SOFOR GIS '98

Proceedings of the 2nd Southern Forestry GIS Conference

October 28-29, 1998
Athens, Georgia

H. J-H Whiffen and W.C. Hubbard, Editors

Sponsored by:

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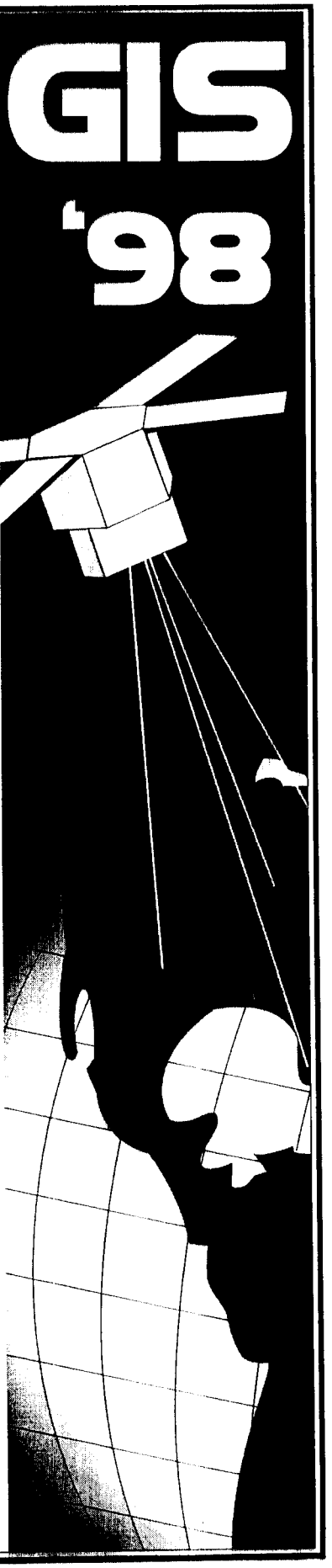

DISCOVERING THE FACTORS CONTRIBUTING TO THE DECLINE AND MORTALITY OF WILLOW OAKS IN THE D'ARBONNE NATIONAL WILDLIFE REFUGE, LA.

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ABSTRACT

Since the early 1990's, mature willow oaks (*Quercus phellos* L.) on certain sites in the D'Arbonne National Wildlife Refuge (DNWR), in northeast Louisiana, have shown crown dieback. The dieback is progressive with some trees continuing to decline, eventually leading to death, within one to three years. This condition has caused the Refuge forester to accelerate harvesting in affected areas.

Flooding during the first third of the growing season appears to predispose all willow oaks to decline by inducing physiological stress. Two different soil types beneath these stands affect further decline by the way they accommodate root growth. Groom soils have a relatively thin (30 to 38 cm) clay-silt layer over silty-sand, whereas Litro soils have a deeper (60 to 90 cm) clay-silt layer over silty-sand. Oak roots tend to be restricted to the clay-silt layer. Therefore, roots in Groom soils are more susceptible to droughty conditions that may occur after flood waters have receded. Fungal pathogens and insects attack the stressed oaks contributing to further decline.

Four research plots were established at three sites. Two plots per site are in stands where willow oaks show severe decline, presumably over Groom soils. The other two plots are in stands where willow oaks are relatively healthy (called non-decline), compared with those in the first set of stands. These oaks are presumably over Litro soils. One decline plot and one non-decline plot per site will be thinned to learn if stand health can be improved through silvicultural treatment. The geopositions and relative elevations of plots, subplots, and trees were recorded using a GPS. A GIS database is being built from these data and from digitized soils maps of the DNWR. Coverages produced from these, and other data, will show relationships between soil types, stand ages, stand densities, site and tree elevations, mean flooding depths and durations, incidences of diseases and insect pests, and tree crown conditions. These coverages, along with appropriate statistical analyses, will define the factors causing willow oaks to decline and die.

INTRODUCTION

In the early 1990's, willow oaks (*Quercus phellos* L.) on certain sites in the D'Arbonne National Wildlife Refuge (DNWR), north of Monroe, Louisiana, began showing signs of dieback in their crowns. Typically, the dieback moved progressively from outer branches in tree tops inward and down the crown eventually killing many trees within one to three years. Declining trees usually have root and bole rots, and are heavily infested with wood boring insects. Although some trees recover from crown dieback, this condition persists up to the present time and has caused the Refuge forester to change his management plan and accelerate harvesting in affected areas.

