EFFECTS OF HYDROLOGY-ALTERING SITE PREPARATION AND FERTILIZATION/RELEASE ON PLANT DIVERSITY AND PRODUCTIVITY IN PINE PLANTATIONS IN THE COASTAL PLAIN OF VIRGINIA

by

James W. Hauser

Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science

in

Department of Forestry

APPROVED:

W. Michael Aust

James A. Burger

Shepard M. Zedaker

August, 1992

Blacksburg, Virginia

ABSTRACT

EFFECTS OF HYDROLOGY-ALTERING SITE PREPARATION AND FERTILIZATION/RELEASE ON PLANT DIVERSITY AND PRODUCTIVITY IN PINE PLANTATIONS IN THE COASTAL PLAIN OF VIRGINIA

by

James W. Hauser

Biological diversity, or biodiversity, is declining on a global scale at unprecedented rates. These declines are largely the result of human activities and resource use. Intensive forestry is often cited as a contributing factor in biodiversity declines. Because forestry practices are being placed under increased scrutiny with respect to biodiversity impacts, the objective of this project was to determine the effects of specific silvicultural practices on plant diversity in pine plantations on wet flats in Virginia.

The study area consisted of three sites in the Coastal Plain. The sites were originally established in 1969 to study the effects of various treatments on loblolly pine growth. The three treatments applied were chop and burn, bedding, and ditching. Fertilization subplots of P, N and P, N,P, and lime, and a control were added to the treatment areas in 1978. This study was conducted in 1991 when stands were 23 years old, nearing rotation age.

Bedding exerted the greatest effect on plant diversity. Diversity was lower on the bedded treatment, although total biomass was higher. Bedding appears to increase pine growth by providing seedlings with more available soil volume and by reducing the vegetative regeneration of hardwoods and shrubs, thereby decreasing site diversity. Ditching likewise increased pine growth by lowering water table levels, but ditching had little effect on plant diversity.

Fertilization exhibited only minor effects on diversity, and those effects that were observed did not reveal any definitive trends. Of the treatments applied, liming appeared to increase pine growth most, possibly due to increased calcium availability.

Water table level was highly correlated to midstory diversity, though it was less correlated to other canopy layers. In addition, correlation analyses indicated a significant degree of interaction between canopy layers. It appears that diversity, particularly in the lower canopy layers, is affected directly by treatments and indirectly by shifts in overstory characteristics.

Intensive forest management involving hydrology-altering site preparation and fertilization impacted plant diversity within these wet flat plantations. Whether such changes affect wildlife habitat or ecosystem functioning requires further study.

ACKNOWLEDGMENTS

I would like to thank my wife Lauren without whose love and support I would never have completed this project.

I would also like to thank my major professor Mike Aust for his significant effort in directing my work. His guidance and assistance allowed me to truly develop as a student and researcher.

Lastly, credit should be given to Union Camp Corp., NCASI, and the U.S. Forest Service for supporting this project and making this research possible. Their concern for environmental protection and commitment to sound forest management are exemplified through their contribution to this work.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Problem Statement

Biological diversity, or biodiversity, has been defined as "the variety and variability among living organisms and the ecological complexes in which they occur" (Office of Technology Assessment, 1987). This definition incorporates all living organisms, from vertebrates and higher plants to insects, fungi, and microorganisms. This assemblage could include up to 30 million species worldwide and billions of genetically distinct populations (Ehrlich, 1990) As a result, there are few human land-use activities which do not in some way impact biodiversity, at least at a local level.

Concern over the conservation of such biological diversity has gained attention among the scientific community due to the rapid global loss of forested lands and the widespread conversion of landscapes to homogeneous communities (Probst and Crow, 1991). Trends suggest that biological diversity, on a global scale, is declining in almost all ecosystems and at every trophic level (Wilson, 1985). Biological diversity loss has been called "the most ubiquitous and irreversible environmental problem facing the planet" (Norse et al., 1986) As a result, Salwasser (1990) states that biodiversity loss in forestlands may become the "environmental issue of the time."

Extensive theoretical articles have been published describing the potential deleterious effects of losing species and simplifying ecosystems (Ehrlich, 1988). Conservation concerns have historically focused on tropical rainforests which are experiencing more rapid declines in diversity, but similar concerns are presently being expressed about temperate forested systems (Falk, 1990). The U.S. Forest Service, for example, is currently required to preserve biological diversity as a multiple-use benefit on all National Forests through the National Forest Management Act of 1976 (Probst and Crow, 1991; Ehrlich, 1990). Such regulations may eventually be extended to private or industrial landowners if the problem of biodiversity loss is perceived to worsen in the future.

The federal government is already extending the scope of biodiversity conservation beyond the National Forests. In 1985, the Congressional report U.S. Strategy on the Conservation of Biological Diversity evaluated the impact of all federal agencies involved with protecting diversity (Wilson, 1985). In addition, Congressional legislation is presently being drafted to establish long-term biodiversity conservation as a national goal (Probst and Crow, 1991, Salwasser, 1990).

The primary anthropogenic factors causing biodiversity declines include conversion of lands to intensive uses, contamination by pollution and toxins, overuse and exploitation of individual species, alteration and simplification of community structure, and landscape fragmentation (Salwasser, 1990). Intensive forest management is often cited as contributing to these deleterious factors. For example, forest fragmentation is thought to be largely responsible for recent migratory bird declines (Ehrlich, 1990). If such effects can be demonstrated, intensive forestry practices may require modification.

Effects of Biological Diversity Loss

Numerous researchers have noted the possible deleterious effects associated with biodiversity loss (Probst and Crow, 1991; Ehrlich, 1990; Salwasser, 1990). Such effects, though potentially serious, are extremely long-term in scope and difficult to quantify. For these reasons, much of the literature concerning the costs of biodiversity loss remains theoretical and few effects have actually been demonstrated. Intuitively, however, there appears to be substantial merit to many of the concerns raised by ecologists and geneticists.

The possible effects of biodiversity loss include: 1) loss of potentially marketable species, 2) loss of genetic material for breeding or adaptation, 3) loss of "free" ecosystem services, and 4) a reduction in the recreational or aesthetic value of lands (Ehrlich, 1988). Loss of potentially beneficial species is obviously of greater importance in the tropics where species may become extinct before they are ever identified or studied. Despite the many commodities derived from various organisms, Wilson (1985) states that tens of thousands of plants and millions of animals have never been studied for economic potential. However, it may also be of importance in southeastern U.S. forests if it is assumed that new markets for species not currently used may be developed in the future. Salwasser (1990) supports this idea and claims that all species have the capacity to become human resources through future technological developments.

The value of genetic material for breeding can be more easily defined and quantified in terms of human value, and as a result, many agricultural and forestry programs already exist to preserve genetic diversity in important marketable species. Despite these efforts, loss of genetic diversity within these and other nonmarketable species is still high. Falk (1990) states that 285 taxa in the continental U.S. are of significant concern genetically, including genera in common agriculture and forestry families. Such a loss limits the potential of a species to adapt to changing environmental conditions and also reduces the future usefulness of the species to society (Ehrlich, 1988; Falk, 1990).

The free ecosystem services which relate to biodiversity include carbon fixation, nutrient cycling, water purification, waste decomposition, soil formation, etc. (Salwasser, 1990; Probst and Crow, 1991; Ehrlich 1990). These processes are essential to the productivity and stability of natural communities. If large-scale simplification of ecosystems interferes with these processes, then the impacts to human society may be severe.

The final point addresses the indefinite value assigned by society to species and natural areas. Though not easily quantified, such values do exist and the loss of biological diversity in natural areas can reduce their aesthetic value as perceived by the general public. Ehrlich (1990) claims that most people find other organisms intrinsically interesting, and their loss results in a feeling of impoverishment.

In general, it can be concluded that reductions in biodiversity may reduce the value of resources and significantly limit land management options in the future (Salwasser, 1990).

Intensive Forestry and Biological Diversity

Intensive forest management is often cited as a contributing factor to global diversity losses (Ehrlich, 1990; Norse, et al., 1986). Short-rotation, plantation forestry, in particular, is claimed to result in nearly pure monocultures having little wildlife or aesthetic value (Hunter, 1990). Wet pine flats in the southeastern U.S. frequently experience such intensive management, and productivity of crop trees can be greatly increased as a result (Allen and Campbell, 1988). Drainage, site preparation, fertilization, and competition control are widely used to increase the growth of overstory crop trees (principally pines). When managed intensively, wet flats can be some of the most productive timber producing lands in the world (Allen and Campbell, 1988). Concerns have been raised that intensive management concentrates all of the site's productive potential into a single species at the expense of all others (Norse, et al., 1986).

However, because of the wide range of potential management intensities, generalizations about the effects of plantation management may be inaccurate. As a result, a better understanding of plant responses to varying levels of management across different community types is needed. This knowledge could ultimately be applied to predict the effects of various combinations of silvicultural treatments on biological diversity both within a stand and between stands at a landscape level.

Objectives

The objectives of this project were to determine the rotation-age effects of hydrology-altering site preparation and fertilization/release on plant diversity and productivity in wet flat loblolly pine plantations. Specific null hypotheses which were tested were:

H_0 := Drainage and bedding have no effect on plant diversity or productivity at rotation age as compared to chop and burn.

H_0 := Windrowing and bedding as a mechanical disturbance has no effect on plant diversity or productivity at rotation age.

H_0 := Fertilization/release at canopy closure (age 10) has no effect on plant diversity or productivity at rotation age.

An additional objective of this project was to observe to what extent water table level and canopy interactions were correlated to plant diversity and productivity in mature pine plantations on wet flats. Such observations could provide a better understanding of possible cause and effect relationships influencing diversity.

LITERATURE REVIEW

Plant biodiversity incorporates numerous concepts, but, definitions usually differentiate between various levels of biodiversity, such as genetic, between-, and within-community biodiversity. Genetic diversity typically involves single species while between-community biodiversity concerns large land areas. Within-community plant biodiversity encompasses an assemblage of species at a localized stand level and relates to measures of species evenness, richness, and abundance.

Plant biodiversity and its associated benefits provide societal values, but, the maintenance of biodiversity involves private lands, including forest lands. Site preparation and fertilization are inherent components of intensive forestry and both may affect the distribution of species and biomass within different vertical layers of the stand. An understanding of how intensive site preparation and fertilization affect within community biodiversity is crucial to maintenance of biodiversity on private lands.

Levels of Biological Diversity

Ecologists and geneticists have recognized three distinct levels of diversity within populations and ecosystems. These levels are: 1) the abundance and distribution of different alleles and genotypes within a species, 2) the diversity of plant and animal species within a given ecosystem type, and 3) the spatial arrangement and relative abundance of ecosystem types within a landscape (Norse, et al., 1986). This project addresses only the second level of biological diversity, that which occurs within a given community. It is assumed that maintaining unmanaged populations of naturally occurring species will incorporate genetic conservation as an indirect benefit. In addition, protecting community types within a landscape involves large-scale land management and public policy considerations which are beyond the scope of this research. By maintaining stable and diverse component communities, however, the effectiveness of the landscape manager should be improved. Ultimately, in order to achieve the overall objective of biodiversity conservation, actions must be integrated at all three levels (Salwasser, 1990).

Within-community Diversity

Within-habitat biodiversity is related to spatial heterogeneity, vertical structure, and level of disturbance of the community (MacArthur, 1965; Hansen, et al., 1991; Denslow, 1980). Obviously, the greater the heterogeneity of soils, topography, etc. and the more stratified the vegetative canopy the greater the expected biological diversity should be (MacArthur, 1965). Spatial heterogeneity increases the number of potential niches for plant species, while complex vertical structure provides a greater variety of animal habitats. Indeed, animal diversity has been shown to be correlated with such increases in habitat structural complexity of the canopy (Huston, 1979; Hansen, et al., 1991). Furthermore, Franklin (1988) argues that the structure provided by fallen logs and standing snags alone can support a significant proportion of a stand's resident fauna.

Several authors have supported the moderate disturbance hypothesis which states that diversity will be greatest in areas subject to occasional, light disturbance as compared to areas with severe, frequent disturbance or no disturbance (Connell, 1978; Huston, 1979). According to this hypothesis, under heavy disturbance, sensitive species are excluded and so diversity is low. With no disturbance, competitive dominants gradually eliminate slower growing species. Moderate disturbance tends to suppress dominants while not extirpating sensitive species. Denslow (1980) defines "moderate disturbance" in plant communities as the disturbance interval which is most consistent with recurrent environmental events (e.g.. fire, hurricane, flood, etc.). These principles have important implications in forestry with respect to rotation ages, harvesting methods, and frequency of prescribed burning.

However, Harris (1984) claims that increasing biological diversity at the habitat level by substituting species which are common for species which are rare is not an appropriate management practice. An increase in local biological diversity can mask the displacement of many native species, especially the displacement of rare specialists for common generalists (Probst and Crow, 1991). As a result, it is important to note whether any rare species are lost by particular management or disturbance regimes.

Species Richness, Evenness, and Abundance

Three commonly used concepts found in biological diversity literature are species richness, evenness, and abundance. Richness refers to the number of species per unit of area, e.g., species per hectare (Pielou, 1975). Evenness or equitability refers to how equally common the species are, or to what degree the community is dominated by a few organisms (Magurran, 1988; Westman, 1990). If all species are found in equal numbers or biomass, then the evenness of the site is 1.0. However, neither richness nor evenness may be useful if the community consists of a few very common species and many rare species, as often occurs in forested ecosystems. Under such conditions, species abundance indices may be more appropriate.

Abundance indices incorporate both the number of species present and the relative importance of each species to some measure of dominance, e.g., biomass per unit area (Pielou, 1975). Thus, species abundance indices incorporate richness and evenness and provide a more complete description of the diversity of plants within a stand (Magurran, 1988). This project utilizes both species richness and species abundance measurements. Richness will be determined by recording cumulative numbers of species within sample plots, and abundance will be measured using biomass samples and equations. Evenness will not be calculated separately, but will obviously be incorporated into the abundance indices.

Both Pielou (1975) and Magurran (1988) provide extensive reviews of numerous mathematical indices of biological diversity and methods for interpretation of data. The most commonly used species abundance indices are the Shannon-Wiener index and the Simpson index. These indices will be used primarily because they are the most universally known among the scientific community. Moreover, use of these indices has been supported by Patil and Taillie (1982). They showed that both of these indices satisfy the requirements for predicting average rarity within a community.

The formulas for the indices consist of functions of each species' proportional contribution to the total canopy productivity. Typical productivity measures for forested systems include biomass, density, basal area, etc. The formulas for the Shannon-Wiener index and the Simpson index are listed below (Magurran, 1988):

Shannon-Wiener Index

$$H' = -\sum p_i * \ln(p_i)$$

Simpson Index

$$s = 1 - \sum (p_i)^2$$

where H' = Shannon-Wiener index (unitless)
s = Simpsons index (unitless)
p_i = Proportional contribution of species i to total
ln = Natural log

Conservation of Biological Diversity on Private Lands

Private forest land managers are experiencing increased pressure to consider biological diversity in management plans because of their unique position as resource managers. Forest industry and private landowners comprise the majority of the land base throughout the country, especially in the East. For example, Brown (1986) states that greater than 75 percent of forested land in Virginia is owned by non-industrial private land owners. In addition, forest managers are often responsible for large, contiguous tracts of forestland which are increasingly rare and therefore crucial (Probst and Crow, 1991). As landscape fragmentation and intensive land use become more widespread, public pressure on private forest land managers is likely to increase.

Several authors have noted that long-term conservation of biological diversity can never be achieved solely on public lands because these lands will never occupy a sufficiently large percentage of the land area (Franklin, 1988; Probst and Crow, 1991; Ehrlich, 1988; Salwasser, 1990). Small, isolated islands of critical habitat are too vulnerable to catastrophes or inbreeding to be adequate for long-term conservation (Salwasser, 1990). In addition, such methods do not effectively protect genetically distinct populations or subspecies which are experiencing the greatest declines (Ehrlich, 1990). For this reason, conserving biological diversity must be extended to private lands if it is to prove effective. Salwasser (1990) argues that biodiversity objectives must be blended with other human land use goals across entire regions. In this manner, land managers should be encouraged to emphasize multiple species communities rather than single species systems (Probst and Crow, 1991).

Effects of Silviculture on Biological Diversity

Hunter (1990) and Norse, et al. (1986) provide extensive reviews of the potential effects of silvicultural activities on biological diversity. They argue that all silviculture is not inherently detrimental to biological diversity and that practices can be selected which have negligible or even positive effects. The effect of any particular treatment depends on its effect on light, water, and nutrient allocations within the forest. Westman (1990) concludes that "management of an ecosystem to adjust the level of certain desired species, inevitably leads to a shift in relative abundance of coexisting species. The extent of change will depend on the tightness of coupling of the target species to others."

Although silviculture in the past has predominantly emphasized wood and fiber production, silvicultural techniques can be modified to incorporate diversity and wildlife habitat. The critical consideration for maintaining diversity in forestlands is allowing for the coexistence of species through site variation, resource partitioning, and stress and disturbance regimes (Norse, et al., 1986). Hansen, et al. (1991) lists three criteria for determining the effect of intensive forestry on biological diversity:

> Are plantations managed intensively for wood production more uniform in tree species, size, and spacing than are natural forests?
>
> Do these plantations offer less habitat diversity and support fewer species than do natural forests?
>
> Is the fragmentation of remaining natural forests likely to reduce biodiversity even further in natural stands?

The first two criteria relate to the partitioning of resources between species within a particular site. The third involves larger scale, between-habitat diversity concerns for forest management.

Hunter (1990) and Norse, et al. (1986) discuss the effects of a wide variety of silvicultural treatments from stand establishment, through intermediate treatments, to final harvests. The silvicultural prescriptions which will be studied as part of this project include drainage, site preparation, and fertilization. Other forestry activities potentially affecting biological diversity and requiring future research are harvest and regeneration methods, thinnings, herbicide and pesticide use, and prescribed fire.

Drainage can have a drastic effect on biological diversity because it has the potential to completely change a site from one type of community to another (Hunter, 1990).

Because wetlands tend to have high species abundance, deep drainage and conversion to pine plantations often results in decreased species diversity. Even modest drainage can eliminate site-specific species with strict moisture requirements (Hunter, 1990). Robinson (1978) concludes from an analysis of 30 rare forested wetland species that 23 would be destroyed or damaged under modest drainage. Damage to the rare plants was predicted to result from both lower water table levels and increased growth in the overstory which provided more shade to the plants. In addition, drainage may permanently alter the succession pattern of a forest such that important ecological stages are excluded (Norse, et al., 1986). Drainage may also allow new species to become established on the site that are not tolerant of high water levels, compensating for species which were extirpated. However, as noted earlier, maintaining diversity by trading one species for another may not be appropriate if the species lost is rare (Harris, 1984).

Site preparation affects species diversity by controlling or eliminating plant matter on the site during stand regeneration (Hunter, 1990). The intensity of the site preparation disturbance will determine whether the diversity effects are temporary or more long-term. Hunter (1990) states that because many species are adapted to fire, site preparation burns should have only a transitory effect on species diversity. This should be particularly true in wet pine flats of the southeast where natural fire is common. Similarly, light mechanical site preparation may have little long-term effect or may increase biodiversity by allowing new species to become established. Light mechanical site preparation was found to have only moderate effects on rare plant species in pine flatwoods (Robinson, 1978). Intensive mechanical site preparation usually decreases diversity by killing a large proportion of the residuals and by providing the crop trees a much greater competitive advantage (Hunter, 1990). As with any forestry practice, any treatment which completely removes all snags and dead wood will significantly decrease animal diversity as well (Hansen, et al., 1991). However, an important consideration with respect to site preparation is the effect it produces in diversity over time. Because early successional stages can be relatively diverse, shortening the time before canopy closure more quickly eliminates a diverse seral stage (Norse, et al., 1986).

Fertilization may affect biological diversity in either a positive or negative way depending on the growth status of the stand. Contrary to initial intuition, an increase in site productivity does not necessarily result in increased biological diversity. Often, there is a correlated decrease in diversity due to greater inequality among species

(MacArthur, 1965; Huston, 1979). If increased productivity is captured by only a few dominant species, then it may provide such species with the resources to more rapidly displace others. For example, Milton (1947) found a decrease in diversity in grassland systems when manure fertilizer was applied, resulting from the rapid growth of two dominant species. Such a condition may exist in forested ecosystems where increases in productivity are usually directed toward the overstory trees. Huston (1979) states that low to intermediate growth rates should provide greater diversity because of reduced competition and prolonged coexistence. However, fertilization can increase species diversity in stands with open canopies where less dominant species may be able to acquire some of the increased nutrients (Hunter, 1990).

Site Preparation and Intensive Forestry on Wet Pine Flats

Wet pine flats of the southeastern U.S. frequently experience intensive forest management for the production of wood and paper. Loblolly pine (Pinus taeda) and other southern pines are the principal species favored under intensive management. However, the fluctuating water tables and low fertility of typical wet flats have prompted the widespread use of drainage, bedding, competition control, and fertilization to improve pine growth rates (Allen and Campbell, 1988). The application of these management practices can convert such marginally productive land into some of the most productive timberlands in the Southeast (Allen and Campbell, 1988). The potential land resource which might benefit from these practices is great. Klawitter (1965) estimates that up to 4 million acres of wet flats in the southeastern U.S. demonstrate high water table levels which may limit tree growth. The use of such intensive forestry practices in wetlands, though, is under increasing scrutiny.

Seasonally high water tables in wet pine flats may restrict the volume of soil which can be occupied by tree roots (Spurr and Barnes, 1980). This is particularly true in regenerating stands because water tables usually rise after harvest due to reduced transpiration. Rooting is generally limited to the soil above average water table level (Spurr and Barnes, 1980). As a result, young pines may have a limited soil rooting depth and may experience higher mortality and slower growth rates. By lowering water table levels, drainage increases the soil volume available to young trees (Olszewski, 1988). Bedding also increases usable soil volume by keeping the seedlings above the surrounding water. In addition, bedding concentrates soil organic matter near the young trees and controls vegetative competition from herbs and hardwoods (Allen and Campbell, 1988).

Mature stands usually do not experience as much difficulty from high water table levels because their transpiration rates during the growing season quickly lower site water. In fact, water may become a limiting resource on some sites in late summer and yet be near the surface during the dormant season. For this reason, water management (raising and lowering water tables as necessary) is emerging as the best forestry alternative (Campbell and Hughes, 1981). By mid-rotation, nondrained stands have generally developed sufficient leaf area to lower water tables through transpiration (Allen and Campbell, 1988). However, such stands will have lost many years of productive growth as compared to bedded or ditched stands. Comparing hydrology regimes in mature drained and undrained stands may not indicate the critical effect of drainage on early growth.

Drainage and bedding have been applied and tested repeatedly in wet flats to determine their potential at lowering water table levels and improving tree growth. In general, both ditching and bedding appear to provide increases in growth on wet sites. Bedding has been shown to increase early stand growth across a variety of sites (Wilhite and Jones, 1981; Langdon, 1962; Prichett and Smith, 1974). Ditching has shown similar results (Maki, 1971; Campbell, 1976; Terry and Hughes, 1975). The extensive number of studies showing favorable pine response to bedding and ditching indicates that water table level is indeed limiting to tree growth. Whether these growth increases are maintained throughout the stand rotation may depend on other site factors (e.g., fertility).

Other authors have suggested that fertilization may be used on marginally wet sites where bedding or ditching have shown minimal effect (Langdon and McKee, 1981). These authors claim that on sites without ponded water, reduced rooting depth primarily affects the ability of the trees to acquire adequate nutrients. Because the accessible soil volume is reduced, the pool of available nutrients is limiting. Under such conditions, fertilization may be sufficient to achieve adequate tree growth, and alteration of site hydrology is unnecessary.

Phosphorous is often a limiting nutrient on wet flat soils (Allen and Campbell, 1988). Application of phosphorous has shown significant increases in pine productivity (Langdon and McKee, 1981; McKee and Wilhite, 1986). These effects appear to be long term and are often additive with ditching or bedding (Allen and Campbell, 1988). Nitrogen fertilization is often applied in addition to phosphorus to further stimulate tree growth. On all but the most productive sites, pines tend to show an increase in growth with added nitrogen (Allen and Campbell, 1988). Responses appear to last 5 to 10 years after fertilization.

Liming has been tested as a soil amenity to reduce soil acidity, thereby increasing nutrient availability. In addition, liming provides calcium which may be a limiting nutrient. Liming significantly affects the availability of phosphorous by changing pH, such that liming has been suggested as an alternative to repeated phosphorous fertilization (Thompson and Troeh, 1978).

The ability of site preparation, fertilization, and competition control to improve tree growth involves interacting factors of water level and nutrient availability. Maximizing these factors often requires very site specific recommendations. In general, it can be concluded that alteration of site hydrology is effective on extremely wet sites where rooting volume is minimal. Fertilization may be applicable as a substitute for hydrology treatments where water tables are not as extreme. Fertilization, however, definitely yields greater pine growth in wet flats when combined with ditching or bedding.

Canopy Layer Interactions

Because of availability of light, water, and soil nutrients, understory vegetation is often directly affected by the extent and species composition of the overstory. Several researches have found an inverse relationship between overstory basal area or percent cover and understory herbage production (Halls and Schuster, 1965; Wolters, 1982; Wolters, et al., 1982; Grelen, et al., 1972,; and Hurst, et al., 1982). However, additional canopy layers can complicate interpretation of competitive interactions. Blair and Feduccia (1977) describe conditions where whereby shrub production was more severely affected by midstory hardwoods than overstory pines. As a result, thinning of overstory pines decreased shrub layer productivity by enhancing midstory growth. Overall, this body of research suggests some inverse relationship between overstory and understory production, but predictions may be confounded by increasing stratification in the canopy.

Compositional changes in understory vegetation following overstory reduction have also been observed. McConnell and Smith (1965) found a change in dominance from grasses to herbaceous plants as overstory stocking increased. Wolters, et al. (1982) describes changes in grass species composition with increasing overstory density. It seems probable that species distributions in the understory of wet pine flats are affected by overstory canopy characteristics. The effect of such responses on overall site diversity is unknown.

A significant concern is that the majority of the existing studies have concentrated on grasses and herbaceous plants which are typically found in early successional environments. These species are not adapted to low resource conditions, and as such their response may be more profoundly impacted by overstory stocking. For example, Halls (1968) found, in a study of growth rates of forage plants, that shade tolerant shrubs showed the least difference between open and woods-grown plants. These results suggest that tolerant shrubs may exhibit less response to overstory release than grasses or herbaceous plants.

For these reasons, analysis of biodiversity impacts in mature forests must address multiple canopy layers. Without such multiple canopy studies, determining whether understory vegetation is exhibiting a direct response to treatments or an indirect response to overstory characteristics is more difficult. Determining direct versus indirect effects is important in predicting the future effects of possible forestry treatment combinations.

METHODS AND PROCEDURES

Study Sites

Project design and history

The study area consisted of three sites in the vicinity of Franklin, Virginia (referred to hereafter as the Windsor, Holland, and Whaleyville blocks) (Figures 3.1-3.3). The lands are owned and managed by Union Camp Corporation and are typical wet pine flats of the Coastal Plain. Each site consisted of 12 hectares (30 acres) of loblolly pine (Pinus taeda) plantations which were 22 years old in 1991 when the study was conducted. The stands were originally established in 1969, following a clearcut in 1968, by the U.S. Forest Service and Union Camp Corp. as part of a pine productivity study. Following regeneration, three years of data were collected on site hydrology, seedling growth, and seedling survival before the original study was completed in 1972. All of the site preparation plots were randomized in the initial study, creating a randomized block design.

The 12 hectare blocks were divided into 4 hectare (10 acre) treatment plots representing the three hydrology manipulations, ie. deep drainage, bedding with windrows, and chop and burn (Figures 3.1-3.3). All areas were chopped and burned after the original clearcuts. In the bedded areas, debris were raked to windrows. For the ditched treatment, ditches were dug approximately 1.5 meters (5 ft.) deep in a

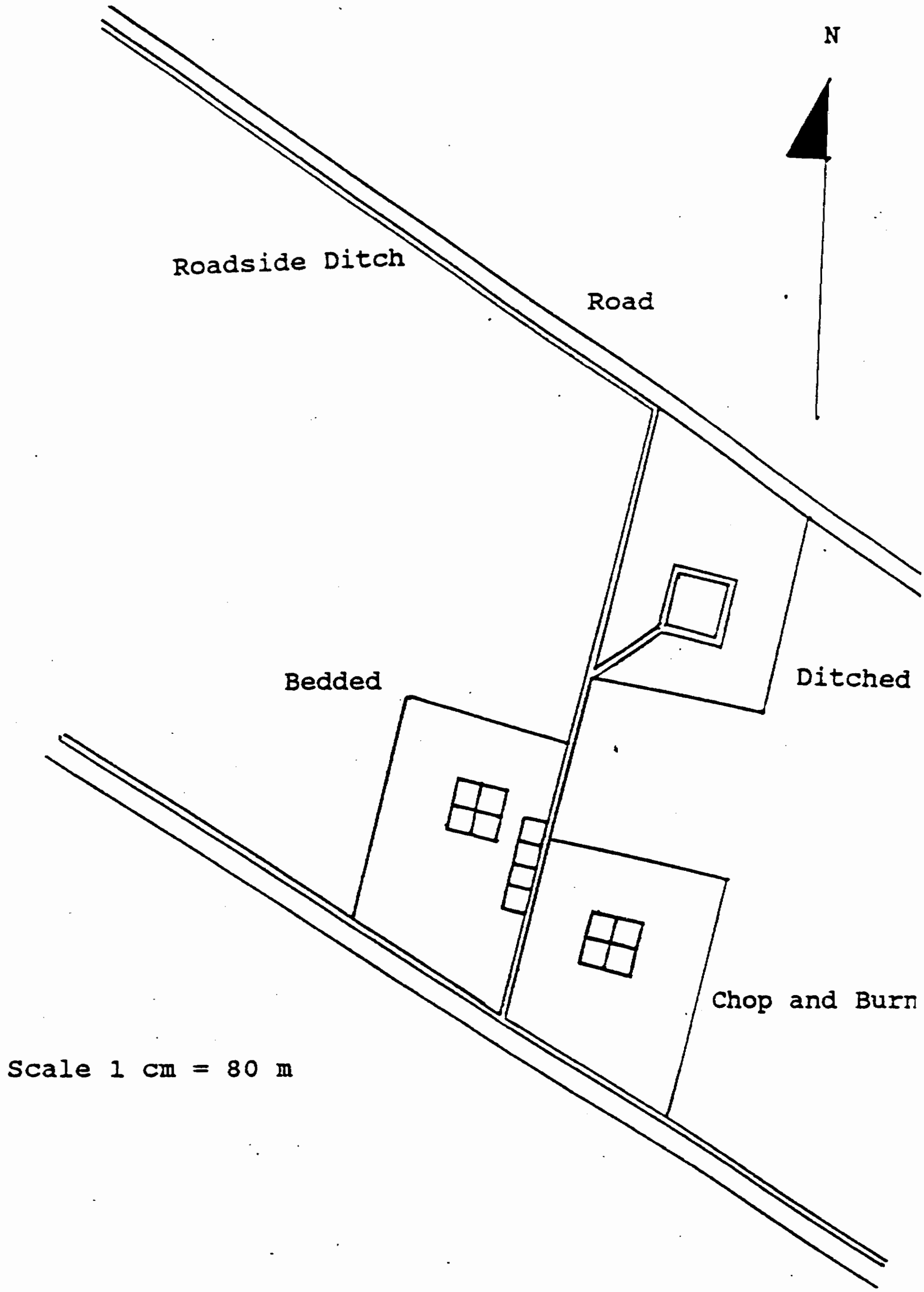
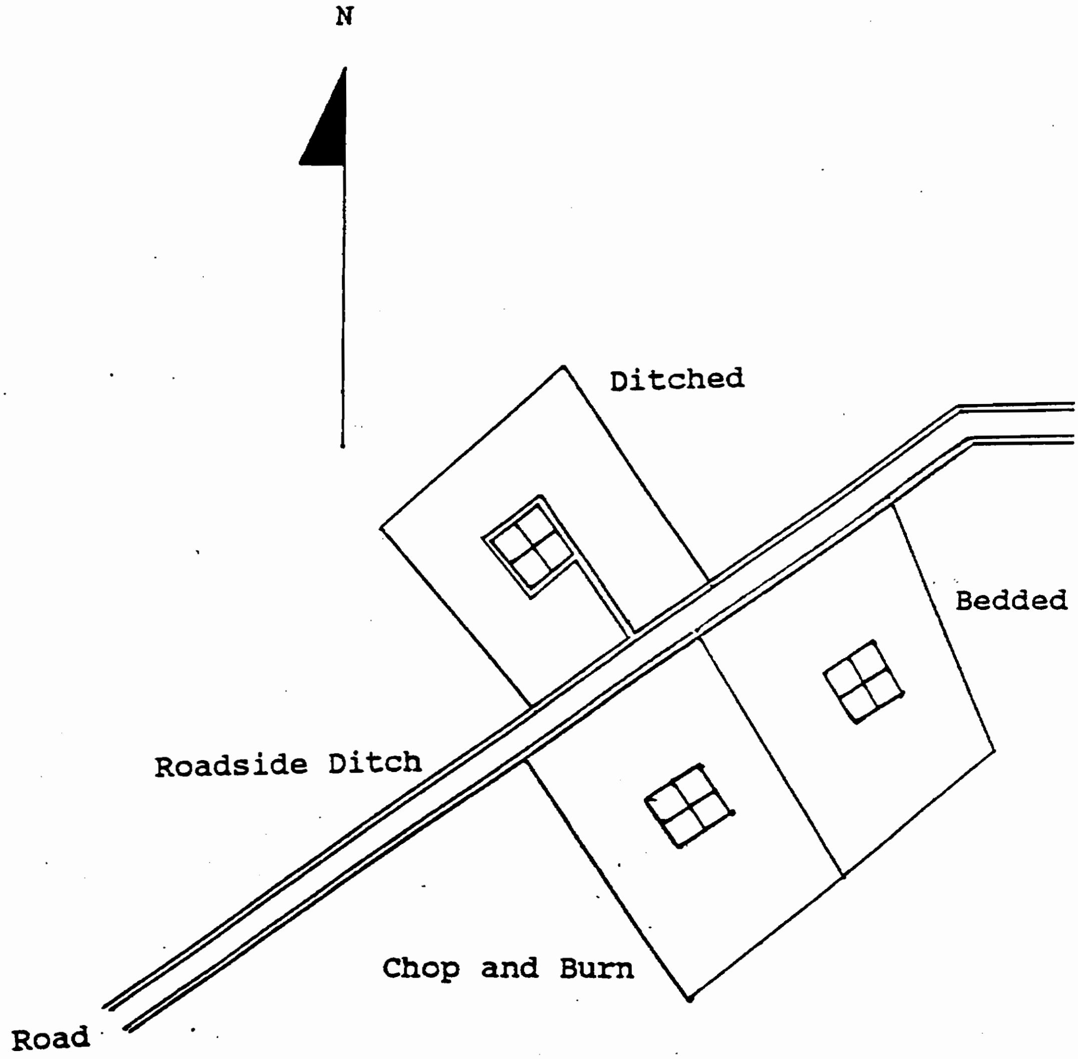
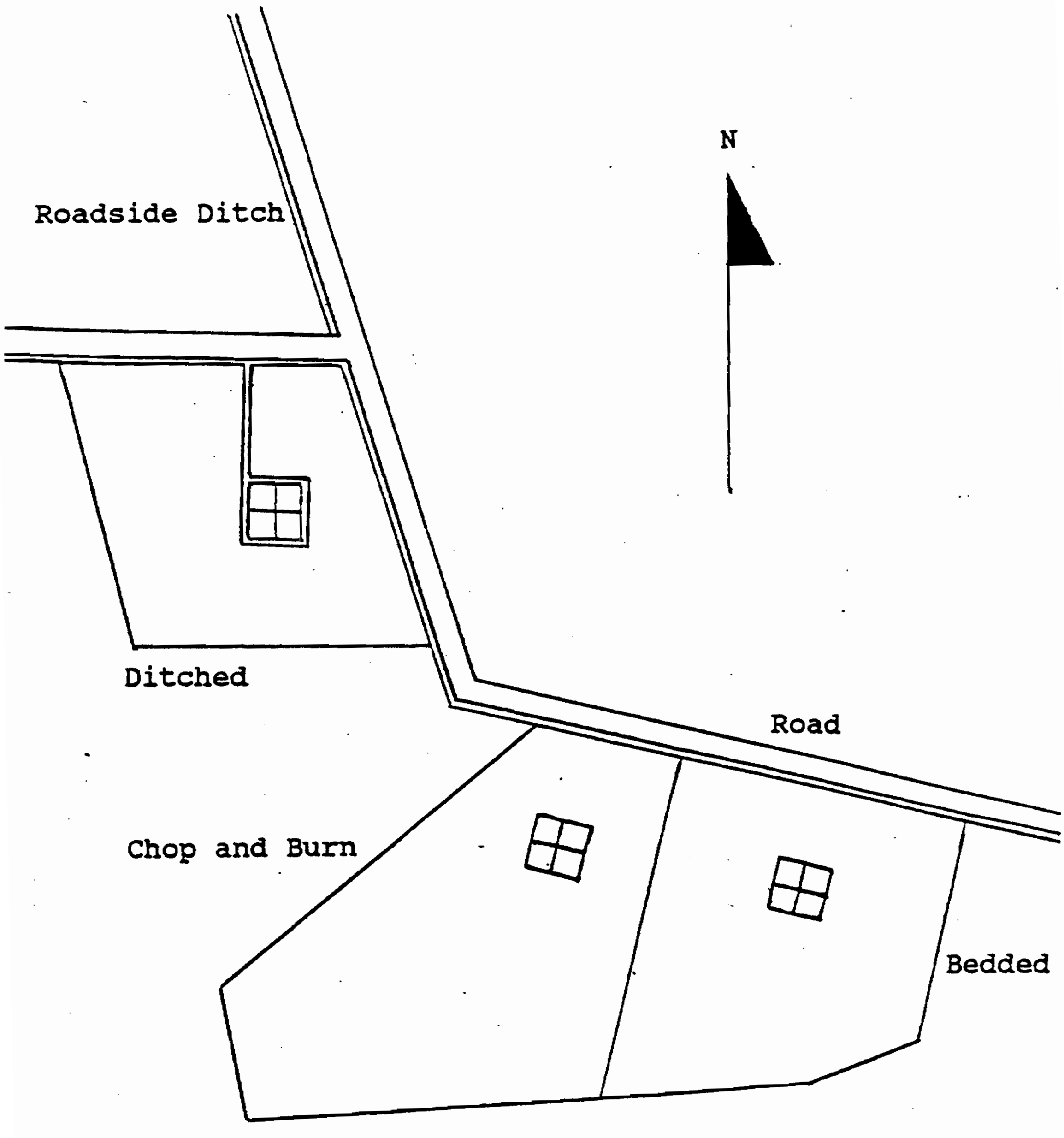


Figure 3.1. Holland block site preparation and fertilization treatment layout.



