SECTION II

REGIONAL IMPACTS OF OAK WILT

OAK WILT IN THE APPALACHIANS

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ABSTRACT

Oak wilt was discovered a few decades after blight nearly eradicated the American chestnut, heightening concern that the oak resource in North America might be threatened similarly. Fortunately, in most Appalachian areas, the disease has spread slowly and erratically among a susceptible population of red oak species. This has occurred in spite of the existence of disease components that are common to areas of the United States where oak wilt is devastating; namely, a highly virulent causal pathogen, *Ceratocyctis fagacearum*, the existence of insects that have been identified as vectors, and the presence of root graft unions among susceptible oak species. A variety of hypotheses have been forwarded as to why the spread of oak wilt has been slow in the Appalachians. Certainly the diversity of hardwood species has limited tree-to-tree spread that is typical of areas in the upper Midwest and southcentral United States where *C. fagacearum* spreads freely through interconnected oak root systems. Likewise, many Appalachian sites possess rocky soils which have been speculated to restrict the development of functional root grafts, thereby further limiting tree-to-tree spread. Although known insect vectors are present in the Appalachians, their effectiveness is highly dependent on a variety of temporal conditions including the availability of inoculum as well as fresh wounds to serve as inoculation sites. All evidence suggests that the vectors are highly inefficient and proof of their relative importance in establishing new infections is circumstantial. In spite of the limited spread of oak wilt in the Appalachians, the disease can have very consequential influences in localized areas where it may smolder for decades, killing hundreds of oaks over time. The future of this disease could change rapidly if a more efficient vector were to emerge in this oak-rich region.

Key words: *Ceratocystis fagacearum,* disease management, insect vectors

Discovery of oak wilt (caused by *Ceratocystis fagacearum* (Bretz) Hunt) in Wisconsin in the 1940s and its subsequent diagnosis in the mid-Atlantic region resulted in immediate concern about the long-term effects of the disease on highly valued eastern oak resources. Extensive early surveys detected the disease from Pennsylvania southward to the Carolinas (True et al. 1960). Early assumptions were that this represented disease spread into new areas of the Appalachians. Obviously, the then relatively recent demise of the American chestnut from chestnut blight weighed heavily on the minds of conservationists and foresters of the day. This concern seemed warranted as even today no forest pathogen is known to be as capable of killing members of the red oak group as efficiently as *Ceratocystis fagacearum*. However, with time, what initially was deemed spread into new forested areas appeared to reflect a more complete recognition of the disease rather than the expansion of the range of a recently emerging pathogen (MacDonald 1995).

Today, the incidence of oak wilt in much of the Appalachians can best be characterized as sporadic. In some locales, the disease is significant but in most regions it is rare or absent. For the Appalachians, the disease may have gone unnoted for decades had the symptomatology and causal agent not been described in the upper Midwest. Many trees die annually in any forest ecosystem and the relative few that contracted oak wilt in the Appalachians easily could have been discounted by anyone not familiar with the disease or not intentionally surveying for it.

Although the range of the disease frequently is depicted by county-by-county maps, this is not indicative of where the disease has its greatest impact. Data from West Virginia in the 1960s when annual surveys were conducted indicated that on average about 3,200 trees died statewide each year (Haynes 1995). However, the majority of infected trees were detected in the eastern panhandle of the state. Further, the disease has never been detected in several counties that are rich in susceptible oak populations. Likewise, oak wilt has never been detected to the northeast of the Susquehanna River in central Pennsylvania, yet susceptible oak populations and recognized vectors occur to the northeast of this area. One must ask why the disease has never spread into oak wilt-free areas in spite of the existence of all the necessary prerequisites for the disease, with the exception of the causal fungus.

Regions of the United States where *C. fagacearum* has been a successful pathogen possess significant populations of susceptible oak hosts, vectors capable of transmitting the pathogen, networks of inter-connected root systems among susceptible species, and appropriate environmental conditions to promote disease. Many of these factors differ vastly from region-to-region and the influence each factor exerts undoubtedly has resulted in the varied disease outcomes that are witnessed in different areas where oak wilt persists.

The two dominant components of oak wilt are the oak host and the fungus. Significant oak populations reside in the Appalachians with some areas comprised of more than 60% oaks (DiGiovanni 1990). Most prominent among the susceptible species are northern red oak (*Quercus rubra*), scarlet oak (*Q. coccinea*), and black oak (*Q. velutina*). Chestnut oak (*Q. montana*), a white oak considered intermediate in susceptibility, and several resistant white oak species, principally *Q. alba* (True et al. 1960) also are common. Although the forest ecosystems of the Appalachians have been altered considerably by a history of previous cuttings and fire, most hardwood species that existed 250 years ago remain today (Hicks 1997). Even though oak dominates many of the forests, it is joined by over 40 other species that make up the diverse Appalachian forests.

Even though molecular studies of *C. fagacearum* isolates from North America have demonstrated limited genetic variability, morphological and pathological variation have been observed among Appalachian isolates (Haynes 1976, Kurdyla et al. 1995). However, to the susceptible oak populations *C. fagacearum* infects, this variability may be irrelevant, as the fungus rapidly colonizes its host resulting almost certainly in sudden death.

TWO MAJOR FACTORS REGULATE DISEASE SPREAD

If both susceptible populations of oak species and the causal fungus exist in the Appalachians, what has limited its spread through the entire region creating a disease that is so sporadic in its occurrence? Two major factors appear to be most responsible for the lack of significant dissemination of *C. fagacearum* in the Appalachians. The first is the frequency of root system spread. In areas of the upper Midwest and in Texas, root grafts among susceptible oaks provide a conduit for the movement of *C. fagacearum* from tree to tree (Appel 1995). Functional root grafts allow this vascular pathogen to move freely from infected host to an adjacent healthy tree. The frequency of root grafting in these high incidence areas appears to be tied to soil depth and texture, with higher rates of grafting occurring in lighter, sandier soils (MacDonald 1995). Likewise, the density and age similarities of like species that occur together clearly enhance the possibility of interconnected, functional grafts.

