ASSESSING OAK DECLINE INCIDENCE AND DISTRIBUTION IN THE SOUTHERN U.S. USING FOREST INVENTORY AND ANALYSIS DATA

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Abstract—Forest Inventory and Analysis data for twelve southern states were used to evaluate regional oak decline status. Total host type, vulnerable host type, and affected areas were determined. The attributes used for classification were forest type, predominant stem size class, oak basal area percent, and dieback damage coding. Host type totaled 104.7 million acres in the most recent inventory cycle (1991-1997), of which 41.6 percent were classified as vulnerable. Oak decline affected over 4.4 million acres, or 10.1 percent of the vulnerable host type. This was a slight incidence increase over the previous inventory cycle (1984-1989). Two-thirds of the decline-affected area was contained in 4 states-Virginia, North Carolina, Arkansas, and Tennessee in decreasing rank order. Large increases in incidence occurred in Arkansas and North Carolina, while incidence decreased markedly in Tennessee. Oak decline incidence in Virginia remained unchanged between inventory cycles.

INTRODUCTION

Hardwoods dominate forest cover in the thirteen states of the southern region, with about two-thirds of the area in upland hardwood, bottomland hardwood, or oak-pine mixtures. Upland hardwood is by far the largest forest type group, accounting for about 37 percent of the forested area (Sheffield and Dickson 1998). Oaks dominate the growing stock volume in upland hardwood stands, comprising 47 percent of the total region wide. The next most abundant species is yellow poplar, which makes up only 12.6 percent (Hansen and others 1992).

Oak species are economically and ecologically important in the southern region as valuable timber species and indispensable habitat components for wildlife feeding on hard mast. However, oak decline is a widely distributed change agent that is altering species composition and forest structure in upland hardwood and mixed oak-pine forests. Oak decline is a disease complex resulting from the interaction of three groups of factors as described by Manion (1991). Physiologic age, soil depth and texture, oak species composition, and oak density are the main long-term predisposing factors. Common inciting factors include prolonged acute drought, spring defoliating insects like fall cankerworm and gypsy moth, and late spring frost. The biotic agents most often identified as contributing factors include Armillaria root disease, Hypoxylon canker and insect pests of opportunity like twolined chestnut borer and red oak borer. The symptom separating oak decline from other diseases of oak is slow, progressive dieback from the top downward and the outside inward in upper canopy trees (i.e., dominants and codominants). This symptom reflects aboveground the condition of the root system underground. The time scale of disease progression from inception to the death of susceptible trees is typically measured in years or decades, but tree mortality after a relatively short period of dieback sometimes occurs.

Oak decline is not a new phenomenon. Forest workers reported occurrences as early as the mid 1800's (Beal 1926, Balch 1927) and in every decade since the 1950's (Millers and others 1988). An apparent increase in incidence and severity in the early 1980's and continuing through the 1990's led to an intensification of survey and monitoring activities (Bassett and others 1982, Starkey and others 1989, Stringer and others 1989, Oak and others 1990, Starkey and others 2000), but most were relatively limited in geographic scale. Periodic multi-resource inventories conducted by the U.S.D.A Forest Service Southern Research Station Forest Inventory and Analysis work unit (FIA) afford the opportunity for regional assessments of oak decline. The results for two inventory cycles- 1984 through 1989 and 1991 through 1997 are reported in this paper.

METHODS

Permanent inventory plots are distributed over the land area of each state and visited at approximately six to eight year intervals by FIA field crews. Detailed accounts of data collection procedures can be found in field instruction manuals (U.S.D.A Forest Service 1984, 1985). Included among these procedures is coding for tree damages. The standard code that correlates most closely with oak decline is dieback, when it occurs in dominant and codominant oak trees. The geographic limit of this analysis was determined by the twelve southern states using common damage coding. These states are Virginia, North Carolina, South Carolina, Tennessee, Georgia, Florida, Alabama, Mississippi, Louisiana, Arkansas, Oklahoma, and Texas.

