculated that
repeated sprouting of vegetatively propagated trees may

result in reduced vigor with each successive cutting. Previous work by Roth and Hepting (1943) illustrated that the ability of oaks to sprout was inversely related to tree age and stump size. However, Wendel (1975) investigated sprouting ability in Appalachian hardwoods and concluded that hardwoods sprouted vigorously regardless of stump size, and produced excellent height and diameter growth on good stem form. Little actual work has been done in relating stump vigor to stem biomass production. Moreover, knowledge concerning the ability of sprout-oak forests in southern New England to produce fuelwood is incomplete. Morrow and Gage (1977) estimated that typical, unmanaged Northeastern forest stands contain between 20 and 40 cords per acre. They further estimated mean annual increment to average one-half cord per acre, with better sites capable of producing at least one cord per acre per year. Very little work, however, has been done to relate wood production to site conditions in the southern New England area.

McGahan et al., (1961) were unable to develop significant site-growth relationships for mixed-oaks in Rhode Island. Variables including tree parameters, soil drainage, slope, basal area and land use did not adequately account for differences in height growth between study areas. Wright (Pers. comm.) speculates that soil physical and chemical properties may be responsible for differences in site productivity. Meaningful correlations between soil

characteristics and wood production could serve as a
valuable tool in assessing and evaluating the potential
of a given site to produce fuelwood. Information from
this study, in combination with cordwood production data
from other typical sites in the region, could be used to
guide management decisions and recommendations for purposes
of growing fuelwood to meet potential demand. Therefore,
this study will attempt to determine fuelwood biomass
production of several hardwood stands growing under
various site conditions on moderately well-drained soils
in Southern Rhode Island. In addition, relationships
between soil characteristics and site productivity will be
evaluated.

II.   LITERATURE REVIEW

Biomass is becoming an important measure for forest managers and forest ecologists. As forest management moves toward complete-tree utilization, biomass may replace volume as a measure of yield and further be used as a measure of site productivity (Young, 1973). Following the International Biological Program, biomass and productivity studies have increased greatly in number.

Wood weight measurement studies have been in progress in Canada for some time. The Wood Measurement Committee of the Canadian Pulp and Paper Association (1928) conducted early investigations and recognized the utility of weight measurements for operational purposes. Today, biomass data for a variety of Canadian forest types provides a background of information that is rapidly accumulating. During the last two decades, forest weight studies have been undertaken in relation to harvesting (Keen, 1963), productivity (Ovington, 1962; Baskerville, 1965; Wells, Jorgensen and Burnette, 1975; Johnston and Bartos, 1977) and complete-tree utilization (Young, 1964; Keays, 1971). The acquisition of such data is laborious and involves a considerable expenditure of time and funds; therefore, it is essential that biomass studies are well planned with regard to collection and statistical analysis of data.

A. Sampling Procedures

Reliable sampling methods are essential for interpreta-

tion and comparison of results. Ovington, Forrest and Armstrong (1967), Madgwick (1971), Crow (1971) and Wells et al. (1975) state that stratified sampling by diameter class provides better estimates of biomass than complete random sampling. Stratified random sampling by diameter class is often used for sampling uneven-aged stands whereas complete random sampling is commonly used in even-aged stands (Baskerville, 1965; Whittaker and Woodwell, 1969).

Complete random sampling involves the "mean tree" technique which estimates biomass for an entire stand by harvesting and weighing one or more trees of mean dimension. Sample tree data are converted to a land-area basis by multiplying the biomass of sample tree(s) by the average number of trees per unit area (Art and Marks, 1971). This technique has been used extensively in plantations and uniform even-aged stands to provide an expedient estimate of biomass production. However, it is not without error. The shortcoming of this method is the difficulty in selecting a tree of mean dimension that approximates a tree of mean biomass (Crow, 1971). Moreover, in comparison to stratified sampling, the mean tree technique provides estimates having less pre-cision and greater bias (Madgwick, 1971).

B. Statistical Analysis

Detailed studies have developed regression models for estimating biomass for species, locale and regional areas (Green and Grigal, 1978). Biomass estimation equations should involve independent variables that are commonly determined in forest mensurational and ecological research that explain most of the variation in weight of trees measured.

Tree stem diameter at 4.5 feet above the ground or breast height (dbh) has been shown to account for most of the variation in weight according to Baskerville (1965), Weetman and Harland (1964), Crow (1971), Skeen (1973), Johnston and Bartos (1977), Wartluft (1977) and Wiant and Castaneda (1978). Others have successfully incorporated height with dbh in developing accurate biomass estimation equations (Young, Strand, and Altenberger, 1964; Haush, Miller and Beers, 1972; Clark and Taras, 1976; Green and Grigal, 1978). However, Crow (1971) and Wiant and Castaneda (1978) state that with uniform, vertical extension of stands, incorporation of total tree height as an independent variable does not improve reliability of regression estimates. Johnstone (1971) further suggests that any attempt to assess site productivity in terms of conventional height-age relationships may result in erroneous conclusions when considering mean height data of similar stands. However,

Schlaegel (1975) did develop a significant regression equation using height in combination with basal area to accurately estimate biomass for trees, diameter classes and forest stands.

Wells et al. (1975) used tree basal areas as the only independent variable and successfully estimated biomass of a loblolly pine plantation. Basal area is often used because it may be directly converted from tree to stand estimates in point sampling (Smith, 1967) and is easily measured in the field. However, use of tree or stand basal area to estimate weight, while very effective for average trees, may mask exceptions completely.

Difficulty in using regression equations to estimate biomass is caused by the fact that size and weights of tree and stand components are determined by a variety of variables (Smith, 1971). Using weight reduces the need to determine the many elements of size, shape and sub- stance that are incorporated into tree and stand growth. Although use of weight has advantages, it often over- simplifies and obscures the importance of these elements (Smith, 1971). In order to understand tree growth well enough to manipulate growth processes to desired objec- tives, it is necessary to study trees on an individual rather than on a stand basis (Smith, Kerr and Csizmazia, 1961).

Both linear and allometric regression models have been
used in biomass studies. Linear regression models
involving untransformed data have been used for sim-
plicity and ease of interpretation (Schreuder and Swank,
1971), and to avoid serious bias inherent in parameter
estimates involving allometric functions (Crow, 1971).
However, Young et al. (1964) believe linear relation-
ships have heterogeneous variance and lower precision
for biomass data. Most investigators use allometric
equations so as to achieve a higher squared correla-
tion coefficient, R^2, and to reduce heteroscedasticity
in order to meet the basic assumptions of regression
analysis.

Natural logarithm transformation on dependent and inde-
pendent values has proven superior in estimating biomass
regardless of selected variables. Furnival (1961) and
Cox (1961) favor the use of natural log transformations
in that they simplify calculations and do not affect
conclusions. Limitations on the precision of estimates
derived from allometric relationships are a function
of the accuracy and representativeness of the data from
which the equations are founded (Johnstone, 1971). The
number of observations used to establish a regression
equation must be sufficient to ensure a true representa-
tion of the relationship. Also, little advantage seems
to be gained by using multiple regression in place of

simple regression functions (Crow, 1971).

Regression equations should not be extrapolated beyond the range of data on which they are based. However, they may provide at least tentative guidelines to develop estimates for many circumstances not involved in the basic data (Smith, 1971). Schreuder and Swank (1971) caution that the usual measure of goodness of fit, R^2, may produce misleading results. This measure is valid if conditions under which it is meant to apply are met. Random sampling from a multivariate, normal population is a primary requirement. This assumption, however, is often violated, since selection of sample trees may not be totally random as, for example, when the stratified random sampling technique is used. Very often, the population is not even approximately normal. For instance, the distribution of tree diameters (D) may be approximately normal, however, the variable $\log_e D$, that is most often used, is not normally distributed; therefore, the assumption is violated and the concept of R^2 can be meaningless. Although the R^2 concept is not always meaningful; it is easily calculated, comparable, extremely accurate and commonly used in biomass studies (Schreuder and Swank, 1971).

III. STUDY AREAS

This study was conducted during the summer and fall of 1978 in three mixed-hardwood stands located in South Kingstown, Rhode Island. Stands selected for study were fully-stocked and similar in elevation, topography and species composition. All areas supported stands of even-aged mixed-hardwoods of coppice origin. Moderately well-drained sites served as the basis for selection of study areas. Each study area was located on a different soil series so as to obtain some indication of variation in wood production associated with soil characteristics on moderately well-drained soils. Two sample plots were randomly established in each study area.

A. Location

Location of each study area is illustrated in Figure 1. Study area 1, designated as Great Swamp I, is located within the Great Swamp Wildlife Management Area in South Kingstown, Rhode Island, at 71°-35'-11" W longitude and 41°-27'-51" N latitude.

Study area 2, designated as Great Swamp II, is also situated within the Great Swamp Wildlife Management Area at 71°-34'-31" W longitude and 41°-27'-57" N latitude.

Study area 3 is located on the University of Rhode Island Hazard Tract in South Kingstown, Rhode Island, at 71°-29'-26" W longitude and 41°-27'-37" N latitude.

Figure 1. Location of Study Areas in South Kingstown,
           Rhode Island. From Left to Right: (1) Great
           Swamp I; (2) Great Swamp II; (3) Hazard Tract.

N

KINGSTON
WEATHER
STATION

RAILROAD

138

LIBERTY LANE

110

108

ROSE HILL ROAD

138

SAUGATUCKET ROAD

① ②

SAUGATUCKET
POND

③

GREAT SWAMP

WORDENS
POND

SCALE: 1CM = 570 M
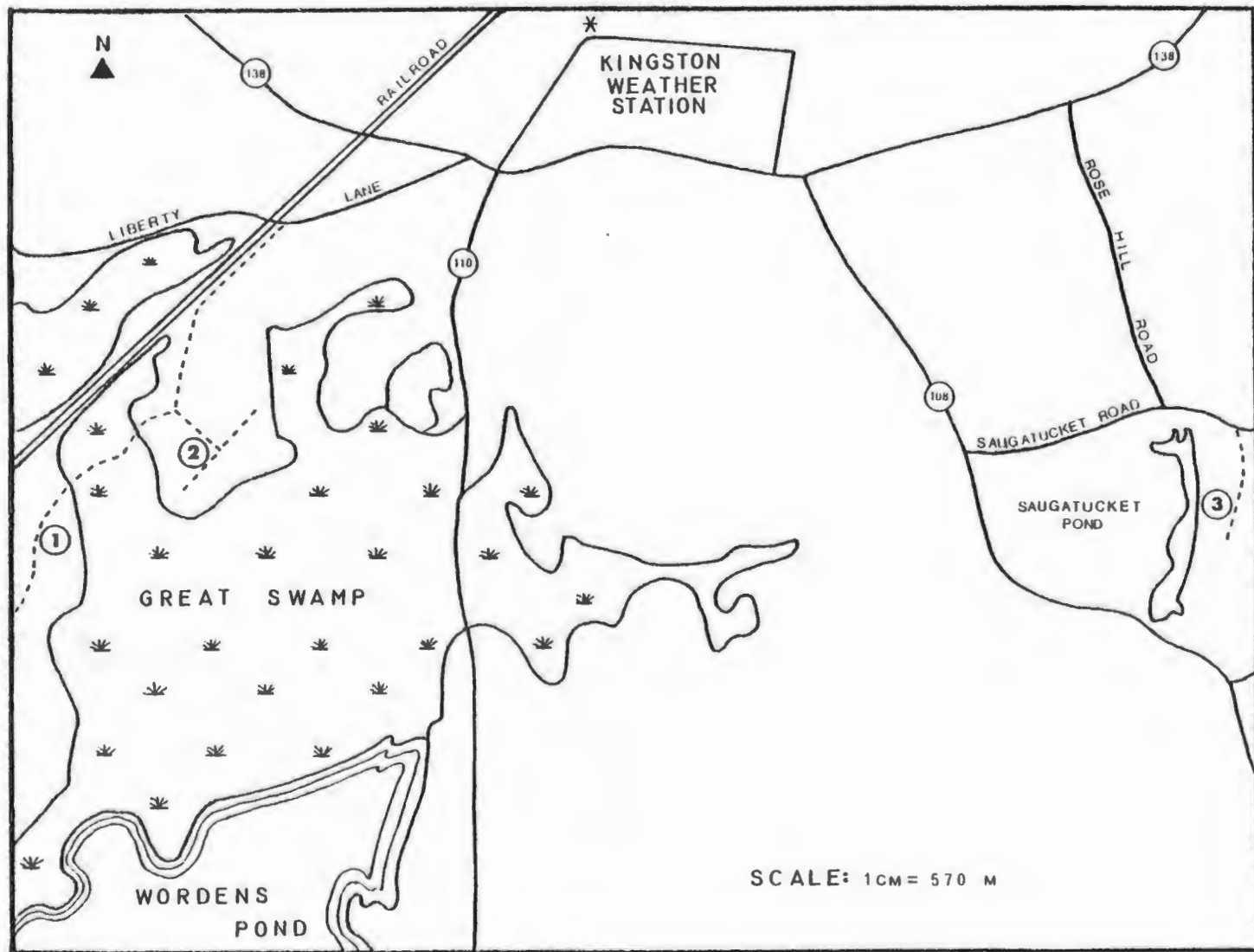
B. Vegetation

Three mixed-hardwood stands representing forest types most commonly occurring in Rhode Island were studied. A mixture of oaks, primarily of coppice origin, occurred in the overstory on all study sites. In addition, red maple (Acer rubrum L.) was an important component of the overstory on two of the three study areas. Even-aged, mixed-oak stands of coppice origin dominate most of Rhode Island's 404,000 acres of forest land. According to Brown (1960), two major factors responsible for these stands have been the widespread occurrence of wild fires and repeated clear-cuttings.