For the Appalachians, root grafting undoubtedly plays a role in maintaining centers of infection where like species are in close proximity to one another; however, the importance of the role of root grafts to pathogen transmission in the Appalachians often has been played down. The hypothesis remains that the rugged, often rocky soils typical of many areas in this region are detrimental to the development of functional root grafts thus restricting tree-to-tree spread (True et al. 1960). Likewise, the pathogen often can be isolated within a single tree or small group of trees if adjacent trees are not susceptible oaks or are other species. Thus, the inherent diversity of the species in the Appalachians likely minimizes root graft transmission as an avenue of pathogen spread. Further, there are instances where healthy oaks, within root graft distance of an infected tree, persist for 2-3 years before symptoms are detected (Rexrode 1978). No explanation exists for this delayed transmission phenomenon or whether root grafting even is involved when disease develops in an adjacent, previously healthy tree.

A second disease regulating factor relates to transmission by insect vectors. *C. fagacearum* largely is a xylem-limited organism. Its only phase outside its host is when it is acquired by a variety of insect vectors and is spread overland by those vectors. The strongest case for such overland transmission of the pathogen can be made for insects in the family Nitidulidae. These sap-feeding insects routinely have satisfied the prerequisites as vectors, particularly so when fresh wounds oozing sap occur during spring months (Merrill and French 1995). Beetles are lured to the fresh wounds on healthy oaks from the fragrant inoculum-producing mats on infected oaks, thereby spreading *C. fagacearum* to the healthy, but wounded trees.

Even though the role of the sap-feeding beetles has been demonstrated, their effectiveness has been questioned especially when evidence of mat production is rare or when spring wounding events have not occurred. Likewise, oak bark beetles of the genus *Pseudopityophthorus* are common in the Appalachians and their biology qualifies them as vectors, but evidence that they contribute significantly to overland spread is not convincing (Merrill and French 1995). There is little doubt that insects can and do vector *C. fagacearum* but apparently only low percentages of the many insects that have been studied actually acquire the fungus through their activities and, for those that do, their dispersal within a diverse hardwood forest makes them very inefficient disseminators. Clearly, for most vectors the critical sequence of events among the pathogen, host, and the environment that promotes vector efficiency seldom is met or the incidence of oak wilt in the Appalachians would be significantly greater.

OTHER DISEASE INFLUENCES

The topographic patterns of oak wilt spread have been studied in Pennsylvania and West Virginia particularly with respect to elevation and aspect and some with implications about insect vectors. For most studies, relationships of new infections to old have been difficult to establish as results often conflicted (MacDonald 1995). In some instances, new oak wilt infections were found to occur more commonly on ridges and upper slopes, particularly on hillsides facing the prevailing wind currents. Presumably, fungal-laden insect vectors were carried downwind until they impacted stand openings or dominant trees protruding above the forest canopy, thereby transmitting the pathogen.

C. fagacearum has proven to be a virulent, aggressive, lethal, and systemic fungal pathogen. As a vascular pathogen, it largely is restricted to an existence within its host or by its relationship with vectors outside the infected host. Fortunately, the incidence of this disease appears to be rather static in the Appalachians and most regions of North America where oaks are a major forest component. In these regions either the pathogen has not been introduced successfully or conditions for its dissemination have not been fulfilled. Therefore, it would appear that for there to be a substantial change in disease incidence in most oak forest regions, a dramatic shift in vector relationships would be necessary. This could readily occur as pathways for the introduction of potential vectors from other continents abound and is made ever more likely by the increasing rates of international trade of logs and lumber. Obviously exotic vectors, capable of infesting sapwood of infected oaks, could establish new vector relationships and enhance pathogen spread in North America. Clearly for many oak regions, *C. fagacearum* is a pathogen in search of a better vector!

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OAK WILT IN THE NORTH CENTRAL REGION

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ABSTRACT

Oak wilt disease, caused by *Ceratocystis fagacearum*, is the single most important disease of oaks in the North Central region. Many factors, including pathogen distribution, forest stand composition, soil characteristics, and human activities, interact to result in variable levels of disease impact across the region. Opportunities for management are closely tied to activities that interrupt the spread of the oak wilt pathogen. Disruption of functional root grafts is most effectively accomplished by a vibratory plow. Overland spread is prevented by avoiding wounding and destroying potential spore-producing trees. Integration of these and other tools into a comprehensive management plan results in effective management of oak wilt. The USDA Forest Service is actively involved in oak wilt management in the region, through essential research, assistance to state programs, and management on federal lands.

Key words: *Ceratocystis fagacearum*, disease impacts, disease management

Oak wilt is the single most important disease of oaks in the North Central region. Although the origin of the causal agent *Ceratocystis fagacearum* (Bretz) Hunt is still unknown, most pathologists now believe that it is not native to the North Central region (Juzwik et al. 2008, Harrington, this proceedings). In fact, oak wilt has recently emerged as a very serious regional threat to oak health, and has been expanding in distribution and impact. Due to many interacting factors, the impact of the disease varies greatly among different locations. In the following pages we will discuss how these many factors affect the occurrence and management of oak wilt in the region. We will also discuss the distribution of the oak resource and the pathogen, variation in disease incidence severity, how biological factors affect opportunity for effective management, and the role of federal agencies in disease management within the North Central region.