The host type population in these states included plots where oaks dominate tree species composition (table 1). These plots represent the area eligible for oak decline. Other forest types may also contain relatively small numbers of oaks subject to decline, but such plots were excluded because resource damage from this disease is unlikely.

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Table 1—Forest Inventory and Analysis forest types and forest-type groups included in host type for oak decline analysis

Physiographic type	Forest-type group	Forest type
Upland	Oak-hickory	Post oak-black oak-bear oak
		Chestnut oak
		White oak-red oak-hickory
		Northern red oak
		Yellow-poplar–white oak–northern red oak
		Southern scrub oak
		Mixed hardwoods
	Oak-pine	White pine-northern red oak-white ash
		Eastern redcedar-hardwood
		Longleaf pine-scrub oak
		Shortleaf pine-oak
		Virginia pine-southern red oak
		Loblolly pine-hardwood
		Slash pine-hardwood
		Other oak-pine
	Oak-gum-cypress	Swamp chestnut oak-cherrybark oak
		Sweetgum-Nuttall oak-willow oak
		Overcup oak-pine

The vulnerable host type population was defined as the subset of host type plots where the predominant size class was pole- or sawtimber, and oaks comprised 30 percent or more of total stand basal area. Plots with these combinations of forest type, size class, and oak density represent the highest risk for oak decline occurrence and resource damage. Affected plots were the subset of vulnerable host type plots where one or more dominant or codominant oaks had dieback recorded as a damage code.

Subjective evaluation of dieback was considered the greatest potential source of error in decline classification. Quality assurance procedures for a similar FIA assessment of oak decline in western Virginia revealed that field crews were proficient at identifying decline symptoms. Field checks of 10 percent of plots classified as decline-affected showed they were correctly diagnosed in 92 percent of the cases (Oak and others 1991). However, all plots in the western Virginia assessment were classified as decline-affected and were inventoried during the growing season when decline symptoms are easier to diagnose. We established the reliability of individual tree coding and decline classification in this assessment by field checking 102 plots in North Carolina and Tennessee. These plots represented both affected and unaffected plots diagnosed in the dormant and growing seasons (table 2). These states were selected because the inventories were the most recently completed at the time of validation and, therefore, least likely to have changed condition over time. Field checks were conducted during the growing season after the statewide inventories were completed (approximately 2-10 months).

Table 2—Number of plots in Tennessee and North Carolina used for dieback and oak decline validation, by initial inventory season and decline status

Inventory season	Decline	Unaffected
	- - - *number of plots* - - -	
Growing	37	29
Dormant	14	22
Combined	51	51

RESULTS

Validation

Individual tree coding by FIA field crews for presence or absence of dieback was correct for 89 percent of the cases (table 3). Accuracy was highest for unaffected trees than for affected overall, with no errors found for unaffected trees diagnosed in the dormant season. Affected trees evaluated in the dormant season were the most difficult for field crews to diagnose, though some of these apparent errors of omission could have been due to dieback that developed between the initial inventory and the validation effort. It is less likely for dieback symptoms to have been lost or masked in the short time between the initial inventory and validation.

Table 3—Validation of dieback and decline status of Forest Inventory and Analysis plots in Tennessee and North Carolina

Season of inventory	Decline plots	Unaffected plots	Both
	- - - - - - - percent correct - - - - - - -		
	Individual tree dieback coding		
Growing	84	93	88
Dormant	79	100	92
Combined	83	96	89
	Stand decline classification		
Growing	84	83	83
Dormant	86	77	81
Combined	84	80	82

1984-1989 Survey Period

The total area of host type was 114.7 million acres in the twelve surveyed states (table 4). Alabama led the region with 13 million acres, but there were six others with more than 11 million acres each (Georgia, Arkansas, North Carolina, Virginia, Tennessee, and Mississippi in decreasing rank order). While the total host type acreage in the remaining states was no higher than 7 million acres (Florida), the differences in host type acreage among states was probably due more to differences in total state land area, than to density of host type plots.