1. Great Swamp I

The overstory (tree stems greater than 4.1 cm dbh) on this area is dominated by black oak (Quercus velutina Lam.) and white oak (Q. alba L.). Nomenclature is according to Fernald (1950). Associated species of lesser importance include red oak (Q. rubra L.), swamp white oak (Q. bicolor Willd.), black gum (Nyssa sylvatica Marsh.) and American holly (Ilex opaca Ait.).

Understory vegetation (woody stems less than 4.1 cm dbh) is sparse, consisting of black huckleberry (Gaylussacia baccata Wang.) and low-bush blueberry (Vaccinium vaccillans Torr.). Tree seedlings and

saplings are sparse on this study area. Also, the area supports a thick sedge (Carex sp.) ground cover.

2.   Great Swamp II

The predominate overstory species in this stand is red maple. Other species present are white, black and swamp white oak, black gum, sassafras (Sassafras albidum Nutt.) and pitch pine (Pinus rigida Mill.).

The understory consists of a tall, dense, ericaceous shrub layer of mountain laurel (Kalmia latifolia L.), great laurel (Rhododendron maximum L.) and high-bush blueberry (Vaccinium corymbosum L.). Tree seedlings and saplings, as well as ground cover, are absent.

3.   Hazard Tract

Major species occurring in the overstory are black, white and scarlet oak (Quercus coccinea Muench.) and red maple. Minor species present, generally in small numbers, are red oak, gray birch (Betula populifolia Marsh.) and planted white spruce (Picea glauca Moench.).

The understory vegetation on this site consists pri-marily of a mixture of black huckleberry and low-bush blueberry of moderate density. Other species present are greenbrier (Smilax rotundifolia L.) and sheep laurel (Kalmia angustifolia L.). Red maple,

white pine (Pinus strobus L.) and Eastern hemlock
(Tsuga canadensis Carr.) seedlings and saplings are
present throughout the area.

C. Soils and Topography

Soils on all six study plots are moderately well-drained
having originated from either glacial granitic till or
outwash. However, soils differ between and within study
areas in terms of classification and associated charac-
teristics as demonstrated in Table 1.

1. Great Swamp I

Soil in this area is a relatively shallow, Birchwood
loamy sand.[1] A fragipan containing large amounts of
coarse gravel occurs at a depth of approximately
90 cm. The site, located at 36 meters above mean
sea level, exhibits a gently rolling, stony topo-
graphy.

2. Great Swamp II

This study area is located on two soil types; one
study plot is situated on a Woodbridge sandy loam
and the other on a Sutton sandy loam. Subsurface
horizons in each soil type contain large amounts of
coarse fragments, however, depth of fragipans in
each soil type differ. A fragipan appears at
approximately 90 cm in the Woodbridge, whereas

[1]Soil series were determined by Dr. William R. Wright, Soil
Scientist, University of Rhode Island.

TABLE 1. Soil Classification, Solum Depth and Slope for the Study Areas.

Study Area	Subgroup	Family	Series	Textural Class	Solum Depth (cm)	Slope (%)
Great Swamp I						
Plot 1	Typic Fragiochrept	Sandy, mixed mesic	Birchwood	loamy sand	90	0-3
Plot 2	Typic Fragiochrept	Sandy, mixed mesic	Birchwood	loamy sand	72.5	3-8
Great Swamp II						
Plot 1	Typic Fragiochrept	Coarse-loamy, mixed mesic	Woodbridge	sandy loam	70	0-3
Plot 2	Umbric Dystrochrept	Coarse-loamy, mixed mesic	Sutton	sandy loam	65	0-3
Hazard Tract						
Plot 1	Umbric Dystrochrept	Coarse-silty, mixed mesic	Scio	silt loam	80	0-3
Plot 2	Umbric Dystrochrept	Coarse-loamy, mixed mesic	Scio	silt loam	82.5	0-3

Sutton displays a fragipan below the control section at 137 cm.

3. Hazard Tract

This area, located 12 meters above mean sea level on gently rolling, very stony terrain, occurs on a Scio silt loam. Soil is deep without a fragipan, and originated from outwash, in contrast to the Great Swamp study areas where soils originated from glacial till. Subsurface horizons contain coarse fragments. Complete profile descriptions of study areas are given in Appendix A.

The presence of plow horizons in each soil profile indicates past agricultural use. There was no evidence of past fires occurring in recent years on any of the study areas.

D. Climate

The National Oceanic and Atmospheric Administration (NOAA) station in Kingston, Rhode Island was used as a source of weather data due to its close proximity to the study areas. Average mean temperature for Kingston, Rhode Island for the period 1941-1970 was 9.4° C (48.9° F) (NOAA, 1974). Due to the effect of the southern New England maritime macroclimate, variation between yearly mean temperatures and monthly mean temperatures is not excessive.

Mean annual precipitation based on the period 1941-1970
was 112.4 cm (44.3 inches) (NOAA, 1974). Harris and
Odland (1948) stated that precipitation in Rhode Island
is uniformly distributed throughout the year with ample
quantities normally deposited during the growing
season. Due to its coastal location and influence of
Narragansett Bay, two commonly destructive climatic
forces, hurricanes and ice storms, periodically and
extensively damage Rhode Island's forests.

IV.   STUDY METHODS AND PROCEDURES

A. Plot Establishment and Tree Measurements

Two .04 hectare circular plots were randomly established on each of the three study areas. All trees greater than 4.1 cm (1.6 in) dbh were permanently tagged with enumerated metal strips. Characteristics recorded for each tree included: species, dbh, height, age and crown class. Tree crown classification is according to Smith (1962). Based upon tree data, basal area stocking and site index were determined for each plot. Also, for each plot, indices of species composition including relative density and relative basal area were computed for each species for stems greater than 7.6 cm (3 in).

B. Biomass Determinations

Trees within plots were stratified into 2.5 cm diameter classes, and classes provided a basis for selection of trees for destructive sampling. To ensure representative sampling, the number of trees sampled from each diameter class was selected in proportion to the frequency of individuals within each class. A total of fifteen trees in each plot was randomly selected for destructive sampling to accurately estimate above-ground biomass. For estimating above-ground biomass, Wells et al. (1975) found that a sample of 15 trees per plot provided representative results.

Sampling was limited to trees greater than 7.6 cm
(3 in) and less than 30.5 cm (12 in) dbh, however, most
sample trees were smaller than 25.4 cm (10 in). Trees
less than 7.6 cm were considered too small for practical
harvest for fuelwood, while trees larger than 30.5 cm,
unless of inferior species or of poor form or vigor,
would best be left as sawtimber. Only three trees,
greater than 30.5 cm dbh occurred on the plots; two in
Hazard Tract and one in Great Swamp II. Thus, biomass
estimates very nearly reflect total production for each
study area.

The following parameters were recorded for all felled
trees: total height, height to live crown and age at
stump height. Once felled, sample trees were separated
into three components; stemwood (portions of trees having
diameters outside bark (dob) greater than 5.1 cm (2 in)),
branchwood (portions of trees having a dob between 5.1
and 2.5 cm), and deadwood greater than 2.5 cm dob.
Branchwood less than 2.5 cm was considered impractical
as a source of fuelwood and was not included in biomass
determinations.

Total green weight by component for felled trees was
recorded at the study sites on a 250 kg capacity scale.
Components were subsampled for specific gravity and per-
cent moisture content; twelve trees on each study area

for specific gravity determinations and all trees for percent moisture content. In the subsampling process, several disks, 2.5 cm thick, were removed from each component and weighed immediately following cutting to avoid errors due to moisture loss. Each sample was subsequently labeled and numbered for later identification.

In the laboratory, samples were immersed in water to obtain green disk volume through water displacement. Following volume determinations, samples were oven-dried at 105°C for 48 hours to obtain percent moisture content. Oven-dry weight to within one-hundredth of a gram was recorded for each sample. Specific gravity was then determined for each sample based upon green disk volume and oven-dry weight. Subsequently, an average specific gravity for each sample tree was determined. This was accomplished by computing an average specific gravity for stemwood and for branchwood for each sample tree. These values were applied proportionally to the amount of stemwood and branchwood in a given tree to obtain an average specific gravity for that tree.

Percent moisture content was calculated for each disk-sample using a ratio of oven-dry weight to green weight. Regardless of species, moisture content between stem and branchwood samples was found to be significantly differ-

ent. Consequently, average moisture content values were calculated separately for stemwood and branchwood. These values were used to project oven-dry weight for stemwood and branchwood of sample trees. Oven-dry weight values weighted proportionally according to total green weight of stemwood and branchwood in a given tree, were used to estimate oven-dry weight of sample trees.

For each plot, sample trees were grouped by diameter class and average oven-dry weight was calculated for each class. Mean oven-dry weight multiplied by the number of trees in a given class provided an estimated total weight per unit area for that diameter class. Subsequently, an estimated weight yield of merchantable fuelwood per plot, inclusive of all diameter classes, was calculated. Sample plot data were combined to arrive at a fuelwood production value for each study area.

Sample sections taken at stump height were used to determine age and mean annual increment of ten codominant and dominant trees from each study area. A Bausch and Lomb stereo-zoom microscope mounted on a DeRouen dendro-chronometer was used to measure annual radial growth to 0.01 mm.

C. Soil Analysis

In order to identify conditions that could influence tree growth and site productivity, several soil physical and

chemical properties were measured in the laboratory.
Properties measured were: bulk density, particle size,
organic carbon content, percent moisture at field
capacity, percent moisture at wilting point, pH, cation
exchange capacity, exchangeable acidity and percent base
saturation.

Soil profiles were described for each stand from soil
pits dug near the center of study plots.[1] Soil samples
were obtained from each horizon for textural and chemical
analyses. Core samples were taken within plot boundaries
to confirm soil profiles as typical for each area.

Bulk density was determined using two techniques. The
core sampling method was used where the percentage of
sand was high, and for soils with relatively high silt
and clay contents, clods were extracted and coated with
paraffin to evaluate bulk densities. Soil cores were
obtained using a core sampler consisting of a cylin-
drical sleeve with two 2.5 cm removable sample cylinders.

Textural class was determined through particle size
analysis using the pipette method to separate soil
fractions.

---

[1]Complete profile descriptions are given in Appendix A.

Organic carbon content was determined through the Walkley-Black method (Black, 1965).

Percent moisture content at field capacity and at permanent wilting point was determined using a pressure membrane apparatus according to the procedure outlined in Methods of Soil Analysis (Black, 1965).

An Orion digital ionalyzer was used to determine hydrogen ion concentration (pH).

Laboratory analyses for each horizon are contained in Appendix B.

A complete nutrient analysis was conducted for Scio silt loam (see Appendix C). Justification for conducting a nutrient analysis on only one soil profile, lay in the fact that each study area had similar land use (past agriculture) and an extremely small range in pH. Since pH is the principal factor in determining nutrient availability, nutrient status of each profile was assumed to be similar.

Chemical properties measured were: total cation exchange capacity using the ammonium acetate method, exchangeable acidity using the barium chloride -- triethanolamine method, percent base saturation and free iron oxide concentration. In addition, calcium, magnesium, potassium and sodium levels were evaluated through use of a

spectrophotometer.

Soils were classified according to Soil Taxonomy
(USDA, 1975a).

D. Statistical Analysis

One way analysis of variance with a standard F-test and
Student's "t" test were used to test differences in wood
production between study areas. Calculated "F" and "t"
values were considered significant at the .05 level and
highly significant at the .01 level. Linear, multiple
and stepwise regressions were used to evaluate relation-
ships between weight, expressed as the dependent vari-
able, versus a matrix of independent variables including
tree, soil and stand characteristics.

Principal component and canonical correlation analyses
were conducted to evaluate relationships among variables.
Processing of data was performed on the I.B.M. System
370 computer at the University of Rhode Island Academic
Computer Center.

V.   RESULTS AND DISCUSSION

A total of 93 trees from three fully-stocked, even-aged, second-growth hardwood stands was destructively sampled. Characteristics of individual sample trees are contained in Appendix D.

A. Stand and Site Characteristics

1. Tree Characteristics

Stands studied contained trees of similar size and age (see Table 2). The major difference between study areas was the difference in average stand age; average age for trees at the Hazard Tract site was 35 years as opposed to 50 years for Great Swamp I and 52 years for Great Swamp II.