OCCURRENCE AND SEVERITY OF OAK WILT DISEASE

Oak wilt is widely distributed throughout much of the region, yet it has not been reported from every county within the states of the North Central region, and there is considerable area with a significant red oak resource that does not have oak wilt disease (Fig. 1). Within the past 10 years, oak wilt expansion (range extensions or intensification of disease within the known range) has specifically been noted in northern Wisconsin, the Upper and Lower Peninsulas of Michigan, southern Indiana, and urban developments north of the metropolitan area of Minneapolis/St. Paul, MN.

Oak wilt does not cause a consistently high level of impact across the region. Several biological factors that affect the spread and intensification of the disease through root graft connections and vector/host relationships account for this variation. These biological factors are intertwined with additional social factors, such as rural versus urban forests, changes in land use and forest cover, and long distance human movement of the pathogen. These factors are more fully addressed in a separate paper (Juzwik, this proceedings).

New infection centers of oak wilt usually arise when spore-contaminated nitidulids (sap beetles) visit fresh wounds on oaks (Gibbs and French 1980). If a tree becomes successfully infected, the fungus can spread to adjacent trees through grafted roots. Species composition and soil characteristics that affect frequency of root grafts determine the likelihood of this type of spread. In addition, ascospores and conidia from fungal mats can spread locally or longer distance via nitidulids. This type of spread leads to intensification of the disease on a site, or initiation of new sites.

In Missouri, older literature indicates that oak bark beetles may also be important in overland movement of the pathogen, and that competing microorganisms and weather factors may reduce the importance of fungal mats in spread of the disease (Rexrode and Jones 1970). However, three sap beetle species have recently been shown to be important vectors in the state (Hayslett, Juzwik and Moltzan 2008, Hayslett et al, this proceedings)). Studies in Minnesota have shown that, although fungal mats can be formed on oaks during the fall, the spring-produced mats are highly synchronized with nitidulid biology and behavior (Juzwik, Skalbeck and Neuman 2004). Furthermore, due to springwood vessel structure, the oak hosts are highly susceptible to successful infection by *C. fagacearum* during the spring. The synchronization of mat formation with nitidulid biology does not occur in fall (Juzwik et al. 2006).

Humans promote initiation of oak wilt centers by creating fresh wounds on oaks during highly susceptible periods. New infection centers in urban areas are well documented to be associated with construction and pruning wounds to oaks in the spring of the year. In forests, harvesting, thinning, road construction, or any other activity that wounds trees during the spring and early summer can lead to new oak wilt infections. This has recently been a problem on National Forest sites in Wisconsin and Michigan, where selective harvest and pruning activities in oak stands were implemented during the spring of the year, resulting in astonishing levels of new oak wilt disease (Joseph O'Brien, unpublished data, USDA Forest Service 2007).

The importance of the various biological factors (frequency of root grafts, stand composition, wounding, etc.) in spread and intensification of oak wilt is also affected by the actual distribution of the oak wilt pathogen. In areas where *C. fagacearum* is not known to occur, humans effect long-distance initiation of oak wilt centers through movement of infected material. Of particular concern is infected firewood or sawlogs that may harbor fungal mats. The presence of oak wilt disease in the Upper Peninsula of Michigan has been attributed to movement of infected firewood to seasonal-use properties (Bob Heyd, personal communication, Michigan DNR 2008).

OAK WILT MANAGEMENT ACROSS THE REGION

The primary tools for managing oak wilt are aimed at disrupting mechanisms of spread of the pathogen. Tools and management practices are available to prevent overland initiation of infection centers via insect transmission of the pathogen, and to prevent below-ground intensification of infection centers via movement of the pathogen through root grafts. In addition, systemic fungicides are being used under certain situations to protect high-value trees. This section expounds on how each of these tools is used in the North Central region.

Prevention of Overland Spread

Avoidance of wounding during the highly susceptible spring period can prevent much overland insect transmission of *C. fagacearum* to healthy oaks. Wounds to oaks during this period require immediate treatment to prevent the cut surface from being infected by spores carried by nitidulid beetles. Even exposed stumps should be treated, as they serve as an open infection court.

In urban and suburban areas, prevention of human-made wounds on oaks is important. In the Midwest, there have been several effective public education campaigns to encourage people, e.g. "Don't prune in April, May and June." Many commercial arborists choose to avoid pruning during this time period. The susceptible period does vary across the region, and between years, so local knowledge is useful. It is also important to protect oaks from wounding at construction sites; this can often be accomplished by putting a fence or barrier around the oaks. This action can be effectively encouraged through education or community ordinances.

In woodlands, it is important to avoid forest disturbance activities during the susceptible period, and again, this can often be accomplished through education, local ordinances, or state guidelines. The Wisconsin DNR recently developed guidelines for harvesting in oak timberlands to minimize the potential for pathogen introduction to oak wilt-free stands or intensification in already affected stands (Wisconsin DNR 2007).

Another means to reduce overland spread is to reduce inoculum from fungal mats and pads. Trees from the red oak subgroup that have died from oak wilt in mid- to late-summer and have suitable sapwood moisture content for production of fungal mats during the following spring are called "potential spore producing trees," or PSPTs. White oaks are not considered to contribute significantly to risk of mat production. To effectively manage oak wilt, all PSPTs should be felled and portions greater than 2" diameter removed, treated, or destroyed prior to vector activity in the spring.

