Chapter 8. Crown Condition

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Introduction

Photosynthetic capacity is dependent upon the size and condition of the tree crown. Trees with full, vigorous crowns are generally associated with more vigorous growth rates (Zarnoch and others 2004). Therefore, the Forest Service Forest Inventory and Analysis (FIA) Program measures a suite of crown condition indicators to evaluate forest health. Among the crown condition indicators are crown dieback and two measures of foliage abundance, crown density and foliage transparency. Crown density is the amount of crown biomass, i.e., branches, foliage, and reproductive structures, that blocks light visibility through the projected crown outline. Foliage transparency is the amount of skylight visible through the live, normally foliated portion of the crown, and crown dieback is the recent mortality of branches with fine twigs, which begins at the terminal portion of a branch and proceeds inward toward the trunk. All three variables are determined by means of ocular estimates to the nearest 5 percent.[1] High levels of crown dieback indicate potentially serious declines in tree health, while low levels of crown density and high levels of transparency may indicate greater amounts of defoliation and signal that a tree may have a reduced capacity for growth.

Analysis

There are various ways to examine the crown condition data for trends in forest health. For this report, the plot-level crown indicator values were mapped to reveal any spatial patterns of crown condition and identify areas having relatively high or low indicator values. Average crown conditions were calculated for softwood and hardwood species groups for each plot. Because crown condition averages at the hardwood or softwood level might mask important patterns at the species level, plot-level averages were calculated for smaller groupings of individual species as well. These smaller groupings generally followed the species groups established by FIA (appendix table A.1). Although all species groupings were examined, maps for only the most abundant species are presented.

Foliage transparency was originally developed as a measure of insect and disease defoliation of hardwoods for the North American Sugar Maple

[1] U.S. Department of Agriculture Forest Service. 2005. Forest inventory and analysis national core field guide, section 12 – crowns: measurements and sampling. Version 3.0. U.S. Department of Agriculture Forest Service, Washington Office. Internal report. On file with: U.S. Department of Agriculture Forest Service, Forest Inventory and Analysis, Rosslyn Plaza, 1620 North Kent Street, Arlington, VA 22209.

Decline Project, whereas crown density was developed as a measure of crown fullness and growth potential among loblolly and shortleaf pines in the Southern United States (Millers and others 1992). Both indicators were adapted by Forest Health Monitoring (FHM) and applied to all species; however, in this report crown density averages are reported only for softwood species and foliage transparency averages only for hardwood species. Average crown dieback is reported for all species groupings. A plot average was not included in the spatial evaluation if the plot contained fewer than five trees (diameter ≥5.0 inches) in a given species group. Available data from all FIA phase 3 plots collected between 2000 and 2004 were included in this analysis (table 8.1). Due to differences in data collection cycles and data processing timeframes among the FIA regions this resulted in an uneven distribution of plots across the country. Analyses were based on plots with perturbed ("fuzzed") geographic coordinates (McRoberts and others 2005).

Available thresholds defining the point at which trees begin to decline biologically (e.g., Steinman 2000) have not taken into account

Table 8.1—Years of data[a] included in the crown condition analysis by State

Years	States
2000–2004	IN, IA, MI, MN, MO, PA, UT, WI
2000–2003	ME
2000–2002, 2004	AL, AR, GA, KY, LA, NC, SC, TN, VA
2001–2004	AZ, CA, IL, KS, NE, OH, OR, SD
2001, 2003–2004	ND
2001–2002, 2004	FL, TX
2002–2004	CO, WA
2002–2003	NH, NY
2003–2004	CT, MA, MT, VT
2004	ID, MD, NE, NJ, RI, WV

[a]Data for the Southern States were obtained from U.S. Forest Service, Southern Research Station, FIA; all other data obtained from FIA Data Mart (http://www.ncrs2.fs.fed.us/FIADatamart/fiadatamart.aspx). [Date Accessed: April 2006].

species-specific differences in typical crown form. As a result, the risk of erroneously classifying trees as unhealthy may be high for some species. Therefore, plots are not classified as having healthy or unhealthy crowns in this report. Instead, spatial clusters of plots with high crown dieback, high foliage transparency, or low crown density averages relative to the other plots were identified visually by analyst interpretation as areas with potential forest health problems. The breakpoints in the figure legends were selected according to the distribution of plot averages for each indicator and in such a way as to best highlight the overall conclusions of the visual inspection.

What Do the Data Show?