Average tree moisture contents for species and study areas are presented in Table 3. Species in the black oak group which included black, red and scarlet oaks contained 74 percent moisture on an oven-dry weight basis, while red maple and white oak contained 60 and 66 percent, respectively. Sassafras and black gum with 82 and 84 percent contained more moisture than other species, but values are based only on single trees of each species. Differences in tree moisture contents between areas and species were not significant.

TABLE 2. Stand Characteristics[1]

Stand	Average dbh		Average Height		Average Age		Basal Area per hectare
	All Trees	Dominants and Codominants	All Trees	Dominants and Codominants	All Trees	Dominants and Codominants	
	-------- cm -------		------ m. ---------		-------yrs. -------		---Sq. m.----
Great Swamp I							
Plot 1	16.76	20.75	13.23	15.36	48.5	54.1	19.94
Plot 2	17.02	21.36	11.34	14.11	51.0	54.0	22.51
Stand Average	16.89	21.06	12.31	14.78	49.8	54.0	21.22
Great Swamp II							
Plot 1	15.75	20.18	11.12	12.92	52.2	63.6	17.12
Plot 2	17.02	20.91	13.53	15.18	51.6	56.4	20.81
Stand Average	16.51	20.55	12.37	14.20	51.9	59.6	18.96
Hazard Tract							
Plot 1	15.75	18.26	14.60	16.12	35.5	37.5	21.74
Plot 2	15.24	20.68	13.72	15.51	35.4	36.7	19.55
Stand Average	15.49	19.47	14.14	15.85	35.5	37.1	20.65

[1] Based upon stems greater than 4.1 cm dbh.

TABLE 3. Average Moisture Content and Specific Gravity for Species by Study Area

Study Area	Species	Moisture Content[1]		Specific Gravity[2]	
		Mean	Range	Mean	Range
		------ o/o ------		----- gm/cc -----	
Great Swamp I					
	Black Oak	73	68-87	.63	.61-.65
	White Oak	65	62-75	.59	.56-.62
	Black Gum	84	---	.50	---
Great Swamp II					
	Black Oak	75	62-84	.65	.61-.68
	White Oak	67	61-72	.62	.58-.66
	Red Maple	61	55-69	.59	.57-.63
	Sassafras	82	---	.48	---
Hazard Tract					
	Black Oak	75	60-87	.63	.61-.64
	White Oak	68	---	.62	---
	Red Maple	58	56-67	.53	.50-.56

[1] Values based upon moisture as a percentage of oven-dry weight.

[2] Values based upon green volume and oven-dry weight.

Tree specific gravities varied within and between species, but averages for species for the study areas were similar (see Table 3). A Student "t" test of mean specific gravities based upon pooled data from all study areas revealed that average specific gravity for black oak of .63 was significantly different from white oak (.61) at the .05 level and from red maple (.55) at the .01 level. Also, white oak was found to differ significantly from red maple at the .05 level. Values for each sample tree are contained in Appendix D.

Specific gravities for trees in the black oak group fell within the range of values (.57-.65) given by Forbes (1955) as normal for that group. White oak specific gravities also fell within the accepted range (.59-.68). However, specific gravities for red maple tended to exceed the range of values (.49-.54) considered normal for that species. In fact, mean specific gravity for red maple on the Great Swamp II study area (.59) fell outside the normal range.

It is widely known that genetic variation causes specific gravity to vary within a species in a given location. Also, Panshin and DeZeeuw (1970) indicate that within tree variation is generally so great

that relationships between specific gravity and location of wood within a tree are impossible to establish. They do indicate, however, that branch-wood in ring-porous hardwoods, such as oaks, generally exhibits higher specific gravities than stemwood. This was not the case in the present study; specific gravities varied throughout individual trees so that patterns were not detectable.

In the case of ring-porous hardwoods, faster growth generally results in strong, dense wood higher in specific gravity than slower-growing trees of the same species (Panshin and DeZeeuw, 1970). However, in this study, there did not appear to be a relationship between specific gravity and growth rate of ring-porous oaks. A linear regression of specific gravity and mean annual radial increment failed to show a significant relationship. Paul (1930) also found growth rate had little effect on specific gravity in selected ring-porous species such as ash, hickory and oak.

In diffuse-porous hardwoods, such as red maple, there is little relationship betwen specific gravity of wood and rate of growth (Panshin and DeZeeuw, 1970). However, Paul (1930) discovered

that for diffuse-porous hardwoods growing under
adverse conditions, narrow rings contained a greater
amount of porous tissue resulting in lower specific
gravity. An examination of specific gravities for
diffuse-porous red maples on the study sites showed
no relationship with growth rate.

2. Species Composition

Oaks clearly dominate stands on two of the study
areas; Great Swamp I and the Hazard Tract (see
Table 4). White oak and red maple contribute con-
siderably less to total stand basal areas than
trees of the black oak group on these study areas.

On Great Swamp II, red maple dominates stand com-
position. It comprises approximately 70 percent of
the basal area present based upon the two plots
sampled.

3. Tree Radial Growth

Radial growth rate curves for the study areas based
upon dominant and codominant trees show marked
differences between areas (see Figure 2). In the
35-year-old stand at the Hazard Tract, mean annual
radial increment averages 3.48 mm, and at the time
of sampling there was no indication of a leveling
off of radial growth. Radial growth rates for Great

TABLE 4. Species Composition of Stands on the Study Areas

| Stand | Black Oak Group | | White Oak | | Red Maple | |
	Relative Density	Relative Basal Area	Relative Density	Relative Basal Area	Relative Density	Relative Basal Area
- - - - - - - - - - - - - - per cent -						
Great Swamp I						
Plot 1	39	67	61	33	-	-
Plot 2	85	92	11	7	4	1
Great Swamp II						
Plot 1	15	8	15	15	70	77
Plot 2	-	-	36	35	64	65
Hazard Tract						
Plot 1	52	63	22	15	26	22
Plot 2	54	67	11	5	35	28

Figure 2. Growth Rate Curves for the Study Areas. From
Left to Right: (1) Hazard Tract; (2) Great
Swamp I; (3) Great Swamp II.
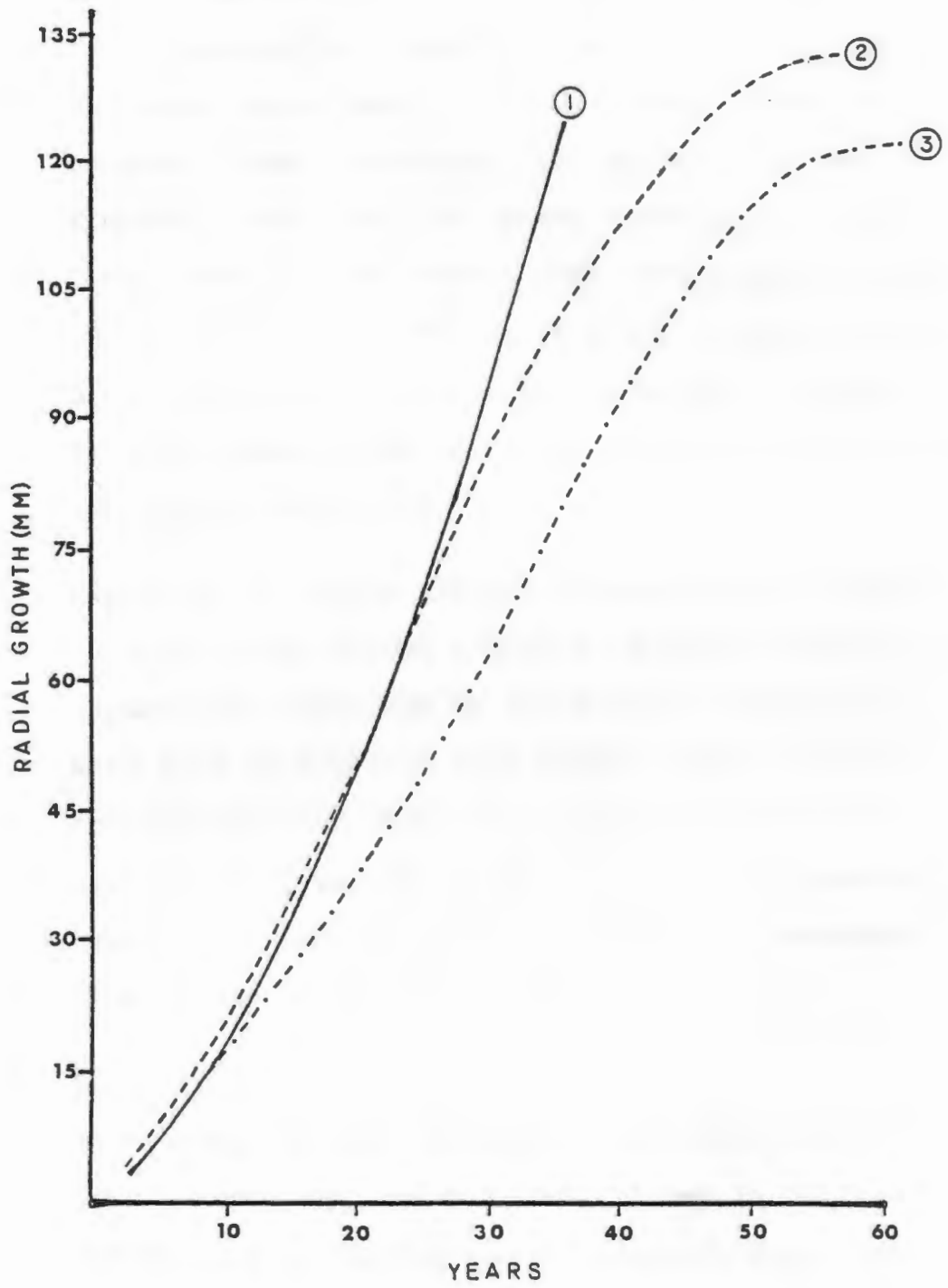
Swamp I paralleled those of the Hazard Tract stand
for the first 20 years, but slowed noticeably there-
after followed by a leveling off of growth at about
50 years. As a result, radial increment for trees
on Great Swamp I averaged 2.63 mm per year, con-
siderably less than the Hazard Tract stand. On
Great Swamp II, the growth rate curve began to taper
off at 50 years, as did Great Swamp I, but rate of
growth was less. Mean radial increment for trees
on Great Swamp II was 2.15 mm per year: lowest of
the three study areas.

According to Schnur (1937), culmination of growth
in total cubic volume occurs at about 50 years for
Appalachian hardwoods on all sites. This agrees
with data obtained in this study. Radial growth in
the Hazard Tract stand will probably taper off as
average stand age approaches 50, but total radial
growth and wood production will have far exceeded
that in the Great Swamp stands.

4. Site Index

Site index for oaks (height in feet attained by
average dominant and codominant trees in 50 years)
was determined for each plot and study area based
upon curves developed by Schnur (1937). The best
site index (60) was computed for the Hazard Tract

stand while site indices for Great Swamp I and Great Swamp II were 45 and 40, respectively.

B. Site Productivity

1. Fuelwood Production

Dry-weight yields and cordwood production values for individual stands are given in Table 5.

Except for plot 1 in the Great Swamp II stand, dry-weight and cordwood yields are similar for all plots. However, mean annual cordwood increment differs. Mean annual increment (MAI) of cordwood for the Hazard Tract stand is 2.3 cords per hectare (.94 cords per acre), making it the most productive stand studied. Cordwood increment for Great Swamp I is only 1.74 cords per hectare (.70 cords per acre) per year which probably reflects the greater average age of the stand. Although average stand age of Great Swamp II is similar to Great Swamp I, annual cordwood increment is only 1.33 cords (.54 cords), reflecting the comparitively low yield from plot 1 in the Great Swamp II stand. Thus, Great Swamp II is the least productive of the three study areas.

Despite differences in production rates, data from the three stands were pooled to obtain an estimate of fuelwood production for moderately well-drained

Table 5. Dry-Weight Yields and Cordwood Production for
          Stands on the Study Areas

| Stand | Yield | | | Mean Annual Increment | |
| | Dry-weight | Cords[1] | | Cords | |
	kg/hectare	per hectare	per acre	per hectare	per acre
Great Swamp I					
Plot 1	114000	84.7	34.3	1.75	.71
Plot 2	117825	87.7	35.5	1.73	.70
Stand Average	117150	86.2	34.9	1.74	.70
Great Swamp II					
Plot 1	78725	58.5	23.7	1.11	.45
Plot 2	108650	80.8	32.7	1.56	.63
Stand Average	93675	69.6	28.2	1.33	.54
Hazard Tract					
Plot 1	121675	90.4	36.6	2.54	1.03
Plot 2	98450	73.1	29.6	2.07	.84
Stand Average	110050	81.7	33.1	2.30	.94

[1] Plot values projected to unit area values based upon one
cord equals 1660 kg (3656 lb) at 20 percent moisture.

sites. Pooled data indicate a total yield of 73.1
cords per hectare (30 cords per acre) at age 45,
and a mean annual increment of 1.6 cords per hectare
(.65 cords per acre).