Vulnerable host type totaled about 40 million acres. The geographic distribution of these plots show more dense concentrations in the Southern Appalachian Mountains of Virginia, North Carolina, Tennessee, South Carolina, and Georgia; along the eastern and western highland rim of middle Tennessee; and in the Ozark-Ouachita highlands of Arkansas and eastern Oklahoma (fig. 1). The regional distribution map showing plot locations is not one snapshot in time, but rather a mosaic of snapshots due to the varying inventory dates for each state.

The total area affected by oak decline was 3.6 million acres during this survey cycle (table 4). Virginia had the largest area (1.1 million acres). About 60 percent of the total affected area was located in Virginia, Tennessee, and North Carolina. Sampling error for affected area varied from 0.89 to 16.82 percent for all States, but was < 2 percent for each of the top three.

Regional incidence (percent of vulnerable host type area affected by decline) averaged 9.13 percent, but this was highly variable among states. Virginia and Florida had incidence approaching 20 percent, though Virginia had nearly 4 times the vulnerable host type acreage of Florida. Tennessee and North Carolina had incidence of about 12 and 10 percent, respectively, while Mississippi, Alabama, Oklahoma, and Louisiana had incidence of 3 percent or less. Relatively high densities of affected plots are located in northern Virginia, western North Carolina, the western highland rim of middle Tennessee, and in the northern Arkansas highlands (fig. 2.)

1990-1997 Survey Period

Host type area totaled 104.7 million acres during this period (table 5), a decrease of over 10 million acres since the earlier inventories. Florida experienced the greatest loss (3 million acres), but Georgia, North Carolina, and South Carolina each lost in excess of 1 million acres. Loss of host type could be due to diversion of former timberland to non-forest uses, such as urbanization; or change from oak dominated forest to a different forest type through management actions or natural forest dynamics (i.e., succession).

Table 4—Area and incidence of oak forest type affected by oak decline, 1984–89

State	Host type		Vulnerable host type		Affected		Incidence	Inventory year
	acres	*no. plots*	*acres*	*no. plots*	*acres*	*no. plots*	*percent*	
Alabama	13,032.5	2,244	4,169.9	718	138.1	24	3.31	1984
Arkansas	12,219.6	2,162	4,758.9	836	289.5	51	6.08	1988
Florida	7,306.4	2,711	1,522.0	568	296.0	114	19.45	1987
Georgia	12,526.3	3,501	4,058.7	1,250	341.2	69	8.41	1989
Louisiana	6,363.2	1,088	1,140.0	195	16.3	3	1.43	1984
Mississippi	11,112.2	1,917	2,465.3	422	93.7	16	3.80	1987
North Carolina	11,913.9	3,510	4,259.7	1,135	422.6	100	9.92	1984
Oklahoma	3,581.0	600	2,005.2	331	29.6	5	1.48	1986
South Carolina	6,606.5	2,378	2,133.8	730	139.9	51	6.56	1986
Tennessee	11,328.4	1,944	5,596.8	963	651.0	114	11.63	1989
Texas	6,843.0	1,137	1,873.3	308	99.2	16	5.30	1986
Virginia	11,887.3	3,327	5,802.3	1,515	1,114.4	272	19.21	1986
Total	114,720.3	26,907	39,785.9	8,852	3,631.5	871		
Overall incidence							9.13	