Softwoods—Figures 8.1A and 8.1B show plot-level crown dieback and crown density averages across the conterminous United States for the softwood species group. Plot-level dieback averages were typically <10 percent with only a few scattered plots averaging more than 20 percent dieback. Plot-level crown density averages typically ranged between 36 and 55 percent. Spatial clusters of relatively high dieback were observed in Arizona, Utah, and Pennsylvania. Further examination of the species-specific plot averages in the West (fig. 8.2) indicated that the plots in Arizona and Utah consisted primarily of pinyon and juniper species (see appendix table A.1). Plot-level dieback averages for this species group ranged between 0.0 and 32.7 percent; 7.6 percent of the plots had dieback averages >10 percent (fig. 8.2D). This clustering of relatively high dieback is likely evidence of the ongoing decline in the pinyon-juniper forest type, which has been caused by prolonged drought and insect and disease outbreaks (Shaw and others 2005). Pinyon pine mortality has been increasing since 2000, and in 2003 over 3.7 million acres were impacted throughout Arizona, California, Colorado, Nevada, New Mexico, and Utah (U.S. Department of Agriculture Forest Service 2005).

Examination of the cluster of plots with relatively high (>10 percent) crown dieback averages in Pennsylvania indicated a species mix of pine (*Pinus resinosa*, *P. rigida*, *P. strobus*, *P. sylvestris*, and *P. virginiana*) and eastern hemlock. Individual eastern hemlock and Scotch pine trees had the highest levels of crown dieback on these plots.