In addition to stand age and site conditions,
species composition, because of specific gravity
differences between species, is important in deter-
mining the biomass production of a given area
(Schnur, 1937). Data from all three stands were
pooled to construct Table 6 which presents average
oven-dry weights of trees by diameter class for
individual species.

Average weights per diameter class were combined for
each species in order to test species totals for
differences. Based upon Student "t" tests, the
total for the black oak group (1107 kg) differed
significantly from white oak (982.3 kg) and red
maple (867.3 kg) at the .05 level. White oak and
red maple totals were not significantly different.
Also, average oven-dry weights for trees in the
black oak group exceeded white oak and red maple
weights for all but one diameter class.

Thus, because of greater average weights regardless
of diameter class, black oak would seem to be a

TABLE 6. Average Oven-dry Weights of Trees by Diameter Class
Separated by Species

Diameter Class	Average Oven-dry Weight			
	Black Oak	White Oak	Red Maple	Species Combined
cm	- - - - - - - - - - - kg - - - - - - - - - - - - -			
6.60- 8.89	17.0	14.9	16.4	16.7
9.14-11.43	26.4	26.4	36.2	32.1
11.68-13.97	57.9	41.2	44.5	50.1
14.22-16.51	90.2	74.5	74.0	82.8
16.76-19.05	145.8	149.3	87.2	182.1
19.30-21.59	193.9	170.7	149.0	180.6
21.84-24.13	233.0	202.7	202.5	222.8
24.38-26.67	342.8	302.6	257.5	311.2
Totals	1107.0	982.3	867.3	1048.4

better source of fuelwood than either white oak or
red maple. The generally accepted faster growth
rates of black oak group species, especially in
comparison to white oak, would further support
superiority of black oak group species as sources
of fuelwood. However, results are based only on
three stands on moderately well-drained sites, and
values may change with the inclusion of more stands
on varied sites.

Average specific gravities were used to relate each
species, in terms of energy value, to home heating
fuel. Values are listed in Table 7.

Black oak, having the highest average specific
gravity (.63), provides the greatest amount of heat:
one cord equivalent to 140 gallons (636 liters) of
heating fuel. Red maple, having the lowest average
specific gravity, provides only moderate heat value
equivalent to 115 gallons (523 liters) of heating
fuel. For the study areas, taking into considera-
tion species composition, the average heat equiva-
lent of a cord would be equal to 126 gallons (573
liters) of fuel oil.

2. Regression Analyses and Yield Tables
   An attempt was made to develop regression models

TABLE 7.   Cordwood Biomass, Energy Values and Heat Equivalents of Various Woods

Species	Weight/cord (kg)	Specific Gravity (gm/cc)	Energy BTU's[1] (Millions)	Efficiency[2] (percent)	Unsable Energy in BTU's (millions)	Heating Fuel Equivalency per cord[3] (gallons)	(liters)
Black Oak	1725	.63	25	55	14.0	140	636
White Oak	1675	.61	23	55	12.6	126	573
Red Maple	1500	.55	21	55	11.5	115	523
Species[4] Combined	1660	.60	23	55	12.6	126	573

[1] Based upon values in British thermal units from Morrow and Gage (1977).

[2] Based on burning wood at 20 percent moisture in late model wood stove.

[3] Based upon 70 percent efficiency for fuel oil.

[4] Based upon average weights and specific gravities for all study areas.

for estimating fuelwood production on moderately well-drained sites. Independent variables included commonly and easily measured tree and site characteristics. The main objective was to develop simple regression models capable of explaining most of the variation in weight (both oven-dry and green) of individual trees and entire stands.

a. Estimating Weights of Individual Trees

Step-wise regression analyses were conducted for each species and study area to determine the importance and significance of independent variables for estimating the weight of individual trees. Independent variables included: tree characteristics - dbh and height; soil characteristics - texture, organic carbon, available water, bulk density, pH and percent coarse fragments for the surface 91 cm of soil, depth of solum and depth of the A horizon; and basal area as a measure of stand density.

Analyses indicated dbh accounted for most of the variation in tree weight. Similarly, Wiant et al. (1977), Wartluft (1977) and Green and Grigal (1978) also found dbh strongly correlated with tree weight and developed regression equations for tree weight as a function of dbh.

Simple linear regression models combining data from all study areas were developed for each species using dbh to estimate oven-dry weight (ODWT) of individual trees. Furnival (1961), Cox (1961) and Young et al. (1964) suggest using allometric regression equations to increase the coefficient of determination, R^2, and reduce heterogeneous variance. Therefore, diameters and oven-dry weights were transformed to natural logs to develop allometric regression equations. Equations and coefficients of determination (R^2) are as follows:

(1) Black Oak Ln(ODWT) =
$-.34052 + 2.65803$Ln(DBH) $R^2 = .96$

(2) White Oak Ln(ODWT) =
$-.82061 + 2.84694$Ln(DBH) $R^2 = .93$

(3) Red Maple Ln(ODWT) =
$.10594 + 2.33968$Ln(DBH) $R^2 = .96$

Linear regressions for species were tested for differences in slope and level according to Freese (1967). Differences were found to be not significant, and data were combined to produce a single regression applicable to all species.

In a similar manner, regression models were
developed for each study area using dbh to
estimate oven-dry weight of individual trees.
Regression lines were tested for differences
in slope and level: differences were not signi-
ficant. As a result, data from each study
area, including all species, were pooled to
develop a single regression to estimate oven-
dry weight as a function of dbh. In a similar
fashion, an allometric equation was developed
to predict green weight (GWT) of individual
trees. The resulting equations are as follows:

(4) $Ln(ODWT) = -.39986 + 2.65919 Ln(DBH)$

$$R^2 = .95$$

(5) $Ln(GWT) = .11714 + 2.66262 Ln(DBH)$

$$R^2 = .94$$

Total tree height did not prove significant
when included in a multiple regression model
with dbh. Crow (1971) and Wiant et al. (1977)
also found this to be true in their studies
and attributed the uniform vertical extension
of tree stands, regardless of crown class, as
being responsible for the lack of significance.
Schlaegel (1975), however, developed regres-
sion models that successfully incorporated tree

height (H) with individual tree basal area (B)
to estimate green and oven-dry weight for
individual trees, diameter classes and entire
stands. Estimates of tree oven-dry weight and
green weight were made by substituting the com-
bined variable, basal area times height (BH),
into the following allometric equations:

(6) $Ln(ODWT) = 2.35524 + .99342Ln(BH)$

$$R^2 = .97$$

(7) $Ln(GWT) = 2.87187 + .99550Ln(BH)$

$$R^2 = .97$$

The R^2 increases slightly since basal area times
total tree height more accurately reflects tree
volume than does diameter alone. However,
equations using DBH estimate tree weights with
nearly the same precision as the equations
using BH. Thus, equations using DBH, because
of ease of measurement, appear to provide the
best tools for estimating individual tree
weights.

A further extension of the individual tree
estimate is to estimate weight by diameter
class for the purpose of constructing stock
tables. Weight estimates can be readily cal-
culated for each diameter class by using

diameter class basal area for (B) and average
total height of trees in that diameter class
for (H) in one equation, and mean diameter (D)
for trees in a given diameter class in another.
Allometric regression models estimating weight
by diameter class are as follows:

(8) $Ln(ODWT) = -.28603 + 2.60319Ln(D)$
$$R^2 = .99$$
(9) $Ln(ODWT) = 2.39230 + .97555Ln(BH)$
$$R^2 = .99$$

Weight estimates derived from each regression
model for each diameter class are listed in
Table 8. Results indicate that use of mean
diameter, (D), slightly underestimates actual
values while use of the combined variable,
(BH), slightly overestimates actual values.
Stock tables may be developed for a given
stand on moderately well-drained soils using
this information in accordance with the number
of trees in each diameter class.

b. Estimating Stand Weights

Equations were developed to predict cordwood
biomass on a unit area basis. In separate
equations, stand basal area (B) and (BH), where
B is total stand basal area and H is the aver-

Table 8. Diameter Class Oven-dry Weight Estimates Using Regression
Models 8 and 9[1]

	Average ODWT Estimates				
Diameter Class	Average Actual ODWT	Equation 8 using(D)	Percent of Actual[2]	Equation 9 using(BH)	Percent of Actual
cm	kg	kg	%	kg	%
6.60- 8.89	16.7	13.1	78	15.8	95
9.14-11.43	32.1	27.7	86	32.5	101
11.68-13.97	50.1	49.6	99	53.1	106
14.22-16.51	82.8	79.7	96	84.7	102
16.76-19.05	132.2	119.0	90	.132.2	100
19.30-21.59	180.6	168.5	93	173.3	96
21.84-24.13	222.8	228.9	103	234.6	105
24.38-26.67	311.2	301.2	97	293.3	95
26.92-29.21	351.2	385.9	110	363.7	103

[1] Estimates include all sample trees of each species from all
study areas. Regression Models are as follows:

$$(8)\ \mathrm{Ln(ODWT)} = .28603 + 2.60319\ \mathrm{Ln}\ (D)\quad R^2 = .99$$

$$(9)\ \mathrm{Ln(ODWT)} = 2.39230 + .97555\ \mathrm{Ln}\ (BH)\quad R^2 = .99$$

[2] The difference between actual yield and estimated yield expressed
as a percentage of actual yield.

age weighted height of all trees in the stand
(each tree was weighted by its squared dia-
meter), were found to effectively predict stand
biomass in kg/ha (ODWT). Equations are as
follows:

(10) $Ln(ODWT) = -1.73061 + 1.22733Ln(BH)$
$$R^2 = .91$$
(11) $Ln(ODWT) = 1.14376 + 1.61363Ln(B)$
$$R^2 = .88$$

Table 9 illustrates the reliability of using
the regression models to estimate biomass pro-
duction for individual study areas. Both
equations 10 and 11 predicted actual yields
with about the same accuracy. Equation 10 us-
ing (BH) and equation 11 using (B) estimated
stand biomass within an average of 5 and 4
percent, respectively, of actual yields. This
being the case, equation 11 seems a logical
choice for obtaining quick, accurate estimates
of cordwood biomass from hardwood stands on
moderately well-drained sites in Rhode Island.

In mixed-oak stands similar to those found in
Rhode Island, Wiant and Charleton (1978) in
northern West Virginia developed two rapid-
weight estimation equations using basal area

Table 9.   Estimates of Oven-dry Weight Biomass (kg/ha) by Study
Area Using Regression Models 10 and 11[1]

		ODWT Estimates			
Study Area	Actual ODWT	Equation 10 using(BH)	Percent of Actual[2]	Equation 11 using(B)	Percent of Actual
Great Swamp I					
Plot 1	114000	105050	92	103750	91
Plot 2	117825	119775	102	126125	107
Great Swamp II					
Plot 1	78725	78725	100	81450	103
Plot 2	108650	108975	100	109775	101
Hazard Tract					
Plot 1	121675	119625	98	117850	97
Plot 2	98450	106200	108	99975	101

[1] Regression models are as follows:

(10) $Ln(ODWT) = 1.73061 + 1.22733 \; Ln \; (BH)$ $R^2 = .91$

(11) $Ln(ODWT) = 1.14376 + 1.61363 \; Ln \; (B)$ $R^2 = .88$

[2] The difference between actual yield and estimated yield expressed
as a percentage of actual yield.

per acre (B) and average stand height (H) in
feet. The equations are as follows:

(12) (.94)(B) = (ODWT) in thousand pounds

per acre

(13) (1.72)(H) = (ODWT) in thousand pounds

per acre

These equations were used to estimate biomass
from the study areas. Equation 12 estimated
biomass within about 3 percent of actual values
and equation 13 within 4 percent. Equations
appear to describe biomass production for the
study sites very well. In fact, equations 12
and 13 are as effective as equations 10 and 11
developed from stand data. This indicates
close similarity of biomass production in West
Virginia and Rhode Island and probably for the
entire oak region in the Northeast. Incorpora-
tion of data from additional stands and a
variety of sites would be advisable to see if
relationships are valid under varied site
conditions.

3. Site Comparisons

a. Yield Comparisons

Cordwood production values for the three study
areas as already indicated are very similar:

approximately 73 cords per hectare (30 cords per acre). However, mean annual cordwood increment differs for each stand ranging from 1.3 cords to 2.3 cords per hectare (.54 cords to .94 cords per acre). Cordwood production values for the stands studied were compared to yield tables for fully-stocked, even-aged, second-growth, Appalachian hardwood stands developed by Schnur (1937) (see Table 10).

Schnur's yield tables are based on site index and on yields of material greater than 10.1 cm (4 inches) dob. For purposes of comparison, stand yields were compared with Schnur's yields for sites with similar site indices. In addition, since cordwood yields for the study stands were based upon yields for stems greater than 2.5 cm dob, it was necessary to adjust values to include only material greater than 10.1 cm dob. Recorded data from sample trees indicated that an average of 11.5 percent of the biomass of sample trees was accounted for by material from 2.5 cm to 5.1 cm in diameter. Thus, it was estimated that about 34.5 percent of total tree weight would be included in the diameter range from 2.5 cm to 10.1 cm. Stand cordwood yields were reduced by this amount.