In most situations, removing the tree immediately after it dies is not recommended, because the pathogen may be pulled into the roots of healthy trees by transpiration of the adjacent living trees. The PSPT can be safely removed and treated to eliminate the possibility of spore mat production after vibratory plowing is completed on a site (usually in the fall). The stems can be safely utilized for timber products if they are removed from the site and processed prior to spring. They also can be utilized for firewood if they are debarked or are sealed with a tarp (to prevent nitidulid beetles from reaching the wood if spore mats are produced) from late winter until late summer of the same year. Acceptable methods to destroy wood from PSPTs include chipping, burning, or burying.

Prevention of Spread Through Grafted Roots

There are several tools to prevent transmission of *C. fagacearum* through root grafts. It has been demonstrated that in order to consistently halt the disease, functional grafts must be broken to a depth of 60 in. (1.5 m) (Bruhn and Heyd 1992). A vibratory plow equipped with a specialized blade is one of the most effective tools available for disrupting root connections between trees in the North Central region.

The placement of vibratory plow lines is critical to treatment success. Two methods are used in the North Central region. The "rule of thumb" method developed by D. W. French places a "primary" line outside the closest apparently healthy trees, so that there is a buffer zone of healthy trees between the oak wilt center and the plow line (French and Juzwik 1999). A secondary line can optionally be placed between the dead or dying trees and some or all of the buffer zone trees to try to 'save' some of these trees. A mathematical model developed by Bruhn, Pickens and Stanfield (1991) defines line placement with an equation that predicts the probability of the pathogen moving to an adjacent healthy tree within one year based on diameter of the healthy tree, diameter of the diseased tree, distance between the two trees, and soil type (Bruhn and Heyd 1992, Carlson and Martin 1996). With either method, oaks within the vibratory plow line are generally removed, either in a single preemptive action or over time as they succumb to oak wilt. Use of the mathematical equation method usually results in the removal of more trees than the "rule of thumb" method. Both methods are used within the North Central region, depending on the situation, location and preferences of the person defining line placement.

If a plow is not available, a trenching machine may be used to sever common roots, but the depth (usually 48") is inadequate to achieve consistent control. A backhoe can be used to dig an effective trench; however this is quite disruptive to a site.

Recently, on National Forest land, a previously untested method was used to control oak wilt center expansion in an area where uneven topography and rocky conditions precluded effective treatment with a vibratory plow. The method involves cutting and removing infected and adjacent trees and then using an excavator to rip out and overturn the stumps and root masses, a procedure coined "root rupture." In doing this, many of the root grafts are broken and diseased tissues are isolated from neighboring healthy oaks. Internal Forest Service documentation indicates that this method was greater than 90% effective in halting the spread of oak wilt (John Lampereur, personal communication, Chequamegon-Nicolet National Forest 2007).

The use of buffer zones alone, or simply cutting out oak wilt pockets, generally fails to halt the spread of oak wilt disease in the North Central region. Use of herbicides to kill a buffer zone of trees, with the hope that the root systems of killed trees will die and deteriorate quickly, has repeatedly been proposed as an alternative means of interfering with the graft connections of oak. Although some herbicide combinations have been identified that consistently kill oaks without sprouting, the root systems of the treated trees do not die quickly, making this method ineffective or impractical (Bruhn et al., 2003, Ed Hayes and Linda Haugen, MN DNR and USFS, respectively, personal observation, 2004).

Fungicide Injection

Systemic chemical treatment of high value oaks with propiconazole (PPZL) is a common practice in urban forests of the region. Preventive treatment of white and bur oaks within root grafting distance of infected oaks of the same species is effective in preventing wilt symptom development in treated trees (Eggers et al. 2005). Therapeutic treatment of *C. fagacearum*-infected white and bur oaks with $\leq$ 30% crown wilt symptoms has also been shown to prevent further wilting in such trees. Due to the observed success, commercial arborists generally only treat these species once they are infected.

Preventive treatment of red oak species within root grafting distance of pathogen-infected red oaks is common practice. In an evaluation of operational treatment by commercial arborists in the Minneapolis/St. Paul, MN, area, 39% of preventively treated red oaks died from oak wilt over 5 years, but the deaths largely occurred 3 to 5 years after the single treatment (Eggers et al. 2005). Thus, many arborists commonly re-treat red oaks with PPZL two seasons after initial treatment.

In an experimental field trial involving paired treated and non-treated plots, differences in PPZL efficacy occurred by soil type/topography and by one versus two time treatments when compared to the control trees (Juzwik unpublished data). Results of a recent experimental study in red oaks suggests that PPZL likely suppresses disease development rather than eradicating *C. fagacearum* from roots or preventing root graft transmission (Blaedow and Juzwik 2008). Treatment of currently wilting red oaks is not advised as success in arresting wilt symptom development only occurred in trees exhibiting $\leq$ 25% crown wilt at the time of injection (Ward, Juzwik and Bernick 2005).

Management Conclusions

Just as the severity of the oak wilt pathogen varies across the region, the usefulness of these tools also varies. In areas with high incidence of root graft spread and deep sandy soils, use of the vibratory plow is highly successful, especially in parts of the region where vibratory plows and the necessary 60" blades are readily available. In other parts of the region, plows are harder to find, and 60" long blades are often not available.

Effective oak wilt control requires integration of tools to address all of the constraints and opportunities. The USDA Forest Service has produced three "How to" guides that provide valuable information to manage oak wilt (O'Brien et al. 1999, Pokorny 1999, Cervenka et al. 2001). The Forest Service has recently prepared other information products to assist with overall management of oak wilt disease.

In 2004, Forest Health Protection and Northern Research Station collaborated to produce a CD product to help communities implement an effective oak control program (Juzwik et al. 2004). This CD, entitled "Oak wilt: People and Trees, A Community Approach to Management", included powerpoint presentations, pdf files of relevant publications, and additional materials. The CD can be obtained from the Northern Research Station publications website, or from the Forest Service authors (Jennifer Juzwik and Linda Haugen).