Oak decline, and tree decline diseases overall, involve complex interactions between environmental and biological stresses and subsequent attacks by secondary pests (Solomon et al. 1997; Tainter 1996; Manion and Lachance 1992). Declines of oaks of various species have been studied throughout the eastern United States this century (e.g., Beal 1926, Hursch and Haasis 1931, Staley 1965, Tainter and Bensen 1982, Law and Gott 1987). Ammon et al. 1989 summarized the distinctive interactions of environmental and biological stresses of many of these historic oak decline events. Predisposing factors, such as genetic potential, climatic factors, or old age, can set the stage, through some inherent or induced adverse physiological state, for damage by later injury. Drought, insect defoliation, unseasonable freezes, root damage, or extended flooding, for example, can incite active decline. Events such as these can move a tree from a healthy state to one of diminished health. Biotic factors such as diseases (e.g., Ganoderma or Armillaria root rots), insects (e.g., carpenterworm or two-lined chestnut borer), or both, can contribute to, and hasten, tree death.

Managing oak decline may involve harvesting oak stands before they become over mature and promoting advanced reproduction in young and middle-aged stands to ensure enough regeneration at harvest. However, removing dead and declining oaks only utilizes trees before they degrade, this will not correct conditions leading to the decline. Understanding the factors contributing to this oak decline will lead to better short-term and long-term stand management and suggest ways possibly to ameliorate the onset of the decline.

Much of the bottomlands in the DNWR are under water when D'Arbonne Bayou floods its banks some time between November and January and remains that way until May or June in most years. This flooding, during at least the first third of the growing season, predisposes oaks to decline by inducing physiological stress through anaerobic conditions in the soils. Two soil types, underlaying these stands, appear to affect the onset of decline by the way they accommodate root growth. Groom soils have a (30 to 38 cm) clay-silt layer over silty-sand subsoil. Litro soils have a deeper (60 to 90 cm) clay-silt layer over silty-sand subsoil. Oak roots tend to be restricted to the upper, clay-silt layers that hold more water than the silt-sand subsoils. Roots in Groom soils therefore are concentrated near the soil surface and are more susceptible to drought stress that may occur later in the growing season months after flood waters have receded. This phenomenon is confirmed by multiple bifurcations of small roots that occur at the interface of the clay-silt and silty-sand layers on the root masses of windthrown oaks. This broomlike branching occurs as roots make repeated excursions into the silty-sand layer when it is moist and

die as the sand dries out. Late-season drought stress may be the main factor that incites these willow oaks to decline by inducing further physiological stress. Diseases and insect attacks contribute to the decline in health, and hasten the death, of trees and stands. The contributions of other biotic or abiotic factors to the onset or development of the decline may be discovered as the study progresses.

GIS technology was used to map the current extent and possible expansion of several forest diseases and insect pests, including oak decline, in the eastern United States (Starkey et al. 1989, Hoffard et al. 1995, Liebhold et al. 1997). The oak decline syndrome described here lends itself to a study using a geographic information system (GIS) because of the number of factors involved, each providing a layer of data. Coverages will be produced to illustrate soil types, tree growth, stand ages, stand densities, site and tree elevations, flood depths and durations, incidences of diseases and insects, and tree crown conditions. These coverages, along with appropriate statistical analyses, will define the factors causing willow oaks to decline and die by allowing comparisons between stands that are declining and stands that are relatively healthy. A second objective is to determine whether thinning affected stands ameliorates the decline. This will be done by comparing tree growth and crown conditions in stands before thinning to those variables some time (1-3 years) after thinning, and between thinned stands and unthinned stands. This study is designed to provide the refuge forester and refuge manager with information to manage better the affected willow oak stands. It may be possible to adapt harvest and reforestation plans to ameliorate the effects of the decline once the main causal factors are known.