TABLE 10. Production Yields of Even-aged, Second-growth Hardwoods by Study Area Compared to Schnur's Yield Tables

	Age (yrs)	Average Height (m)	Trees per hectare[1] (number)	Basal Area per hectare (sq. m)	Average DBH (cm)	$\frac{Yield}{(cords/ha)^2}$	$(cords/ha)^3$	Mean Annual Increment $(cords/ha)^2$
				SITE INDEX - 40				
Great Swamp II	52	14.0	1112	18.23	16.5	44.7	69.6	.86
Schnur	50	12.2	1981	19.79	11.4	30.9	--	.62
				SITE INDEX - 45				
Great Swamp I	50	14.6	926	20.45	16.8	54.8	86.2	1.09
Schnur	50	13.7	1760	21.12	12.5	38.8	--	.79
				SITE INDEX - 60				
Hazard Tract	35	15.9	1482	19.79	15.2	51.9	81.8	1.48
Schnur	40	15.6	1510	20.67	13.5	45.9	--	1.14

[1] Based upon stems greater than 4.1 cm dbh.

[2] Based upon merchantable stem to 10.1 cm dob.

[3] Based upon merchantable stem to 2.5 cm dob.

Stand yields were further adjusting by subtracting weights of all stems less than 12.7 cm dbh.

Table 10 shows that adjusted production yields are similar to values given by Schnur for sites with similar site indices. Adjusted yields exceed Schnur's values by an average 10.6 cords per hectare (4.3 cords per acre), but some of the difference may be related to assumptions made in adjusting values to permit direct comparison with Schnur's values.

Data from this study indicate that cordwood production yields may increase by approximately 36 percent when including stems from 6.6 to 12.7 cm (2.6 to 5.0 in) dbh and branchwood material from 2.5 to 10.1 cm (1 to 4.0 in). As a result, fuelwood management plans should allow for harvesting smaller diameter branchwood in order to increase cordwood yields by one-third.

Production values for the study areas also closely parallel those given by Morrow and Gage (1977) for typical, unmanaged, Northeastern hardwood stands. Based on stem material not less than 7.6 cm in diameter, they estimated stands to contain between 49.4 and 98.8 cords

per hectare with growth occurring at an aver-
age rate of 1.2 cords per hectare.

Wiant and Castaneda (1978) investigated oak
forest biomass production in northwestern West
Virginia. They developed yield tables based
upon stand tables published by Schnur (1937)
and regression estimation equations developed
by Wiant et al. (1977). Wiant and Castaneda
indicate that their yield tables (based upon
stemwood greater than 5.1 cm dob) should prove
applicable in even-aged, Eastern oak forests.
In fact, their yield tables closely approximate
measured yields for the study areas. Estimated
yields for Great Swamp I and Great Swamp II
were within 6 and 8 percent of actual yields,
and within 1 percent of the actual yield for
the Hazard Tract.

b. Soil-Productivity Relationships

Soil properties were evaluated in an effort to
relate differences in site productivity to soil
characteristics. Soil properties for the A and
B horizons on each study site are given in
Table 11.

Although soil-related variables were not signi-
ficant in explaining differences in wood pro-

TABLE 11. Average Soil Properties for A and B Horizons on the Study Sites

Study Site	Horizon	Texture (% silt + clay)	Organic Carbon (%)	Available Water (%)	Bulk Density (g/cc)	pH 1:1 H_2O	Depth (cm)	Coarse Fragments(%)
Great Swamp I								
Plot 1	A	23.4	1.41	9.8	1.28	4.75	18	.7
	B	12.2	.20	5.5	1.51	4.81	74	.6
Plot 2	A	19.7	1.49	6.4	1.32	4.68	18	.9
	B	13.0	.27	4.7	1.49	4.75	71	.5
Great Swamp II								
Plot 1	A	51.6	4.62	13.5	1.02	4.40	15	2.3
	B	41.3	.52	9.0	1.50	4.54	56	4.7
Plot 2	A	48.5	5.16	11.2	1.09	4.35	13	3.1
	B	42.3	.55	8.6	1.44	4.58	53	7.8
Hazard Tract								
Plot 1	A	64.8	7.18	18.7	1.09	4.00	15	2.0
	B	61.0	.44	22.1	1.23	4.56	66	1.7
Plot 2	A	53.0	2.43	14.6	1.02	4.35	15	3.1
	B	61.3	.43	12.1	1.35	4.58	69	8.2

duction on a tree or unit area basis in regres-
sion analyses, other analyses indicate
correlations between tree-growth parameters
and soil characteristics. Principal component
analysis was conducted on a variable matrix
including tree, soil and stand characteristics.
This permitted an examination of linear com-
binations between all variables. Soil variables
highly correlated with tree-growth (productivity
related) parameters including dbh, height and
weight were: soil texture, organic carbon,
available water and depth of solum. Soil bulk
density, pH, depth of the A horizon and coarse
fragment content were not significantly corre-
lated with tree-growth parameters.

In addition to principal component analysis, a
canonical variate analysis was conducted to
develop a single correlation between two sets
of variables; biotic tree-growth parameters
and soil characteristics. Despite an extremely
high correlation (.97) between dbh and weight
with soil texture, organic carbon, available
water and depth of solum, sample size was
insufficient to permit the development of
meaningful equations for determining site
productivity.

An examination of soil properties and yields
for the plots sampled, reveals inconsistencies
in relationships between soils and yields. For
example, the Hazard Tract site and the Great
Swamp II site have similar soil conditions but
yields are much different. Both sites have
soil characteristics typically associated with
optimal tree growth. The Hazard Tract is the
most productive site and Great Swamp II is the
least productive. Apparently, factors other
than edaphic must be limiting tree growth on
the Great Swamp II site. The major difference
between sites is the presence of a dense
ericaceous shrub understory at Great Swamp II.
Competition for water and nutrients may account
for differences in productivity.

Inconclusive findings, as to the significance
of soil-productivity relationships, indicate
the need to sample additional areas and to
expand sampling to include all drainage classes.
Biological considerations may overshadow soil
conditions to the point where the development of
meaningful soil-site productivity relationships
may not be possible.

Interpretation tables for Rhode Island soils,
compiled by the U.S. Soil Conservation Service
(U.S.D.A., 1975b), contain average site in-
dices for hardwoods and softwoods growing on
different soil series. The site index given
for the Scio silt loam soil at the Hazard Tract
site is 62 for hardwoods: similar to the actual
value of 60. However, soils at the Great Swamp
study areas would also indicate site indices
of about 60, but actually have site indices of
only about 40. Thus, it appears that site index
varies considerably on soils of the same drain-
age class that are considered similar in terms
of their abilities to grow trees.

Although based on limited data, tree and stand
heights in this study do not appear to work
well in indexing site productivity, since height
was not significantly correlated with biomass
or site factors. Similarly, McGahan et al.
(1961) found tree height in Rhode Island mixed-
oak stands was extremely variable and not
strongly correlated with edaphic and stand
characteristics. Consequently, height as an
index of site productivity, for mixed-oak for
the Rhode Island area, appears to be of ques-
tionable value. Therefore, further study

relating soil properties and wood production
is warranted.

VI.   SUMMARY AND CONCLUSIONS

The study was conducted in three mixed-hardwood stands located in Washington County in the town of South Kingstown, Rhode Island: one on the University of Rhode Island Hazard Tract and two on the Great Swamp Wildlife Management Area. Even-aged, sprout-origin forest stands on the study sites were either mixed-oak or red maple which are two of the most common forest types in Rhode Island.

Moderately well-drained soils served as the basis for selection of study areas.   Each study area was located on a different soil type so as to relate variation in wood production to soil characteristics.   Soil types included Scio silt loam at the Hazard Tract, and Birchwood loamy sand, Woodbridge sandy loam and Sutton sandy loam at the Great Swamp study sites.

Tree characteristics including species, dbh, total tree height, height to live crown, crown class and age were recorded for each stem greater than 4.1 cm dbh.   To ensure representative and reliable estimates of above-ground biomass, stratified random sampling of trees by diameter class was used to select sample trees.   A total of 93 stems representing seven hardwood species was destructively sampled on the study sites.

Sample trees were felled, sectioned and separated into two components: stemwood and branchwood.   Total green weight by component was recorded for each tree in the field.   Com-

ponents were subsampled to permit oven-dry weight and specific gravity determinations. Following determination of green disk volume by water displacement, samples were placed in drying ovens to determine moisture content. Specific gravity was determined for each sample based upon green volume and oven-dry weight. Values based upon sub-samples were used to project fuelwood production per unit area on a weight and volume basis for each study area.

Mean radial growth and growth rate curves for co-dominant and dominant trees on each study area were deter-mined from sample sections taken at stump height.

Several physical and chemical soil properties were evaluated on the study sites. Properties measured were; bulk density, particle size, organic carbon, percent mois-ture at field capacity, percent moisture at wilting point, pH, cation exchange capacity, exchangeable acidity and per-cent base saturation. Also, nutrient concentrations were determined using a spectrophotometer.

Regression analyses were employed to develop equa-tions to estimate fuelwood biomass. Principal component and canonical correlation analyses were used to evaluate relationships between tree-growth parameters and soil characteristics. Analyses were performed on the University of Rhode Island I.B.M. System 370 computer.

Results may be concluded as follows:

1. Average specific gravity for black oak (.63) was found
   to be significantly higher than averages for white oak
   (.61) and red maple (.55) at the .05 and .01 levels,
   respectively. Also, white oak was found to differ
   significantly from red maple at the .05 level. An
   examination of specific gravities for ring-porous and
   diffuse-porous hardwoods showed no relationship with
   growth rate.

2. Mean radial increment for the study areas based upon
   dominant and codominant trees was markedly different
   between study areas. Radial increment was greatest on
   the Hazard Tract (3.48 mm per year) in contrast to the
   Great Swamp sites where mean radial increment was 2.63
   on one site and 2.15 on the other. Radial growth rate
   curves for the Great Swamp study sites began to level
   off as average stand age approached 50 years. There
   was no indication of radial growth leveling off in the
   35-year-old Hazard Tract stand.

3. Data from the three study areas were pooled to obtain
   an estimate of fuelwood production for moderately well-
   drained sites. Pooled data indicated a total yield of
   73 cords per hectare (30 cords per acre) at age 45, and
   a mean annual increment of 1.6 cords per hectare (.65
   cords per acre). Cordwood yields were based upon
   including branchwood material down to 2.5 cm in diameter.

4. Recorded data from sample trees indicated that an average of 11.5 percent of tree biomass was accounted for by material from 2.5 cm to 5.1 cm in diameter. Thus, it was estimated that about 34.5 percent of total tree weight would be included in the diameter range from 2.5 to 10.1 cm. By including stems from 6.6 to 12.7 cm (2.6 to 5.0 in) dbh and branchwood from 2.5 to 10.1 cm (1 to 4.0 in) dob, cordwood yields from the study sites increased by approximately 36 percent.

5. Regression analyses indicated that dbh accounted for most of the variation in whole-tree weight. Allometric regression equations, combining data from all study areas, were developed in order to estimate green (GWT) and oven-dry weight (ODWT) of individual trees and stand biomass.

   a. Data were pooled to develop regression equations to estimate whole-tree weight as a function of (DBH); and as a function of the combined variable (BH) where (B) is tree basal area and (H) is tree height. Equations are as follows:

   $$Ln(ODWT) = -.39986 + 2.65919Ln(DBH) \quad R^2 = .95$$
   $$Ln\ (GWT) = .11714 + 2.66262Ln(DBH) \quad R^2 = .94$$

   $$Ln(ODWT) = 2.35524 + .99342Ln(BH) \quad R^2 = .97$$
   $$Ln\ (GWT) = 2.87187 + .99550Ln(BH) \quad R^2 = .97$$

b. Equations were also developed to predict cordwood
    biomass on a unit area basis. In the following
    equations, stand basal area (B) and (BH), where (B)
    is total stand basal area and (H) is the average
    weighted height of all trees in the stand (each
    tree weighted by its squared diameter), were found
    to effectively predict stand biomass.

$$Ln(ODWT) = -1.73061 + 1.22733Ln(BH) \quad R^2 = .91$$
$$Ln(ODWT) = 1.14376 + 1.61363Ln(B) \quad R^2 = .88$$

6. Cordwood production values for the study areas closely
    paralleled those given by Schnur (1937), Morrow and
    Gage (1977) and Wiant and Castaneda (1978) for fully-
    stocked, even-aged, second-growth, Appalachian hard-
    wood stands.

7. Soil properties were evaluated in an effort to relate
    differences in site productivity to soil characteristics.
    Soil variables highly correlated with tree-growth para-
    meters including dbh, height and weight were: soil
    texture, organic carbon, available water and depth of
    solum. However, sample size was insufficient to permit
    the development of meaningful equations for determining
    site productivity.