Scale 1 cm = 80 m

Figure 3.2. Windsor block site preparation and fertilizaiton treatment layout.



Scale 1 cm = 80 m

Figure 3.3. Whalyeville block site preparation and fertilization treatment layout.

box pattern around a 0.4 hectare (1-acre) plot in the center of the treatment area (Figures 3.1-3.3). This ditch was then joined to a roadside ditch, resulting in very intensive drainage for the 0.4 hectare center plot. Loblolly pines were planted at a 1.8 m. by 3.1 m. (6 ft. by 10 ft.) spacing (1792 trees/ha; 726 trees/ac).

The undisturbed control for the original 1969 experiment had been harvested, and so was not available for comparisons. However, because this study involves the response of vegetation to hydrology manipulations, the chop and burn treatment will serve as a control, assuming that this treatment has little direct effect on site hydrology. In addition, because such industry-owned lands will undoubtedly receive site preparation, the chop and burn treatment can be considered the minimum level of disturbance following clearcutting. Management consisting of no harvesting or site preparation whatsoever is not a probable alternative for these industrial lands. Therefore, comparisons between treatments, with the chop and burn as the control, remain valid.

When the stands were ten years old (1978), fertilizer treatments were added to subplots within the same areas by U.S. Forest Service and Virginia Tech scientists to study growth responses. Data on this aspect of the study, however, were never analyzed for the response. In the center of each 4 hectare treatment plot, a 0.4 hectare (1 acre) fertilization subplot was established. The fertilization plot consists of four, 0.1 ha. (0.25 acre) plots with treatments of P, N and P, N,P, and lime, and an unfertilized control (Figure 3.4). All fertilization plots were randomized. It should be noted that at the Holland site (Figure 3.1) the ditched fertilizer treatments were not located within the ditched site preparation treatment area. Instead, they were located along a ditch in the bedded treatment area. The reason these plots were established in this manner is unknown.

Phosphorous was applied at a rate of 75 lb/acre of Triple Super Phosphate, nitrogen was applied at 100 lb/acre of urea, and lime was applied at 2000 lb/acre of Dolomitic lime. According to a project progress report in 1979, these fertilization plots experienced some hardwood control by hand cutting in April of 1978 which may influence results. The intensity of release or the consistency of application across treatments is uncertain, creating a significant confounding factor in any observed results. It is probable, however, that this release elicited a response in addition to a fertilization effect. For purposes of simplification, the fertilizer/release treatments will be referred to as fertilizer treatments, and possible release effects will be noted where applicable.

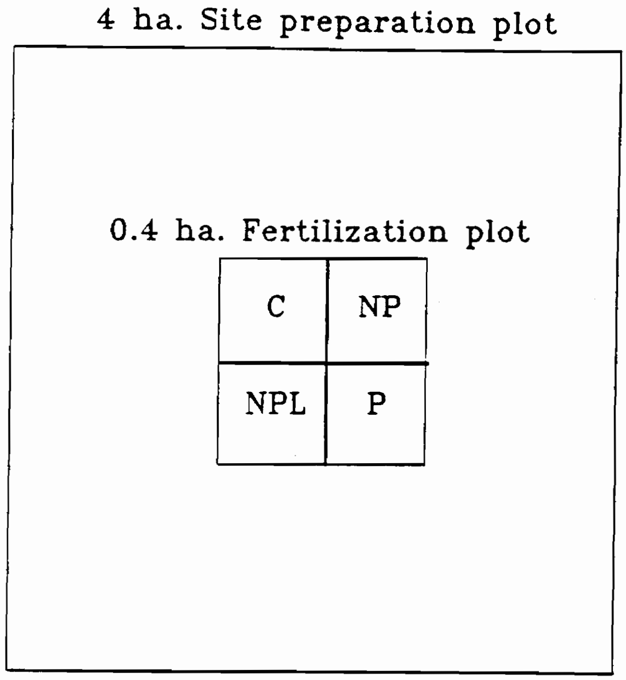


Figure 3.4. Sample fertilization subtreatment within a site preparation treatment.

Site characteristics

The soils in the study area are all poorly drained, deep, acidic soils formed on unconsolidated marine sediments. The topography of all sites is flat (0-2% slope), and altitudes are approximately 15-30 m (50-100 ft.) above sea level. The two soil series which were present were the Myatt (Windsor) and the Rains (Holland and Whaleyville). The Myatt series is a Typic Ochraquult with a fine sandy loam texture in the surface horizons (to 38 cm) (Kitchel, et al., 1986). Subsurface horizons tend to be mottled sandy clay loams. The Rains series is a Typic

Paleaquult with a fine sandy loam texture in the surface horizons (to 15 cm) (Reber, et al., 1981). Subsurface soil horizons are predominantly mottled sandy clay loams. The natural fertility and organic matter content of both soils is low.

Typical vegetation for these areas includes loblolly pine, red maple (Acer rubrum), sweetgum (Liquidambar styraciflua), black gum (Nyssa sylvatica), sweetbay (Magnolia virginiana), and water oak (Quercus nigra) in the overstory and midstory. The shrub and ground layers are dominated by switch cane (Arundinaria gigantea), pepperbush (Clethra alnifolia), and various species of catbrier (Smilax spp.). Average annual rainfall is 122 cm (48 in.), with 69 cm (27 in.) falling between April and September. Average winter temperature is 5 degrees Celsius (41 Fahrenheit), and average summer temperature is 24.5 degrees Celsius (76 Fahrenheit) (Virginia Tech Tidewater Experiment Station unpublished data, 1992).

The sites all meet the criteria of jurisdictional wetlands as defined in the Federal Manual for Identifying and Delineating Jurisdictional Wetlands (Federal Interagency Committee for Wetland Delineation, 1989). Water tables are within 60 cm (24 inches) of the surface for at least 7 consecutive days during the growing season of an average year. The sites have hydric soils (National Technical

Committee for Hydric Soils, 1987) and are vegetated by predominantly obligate wetland to facultative plants (Reed, 1988).

Survey Methods

Vegetation in the treatment areas was sampled using plots of various sizes, depending on the treatment and the canopy layer. In each sampling plot, the number of plants was recorded by species, and biomass per species was determined by either direct sampling (shrub and ground layers) or biomass equations (midstory and overstory). Diameter at breast height (dbh) and total height were measured for overstory and midstory trees. Basal area was calculated for each species from measured diameters. Average height for each species was estimated in the shrub and ground layers. Height and depth of the canopy layer and percent cover was also estimated in each plot for the shrub and ground layer.

Strip cruises were used to sample the 4 hectare site preparation treatments outside the fertilizer treatment plots. In the standard design each strip was 160 m (8 chains) long, spaced approximately 50 m (2.5 chains) apart (Figure 3.5). However, this design was modified on three of the nine treatment areas because of the block shape and size. The strips were divided into sampling units each 20 m (1 chain) long and 5 m (0.25 chain) wide, which were then

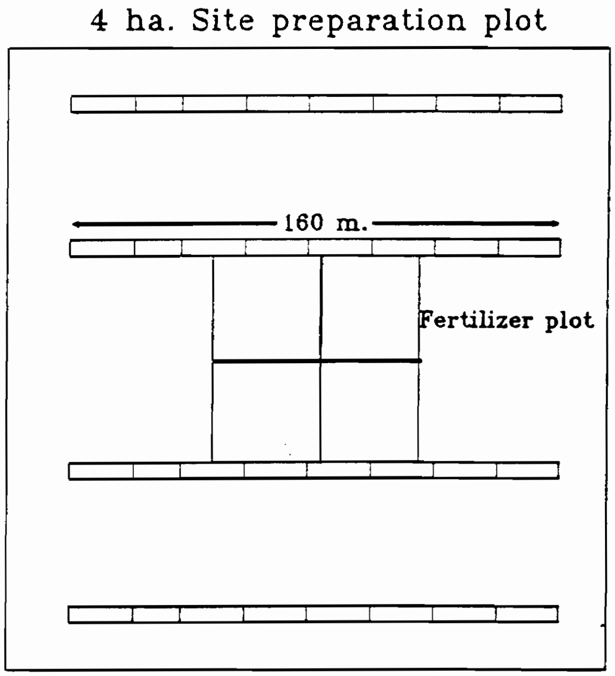


Figure 3.5. Typical strip cruise survey design.

subdivided into smaller units for the midstory, shrub layer, and ground layer surveys (Figure 3.6). The overstory was sampled in the entire 100 m^2 plot, the midstory in one-quarter of the area, and the shrub and ground layer in a 0.5 m^2 plot within the unit. A total of 32 such sampling units were located in each site preparation treatment area.

Circular plots were used to sample vegetation within the 0.1 hectare fertilization treatments. A 0.02 hectare plot (8 m radius) was established in the center of each fertilization treatment (Figure 3.7). These were again subdivided for the midstory, shrub layer, and ground layer

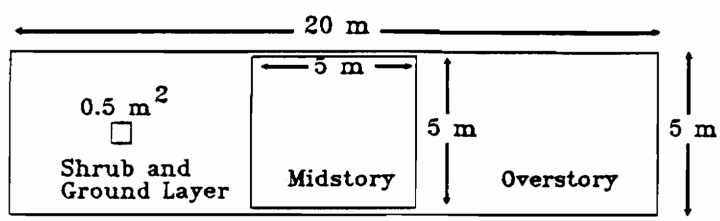


Figure 3.6. Typical strip cruise sampling unit.

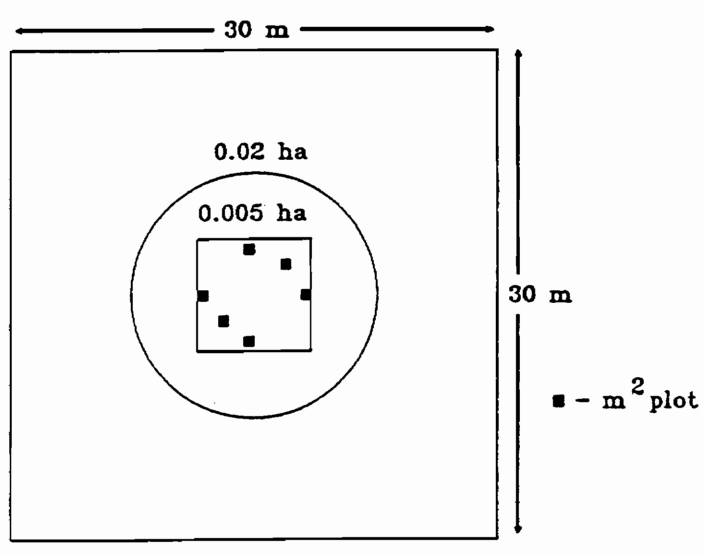


Figure 3.7. Typical fertilization plot sampling unit.

surveys. The overstory was sampled in the entire 0.02 hectare plot. The midstory was sampled in one-quarter of the overstory plot (0.005 ha) by a square plot located in the center. The shrub and ground layers were surveyed by six 1 m by 1 m plots located randomly within the 0.02 hectare circular plot.

All species identifications were performed by the principal investigator to ensure consistency. Several texts were used to assist in this process, but the primary sources were Aquatic and Wetland Plants of Southeastern United States (Godfrey and Wooten, 1981) and Manual of the Vascular Flora of the Carolinas (Radford et al, 1983). All scientific and common names are derived from these texts. Other texts which assisted in the identification process were A Field Guide to Coastal Wetland Plants of the Northeastern United States (Tiner, 1987) and Illustrated Guide to Trees and Shrubs (Graves, 1956). However, of the 52 total plants inventoried, 4 remained unidentified and so were labeled Unknowns A-D. A complete list of all species identified, with scientific and common names, is provided in Appendix A. All grasses and mosses (except sphagnum moss) were grouped together with no species identification.

Wetland values were assigned to each species based on the National List of Plant Species that Occur in Wetlands: National Summary (Reed, 1988). This reference ranks species into one of five categories based on frequency of occurrence in wetlands: obligate wetland (>99% occurrence in wetlands), facultative wetland (66-99% occurrence), facultative (33-66% occurrence), facultative upland (1-33% occurrence), and upland (<1% occurrence). Each species identified on the sites was located in the manual and its appropriate rank noted. Region I was used for the Virginia sites. A number from 1 to 5 was then given to each species based on rank:

Obligate wetland	1
Facultative wetland	2
Facultative	3
Facultative upland	4
Upland	5

Weighted averages were then taken based on numbers and biomass to determine whether treatments caused a shift in vegetation values. Unidentified species, grasses, and mosses were all given a value of 3. Sphagnum moss was given a value of 1.

Vegetation was surveyed from June, 1991 to March 1992. Ground and shrub layer vegetation was surveyed from June to August in 1991. Overstory trees were also sampled during this period. Midstory trees were surveyed from December, 1991 to March 1992.

Site Preparation Treatment Survey

Overstory Survey

Overstory trees were surveyed along the strip cruise in the 4 hectare site preparation treatment plots (see above). Each strip was divided into 20 m (1 chain) by 5 m (0.25 chain) measurement subplots. All trees greater than 8.9 cm (3.5 in.) in diameter at breast height (dbh) were recorded by species. The diameter of every tree was measured with a diameter tape. The height of approximately every fifth loblolly pine was recorded with a height pole. These heights were used to develop a regression equation for loblolly pine to predict height from dbh. This equation was then applied to all loblolly pine trees in the sample plots, even those measured, to estimate heights. The regression equation for loblolly pine is:

$$H = 8.6754 + 0.3170\ D \qquad (r^2=0.4036)$$

where H = height in meters
D = dbh in centimeters

The loblolly height regression equation is discussed more fully in the results section.

The heights of all overstory hardwoods were to be measured with a height pole. Unfortunately, however, due to time constraints, some red maples were not measured for heights. As a result, a regression equation for height based on dbh was developed for this species also and applied to only those trees where height values were not recorded. All heights for all other species were directly measured. The regression equation for red maple is:

$$H = 8.2990 + 0.3714\ D \qquad (r^2=0.3172)$$

where H = height in meters
D = dbh in centimeters

The red maple height regression equation is discussed more fully in the results section.

Dry weight biomass per tree was calculated for the overstory from existing biomass equations in the literature. Two sources were used for these equations. The specific biomass equations used and their sources are:

Loblolly Pine

$$\mathrm{Log}B = -1.0293 + 0.98788\ \mathrm{Log}(D^2H) \qquad (r^2=0.99)$$

where B = dry weight biomass in pounds
D = dbh in inches
H = total height in feet
(Clark and Taras, 1976)

Hardwoods

Red Maple

$$B = 0.14868\ (D^2H)^{0.93969} \qquad (r^2=0.99)$$

Sweetgum

$$B = 0.13234\ (D^2H)^{0.94165} \qquad (r^2=0.99)$$

Water Oak

$$B = 0.23742\ (D^2H)^{0.92299} \qquad (r^2=0.99)$$

White Oak

$$B = 0.20007\ (D^2H)^{0.93915} \qquad (r^2=0.99)$$

Soft Hardwoods

$$B = 0.17484\ (D^2H)^{0.91066} \qquad (r^2=0.99)$$

Hard Hardwoods

$$B = 0.22508\ (D^2H)^{0.92399} \qquad (r^2=0.99)$$

where B = dry weight biomass in pounds
D = dbh in inches
H = total height in feet
(Clark, et al., 1985)

Species specific equations were used where possible. However, the biomass of some species in the overstory was determined using the soft hardwood (swamp tupelo, sassafras, sweetbay, black cherry, and sourwood) and hard hardwood (holly) equations. Also, two species were estimated using the equations from closely related species: willow oak was estimated using the water oak equation and swamp chestnut oak biomass was estimated using the white oak equation.

Midstory Survey

Midstory trees were surveyed along the strip cruise in the 4 hectare site preparation treatment plots. At the midpoint of each 20 m by 5 m overstory plot, a 5 meter by 5 meter square plot was established and all trees less than

8.9 cm (3.5 in.) dbh but greater than 2.5 cm (1 in.) dbh were recorded by species. Diameters were measured with a diameter tape. Heights for all trees were measured with a height pole. Biomass per species was calculated from diameter and height regression equations developed for each species. The methodology for the development of the biomass equations is described later. The equations developed for the midstory trees are:

Red Maple
$B = 380.508 + 31.530\ D^2H$ $(r^2=0.9562)$

Sweetgum
$B = 80.364 + 22.603\ D^2H$ $(r^2=0.9868)$

Black Gum
$B = 565.710 + 26.653\ D^2H$ $(r^2=0.9510)$

Loblolly Pine
$B = 312.611 + 20.513\ D^2H$ $(r^2=0.9056)$

Sweetbay
$B = -122.836 + 29.021\ D^2H$ $(r^2=0.8840)$

Water Oak
$B = 1280.568 + 39.404\ D^2H$ $(r^2=0.9376)$

Holly
$B = 337.443 + 42.665\ D^2H$ $(r^2=0.9947)$

Sourwood
$B = 108.511 + 30.207\ D^2H$ $(r^2=0.9554)$

Swamp Tupelo
$B = 1116.791 + 26.278\ D^2H$ $(r^2=0.9542)$

Shrubs
$B = 755.121 + 42.751\ D^2H$ $(r^2=0.6913)$

where B = biomass in grams
D = dbh in centimeters
H = total height in meters

The midstory biomass regression equations are discussed more fully in the results section.

Shrub and Ground Layer Survey

The shrub and ground layers were surveyed in the 4 hectare site preparation treatment plots using 0.71 meter by 0.71 meter subplots spaced every 20 m (1 chain) along the strip cruise. The first subplot was located 5 m (0.25 chains) from the endpoint, and subplots were spaced 20 m thereafter. This was to prevent disturbance of the ground and shrub layer plots by the midstory plots. Subplots were located in the center of the overstory plot, 2.16 m (7.1 ft.) from each side. All plants less than 2.5 cm (1 in.) dbh and greater than 0.5 meters tall were recorded by species in the shrub layer. All plants less than 0.5 meters tall were recorded in the ground layer. Because of the large number of plants in the shrub and ground layer, average heights for each species were estimated by the surveyor without direct measurement of individual plants. No diameters were taken in either the shrub or ground layer.

Biomass per species in the shrub and ground layers was determined by direct sampling. After number, height, canopy depth, and percent cover measurements had been taken, all material was cut at ground level and bagged by species in paper bags. All collected material was dried at 74 degrees

Celsius in a drying oven for 2 d and then weighed to the nearest 0.01 g. Very small plants, less than 2.5 cm (1 in.) in height, were not collected and were given an assigned value of 0.01 g. In addition, values for sphagnum moss and other mosses were assigned rather than directly measured. Numbers of individuals for mosses were not counted but instead were measured as square centimeters. Biomass was then assigned as 0.01 grams per sq. cm.

Fertilization Treatment Survey

Overstory Survey

Within the fertilization treatments, overstory trees were surveyed in a 0.02 hectare (0.05 acre) circular plot located in the center of the 0.1 acre treatment. All trees greater than 8.9 cm (3.5 in.) dbh were be recorded by species. Diameters were taken with a diameter tape for all trees, and heights were measured with a height pole for every fifth overstory pine and all overstory hardwoods. The measured loblolly pine heights were used in the development of the height equation described earlier, and this same equation was then used to estimate heights for all loblolly pines within the plots. Biomass per tree was calculated from the same biomass equations which were listed previously.

Midstory Survey

Within the fertilization subplots, midstory trees were surveyed on a 0.005 hectare (0.0125 acre) square plot located in the center of the 0.1 hectare treatment. All trees greater than 2.5 cm (1 in.) dbh but less than 8.9 cm (3.5 in.) dbh were recorded by species. Diameters and heights for all trees were measured with a diameter tape and height pole. Biomass per species was calculated using the developed regression equations given earlier.

Shrub and Ground Layer Survey

Shrub and ground layer diversity in the fertilizer treatments was surveyed using 1.0 meter by 1.0 meter plots. Six such plots were located in a hexagonal pattern around the center of the treatment and within the 0.02 hectare overstory plot. The compass bearing and distance from center for the plots was generated randomly. Data collected for these plots was identical to that for the strip cruise plots.

Diversity Indices

Two indices of diversity were used to compare the effects of treatments on species abundance: Simpsons index and the Shannon-Wiener index. Number of individuals and biomass were used as weighting criteria for the determination of proportion values for each canopy layer. In addition, basal area was used as a weighting variable in the midstory and overstory.

Biomass Equations

Midstory biomass equations were developed to predict the dry weight biomass of the trees from dbh and height measurements. The use of biomass equations and direct measurements of dbh and height were suggested by Phillips and Saucier (1982) to accurately predict understory biomass. An equation was derived for each species by sampling 9 trees of various heights and diameters within the 2.5-8.9 cm (1.0-3.5 in.) dbh classes, and a regression curve was fit to the dry weight results. Ten such equations were developed, one for each of nine species and a tenth as a composite for all shrub-like trees. The general form for all equations was:

$$B = a\ D^2H + b$$

where B = biomass in grams
D = dbh in cm
H = total height in meters
a,b = regression coefficients

Sample trees were measured for height and dbh with a height pole and diameter tape, and were cut at ground level with chain saws. All above ground material was then chipped with a 4 HP gasoline chipper. Chipped material was bagged and labeled in paper bags. Harvesting was conducted in September and October of 1991 and again in April 1992. All collected plant material was dried at 74 degrees Celsius in a drying oven for at least 5 days and then weighed to the nearest 0.01 gram.

The nine species for which equations were developed are: red maple, loblolly pine, sweetgum, black gum, swamp tupelo, sweetbay, holly, sourwood, and water oak. The tenth equation was a composite for shrubs such as wax myrtle, gallberry, highbush blueberry, chokeberry, and swamp azalea. The 9 sample trees collected for the shrub equation included 1-3 examples of each species of various diameters. Equations were not developed for some midstory trees inventoried in the survey because they occurred in such low numbers. Instead, one of the other 9 equations was selected which appeared to have a similar growth form to the given species. The rare species and their substitute equations were: sassafras-sweetbay, redbay-swamp tupelo, and black cherry-red maple.

Three trees of each species were harvested and used to test the developed equations. Dbh and height of the trees was measured and the trees were then harvested and chipped. Trees were collected, dried, and weighed in the same manner as the regression samples, and were harvested at the same time. Actual biomass of the test trees was then compared to the predicted biomass from the equations.

Water Table Wells

Water table wells were established on the sites to provide a possible explanation to observed variance within and between treatments. Wells were 3.8 cm (1.5 in.) in diameter and were hand-augered to a depth of approximately 1.8 m (6 ft.). Perforated PVC pipe was used to line the wells. A well was located at the center of each fertilizer treatment plot as well as at the ends and midpoint of each strip cruise line (Figure 3.8). The height of each well above ground level was measured and subtracted from the water table depth recording to standardize data to ground level. Well data were collected every two weeks for 12 months, beginning in June, 1991 and ending in May, 1992. These data were correlated with vegetation measurements of biomass, density, and diversity indices to investigate water table level as a potential causative factor in observed vegetation characteristics.

Vertical structure and percent cover

Vertical structure and percent cover were estimated for the shrub and ground layers as an indicator of potential wildlife diversity. Estimations for percent cover were based on visual estimation. Vertical structure estimations were based on the height of the tallest plant in the canopy layer and the lowest branch height in the layer. Visual estimation of canopy heights were also used for the shrub

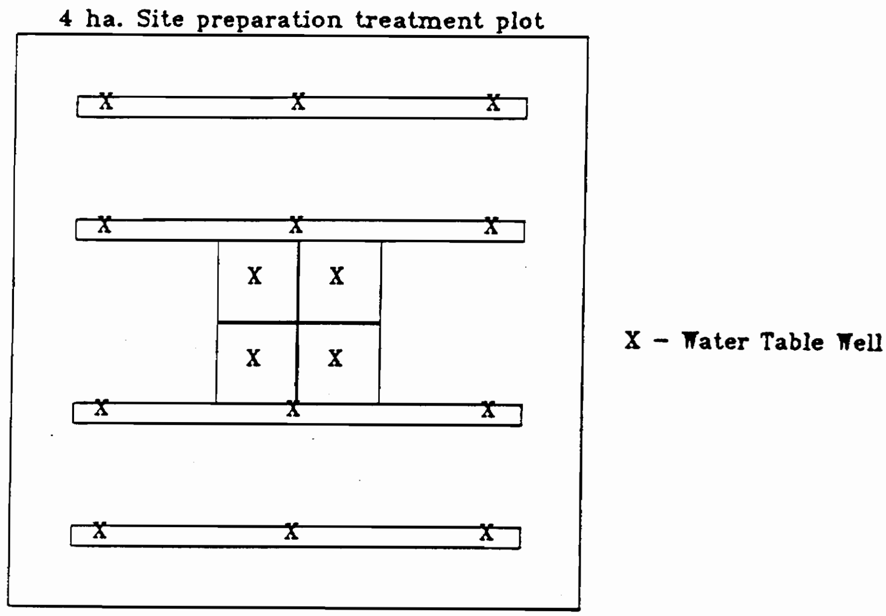


Figure 3.8. Typical well locations in site preparation and fertilization treatments.

and ground layer. Estimations were not made for the midstory and overstory because of the extreme difficulty in separating out the two layers. Because of the often dense, overlapping canopies, estimation of the percent cover and vertical structure in each layer separately would be highly arbitrary and subject to significant bias.

Statistical Analysis

Site Preparation Treatments Analysis

Analyses of the 4-hectare site preparation treatments were accomplished using a standard ANOVA for a randomized block design (Steel and Torrie, 1980). The standardized ANOVA is provided.

Standardized ANOVA for site preparation treatment tests

SOURCE OF VARIANCE	df
Block (B)	2
Site Preparation (SP)	2
Error	4
Total	8

This ANOVA design was used separately from the fertilization split plot design because of potential for the fertilizer plots to be influenced by localized conditions. The fertilization treatment plots were small, only 0.4 hectares in size, and were located in the approximate center of each site preparation treatment area. Therefore, subsampling of the fertilization areas was highly concentrated at one location in the stand and were more susceptible to unrepresentative conditions.

In particular, the bedded treatments exhibited localized, unrepresentative conditions for the fertilization treatment plots. The Holland-bedded fertilizer plot was in the wettest location of the entire study area, and a large portion of the pines in the Whaleyville-bedded fertilizer plot had been killed by bark beetles. Thus, two of the three plots for the bedded and fertilizer treatments had unrepresentative conditions. Therefore, data from the larger, 4-hectare site preparation treatment areas were used to analyze the effect of site preparation, and data from the smaller fertilization treatments were used for the analyses of fertilization effects.

Fertilization Treatment Analysis

Analyses of the 0.1 hectare fertilization treatments was accomplished using a completely randomized block design with a split plot to account for fertilization affects. The generalized ANOVA is given.

Standardized ANOVA for fertilization treatment tests

SOURCE OF VARIANCE	df
Block (B)	2
Site Preparation (SP)	2
Error a	4
Fertilization (F)	3
Site Prep * Fertilization (SP*F)	6
Error b	18
Total (Corrected)	35

Friedman Nonparametric Test

A Friedman nonparametric test was used to synthesize the results of the various parameters across canopy layers. Values for each parameter within a canopy layer were ranked and ranks were then summed and analyzed for all parameters across all canopy layers (Conover, 1971). This analysis allowed overall treatment effects on all parameters to be tested. All parameters were assumed to have equal weight.

Roadside Ditch Covariate

A covariate was used to partition some of the variability within treatments caused by nearby road ditches. Ditches were associated with all roads in the study areas, and the chop and burn and bedded treatments undoubtedly received some drainage. For this reason, distance from individual plots to such roadside ditches was used as a covariate to potentially explain some of the variability within plots in a given treatment. If the covariate proved significant, it was be used on the individual plots of the site preparation treatment data set, and treatment means were calculated from the residuals (Steel and Torrie, 1980).

Diversity Indices and Measurement Data

Biomass, basal area, and density data for each species were used as measures of dominance in the Shannon-Wiener index and Simpsons index. A biodiversity value was calculated for each canopy layer (overstory, midstory, shrub layer, and ground layer) separately. Number of species, total number of plants, total biomass, total basal area, average dbh, average height, percent cover, canopy depth, and average wetland value were also analyzed. Average wetland values were calculated from weighted averages of the vegetation with either biomass or numbers serving as the weighting variable.

Individual Species Responses

The response of individual species to drainage and fertilization treatments was also analyzed. Density and biomass were analyzed for each species occurring in each canopy layer. Not all potential species in a particular canopy layer were tested. Species were selected based on their importance economically, to wildlife habitat, as wetland indicators, or as significant canopy dominants. Individual species were tested only in the site preparation treatment data sets using the same ANOVA design as for the site preparation treatment tests.

Well Data and Canopy Correlations

Well data were correlated to various vegetation characteristics and biodiversity measures for plots which were adjacent to the wells. These tests were first performed with the individual plot as the experimental unit. There was therefore a greatly increased number of observations. However, because all plots were not adjacent to wells, there were fewer tested plots (12) than there were total plots (32) in a treatment area.

These same well data correlations were later tested for the entire treatment area. Water table level recordings for each well were averaged for the treatment area. These results were then correlated to the average vegetation measurements used in the site preparation treatment tests.

Vegetative characteristics were correlated to one another within a canopy layer and between canopy layers. For these tests, both the individual plots and the combined treatment averages were tested. For the individual plot analyses, all plots were used so that the total number of observations was 288. In the combined plot analyses, there were only 9 observations per measurement variable.

Midstory Biomass and Overstory Height Equations

Regression equations were developed for midstory trees to predict biomass from dbh and height and for overstory trees to predict height from dbh. The form of the equations was given previously. The statistical design for all equations was a simple linear regression including a y-intercept.

For the midstory biomass equations, 9 sample trees were used to develop the equation. The general form of the regression design is provided.

Statistical design for midstory biomass regression

SOURCE OF VARIANCE	df
Intercept	1
D^2H	1
Error	6
Total	8

For the two overstory height equations (loblolly pine and red maple), the number of trees in the sample was different. Approximately 700 trees were measured for the loblolly pine equations and 300 trees were measured for red maple. The general form of the regression design for loblolly pine is provided. The design for red maple is identical except for the difference in total and error degrees of freedom.

Statistical design for loblolly height regression

SOURCE OF VARIANCE	df
Intercept	1
Diameter	1
Error	697
Total	699

RESULTS AND DISCUSSION

Midstory Biomass Regression Equations

The ten biomass equations developed for the midstory species all exhibited exceptional linear association (Appendix B). The poorest equation developed was for the miscellaneous shrub category (r^2=0.691), which included five species (highbush blueberry, gallberry, chokeberry, titi, and wax myrtle), all of which tended to have pronounced leaning and extensive horizontal branching. The remaining 9 equations were developed for individual midstory species; the lowest r^2 value was 0.884 for sweetbay, and the average r^2 value was 0.947. The equation for American holly had the highest r^2 value at 0.995.

Models were validated by comparing predicted values to actual values for three trees not used in the model data set (Table 4.1). The ratio of actual biomass to predicted biomass, can be used to judge the equation accuracy. The average ratio for all trees in all equations was 1.068, indicating an underestimation by the equations of approximately 7 percent, which is within an acceptable range. Similarly, Phillips and Saucier (1982) found only a 3.7% overestimation in predicting biomass when using the same methods. The equations for the two most important species, red maple and sweetgum, had good predicted:actual biomass ratios. In general, the results indicate that the

Table 4.1. Comparison of actual and predicted biomass for midstory test trees.

Species	DBH (cm)	Height (m)	Actual Biomass (g)	Predicted Biomass (g)	Ratio
Red Maple	6.45 5.60 6.60	10.80 10.70 11.15	13101 10484 16680	14666 10915 15713	0.893 0.961 1.062
Sweetgum	2.80 5.60 6.60	5.60 8.40 9.40	1088 6239 10234	1068 6009 9347	1.019 1.038 1.095
Black Gum	4.20 3.15 7.60	6.35 5.75 7.35	2986 1534 13090	3538 2111 11941	0.844 0.727 1.096
Loblolly	8.10 8.00 8.25	10.35 9.70 10.65	14688 14229 13238	14339 13050 15200	1.024 1.090 0.871
Water Oak	5.70 8.00 6.75	8.60 10.50 10.70	14129 38408 24760	12349 27767 20383	1.144 1.383 1.215
Swamp Tupelo	6.60 5.60 8.25	7.30 7.80 7.60	12728 8874 18696	9483 7517 14726	1.342 1.181 1.270
Sweetbay	7.60 5.85 7.50	12.30 9.50 12.00	20986 10215 19562	20849 9532 19675	1.007 1.072 0.994
Holly	8.40 8.40 6.35	6.10 7.60 6.60	24052 25513 9392	18622 23119 11692	1.292 1.104 0.803
Sourwood	7.25 8.00 4.05	7.50 9.90 4.65	16637 20659 2839	11981 19252 2428	1.389 1.073 1.169
Shrubs	3.05 2.65 3.15	4.90 4.80 3.10	3892 1721 1389	2701 2215 2091	1.441 0.777 0.664
Average					1.068

methodology for the development of the midstory equations was adequate.

Overstory Height Regression Equations

The regression equations developed for predicting heights of overstory trees did not exhibit very strong correlations (Figures 4.1 and 4.2). The equation for loblolly pine which was developed from 741 trees had an r^2 value of 0.404. The equation for red maple was developed from 377 trees and had an r^2 value of 0.317. Figures 4.1 and 4.2 show that the data were linearly oriented but exhibited wide fluctuations about the regression line.

Regression equations were also tested for loblolly pine in which the data were sorted according to site and treatment. A regression equation for predicting height from dbh was developed for each site and treatment combination (9 equations). However, these equations did not significantly improve upon the predictive value of the original single equation. The single equations developed from all sites combined were thus used to predict heights for loblolly pine and red maple.