METHODS

Four research plots, each made up of eight 0.1 acre subplots, were established at each of three sites (Figures 1 and 2). Two plots per site were placed in stands with severe oak decline, presumably over Groom soils. The other two plots were placed in stands that are relatively healthy (referred to as non-decline), compared to the decline plots; these are presumed to be over Litro soils. One decline plot and one non-decline plot per site will be thinned in 1998 to determine if stand health can be improved through silvicultural treatment. Plots which will remain unthinned are enclosed in a one-chain-wide buffer to minimize logging damage to the stand. The geopositions, distances, and elevations relating tree locations, plots, and subplots were recorded using a Pathfinder Pro XL geographic positioning system (Trimble Navigation Limited, Sunnyvale, CA) and a Criterion laser range finder (Laser Technology Inc., Englewood, CO). A GIS database is being built in ArcInfo (Environmental Systems Research Institute, Inc., Redlands, CA) from these data and from a digitized soils map of the DNWR. Additional data will be collected to describe tree health and flooding events. Coverages will be produced to illustrate soil types, tree growth, stand ages, stand densities, site and tree elevations, flood depths and durations, disease and insect incidences, and tree crown conditions. These coverages, along

with the appropriate statistical analyses, will define the factors causing willow oaks to decline and die.

Experimental Approach

A map of soil types in Union Parish, LA, where all three research sites are located, was digitized from a 1960's-era soils map and will be the primary component of the GIS database. Soil series at each plot will be verified by a soils expert from the Natural Resources Conservation Service of the USDA, and by sampling more intensively across the plots.

Tree, plot, and subplot elevations were recorded using a GPS. Coverages of elevation will be constructed in the GIS from geopositional data. Flooding events and history will be characterized by data obtained from the U.S. Army Corps of Engineers. Data from the appropriate gauging station(s) will be placed in the GIS database to build coverages of flood depths and flood duration histories.

Soil chemical contents of exchangeable aluminum, phosphorous, potassium, calcium, magnesium, zinc, and sodium, as well as, pH, cation exchange capacity (C.E.C.), base saturation, organic matter content, and soil texture will be determined from soils sampled at 20 and 40 cm below the soil surface at one location per plot.

Tree growth and stand ages will be characterized for each plot using increment cores removed from sixteen willow oaks per plot. Two increment cores will be taken from opposite sides of the trees sampled. Annual growth increments will be measured to the nearest 0.001 mm using a color scanner, desktop computer, and WinDendro tree ring analysis software (Regent Ltd., Quebec, Canada). Chronologies of average ring widths for the willow oaks on each plot will be used in appropriate statistical analyses comparing growth between decline and non-decline plots. Stand densities of all plots will be measured before and after harvesting in order to verify the impact of this variable on overall stand health.

Numbers of diseases and numbers of insect borer attacks will be recorded for each tree from which an increment core is collected. These will be recorded to the extent which they can be identified and verified. GIS coverages will be produced, as needed, from the data.

Tree crown conditions will be estimated for each tree, from which an increment core is collected, using a rating system developed for the USDA, Forest Service, Forest Health Monitoring Program (Tallent-Halsell 1994). Crown conditions are characterized by five variables including: 1) crown diameter, a measure of the greatest width of a crown and the width of the crown measured at 90° to the greatest width; 2) live crown ratio, the percentage of living crown compared to total tree height (trees with greater live crown ratios are typically healthier and grow faster); 3) foliage density, an approximation of branch and foliage biomass; 4) foliage transparency, defined as the amount of sky light visible through the live, normally-foliated parts of the crown; and 5) crown dieback, which is a measure of recent twig and branch mortality.

Analyses

Inferences about the factors causing willow oaks to decline will be drawn from relationships depicted in maps created using the GIS database. Statistical analyses will be used to compare site and stand data collected for the database. For instance, the analysis of tree growth may involve analysis of covariance in which growth is compared prior to and after certain growth-rate-changing events (such as flooding or drought), with average annual precipitation as the covariate. Other appropriate statistical analyses may be used as deemed necessary.

Analysis of variance will be used to detect differences between decline and non-decline plots in soil physicochemical properties of exchangeable Al, P, K, Ca, Mg, Zn, Na concentrations, pH, C.E.C., base saturation, organic matter content, and soil texture; as well as average annual increment and basal area increment; occurrences of insect indicators and fungal diseases, and tree crown conditions. These analyses, along with GIS coverages, will define the factors causing willow oaks to decline and die.