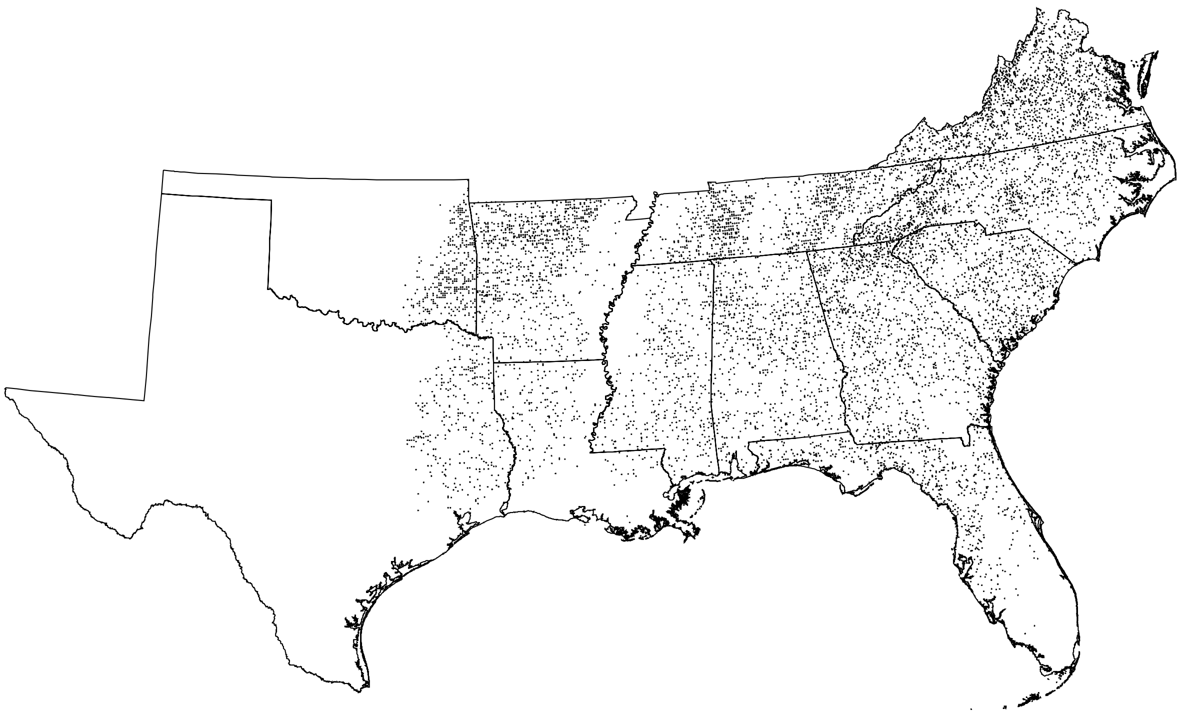

Figure 1—Geographic distribution of vulnerable host type plots for 12 Southern States, 1984-1989.