The poor predictive value of these equations undoubtedly reduced the ability to accurately predict the actual height and, consequently, biomass of the treatment areas. However, because the equations were developed based

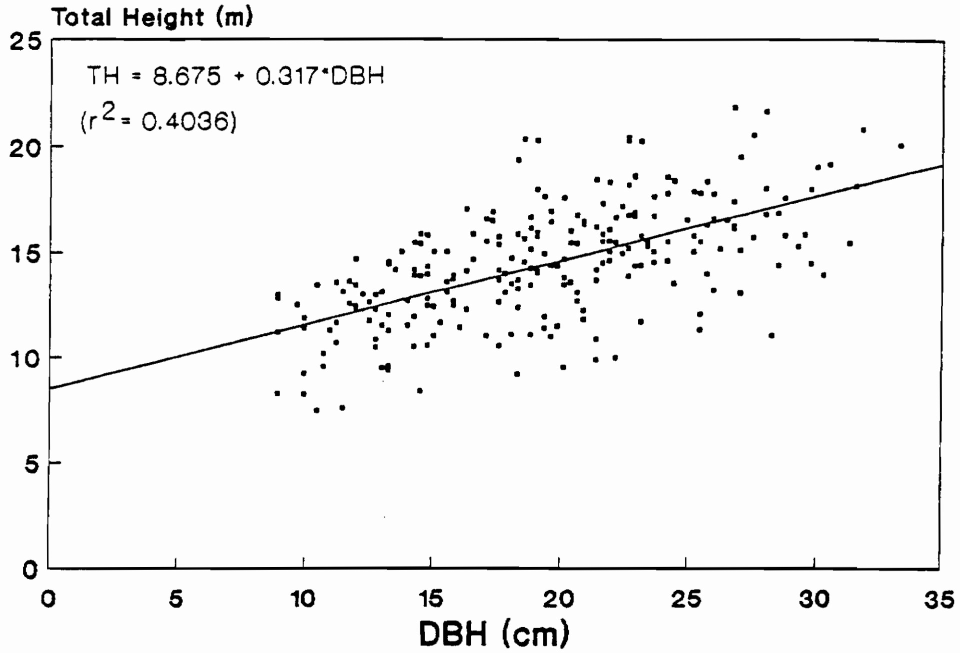


Figure 4.1. Height regression equation for overstory loblolly pine.

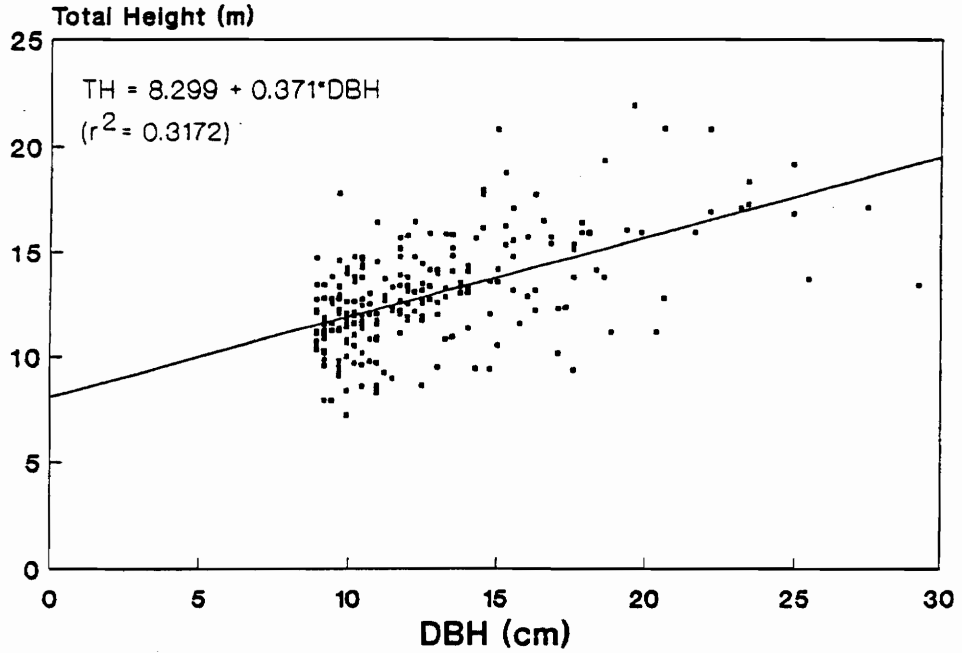


Figure 4.2. Height regression equation for overstory red maple.

on data from all treatment areas and were then applied to all treatment areas, differences detected between treatments were still valid.

Site Preparation Treatment Effects on Biodiversity

Sample Size and Species Richness

Species richness (number of species per treatment area) is strongly influenced by sample size. Richness increases as sample size increases, eventually leveling off asymptotically (Pielou, 1975). It was therefore important to observe whether the samples taken in each canopy layer approached a constant richness value.

To conduct this test, the 32 sample plots in the hydrology treatment areas were randomly selected and ordered. Cumulative species counts were made in each canopy layer as each plot was recorded (Figures 4.3-4.6). In all cases, the overstory, midstory, and shrub layer appear to have reached an approximate asymptote and richness is not increasing with added samples. The ground layer was an exception and an asymptote was not definitely achieved. Much greater variability existed across a treatment area for ground layer vegetation because of the microscale of habitat heterogeneity. Adequate sampling was therefore more difficult. It is possible that the ground layer was under-sampled for determining species richness. However, the presence or absence of such very rare species is unlikely to

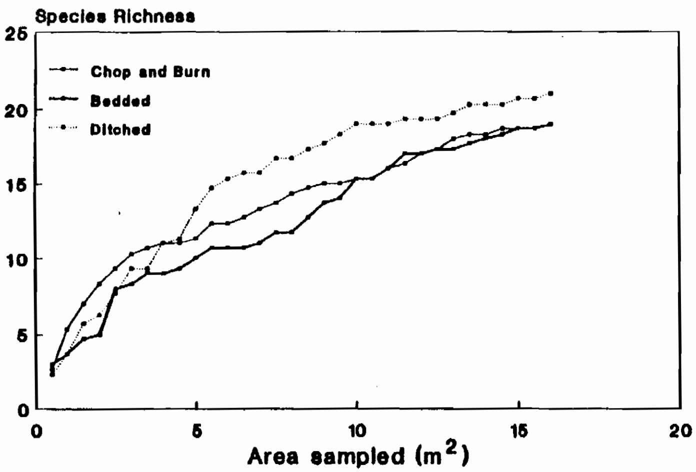


Figure 4.3. Ground layer species richness with increasing sample size.

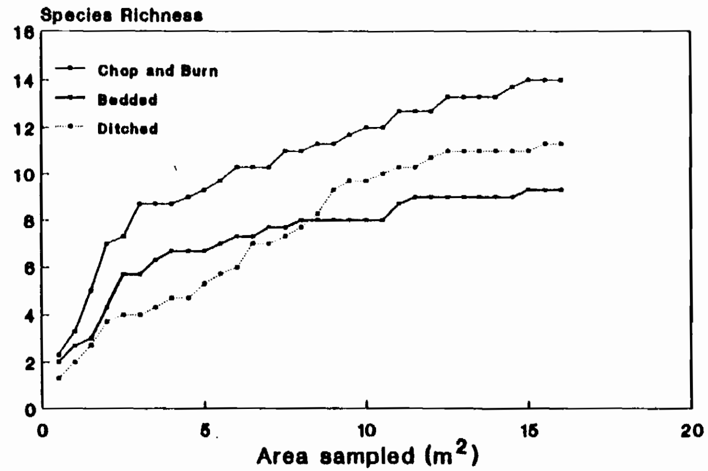


Figure 4.4. Shrub layer species richness with increasing sample size.

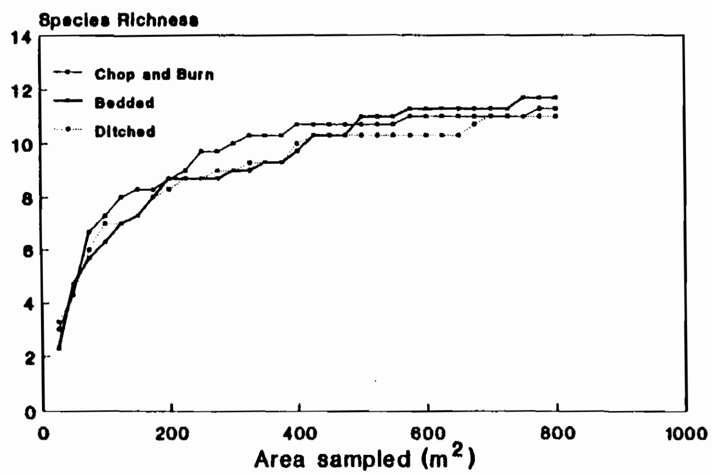


Figure 4.5. Midstory species richness with increasing sample size.

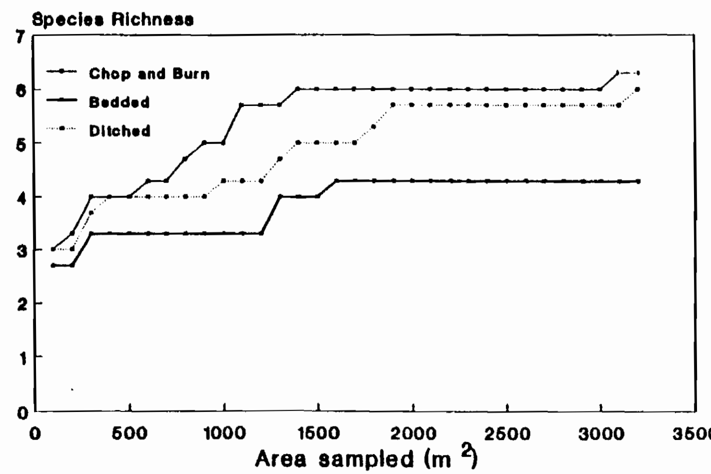


Figure 4.6. Overstory species richness with increasing sample size.

affect the results of other vegetation measurements, such as total biomass or percent cover, and so comparisons among these should remain valid.

The relationship between species richness among the canopy layers can also be observed (Figures 4.3-4.6). In general, richness increased in the lower canopy layers. The average number of species in each canopy layer across all treatments was:

ground layer	19.7 species
shrub layer	11.5 species
midstory	11.3 species
overstory	5.5 species

Again, this is due in part to the scale of habitat heterogeneity for small versus large plants. Also, in each layer there existed certain "resident species," and the juveniles of all of the higher canopy layers. For example, the ground layer contained species which were naturally small or low-growing and a variety of seedlings and sprouts of species found in higher canopy layers. The only two canopy layers which seemed to violate this trend are the midstory and shrub layers (Holland-bedded, Holland-ditched, and Whaleyville-bedded). This may be due to overlap in species with the potential to occupy both layers. It may also be due to a direct site preparation treatment effect because bedding may have decreased the shrub layer species richness more than the midstory species richness Two of the three cases involve the bedding treatment.

Site Differences

Notable site (block) differences were detected from the analyses of the site preparation treatment data (Tables 4.2-4.5). In general, site differences in the ground layer were slight (Table 4.2) while differences in the shrub layer, midstory, and overstory were more pronounced (Tables 4.3-4.5). None of the parameters showed a significant difference between sites in the ground layer. Within the shrub layer, the Windsor block possessed greater biomass and diversity, and the Whaleyville block had higher average wetland values. The Holland block midstory was clearly more diverse than either the Windsor or Whaleyville blocks. The Whaleyville and Windsor sites possessed greater overstory biomass, average dbh, and average height than the Holland site. These site results do not suggest any direct management alternatives, but they are pertinent to the water table data which are given later. Differences observed are probably the result of differences in water table level between sites.

Table 4.2. Ground layer site differences based on site preparation treatment data.

	Block			Statistics	
Parameter	Holland	Windsor	Wh.ville	Std.Dev.	p-level
Total Biom (kg/Ha)	130.15	126.84	188.04	17.532	0.1167
S-W Biom[1]	1.836	1.434	1.453	0.1764	0.2997
Sim Biom[2]	0.759	0.674	0.680	0.0551	0.5290
Total N/Ha	1234167	2438958	1321667	1176365	0.7393
S-W Num[3]	1.622	0.782	1.231	0.5140	0.5617
Sim Num[4]	0.591	0.324	0.501	0.2183	0.7015
Av. Height (cm)	8.47	8.93	11.01	1.006	0.2751
% Cover	4.73	4.19	4.70	1.402	0.9546
Can. Dep.[5] (cm)	23.79	25.22	29.48	2.067	0.2240
# Species	22.3	18.7	18.0	1.811	0.2984
Val. Num[6]	2.277	1.666	2.321	0.6358	0.7362
Val. Biom[7]	2.201	2.138	2.521	0.1087	0.1293

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Canopy depth (top of canopy layer to lowest branch)
6 - Wetland value weighted for numbers
7 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Table 4.3. Shrub layer site differences based on site preparation treatment data.

	Block			Statistics	
Parameter	Holland	Windsor	Wh.ville	Std.Dev.	p-level
Total Biom (kg/Ha)	6544.7**b***	8466.2**b**	3967.4**a**	680.840	0.0237
S-W Biom[1]	1.427**a**	1.765**b**	1.333**a**	0.0571	0.0126
Sim Biom[2]	0.690**a**	0.779**b**	0.641**a**	0.0289	0.0648
Total N/Ha	99167	130000	102708	9568.60	0.1532
S-W Num[3]	1.355	1.210	1.303	0.1635	0.8248
Sim Num[4]	0.555	0.495	0.601	0.0682	0.5853
Av. Height (m)	1.561	1.308	0.948	0.2724	0.3727
% Cover	15.78	15.07	8.09	2.1626	0.1165
Can. Dep.[5] (m)	1.314	1.451	0.981	0.1800	0.2765
# Species	12.3	12.0	10.3	1.0184	0.4143
Val. Num[6]	2.232**a**	2.179**a**	2.425**b**	0.0550	0.0699
Val. Biom[7]	2.253	2.301	2.244	0.0782	0.8628

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Canopy depth (top of canopy layer to lowest branch)
6 - Wetland value weighted for numbers
7 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Table 4.4. Midstory site differences based on site preparation treatment data.

	Block			Statistics	
Parameter	Holland	Windsor	Wh.ville	Std.Dev.	p-level
Total Biom (kg/Ha)	20016.2	16781.9	14994.9	2034.11	0.3146
S-W Biom[1]	1.739b*	1.395a	1.493a	0.0613	0.0372
Sim Biom[2]	0.738b	0.638a	0.642a	0.0212	0.0471
Total N/Ha	3175.0	2991.7	2545.8	272.59	0.3442
S-W Num[3]	1.989b	1.554a	1.748a	0.0673	0.0256
Sim Num[4]	0.795b	0.694a	0.740ab	0.0196	0.0546
Total BA (m^2/Ha)	6.09	5.39	4.63	0.5346	0.2682
S-W BA[5]	1.833b	1.469a	1.648ab	0.0710	0.0545
Sim BA[6]	0.768b	0.682a	0.711ab	0.0208	0.0985
Av. DBH (cm)	4.63	4.56	4.40	0.0897	0.3090
Av. Height (m)	6.73	6.95	6.52	0.1589	0.2731
# Species	13.0b	10.3a	10.7a	0.4714	0.0302
Val. Num[7]	2.936	2.877	2.932	0.0454	0.6323
Val. Biom[8]	2.952	2.930	2.978	0.0332	0.6325

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Shannon-Wiener index weighted for basal area
6 - Simpsons index weighted for basal area
7 - Wetland value weighted for numbers
8 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Table 4.5. Overstory site differences based on site preparation treatment data.

	Block			Statistics	
Parameter	Holland	Windsor	Wh.ville	Std.Dev.	p-level
Total Biom (kg/Ha)	87940**a***	95781**ab**	110214**b**	5087.58	0.0832
S-W Biom[1]	0.805	0.571	0.566	0.1027	0.2816
Sim Biom[2]	0.420	0.286	0.270	0.0641	0.2992
Total N/Ha	1284.9	1152.6	1278.1	88.750	0.5468
S-W Num[3]	0.977	0.892	0.815	0.0753	0.4012
Sim Num[4]	0.522	0.483	0.427	0.0482	0.4451
Total BA (m^2/Ha)	23.89	25.50	29.09	1.3592	0.1178
S-W BA[5]	0.791	0.588	0.556	0.0957	0.2800
Sim BA[6]	0.413	0.296	0.267	0.0603	0.3015
Av. DBH (cm)	14.74**a**	16.06**b**	16.19**b**	0.3374	0.0689
Av. Height (m)	13.36**a**	13.67**b**	13.87**b**	0.1002	0.0534
# Species	6.0	6.0	4.7	1.3472	0.7390
Val. Num[7]	2.998	2.999	2.997	0.0025	0.8956
Val. Biom[8]	2.998	3.000	3.000	0.0010	0.3901

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Shannon-Wiener index weighted for basal area
6 - Simpsons index weighted for basal area
7 - Wetland value weighted for numbers
8 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Site Preparation Effects

Ground Layer

Total biomass in the ground layer was highest on the bedded areas (p=0.1081), but density was not affected (Figure 4.7). Bedding produced greater ground layer biomass than the ditched treatment. The chop and burn treatment's total biomass was intermediate between the bedded and the ditched. None of the other vegetative parameters analyzed were significantly affected by the three site preparation treatments (Table 4.6). Numbers of plants per hectare followed the same trend as biomass but differences were not significant. Diversity was not significantly affected by the treatments. Average wetland

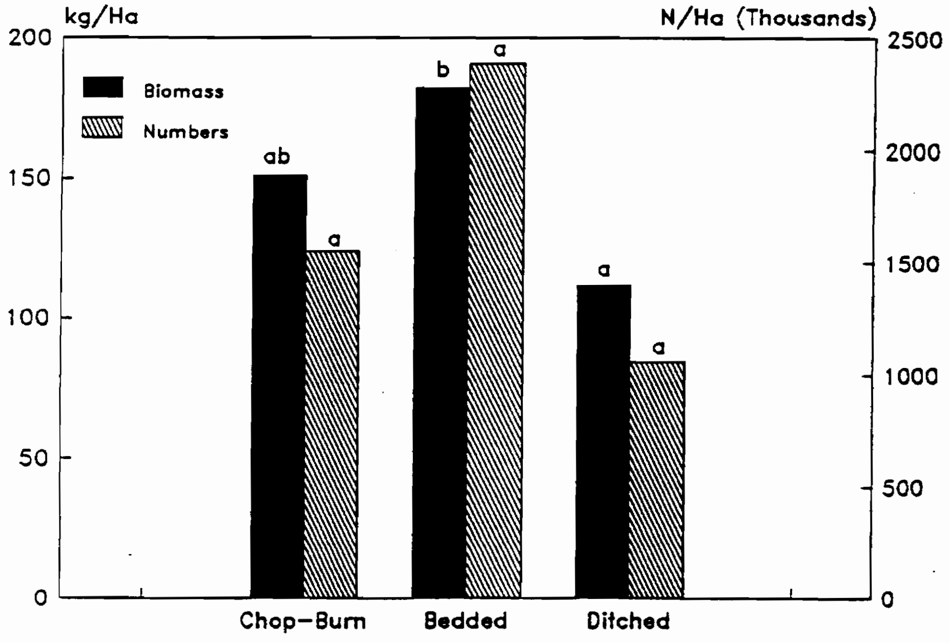


Figure 4.7. Effects of site preparation treatments on ground layer biomass and density (Same letters indicate no significant difference, Fishers LSD test).

Table 4.6. Ground layer site preparation treatment differences.

	Site Preparation Treatment			Statistics	
Parameter	Chop-Burn	Bedded	Ditched	Std.Dev.	p-level
Total Biom (kg/Ha)	151.07**ab**	182.32**b***	111.64**a**	17.532	0.1081
S-W Biom[1]	1.583	1.439	1.701	0.1764	0.6143
Sim Biom[2]	0.728	0.686	0.699	0.0551	0.8615
Total N/Ha	1550625	2387292	1056875	1176365	0.7388
S-W Num[3]	1.313	0.784	1.539	0.5140	0.6068
Sim Num[4]	0.502	0.324	0.590	0.2183	0.7041
Av. Height (cm)	9.68	10.06	8.67	1.0064	0.6350
% Cover	4.53	6.30	2.78	1.4024	0.3129
Can. Dep.[5] (cm)	25.14	27.49	25.85	2.0673	0.7298
# Species	19.0	19.0	21.0	1.8105	0.6905
Val. Num[6]	2.204	1.675	2.386	0.6358	0.7320
Val. Biom[7]	2.186	2.400	2.274	0.1087	0.4506

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Canopy depth (top of canopy layer to lowest branch)
6 - Wetland value weighted for numbers
7 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

vegetation value was similarly unaffected by treatments.

The increase in ground layer biomass caused by the bedded treatment has two possible explanations. First, bedding creates an irregular soil surface composed of ridges and furrows. Such conditions may create increased surface heterogeneity, thus supporting more ground layer plants. However, the diversity measurements did not support this hypothesis. The increase in biomass in the bedded ground layer is probably a response to reduced competition from the midstory and shrub layer. As presented later, bedding reduced midstory and shrub layer biomass. Halls and Schuster (1965) and Wolters (1982) found an inverse relationship between overstory basal area or percent cover and understory production in pine forests. Thus, the ground layer may be exhibiting a response to reduced competition.

Data of interest in these results include the very low percent cover values and the high number of species encountered in the 4 ha treatment areas. Total numbers per hectare are very high because of the presence of sphagnum moss in the ground layer. In addition, average wetland value weighted by numbers for the bedded treatment is very low because of the occurrence of sphagnum moss (wetland value = 1).

Shrub Layer

Secondary ditching reduced the number of plants in the shrub layer by almost 50 percent at age 23 (p=0.0191) (Figure 4.8). However, biomass results for the shrub layer did not follow the same trend and effects were not significant. Ditching may have affected numbers and not biomass due to its effect on switch cane. Switch cane density was reduced by the ditched treatment, and since cane has little mass per individual, total numbers were reduced more than biomass.

Bedding reduced diversity in the shrub layer based on three of five measures (Table 4.7). The Shannon-Wiener index and Simpson's index weighted for biomass showed

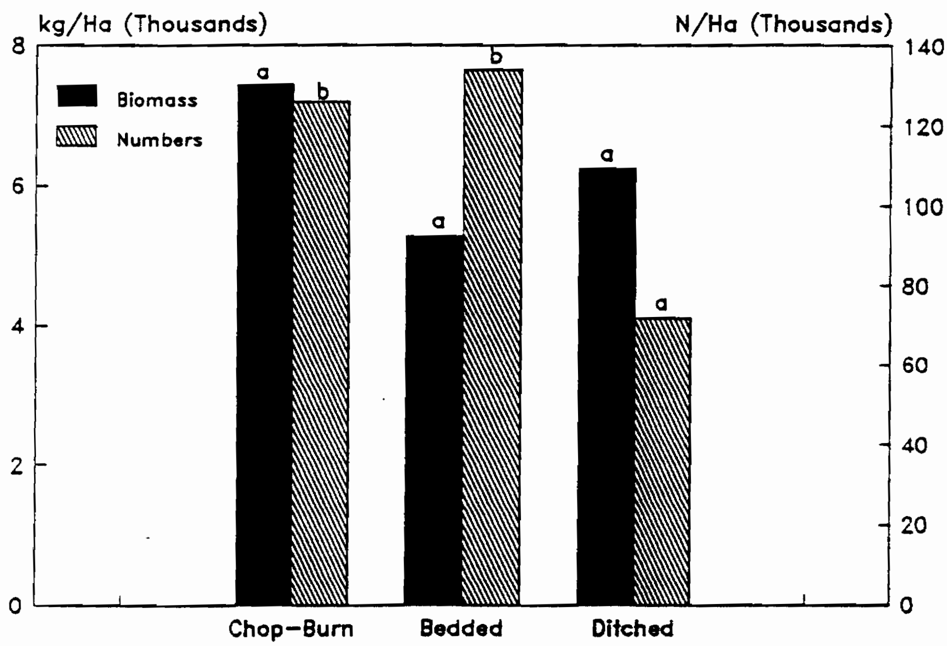


Figure 4.8. Effects of site preparation treatments on shrub layer biomass and density (Same letters indicate no significant difference, Fishers LSD test).

Table 4.7. Shrub layer site preparation treatment differences.

	Site Preparation Treatment			Statistics	
Parameter	Chop-Burn	Bedded	Ditched	Std.Dev.	p-level
Total Biom (kg/Ha)	7444.8	5289.8	6243.8	680.840	0.1962
S-W Biom[1]	1.637**b**[*]	1.276**a**	1.613**b**	0.0571	0.0191
Sim Biom[2]	0.715**ab**	0.633**a**	0.760**b**	0.0289	0.0823
Total N/Ha	126042**b**	133958**b**	71875**a**	9568.60	0.0191
S-W Num[3]	1.376	1.000	1.492	0.1635	0.2000
Sim Num[4]	0.582	0.452	0.618	0.0682	0.3007
Av. Height (m)	1.349	1.048	1.419	0.2724	0.6283
% Cover	16.90	13.32	8.73	2.1626	0.1283
Can. Dep.[5] (m)	1.56	1.08	1.10	0.1800	0.2237
# Species	14.0**b**	9.3**a**	11.3**ab**	1.0184	0.0754
Val. Num[6]	2.293	2.196	2.347	0.0550	0.2577
Val. Biom[7]	2.234	2.179	2.385	0.0782	0.2679

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Canopy depth (top of canopy layer to lowest branch)
6 - Wetland value weighted for numbers
7 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

significant decreases for the bedded treatment (Figure 4.9). Number of species was also reduced 33 percent in the bedded treatment as compared to the chop and burn (p=0.0754) (Figure 4.10). The other two measures of diversity (Shannon-Wiener index and Simpson's index weighted to numbers) showed identical trends though the effects were not significant. Overall, bedding decreased shrub layer diversity while not affecting shrub layer biomass or density.

These results suggest that certain shrub layer species of these wet pine flats may be sensitive to bedding disturbances. Bedding involves considerable soil movement and redistribution, especially when combined with windrowing as in these study areas, affecting stump sprouting and vegetative regeneration. Allen and Campbell (1988) state that shrub and hardwood competition control is a distinct benefit of bedding to pine growth, in addition to improving soil aeration. Bedding-sensitive species may be reduced or eliminated in the shrub layer throughout stand development, resulting in reduced diversity. The elimination of such rare species would have minimal impact on total biomass or density for the stand. In addition, species which survive the disturbance (e.g., switch cane and pepperbush) may proliferate from reduced competition, causing productivity to be unaffected.

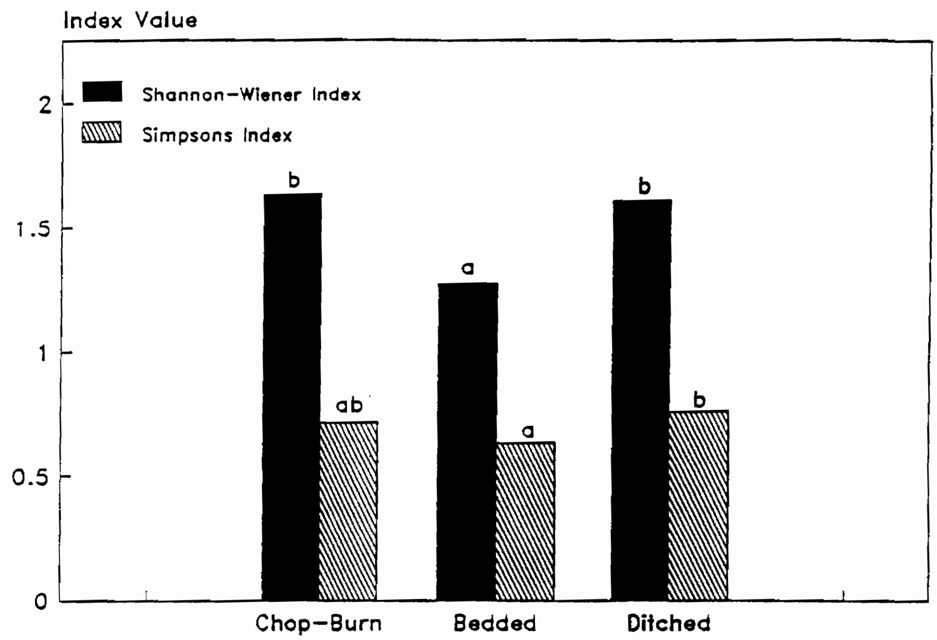


Figure 4.9. Effects of site preparation treatments on shrub layer diversity indices weighted by biomass (Same letters indicate no significant difference, Fishers LSD test).

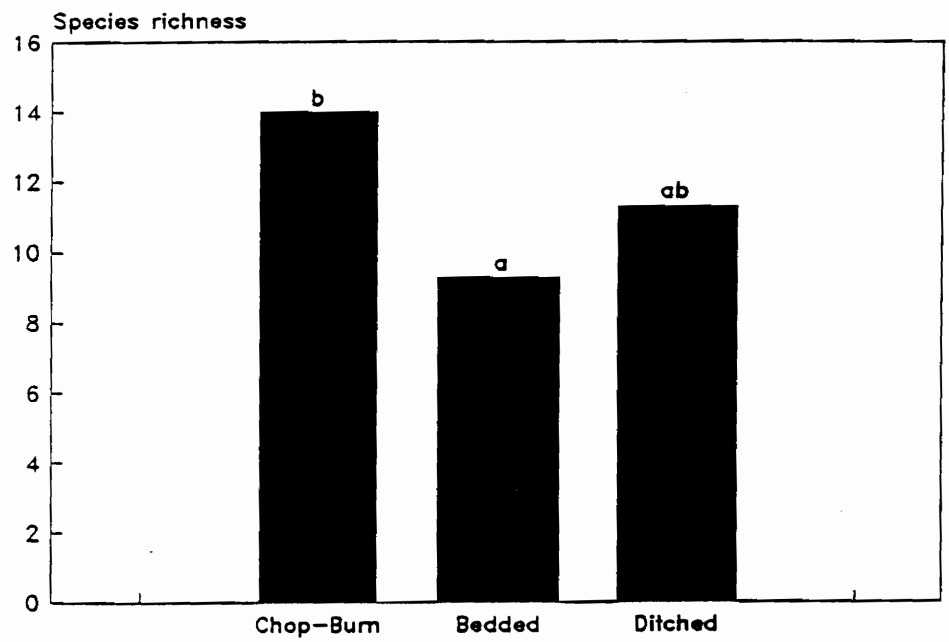


Figure 4.10. Effects of site preparation treatments on shrub layer species richness (Same letters indicate no significant difference, Fishers LSD test).

Midstory

The bedding treatment greatly affected biomass, density, and diversity within the midstory canopy layer (Table 4.8). All measures of productivity (biomass, density, and basal area) indicated that bedding caused a significant decrease for midstory vegetation (Figures 4.11 and 4.12). Biomass exhibited a greater relative decrease (>50 percent) than either density or basal area, suggesting that the trees are smaller in addition to being fewer in number. Productivity parameters within the chop and burn treatment and the ditched treatment were not different. These treatments were probably similar because of the limited effect of ditching beyond approximately 50 meters from the ditch.

Although bedding produced a significant decrease in midstory biomass and density, the bedded treatment interestingly exhibited significantly greater diversity (Figures 4.13 and 4.14). Simpson's index weighted by either biomass or numbers indicated an increase in diversity for the bedded treatment. All other diversity indices followed the same trend though the results were not significant (Table 4.8). The chop and burn and ditched treatments had no effect on midstory diversity, again suggesting a limited ditching effect.

Bedding treatments reduced midstory biomass and density while increasing midstory diversity. This suggests that

Table 4.8. Midstory site preparation treatment differences.

	Site Preparation Treatment			Statistics	
Parameter	Chop-Burn	Bedded	Ditched	Std.Dev.	p-level
Total Biom (kg/Ha)	21198.8**b***	9146.1**a**	21448.0**b**	2034.11	0.0206
S-W Biom[1]	1.464	1.646	1.518	0.0613	0.2151
Sim Biom[2]	0.630**a**	0.737**b**	0.651**a**	0.0212	0.0479
Total N/Ha	3318.8**b**	1883.3**a**	3510.4**b**	272.59	0.0250
S-W Num[3]	1.673	1.840	1.778	0.0673	0.3143
Sim Num[4]	0.697**a**	0.783**b**	0.749**ab**	0.0196	0.0851
Total BA (m^2/Ha)	6.49**b**	3.25**a**	6.37**b**	0.5346	0.0209
S-W BA[5]	1.582	1.712	1.657	0.0710	0.4943
Sim BA[6]	0.687	0.763	0.711	0.0208	0.1334
Av. DBH (cm)	4.64	4.45	4.50	0.0897	0.3810
Av. Height (m)	6.73	6.95	6.52	0.1589	0.2731
# Species	11.3	11.7	11.0	0.4714	0.6400
Val. Num[7]	2.942	2.938	2.865	0.0454	0.4719
Val. Biom[8]	2.976	2.952	2.931	0.0332	0.6527

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Shannon-Wiener index weighted for basal area
6 - Simpsons index weighted for basal area
7 - Wetland value weighted for numbers
8 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

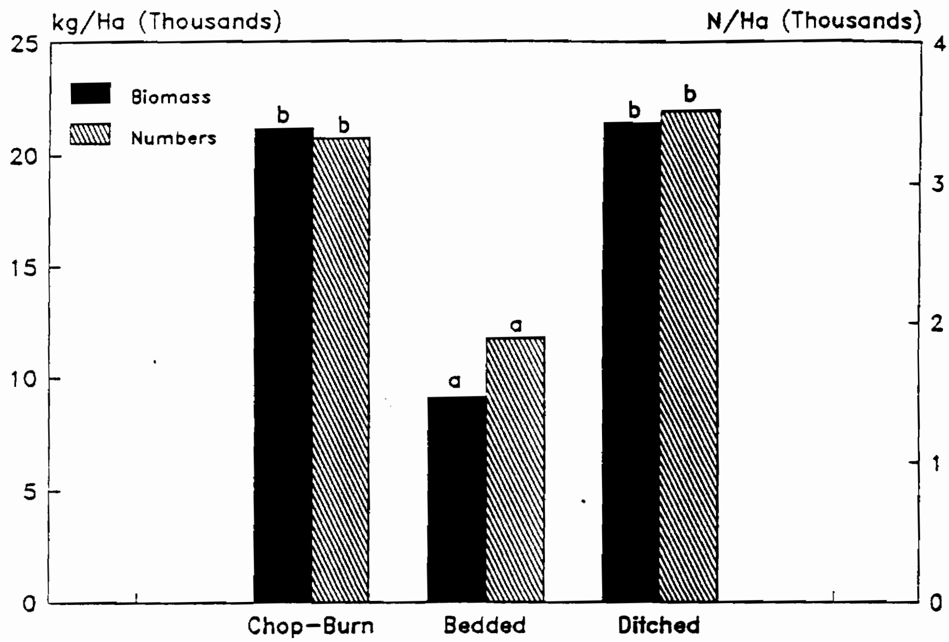


Figure 4.11. Effects of site preparation treatments on midstory biomass and density (Same letters indicate no significant difference, Fishers LSD test).

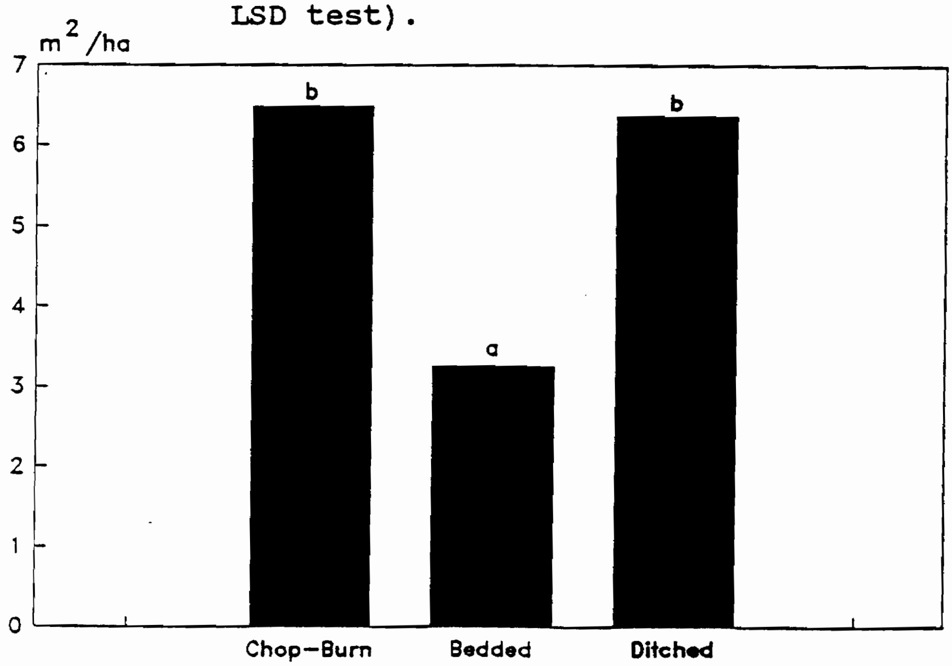


Figure 4.12. Effects of site preparation treatments on midstory basal area (Same letters indicate no significant difference, Fishers LSD test).