    Inconclusive findings as to the significance of soil-
    productivity relationships indicate the need to sample
    additional areas and to expand sampling to include all

drainage classes. However, as indicated in this study,
biological considerations may overshadow soil conditions
to the point where the development of meaningful soil-
site productivity relationships may not be possible.

8. Although based on limited data, tree and stand heights
in this study did not appear to work well in indexing
site productivity. Site index was found to vary con-
siderably on soils of the same drainage class that are
considered similar in terms of their abilities to grow
trees. As a result, height as an index of site pro-
ductivity for mixed-oak stands in the Rhode Island
area appears to be of questionable value.

REFERENCES CITED

Art, T. R. and P. L. Marks. 1971. A summary table of
  biomass and net annual primary production in forest
  ecosystems of the world. p. 3-32. In Forest biomass
  studies. Univ. Me. Life Sci. and Agri. Expt. Sta.
  Misc. Publ. 132. Orono, Me. 240 p.

Baskerville, G. L. 1965. Estimation of dry weight of tree
  components and total standing crop in conifer stands.
  Ecol. 46:867-869.

Black, C. A., ed. 1965. Methods of Soil Analysis. Amer.
  Soc. Agron. Inc. Madison, Wisc. 1572 p.

Brown, J. H., Jr. 1960. The role of fire in altering
  species composition of forests in Rhode Island.
  Ecol. 41(2):310-316.

Clark, A. III and M. A. Taras. 1976. Comparison of above-
  ground biomasses of the four major southern pines.
  For. Prod. J. 26(10):25-29.

Cox, D. R. 1961. Tests of separate families of hypotheses.
  4th Berkeley Symp. Proc. 1:101-123.

Crow, T. R. 1971. Estimination of biomass in an even-aged
  stand -- regression and "mean tree" techniques. Sci.
  J. Serv. Pap. No. 7487. Univ. Minn. Agri. Expt.
  Sta., St. Paul, Minn. 13 p.

Dalton, M. M., J. H. Herrington, O. B. Durgin and R. A.
  Andrews. 1977. Household fuelwood use and procure-
  ment in New Hampshire. Univ. N. H. Agri. Expt. Sta.

Rpt. No. 59. Durham, N. H. 24 p.

Fernald, L. M. 1950. Gray's Manual of Botany. Amer.
Book Co. N. Y. 1632 p.

Forbes, R. D. 1955. Forestry Handbook. Ronald Press Co.
N. Y. 1137 p.

Freese, F. 1967. Elementary statistical methods for
foresters. U.S.D.A. For. Serv. Agri. Handb. 317.
U.S. Govt. Printing Office. Washington, D.C. 87 p.

Furnival, G. M. 1961. An index for comparing equations
used in constructing volume tables. For. Sci.
7:337-341.

Green, D. C. and D. F. Grigal. 1978. Generalized biomass
estimation equations for jack pine (Pinus banksiana
Lamb.). Sci. J. Serv. Pap. No. 1698. Univ. Minn.
Agri. Expt. Sta., St. Paul, Minn. 4 p.

Harris, B. K. and T. E. Odland. 1948. Rhode Island
weather. Univ. R. I. Agri. Expt. Sta. Bull. No. 299.
Kingston, R. I. 32 p.

Haush, B., C. I. Miller and T. W. Beers. 1972. Forest
Mensuration. Second edition. Ronald Press Co.
N. Y. 410 p.

Johnston, R.S. and D. L. Bartos. 1977. Summary of nutrient
and biomass data from two aspen sites in western
United States. U.S.D.A. For. Serv. Res. Pap. INT-227.
Interm. For. and Range Expt. Sta., Ogden, Utah. 15 p.

Johnstone, W. D. 1971. Total standing crop and tree component distributions in three stands of 100-year-old lodge pole pine. p. 81-89. In Forest biomass studies. Univ. Me. Life Sci. and Agri. Expt. Sta. Misc. Publ. 132. Orono, Me. 240 p.

Keays, J. L. 1971. Complete-tree utilization: an analysis of the literature. Can. For. Serv. For. Prod. Lab. Info. Rpt. VP-X-71. Vancouver, B.C. 67 p.

Keen, R. E. 1963. Weights and centres of gravity involved in handling pulpwood trees. Pulp Pap. Res. Inst. Can., Woodlands Res. Index No. 147. 93 p.

Madgwick, H. A. I. 1971. The accuracy and precision of estimates of the dry matter in stems, branches, and foliage in an old-field Pinus virginiana stand. p. 105-109. In Forest biomass studies. Univ. Me. Life Sci. and Agri. Expt. Sta. Misc. Publ. 132. Orono, Me. 240 p.

McGahan, M. W., J. H. Brown, Jr., W. P. Gould, H. C. Lampe and A. E. Shearin. 1961. Site conditions and tree growth analyses in Rhode Island forests. Univ. R. I. Agri. Expt. Sta. Bull. 357. Kingston, R. I. 32 p.

Morrow, R. R. and T. E. Gage. 1977. The use of wood for fuel. Cornell Univ. Cons. Circ. 15(1):1-11.

NOAA. 1974. Annual summary of climatological data. U.S. Dept. Comm. Nat. Climatic Cent. Asheville, N.C.

Ovington, J. D. 1962. Quantitative ecology and the woodland concept. Adv. Ecol. Res. 1:103-192.

69

Ovington, J. D., W. G. Forrest and J. E. Armstrong. 1967. Tree biomass estimation. p. 4-31. In Primary productivity and mineral cycling in natural ecosystems. Ecol. Soc. Amer. and AASS. Univ. Me. Press. Orono, Me.

Panshin, A. J. and C. DeZeeuw. 1970. Textbook of Wood Technology. Volume 1. Third edition. McGraw-Hill Book Co. N. Y. 705 p.

Paul, B. H. 1930. The application of silviculture in controlling specific gravity. U.S.D.A. Tech. Bull. No. 168. U. S. Govt. Printing Office. Washington, D.C.

Pulp and Paper Association of Canada. 1928. Report of the wood measurement committee. Pulp Pap. Mag. Can., Int. No. 139-149.

Roth, E. R. and G. H. Hepting. 1943. Origin and development of oak stump sprouts as affecting their likelihood to decay. J. For. 41:27-36.

Schlaegel, B. E. 1975. Estimating aspen volume and weight for individaul trees, diameter classes, or entire stands. U.S.D.A. For. Serv. Gen. Tech. Rpt. NC-20, North Cent. For. Expt. Sta., St. Paul, Minn. 16 p.

Schnur, G. L. 1937. Yield, stand and volume tables for even-aged upland oak forests. U.S.D.A. Tech. Bull. No. 560. U.S. Govt. Printing Office. Washington, D. C. 87 p.

Schreuder, H. T. and W. T. Swank. 1971. A comparison of several statistical models in forest biomass and surface area estimation. p. 125-136. In Forest biomass studies. Univ. Me. Life Sci. and Agri. Expt. Sta. Misc. Publ. 132. Orono, Me. 240 p.

Skeen, J. N. 1973. Biomass and productivity estimates for a temperate mesic slope forest. J. Tenn. Acad. Sci. 48(3):103-106.

Smith, D. M. 1962. The Practice of Silviculture. Seventh edition. John Wiley & Sons, Inc. N.Y. 578 p.

Smith, J. H. G. 1967. A procedure for simple definition of land capability for wood growth and for estimation of yield. Dept. For. and Rural Dev., Nat. Comm. For. Land Proc. 126-42.

Smith, J. H. G. 1971. Bases for sampling and simulation in studies of tree and stand weights. p. 139-149. In Forest biomass studies. Univ. Me. Life Sci. and Agri. Expt. Sta. Misc. Publ. 132. Orono, Me. 240 p.

Smith, J. H. G., J. W. Kerr and J. Csizmazia. 1961. Economics of reforestation in the Vancouver forest district. Univ. B. C. Fac. For. Bull. No. 3. Vancouver, B.C. 144 p.

Stoddard, W. R. 1979. Estimation of a demand function for household firewood usage in Rhode Island. Unpublished master's thesis. Univ. R. I., Kingston, R. I. 73 p.

Toumey, J. W. and C. F. Korstian. 1947. Foundation of
     Silviculture Upon an Ecological Basis. John Wiley and
     Sons, Inc. N. Y. 468 p.

U.S. Dept. Agri. 1975a. Soil Taxonomy. Soil Cons. Serv.
     U. S. Govt. Printing Office. Washington, D.C.

U.S. Dept. Agri. 1975b. Rhode Island Interpretation Tables
     Soil Cons. Serv. U.S. Govt. Printing Office.
     Washington, D.C.

Wartluft, J. L. 1977. Weights of small Appalachian hard-
     wood trees and components. U.S.D.A. For. Serv. Res.
     Pap. NE-366. NE For. Expt. Sta., Upper Darby, Pa. 4 p.

Weetman, G. F. and R. Harland. 1964. Foliage and wood
     production in unthinned black spruce in northern
     Quebec. For. Sci. 10(1):80-88.

Wells, C. G., J. R. Jorgensen and C. E. Burnette. 1975.
     Biomass and mineral elements in a thinned loblolly
     pine plantation at age 16. U.S.D.A. For. Serv. Res.
     Pap. SE-126. SE For. Expt. Sta., Asheville, N.C. 10 p.

Wendel, G. W. 1975. Stump sprout growth and quality of
     several Appalachian hardwood species after clear-
     cutting. U.S.D.A. For. Serv. Res. Pap. NE-329. NE
     For. Expt. Sta., Upper Darby, Pa. 9 p.

Whittaker, R. H. and G. M. Woodwell. 1969. Measurement of
     net primary production of forests. In Conference of
     forest productivity of the world. Inter. Bio. Prog.
     Bruxelles, Belgium. 43 p.

Wiant, H. V., Jr. and F. Castaneda. 1978. Preliminary
    weight yield tables for even-aged upland oak forests.
    W. Va. Univ. Agri. and Expt. Sta. Bull. 664T.
    Morgantown, W. Va. 20 p.

Wiant, H. V., Jr. and P. M. Charleton. 1978. Rapid weight
    estimations for upland oak stands. W. Va. Univ. Agri.
    and For. Expt. Sta. 7(3):12. Morgantown, W. Va. 18 p.

Wiant, H. V., Jr., C. E. Sheetz, A. Colaninno, J. C. DeMoss
    and F. Castaneda. 1977. Tables and procedures for
    estimating weights of some Appalachian hardwoods.
    W. Va. Univ. Agri. and For. Expt. Sta. Bull. 659T.
    Morgantown, W. Va. 36 p.

Young, H. E. 1964. The complete tree concept - a challenge
    and an opportunity. Proc. 1964 annual meeting of the
    Soc. Amer. Foresters.

Young, H. E. 1973. Growth, yield and inventory in terms
    of biomass. p. 1-10. In IUFRO biomass studies,
    Univ. Me. Life Sci. and Agri. Expt. Sta., Orono, Me.
    531 p.

Young, H. E., L. Strand and R. Altenberger. 1964. Pre-
    liminary fresh and dry weight tables for seven tree
    species in Maine. Univ. Me. Agri. Expt. Sta. Bull.
    No. 12. Orono, Me. 76 p.

APPENDICES

APPENDIX A

Profile Description

of a

Birchwood Sandy Loam

(Typic Fragiochrept/Sandy, mixed mesic)

Typifying Pedon: Birchwood sandy loam - forested

Horizon	Depth(cm)	Description
02	3-0	Organic layer of decomposed forest litter.
Ap	0-18	Dark brown (10YR 3/3, moist) fine sandy loam; weak medium subangular structure breaking to moderate fine granular structure; friable; many medium woody and fibrous roots; strongly acid; abrupt smooth boundary.
B21	18-35	Yellow-brown (10YR 5/6, moist) fine sandy loam; weak medium subangular blocky structure; friable; many medium woody roots; strongly acid; gradual wavy boundary.
B22	35-53	Light olive-brown (2.5Y 5/6, moist) sandy loam; weak medium subangular blocky structure breaking to moderate fine granular structure; very friable; common fine woody roots; strongly acid; clear wavy boundary.
B3g	53-90	Light olive-gray (5Y 6/2, moist) loamy sand; weak medium subangular blocky structure breaking to moderate fine granular structure; very friable; few fine woody roots; many medium prominent reddish-yellow (7.5YR 6/8, moist) mottles; strongly acid; abrupt smooth boundary.
Cx	90-110	Light yellowish-brown (2.5Y 6/4, moist) gravelly sand; structureless massive; firm; many coarse fragments; strongly acid.