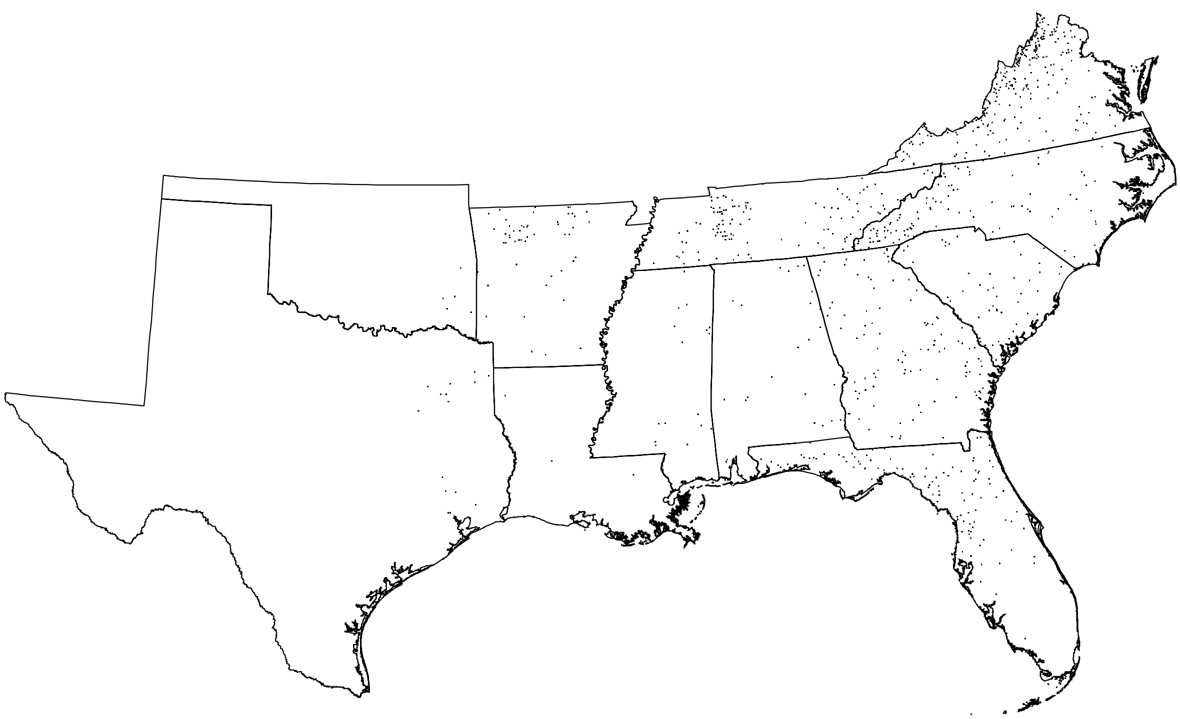

Figure 2—Geographic distribution of affected plots for 12 Southern States, 1984-1989.

Despite the loss of host type, vulnerable host type increased by 3.7 million acres regionwide. Arkansas registered the largest increase among the 12 states, almost 2 million acres, and led the region in total vulnerable host type area with 6.7 million acres. Virginia, Tennessee, and Alabama each had more than 4 million acres of vulnerable host type, but other large increases were noted in Mississippi, Louisiana, and Texas (1.4, 1.0, and 0.9 million acres, respectively). Geographic patterns similar to those observed in the earlier inventory were also seen during this period (fig. 3).

Table 5—Area and incidence of oak forest type affected by oak decline, 1990–97

State	Host type		Vulnerable host type		Affected		Incidence	Inventory year
	acres	*no. plots*	*acres*	*no. plots*	*acres*	*no. plots*	*percent*	
Alabama	13,402.9	2,835	4,272.1	756	260.5	47	6.10	1990
Arkansas	12,252.4	2,081	6,734.2	1,145	707.0	121	10.50	1995
Florida	4,271.8	1,621	1,601.8	595	211.7	80	13.22	1995
Georgia	9,797.3	3,501	3,747.1	1,250	250.7	69	6.69	1997
Louisiana	6,317.3	1,106	2,174.4	385	167.0	31	7.68	1991
Mississippi	11,381.5	1,930	3,900.6	659	203.4	37	5.21	1994
North Carolina	9,280.8	2,711	3,861.3	1,040	754.3	178	19.53	1990
Oklahoma	3,602.1	593	1,960.9	321	135.5	21	6.91	1992
South Carolina	5,106.6	1,798	1,809.8	611	164.0	55	9.06	1993
Tennessee	11,343.3	2,672	5,176.6	1,126	357.5	74	6.91	1997
Texas	6,962.7	1,197	2,763.4	476	105.8	19	3.83	1992
Virginia	10,945.6	2,960	5,510.1	1,413	1,090.5	268	19.79	1992
Total	104,664.3	24,555	43,512.3	9,777	4,407.9	1,000		
Overall incidence							10.13	