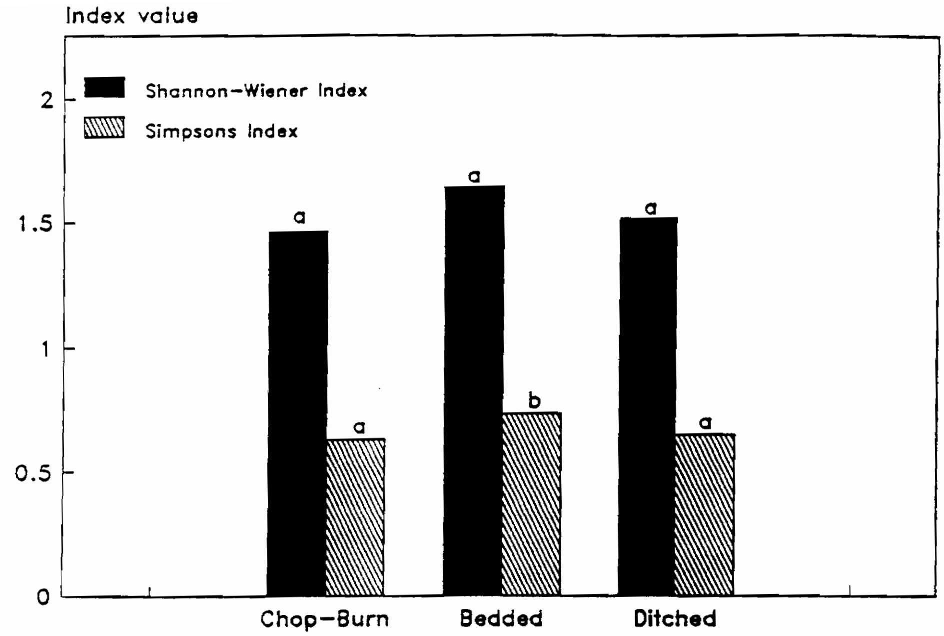


Figure 4.13. Effects of site preparation treatments on midstory diversity indices weighted by biomass (Same letters indicate no significant difference, Fishers LSD test).

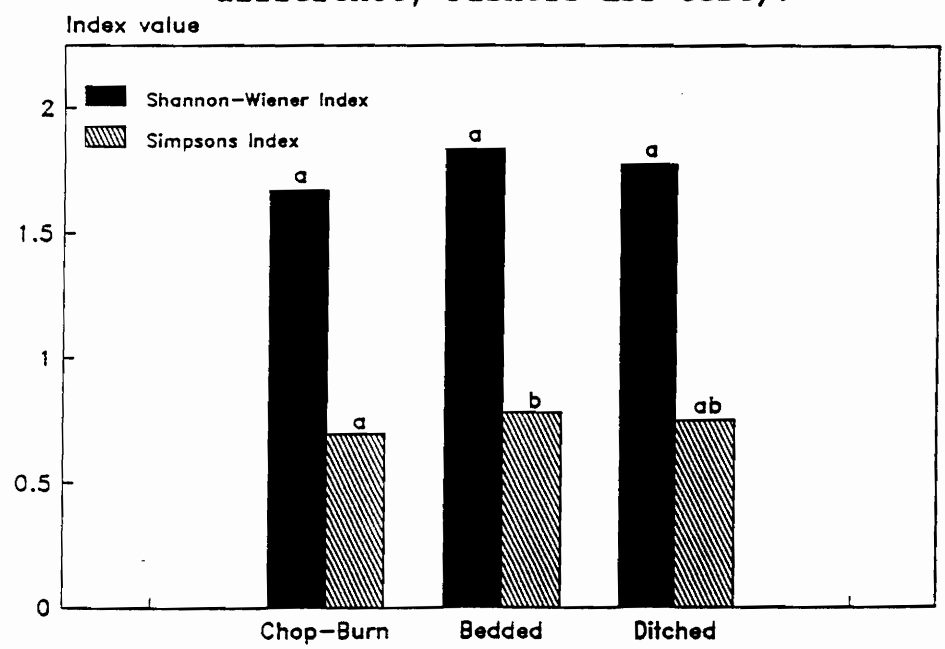


Figure 4.14. Effects of site preparation treatments on midstory diversity indices weighted by numbers (Same letters indicate no significant difference, Fishers LSD test).

bedding disturbances may impact the regeneration and growth of dominant midstory species. The most common midstory tree in the study areas was red maple which tended to grow in dense clusters from a common rootstock. Many other species grew singly or in smaller clusters. The drastic site disturbance of bedding may have limited the sprouting of red maple and other dominants. If bedding reduced the sprouting vigor of red maple, total numbers and biomass would be reduced while diversity would increase as the proportional contributions of other midstory species increased.

Overstory

Total biomass (p=0.0154) and basal area (p=0.0214) were significantly affected by site preparation treatment (Figures 4.15 and 4.16). In addition, average total height results followed the same trend (p=0.0270) (Figure 4.16). Bedding produced the highest results for the three variables, followed by ditched and then chop and burn. Treatment means were all significantly different from one another for all three variables. Number of trees was not affected by treatment, although the trend was identical.

Diversity at age 23 years was not affected in the overstory by any of the seven parameters used (Table 4.9). In addition, all diversity values were relatively low compared to values of the other canopy layers. Auclair and Goff (1971) found Shannon-Wiener index values ranging from

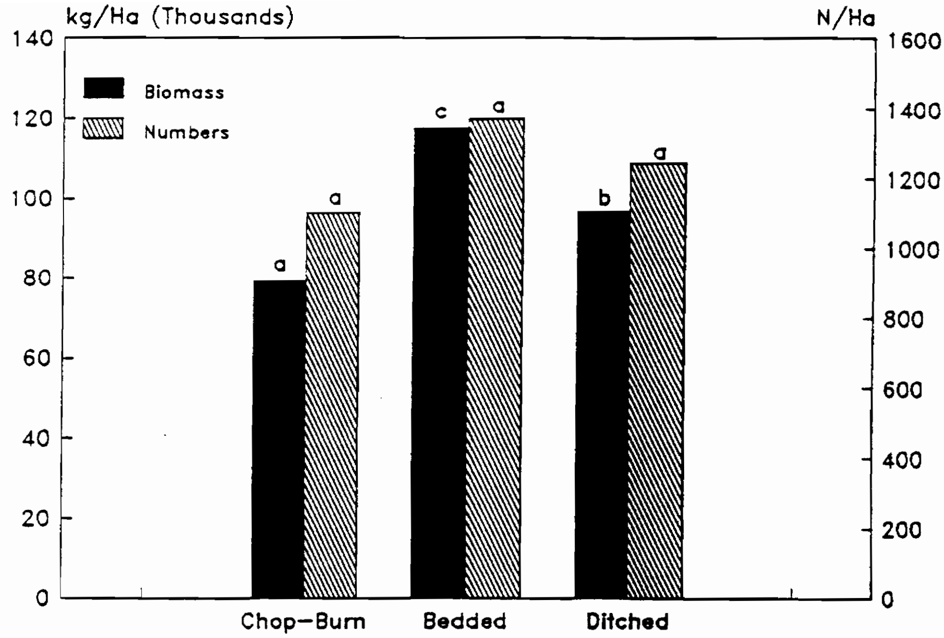


Figure 4.15. Effects of site preparation treatments on overstory biomass and density (Same letters indicate no significant difference, Fishers LSD test).

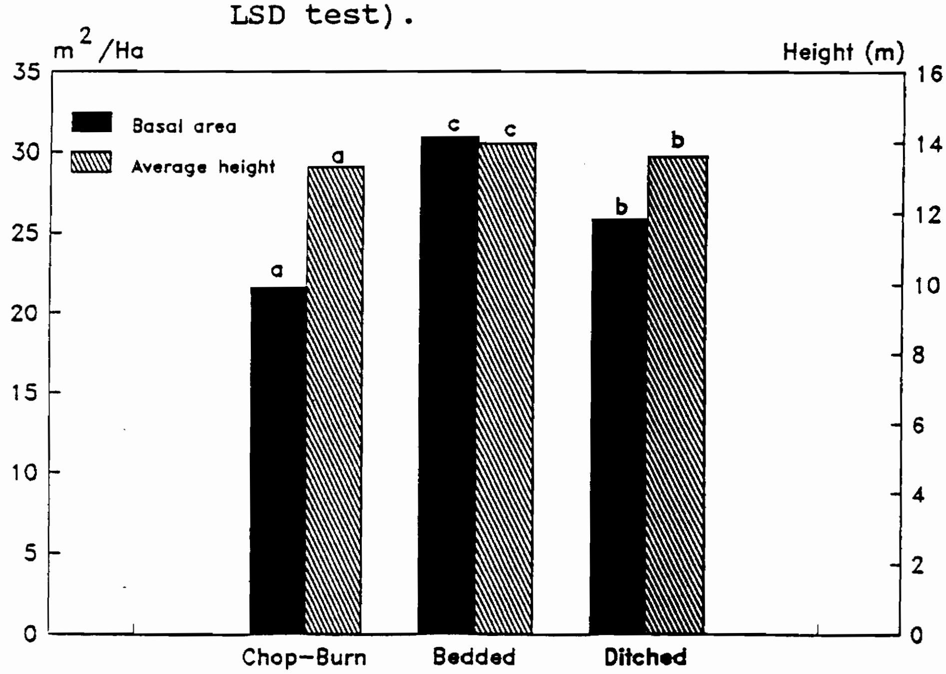


Figure 4.16. Effects of site preparation treatments on overstory basal area and height (Same letters indicate no significant difference, Fishers LSD test).

Table 4.9. Overstory site preparation treatment differences.

	Site Preparation Treatment			Statistics	
Parameter	Chop-Burn	Bedded	Ditched	Std.Dev.	p-level
Total Biom (kg/Ha)	79413**a**[*]	117587**c**	96934**b**	5087.58	0.0154
S-W Biom[1]	0.597	0.681	0.665	0.1027	0.8333
Sim Biom[2]	0.281	0.373	0.321	0.0641	0.6328
Total N/Ha	1101.6	1369.8	1244.3	88.750	0.2177
S-W Num[3]	0.908	0.830	0.946	0.0753	0.5849
Sim Num[4]	0.475	0.467	0.490	0.0482	0.9468
Total BA (m^2/Ha)	21.66**a**	30.94**c**	25.88**b**	1.3592	0.0214
S-W BA[5]	0.610	0.673	0.652	0.0957	0.8954
Sim BA[6]	0.293	0.364	0.318	0.0603	0.7194
Av. DBH (cm)	15.31	16.27	15.41	0.3374	0.1987
Av. Height (m)	13.31**a**	13.95**c**	13.63**b**	0.1002	0.0270
# Species	6.3	4.3	6.0	1.3472	0.5771
Val. Num[7]	2.994	3.001	3.000	0.0025	0.2199
Val. Biom[8]	2.998	2.999	3.000	0.0010	0.5011

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Shannon-Wiener index weighted for basal area
6 - Simpsons index weighted for basal area
7 - Wetland value weighted for numbers
8 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

approximately 1.0 to 1.9 with an average of 1.4 across a variety of upland stands in the Great Lakes area. Swindel, et al. (1984) noted Simpsons index diversity values of approximately 0.9 for six-year old slash pine plantations in Florida. Overstory diversity in these wet flat plantations was low due to the extreme dominance of loblolly pine. The fact that diversity was not affected by treatments indicates that some hardwoods persist and reach the overstory regardless of site preparation methods.

Wetland vegetation values, weighted by either numbers or biomass, were virtually identical for all site preparation treatments (Table 4.9) because the four most dominant trees in the overstory (loblolly pine, red maple, sweetgum, and water oak) all have an wetland index value of 3. Overstory species in these wet flat plantations were largely ubiquitous, common species in the southeastern U.S.

Overall, these results indicate that bedding and ditching can increase overstory productivity without decreasing overstory diversity. For example, the bedded treatment yielded 48 percent more biomass than the chop and burn control, but none of the measures of diversity were significant different ($p>0.50$). Bedding and ditching have consistently been reported to increase the growth of overstory pines in wet flats (Wilhite and Jones, 1981; Langdon, 1962; Maki, 1971; Campbell, 1976). This study supports those previous findings. Altering site hydrology during regeneration produces long-term gains in overstory growth. The fact that overstory diversity was unaffected is an important observation. However, as noted earlier, diversity in other canopy layers has been affected, particularly by bedding.

The increase in overstory biomass for the bedded treatment over the ditched could result from several factors. First, bedding provides a degree of competition control that is not achieved by ditching. Secondly, the ditched areas may actually be over-drained during dry periods, allowing overstory trees to experience moisture stress. In addition, the beneficial effects of ditching may decrease with increasing distance from the ditches. This would result in a stand with regions of high and low overstory biomass, the overall effect depending on ditch spacing.

Fertilization Treatment Effects on Biodiversity

Site Differences

Site (block) differences were detected by the analyses of fertilizer data (Appendix C). These results are generally consistent with those observed in the site preparation treatment data. Ground layer and overstory vegetation data were similar for all sites. Only species richness varied between sites in the ground layer, with the Holland site having a greater number of species. No significant site differences were detected in the overstory data. However, unlike the site preparation treatment data, the shrub layer and midstory data also exhibited few differences. Total shrub layer biomass was significantly less for the Whaleyville site, as was canopy depth. At the Holland site, midstory vegetation exhibited higher average wetland values when weighted by numbers or biomass.

The site preparation treatment data will be considered to be more representative of site differences because the site preparation data had a larger, more widely dispersed sampling design. Any discrepancies in site differences between the site preparation and fertilizer treatment data sets are probably due to localized conditions in the small fertilizer plots.

Site Preparation Treatment Effects

Some discrepancies existed between the site preparation treatment effects in the fertilization treatment data as opposed to the site preparation treatment data. Again, these differences are probably due to the area of sampling. The fertilization treatment plots were small, only 0.1 hectares in size apiece, and were located in the approximate center of each site preparation treatment area. Therefore, subsampling of the fertilization areas was highly concentrated at one location in the stand and were more susceptible to unrepresentative conditions.

The results of the site preparation treatment analyses for the fertilizer data set are provided in Appendix D. Due to the difficulties presented above, these results are provided primarily as references. The unrepresentative conditions of the bedded treatments are primarily apparent in the overstory biomass results. Bedding exhibited significantly greater biomass in the overstory based on the site preparation data analyses, but shows significantly less biomass than either the chop and burn or the ditched in the fertilization data. This is probably due to the localized water table and insect damage conditions in the bedded-fertilizer plots discussed previously. Because drastic changes in overstory composition can cause "trickle down" effects in lower canopy layers, the results observed in these analyses have been confounded by previous events. For example, many ground layer differences in diversity, density, and wetland value appeared in the fertilization data which were not detected in the site preparation data.

Fertilization Treatment Effects

Ground Layer

Fertilization at stand age 10 resulted in few significant effects in the ground layer vegetation at stand age 23 (Table 4.10). Species richness (number of species)

Table 4.10. Ground layer fertilization treatment differences.

	Fertilization Treatment				Statistics	
Parameter	Control	P	NP	NPL	St.Dev.	p-level
Total Biom (kg/Ha)	222.74	215.79	170.58	179.31	33.941	0.8774
S-W Biom[1]	1.007	0.969	0.990	0.933	0.0849	0.9541
Sim Biom[2]	0.502	0.492	0.488	0.462	0.0281	0.9633
Total N/Ha	246852	286482	881482	351482	324246	0.1898
S-W Num[3]	1.506	1.340	1.510	1.273	0.1389	0.4556
Sim Num[4]	0.672	0.608	0.646	0.572	0.0541	0.5569
Av. Height (cm)	9.92	9.88	8.60	9.11	3.4046	0.7321
% Cover	4.72**a**[*]	5.52**a**	8.02**b**	5.17**a**	2.9515	0.0570
Can. Dep.[5] (cm)	30.95	26.48	31.66	24.69	9.0480	0.2145
# Species	9.8**a**	9.0**a**	12.0**b**	9.0**a**	0.8165	0.0500
Val. Num[6]	2.718	2.592	2.587	2.581	0.1314	0.9540
Val. Biom[7]	2.331	2.466	2.398	2.376	0.0694	0.8089

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Canopy depth (top of canopy layer to lowest branch)
6 - Wetland value weighted for numbers
7 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

was significantly greater (p=0.0500) in the NP treatment as compared to the other fertilizer treatments. In addition, percent cover was higher in the NP treatment compared to other treatments (p=0.0570). There was no significant interaction between site preparation and fertilization treatments.

These results, like the site preparation results, may be an indirect result of conditions in higher canopy layers. Because many of the species in the ground layer are seedlings or sprouts surviving on parental nutrients, it is likely that their most limiting resources are light and water. Fertilization may have affected higher canopy layers, altering competition conditions for these resources in the ground layer. This possibility will be discussed in greater detail with the shrub layer results presented hereafter.

Percent cover in the ground layer was closely associated with the presence of sphagnum moss. Supporting this concept, density followed the same trend as percent cover though the response was not significant (Table 4.10). Total biomass showed the opposite trend as percent cover. Perhaps the presence of dense sphagnum moss limits the growth of other ground layer species (e.g., by holding water within its tissues). Sphagnum moss may be responding to nitrogen fertilization, but not to nitrogen and lime because of changes in soil acidity. Sphagnum moss is commonly associated with acidic sites (Mitsch and Gosselink, 1986). The reason such changes in competition affected percent cover and species richness while not significantly affecting total biomass, total numbers or plant diversity is unclear.

Shrub Layer

Shrub layer biomass was lower in the NP treatment compared to both the control and the NPL treatment (Figure 4.22). These results suggested that fertilization with nitrogen and phosphorous increases midstory and overstory production, thereby limiting shrub layer growth. Liming appeared to provide a mitigating effect to such overstory dominance. However, as will be discussed later, trends in

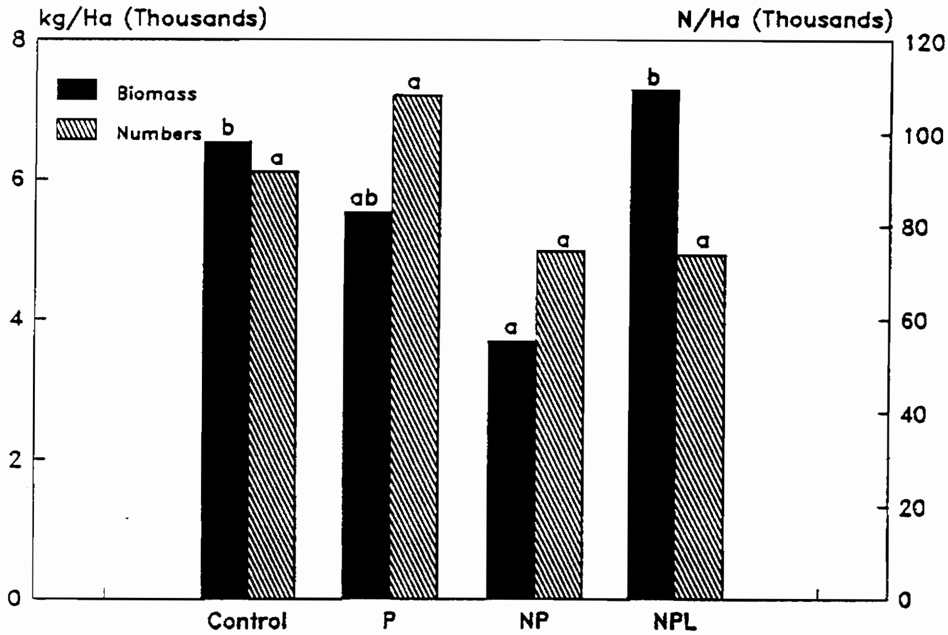


Figure 4.17. Effects of fertilizer treatments on shrub layer biomass and density (Same letters indicate no significant difference, Fishers LSD test).

the midstory and overstory do not support such a hypothesis.

It is speculated that fertilizing with phosphorous produces little effect in the shrub layer. However, the addition of nitrogen allows for the increased growth of sphagnum moss in the ground layer as discussed earlier, exerting a negative effect on growth in the shrub layer. Lime may restrict the growth of sphagnum moss (which prefers acidic conditions (Mitsch and Gosselink, 1986), allowing the shrub layer to utilize the increased levels of nitrogen and phosphorous.

Shrub layer results also support the assertion that nitrogen had a direct negative effect on shrub layer growth. Studies have shown decreases in tree growth when both nitrogen and phosphorous are applied compared to applications of only phosphorous (Blatt, 1964; Das, 1963). Such effects may result from changes in N:P ratio, affecting protein synthesis, or by inhibiting mycorrhizal growth. These effects may also limit shrub layer productivity with nitrogen fertilization. Liming would appear to mitigate the response, possibly by increasing phosphorous availability and changing the N:P ratio yet again. Given this possibility, the ground layer increases in percent cover and species richness may have been due to decreased competition. However, as noted earlier, it is unclear as to which is the cause and which is the effect. Ground layer results may be due to shrub layer conditions or vice versa.

Similar to biomass results, wetland vegetation value results exhibited unexpected trends which were not consistent between the two weighting measures used (Table 4.11). When the wetland values were weighted by number of individuals, the NP treatment showed a significantly higher value (p=0.0480). When wetland values were weighted by biomass, P and NPL showed the highest value and NP and the control were lowest. The reason for this complex interaction is uncertain, but it probably relates to individual species responding to nutrient conditions from fertilization rather than hydrology characteristics.

Midstory

The midstory exhibited only one significant response to the fertilization treatments. The wetland vegetation value weighted by biomass was greater in the P treatment as compared to the other three (p=0.0814) (Table 4.12). However, although the difference was significant, the absolute difference between treatment values was relatively small. The difference between the lowest value (NP) and the highest value (P) was only 0.111. The observed differences may relate to the nutritional requirements of a few midstory species. The narrow range of absolute differences suggests that several species with higher wetland values (3 or 4)

Table 4.11. Shrub layer fertilization treatment differences.

	Fertilization Treatment				Statistics	
Parameter	Control	P	NP	NPL	St.Dev.	p-level
Total Biom (kg/Ha)	6547**b***	5516**ab**	3689**a**	7294**b**	1090.9	0.0754
S-W Biom[1]	1.162	0.980	1.138	1.104	0.0981	0.6702
Sim Biom[2]	0.606	0.511	0.583	0.579	0.0563	0.6521
Total N/Ha	91667	108148	74630	73704	12509	0.4141
S-W Num[3]	1.119	0.993	1.162	1.083	0.1089	0.6477
Sim Num[4]	0.545	0.511	0.591	0.517	0.0432	0.6445
Av. Height (m)	1.13	1.34	1.01	1.33	0.4387	0.2918
% Cover	23.76	22.57	15.91	23.63	8.5359	0.1187
Can. Dep.[5] (m)	1.69	1.87	1.36	2.03	0.7732	0.2136
# Species	6.1	5.3	5.4	5.9	0.5949	0.6895
Val. Num[6]	2.293**a**	2.375**ab**	2.503**b**	2.317**a**	0.0727	0.0480
Val. Biom[7]	2.351**a**	2.660**c**	2.449**ab**	2.618**bc**	0.0872	0.0610

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Canopy depth (top of canopy layer to lowest branch)
6 - Wetland value weighted for numbers
7 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Table 4.12. Midstory fertilization treatment differences.

	Fertilization Treatment				Statistics	
Parameter	Control	P	NP	NPL	St.Dev.	p-level
Total Biom (kg/Ha)	13059	14803	14265	15747	2208.1	0.7311
S-W Biom[1]	0.954	0.756	0.992	0.888	0.1095	0.6331
Sim Biom[2]	0.533	0.432	0.543	0.499	0.0504	0.6160
Total N/Ha	2688.9	3188.9	2911.1	2800.0	362.72	0.8002
S-W Num[3]	1.023	0.835	1.122	1.034	0.1344	0.4561
Sim Num[4]	0.559	0.464	0.624	0.556	0.0628	0.2134
Total BA (m^2/Ha)	4.27	4.66	4.47	5.27	0.6249	0.5437
S-W BA[5]	0.979	0.816	1.038	0.892	0.1096	0.5908
Sim BA[6]	0.548	0.466	0.577	0.500	0.0474	0.4996
Av. DBH (cm)	4.41	4.22	4.17	4.62	0.1744	0.2780
Av. Height (m)	7.12	7.15	7.05	7.13	0.2170	0.9892
# Species	3.8	3.4	3.8	3.8	0.4681	0.9434
Val. Num[7]	2.956	3.077	2.936	3.004	0.0482	0.2432
Val. Biom[8]	2.946**a***	3.056**b**	2.945**a**	2.996**ab**	0.0231	0.0814

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Shannon-Wiener index weighted for basal area
6 - Simpsons index weighted for basal area
7 - Wetland value weighted for numbers
8 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

increased with the application of phosphorous due to nutritional needs rather than hydrology conditions.

No other measured vegetative characteristic varied significantly between treatments. Of particular importance, the total biomass and total numbers results were not significantly different ($p>0.70$). Diversity values were also unaffected by treatments. These results suggest that midstory productivity and diversity are more closely associated with hydrologic characteristics and disturbance during regeneration. The site preparation results revealed a variety of productivity and diversity responses while fertilization showed almost none.

Overstory

Total biomass, total basal area, and average height were all significantly affected by fertilization (Figures 4.18 and 4.19). The NPL treatment increased values for all measurements. Other treatments were not significantly different. Total numbers and average dbh followed the same trend as the biomass and basal area results (C=P=NP<NPL), though differences were not significant (Table 4.13).

These productivity results suggest that liming produces an important productivity response in the overstory. While the control, P, and NP treatments exhibited almost identical biomass results, the NPL treatment showed an increase of approximately 25 percent. Similar responses were observed

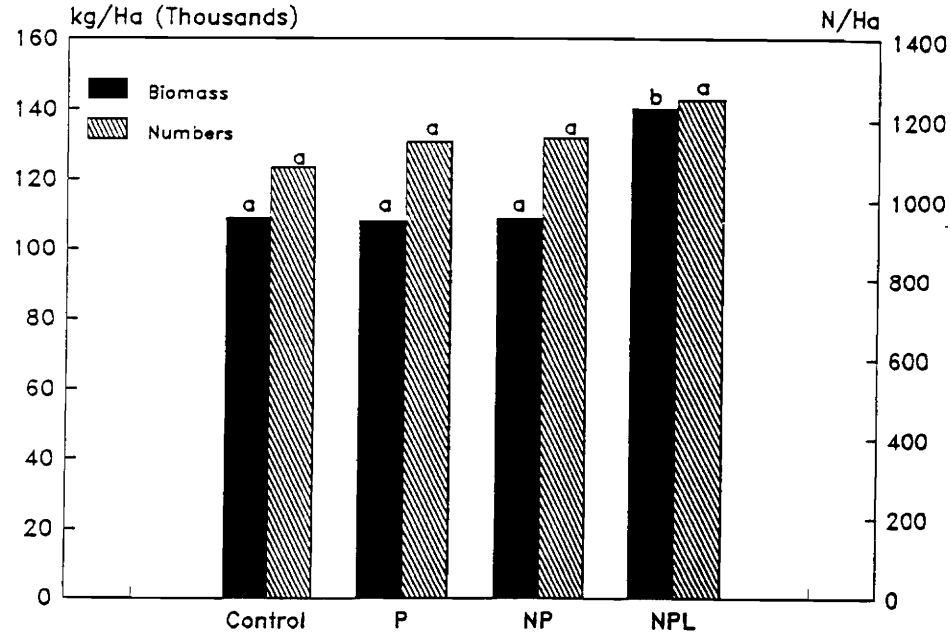


Figure 4.18. Effects of fertilizer treatments on overstory biomass and density (Same letters indicate no significant difference, Fishers LSD test).

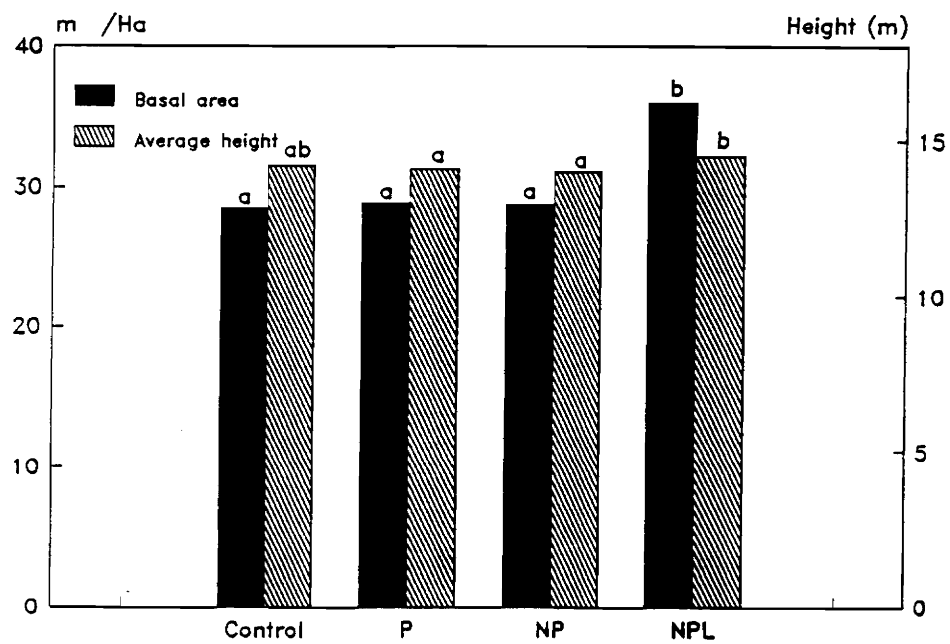


Figure 4.19. Effects of fertilizer treatments on overstory basal area and average height (Same letters indicate no significant difference, Fishers LSD test).

Table 4.13. Overstory fertilization treatment differences.

	Fertilization Treatment				Statistics	
Parameter	Control	P	NP	NPL	St.Dev.	p-level
Total Biom (kg/Ha)	109248a	*108403a	109129a	140254b	6739.3	0.0220
S-W Biom[1]	0.157	0.140	0.167	0.126	0.0453	0.8356
Sim Biom[2]	0.075	0.070	0.078	0.058	0.0269	0.8828
Total N/Ha	1080.6	1144.4	1152.8	1250.0	43.182	0.1998
S-W Num[3]	0.360	0.289	0.392	0.309	0.0774	0.6861
Sim Num[4]	0.207	0.167	0.227	0.179	0.0516	0.6983
Total BA (m^2/Ha)	28.5a	28.9a	28.8a	36.0b	1.6932	0.0281
S-W BA[5]	0.175	0.156	0.191	0.141	0.0511	0.7986
Sim BA[6]	0.086	0.081	0.093	0.066	0.0314	0.8461
Av. DBH (cm)	17.44	17.23	16.93	18.23	0.4209	0.1978
Av. Height (m)	14.2ab	14.1a	14.0a	14.5b	0.1375	0.0862
# Species	2.1	1.9	2.1	2.0	0.1727	0.8898
Val. Num[7]	3.000	3.000	3.006	3.000	0.0028	0.4155
Val. Biom[8]	3.000	3.000	3.002	3.000	0.0008	0.4155

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Shannon-Wiener index weighted for basal area
6 - Simpsons index weighted for basal area
7 - Wetland value weighted for numbers
8 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

in the shrub layer and midstory, though the midstory response was not significant ($p>0.70$). Liming may reduce soil acidity in wet pine flats, thereby, increasing nutrient availability and uptake. Thompson and Troeh (1978) state that liming could often be used in place of repeated phosphorous fertilization to increase tree growth. However, the fact that phosphorous fertilization did not show a response suggests that phosphorous may not be limiting. Liming may also increase the availability of calcium which is essential to tree growth. Wetland soils (including the Myatt and Rains series) have been found to be deficient in calcium (Plummer, 1963; Monk, 1965). Due to the lack of response in nitrogen or phosphorous fertilization, calcium or magnesium deficiencies may be a distinct possibility in these stands.

Diversity measurements were not significantly affected by fertilization treatments. Of particular interest are the generally low values of all of the diversity indices and species richness measurements in the overstory. Diversity index values are much lower (average of 0.07 for Simpsons index weighted by biomass) inside the fertilizer plots than outside in the site preparation treatment areas (average of 0.33). This condition may be the result of the hand release which was used on the fertilizer plots during time of fertilization. Hardwood trees were cut with hand tools to release the pines in coordination with fertilization. This treatment appears to have had a long-term impact on overstory diversity.

Total Site Biomass and Canopy Proportions

Total site biomass was determined by simply summing the biomass of each canopy layer. The proportional contribution of each canopy layer to the total was then calculated. Statistical analyses were conducted on the total site biomass and canopy proportions data. Block differences (Holland, Windsor, or Whaleyville) are not presented because these results have few management implications. In addition, site preparation treatment differences for the fertilization data are not presented for the reasons discussed earlier.

Site Preparation Treatment Results

The chop and burn treatment had significantly less biomass (p=0.0540) than either the bedded or the ditched treatments (Figure 4.20). Because the ground and shrub layers constituted such a small percentage of total site biomass, these results primarily indicate the response of midstory and overstory trees. This suggests that altered water levels during the regeneration stage of development had a long-term impact on total stand growth through rotation age. Allen and Campbell (1988) state that bedding

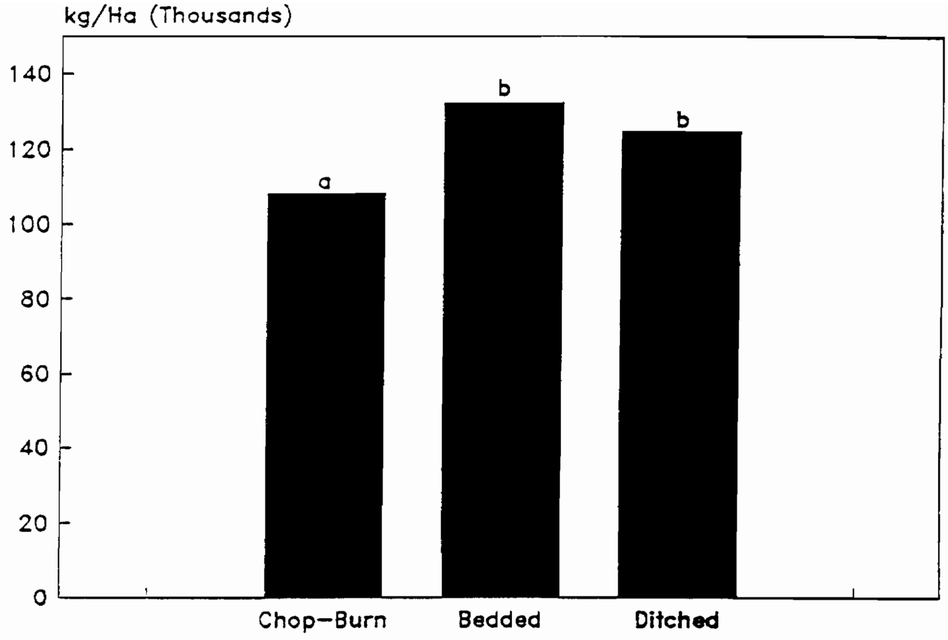


Figure 4.20. Effects of site preparation treatments on total site biomass (Same letters indicate no significant difference, Fishers LSD test).

or ditching increases in early stand growth can be maintained through stand development if fertility is adequate. Whether this increase in growth justifies the added expense of bedding or ditching from a wood production perspective is undetermined for these sites.