In 2007, the Forest Service Forest Health Protection staff prepared "Northeastern Area Participation Guidelines for Oak Wilt Cooperative Prevention and Suppression Projects". This document provides guidance to help States and federal agencies implement effective oak wilt suppression projects. Suitable for a 3-ring binder, it includes appendices with detailed information on oak wilt biology, technical details of control measures, factors to consider when prioritizing treatment areas, and description of necessary documentation for federal projects. The guidelines are available from the US Forest Service Northeastern Area, State and Private Forestry, Forest Health Protection, St. Paul, MN.

THE ROLE OF FEDERAL AGENCIES IN OAK WILT CONTROL

The USDA Forest Service (FS) plays a vital role in the management and control of oak wilt disease in the North Central region. Its role is multifaceted and involves programs administered through State and Private Forestry and Research and Development.

State and Private Forestry programs, as authorized by Federal law, provide financial and technical assistance to protect state, private, and federal lands from the impacts of forest insects and diseases that pose a serious threat to the health and sustainability of urban and rural forest resources. Oak wilt is recognized as the single most important disease of oaks in the North

Central region, and the need to implement effective oak wilt management strategies has been identified as a high priority in several states.

To facilitate the effective management of oak wilt, State forestry agencies can use core-level funding provided by the FS annually, and they can apply for Cooperative Prevention and Suppression Grants. State agencies normally request Cooperative Prevention and Suppression funding because the anticipated costs of an eradication or suppression project exceed available state, local, or private funds. Federal land managers can also apply for Cooperative Prevention and Suppression Grants. To date, Oak Wilt Cooperative Prevention and Suppression Grants have been provided to State forestry agencies in MN, MI and WI; the Chequamegon-Nicolet and Huron-Manistee National Forests; and other federal agencies including the Department of Defense, Department of Interior, and Bureau of Indian Affairs.

State and Private Forestry staff also provides technical assistance to State and Federal partners. Technical assistance usually comes in the form of helping partners complete project documentation needed to meet NEPA requirements, including completion of biological evaluations, site specific environmental assessments, and consultations with the US Fish and Wildlife Serve (US F&WS) and the State Historic Preservation Office (SHPO).

Research and Development staff has dedicated significant efforts to conduct studies that have led to new or improved oak wilt management tools. A protocol was developed for monitoring flight activity of the predominant sap beetle vectors, particularly in early spring in Minnesota and Wisconsin (Kyhl et al. 2002). Sap beetle dispersal studies and frequencies of *C. fagacearum* contaminated beetle occurrence have been used to refine high, low and no risk time periods for tree pruning and harvesting activities (Ambourn, Juzwik and Moon 2005, Juzwik et al. 2006, Hayslett, Juzwik and Moltzan 2008). Experimental and observational studies on efficacy of PPZL for oak wilt control have resulted in improved guidelines (Eggers et al. 2005).

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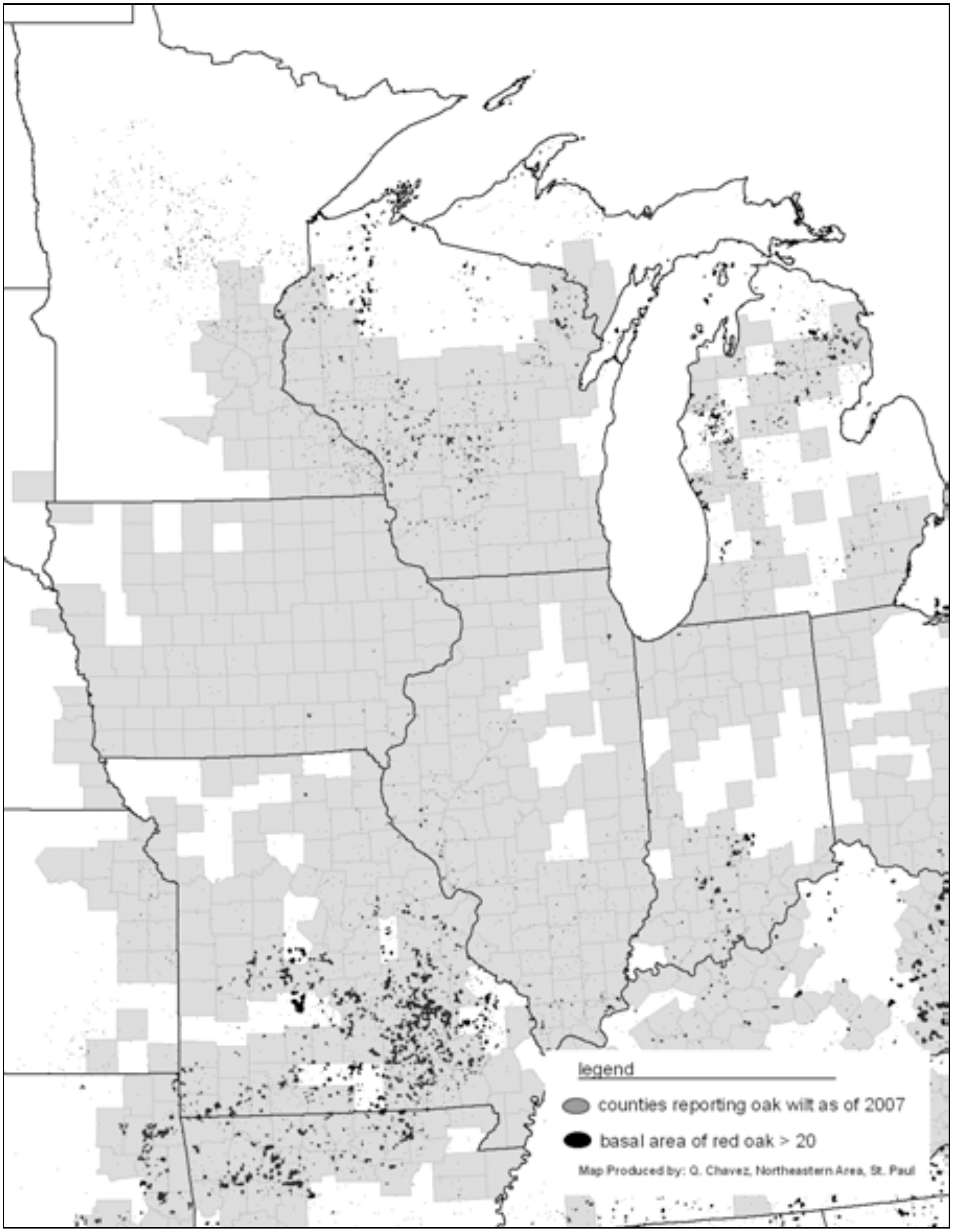