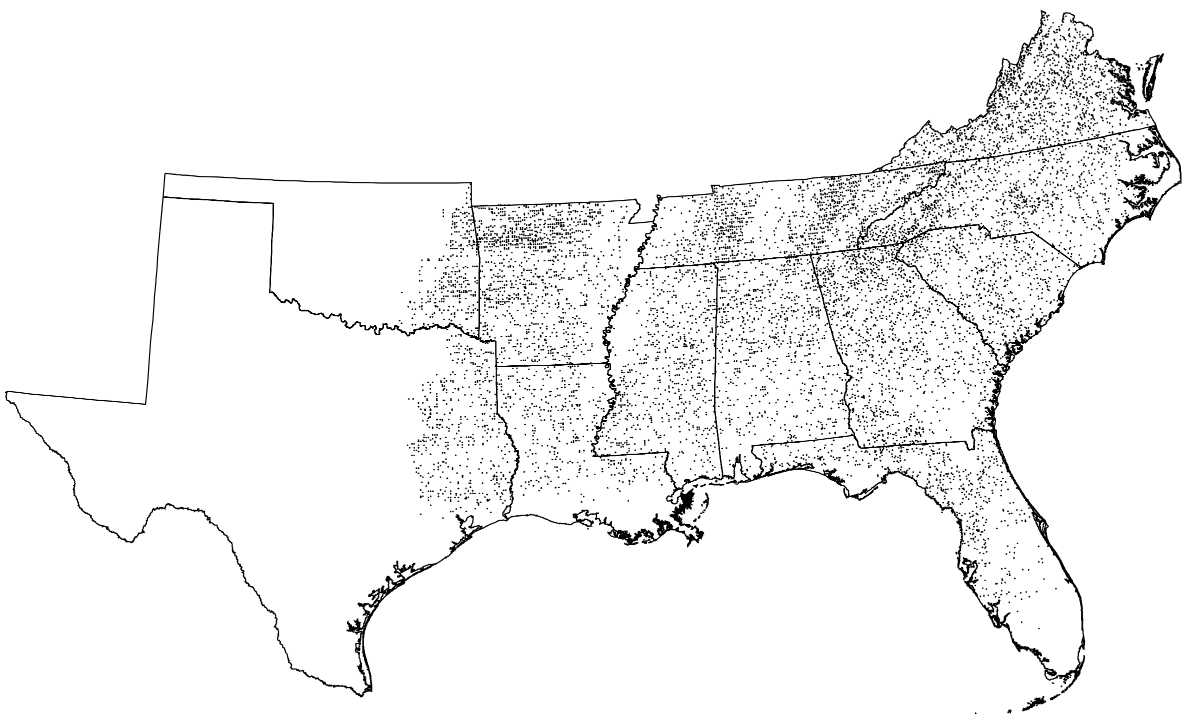

Figure 3—Geographic distribution of vulnerable host type plots for 12 Southern States, 1990-1997.

Area affected by oak decline totaled 4.4 million acres, up 0.8 million acres since the previous inventory. Virginia affected area remained almost the same (1.1 million acres in both inventories), but large changes occurred in North Carolina, Arkansas, and Tennessee. Despite a decrease in vulnerable host type in North Carolina, affected area nearly doubled to 0.8 million acres. In Arkansas, the large increase in vulnerable host type was mirrored by an increase in affected area of more than double, while in Tennessee, vulnerable host type remained the same and affected area decreased to half the area reported for the earlier inventory period. As for the earlier survey period, sampling error was low for the top three States in affected area.

Regional incidence increased slightly to 10.13 percent. Incidence in Virginia remained close to 20 percent, while incidence in North Carolina almost doubled to a similar figure. As in the earlier inventory, about 60 percent of the total affected area was represented by three states, with Arkansas replacing Tennessee and joining Virginia and