Bedding tended to concentrate total site biomass in the overstory at the expense of lower layers (Figure 4.21). Shrub layer (p=0.1032) and midstory (p=0.0146) biomass were reduced compared to both the chop and burn and the ditched treatments. Overstory biomass in the bedded treatment had a significantly greater (p=0.0148) percentage of the total

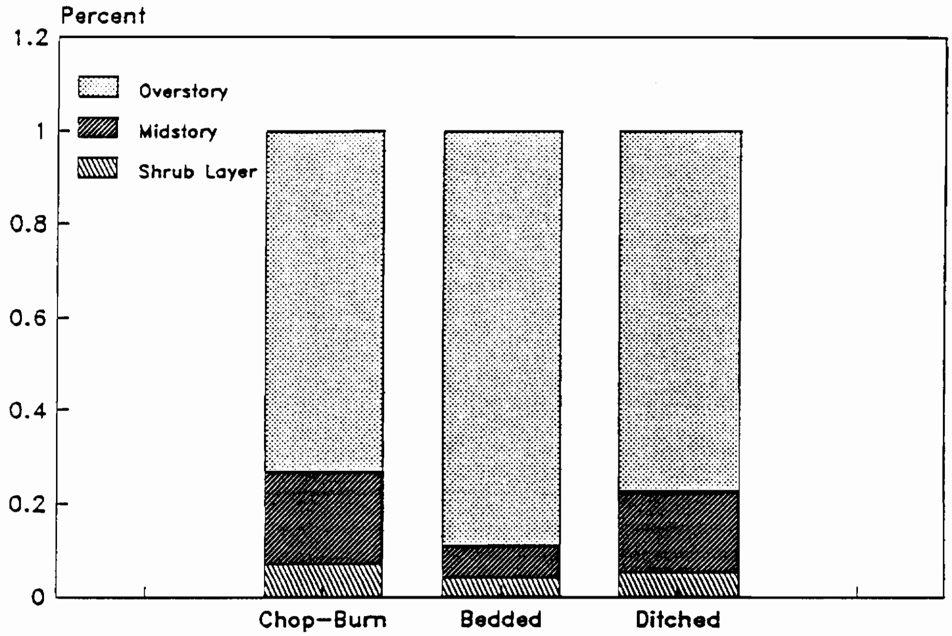


Figure 4.21. Effects of site preparation treatments on distribution of biomass between canopy layers (Same letters indicate no significant difference, Fishers LSD test).

biomass than either the chop and burn or the ditched. These results support the earlier assertion that bedding, in addition to altering site hydrology during regeneration, reduces the sprouting vigor of shrubs and midstory hardwoods, thereby, creating a long-term shift in stand biomass and diversity. The ground layer was unaffected primarily because it contained such a small percentage of the total site biomass and because few of the plants in the ground layer regenerate from sprouts.

Fertilization Treatment Results

Fertilization significantly affected total site biomass (Figure 4.22). Total biomass was greatest on the NPL treatment compared to the other three (p=0.0078). These results are similar to the overstory results reported earlier, indicating the degree to which total site biomass is dominated by the overstory. Apparently, liming produces a vigorous response in tree growth which is not achieved by fertilization alone. As noted, this is believed to result from increases in calcium availability which may be deficient on these soils (Monk, 1965; Plummer, 1963), although magnesium was also applied through the lime and could be limiting.

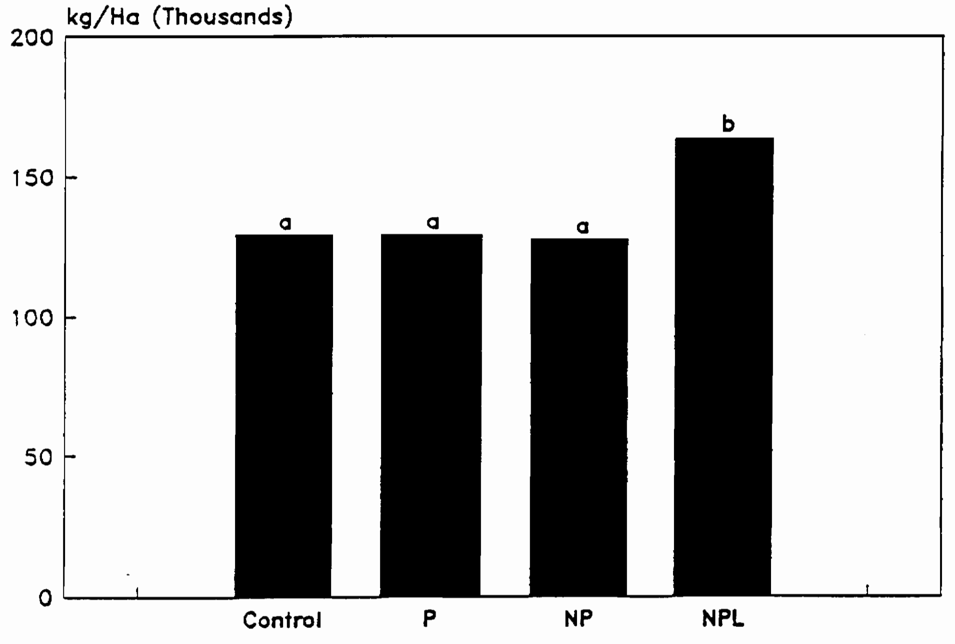


Figure 4.22. Effects of fertilizer treatments on total site biomass (Same letters indicate no significant difference, Fishers LSD test).

The proportional distribution of biomass within the canopy layers exhibited only one significant fertilization effect (Table 4.14). The control fertilization treatment resulted in an allocation of more biomass to the shrub layer compared to the NP treatment (p=0.0682). The P and NPL treatments were intermediate and not statistically different from either the control or the NP treatment. As shown earlier, the NP treatment exhibited reduced shrub layer biomass, probably because of increased sphagnum moss growth based on percent cover in the ground layer.

Table 4.14. Canopy layer biomass proportions for fertilizer treatments.

	Fertilizer Treatment				Statistics	
Canopy Layer	Control	P	NP	NPL	St.Dev.	p-level
Ground Layer	0.002	0.002	0.002	0.001	0.0007	0.7259
Shrub Layer	0.056b*	0.042ab	0.030a	0.045ab	0.0063	0.0682
Midstory	0.101	0.114	0.113	0.096	0.0131	0.7062
Overstory	0.842	0.842	0.855	0.858	0.0166	0.8431

* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Water Table Depth Results

Average water table depths were calculated for each recording date from the 12 wells in the site preparation treatment areas. These results were then averaged over the entire year (June 1991 - May 1992) and for the growing season (April 1 - October 1). Annual and growing season averages were also calculated for the single wells in the fertilization treatment plots. These data were tested to determine any possible effect of treatments on water table level.

No significant differences were found for either mean annual or mean growing season water table depth between any site preparation or fertilization treatments (Tables 4.15 and 4.16). Ditching had the lowest water table among the site preparation treatments. Although this difference was not significant, subtle changes in water table may be sufficient to affect overall vegetation characteristics or the distribution of highly sensitive species (Hunter, 1990; Robinson, 1978). Fertilization results were virtually identical among treatments.

An important consideration is that these results may not reflect the degree of difference between treatments during regeneration. At the present time, transpiration in all treatment areas is sufficient to remove excess water. Water table levels at stand establishment may have been more

Table 4.15. Water table results for site preparation treatments.

	Site Preparation Treatment			Statistics	
	Chop-Burn	Bedded	Ditched	Std.Dev.	p-level
Mean ann.[1] (cm)	99.8	101.0	111.2	3.900	0.1907
Mean Gr. Season[2] (cm)	112.4	111.5	122.4	3.444	0.1549

1 - Mean annual water table depth
2 - Mean growing season (April 1 - October 1) water table depth

Table 4.16. Water table results for fertilization treatments.

	Fertilizer Treatment				Statistics	
	Control	P	NP	NPL	St.Dev.	p-level
Mean ann.[1] (cm)	114.5	115.0	111.4	114.4	2.023	0.5838
Mean Gr. Season[2] (cm)	126.6	125.9	123.6	126.1	1.708	0.6229

1 - Mean annual water table depth
2 - Mean growing season (April 1 - October 1) water table depth

important to current vegetation than water tables at rotation age.

In addition, the ditched treatment exhibited a decreasing effect at lowering water tables with increasing distance from the ditches (Figure 4.23). The distance from each water table well to the closest treatment ditch was estimated to the nearest 5 m from maps of the study area. Water table data were then compared between wells for the wettest months observed (February-May) during data collection. As expected, water tables were closer to the surface farther away from the ditch (Figure 4.23). This situation probably caused fewer treatment differences to be detected for the ditched treatment compared to the chop and

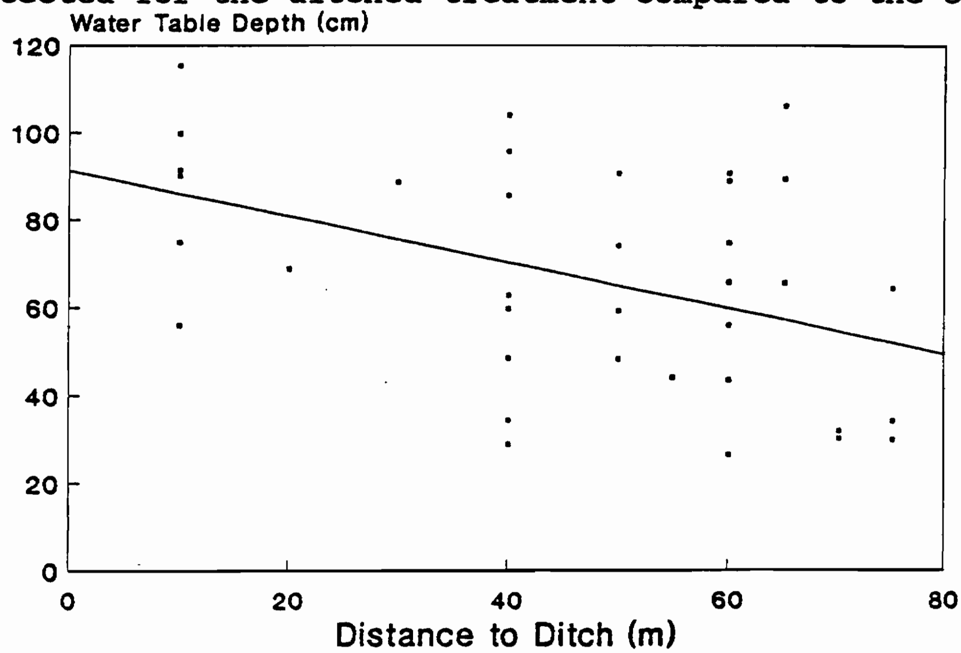


Figure 4.23. Relationship between distance to treatment ditches and depth to water table during the wet season.

burn. Unfortunately, the intensity and distribution of well measurements did not allow for more precise calculations. The actual distance at which the treatment ditches ceased to be effective is unclear.

Individual Species Responses

The response of individual species to site preparation and fertilization treatments was tested. Not all possible species in each canopy layer are presented because of the large number of potential tests. Instead, species are presented which have particular value commercially, as wildlife habitat, as a wetland indicator, or as a canopy dominant. Complete lists of all species and their biomass means are provided in Appindices E and F.

Species determined to have wildlife habitat value were generally mast producing species. The forage or cover value of species was not evaluated. Wetland indicators were defined as species with either a 1 or 2 wetland index value. Such species should hypothetically be more sensitive to changes in site hydrology.

Results are discussed for only those species which showed a response to treatments. Species were tested only for effects on biomass and numbers per hectare. Site (block) differences in species characteristics are not given because they are of little interest to management alternatives. Only treatment differences are presented. In addition, site preparation treatment effects are not presented for the fertilization treatment data. The site preparation treatment data is a more thorough and representative sample that effectively reveals site preparation treatment differences.

Ground Layer

The species which were tested for treatment response in the ground layer (and the reason for being selected) were:

Pepperbush	Canopy dominant
Dog hobble	Wetland indicator
Sphagnum moss	Wetland indicator
Marsh fern	Wetland indicator
Pink lady slipper	Rare

Of these, only pepperbush showed significant treatment effects. Three of the species (dog hobble, marsh fern, and pink lady slipper) occurred in too few numbers to provide definitive tests between treatments. A distinct problem that emerged in testing for treatment effects on rare species was in acquiring a sufficient sample to test statistically. As a result, many of the species which could be most important to test did not yield significant results due to small sample size.

Site preparation treatment results

Pepperbush exhibited significant differences between site preparation treatments based on both biomass (p=0.0200) and numbers (p=0.0816) per hectare (Figure 4.24). Bedding produced the highest results for both measures. Ditching was lowest for both measures, though not statistically different from chop and burn.

Pepperbush probably grew well under the bedded treatment because of its small size and its ability to sprout prolifically. Bedding reduced sprouting in most shrubs and hardwoods due to soil disturbance and windrowing, but a small species like pepperbush might survive. With its ability to sprout from roots, it could then take advantage of reduced competition from the shrubs and hardwoods which were removed.

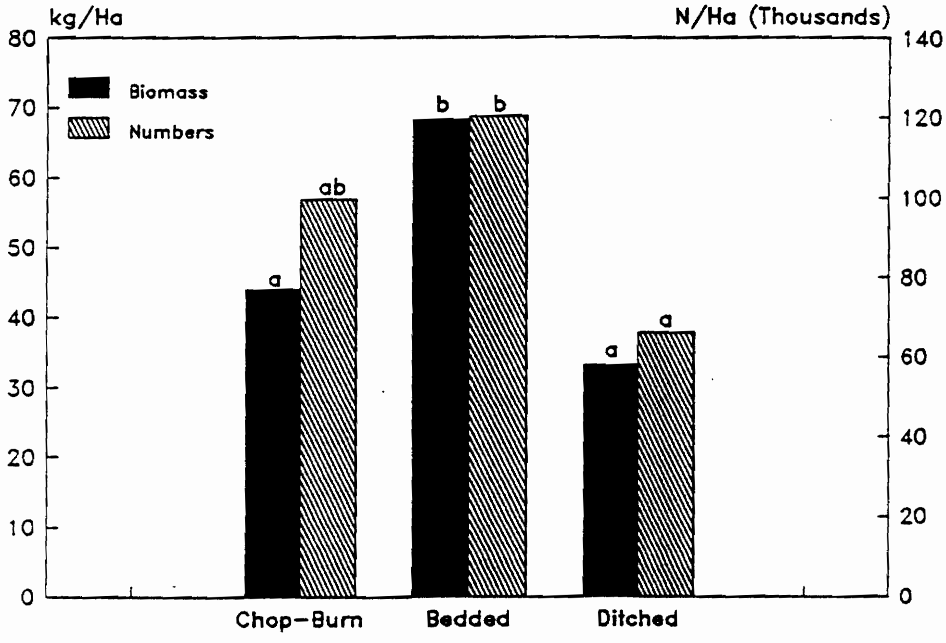


Figure 4.24. Effects of site preparation treatments on pepperbush biomass and density in the ground layer (Same letters indicate no significant difference, Fishers LSD test).

Fertilization treatment results

None of the species tested showed a significant response to the fertilizer treatments.

Shrub Layer

Thirteen species in the shrub layer were tested for treatment responses. The species which were tested and the reason for testing were:

Cane	Canopy Dominant
Pepperbush	Canopy Dominant
Smilax glauca	Wildlife value
Smilax rotundifolia	Wildlife value
Highbush blueberry	Wildlife value
Gallberry	Wildlife value
Swamp azalea	Wetland indicator
Virginia willow	Wetland indicator
Smilax laurifolia	Wetland indicator
Fetterbush	Wetland indicator
Swamp leucothoe	Wetland indicator
Chokeberry	Wetland indicator
Cinnamon fern	Wetland indicator

Of these species, only switch cane, pepperbush, and swamp leucothoe exhibited a significant response to treatments. Swamp azalea, Virginia willow, Smilax laurifolia, and fetterbush occurred in too few numbers to test accurately.

Site preparation treatment results

Ditching resulted in the lowest cane biomass ($p=0.0452$) and numbers ($p=0.0378$), while bedding and chop and burn were not significantly different (Figure 4.25). Switch cane appears to be sensitive to changes in water table depth. Although the mean annual water table was not significantly

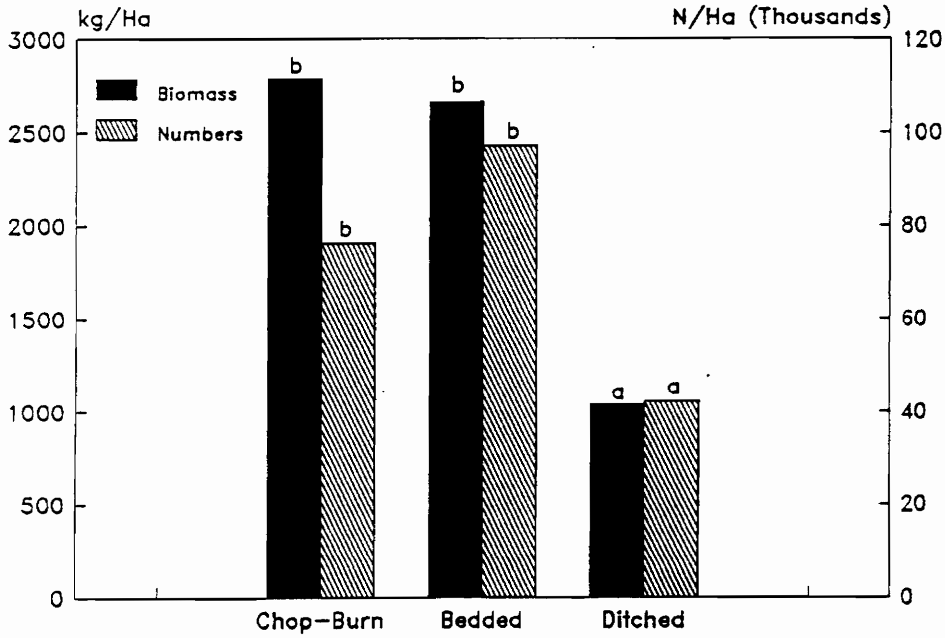


Figure 4.25. Effects of site preparation treatments on switch cane biomass and density in the shrub layer (Same letters indicate no significant difference, Fishers LSD test).

lowered on the ditched treatment at the present time, water table differences at stand regeneration may have limited switch cane's success. This may be sufficient to reduce cane numbers and biomass as observed in the ditched treatment at rotation age.

Switch cane was not affected by bedding for the same reasons that pepperbush was unaffected. Bedding and windrowing probably removed or buried a large percentage of the shrub and hardwood stumps. However, since cane can resprout from its rhizome, it was not reduced by bedding.

These observations support an earlier assertion that bedding had a more severe effect on the rarer species than on the dominants such as cane.

Fertilization treatment results

Pepperbush and swamp leucothoe of the shrub layer were significantly affected by fertilization treatments (Figures 4.26 and 4.27). Only numbers per hectare showed a significant response for both species. For pepperbush, the NP treatment produced the greatest pepperbush density. The NPL treatment and the control had significantly fewer pepperbush plants, while the P treatment was intermediate. For swamp leucothoe, the control produced the greatest density, with P and NP significantly different. The NPL treatment was intermediate and was not significantly different from any of the others.

From these results, certain hypothesis can be developed. Swamp leucothoe appears to be a poor competitor under conditions of high fertility. It seems to be suppressed by other species which capitalize on increased nutrients. Pepperbush appears to respond favorably to fertilization with phosphorous and nitrogen, but is reduced by additions of lime. Liming may cause changes in pH or calcium availability which favor other species. As a result, pepperbush would be competitively reduced in numbers and biomass.

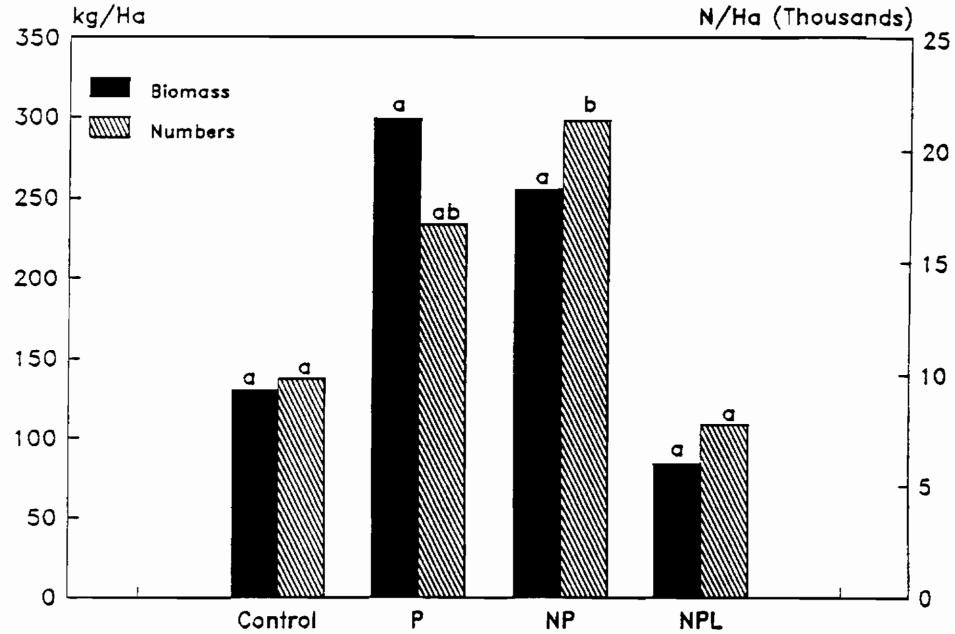


Figure 4.26. Effects of fertilizer treatments on pepperbush biomass and density in the shrub layer (Same letters indicate no significant difference, Fishers LSD test).

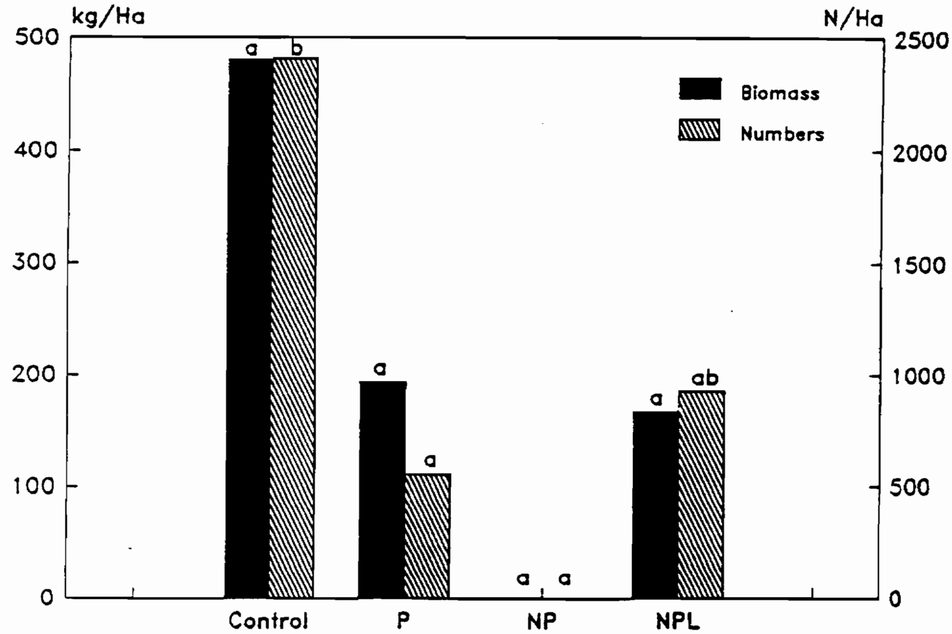


Figure 4.27. Effects of fertilizer treatments on swamp leucothoe biomass and density in the shrub layer (Same letters indicate no significant difference, Fishers LSD test).

Midstory

Seven species in the midstory were tested for treatment effects. The species tested and the reason for testing were:

Red maple	Canopy dominant
Sweetgum	Canopy dominant
Black gum	Canopy dominant
American holly	Wildlife value
Water oak	Wildlife value
Loblolly pine	Commercial value
Swamp tupelo	Wetland indicator

Site preparation treatment results

Red maple, water oak, and swamp tupelo all responded to site preparation treatments (Figures 4.28-4.30). Both biomass ($p=0.0156$) and density ($p=0.0133$) were affected for red maple, with the bedded treatment having the lowest values. Red maple is probably affected by bedding through disruption of stumps and roots during the bedding and windrowing application. These results support an earlier assertion that bedding decreases red maple sprouting, thereby decreasing overall midstory biomass, while increasing site diversity.

For water oak and swamp tupelo, only numbers showed a significant treatment effect (Figures 4.29 and 4.30). Bedding produced significantly fewer water oak plants ($p=0.0348$) than either the chop and burn or the ditched. Water oak appears to be affected by bedding in the same

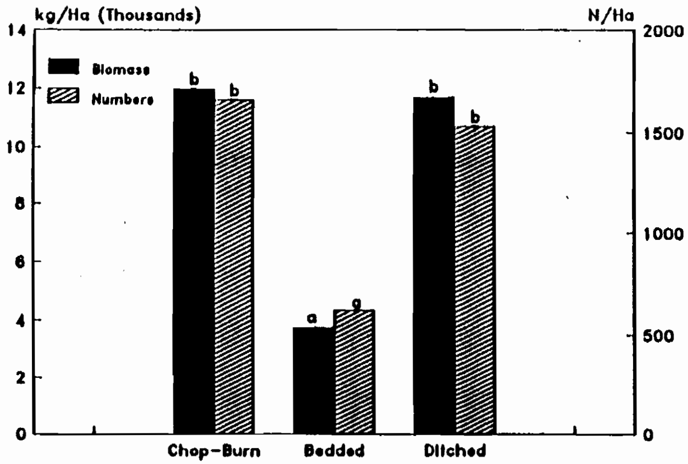


Figure 4.28. Effects of site preparation treatments on red maple biomass and density in the midstory (Same letters indicate no significant difference, Fishers LSD test).

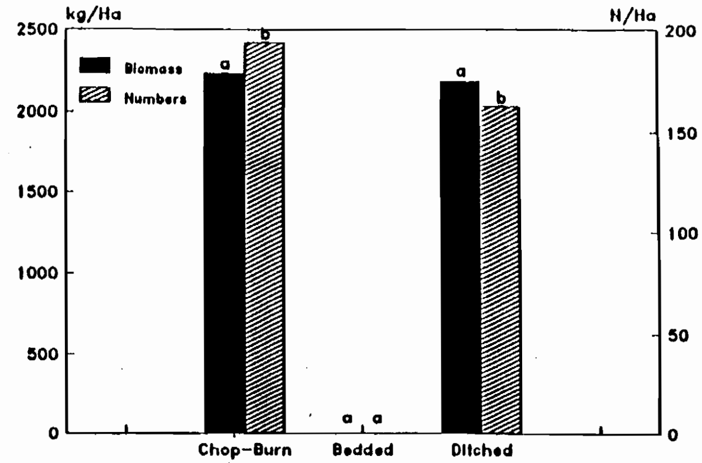


Figure 4.29. Effects of site preparation treatments on water oak biomass and density in the midstory (Same letters indicate no significant difference, Fishers LSD test).

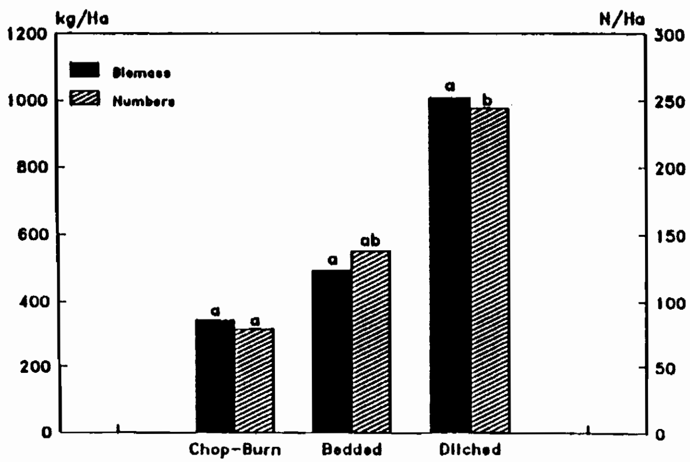


Figure 4.30. Effects of site preparation treatments on swamp tupelo biomass and density in the midstory (Same letters indicate no significant difference, Fishers LSD test).

manner as red maple, only the results are more extreme. Because water oak is a poor natural seeder, it seems to have been completely removed from the bedded sites.

Ditching exhibited the highest swamp tupelo density which was significantly greater than the chop and burn (p=0.1079). Bedding was intermediate and not statistically different from the others. Swamp tupelo density was highest in the ditched treatment areas, in spite of its acknowledged flood tolerance.

Fertilization treatment results

Sweetgum, water oak, and swamp tupelo of the midstory were affected by fertilization treatments (Figures 4.31-4.33). Only biomass results were affected for sweetgum (p=0.0394) and for water oak (p=0.0792). The NPL treatment produced the greatest biomass for sweetgum, and oak, the NP treatment produced significantly greater biomass (approximately 10 times as much) for water oak.

Sweetgum appears to respond well to applications of lime. Whether this response is due to changes in pH or to increases in calcium availability is unknown. Water oak exhibited a dramatic increase to nitrogen fertilization, but then declined with liming. Water oak appears to respond to nitrogen fertilization, but then is a poor competitor when lime is added. Liming may increase the growth of other hardwoods (such as sweetgum), thereby suppressing water oak.

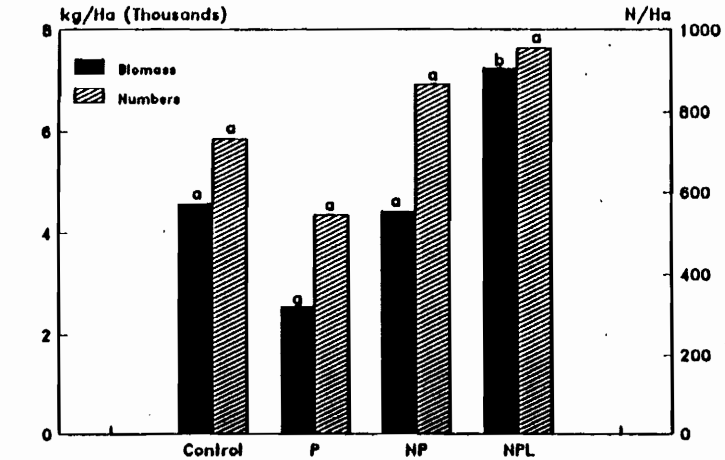


Figure 4.31. Effects of fertilization treatments on sweetgum biomass and density in the midstory (Same letters indicate no significant difference, Fishers LSD test).

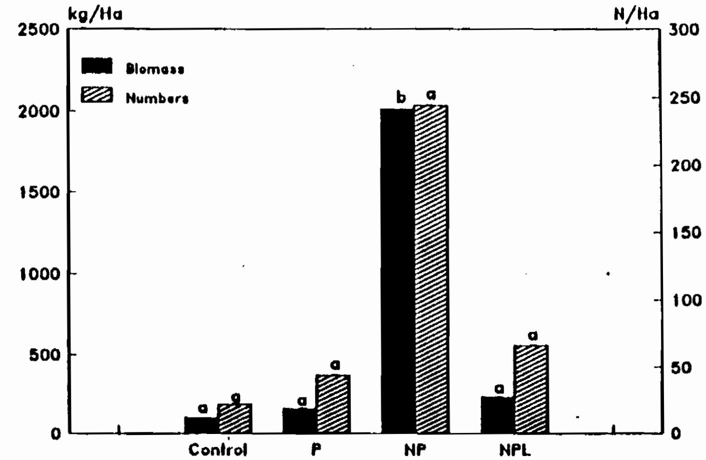


Figure 4.32. Effects of fertilization treatments on water oak biomass and density in the midstory (Same letters indicate no significant difference, Fishers LSD test).

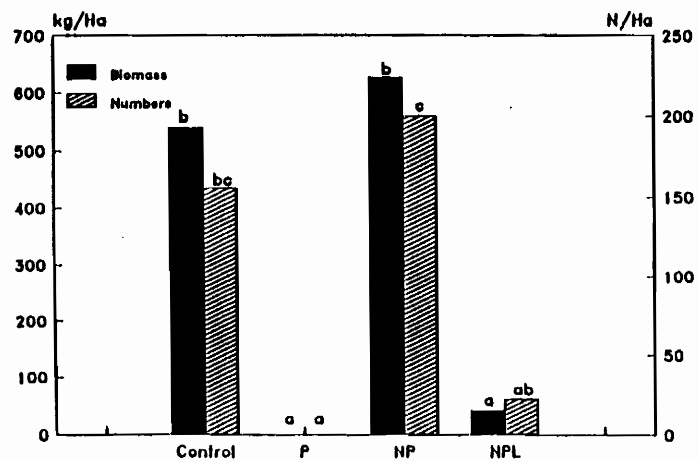


Figure 4.33. Effects of fertilization treatments on swamp tupelo biomass and density in the midstory (Same letters indicate no significant difference, Fishers LSD test).

Both numbers (p=0.0474) and biomass (p=0.0782) per hectare showed significant treatment responses for swamp tupelo (Figure 4.33). The control and the NP treatment produced significantly greater densities of swamp tupelo than either the P or NPL treatments. For biomass, the control and NP treatment were again significantly greater than the P treatment, but NPL was not significantly different from the control.

It is possible that swamp tupelo is a nitrogen-limited plant which is a very poor competitor with phosphorous-limited plants. When phosphorous is added, phosphorous-limited species gain the advantage over swamp tupelo. When nitrogen is added, swamp tupelo is able to capitalize and maintains its position in the canopy. Lastly, when lime is added, phosphorous becomes more available and swamp tupelo is again reduced.

Overstory

The overstory species which were tested for treatment effects and the reason for testing were:

Loblolly pine	Commercial value
Red maple	Commercial value
Sweetgum	Commercial value
Water oak	Wildlife value
White oak	Wildlife value

Site preparation treatment results

Loblolly pine, red maple, and water oak in the overstory exhibited significant responses to site preparation treatments (Figures 4.34-4.36). For loblolly pine and red maple, only biomass was significantly affected. Pine biomass was significantly greater (p=0.0896) on the bedded treatment as compared to the chop and burn, while the ditched treatment was intermediate. Loblolly pine was probably responding to reduced competition from midstory vegetation and to increased rooting volume during regeneration (Allen and Campbell, 1988). For red maple, the bedded treatment again yielded the greatest biomass and was significantly greater (p=0.0813) than either the chop and burn or the ditched. These results appear to conflict with the observed effect of bedding on red maple in the midstory. However, the majority of the overstory red maple existed on the windrows. Windrows were almost exclusively red maple and the trees appeared to be growing very well. They undoubtedly became established there from seed after harvest. Windrows tend to concentrate soil fertility (Allen and Campbell, 1988), in addition to providing a raised surface much higher than the surrounding soil surface. In the absence of these windrow red maple trees, bedding may not have exhibited such a favorable response.

Water oak biomass and numbers per hectare both exhibited a site preparation treatment response. Biomass

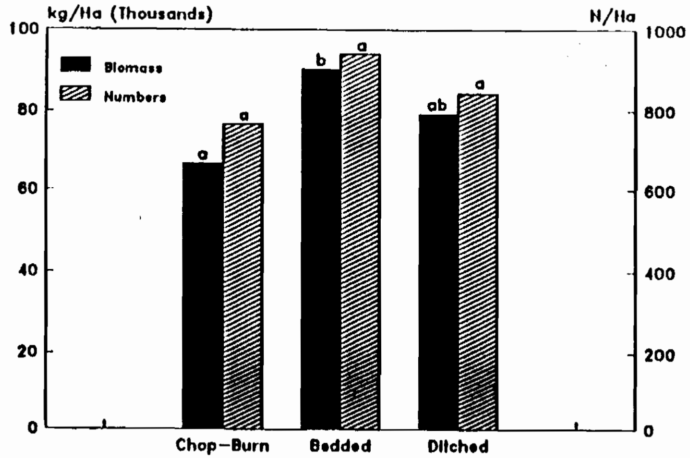


Figure 4.34. Effects of site preparation treatments on loblolly pine biomass and density in the overstory (Same letters indicate no significant difference, Fishers LSD test).

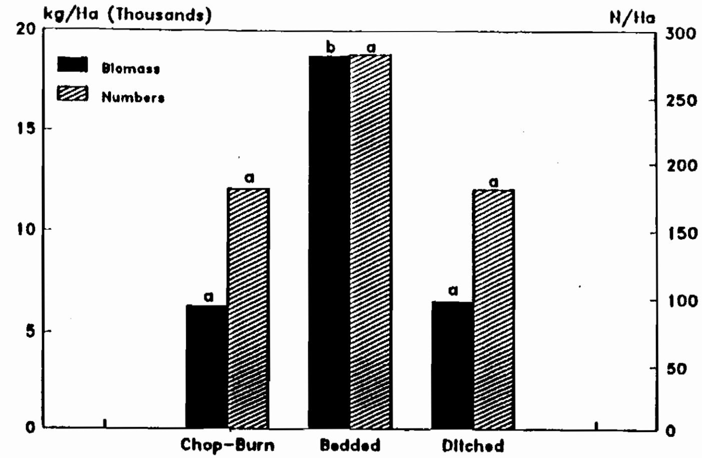


Figure 4.35. Effects of site preparation treatments on red maple biomass and density in the overstory (Same letters indicate no significant difference, Fishers LSD test).