Figure 1. Distribution of oak wilt by county in 2007 and areas with basal area of red oak > 20 ft^2 according to Forest Inventory and Analysis (FIA) in the North Central region.

OAK WILT: ITS IMPACT ON A GROWING TEXAS

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ABSTRACT

Since its official laboratory confirmation in the state of Texas in the early 1960s, the fungus which is responsible for the disease known as oak wilt (*Ceratocystis fagacearum*) has been confirmed in over 60 counties in central and west Texas. Since that time, explosive human population growth throughout central Texas has led to the fragmentation of traditionally large agricultural property holdings into smaller 10-50 acre "ranchettes." This fragmentation has been partly responsible for a transition in land use that moves away from traditional agriculture and toward a more multi-use management style. This new management regime also recognizes the added value that trees and tree canopy can provide. Not only do the introduction and preservation of trees satisfy these new multi-land use objectives which include recreation, aesthetics, and wildlife habitat, but trees directly contribute to an increase in overall property value. This newfound fondness of trees and their value to a growing population of tree-loving Texans also creates certain opportunities. The key lies in the ability of state forestry officials and their public and private partners to effectively increase the level of oak wilt awareness among these environmentally-conscious landowners. Currently, this is being addressed by creating one-stop sources of technical oak wilt information and assistance, and making them more easily accessible to the public by way of web-based services and GIS technology. By increasing the current levels of oak wilt awareness and providing the public with accurate and timely information on management of the disease, citizens and communities alike can be empowered to partner with state officials in better managing this statewide epidemic.

Key words: *Ceratocystis fagacearum*, disease management

Since the official laboratory confirmation of oak wilt in Texas in the early 1960s (Dooling 1961), and reports of oak disease centers long before that in many other areas of the state (Tabubenhaus 1934), forested areas throughout regions of central Texas (Fig. 1) have been severely impacted by this tree disease.

Oak wilt is caused by the fungus *Ceratocystis fagacearum* (Bretz) Hunt. The most obvious impact of this pathogen has been the loss of millions of Texas oaks over the last four decades (Lewis 1977, Appel and Maggio 1984). The continuing loss of these valuable tree resources has played a slow but steady role in altering many forest stewardship and land management decisions, if not permanently changing the perspectives that both rural and urban Texas communities have regarding the value and benefits of trees.

The occurrence and subsequent spread of the disease can be partly attributed to various human activities that result in the improper maintenance and wounding of trees (Craighead and Nelson 1960, French and Stienstra 1975, Juzwik and French 1983). Thus, oak wilt occurrences and impact have shown to be most significant in areas of greater human population.

TEXAS POPULATION GROWTH

Texas is growing, and growing fast (Fig. 2). To get a clear perspective on just how fast, consider the following statistics: During a period from 1990 to 2000, Texas' population grew by an estimated 3.9 million people, surpassing New York as the nation's second most populated state (Gilmer 2005). Currently, Texas ranks 8th in the US for percent population gain (22.8%). This considerable gain in net population now gives the state 13 of the top 100 fastest growing counties in the U.S. (Wilkins et al. 2003)

FRAGMENTATION

The steady increase in population directly results in an increased demand for land and housing. Fragmentation is a term commonly used by economists to describe the process in which traditionally large agricultural property holdings are broken down, or fragmented, into smaller 10-50 acre "ranchettes" (Fig. 3). To illustrate the impact of this trend; in a period from 1982 to 1997, Texas led all other states in the conversion of rural farming and ranching lands into some form of residential-based development. It is also estimated that the conversion of formerly agricultural-based landholdings into urban uses during this period exceeded 2.6 million acres. This is approximately double the rate of conversion compared to the previous 10 years (American Farmland Trust[1]).

A NEW BREED OF TEXAS LANDOWNER

The fragmentation of traditional agricultural land produces many smaller parcels. These parcels simply do not have the acreage needed to justify any type of potentially profitable farming, ranching or forestry practices. Most of these new landowners have little or very limited interest in working the land for a living – but are interested in land management from a non-conventional perspective. This new perspective has evolved into a new generation of land and forest stewardship for Texas landowners. This new type of stewardship has placed new emphasis on developing land for uses other than traditional agriculture.