RESULTS

None of the stands in this study are healthy because of flood-induced physiological stress. A visual inspection of both non-decline and decline stands reveals many pole-size willow oaks that are 55 to 65 years old, with several older, sawlog-size willow oaks. Willow oaks make up an average 70% of all live stems > 10 cm d.b.h. on all three sites. Most stands contain pole-size overcup oaks (*Quercus lyrata* Walt.); these average 11% of all live stems > 10 cm d.b.h. on all three sites. One plot has a higher percentage of overcup oaks than willow oaks. However, the overcup oaks do not appear to be declining to the same degree as the willow oaks. The average percentage of dead oaks (snags) of all measured oaks on decline plots is 21%; it is 9% on non-decline plots. The average percentage of oak snags of all measured trees on decline plots is 15% and 7% on non-decline plots. As a result, it is apparent visually that more sunlight reaches the forest floor in the decline plots.

Currently, it is thought that decline plots are underlain with Groom soils which have a shallower upper soil horizon compared to Litro soils with a deeper upper soil horizon. The upper horizons of both soil types are underlain by deep layers of silty-sand which dry out quickly during periods of drought. It is the droughty conditions that are likely inciting willow oaks to begin actively declining having been predisposed to decline by flood-induced physiological stress. This relationship between soil types and stand health types, given the existing soils map, is evident to some degree at sites two and three (Figure 2) where the decline plots lie within Groom soils and one of the two non-decline plots at each site lies within Litro soils. The other non-decline plot at each of sites two and three, and both non-decline plots at site one (Figure 1), lie within Groom soils. The decline plots at site one lie within Groom soils. The relationships between soil types and stand health are based on a 1960's-era soils map. Forest soils definitions on this map are based on about one soil sample for several acres and interpolations about larger areas based on topography. A more thorough evaluation of soil types will be made on each of the four plots per site. If the working hypothesis is correct, better soil definition will provide good alignment between soil type and stand health.