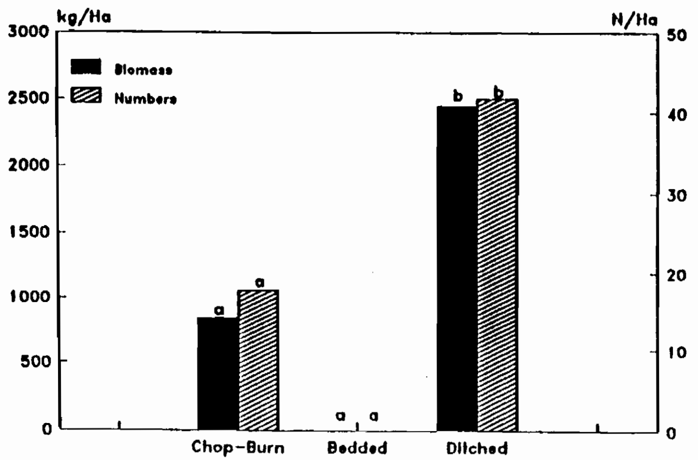


Figure 4.36. Effects of site preparation treatments on water oak biomass and density in the overstory (Same letters indicate no significant difference, Fishers LSD test).

(p=0.0526) and density (p=0.0327) were significantly greater for the ditched treatment than for either the chop and burn or bedded treatments. Water oak appeared to respond to the drier soil conditions produced by ditching despite its acknowledged flood tolerance. Although not significant, it is interesting to note the effect of bedding on water oak biomass and density. As in the midstory, water oak did not appear on any of the three bedded sites in the overstory. These results suggests that bedding has a severe suppressive effect on water oak vegetative regeneration.

Fertilization treatment results

Only loblolly pine exhibited a significant response to fertilizer treatments with regard to the overstory (Figure 4.37). Pine biomass was significantly greater (p=0.0236) on the NPL treatment than on any other treatment. Pine density was not affected by fertilization. These results are consistent with the total biomass results discussed earlier, indicating the degree of dominance in the overstory by loblolly pine.

It appears that loblolly pine may exhibit a beneficial response to liming in these wet pine flats. Whether this response is due to changes in pH or increased calcium or magnesium availability is unknown. Calcium has been observed as a deficient nutrient on the Myatt and Rains soil series (Plummer, 1963; Monk, 1965). However, liming

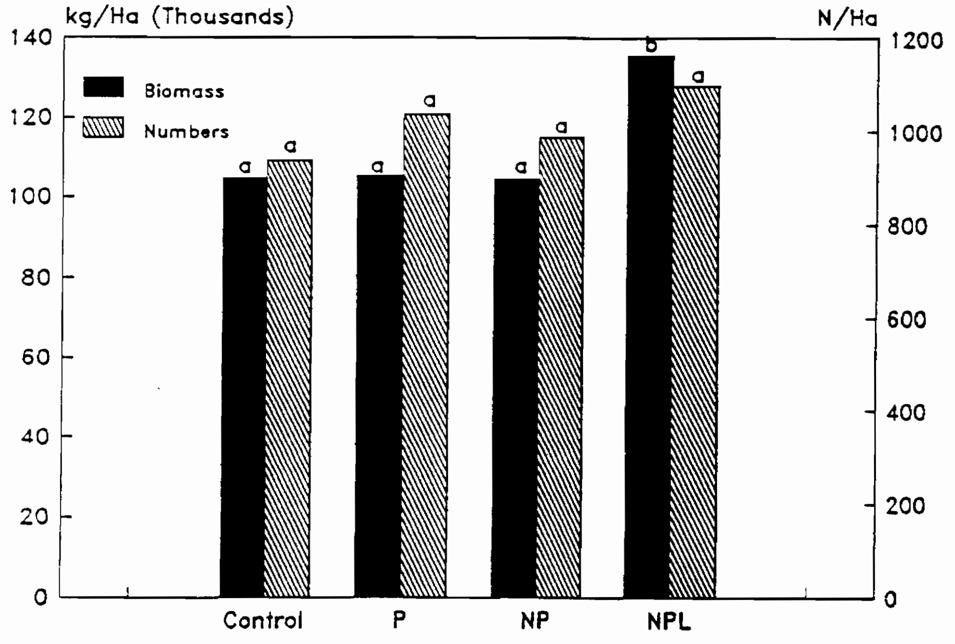


Figure 4.37. Effects of fertilizer treatments on loblolly pine biomass and density in the overstory (Same letters indicate no significant difference, Fishers LSD test).

definitely produced a growth response which was not achieved at all by fertilization alone.

Vegetation Correlations

Within-Canopy Vegetation Correlations

Correlation analyses were used to determine the relatedness of various vegetation characteristics to one another. Of particular interest were the relationships between diversity and productivity parameters. Data were initially analyzed for all 288 individual plots in the site preparation treatment areas. However, these tests yielded such poor results that they were not useful. Analyses were then conducted on the combined plot data used in the ANOVA tests for site preparation effects. These data yielded much better results and will be discussed further.

To simplify such comparisons, certain parameters were excluded. Preliminary analyses showed that the Shannon-Wiener index was highly correlated to Simpsons index ($p>0.90$), so the Shannon-Wiener index was excluded from further use. Any significant correlations determined for Simpsons index would be true for the Shannon-Wiener index also. In addition, basal area measurements were found to be highly correlated to biomass values ($p>0.95$). Therefore, only biomass data were used for further correlations with the assertion that any significant results would be consistent for basal area. Average distance of the 32 plots from the nearest roadside ditch was included in the analysis to indicate to what degree such ditches could be serving as a source of variation.

Ground Layer

Several important correlations were demonstrated by the ground layer vegetation (Table 4.17). First, Simpsons index weighted by biomass showed a positive correlation with species richness. This is to be expected since number of

Table 4.17. Coefficients of correlation between vegetative characteristics in the ground layer.

	Biom. kg/Ha	Sim. Biom	Num/ Ha	Sim. Num	# of Spec.	Val. Biom	Val. Num	Dist. Ditch
Total Biom (kg/Ha)		0.07	0.27	-0.36	-0.26	0.56	-0.31	0.08
Sim Biom[1]	0.07		0.45	-0.34	**0.73**	-0.42	-0.48	-0.21
Total N/Ha	0.27	0.45		**-0.98**	0.11	-0.48	**-0.98**	0.40
Sim Num[2]	-0.36	-0.34	**-0.98**		0.04	0.39	**0.98**	-0.51
# Species	-0.26	**0.73**	0.11	0.04		-0.37	-0.16	-0.21
Val. Biom[3]	0.56	-0.42	-0.48	0.39	-0.37		0.46	-0.34
Val. Num[4]	-0.31	-0.48	**-0.98**	**0.98**	-0.16	0.46		-0.46
Dist.Dit.[5]	0.08	-0.21	0.40	-0.51	-0.21	-0.34	-0.46	

1 - Simpsons index weighted for biomass
2 - Simpsons index weighted for numbers
3 - Wetland value weighted for biomass
4 - Wetland value weighted for numbers
5 - Distance to roadside ditch

species is a calculation component of Simpsons index. It also suggests that biomass evenness among the species in the ground layer is relatively high, such that species richness has a strong influence on the index value (Pielou, 1975).

The remaining significant correlations all appear to have the same primary cause - the dominance of total numbers of individuals by sphagnum moss. Whenever sphagnum moss occurred, it was counted as square centimeters rather than individual plants. As a result, with the presence of only a few large patches, this species could vastly dominate all other plants in the ground layer in terms of density. The highly significant negative correlation between total numbers and Simpsons index is a result of this effect. Large values in numbers per hectare were almost always associated with large patches of sphagnum moss, which caused Simpsons index to decline drastically. Similarly, the strong negative correlation between average wetland value weighted by numbers and total numbers per hectare was the result of the presence of sphagnum moss, which had a value of 1 (the lowest possible value). Large increases in total numbers caused average wetland value to decline.

These results primarily reveal the difficulty in combining data for vascular and non-vascular plants. Counting individuals for mosses would be an intensive practice and would bias measurements in favor of moss characteristics. For this reason, biomass appears to be a more desirable measurement trait for incorporating vascular and non-vascular plants.

Shrub Layer

Shrub layer vegetation correlations revealed an interesting relationship between total biomass and diversity. Total biomass was positively correlated with species richness and Simpsons index weighted by biomass (Table 4.18). These results suggest a significant degree of niche differentiation for shrub species, such that biomass increases with increasing numbers of species. Increases in total biomass were generally observed where switch cane was reduced. Thus, where switch cane is excluded due to various hydrologic, disturbance, or fertility factors, both biomass and diversity increase.

Dramatically different results were observed in the relationship between total numbers and diversity. A significant negative correlation existed between total number per hectare and Simpsons index weighted by number. In addition, there was no correlation between total number and species richness. Wetland value weighted by numbers showed a negative correlation with total numbers and a positive correlation with Simpsons index weighted by numbers. The cause of these observed effects may be the individual response of switch cane to site conditions.

Table 4.18. Coefficients of correlation for vegetative characteristics in the shrub layer.

	Biom. kg/Ha	Sim. Biom	Num/ Ha	Sim. Num	# of Spec.	Val. Biom	Val. Num	Dist. Ditch
Total Biom (kg/Ha)		**0.75**	0.32	-0.22	**0.65**	0.34	-0.58	0.32
Sim Biom[1]	**0.75**		-0.24	0.15	0.44	0.43	-0.15	0.23
Total N/Ha	0.32	-0.24		**-0.66**	0.00	-0.41	**-0.64**	0.38
Sim Num[2]	-0.22	0.15	**-0.66**		0.23	0.22	**0.75**	-0.32
# Species	**0.65**	0.44	0.00	0.23		0.44	0.06	-0.18
Val. Biom[3]	0.34	0.43	-0.41	0.22	0.44		0.23	0.10
Val. Num[4]	-0.58	-0.15	**-0.64**	**0.75**	0.06	0.23		-0.38
Dist.Dit.[5]	0.32	0.23	0.38	-0.32	-0.18	0.10	-0.38	

1 - Simpsons index weighted for biomass
2 - Simpsons index weighted for numbers
3 - Wetland value weighted for biomass
4 - Wetland value weighted for numbers
5 - Distance to roadside ditch

Switch cane was the most dominant species in the shrub layer and its wetland index value was 2. Because switch cane is a slender, hollow reed, numbers of individuals can be increased greatly while above-ground biomass increases much less compared to larger shrubs. This would explain why biomass results did not reveal the same trends. As with sphagnum moss in the ground layer, large increases in total number in the shrub layer primarily indicate increases in switch cane numbers. This would tend to cause decreases in Simpsons biomass and average wetland value. Simpsons index was positively correlated with average wetland value because increases in the index value generally indicate decreases in switch cane numbers.

Midstory

Results from the midstory vegetation correlations indicate that total numbers and total biomass are closely correlated for midstory trees (Table 4.19). Total biomass was highly correlated to total numbers, Simpsons index weighted by biomass was highly correlated to Simpsons index weighted by numbers, and average wetland value weighted by numbers was highly correlated to wetland value weighted by biomass. These results are due to the decrease in the number of growth forms (shrub, vine, or herb) in the midstory as compared to the ground or shrub layer, and also from the narrow range of diameter classes included in the

Table 4.19. Coefficients of correlation for vegetative characteristics in the midstory.

	Biom. kg/Ha	Sim. Biom	Num/ Ha	Sim. Num	# of Spec.	Val. Biom	Val. Num	Dist. Ditch
Total Biom (kg/Ha)		-0.38	**0.98**	-0.27	0.05	-0.10	-0.27	-0.03
Sim Biom[1]	-0.38		-0.40	**0.89**	**0.63**	0.01	0.32	-0.45
Total N/Ha	**0.98**	-0.40		-0.28	0.01	-0.17	-0.33	-0.01
Sim Num[2]	-0.27	**0.89**	-0.28		**0.63**	0.12	0.34	-0.51
# Species	0.05	**0.63**	0.01	**0.63**		0.06	0.35	**-0.65**
Val. Biom[3]	-0.10	0.01	-0.17	0.12	0.06		**0.93**	0.33
Val. Num[4]	-0.27	0.32	-0.33	0.34	0.35	**0.93**		0.11
Dist.Dit.[5]	-0.03	-0.45	-0.01	-0.51	**-0.65**	0.33	0.11	

1 - Simpsons index weighted for biomass
2 - Simpsons index weighted for numbers
3 - Wetland value weighted for biomass
4 - Wetland value weighted for numbers
5 - Distance to roadside ditch

midstory. Thus, plants in the midstory were all relatively the same size with the same growth form. Numbers of individuals and biomass were largely interchangeable.

Both diversity indices (Simpsons index weighted by biomass or numbers) were significantly correlated with species richness. As noted earlier, this is to be expected since number of species is a factor in the calculation of Simpsons index. Such a condition, however, suggests that midstory species are relatively even in their distribution of biomass between species. Diversity at rotation age is thus determined largely by the number of species successfully regenerating on the site after disturbance.

The only significant correlation to be detected in any canopy layer for average distance to ditch occurred in the midstory. Number of species was negatively correlated with distance to roadside ditches, suggesting that drainage actually increases midstory species richness. Apparently, higher water tables result in the elimination of flood intolerant species which are not replaced by other species.

Overstory

As in the midstory, total biomass in the overstory was consistently correlated with total numbers, though not as strongly (Table 4.20). Total biomass was correlated with total numbers, Simpsons index weighted by biomass was correlated with Simpsons index weighted by numbers, and

Table 4.20. Coefficients of correlation for vegetative characteristics in the overstory.

	Biom. kg/Ha	Sim. Biom	Num/ Ha	Sim. Num	# of Spec.	Val. Biom	Val. Num	Dist. Ditch
Total Biom (kg/Ha)		0.06	**0.73**	-0.37	-0.52	0.38	0.47	-0.17
Sim Biom[1]	0.06		0.47	**0.81**	-0.09	0.05	0.39	-0.21
Total N/Ha	**0.73**	0.47		-0.07	-0.12	-0.10	0.26	-0.48
Sim Num[2]	-0.37	**0.81**	-0.07		0.08	0.22	0.31	0.18
# Species	-0.52	-0.09	-0.12	0.08		-0.58	**-0.68**	0.25
Val. Biom[3]	0.38	0.05	-0.10	0.22	-0.58		**0.69**	0.39
Val. Num[4]	0.47	0.39	0.26	0.31	**-0.68**	**0.69**		0.05
Dist.Dit.[5]	-0.17	-0.21	-0.48	0.18	0.25	0.39	0.05	

1 - Simpsons index weighted for biomass
2 - Simpsons index weighted for numbers
3 - Wetland value weighted for biomass
4 - Wetland value weighted for numbers
5 - Distance to roadside ditch

average wetland value weighted by biomass was correlated with wetland value weighted by numbers. These correlations were not as strong as in the midstory because of the larger range of diameters represented in the overstory. Biomass increased exponentially with increasing diameter, according to the equations used, creating a much wider range of potential biomasses in the overstory. As a result, density became less indicative of total biomass and average diameter gained importance.

The only other significant correlation to be observed in the overstory was a negative correlation between number of species and average wetland value weighted by number. The correlation for average wetland value weighted by biomass was similar, though not quite significant. This suggests that the rarer species in the overstory tend to have lower wetland values. Such species may be rare because of the treatments applied or because they are more restricted in their microsite conditions. Because the three most dominant species in the overstory (loblolly pine, red maple, and sweetgum) all have wetland values of 3, even rare species may cause a significant decrease in average wetland value (though the absolute change may be small).

Overstory-Understory Correlations

The effect of various canopy layers upon one another may also be an important determining factor in observed diversity. Auclair and Goff (1971) found pronounced correlations between tree, shrub, and herb diversity which were dependent on forest structural characteristics. In addition, changes in species dominance have been observed in the understories of forest stands in response to overstory cover and biomass (McConnell and Smith, 1965; Wolters, et al., 1982). From these studies, it is clear that understory productivity and diversity can be directly affected by overstory composition.

As with the within-canopy correlations, analyses were first tested on all of the individual plots in the site preparation treatment data. These initial correlations were again very poor, and so the combined plot data were then analyzed.

For these correlations, only biomass variables (total biomass and Simpsons weighted by biomass) and species richness were used for comparisons. Basal area was not a measurement variable for the shrub and ground layers and so direct comparisons were not possible. In addition, as discussed previously, total numbers appear more subject to the response of individual species in the shrub and ground layer than is biomass. Thus, biomass is the most consistent measurement for comparing vegetation between canopy layers, with its differing growth forms. The Shannon-Wiener index was not used because of its high correlation to Simpsons index.

For each canopy layer, there are portions of the data presented which will not be discussed to reduce repetition. For example, the ground layer to ground layer correlations which are provided in the first section will not be discussed because they are identical to those given under the previous heading and were discussed there. In addition, each possible overstory-understory correlation is provided twice but will only be discussed in the first section in which it appears (e.g., shrub to midstory correlations will be discussed but not midstory to shrub correlations). It was assumed that most competitive interactions were top-down (overstory characteristics affect the understory but not vice versa), though certain possible exceptions are noted.

Ground layer

Biomass in the ground layer was negatively correlated with shrub layer diversity and midstory total biomass (Table 4.21). Shrub layer diversity may affect ground layer vegetation due to the growth forms of the plants involved. Increases in shrub layer diversity were usually associated with decreases in switch cane biomass and increases in the biomass of other shrubs. If these other shrubs provided more cover or captured more soil water and nutrients, then ground layer biomass could be reduced. Midstory biomass

Table 4.21. Overstory-understory correlations for ground and shrub layer vegetation.

	Canopy Layer					
	Ground Layer			Shrub Layer		
	# Spec.	Biom. kg/Ha	Sim. Biom.	# Spec.	Biom. kg/Ha	Sim. Biom.
Ground Layer						
# Species		-0.26	**0.73**	0.24	0.35	0.30
Total Biom. (kg/Ha)	-0.26		0.07	-0.37	-0.49	**-0.79**
Sim. Biom.[1]	**0.73**	0.07		0.28	0.25	0.09
Shrub Layer						
# Species	0.24	-0.37	0.28		**0.65**	0.44
Total Biom. (kg/Ha)	0.35	-0.49	0.25	**0.65**		**0.75**
Sim. Biom.	0.30	**-0.79**	0.09	0.44	**0.75**	
Midstory						
# Species	0.59	-0.05	**0.70**	0.08	-0.06	-0.22
Total Biom. (kg/Ha)	0.39	**-0.72**	0.19	**0.63**	0.43	**0.65**
Sim. Biom.	0.43	0.19	0.18	-0.18	-0.14	-0.47
Overstory						
# Species	0.11	-0.16	0.16	**0.61**	0.45	0.15
Total Biom. (kg/Ha)	-0.39	0.45	-0.46	**-0.75**	**-0.68**	-0.51
Sim. Biom.	-0.02	-0.26	-0.21	-0.31	-0.24	-0.30

1 - Simpsons index weighted for biomass

probably affected ground layer biomass through direct shading and soil resource use. These results are consistent with those observed by Blair and Feduccia (1977). They found ground layer vegetation was more closely related to midstory rather than overstory trees because of more intense shading from hardwoods.

Diversity in the ground layer was positively correlated with species richness in the midstory. This may be due to the presence of midstory species seedlings in the ground layer. As midstory species increase, a greater variety of germinating seeds should exist in the ground layer, increasing diversity. Species richness in the ground layer was also correlated with midstory species richness.

Species richness in the ground layer was unaffected by any overstory canopy feature. This is probably due to two factors. First, ground layer vegetation is adapted to survive under conditions of low light and soil resources, and although the plants may demonstrate growth decreases, they are still able to survive and persist. Secondly, many plants in the ground layer are seedlings or sprouts surviving temporarily on parental resources. Their presence, however, still adds to ground layer diversity.

Shrub layer

Shrub layer species richness was positively correlated with total biomass in the midstory and with species richness in the overstory (Table 4.21). A negative correlation between shrub layer species richness and overstory total biomass was also observed. In addition, biomass in the shrub layer was negatively correlated with total biomass in the overstory, but interestingly, there was not a similar negative correlation in the midstory. Lastly, shrub layer diversity was positively correlated with midstory biomass.

These results all primarily indicate the effect of bedding on productivity and diversity in each canopy layer. As discussed earlier, bedding produced a significant increase in overstory biomass. However, bedding also reduced midstory and shrub layer biomass and also shrub layer diversity. For this reason, in this data set, an increase in overstory biomass generally indicates the presence of bedding. Thus, shrub layer biomass and diversity are negatively correlated with overstory biomass. Midstory biomass showed a positive correlation to shrub layer diversity and to shrub layer biomass (though not significantly) because this layer was similarly reduced by bedding. Midstory and shrub layer characteristics were positively correlated because bedding affected these layers in similar ways.

Midstory

Midstory biomass showed a significant negative correlation with overstory biomass (Table 4.22). This

Table 4.22. Overstory-understory correlations for midstory and overstory vegetation.

	Canopy Layer					
	Midstory			Overstory		
	# Spec.	Biom. kg/Ha	Sim. Biom.	# Spec.	Biom. kg/Ha	Sim. Biom.
Ground Layer						
# Species	0.59	0.39	0.43	0.11	-0.39	-0.02
Total Biom. (kg/Ha)	-0.05	**-0.72**	0.19	-0.16	0.45	-0.26
Sim. Biom.[1]	**0.70**	0.19	0.18	0.16	-0.46	-0.21
Shrub Layer						
# Species	0.08	**0.63**	-0.18	**0.61**	**-0.75**	-0.31
Total Biom. (kg/Ha)	-0.06	0.43	-0.14	0.45	**-0.68**	-0.24
Sim. Biom.	-0.22	**0.65**	-0.47	0.15	-0.51	-0.30
Midstory						
# Species		0.05	**0.63**	-0.07	-0.19	0.44
Total Biom. (kg/Ha)	0.05		-0.38	0.26	**-0.80**	-0.04
Sim. Biom.	**0.63**	-0.38		-0.04	0.28	0.53
Overstory						
# Species	-0.07	0.26	-0.04		-0.52	-0.09
Total Biom. (kg/Ha)	-0.19	**-0.80**	0.28	-0.52		0.06
Sim. Biom.	0.44	-0.04	0.53	-0.09	0.06	

1 - Simpsons index weighted for biomass

relationship probably arises from two causes. First, there is the direct suppression that the overstory exerts on the understory. In addition, as discussed in the previous section, the bedding treatment caused a significant increase in overstory biomass and a decrease in midstory biomass due to mechanical disturbance. As a result, increases in overstory biomass generally indicate bedding which coincides with reduced midstory regeneration. Midstory diversity was poorly correlated to overstory characteristics.

Overstory

All of the correlations for the overstory have been discussed in the previous sections. Table 4.22 presents the results for completeness.

Water Table Correlations

Individual Plot Analyses

Depth to water table data were averaged for the site preparation treatments over the entire year and for the growing season (April 1 - October 1). These data were correlated to vegetation characteristics in each canopy layer for individual plots. The plot nearest the well was used, creating a data set of 12 plots per treatment (corresponding to the 12 water table wells).

Correlation analysis was performed for the well data and all measured vegetative characteristics for each canopy layer. The results were generally poor for all characteristics in all canopy layers. The greatest correlation coefficients recorded for each canopy layer and the corresponding vegetation and hydrology parameters were:

i) ground layer, -0.2615 (Number of species - Annual average),
ii) shrub layer, -0.2094 (Percent cover - Annual average),
iii) midstory, -0.2073 (Wetland value weighted by number - Annual average),
iv) overstory, 0.3093 (Total biomass - Annual average).

The poor correlation of average water table depth to vegetative characteristics in the individual plot data is probably due to the high variability caused by canopy interactions. Water table may exert an influence on local vegetation conditions, but other factors are also significant and reduce the predictive value of water table alone. Over the entire site, however, many of these local factors balance out and significant correlations appear.

Combined Plot Analyses

Mean annual water table depth

Results from the mean annual water table depth correlation analyses for the site preparation data revealed significant correlations for ground layer and midstory diversity (Table 4.23). Ground layer diversity showed a significant negative correlation with increasing water table depth when indices were weighted by biomass. This suggests

Table 4.23. Correlation coefficients for mean annual water table depth.

	Canopy Layer			
	Ground	Shrub	Midstory	Overstory
Number of Species	-0.5776	-0.1959	**-0.9030**	-0.1046
Biomass (kg/Ha)	0.1008	-0.1865	-0.1616	0.4381
Sh-Wien. Biomass[1]	**-0.6212**	0.1881	**-0.7035**	-0.5399
Simpsons Biomass[2]	**-0.6410**	0.1487	**-0.6061**	-0.5384
Total Number (N/Ha)	-0.1425	-0.0799	-0.0932	-0.0433
Sh-Wien. Number[3]	-0.0507	-0.0230	**-0.6641**	-0.3727
Simpsons Number[4]	0.0542	0.0736	-0.4916	-0.4192
Basal Area (m^2/Ha)			-0.1782	0.4153
Sh-Wien. BA[5]			**-0.6133**	-0.5770
Simpsons BA[6]			-0.5366	-0.5682
Wetland Val. Num.[7]	0.1700	0.4451	-0.4446	0.0556
Wetland Val. Biom.[8]	0.4389	0.3121	-0.1837	**0.6053**

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Shannon-Wiener index weighted for basal area
6 - Simpsons index weighted for basal area
7 - Wetland value weighted for numbers
8 - Wetland value weighted for biomass

two alternatives: 1) sensitive ground layer species are eliminated by drier conditions or 2) drier conditions allow greater growth in higher canopy layers, resulting in competitive exclusion. The water table results for the other canopy layers suggest that the first alternative is more likely. None of the other layers exhibited a significant increase in production with increasing water table depth.

Diversity indices for the ground layer did not show the same effect when weighted by numbers, possibly due to the effects of sphagnum moss. When water tables were lowered, sphagnum moss was not as dominant, resulting in unpredictable changes in diversity. These results again indicate the difficulty in using density when testing very small species.

Shrub layer vegetation appears to be virtually unaffected by water table depth. This suggests that shrub species in these wet flats are somewhat generic with respect to hydrology and that competition, canopy interactions, and regeneration following disturbance are more important for determining shrub layer productivity and diversity.

Midstory vegetation was strongly affected by water table depth. All measures of diversity in the midstory showed a negative correlation to increasing water table depth and most were significant. Apparently, vegetation in the midstory layer is highly sensitive to hydrologic conditions. Reynolds and Parrott (1980) similarly found tree species distributions to be affected by hydrologic conditions in a New Jersey hardwood swamp. Because productivity values (total biomass, numbers, and basal area) were not significantly correlated, this suggests that increasing water table depth primarily affects the rarer species. These results conflict with the earlier observations concerning the negative correlation of midstory species richness to increasing distance from roadside ditches. Previous results indicated that midstory species richness declined with increasing average distance to ditches. Due to the high degree of consistency between these diversity parameters, the current data is probably more accurate in depicting the effect of water table depth on midstory diversity.

The overstory showed a consistent trend of negative correlations for diversity, but the effects were not significant. The only significant effect to appear in the overstory is for average wetland value weighted by biomass which exhibited a positive correlation. As the sites became drier, average wetland value increased. This is as expected given the purpose of the value as an indicator of wetland prevalence. However, it is important to note that in most cases average wetland value was not well correlated to water table depth. This indicates that either the index values are inaccurate or the species are responding to other site characteristics (e.g., fertility or canopy competition) The usefulness of these wetland vegetative values for wetland delineation appears questionable.

Mean growing season water table depth

Mean growing season water table analyses did not reveal as many significant correlations (Table 4.24). This is probably due to the fact that for extended periods during the growing season water tables fell below the depth of the measurement wells. When this occurred, between site differences were not detectable and all wells were simply dry. As a result, less variation was detected between treatments.

However, a few significant correlations were observed. Average wetland value weighted by biomass was positively correlated to growing season water table depth in the ground layer, and average wetland value weighted by numbers was positively correlated in the shrub layer. However, most wetland value parameters were uncorrelated to average growing season water table depth. As in the annual water table results, these results also suggest that wetland vegetation values may not be effective in delineation of wetlands.

Table 4.24. Correlation coefficients for mean growing season water table depth.

	Canopy Layer			
	Ground	Shrub	Midstory	Overstory
Number of Species	-0.3478	-0.1562	**-0.6234**	-0.1572
Biomass (kg/Ha)	0.1344	-0.4879	0.0001	0.4358
Sh-Wien. Biomass[1]	-0.3550	-0.0699	-0.4068	-0.4259
Simpsons Biomass[2]	-0.4632	-0.0379	-0.4506	-0.4741
Total Number (N/Ha)	-0.4236	-0.4579	0.0243	0.1195
Sh-Wien. Number[3]	0.2915	0.2345	-0.2744	-0.3681
Simpsons Number[4]	0.3645	0.3562	-0.1647	-0.4951
Basal Area (m^2/Ha)			-0.0432	0.4233
Sh-Wien. BA[5]			-0.2285	-0.5026
Simpsons BA[6]			-0.2811	-0.5359
Wetland Val. Num.[7]	0.4564	**0.8077**	-0.3521	-0.0408
Wetland Val. Biom.[8]	**0.6738**	0.3738	-0.0956	0.4495

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Shannon-Wiener index weighted for basal area
6 - Simpsons index weighted for basal area
7 - Wetland value weighted for numbers
8 - Wetland value weighted for biomass

Midstory species richness was negatively correlated to increasing water table depth, consistent with the annual water table results. In fact, all of the diversity values in the midstory and overstory exhibited the same negative correlations (though not significantly) as they did in the annual water table results. This high degree of consistency between vegetative parameters for both mean annual and mean growing season water table depth suggests that there may be a definitive impact of increasing water table depth on midstory and overstory diversity.

Roadside Ditch Covariate

Distance from roadside ditches was used as a covariate for ground and shrub layer data to reduce variability within treatments. The objective was to eliminate the effect such non-treatment ditches would have on the vegetation. It was hypothesized that gradients would be observed across treatment areas with increasing distances from roadside ditches. However, this covariate proved to be nonsignificant for all tests in both layers. It did not affect the results or reduce the variability of any of the analyses. For this reason, it was discarded from the analyses. The ineffectiveness of this covariate is exemplified by the low correlation coefficients between distance to roadside ditch and all analysis variables (Table

4.17-4.20). Although the tabled coefficients are for the combined plot data, the individual plot data yielded much lower values because of the variability induced by microsite conditions.

Summary of Site Preparation and Fertilation\Release Results

A Friedman nonparametric test was used to summarize all results from the tests of site preparation and fertilization treatment effects. Results of each test in a canopy layer were ranked for each site preparation (1-3) and fertilization (1-4) treatment. A 1 represents the lowest mean observed in that canopy layer for each parameter, except for the average wetland values where 1 represents the highest value recorded (higher numbers indicate drier vegetation for wetland values). These ranks were then summed (within a canopy layer and between canopy layers) and tested.

Ranks were also averaged over all measurements and all canopy layers for a particular treatment. The average rank for the treatment represents the general effect of the treatment on the total stand's productivity and diversity, with higher numbers indicating more positive effects. This assumes that all parameters have equal weight. For certain management objectives, this may not be appropriate. However, data are provided so that weighting of parameters is possible if desired. Average ranks were also calculated with productivity and diversity parameters considered independently.

Site Preparation Treatment Effects

No differences were detected between the site preparation treatments for all vegetative parameters in either the individual canopy layers or the combined canopy layers (Table 4.25). In addition, when productivity and diversity parameters were considered independently, treatments were again not significantly different (Table 4.26 and 4.27). Given the assumption that all of these characteristics have equal value, these results indicate that none of the site preparation treatments can be universally recommended. Trade-offs apparently exist between productivity and diversity in each canopy layer and between canopy layers. Overall, there appears to be no difference between these treatments in either productivity or diversity when all vegetative characteristics and all canopy layers are given equal weight.

Fertilization Treatment Effects

Differences were detected from the analysis of ranks of fertilizer treatments for the combined canopy layers ($p<0.005$) (Table 4.28). The phosphorous treatment showed the lowest ranks, primarily due to values in the midstory and shrub layer. The NPL treatment was intermediate, and

Table 4.25. Average rank of all parameters by canopy layer and site preparation treatment.

	Site Preparation Treatment											
	Chop and Burn				Bedded				Ditched			
Parameter	G[1]	S[2]	M[3]	O[4]	G	S	M	O	G	S	M	O
Total Biom	2	3	2	1	3	1	1	3	1	2	3	2
S-W Biom[5]	2	3	1	1	1	1	3	3	3	2	2	2
Sim Biom[6]	3	2	1	1	1	1	3	3	2	3	2	2
Total N/Ha	2	2	2	1	3	3	1	3	1	1	3	2
S-W Num[7]	2	2	1	2	1	1	3	1	3	3	2	3
Sim Num[8]	2	2	1	2	1	1	3	1	3	3	2	3
Total BA			3	1			1	3			2	2
S-W BA[9]			1	1			3	3			2	2
Sim BA[10]			1	1			3	3			2	2
Av. DBH			3	1			1	3			2	2
Av. Height	2	2	3	1	3	1	1	3	1	3	2	2
% Cover	2	3			3	2			1	1		
Can. Dep.[11]	1	3			3	1			2	2		
# Species	1.5	3	2	3	1.5	1	3	1	3	2	1	2
Val. Num[12]	2	2	1	3	3	3	2	1	1	1	3	2
Val. Biom[13]	1	2	1	3	3	3	2	2	2	1	3	1
Average	1.9	2.4	1.6	1.6	2.2	1.6	2.1	2.4	1.9	2.0	2.2	2.1
Treatment Average	1.88				2.07				2.05			

1 - Ground layer
2 - Shrub layer
3 - Midstory
4 - Overstory
5 - Shannon-Wiener index weighted for biomass
6 - Simpsons index weighted for biomass
7 - Shannon-Wiener index weighted for numbers
8 - Simpsons index weighted for numbers
9 - Shannon-Wiener index weighted for basal area
10 - Simpsons index weighted for basal area
11 - Canopy depth (top of canopy layer to lowest branch)
12 - Wetland value weighted for numbers
13 - Wetland value weighted for biomass

Table 4.26. Average rank of productivity parameters by canopy layer and site preparation treatment.

	Site Preparation Treatment											
	Chop and Burn				Bedded				Ditched			
Parameter	G[1]	S[2]	M[3]	O[4]	G	S	M	O	G	S	M	O
Total Biom	2	3	2	1	3	1	1	3	1	2	3	2
Total N/Ha	2	2	2	1	3	3	1	3	1	1	3	2
Total BA			3	1			1	3			2	2
Av. DBH			3	1			1	3			2	2
Av. Height	2	2	3	1	3	1	1	3	1	3	2	2
% Cover	2	3			3	2			1	1		
Average	2.0	2.5	2.6	1.0	3.0	1.8	1.0	3.0	1.0	1.8	2.4	2.0
Treatment Average	2.03				2.19				1.79			

1 - Ground layer
2 - Shrub layer
3 - Midstory
4 - Overstory

Table 4.27. Average rank of diversity parameters by canopy later and site preparation treatment.

	Site Preparation Treatment											
	Chop and Burn				Bedded				Ditched			
Parameter	G[1]	S[2]	M[3]	O[4]	G	S	M	O	G	S	M	O
S-W Biom[5]	2	3	1	1	1	1	3	3	3	2	2	2
Sim Biom[6]	3	2	1	1	1	1	3	3	2	3	2	2
S-W Num[7]	2	2	1	2	1	1	3	1	3	3	2	3
Sim Num[8]	2	2	1	2	1	1	3	1	3	3	2	3
S-W BA[9]			1	1			3	3			2	2
Sim BA[10]			1	1			3	3			2	2
# Species	1.5	3	2	3	1.5	1	3	1	3	2	1	2
Average	2.1	2.4	1.1	1.6	1.1	1.0	3.0	2.1	2.8	2.6	1.9	2.3
Treatment Average	1.80				1.81				2.39			

1 - Ground layer
2 - Shrub layer
3 - Midstory
4 - Overstory
5 - Shannon-Wiener index weighted for biomass
6 - Simpsons index weighted for biomass
7 - Shannon-Wiener index weighted for numbers
8 - Simpsons index weighted for numbers
9 - Shannon-Wiener index weighted for basal area
10 - Simpsons index weighted for basal area

Table 4.28. Average rank of all parameters by canopy layer and fertilization treatment.