Site Characteristics

Location: South Kingstown, Rhode Island; Great Swamp I
            Area, plot 1

Parent Material: Glacial till

Topography: Gently sloping

Slope and Aspect: 2 percent; east

Elevation: 36 meters

Drainage and Permeability: Moderately well-drained; rapid

Available water holding capacity: Low

Ground Water: Deep; not observed during description

Vegetation: Mixed-oak forest/sparse shrub layer

Root Distribution: Many roots to B3g horizon

Erosion: Slight

Stoniness: Stony

Date: September 19, 1978

Described by: Jeffrey A. Bridge

Profile Description

of a

Birchwood Sandy Loam

(Typic Fragiochrept/Sandy, mixed mesic)

Typifying Pedon: Birchwood very stony sandy loam - forested

Horizon	Depth(cm)	Description
02	3-0	Organic layer of decomposed forest litter.
Ap	0-18	Dark brown (10YR 3/3, moist) fine sandy loam; weak medium subangular blocky structure breaking to moderate fine granular structure; very friable; many medium woody and fibrous roots; strongly acid; abrupt smooth boundary.
B21	18-48	Yellowish-brown (10YR 5/8, moist) sandy loam; weak medium subangular blocky structure; very friable; many medium woody roots; strongly acid; clear wavy boundary.
B22	48-73	Yellowish-brown (10YR 5/6, moist) sandy loam; weak medium subangular blocky structure breaking to moderate fine granular structure; very friable; common fine woody roots; layer of many large coarse fragments strongly acid; clear wavy boundary.
B3	73-88	Olive-yellow (2.5Y 6/6, moist) loamy sand; structureless, single grain; loose; few medium faint yellowish-brown (10YR 5/8, moist) mottles; strongly acid; abrupt smooth boundary.
Cx	88-105	Light brownish-gray (10YR 6/1, moist) gravelly sand; structureless, massive, firm; many coarse fragments; strongly acid.

Site Characteristics

Location: South Kingstown, Rhode Island; Great Swamp I
            Area, plot 2

Parent Material: Glacial till

Topography: Gently sloping

Slope and Aspect: 8 percent; east

Elevation: 36 meters

Drainage and Permeability: Moderately well-drained; rapid

Available Water Holding Capacity: Low

Ground Water: Deep; not observed during description

Vegetation: Mixed-oak forest/sparse shrub layer

Root Distribution: Many roots to B3 horizon

Erosion: Slight

Stoniness: Very stony

Date: September 19, 1978

Described by: Jeffrey A. Bridge

Profile Description

of a

Woodbridge Fine Sandy Loam

(Typic Fragiochrept/Coarse-loamy, mixed mesic)

<u>Typifying Pedon:</u> Woodbridge fine sandy loam - forested

Horizon	Depth(cm)	Description
02	5-0	Organic layer of decomposed forest litter.
Ap	0-15	Very dark grayish-brown (10YR 3/2, moist) silt loam; weak medium sub-angular blocky structure breaking to moderate fine granular structure; friable; many large woody roots; many coarse fragments; strongly acid; abrupt smooth boundary.
B21	15-38	Yellowish-brown (10YR 5/6, moist) loam; weak medium subangular blocky structure; friable; many large woody roots; many coarse fragments; strongly acid; gradual wavy bound-ary.
B22	38-50	Light yellowish-brown (2.5Y 6/4, moist) fine sandy loam; weak medium subangular blocky structure; friable; common medium woody roots; many coarse fragments; strongly acid; clear wavy boundary.
B3g	50-70	Pale brown (10YR 6/3, moist) fine sandy loam; weak medium subangular blocky structure; very friable; few fine woody roots; many large pro-minent strong brown (7.5YR 5/8, moist) mottles; many coarse frag-ments; strongly acid; clear wavy boundary.

Horizon	Depth(cm)	Description
C1g	70-90	Light brownish-gray (2.5Y 6/2, moist) silt loam; weak medium sub-angular blocky structure; friable; many large prominent strong brown (7.5YR 5/8, moist) mottles; strongly acid; abrupt smooth boundary.
IICx	90-109	Light brownish-gray (10YR 6/2, moist) sand; structureless, massive; firm; many coarse fragments; strongly acid.

Site Characteristics

Location: South Kingstown, Rhode Island; Great Swamp II
            Area, plot 1

Parent Material: Glacial till

Topography: Gently sloping

Slope and Aspect: 2 percent; southeast

Elevation: 30 meters

Drainage and Permeability: Moderately well-drained;
                            moderate

Available Water Holding Capacity: High

Ground Water: Deep; not observed during description

Vegetation: Red maple forest/dense ericaceous shrub layer

Root Distribution: Many dense roots to B3g horizon

Erosion: Slight

Stoniness: Stony

Date: September 25, 1978

Described by: Jeffrey A. Bridge

Profile Description

of a

Sutton Fine Sandy Loam

(Umbric Dystrochrept/Coarse-loamy, mixed mesic)

<u>Typifying</u> <u>Pedon</u>:   Sutton very stony fine sandy loam -
                forested

Horizon	Depth(cm)	Description
02	5-0	Organic layer of decomposed forest litter.
Ap	0-13	Very dark grayish-brown (10YR 3/2, moist) silt loam; weak medium sub-angular blocky structure breaking to moderate fine granular structure; friable; many large woody roots; many coarse fragments; strongly acid; abrupt smooth boundary.
B21	13-35	Yellowish-brown (10YR 5/6, moist) silt loam; weak medium subangular blocky structure; friable; many medium woody roots; many coarse fragments; strongly acid; gradual wavy boundary.
B22	35-53	Light yellowish-brown (2.5Y 6/4, moist) fine sandy loam; weak medium subangular blocky structure; fri-able; many medium woody roots; common organic stains (2-20%); many coarse fragments; strongly acid; clear wavy boundary.
B3	53-65	Light yellowish-brown (2.5Y 6/4, moist) fine sandy loam; weak medium subangular blocky structure; fri-able; few fine woody roots; many medium distinct strong brown (7.5YR 5/8, moist) mottles; strongly acid; clear wavy boundary.

Horizon	Depth(cm)	Description
C1g	65-123	Light brownish-gray (2.5Y 6/2, moist) silt loam; structureless, massive; friable; many large prominent strong brown (7.5YR 5/8, moist) mottles; strongly acid; clear wavy boundary.
IICx	123-138	Light brownish-gray (2.5Y 6/2, moist) gravelly sand; structureless, massive; firm; many coarse fragments; strongly acid.

84

Site Characteristics

Location: South Kingstown, Rhode Island; Great Swamp II
            Area, plot 2

Parent Material: Glacial till

Topography: Gently sloping

Slope and Aspect: 2 percent; southeast

Elevation: 30 meters

Drainage and Permeability: Moderately well-drained;
                            moderate

Available Water Holding Capacity: High

Ground Water: Deep; not observed during description

Vegetation: Red maple forest/dense ericaceous shrub layer

Root Distribution: Many dense roots to B3 horizon

Erosion: Slight

Stoniness: Very stony

Date: September 25, 1978

Described by: Jeffrey A. Bridge

Profile Description

of a

Scio Silt Loam

(Umbric Dystrochrept/Coarse-silty, mixed mesic)

<u>Typifying Pedon</u>: Scio very stony silt loam - forested

Horizon	Depth(cm)	Description
O2	3-0	Organic layer of decomposed forest litter.
Ap	0-15	Black (10YR 2/1, moist) silt loam; weak medium subangular blocky structure breaking to moderate fine granular structure; friable; many medium woody and fibrous roots; many large coarse fragments; strongly acid; abrupt smooth boundary.
B21	15-28	Dark brown (10YR 3/3, moist) silt loam; weak medium subangular blocky structure; friable; common medium woody roots; many large coarse fragments; strongly acid; clear wavy boundary.
B22	28-43	Olive brown (2.5Y 4/4, moist) silt loam; weak medium subangular blocky structure; friable; common fine woody roots; strongly acid; clear wavy boundary.
B23	43-63	Olive (5Y 5/3, moist) silt loam; weak medium subangular blocky structure; friable; few fine woody roots; many coarse fragments; common organic stains (2-20%); strongly acid; gradual wavy boundary.
B3g	63-81	Gray (5Y 6/1, moist) silt loam; weak coarse subangular blocky structure; friable; few fine woody roots; many coarse fragments; many medium distinct yellow (2.5Y 7/6, moist) mottles; strongly acid; clear wavy boundary.

Horizon	Depth(cm)	Description
C1g	81-109	Gray (5Y 6/1, moist) silt loam; structureless; massive; friable; many medium prominent reddish-yellow (7.5YR 6/8, moist) mottles; strongly acid; abrupt smooth boundary.
IIC2	109-137	Strong brown (7.5YR 5/8, moist) fine sand; structureless; single grain; loose; many coarse fragments; strongly acid.

Site Characteristics

Location: South Kingstown, Rhode Island; Hazard Tract, plot 1

Parent Material: Glacial outwash

Topography: Gently sloping

Slope and Aspect: 2 percent; northwest

Elevation: 12 meters

Drainage and Permeability: Moderately well-drained; moderate

Available Water Holding Capacity: High

Ground Water: 96 cm when described

Vegetation: Mixed-oak and maple forest/medium shrub layer

Root Distribution: Many roots to C horizon

Erosion: Slight

Stoniness: Very stony

Date: May 3, 1978

Described by: Jeffrey A. Bridge and William R. Wright

Profile Description

of a

Scio Silt Loam

(Umbric Dystrochrept/Coarse-loamy, mixed mesic)

<u>Typifying</u> <u>Pedon</u>:   Scio very stony silt loam - forested

Horizon	Depth(cm)	Description
02	3-0	Organic layer of decomposed forest litter.
Ap	0-15	Very dark brown (10YR 2/2, moist) silt loam; medium subangular blocky structure breaking to moderate fine granular structure; friable; many medium woody and fibrous roots; many coarse fragments; strongly acid; abrupt smooth boundary.
B21	15-45	Dark brown (7.5YR 4/4, moist) very fine sandy loam; weak medium sub-angular blocky structure; friable; common medium woody roots; many coarse fragments; strongly acid; clear wavy boundary.
B22	45-65	Light olive brown (2.5Y 5/6, moist) silt loam; weak medium subangular structure; friable; few woody roots; many coarse fragments; strongly acid; clear wavy boundary.
B3g	65-84	Olive (5Y 5/3, moist) silt loam; weak medium subangular blocky struc-ture; friable; few medium distinct olive-yellow (2.5Y 6/8, moist) mottles; few woody roots; strongly acid; clear wavy boundary.
Clg	84-128	Gray (5Y 6/1, moist) silt loam; structureless, massive; friable; many medium prominent reddish-yellow (7.5YR 6/8, moist) mottles; strongly acid; gradual wavy boundary.
C2	128-148	Brown (10YR 5/3, moist) sand; struc-tureless, single grain; loose; many coarse fragments; strongly acid.

Site Characteristics

Location: South Kingstown, Rhode Island; Hazard Tract,
           plot 2

Parent Material: Glacial outwash

Topography: Gently sloping

Slope and Aspect: 2 percent; east

Elevation: 12 meters

Drainage and Permeability: Moderately well-drained; moderate

Available Water Holding Capacity: High

Ground Water: Deep; not observed during description

Vegetation: Mixed-oak and maple forest/medium shrub layer

Root Distribution: Many roots to C horizon

Erosion: Slight

Stoniness: Very stony

Date: September 19, 1978

Described by: Jeffrey A. Bridge

APPENDIX B

LABORATORY ANALYSIS FOR SOILS OF GREAT SWAMP I

Plot 1	Horizon	Sand	Silt	Clay	Coarse Frag.	Textural Class(lab)[1]	1/3 ATM.	15 ATM	Organic Carbon (percent)	pH 1:1 H_2O	Bulk Density (g/cc)
Birchwood loamy sand	Ap	76.6	18.6	4.6	.7	ls	13.8	4.0	1.41	4.75	1.28
	B21	78.4	19.6	2.0	.9	ls	12.2	3.5	.33	4.80	1.39
	B22	87.9	11.3	.8	.4	s	7.6	1.7	.24	4.80	1.45
	B3g	92.2	7.4	.4	.6	s	5.2	1.3	.11	4.83	1.60
	Cx	92.8	7.1	.1	23.5	gs	4.3	1.0	-	4.85	1.82
Plot 2											
Birchwood loamy sand	Ap	80.3	16.2	3.5	.9	ls	10.5	4.1	1.49	4.68	1.32
	B21	83.6	15.4	1.0	.2	ls	8.5	2.5	.33	4.71	1.42
	B22	91.2	8.4	.4	.6	s	5.7	2.0	.29	4.78	1.50
	B3	86.7	13.0	.3	.8	s	5.9	1.9	.13	4.80	1.62
	Cx	82.7	17.0	.3	20.4	ls	4.6	1.1	-	4.95	1.85

Soil Separates in percent — Sand, Silt, Clay, Coarse Frag.
Moisture Retention (in percent) — 1/3 ATM., 15 ATM

[1] ls-loamy sand; s-sand; gs-gravelly sand.

| Plot 1 | Horizon | Soil Separates in percent | | | | Textural Class(lab)[1] | Moisture Retention (in percent) | | Organic Carbon (percent) | pH 1:1 H_2O | Bulk Density (g/cc) |
		Sand	Silt	Clay	Coarse Frag.		1/3 ATM.	15 ATM			
Woodbridge sandy loam	Ap	48.6	43.6	7.8	2.3	l	28.4	14.9	4.62	4.40	1.02
	B21	33.5	44.1	2.4	6.3	sl	19.5	9.2	.80	4.51	1.41
	B22	61.1	37.6	1.3	3.5	sl	13.8	4.7	.37	4.54	1.54
	B3g	63.1	35.7	1.2	3.8	sl	11.7	4.2	.31	4.58	1.57
	Clg	29.4	69.5	1.1	1.1	sil	16.6	4.8	.13	4.71	1.64
	IICx	73.5	25.3	1.2	15.0	ls	8.5	2.1	-	4.76	1.85
Plot 2											
Sutton sandy loam	Ap	51.5	38.7	9.8	3.1	l	32.5	21.3	5.16	4.35	1.09
	B21	56.1	41.8	2.1	9.4	sl	21.7	12.6	.90	4.55	1.42
	B22	58.2	40.9	.9	7.1	sl	13.7	5.7	.29	4.58	1.44
	B3	60.0	34.8	5.2	6.1	sl	13.1	4.5	.27	4.65	1.48
	Clg	25.1	73.0	1.9	.8	sil	19.6	5.4	.13	4.71	1.50
	IICx	77.7	20.6	1.7	21.8	ls	7.4	1.9	-	4.93	1.78

[1] l-loam; sl-sandy loam; sil-silt loam; ls-loamy sand.