Research has shown that the new landowners actively seek out properties that are away from the crowded urban areas; a place where they can escape the crowds and noise of urban life. These new land stewards commonly spend large sums of money in developing their properties to enhance various natural features such as wildlife habitat, picturesque view-scapes, and hiking trails. The only livestock that are managed on these properties are typically very small populations consistent with hobby farming or which allow the landowner to qualify for various agricultural tax exemptions or credits. In all - it's just enough to reconnect them to the spirit of the old West. In addition, a recent survey found that 80% of these new Texans stated that finding land for non-agricultural uses, like hunting, fishing and other recreation was a "very important" motive for their purchase (American Farmland Trust[2]).

As stated earlier, this new breed of Texas landowner seems to find great excitement in staking claim to a small piece of the rustic and colorful legacy of the state. These new landowners are younger, more educated and notably more affluent than their predecessors. According to a publication sponsored by the Federal Reserve Bank of Dallas (Gilmer 2005), this trend toward increased wealth can be further verified by monitoring levels of Texas employment and income growth records. Their data confirms that the Texas economy has outperformed the U.S. economy since 1969 (Fig. 4). And, by 2001, the state as a whole had raised its per capita income to 94 percent of the national average, up from 88 percent in 1969. Over the same period, the average annual growth rate of per capita income was 2.3 percent for Texas versus 2.1 percent for the United States (Fig. 5) (Bryson 2006).

When it comes to the purchase of land in Texas, wealth does have its advantages. According to the American Farmland Trust[1], since 1994, residential development consisting of lots 10 acres in size or greater, has accounted for 55 percent of the land developed. Consequently, land prices are no longer driven by productivity of the land in terms of cattle and crops, but rather by its scenic and recreational value. These are natural features that have become the dominate factor in determining land value, and in many counties across Texas, these attributes have pushed prices to unprecedented levels (Gilliand 2007). The Texas Hill Country serves as a prime example; over the last decade, in a relatively isolated location of central Texas known as the Llano uplift (a region lacking a metropolitan area), the average market value for rural land increased by more than 86% over the last decade. This equates to approximately $514 per acre for land with an average agricultural value of $62 per acre (Wilkins et al. 2003).

VALUE OF TREES IN URBAN AND RURAL AREAS

The new style of stewardship also recognizes the importance of trees, both for their beauty and for the economic value they add to the property. Recognized methods of tree valuation have revealed that the presence of trees on a particular property may range from 13-19 percent of the total land value (Martin 1986). Unlike the economic contributions of trees, the aesthetic, social, communal, and environmental values are much more difficult to quantify, therefore, tend to be very subjective.

Although trees provide numerous aesthetic and economic benefits, they do come at a cost. For example; Texas landowners who are interested in reforesting an area denuded by oak wilt will quickly become aware that a sizable investment is required in order to purchase, plant, protect, and maintain the trees they desire. The largest expenditure besides the purchase and planting of new trees is the removal of the dead trees. This cost alone can be more than enough incentive for the landowner to increase his/her level of knowledge and awareness of not only oak wilt, but also of other potential forest and tree health issues that must be actively managed in order to protect the investment.

TREES FOR A GROWING TEXAS; RESPONSE OF STATE AND COMMUNITY FORESTRY PROGRAMS

As the population in Texas grows and land becomes more fragmented, the need for comprehensive tree and forest awareness programs increases. In 1982, in an attempt to address this need, the Texas Forest Service (TFS) initiated ane oak wilt demonstration project within selected counties of central Texas with funding from the United States Forest Service' Forest Health Protection Program. After 5 years (in 1988), the project was further expanded to include approximately 40 counties and became a federal suppression project. The Texas Forest Service strategically placed field offices throughout the region of central Texas to provide on-site technical and financial assistance to landowners battling this difficult tree disease. This was the first presence of TFS in this portion of the state (Billings et al. 2001).

To date, the Texas Oak Wilt Suppression Project has worked cooperatively with private and public partners in the field to effectively manage over 2,400 oak wilt centers (see Billings, these proceedings). TFS has placed further emphasis on increasing levels of public awareness regarding oak wilt and worked with multiple public and private partners to provide technical training for county extension volunteers and professional arborists. In 2005, TFS in cooperation with the Lady Bird Johnson Wildflower Center in Austin created an Internet web page (http://www.texasoakwilt.org). Devoted exclusively to the identification and management of oak wilt in Texas, this web page received some 385,000 visitors in 2006.

Currently, seven multi-disciplined TFS foresters provide technical on-site services to landowners in six central Texas program delivery regions (Fig. 4). To complement the oak wilt management services, these foresters also have resources to provide technical assistance in areas of forest stewardship, reforestation, forest health, urban/community forestry, and other forestry-based practices. In 2007, the Texas Oak Wilt Suppression Project will have completed 20 years of service to the citizens of central Texas, one of the longest federal suppression projects on record.

In an on-going effort to get the word out to landowners throughout central Texas, specialists with TFS, Texas Cooperative Extension (now Texas AgriLife Extension Service), and Texas Agricultural Experiment Station (now Texas AgriLife Research) have trained various groups of Master Gardeners/Master Naturalists and ISA-certified arborists on the basics of oak wilt identification and management. These volunteers and professionals are now intercepting many of the numerous inquiries about oak wilt, lessening the burden on the few TFS foresters that deliver the Suppression Project.

CONCLUSION

By increasing the current levels of oak wilt awareness and empowering the public with accurate and timely information on management of the disease, citizens and communities alike can become partners with state officials in effectively addressing oak wilt at the local level and collectively managing a serious tree disease at the state level.