	Fertilizer Treatment															
	Control				P				NP				NPL			
Parameter	G[1]	S[2]	M[3]	O[4]	G	S	M	O	G	S	M	O	G	S	M	O
Total Biom	4	3	1	3	3	2	3	1	1	1	2	2	2	4	4	4
S-W Biom[5]	4	4	3	3	2	1	1	2	3	3	4	4	1	2	2	1
Sim Biom[6]	4	4	3	3	3	1	1	2	2	3	4	4	1	2	2	1
Total N/Ha	1	3	1	1	2	4	4	2	4	2	3	3	3	1	2	4
S-W Num[7]	3	3	2	3	2	1	1	1	4	4	4	4	1	2	3	2
Sim Num[8]	4	3	3	3	2	1	1	1	3	4	4	4	1	2	2	2
Total BA			1	1			3	3			2	2			4	4
S-W BA[9]			3	3			1	2			4	4			2	1
Sim BA[10]			3	3			1	2			4	4			2	1
Av. DBH			3	3			2	2			1	1			4	4
Av. Height	4	2	2	3	3	4	4	2	1	1	1	1	2	3	3	4
% Cover	1	4			3	2			4	1			2	3		
Can. Dep.[11]	3	2			2	3			4	1			1	4		
# Species	3	4	3	3.5	1.5	1	1	1	4	2	3	3.5	1.5	3	3	2
Val. Num[12]	1	4	3	3	2	2	1	3	3	1	4	1	4	3	2	3
Val. Biom[13]	4	4	3	3	1	1	1	3	2	3	4	1	3	2	2	3
Average	3.0	3.3	2.4	2.8	2.2	1.9	1.8	1.9	2.9	2.2	3.1	2.8	1.9	2.6	2.6	2.6
Treatment Average	2.88				1.96				2.75				2.42			

1 - Ground layer
2 - Shrub layer
3 - Midstory
4 - Overstory
5 - Shannon-Wiener index weighted for biomass
6 - Simpsons index weighted for biomass
7 - Shannon-Wiener index weighted for numbers
8 - Simpsons index weighted for numbers
9 - Shannon-Wiener index weighted for basal area
10 - Simpsons index weighted for basal area
11 - Canopy depth (top of canopy layer to lowest branch)
12 - Wetland value weighted for numbers
13 - Wetland value weighted for biomass

the NP and control had the highest values. The individual canopy layers showed similar differences (ground layer, $p<0.10$; shrub layer, $p<0.05$; midstory, $p<0.05$; overstory, not significant). The reason for this observed effect is unclear.

The productivity parameters likewise exhibited significant differences between treatments ($p<0.025$) (Table 4.29). The NP treatment had the lowest value, the control was second, P was third, and NPL had the highest total ranks. The reason for the poor productivity of the NP treatment as compared to the others is uncertain. However, Blatt (1964) and Das (1963) found decreased productivity with nitrogen fertilization, possibly due to an imbalance in N:P ratio or to reduced mycorrhizal growth.

Diversity rankings revealed highly unpredictable results. The P and NPL treatments had much lower average ranks than either the control or the NP treatment ($p<0.001$) (Table 4.30). Although seemingly unrelated, these results may be explained by differing nutrient requirements for various species. It is possible that there exist in the study areas certain phosphorous-limited plants and other nitrogen-limited plants. Under the control treatment, both groups are limited and diversity is high. Under the P treatment, the phosphorous-limited plants experience a growth increase and diversity declines. In the NP treatment, the nitrogen-limited plants respond and diversity again increases. With the addition of lime, phosphorous is made more available and the phosphorous-limited plants respond with increased growth. As a result, diversity declines. Overall, these results suggest that changing the nutrient status of the stand is likely to favor some species over others and thus change stand composition and diversity.

Table 4.29. Average rank of productivity parameters by canopy layer and fertilization treatment.

	Fertilizer Treatment															
	Control				P				NP				NPL			
Parameter	G[1]	S[2]	M[3]	O[4]	G	S	M	O	G	S	M	O	G	S	M	O
Total Biom	4	3	1	3	3	2	3	1	1	1	2	2	2	4	4	4
Total N/Ha	1	3	1	1	2	4	4	2	4	2	3	3	3	1	2	4
Total BA			1	1			3	3			2	2			4	4
Av. DBH			3	3			2	2			1	1			4	4
Av. Height	4	2	2	3	3	4	4	2	1	1	1	1	2	3	3	4
% Cover	1	4			3	2			4	1			2	3		
Average	2.5	3.0	1.6	2.2	2.8	3.0	3.2	2.0	2.5	1.3	1.8	1.8	2.3	2.8	3.4	4.0
Treatment Average	2.33				2.75				1.85				3.13			

1 - Ground layer
2 - Shrub layer
3 - Midstory
4 - Overstory

Table 4.30. Average rank of diversity parameters by canopy layer and fertilization treatment.

	Fertilizer Treatment															
	Control				P				NP				NPL			
	G[1]	S[2]	M[3]	O[4]	G	S	M	O	G	S	M	O	G	S	M	O
S-W Biom[5]	4	4	3	3	2	1	1	2	3	3	4	4	1	2	2	1
Sim Biom[6]	4	4	3	3	3	1	1	2	2	3	4	4	1	2	2	1
S-W Num[7]	3	3	2	3	2	1	1	1	4	4	4	4	1	2	3	2
Sim Num[8]	4	3	3	3	2	1	1	1	3	4	4	4	1	2	2	2
S-W BA[9]			3	3			1	2			4	4			2	1
Sim BA[10]			3	3			1	2			4	4			2	1
# Species	3	4	3	3.5	1.5	1	1	1	4	2	3	3.5	1.5	3	3	2
Average	3.6	3.6	2.9	3.1	2.1	1.0	1.0	1.6	3.2	3.2	3.9	3.9	1.1	2.2	2.3	1.4
Treatment Average	3.30				1.43				3.55				1.75			

1 - Ground layer
2 - Shrub layer
3 - Midstory
4 - Overstory
5 - Shannon-Wiener index weighted for biomass
6 - Simpsons index weighted for biomass
7 - Shannon-Wiener index weighted for numbers
8 - Simpsons index weighted for numbers
9 - Shannon-Wiener index weighted for basal area
10 - Simpsons index weighted for basal area

SUMMARY AND CONCLUSIONS

The results of this research project indicate that hydrology manipulations and site preparation can have an impact on plant diversity at rotation age. These observations suggest that the effects of treatments applied during regeneration may be long-term. Further research into such rotation-age effects of silvicultural treatments is needed because the application of early stand results (before canopy closure) to mature forests is questionable.

Of the three techniques studied, bedding appears to exert the greatest influence on plant diversity. This is due to the fact that bedding not only alters site hydrology during regeneration but also serves as competition control through mechanical disturbance. Such disturbance limits the sprouting of shrub and hardwood species and provides the overstory pines with a competitive advantage which persists through rotation age. As a result, productivity in the midstory of bedded treatments was reduced. Diversity in the shrub layer was also reduced, though midstory diversity was increased by bedding. The observed increase in midstory diversity is believed to be the result of reduced sprouting in midstory dominants (e.g. red maple). By limiting hardwood and shrub resprouting, stand biomass production is allocated more to the overstory and less to the midstory or understory.

The bedded treatment used in this study also involved piling and burning debris in windrows. Windrowing can represent a severe soil disturbance, and can greatly reduce hardwood sprouting. It, therefore, cannot be determined from these results whether bedding without windrowing would have as drastic effect on hardwood and shrub sprouting. It has been hypothesized from these results that a reduction in hardwood and shrub sprouting is the primary reason that the bedded treatment exhibited less diversity in the shrub layer and reduced productivity midstory.

Ditching in most cases did not exhibit a significant effect on plant diversity in any canopy layer. This may result from the limited ability of the ditches to drain the entire site. Ditches generally exhibited a "zone of influence" of approximately 40-50 meters (personal observation) in which diversity effects might be observed. Beyond this zone, however, ditching was much less effective in controlling water table level, and thus, had less effect on controlling diversity. It should be noted, however, that ditching did improve the growth of overstory vegetation compared to the unditched chop and burn. These results demonstrate that secondary ditching in these wet pine flats improves rotation-age tree productivity.

Roadside ditches provided primary drainage for all sites but did not affect vegetation characteristics sufficiently to alter results. It is likely that these ditches also exhibited a zone of influence, but this zone was not sampled due to the borders along the edges of treatments. The results of water table analyses in general suggest that roadside ditches are not removing sufficient water from the site at the present time to alter hydrology conditions.. Perhaps the slow percolation of water through the thick, clayey subsoil prevents areas greater than 50 meters from the ditch to experience any effect. The years of data collection (1991-1992) were also somewhat dry compared to normal rainfall. Regardless, almost all treatment and roadside ditches were dry during the growing season, so that any beneficial effects of ditching were only experienced during the dormant season. Ditching may alter site hydrology and improve growth of young loblolly pine stands, but at this stage of development, transpiration appears to be much more effective at lowering water levels than is ditching.

Fertilization\release exhibited unusual and inconsistent effects on plant diversity at rotation age. Although fertilization was relatively light and occurred over ten years prior to this study, significant responses were still detected. Difficulty arises in applying these results because there were no consistent patterns to suggest that certain practices were uniformly beneficial or detrimental. It is possible that the unique nutrient requirements of each species, particularly in the understory, create a situation where different combinations of fertilizer and lime favor or hinder each species independently. Under such conditions, the effects of fertilization on plant diversity would be a matrix of competitive interactions, some species increasing in relative dominance and some declining. The effects on overall diversity would be very difficult to predict. Liming, however, did exhibit a definite productivity response in the shrub layer and the overstory. Whether this gain was due to changes in pH or increased availability of calcium or magnesium is uncertain.

A confounding factor to the fertilization results was the cutting of hardwoods as a release treatment in association with fertilization. According to available records, there was little control of cutting intensity or consistency between treatment areas. It is probable, however, that this release did impact vegetation characteristics, though quantification of the effects are not possible.

Water table level exerted a significant influence on midstory diversity, but the effect was not as pronounced on other canopy layers. Apparently, wet flat hardwoods are more sensitive to water table alterations than either overstory loblolly pines or understory shrubs. Because midstory hardwoods are also severely impacted by mechanical disturbance, this may be the most critical canopy layer in determining overall stand diversity. The effect of shading and root competition of this layer on shrub and ground layer vegetation may be significant. It is possible that diversity in all three layers (midstory, shrub layer, and ground layer) are dependent upon the interacting factors of water table, soil fertility, and disturbance on the midstory.

Correlation analyses indicated that lower canopy layers experience direct competitive effects from overstory vegetation. As noted above, this can create complications for predicting the impacts of treatments on various canopy layers. Treatments may have direct effects (disturbance or alteration of site hydrology), indirect effects (alteration of competitive interactions between canopy layers), or most likely both. Given these overlapping responses, predicting the effects of various combinations of treatments at this time is highly speculative. More research is needed into the effects of treatment combinations, with emphasis on better understanding direct and indirect responses on various canopy layers.

Correlation analyses also indicated the degree of similarity between various vegetation measures. Results indicated that in the midstory and overstory basal area was highly correlated to biomass. For this reason, only basal area needs to be measured for diversity estimation. Biomass estimation is much more difficult and labor intensive, and results are not significantly different than basal area.

Biomass and density were not as well correlated, particularly in the shrub and ground layer. Of the two, biomass appears to be the more effective measure for determining evenness between species. Despite the difficulty in obtaining accurate data, biomass seemed less subject to wide fluctuations due to single species responses. Density, especially for very small plants, may increase drastically with only small increases in biomass, causing results to be skewed toward the smallest plants.

Furthermore, the Shannon-Wiener index results were highly correlated to Simpsons index. To acquire an acceptable measure of diversity, only one index needs to be used.

The procedure for developing the midstory biomass equations yielded very good results. Biomass exhibited a high linear association to dbh and height. The ability for such equations to be used between sites of differing quality, however, is untested. Overstory height was poorly predicted from the regression equations based on dbh. This was due primarily to the wide range in potential diameters, and the ability of loblolly to develop tall, slender trees under crowded conditions. It may have also resulted from pine crown damage caused by ice storms (personal observation). Given sufficient time, all heights should be measured if possible.

An important limitation in the application of these results is the absence of prescribed fire and thinnings from the study areas. Typical intensive forestry in the Coastal Plain incorporates periodic prescribed fire and at least one thinning during a rotation. The application of these results to such stands is questionable. In addition, because limited fires are a natural occurrence in the Coastal Plain, it is possible that the exclusion of fire has created an unnatural condition. It is possible that these stands are under- or over-diverse as compared to their natural state, due to fire suppression.

Thinning should, hypothetically, increase stand diversity by opening up the canopy and providing more water and nutrients for understory species. How long such a "flush" of understory productivity and diversity would persist as the canopy closed after thinning is in need of further study. At the very least, thinning will reduce pine biomass temporarily, causing an increase in either Simpsons index or the Shannon-Wiener index. Partial elimination of the most dominant species will invariably increase either index, regardless of whether other species respond.

The effect of prescribed fire on diversity in wet pine flats is more variable, depending largely on the timing and frequency of burning. Frequent fires (5 year intervals or less) would probably reduce diversity by not allowing shrub species sufficient time to recover between burns. Prescribed fire should alter species competition in favor of more fire tolerant species, but whether this will increase or decrease overall diversity is unpredictable. The effects on diversity of thinning and prescribed fire in combination are too unpredictable for speculation.

It is important to note, however, that none of the species which showed a significant response to treatments are considered to be threatened or endangered. In fact, almost all of the species encountered in the study areas are extremely common and are in no danger of extinction in the foreseeable future. The question must then be asked as to whether a reduction in density or biomass for such common species actually represents a social loss. Given that commodity production can be increased by controlling competing species, then conservation of these species implies equal value. Obviously, if reductions in these species result in wildlife extirpations or reduced ecosystem functioning, then protection of such plant species must receive greater priority. If such effects cannot be demonstrated, however, the decision of balancing acceptable levels of understory and overstory production ultimately becomes a social one.

LITERATURE CITED

Allen, H.L. and R.G. Campbell. 1988. Wet site pine management in the southeastern United States. In The Ecology and Management of Wetlands, Vol. 2: Management, Use and Value of Wetlands. D.D. Hook, et al. (eds.) Timber Press, Portland, Ore. pp 173-184.

Auclair, A.N. and F.G. Goff. 1971. Diversity relations of upland forests in the western Great Lakes area. Am. Natur. 105:499-528.

Blair, R.M. and D.P. Feduccia. 1977. Midstory hardwoods inhibit deer forage in loblolly pine plantations. J. Wildl. Manage. 41(4):677-683.

Blatt, C.R. 1964. Nitrogen-phosphorous relationships in the nutrition of pitch pine (*Pinus rigida* Mill.). Ph.D. Dissertation. Rutgers Univ. Univ. Microfilms. Ann Arbor, Mich. 60 pp.

Brown, M.J. 1986. Forest statistics for Virginia. USDA Forest Service, Southeastern Forest Experiment Station Resource Bulletin SE-87. Asheville, N.C. 67 pp.

Campbell, R.G. and J.H. Hughes. 1981. Forest management systems in North Carolina pocosins: Weyerhaeuser. In Pocosin Wetlands. C.J. Richardson (ed.) Hutchinson Ross, Stroudsburg, PA. pp.199-213.

Campbell, R.G. 1976. Drainage of lower coastal plain soils. In Proceedings: Sixth Southern Forest Soils Workshop. U.S.D.A. Forest Service.

Clark, A., D.R. Phillips, and D.J. Frederick. 1985. Weight, volume, and physical properties of major hardwood species in the Gulf and Atlantic Coastal Plains. USDA Forest Service, Southern Forest Experiment Station, Res. Paper SE-250. 66 pp.

Clark, A. and M.A. Taras. 1976. Comparison of aboveground biomasses of the four major southern pines. Forest Products Journal 26(10):25-29.

Connell, J.H. 1978. Diversity in tropical rainforests and coral reefs. Science 199:1302-1310.

Conover, W.J. 1971. Practical Nonparametric Statistics. Wiley and Sons, New York. 462 pp.

Das, A.C. 1963. Utilization of insoluble phosphates by soil fungi. J. Indian Soc. Soil Sci. 11:203-207.

Denslow, J.S. 1980. Patterns of plant species diversity during succession under different disturbance regimes. Oecologia 46:18-21.

Ehrlich, P.R. 1990. Habitats in crisis: why we should care about the loss of species. Forest Ecol. and Manage. 35:5-11.

Ehrlich, P.R. 1988. The Loss of Diversity: Causes and Consequences. In Biodiversity. E.O. Wilson (ed.) National Academy Press. Washington, D.C. pp. 21-27.

Falk, D.A. 1990. Endangered forest resources in the U.S.: integrated strategies for conservation of rare species and genetic diversity. For. Ecol. and Manage. 35:91-117.

Federal Interagency Committee for Wetland Delineation. 1989. Federal Manual for Identifying and Delineating Jursidictional Wetlands. U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and U.S.D.A. Soil Conservation Service, Washington, D.C. Cooperative technical publication. 76 pp. plus appendices.

Franklin, J.F. 1988. Structural and Functional Diversity in Temperate Forests. In Biodiversity. E.O. Wilson (ed.) National Acedemy Press. Washington, D.C. pp. 166-175.

Godfrey, R.K. and J.W. Wooten. 1981. Aquatic and Wetland Plants of Southeastern United States: Dicotyledons. The University of Georgia Press. Athens, Ga. 933 pp.

Graves, A.H. 1956. Illustrated Guide to Trees and Shrubs. Harper and Brothers, Publishers. New York.

Grelen, H.E., L.B. Whitaker, and R.E. Lohrey. 1972. Herbage response to precommercial thinning in direct-seeded slash pine. J. of Range Manage. 25:435-437.

Halls, L.K. and J.L. Schuster. 1965. Tree-herbage relations in pine-hardwood forests of Texas. J. of Forestry 63:282-283.

Halls, L.K. 1968. Browse plants yield best in forest openings. J. of Wildl. Manage. 32(1):185-186.

Hansen, A.J., T.A. Spies, F.J. Swanson, and J.L. Ohmann. 1991. Conserving biodiversity in managed forests. Bioscience 41(6):382-392.

Harris, L.D. 1984. The Fragmented Forest: Island Biogeography Theory and Preservation of Biotic Diversity. p. 104-107. University of Chicago Press, Chicago, IL. 211 pp.

Hunter, M.L. 1990. Wildlife, Forests, and Forestry: Principles of Managing Forests for Biological Diversity. Prentice Hall. Englewood Cliffs, N.J. 370 pp.

Hurst, G.A., J.J. Campo, and M.B. Brooks. 1982. Effects of precommercial thinning and fertilizing on deer forage in a loblolly pine plantation. South. J. of Appl. Forestry 6:140-144.

Huston, M. 1979. A general hypothesis of species diversity. Am. Nat. 113(1):81-101.

Kitchel, W.F., H.T. Saxton III, R.A. Strauss, S.K. Thomas, and C.D. Peacock, Jr. 1986. Soil Survey of Isle of Wight County, Virginia. USDA Soil Conservation Service and Virginia Polytechnic Inst. and State Univ., Blacksburg, VA. 105 pp.

Klawitter, R.A. 1965. Woodland drainage in the Southeast. J. of Soil and Water Cons. 20(4):181-182.

Langdon, O.G. and W.H. McKee, Jr. 1981. Can fertilization of lobllolly pine on wet sites reduce the need for drainage? In First Biennial Southern Silvicultural Research Conference. J.P. Barnett (ed.) Gen. Tech. Rep. SO-34. U.S.D.A. Forest Service, Southern Forest Exp. Sta. New Orleans, La. pp. 212-218.

Langdon, O.G. 1962. Ridge planting improves early growth of South Florida slash pine. J. of For. 60:437.

MacArthur, R.H. 1965. Patterns of species diversity. Biol. Rev. 40:510-533.

Magurran, A.E. 1988. Ecological Diversity and Its Measurement. Princeton University Press. Princeton, N.J. 179 pp.

Maki, T.E. 1971. Drainage: effect on productivity. In Proceedings 50th Annual Meeting. Appal. Sect., Soc. Amer. For. Charleston, SC. pp. 16-23.

McConnell, B.R. and J.G. Smith. 1965. Understory response three years after thinning pine. J. of Range Manage. 18:129-132.

McKee, W.H., Jr. and L.P. Wilhite. 1986. Loblolly pine response to bedding and fertilization varies by drainage class on lower Atlantic coastal plain sites. South. J. of Appl. Forestry 10:16-21.

Milton, W.E.J. 1947. The yield, botanical, and chemical composition of natural hill herbage under manurinig, controlled grazing and hay conditions. J. Ecol. 35:65-89.

Mitsch, W.J. and J.G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold, New York. 539 pp.

Monk, C.D. 1965. Southern mixed hardwood forest of northcentral Florida. Ecol. Monog. 35:335-354.

National Technical Committee for Hydric Soils. 1987. Hydric Soils of the United States. USDA Soil Cons. Service.

Norse, E.A., K.L. Rosenbaum, D.S. Wilcove, B.A. Wilcox, W.H. Romme, D.W. Johnston, and M.L. Stout. 1986. Conserving Biological Diversity on Our National Forests. The Wilderness Society of America.

Office of Technology Assessment. 1987. Technologies to maintain biological diversity. U.S. Government Printing Office, Washington, D.C. OTA-F-330.

Olszewski, R.J. 1988. Forestland drainage and regulations in the Southern Coastal Plain. In Proceedings of the Symposium: The Forested Wetlands of the Southern United States. D.D. Hook and R. Lea (eds.) Orlando, Fla. pp. 59-62.

Patil, G.P. and C. Taillie. 1982. Diversity as a concept and its measurement. J. Am. Stat. Assoc. 77:548-561.

Phillips, D.R. and J.R. Saucier. 1982. Estimating understory biomass. South. J. of Appl. Forestry 6(1):25-27.

Pielou, E.C. 1975. Ecological Diversity. John Wiley and Sons, Inc. New York. 165 pp.

Plummer, G.L. 1963. Soils of the pitcher plant habitats in the Georgia Coastal Plain. Ecology 44:727-734.

Prichett, W.L. and W.H. Smith. 1974. Management of wet savannah forest soils for pine production. Univ. Fla. Agr. Expt. Stn., Gainesville. Bull. 762. 22 pp.

Probst, J.R. and T.R. Crow. 1991. Integrating biological diversity and resource management. Journal of Forestry 89:(2):12-17.

Radford, A.E., H.E. Ahles, and C.R. Bell. 1983. Manual of the Vascular Flora of the Carolinas. The University of North Carolina Press. Chapel Hill, N.C. 1183 pp.

Reber, E.J., M.A. Bailey, P.J. Swecker, J.S. Quesenberry, and D. Bradshaw. 1981. Soil Survey of City of Suffolk, Virginia. USDA Soil Conservation Service and Virginia Polytechnic Institute and State Univ., Blacksburg, VA. 99 pp.

Reed, P.B., Jr. 1988. National list of plant species that occur in wetlands: national summary. U.S. Fish Wildl. Serv. Biol. Rep. 88(24). 244 pp.

Reynolds, P.E. and W.R. Parrott. 1980. Hydrologic, soils and vegetation measurements for a southern New Jersey hardwood swamp. In Proceedings of the Central Hardwood Forest Conference III. H.E. Garrett and G.S. Cox (eds.) Univ. of Missouri, Columbia, MO. pp. 38-65.

Robinson, A.F. 1978. Possible impacts of silvicultural activities on proposed endangered and threatened plant species of pine flatwoods. In Proceedings: Soil Moisture Site Productivity Symposium. W.E. Balmer (ed.) USDA Forest Service, Southeastern Area State and Private Forestry, Atlanta, Ga. pp.336-342.

Salwasser, H. 1990. Conserving biological diversity: a perspective on scope and approaches. For. Ecol. and Manage. 35:79-90.

Spurr, S.H. and B.V. Barnes. 1980. Forest Ecology. 3rd ed. John Wiley and Sons, New York. 687 pp.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics: A Biometrical Approach. 2nd ed. McGraw-Hill, New York. 633 pp.

Swindel, B.F., L.F. Conde, and J.E. Smith. 1984. Species diversity: concept, measurement and response to clearcutting and site-preparation. For. Ecol. and Manage. 8:11-22.

Thompson, L.M. and F.R. Troeh. 1978. Soils and Soil Fertility. McGraw-Hill, Inc., New York. 516 pp.

Tiner, R.W., Jr. 1987. A Field Guide to Coastal Wetland Plants of the Northeastern United States. The University of Massachusetts Press, Amherst, Mass.

Westman, W.E. 1990. Managing for biodiversity. Bioscience 40(1):26-33.

Wilhite, L.P. and E.P. Jones, Jr. 1981. Bedding effects in maturing slash pine stands. South. J. of Appl. Forestry 5(1):24-27.

Wilson, E.O. 1985. The biological diversity crisis. Bioscience 35(11):700-706.

Wolters, G.L. 1982. Longleaf and slash pine decreases herbage production and alters herbage composition. J. of Range Manage. 35(6):761-763.

Wolters, G.L., A. Martin, and H.A. Pearson. 1982. Forage response to overstory reduction on loblolly-shortleaf pine-hardwood forest range. J. of Range Manage. 35(4):443-446.

Appendix A

Scientific and common names of all species encountered in vegetation sampling.

SPECIES LIST

Scientific name	Common name	Canopy layers
Acer rubrum	Red Maple	O,M,S,G
Amelanchier canadensis	Serviceberry	S,G
Aronia arbutifolia	Chokeberry	M,S,G
Arundinaria gigantea	Switch Cane	S,G
Botrychium virginianum	Rattlesnake Fern	G
Clethra alnifolia	Sweet Pepperbush	S,G
Cornus ammomum	Silky Dogwood	S,G
Cypripedium acaule	Pink Lady Slipper	G
Cyrilla racemiflora	Titi	M
Ilex decidua	Possumhaw	M
Ilex glabra	Gallberry	M,S,G
Ilex opaca	American Holly	O,M,S,G
Itea virginica	Virginia Willow	S,G
Leucothoe axillaris	Dog Hobble	S,G
Leucothoe racemosa	Swamp Leucothoe	S,G
Liquidambar styraciflua	Sweetgum	O,M,S,G
Lonicera japonica	Honeysuckle	S,G
Lyonia lucida	Fetterbush	S,G
Magnolia virginiana	Sweetbay	O,M,S,G
Mitchella repens	Partridge Berry	G
Myrica cerifera	Wax Myrtle	M,S,G
Nyssa sylvatica	Black Gum	O,M,S,G
Nyssa sylvatica var. biflora	Swamp Tupelo	O,M,S,G

Onoclea sensibilis	Sensitive Fern	G
Osmunda cinnamomea	Cinnamon Fern	S,G
Oxydendrum arboreum	Sourwood	O,M,S,G
Parthenocisus quinqifolia	Virginia Creeper	S,G
Persea borbonia	Red Bay	M
Pinus taeda	Loblolly Pine	O,M
Prunus serotina	Black Cherry	O,M
Quercus alba	White Oak	O,G
Quercus michauxii	Swamp Chestnut Oak	O
Quercus nigra	Water Oak	O,M,S,G
Quercus phellos	Willow Oak	O,G
Rhododendron viscosum	Swamp Azalea	M,S,G
Rubus hispidus	Swamp Dewberry	G
Sassafras albidum	Sassafras	O,M,S,G
Selaginella apoda	Lycopod	G
Smilax glauca	Catbrier	S,G
Smilax laurifolia	Catbrier	S,G
Smilax rotundifolia	Catbrier	S,G
Sphagnum spp.	Sphagnum Moss	G
Thelypteris palustris	Marsh Fern	S,G
Toxicodendron radicans	Poison Ivy	S,G
Vaccinium corymbosum	Highbush Blueberry	M,S,G
Vitis rotundifolia	Muscadine Grape	S,G

Appendix B

Scatter plots for midstory biomass regression equations developed from diameter at breast height and height.

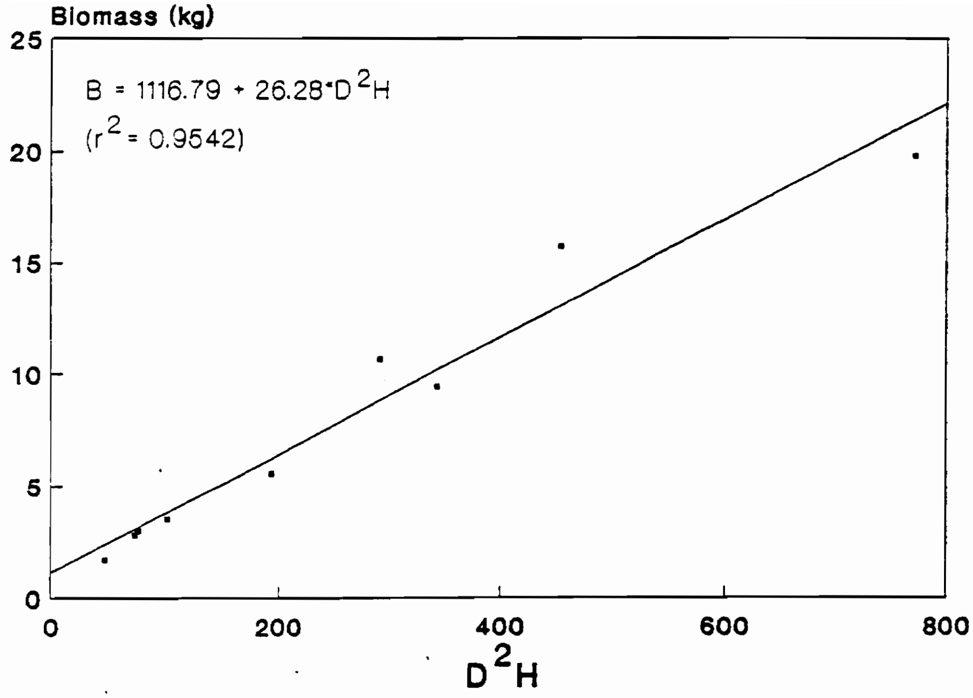


Figure B.1. Midstory biomass regression equation for swamp tupelo.

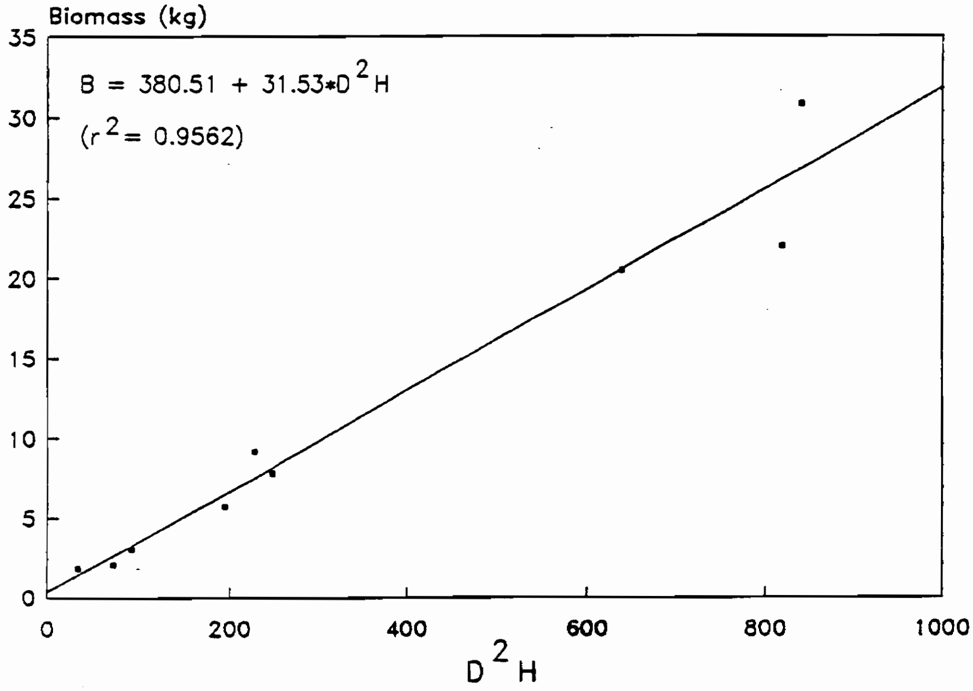


Figure B.2. Midstory biomass regression equation for red maple.

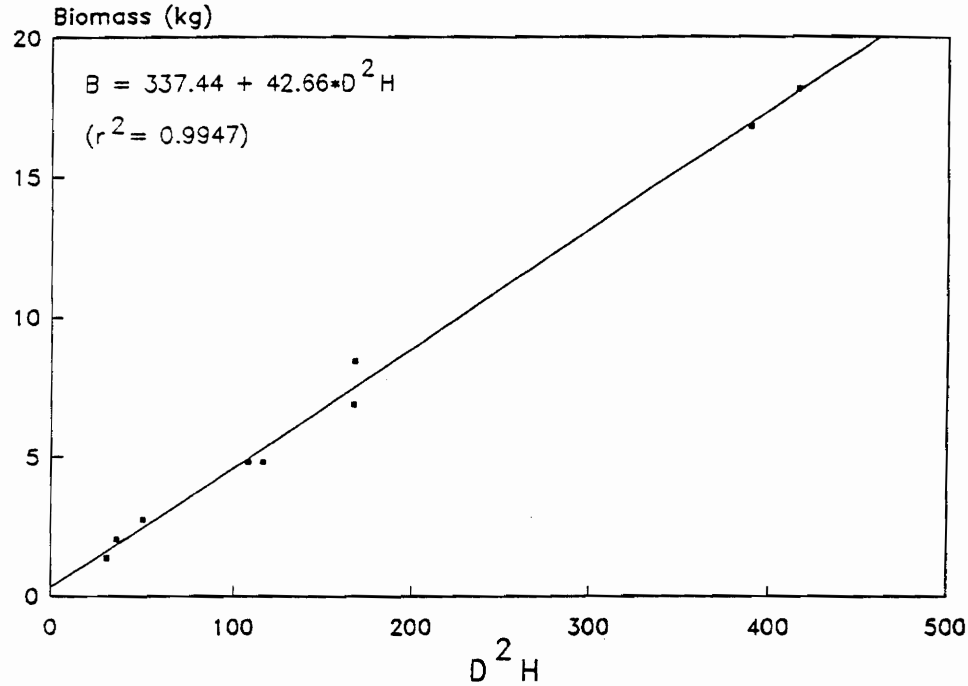


Figure B.3. Midstory biomass regression equation for american holly.

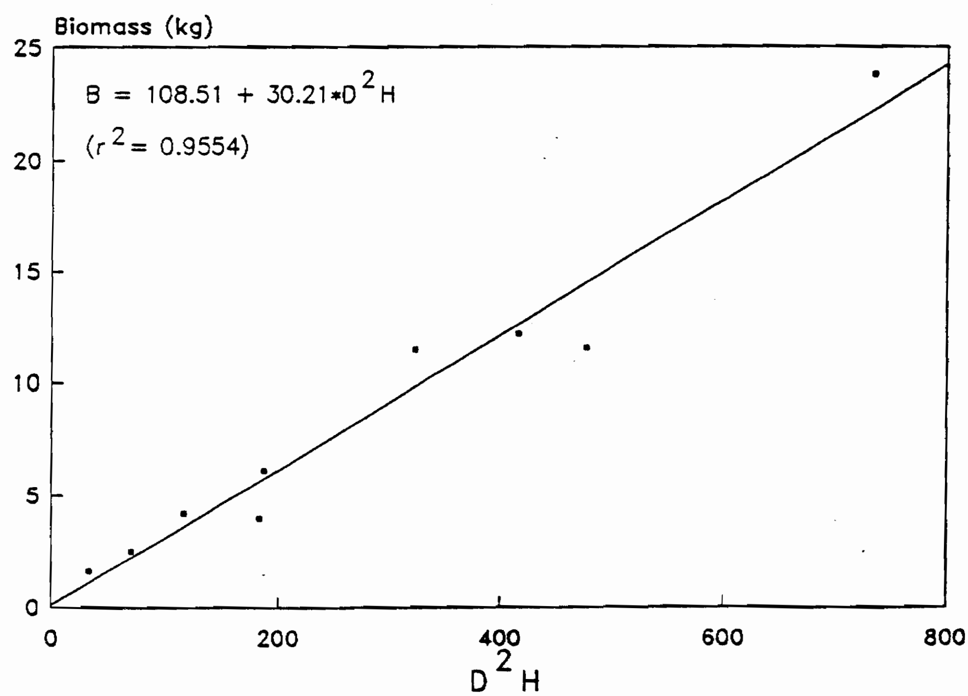


Figure B.4. Midstory biomass regression equation for sourwood.