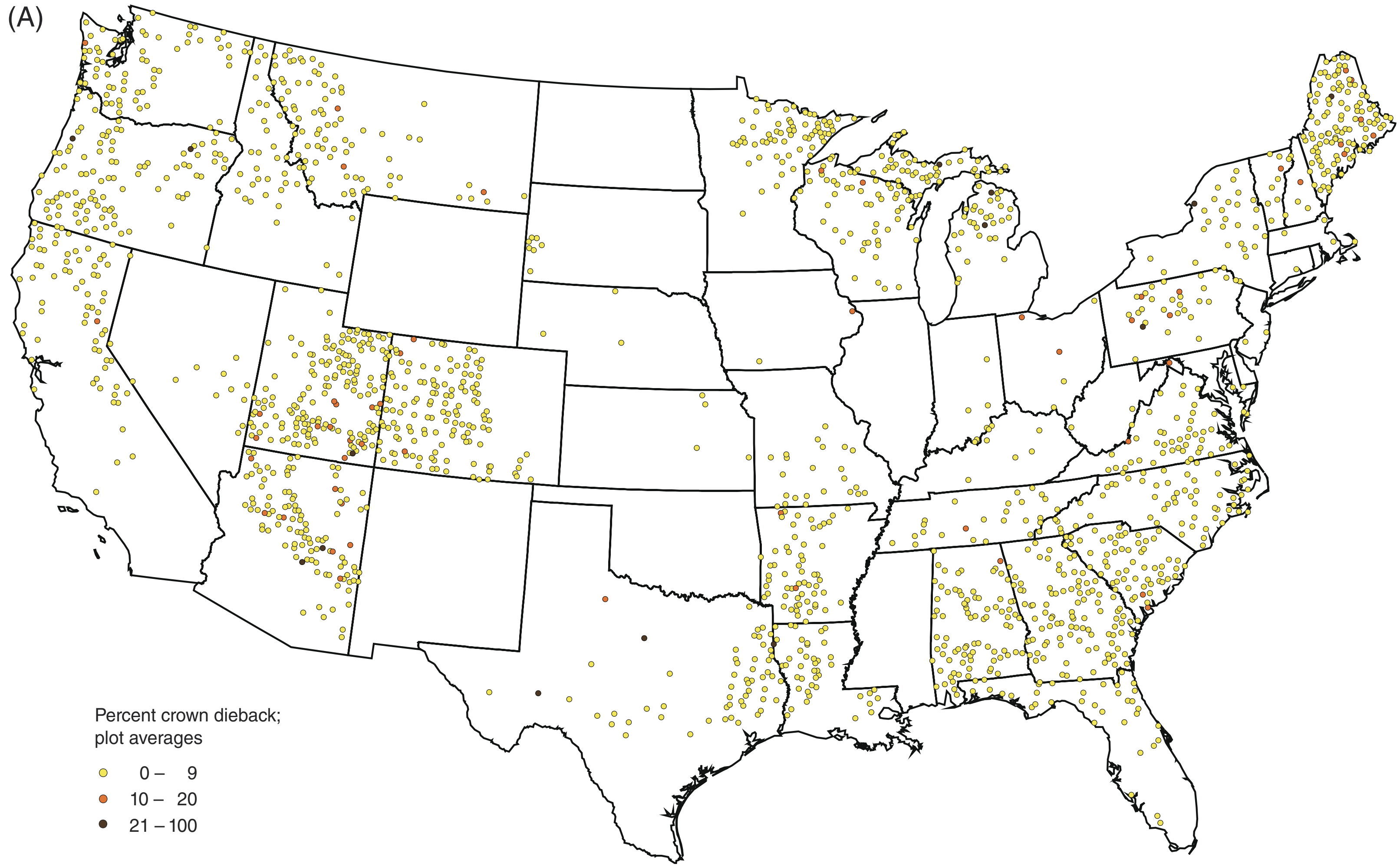


Figure 8.1—Crown dieback (A) and crown density (B) plot averages for softwood trees in the United States. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) *(continued to next page)*

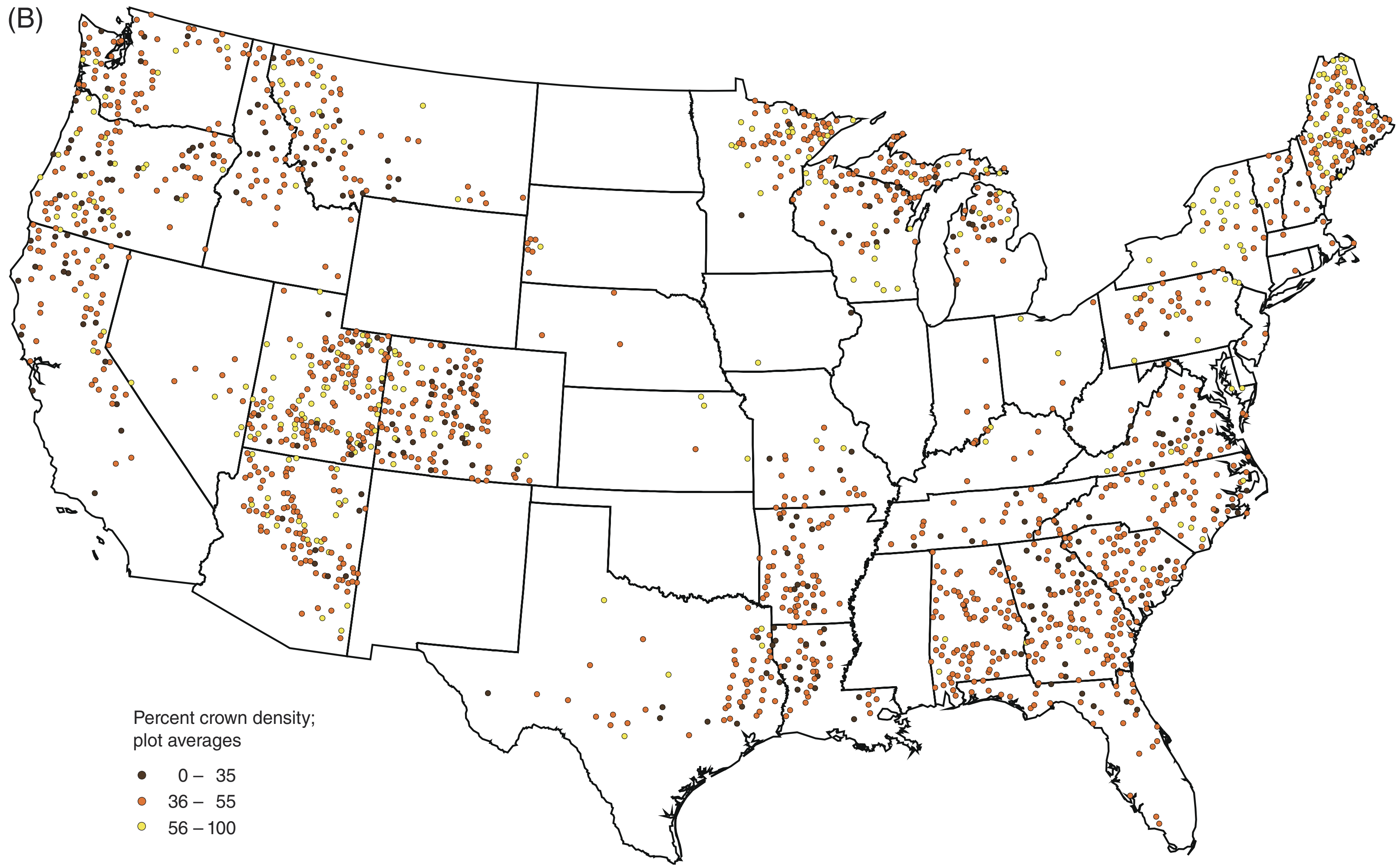


Figure 8.1 (continued)—Crown dieback (A) and crown density (B) plot averages for softwood trees in the United States. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program)