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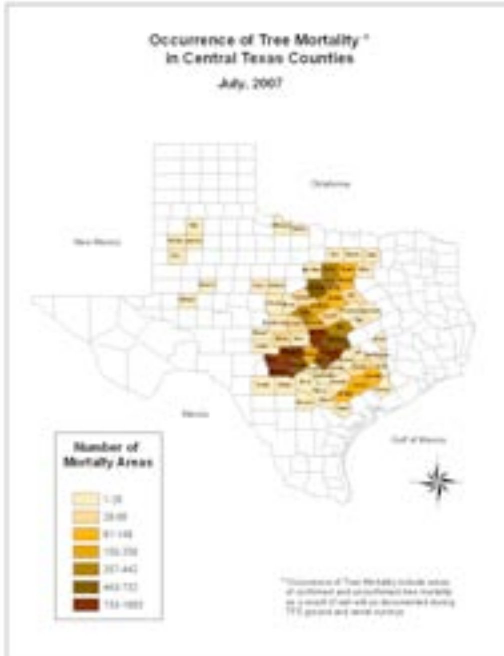


Figure 1: Tree mortality in Texas counties, July, 2007 (Texas Forest Service unpublished data).

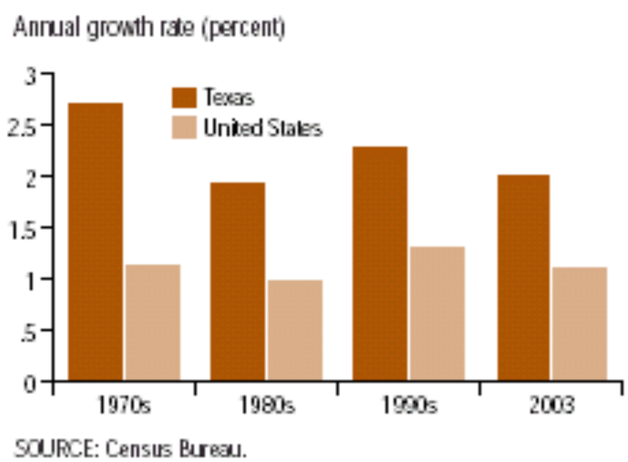
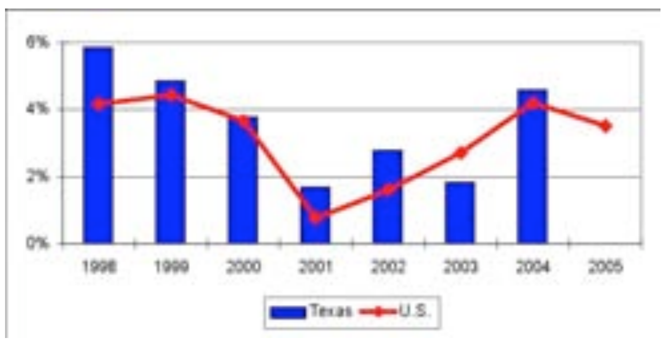


Figure 2: Texas and U.S. population growth, 1970-2003 (Source: U.S. Census Bureau).

Figure 3: Tree-friendly “ranchettes” located in central Texas (Photo by J.B. Rooni).



Sources: Economy.com and Wachovia Corp.

Figure 4: Texas and U.S. economic growth 1998 – 2005: Strong population growth has helped fuel the Texas economy.

	2001 per capita income (dollars)	Percent of U.S. level	Annual growth rate 1969–2001 (percent per year)
United States	30,413	100	2.1
Texas	28,472	94	2.3
Dallas–Fort Worth	33,247	109	2.2
Houston	34,916	115	2.5
Austin	31,511	104	2.8
San Antonio	26,887	88	2.3
Texas Triangle	32,897	108	2.4
Rest of Texas	21,357	70	1.8

SOURCES: Bureau of Economic Analysis; author's calculations.

Figure 5: Performance of regions of the Texas economy.

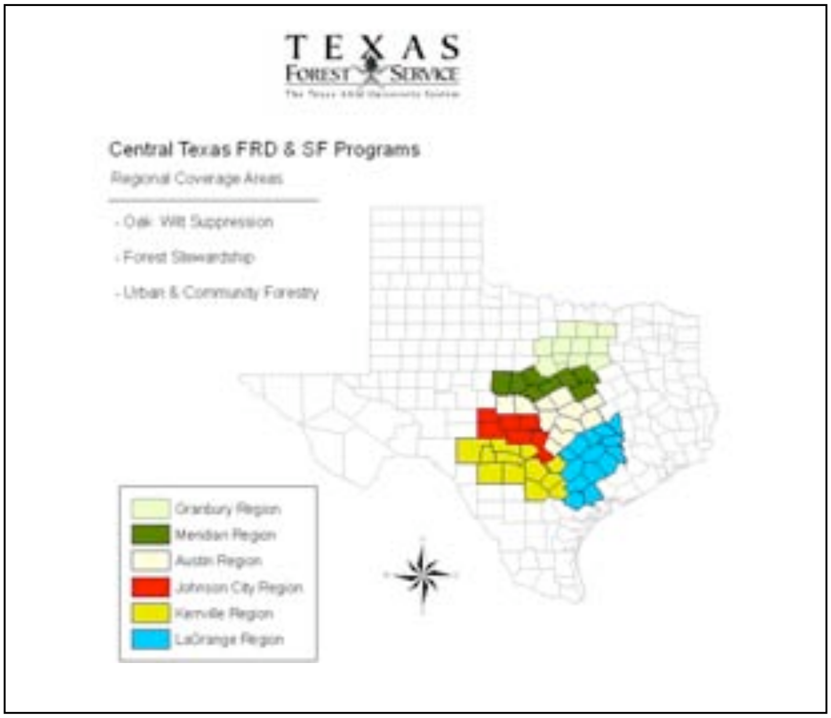


Figure 6: Texas Forest Service program delivery regions.