LABORATORY ANALYSIS FOR SOILS OF HAZARD TRACT

| Plot 1 | Horizon | Soil Separates in percent | | | | Textural Class(lab)[1] | Moisture Retention (in percent) | | Organic Carbon (percent) | pH 1:1 H_2O | Bulk Density (g/cc) |
		Sand	Silt	Clay	Coarse Frag.		1/3 ATM.	15 ATM.			
Scio silt loam	Ap	35.2	52.2	12.6	2.0	sil	43.5	24.8	7.18	4.00	1.09
	B21	53.8	42.7	3.5	1.4	fsl	38.6	16.9	1.68	4.65	1.15
	B22	44.6	51.5	3.9	.5	sil	32.4	9.7	.64	4.65	1.21
	B23	33.8	62.1	4.1	1.9	sil	30.7	6.8	.38	4.45	1.26
	B3g	29.4	66.7	3.9	2.6	sil	24.7	4.9	.20	4.55	1.29
	C1g	27.5	69.4	3.1	.3	sil	26.7	3.9	.04	4.55	1.26
	IIC2	90.0	6.9	3.1	1.9	s	8.1	2.7	—	4.55	1.38
Plot 2											
Scio silt loam	Ap	47.0	42.4	10.6	3.1	l	27.7	13.1	2.43	4.35	1.02
	B21	47.6	46.6	5.8	15.7	fsl	19.9	9.6	.58	4.58	1.38
	B22	33.7	60.6	5.7	3.6	sil	20.6	8.3	.37	4.58	1.33
	B3g	29.1	68.6	2.3	.8	sil	21.4	6.5	.24	4.59	1.34
	C1g	23.6	74.3	2.1	.6	sil	22.3	6.2	.11	4.66	1.41
	C2	43.0	52.7	4.3	18.9	sil	20.3	6.5	—	4.62	1.36

[1] sil-silt loam; fsl-fine sandy loam; s-sand; l-loam.

APPENDIX C

NUTRIENT ANALYSIS FOR SCIO SILT LOAM[1]

Horizon	Extractable Cations Ca Mg K Na (meq/100g)				Exchangeable Acidity (meq/100g)	Total Cation Exchange Capacity (meq/100g)	Base Saturation (percent)	Free Iron (percent)
Ap	.1	.4	.3	.1	36.83	37.73	2.4	.75
B21	T[2]	.1	.1	.1	22.37	22.72	1.5	.64
B22	T	T	.1	.1	13.46	13.76	2.2	.46
B23	T	T	.1	.1	10.30	10.60	2.8	.27
B3g	T	T	.1	.1	7.72	8.02	3.7	.25
Clg	T	T	.1	.1	6.14	6.44	4.7	.10
IIC2	T	T	.1	.1	3.96	4.26	7.0	.15

[1] Hazard Tract Study Area, Plot 1

[2] Trace

APPENDIX D

SAMPLE TREE DATA FOR GREAT SWAMP I, PLOT 1

Sample Tree	Species	D.B.H. (cm)	Height (m)	Age (yrs)	Crown Class	Fresh Weight(kg)	Oven-dry Weight(kg)	Moisture Content(%)[1]	Specific Gravity(g/cc)
1	WO	8.64	7.62	41	OT	23.6	14.0	67	--
2	WO	8.64	5.79	25	OT	14.5	8.9	62	--
3	WO	9.14	9.14	38	OT	34.0	20.9	62	--
4	WO	10.67	12.80	40	OT	52.6	31.9	65	.56
5	WO	12.70	10.36	45	OT	66.2	40.4	64	--
6	WO	13.21	12.50	47	INT	85.8	52.7	62	.61
7	BO	15.75	14.93	49	CD	150.4	89.5	69	--
8	WO	16.26	13.41	50	CD	165.4	100.7	63	--
9	WO	18.54	14.93	58	CD	255.2	156.5	62	.58
10	BO	19.05	14.63	55	CD	251.7	146.4	74	--
11	BO	19.81	16.15	57	D	298.1	175.3	72	--
12	BO	21.34	15.24	50	CD	380.7	221.2	75	.63
13	BO	22.35	15.24	55	CD	399.2	231.9	74	--
14	BO	24.13	16.46	53	D	442.8	255.4	76	.62
15	BO	24.89	15.85	57	D	553.0	320.9	77	--
16	BO	25.40	16.76	57	D	596.3	359.2	68	.65

[1] Weighted average for entire tree on dry weight basis.

97

SAMPLE TREE DATA FOR GREAT SWAMP I, PLOT 2

Sample Tree	Species	D.B.H. (cm)	Height (m)	Age (yrs)	Crown Class	Fresh Weight(kg)	Oven-dry Weight(kg)	Moisture Content(%)[1]	Specific Gravity(g/cc)
1	RO	7.62	7.62	48	OT	19.9	11.9	68	--
2	T	8.13	7.01	28	OT	18.9	9.9	84	.50
3	RO	10.16	3.66	53	OT	21.0	11.8	79	.61
4	WO	11.94	4.57	47	OT	26.5	16.2	63	.62
5	RO	12.19	9.14	51	OT	79.4	43.2	87	--
6	BO	14.73	10.97	53	INT	139.3	83.0	70	.65
7	BO	16.51	12.80	54	CD	171.0	100.2	75	--
8	BO	18.03	14.02	54	CD	234.5	134.1	77	--
9	BO	19.05	15.24	54	CD	264.7	159.7	69	--
10	BO	20.32	14.02	52	D	298.4	176.3	70	--
11	BO	21.34	11.28	52	CD	262.3	154.7	70	--
12	BO	22.61	16.15	58	CD	324.8	192.0	70	--
13	BO	22.86	15.24	56	CD	432.1	252.0	73	--
14	WO	24.89	11.89	52	D	490.9	281.7	75	.61
15	BO	26.67	16.46	54	D	556.2	331.7	69	--

[1] Weighted average for entire tree on dry weight basis.

SAMPLE TREE DATA FOR GREAT SWAMP II, PLOT 1

Sample Tree	Species	D.B.H. (cm)	Height (m)	Age (yrs)	Crown Class	Fresh Weight(kg)	Oven-dry Weight(kg)	Moisture Content(%)[1]	Specific Gravity(g/cc)
1	BO	7.37	7.01	23	OT	21.2	11.8	76	.68
2	BO	8.38	8.23	23	OT	31.6	19.1	65	.64
3	RM	10.67	9.14	31	INT	55.9	33.7	65	--
4	RM	11.18	10.36	37	INT	48.9	31.0	55	--
5	BO	13.46	9.45	53	INT	101.3	55.8	84	.61
6	RM	13.97	10.97	56	OT	67.3	41.3	63	--
7	BO	15.24	10.06	52	INT	110.2	64.1	74	.67
8	RM	15.24	10.97	63	INT	116.5	71.0	63	--
9	RM	15.49	10.36	59	CD	97.4	61.8	57	--
10	RM	16.76	11.74	63	CD	140.8	87.2	61	--
11	WO	19.05	11.58	62	CD	206.4	124.3	68	--
12	WO	20.32	12.50	61	D	300.4	181.2	65	.66
13	WO	20.57	13.41	57	D	313.3	188.2	67	.61
14	RM	22.86	15.24	70	D	315.4	195.6	60	.63
15	RM	25.91	15.85	73	D	375.1	235.8	58	--

[1] Weighted average for entire tree on dry weight basis.

SAMPLE TREE DATA FOR GREAT SWAMP II, PLOT 2

Sample Tree	Species	D.B.H. (cm)	Height (m)	Age (yrs)	Crown Class	Fresh Weight(kg)	Oven-dry Weight(kg)	Moisture Content(%)[1]	Specific Gravity(g/cc)
1	WO	8.38	9.14	29	OT	22.9	14.7	70	--
2	RM	8.64	11.28	37	INT	38.5	23.8	61	.57
3	RM	10.92	12.19	33	INT	68.1	41.9	60	--
4	RM	11.43	13.11	53	INT	66.1	39.1	69	.60
5	WO	12.70	12.50	48	CD	78.5	45.5	71	.64
6	RM	12.95	12.19	57	INT	78.6	47.6	65	--
7	RM	15.24	10.06	48	INT	122.8	74.2	64	--
8	WO	15.75	11.89	60	INT	80.5	48.3	66	.58
9	WO	18.29	14.63	56	CD	274.1	168.4	61	--
10	WO	19.05	13.11	58	CD	241.5	148.0	66	--
11	WO	19.56	14.93	57	D	235.6	142.7	65	--
12	RM	20.57	16.15	52	CD	280.2	177.8	57	--
13	WO	22.86	14.93	57	D	348.3	202.7	72	--
14	S	24.13	15.55	58	D	376.7	209.4	82	.48
15	RM	25.15	18.90	61	D	454.7	279.2	61	.57
16	WO	25.91	15.85	61	D	530.8	323.5	64	--

[1] Weighted average for entire tree on dry weight basis.

SAMPLE TREE DATA FOR HAZARD TRACT, PLOT 1

Sample Tree	Species	D.B.H. (cm)	Height (m)	Age (yrs)	Crown Class	Fresh Weight(kg)	Oven-dry Weight(kg)	Moisture Content(%)[1]	Specific Gravity(g/cc)
1	RM	8.64	11.28	27	INT	32.1	21.4	46	.54
2	BO	8.64	10.36	29	INT	33.9	21.5	57	.64
3	BO	10.41	12.19	32	INT	67.8	41.5	60	--
4	RM	10.92	13.11	37	CD	67.6	43.5	53	.56
5	BO	11.68	12.19	36	INT	73.3	45.4	62	--
6	RO	12.70	14.02	37	CD	129.0	78.0	67	.61
7	SO	16.00	15.55	35	CD	212.8	118.3	82	.62
8	RM	16.26	14.63	34	OT	139.1	88.8	57	--
9	SO	18.03	15.55	41	D	211.9	119.3	80	--
10	SO	18.29	16.15	36	CD	228.9	127.1	82	--
11	SO	18.54	16.46	34	D	288.2	167.4	75	--
12	SO	21.34	16.15	37	D	384.3	225.6	73	--
13	RO	21.59	15.85	36	CD	360.4	213.2	70	--
14	BO	22.35	17.98	39	D	399.6	221.1	87	.63
15	BO	22.86	17.37	43	D	430.9	245.7	79	--

[1] Weighted average for entire tree on dry weight basis.

SAMPLE TREE DATA FOR HAZARD TRACT, PLOT 2

Sample Tree	Species	D.B.H. (cm)	Height (m)	Age (yrs)	Crown Class	Fresh Weight(kg)	Oven-dry Weight(kg)	Moisture Content(%)[1]	Specific Gravity(g/cc)
1	RM	8.13	11.58	33	OT	29.8	18.0	64	.50
2	SO	8.89	10.67	35	OT	36.4	20.7	79	--
3	WO	8.66	10.67	37	INT	36.3	21.9	68	.62
4	RM	9.91	12.19	34	INT	46.4	29.1	59	--
5	SO	10.41	11.89	32	INT	45.2	25.5	78	.63
6	RM	11.43	10.67	34	INT	59.6	35.3	67	--
7	BO	13.21	14.33	36	INT	119.6	68.2	76	--
8	SO	13.46	14.63	36	INT	99.1	56.8	75	--
9	SO	14.73	14.33	33	INT	150.5	87.9	73	--
10	SO	14.99	14.93	33	CD	157.0	88.4	79	--
11	SO	17.78	15.85	40	D	254.1	147.3	75	.63
12	SO	18.54	15.55	32	CD	280.9	164.8	73	--
13	SO	20.32	16.46	34	D	345.1	190.8	85	--
14	RM	20.32	13.41	42	CD	196.0	120.2	60	.53
15	SO	25.40	15.55	37	D	617.8	360.0	74	--
16	SO	27.43	16.76	39	D	612.8	351.2	78	--

[1] Weighted average for entire tree on dry weight basis.