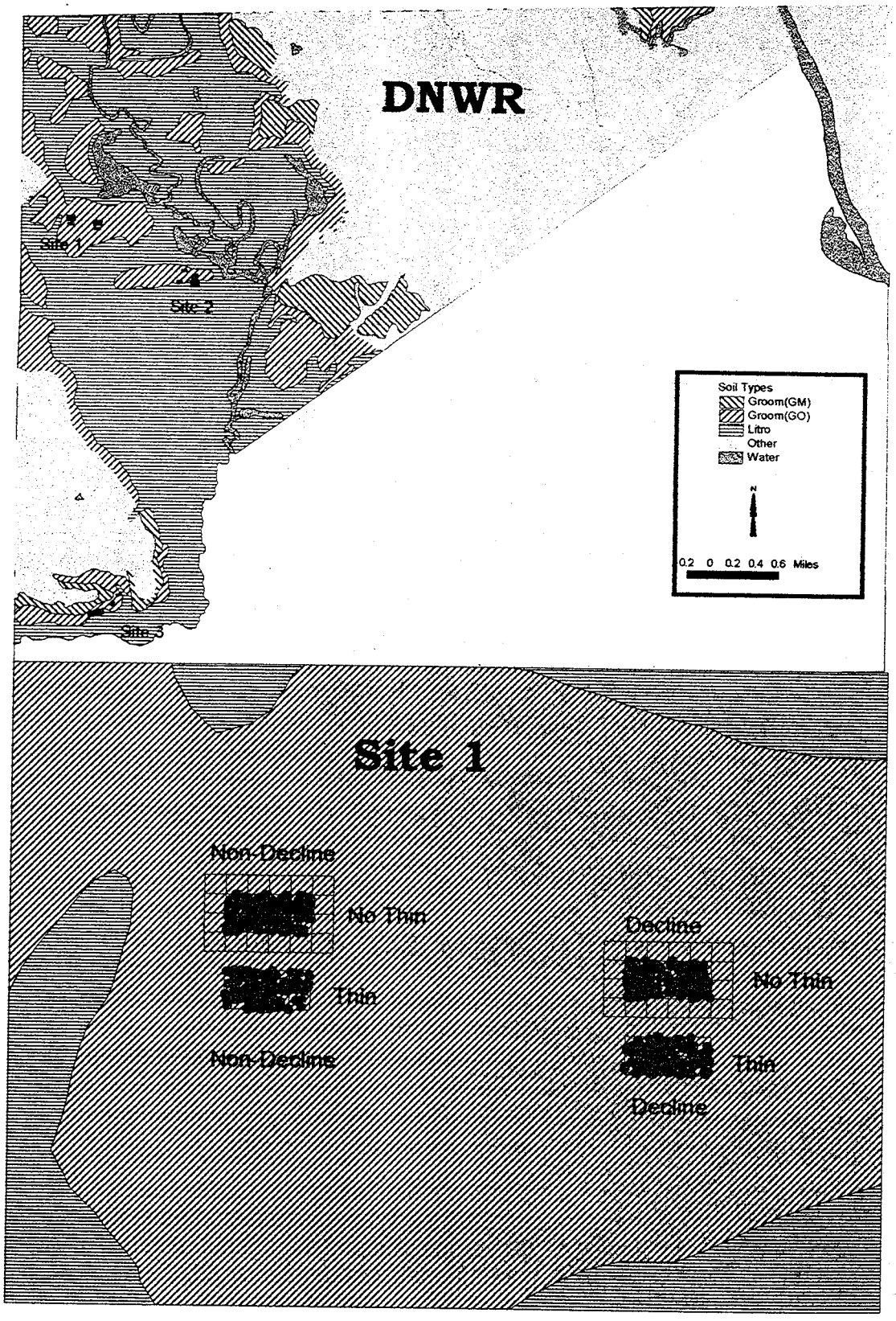

Figure 1. Locations of plots and sites in relation to soil types in D'Arbonne National Wildlife Refuge north of Monroe, La. These maps were created in ArcView from a 1960's-era soils map.