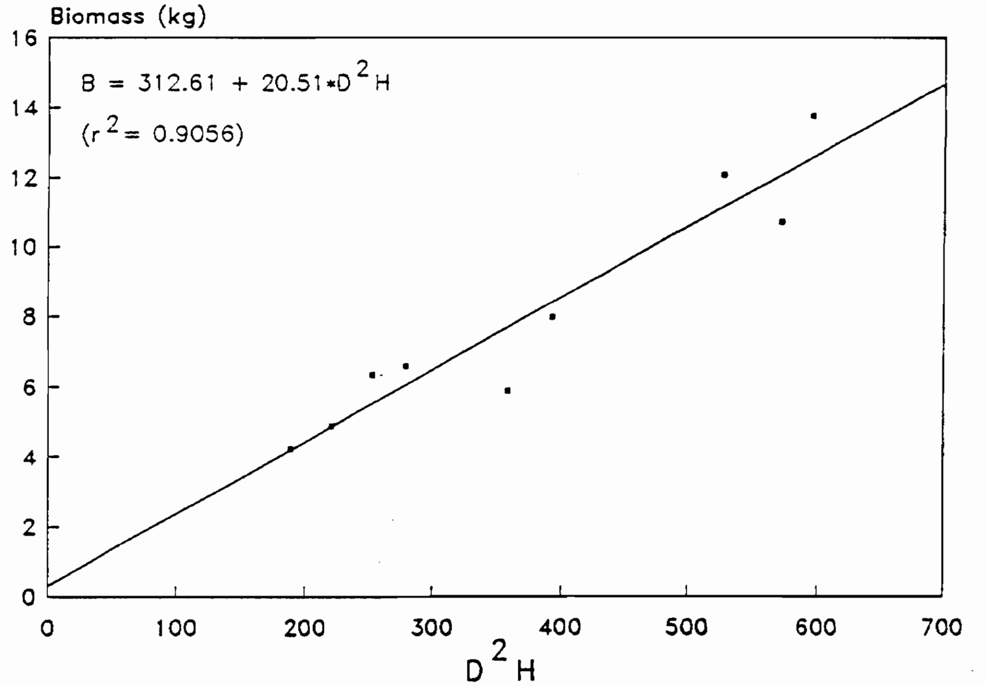


Figure B.5. Midstory biomass regression equation for loblolly pine.

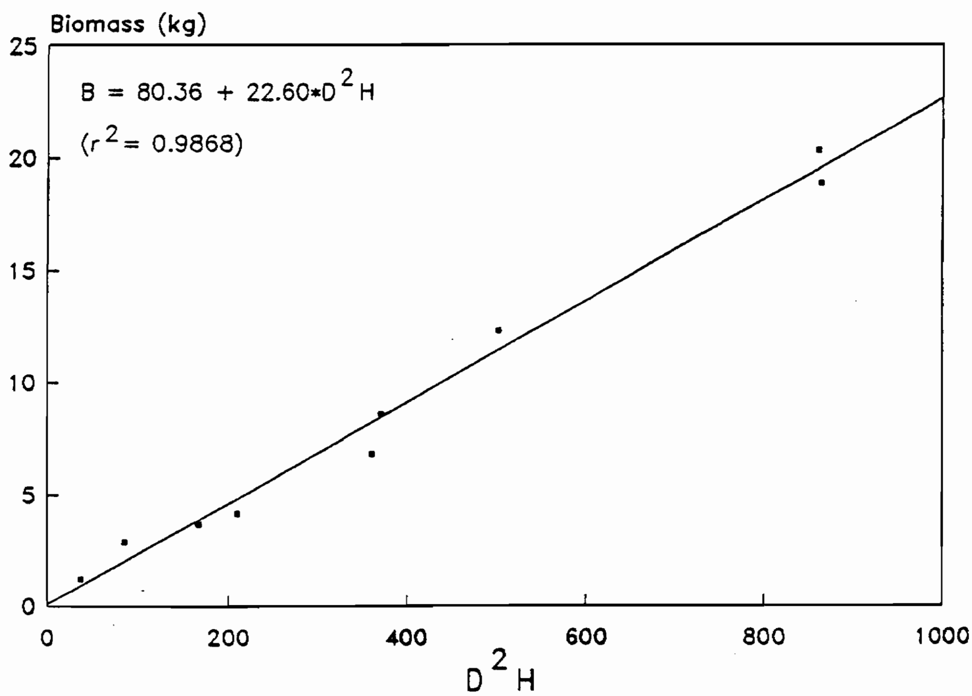


Figure B.6. Midstory biomass regression equation for sweetgum.

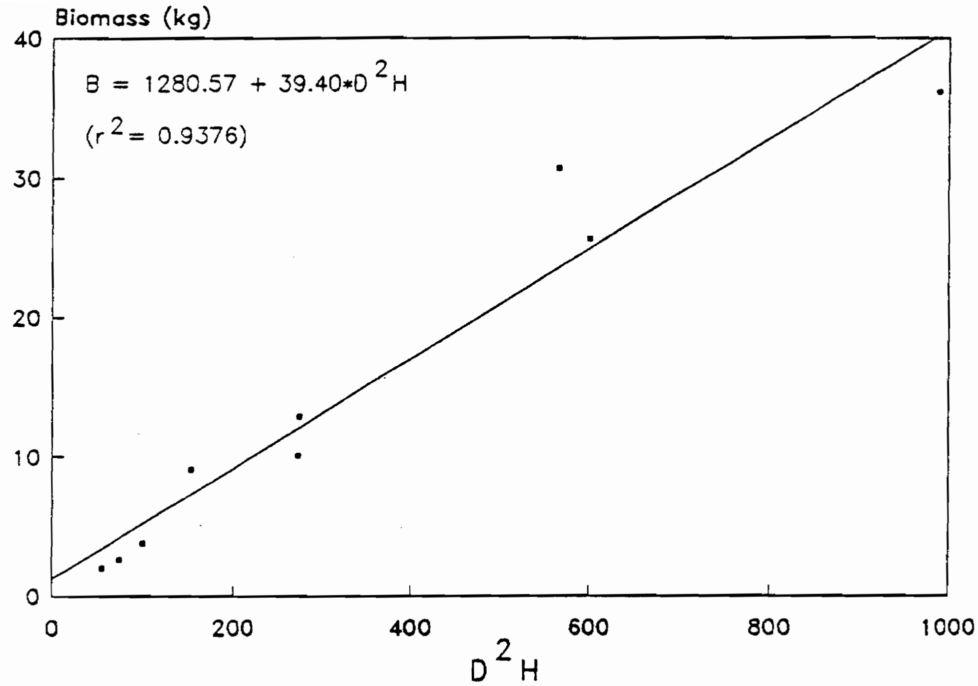


Figure B.7. Midstory biomass regression equation for water oak.

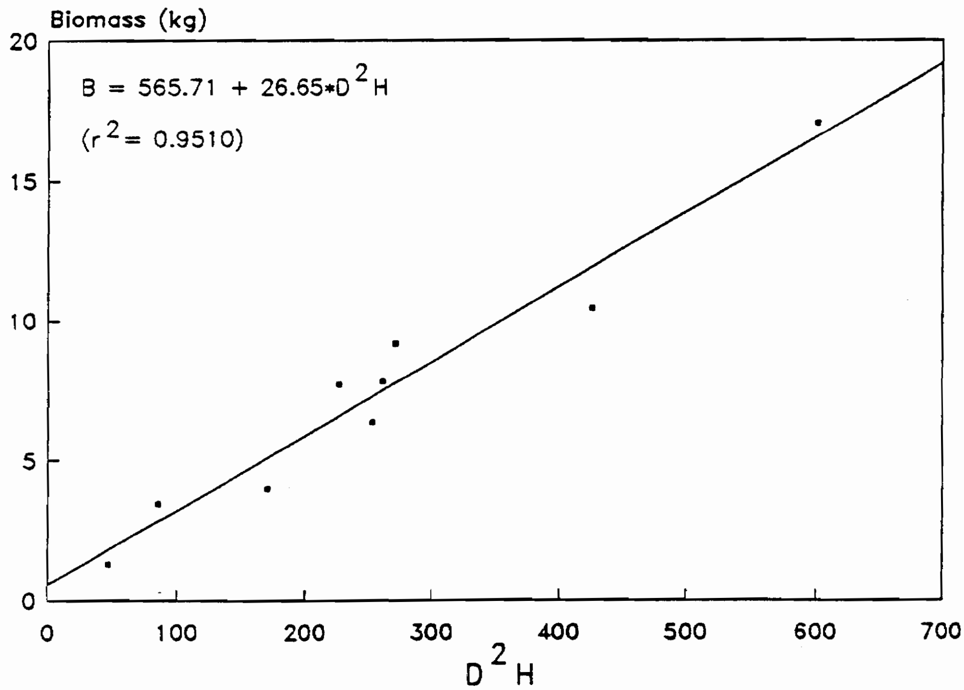


Figure B.8. Midstory biomass regression equation for black gum.

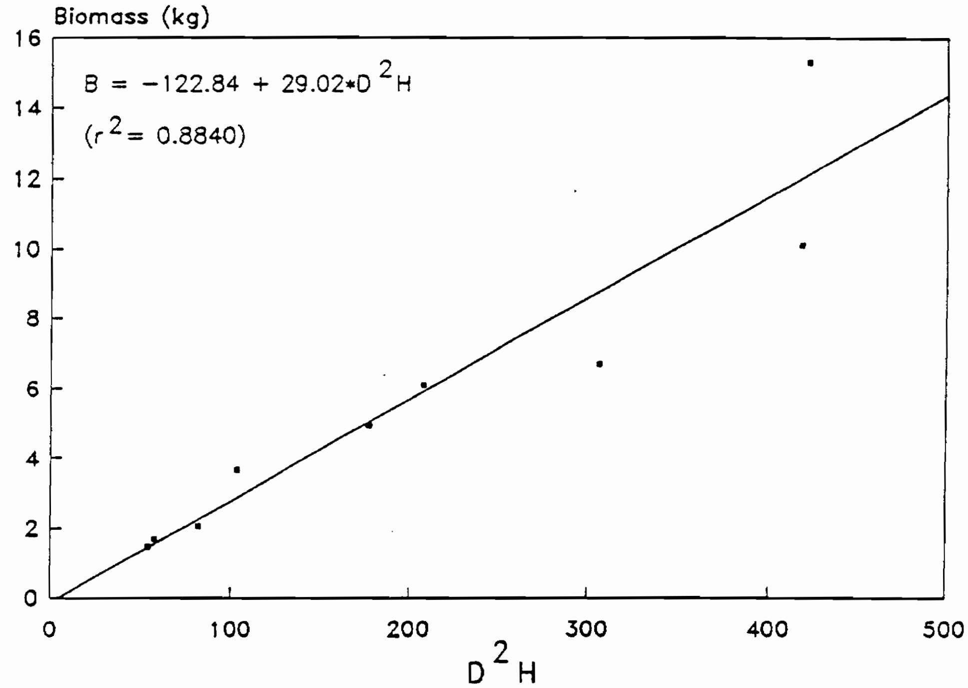


Figure B.9. Midstory biomass regression equation for sweet bay.

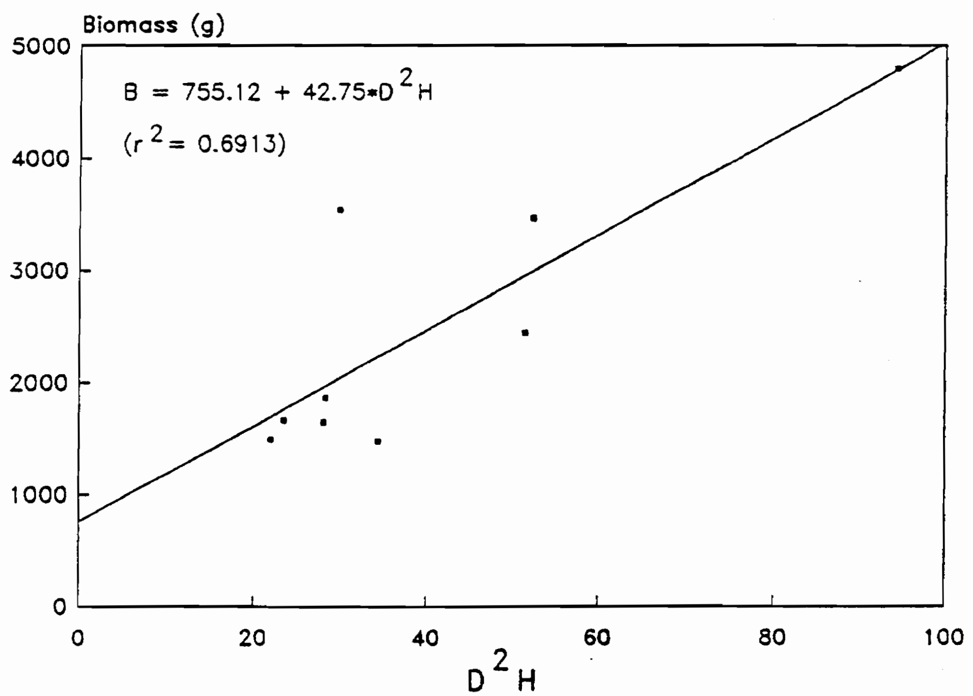


Figure B.10. Midstory biomass regression equation for shrubs.

Appendix C

Site differences based on analysis of fertilization treatment data.

Table C.1. Ground layer site differences based on fertilization treatment data.

	Block			Statistics	
Parameter	Holland	Windsor	Wh.ville	Std.Dev.	p-level
Total Biom (kg/Ha)	244.49	127.30	219.51	74.132	0.5514
S-W Biom[1]	1.135	0.840	0.949	0.1094	0.2690
Sim Biom[2]	0.538	0.431	0.488	0.0469	0.3645
Total N/Ha	583889	310417	430417	139970.9	0.4568
S-W Num[3]	1.658	1.337	1.227	0.1265	0.1515
Sim Num[4]	0.683	0.630	0.560	0.0559	0.3843
Av. Height (cm)	9.85	9.54	8.74	1.2636	0.8222
% Cover	8.65	3.56	5.36	1.9901	0.2943
Can. Dep.[5] (cm)	30.23	27.87	27.23	2.8799	0.7555
# Species	12.8**b**[*]	8.1**a**	9.0**a**	0.6684	0.0163
Val. Num[6]	2.690	2.495	2.673	0.1658	0.6805
Val. Biom[7]	2.363	2.301	2.515	0.0825	0.2795

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Canopy depth (top of canopy layer to lowest branch)
6 - Wetland value weighted for numbers
7 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Table C.2. Shrub layer site differences based on fertilization treatment data.

	Block			Statistics	
Parameter	Holland	Windsor	Wh.ville	Std.Dev.	p-level
Total Biom (kg/Ha)	6640.3**b***	7490.2**b**	3154.1**a**	780.22	0.0351
S-W Biom[1]	1.321	1.113	0.855	0.1580	0.2284
Sim Biom[2]	0.657	0.599	0.454	0.0599	0.1562
Total N/Ha	98194.5	89166.7	73750.0	15162.34	0.5634
S-W Num[3]	1.242	1.009	1.016	0.0931	0.2460
Sim Num[4]	0.585	0.504	0.535	0.0419	0.4540
Av. Height (m)	1.37	1.32	0.91	0.1259	0.1119
% Cover	24.61	25.25	14.54	2.9917	0.1100
Can. Dep.[5] (m)	2.13**b**	2.06**b**	1.03**a**	0.2157	0.0393
# Species	7.3	5.1	4.7	0.7257	0.1146
Val. Num[6]	2.417	2.263	2.435	0.0965	0.4571
Val. Biom[7]	2.527	2.411	2.620	0.1058	0.4516

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Canopy depth (top of canopy layer to lowest branch)
6 - Wetland value weighted for numbers
7 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Table C.3. Midstory site differences based on fertilization treatment data.

	Block			Statistics	
Parameter	Holland	Windsor	Wh.ville	Std.Dev.	p-level
Total Biom (kg/Ha)	13053.2	17891.9	12460.2	2766.43	0.4006
S-W Biom[1]	0.889	0.942	0.861	0.0380	0.3959
Sim Biom[2]	0.488	0.531	0.486	0.0212	0.3314
Total N/Ha	2716.7	3691.7	2283.3	359.77	0.1104
S-W Num[3]	1.066	0.941	1.004	0.0622	0.4385
Sim Num[4]	0.576	0.519	0.558	0.0263	0.3891
Total BA (m^2/Ha)	4.37	5.61	4.02	0.6816	0.3248
S-W BA[5]	0.917	0.960	0.917	0.0541	0.8189
Sim BA[6]	0.501	0.548	0.519	0.0261	0.5008
Av. DBH (cm)	4.40	4.21	4.45	0.1196	0.4240
Av. Height (m)	6.89	7.41	7.05	0.4100	0.6870
# Species	3.9	3.6	3.6	0.2679	0.6318
Val. Num[7]	3.066**b***	2.945**a**	2.970**a**	0.0237	0.0465
Val. Biom[8]	3.031**b**	2.945**a**	2.981**a**	0.0147	0.0348

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Shannon-Wiener index weighted for basal area
6 - Simpsons index weighted for basal area
7 - Wetland value weighted for numbers
8 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Table C.4. Overstory site differences based on fertilization treatment data.

	Block			Statistics	
Parameter	Holland	Windsor	Wh.ville	Std.Dev.	p-level
Total Biom (kg/Ha)	104423	123338	122514	6790.81	0.1994
S-W Biom[1]	0.079	0.200	0.164	0.0705	0.5156
Sim Biom[2]	0.034	0.101	0.076	0.0392	0.5275
Total N/Ha	1214.6	1175.0	1081.3	58.864	0.3557
S-W Num[3]	0.181	0.423	0.409	0.1138	0.3397
Sim Num[4]	0.097	0.260	0.228	0.0755	0.3643
Total BA (m^2/Ha)	28.26	31.92	31.53	1.5851	0.3081
S-W BA[5]	0.087	0.222	0.188	0.0754	0.4880
Sim BA[6]	0.039	0.116	0.090	0.0435	0.5072
Av. DBH (cm)	16.53	17.62	18.23	0.5101	0.1697
Av. Height (m)	13.88	14.28	14.40	0.1643	0.1788
# Species	1.7	2.1	2.3	0.2257	0.2238
Val. Num[7]	3.000	3.004	3.000	0.0024	0.4444
Val. Biom[8]	3.000	3.001	3.000	0.0007	0.4444

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Shannon-Wiener index weighted for basal area
6 - Simpsons index weighted for basal area
7 - Wetland value weighted for numbers
8 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Appendix D

Site preparation treatment differences based on analysis of fertilzation treatment data.

Table D.1. Ground layer site preparation treatment differences based on fertilization treatment data.

	Site Preparation Treatment			Statistics	
Parameter	Chop-Burn	Bedded	Ditched	Std.Dev.	p-level
Total Biom (kg/Ha)	82.04	330.94	178.33	74.132	0.1689
S-W Biom[1]	0.788	0.929	1.206	0.1094	0.1194
Sim Biom[2]	0.361**a***[*]	0.499**ab**	0.597**b**	0.0469	0.0565
Total N/Ha	135278**a**	990695**b**	198750**a**	139970.9	0.0216
S-W Num[3]	1.607	1.138	1.477	0.1265	0.1244
Sim Num[4]	0.715	0.525	0.633	0.0559	0.1665
Av. Height (cm)	9.11	10.30	8.72	1.2636	0.6813
% Cover	2.28	8.03	7.26	1.9901	0.2009
Can. Dep.[5] (cm)	21.98**a**	35.56**b**	27.80**ab**	2.8799	0.0693
# Species	8.3**a**	10.5**b**	11.0**b**	0.6684	0.0947
Val. Num[6]	2.708**b**	2.161**a**	2.989**b**	0.1658	0.0561
Val. Biom[7]	2.272	2.334	2.574	0.0825	0.1218

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Canopy depth (top of canopy layer to lowest branch)
6 - Wetland value weighted for numbers
7 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Table D.2. Shrub layer site preparation treatment differences based on fertilization treatment data.

	Site Preparation Treatment			Statistics	
Parameter	Chop-Burn	Bedded	Ditched	Std.Dev.	p-level
Total Biom (kg/Ha)	6412.8	6347.5	4524.3	780.22	0.2646
S-W Biom[1]	1.042	1.128	1.119	0.1580	0.9155
Sim Biom[2]	0.562	0.576	0.572	0.0599	0.9848
Total N/Ha	66944**a**[*]	149167**b**	45000**a**	15162.3	0.0175
S-W Num[3]	0.986**a**	0.939**a**	1.342**b**	0.0931	0.0694
Sim Num[4]	0.493**a**	0.461**a**	0.670**b**	0.0419	0.0466
Av. Height (m)	1.28	1.22	1.11	0.1259	0.6348
% Cover	18.17	27.72	18.51	2.9917	0.1434
Can. Dep.[5] (m)	1.93	1.89	1.39	0.2157	0.2622
# Species	5.3	6.1	5.8	0.7257	0.7342
Val. Num[6]	2.281	2.313	2.522	0.0965	0.2721
Val. Biom[7]	2.509	2.318	2.732	0.1058	0.1174

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Canopy depth (top of canopy layer to lowest branch)
6 - Wetland value weighted for numbers
7 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Table D.3. Midstory site preparation treatment differences based on fertilization treatment data.

	Site Preparation Treatment			Statistics	
Parameter	Chop-Burn	Bedded	Ditched	Std.Dev.	p-level
Total Biom (kg/Ha)	17344.1	10906.0	15155.2	2766.43	0.3460
S-W Biom[1]	0.883	0.944	0.864	0.0380	0.3887
Sim Biom[2]	0.492**ab**	0.548**b***	0.464**a**	0.0212	0.1093
Total N/Ha	3458.3	2341.7	2891.7	359.77	0.2058
S-W Num[3]	0.931	1.060	1.020	0.0622	0.4115
Sim Num[4]	0.510	0.603	0.538	0.0263	0.1425
Total BA (m^2/Ha)	5.32	3.95	4.73	0.6816	0.4426
S-W BA[5]	0.928	0.941	0.925	0.0541	0.9752
Sim BA[6]	0.523	0.543	0.502	0.0261	0.5820
Av. DBH (cm)	4.34	4.35	4.37	0.1196	0.9797
Av. Height (m)	7.56	6.61	7.18	0.4100	0.3507
# Species	3.7	3.5	3.9	0.2679	0.5859
Val. Num[7]	2.967	2.968	3.045	0.0237	0.1299
Val. Biom[8]	2.984**ab**	2.945**a**	3.028**b**	0.0147	0.0401

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Shannon-Wiener index weighted for basal area
6 - Simpsons index weighted for basal area
7 - Wetland value weighted for numbers
8 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Table D.4. Overstory site preparation treatment differences based on fertilization treatment data.

	Site Preparation Treatment			Statistics	
Parameter	Chop-Burn	Bedded	Ditched	Std.Dev.	p-level
Total Biom (kg/Ha)	121613**b***	100045**a**	128617**b**	6790.81	0.0863
S-W Biom[1]	0.146	0.145	0.152	0.0705	0.9972
Sim Biom[2]	0.067	0.071	0.073	0.0392	0.9934
Total N/Ha	1200.0	1070.8	1200.0	58.864	0.3078
S-W Num[3]	0.354	0.300	0.359	0.1138	0.9215
Sim Num[4]	0.197	0.175	0.214	0.0755	0.9348
Total BA (m^2/Ha)	31.86**b**	26.68**a**	33.18**b**	1.5851	0.0892
S-W BA[5]	0.162	0.164	0.171	0.0754	0.9963
Sim BA[6]	0.077	0.083	0.085	0.0435	0.9906
Av. DBH (cm)	17.52	17.05	17.80	0.5101	0.6104
Av. Height (m)	14.22	14.01	14.34	0.1643	0.4269
# Species	2.3	1.8	2.0	0.2257	0.4878
Val. Num[7]	3.000	3.000	3.004	0.0024	0.4444
Val. Biom[8]	3.000	3.000	3.001	0.0007	0.4444

1 - Shannon-Wiener index weighted for biomass
2 - Simpsons index weighted for biomass
3 - Shannon-Wiener index weighted for numbers
4 - Simpsons index weighted for numbers
5 - Shannon-Wiener index weighted for basal area
6 - Simpsons index weighted for basal area
7 - Wetland value weighted for numbers
8 - Wetland value weighted for biomass
* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Appendix E

Average biomass of all species in each canopy layer by site preparation treatment.

Table E.1. Average biomass of ground layer species for site preparation treatments.

	Site Preparation Treatment		
Species	Chop-Burn (kg/Ha)	Bedded (kg/Ha)	Ditched (kg/Ha)
Switch cane	52.1	63.5	41.3
Pepperbush	44.0**a***	68.3**b**	33.2**a**
Sphagnum moss	13.3	20.6	7.8
Gallberry	11.1**b**	0.5**a**	2.2**a**
Dog hobble	9.1	0.0	1.6
Fetterbush	8.4	4.5	2.0
Swamp leucothoe	3.7	2.4	1.4
Smilax rotundifolia	3.2	1.0	2.9
Virginia willow	1.0	0.1	0.1
Swamp tupelo	1.0**a**	0.2**a**	3.9**b**
Highbush blueberry	0.6	2.4	4.3
Marsh fern	0.6	0.0	0.2
Smilax glauca	0.6	0.4	0.8
Swamp azalea	0.4	0.0	0.5
Partridge berry	0.4	0.3	0.1
Black gum	0.4	0.0	0.4
Red maple	0.3	4.7	0.4
Chokeberry	0.2	0.0	0.7
Wax myrtle	0.1	0.0	0.5
Grape	0.1	0.0	0.0
Sassafras	0.1	0.4	0.5
Sweetgum	0.1	0.1	0.3
Cinnamon fern	0.1	1.8	1.4
Moss	0.1	0.9	0.8
Serviceberry	0.1	0.0	0.0
Poison ivy	0.04	0.04	0.01
Willow oak	0.03	0.0	0.0
Grass	0.02	0.6	0.2
Lady slipper	0.01	0.0	0.0
Water oak	0.01	0.2	0.1
Sensitive fern	0.0	0.1	0.0
Holly	0.0	8.6	0.1
Sweetbay	0.0	0.0	3.6
Honeysuckle	0.0	0.3	0.0
Swamp dewberry	0.0	0.4	0.0
Virginia creeper	0.0	0.01	0.0
Rattlesnake fern	0.0	0.0	0.2
White oak	0.0	0.0	0.2

* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Table E.2. Average biomass of shrub layer species for site preparation treatments.

	Site Preparation Treatment		
Species	Chop-Burn (kg/Ha)	Bedded (kg/Ha)	Ditched (kg/Ha)
Switch cane	2789.8**b***	2663.2**b**	1038.1**a**
Red maple	1535.7	452.6	1214.1
Highbush blueberry	1196.7	683.4	1445.4
Gallberry	395.5	506.7	50.5
Swamp azalea	319.3	0.0	0.0
Pepperbush	222.3	160.6	55.9
Smilax laurifolia	182.2	0.0	0.0
Sweetbay	172.5	0.0	600.1
Sweetgum	157.4	0.0	717.9
Smilax rotundifolia	120.2	73.8	127.5
Fetterbush	116.7	434.5	0.0
Black gum	52.0	0.0	256.7
American holly	35.2	0.0	0.0
Smilax glauca	34.6	87.9	57.3
Chokeberry	33.6	20.0	122.0
Serviceberry	21.2	0.0	0.0
Poison ivy	16.4	0.1	0.0
Swamp leucothoe	16.0	14.1	522.2
Water oak	14.9	0.0	0.0
Dog hobble	11.0	0.0	1.8
Marsh fern	1.8	14.2	0.0
Swamp tupelo	0.0	90.4	8.5
Sourwood	0.0	73.2	20.7
Honeysuckle	0.0	12.8	0.0
Virginia willow	0.0	2.1	0.9
Cinnamon fern	0.0	0.4	2.0
Wax myrtle	0.0	0.0	2.0
Sassafras	0.0	0.0	0.3

* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Table E.3. Average biomass of midstory species for site preparation treatments.

	Site Preparation Treatment		
Species	Chop-Burn (kg/Ha)	Bedded (kg/Ha)	Ditched (kg/Ha)
Red maple	12010.4**b***	3776.0**a**	11704.0**b**
Sweetgum	2550.1	2197.1	2101.6
Water oak	2234.1	0.0	2186.1
Loblolly pine	1832.9	873.1	1089.4
Black gum	670.0	595.9	1120.7
Sweetbay	613.1	197.4	1128.2
Swamp tupelo	345.3	495.5	1008.9
Sourwood	262.9	27.8	581.6
American holly	234.2	281.8	161.7
Sassafras	195.1	266.6	62.0
Highbush blueberry	139.6	83.8	118.3
Titi	57.2	274.7	0.0
Possumhaw	25.1	0.0	0.0
Gallberry	18.2	9.3	0.0
Swamp azalea	10.5	0.0	0.0
Wax myrtle	0.0	30.7	102.6
Black cherry	0.0	28.3	0.0
Chokeberry	0.0	8.0	83.0

* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Table E.4. Average biomass of overstory species for site preparation treatments.

	Site Preparation Treatment		
Species	Chop-Burn (kg/Ha)	Bedded (kg/Ha)	Ditched (kg/Ha)
Loblolly pine	66508.3**a***	90249.7**b**	79236.3**ab**
Red maple	6306.1**a**	18783.1**b**	6567.1**a**
Sweetgum	5310.4	8326.1	8467.7
Water oak	844.8**a**	0.0**a**	2449.0**b**
White oak	186.2	0.0	69.7
Swamp tupelo	92.9	89.5	26.2
Willow oak	76.4	0.0	40.2
Swamp chestnut oak	63.7	0.0	0.0
Holly	24.6	0.0	0.0
Sassafras	0.0	86.0	18.2
Black cherry	0.0	32.7	0.0
Sweetbay	0.0	20.0	34.8
Sourwood	0.0	0.0	24.8

* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Appendix F

Average biomass of all species in each canopy layer by fertilization treatment.

Table F.1. Average biomass of ground layer species for fertilization treatments.

	Fertilization Treatment			
Species	Control (kg/Ha)	P (kg/Ha)	NP (kg/Ha)	NPL (kg/Ha)
Switch cane	98.2	128.1	78.0	82.3
Pepperbush	43.4	62.4	68.0	47.2
Gallberry	34.8	2.9	2.8	1.0
Fetterbush	24.6	5.0	0.3	0.0
Sweetgum	5.2	0.0	1.6	0.4
Swamp leucothoe	2.4	0.1	0.6	0.2
Smilax rotundifolia	2.3	4.2	4.9	0.8
Swamp tupelo	1.8	1.1	1.2	1.0
Smilax glauca	1.5	0.5	0.4	0.7
Black gum	1.5	0.7	0.3	0.4
Dog hobble	1.3	0.9	0.1	0.0
Highbush blueberry	1.2	1.9	1.0	20.9
Sweetbay	0.9	0.2	0.0	0.0
Rattlesnake fern	0.7	0.2	0.0	0.5
Red maple	0.6	3.1	0.3	1.1
Cinnamon fern	0.6	0.6	2.1	10.5
Sphagnum moss	0.3	1.2	6.1	1.9
Swamp azalea	0.3	0.0	0.8	0.0
Sassafras	0.3	0.6	0.3	0.0
Chokeberry	0.2	0.2	0.2	1.5
Moss	0.2	0.0	0.8	0.2
Virginia willow	0.2	0.0	0.0	0.0
Water oak	0.1	0.7	0.1	0.0
Partridge berry	0.1	0.0	0.1	0.1
Wax myrtle	0.0	0.7	0.0	0.4
Sourwood	0.0	0.2	0.0	7.2
Poison ivy	0.0	0.1	0.3	0.0
Swamp dewberry	0.0	0.1	0.0	0.6
Grape	0.0	0.002	0.002	0.0
Honeysuckle	0.0	0.002	0.0	0.0
Grass	0.0	0.0	0.2	0.0
Smilax laurifolia	0.0	0.0	0.1	0.0
Silky dogwood	0.0	0.0	0.1	0.0
Sensitive fern	0.0	0.0	0.1	0.0
Lady slipper	0.0	0.0	0.01	0.05
American holly	0.0	0.0	0.0	0.2
Virginia creeper	0.0	0.0	0.0	0.1
Lycopod	0.0	0.0	0.0	0.002

* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Table F.2. Average biomass of shrub layer species for fertilization treatments.

	Fertilization Treatment			
Species	Control (kg/Ha)	P (kg/Ha)	NP (kg/Ha)	NPL (kg/Ha)
Switch cane	1903.4	1591.3	888.2	1475.3
Highbush blueberry	1011.5	608.4	680.7	344.0
Chokeberry	522.9	0.0	162.0	0.0
Swamp leucothoe	480.8	194.1	0.0	166.6
Red maple	477.9**a***	1918.4**ab**	442.9**a**	3307.8**b**
Sourwood	390.2	6.7	0.0	231.8
Swamp tupelo	319.7	29.1	87.5	382.7
Smilax laurifolia	301.3	0.3	0.8	433.4
Sweetgum	197.9	299.6	100.9	76.9
Fetterbush	160.0	29.5	2.9	0.0
American holly	149.6	0.0	23.2	3.5
Smilax rotundifolia	136.5	59.1	99.6	211.2
Pepperbush	130.6	299.2	255.7	84.1
Swamp azalea	92.5	0.0	14.7	0.0
Gallberry	88.0	35.5	500.9	1.1
Sweetbay	78.2	68.6	0.0	0.0
Black gum	68.0	176.6	98.4	413.4
Smilax glauca	35.9	6.8	44.1	5.1
Rattlesnake fern	1.8	0.0	0.0	0.0
Virginia willow	0.7	0.0	0.0	0.0
Sassafras	0.0	192.5	0.0	0.0
Grape	0.0	0.0	210.6	0.0
Silky dogwood	0.0	0.0	66.2	0.0
Poison ivy	0.0	0.0	9.9	0.1
Water oak	0.0	0.0	0.0	81.6
Wax myrtle	0.0	0.0	0.0	66.7
Virginia creeper	0.0	0.0	0.0	8.8

* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Table F.3. Average biomass of midstory species for fertilization treatments.

	Fertilization Treatment			
Species	Control (kg/Ha)	P (kg/Ha)	NP (kg/Ha)	NPL (kg/Ha)
Red maple	6457.7	10236.9	5743.6	7021.2
Sweetgum	4584.3**a***	2568.9**a**	4432.8**a**	7247.0**b**
Swamp tupelo	540.6**b**	0.0**a**	628.1**b**	42.0**a**
Sweetbay	399.5	233.1	263.2	99.8
Black gum	323.5	295.4	31.4	73.4
American holly	323.0	69.8	81.6	51.5
Water oak	102.8**a**	157.7**a**	2019.0**b**	234.3**a**
Sourwood	98.4	622.4	315.5	146.1
Wax myrtle	84.5	0.0	0.0	295.3
Red bay	75.9	59.2	0.0	50.0
Titi	68.5	0.0	0.0	0.0
Loblolly pine	0.0	326.2	710.6	470.1
Sassafras	0.0	233.1	0.0	16.8
Highbush blueberry	0.0	0.0	39.4	0.0

* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

Table F.4. Average biomass of overstory species for fertilization treatments.

	Fertilization Treatment			
Species	Control (kg/Ha)	P (kg/Ha)	NP (kg/Ha)	NPL (kg/Ha)
Loblolly pine	104833**a***	105270**a**	104435**a**	135731**b**
Sweetgum	3991	2830	4251	4101
Red maple	425	303	274	423
White oak	0	0	169	0

* - Same letters indicate no significant difference for parameter (Fishers LSD test, p=0.10)

VITA

The author was born in Durham, North Carolina in 1966. He completed a B.S. degree in Forestry at North Carolina State University in 1990. He then attended Virginia Polytechnic Institute and State University and earned a Master of Science degree in Forestry in 1992.

James W. Hauser