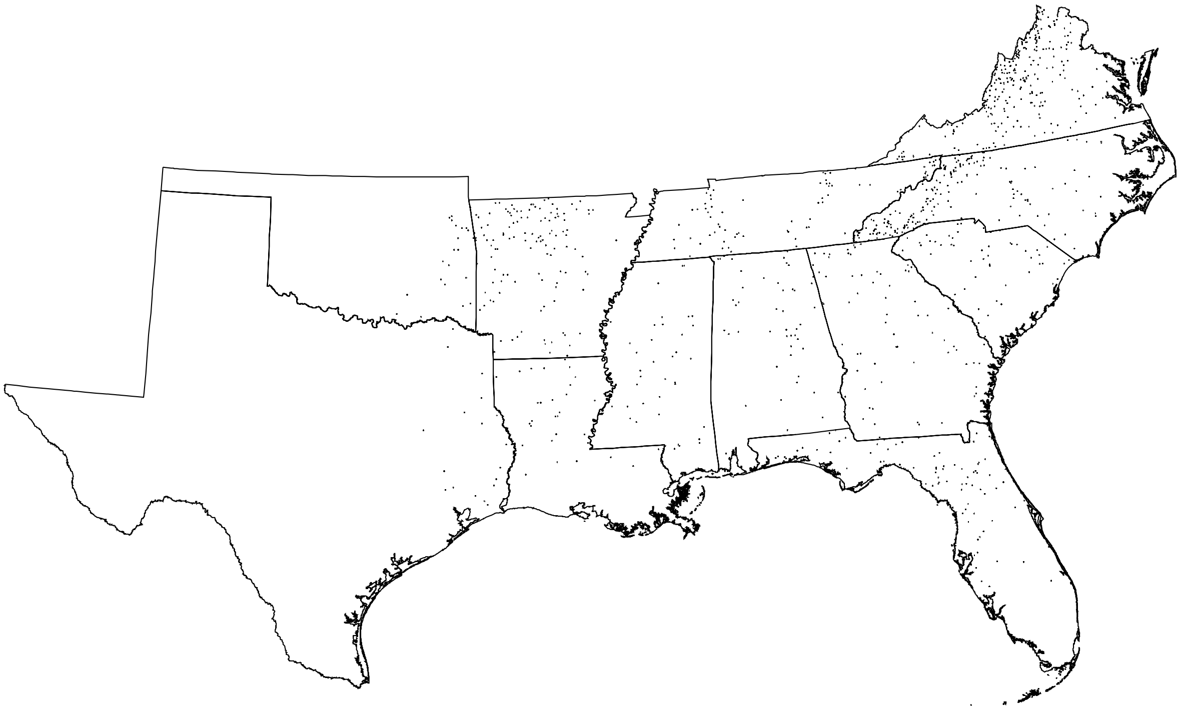

Figure 4—Geographic distribution of affected plots for 12 Southern States, 1990-1997.

North Carolina in the more recent inventory. Florida had high incidence in both inventories, but relatively low host type, vulnerable, and affected areas. The density of affected plots remained high in northern Virginia, but appeared to have intensified between inventory periods in western North Carolina and the Ozark-Ouachita highlands of Arkansas and Oklahoma. By contrast, affected plot density appeared to decrease in eastern Tennessee and the western highland rim (fig. 4).

DISCUSSION

Virginia, North Carolina, and Tennessee had consistently large oak decline affected area in the inventories conducted between 1984 and 1997, ranking in the top four among the 12 states in both inventories. Together they accounted for about 60 percent of the total affected area in the region. Florida had among the highest oak decline incidence during the period, but this was applied against vulnerable host type area that was the smallest among the states evaluated.

The aging and growth of upland hardwood forests in Arkansas resulted in large increases in vulnerable host type, and affected area over the inventory period. Vulnerable host type increased about 1.5 times between 1988 and 1995, while affected area increased about 2.5 times from 290,000 acres to 707,000 acres. This change captured by the 1995 inventory represents the beginning of the current unprecedented oak decline episode in the Ozark-Ouachita highlands. The earliest reports of the current episode were not made until about four years later in 1999 (Starkey and others 2000).

FIA inventories are useful for evaluating oak decline incidence and distribution. Other conditions can result in dieback that does not constitute oak decline. However, the presence of dieback symptoms in dominant and codominant oak trees in combination with the forest types, predominant tree size classes, and oak densities we recognized reliably represented oak decline. Future work will present finer spatial resolution of these data by breaking out individual survey units within states and by application of nearest neighbor statistical tools to individual plots.

Changes in methods instituted since the 1997 inventory cycle have made future analysis by these methods obsolete. New procedures will have to be developed for use with the new sampling designs. As long as the dieback symptom is recognized and recorded, oak decline analyses with FIA data sets will be possible.

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