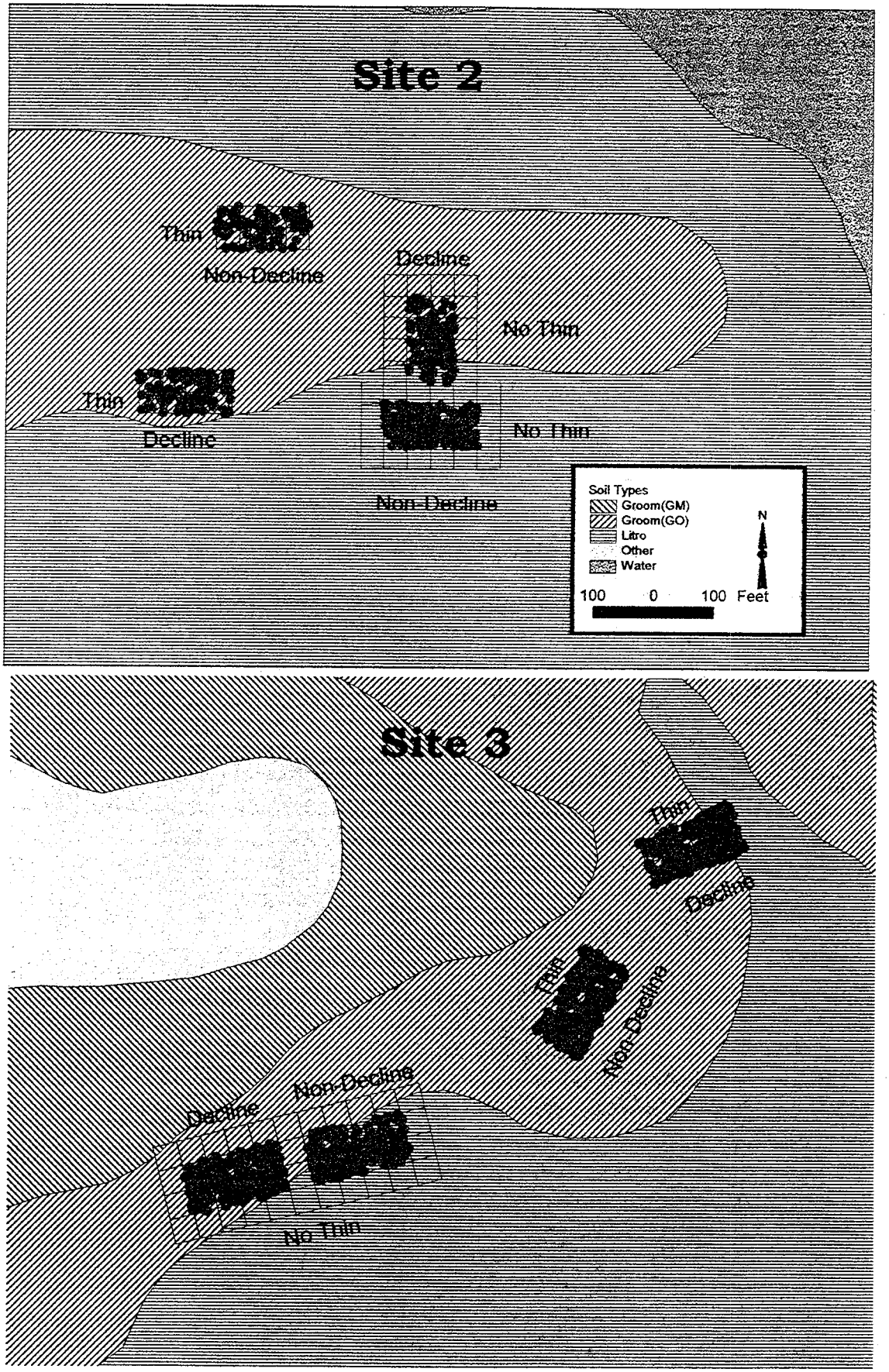

Figure 2. Locations of plots in sites 2 and 3 in relation to soil types in D'Arbonne National Wildlife Refuge north of Monroe, La. These maps were created in ArcView from a 1960's-era soils map.

DISCUSSION

The areas being studied in the DNWR are fairly typical southern bottomland hardwood sites. These forests support natural stands that undergo seasonal flooding from late fall to spring. The sites in this study are often flooded well into May each year. Higher sites in the DNWR support loblolly pine. Drainages and sloughs meander through and intersect the sites. These sites are nearly flat, however, even a one to two foot change in elevation can alter species composition and soil type. Relationships between soil types and species composition have created a situation that leads to the onset of active oak decline in stands with high percentages of willow oak. Willow oaks, as well as other oaks and other hardwoods, routinely are being stressed physiologically by flooding that extends well into growing seasons. Late-season drought conditions on certain sites (Groom soils) incite the onset of active oak decline. Once the oaks have begun to decline, fungal pathogens invade causing decay in roots and boles. Wood boring insects also invade boles in large numbers.

Currently, the decline in willow oaks is causing the DNWR forester to conduct pulpwood sales in stands that are 55 to 60 years old. These are essentially salvage cuts since stand growth likely has been reduced from what it ought to be, and stand volume is being lost to decay and insect degradation. The benefit of this research could be substantial beyond that of the DNWR in that users of these results would have a better understanding of how prolonged periods of flooding on certain soil types can affect the decline of the dominant forest cover in other bottomlands. Users will also learn whether thinning declining stands will ameliorate the decline symptoms and increase the growth and productivity of the residual trees. It may be that for the DNWR, given the flooding scenario, the rotation age for sites impacted by oak decline should be 50 years so that trees are harvested before the decline occurs. The research described here will use GIS database mapping and conventional parametric statistics to discover the main factors causing willow oaks to the decline in the D'Arbonne National Wildlife Refuge.

ACKNOWLEDGMENTS

Thanks to Mr. Steve Pagans, DNWR forester and Mr. Lee Fulton, Refuge Manager for help in selecting study sites and for overseeing the harvests on and around the research plots. Thanks to Mr. Curt McCasland and Mr. Keith Willis for help with establishing plots, collecting data, creating the ArcInfo database, and making maps. Thanks to Mr. Chris Woodson, Mr. Ty Swirin and Mr. Uwe Sander for help with collecting data.

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