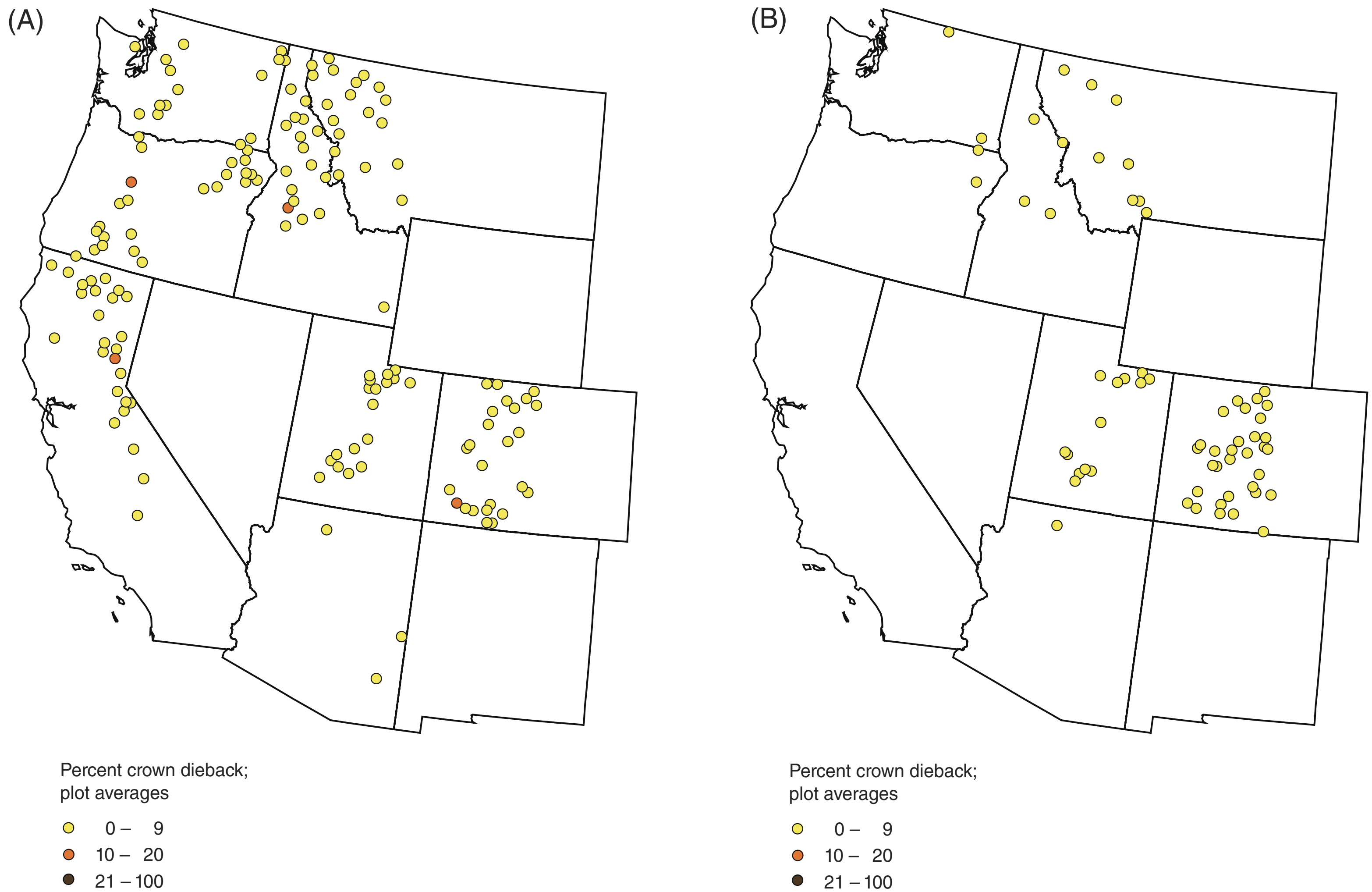


Figure 8.2—Crown dieback plot averages for major softwood species of the Western United States: (A) true fir, (B) Englemann spruce and other spruces, (C) lodgepole pine, (D) pinyon pine and juniper, (E) Douglas-fir, and (F) ponderosa and Jeffrey pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)

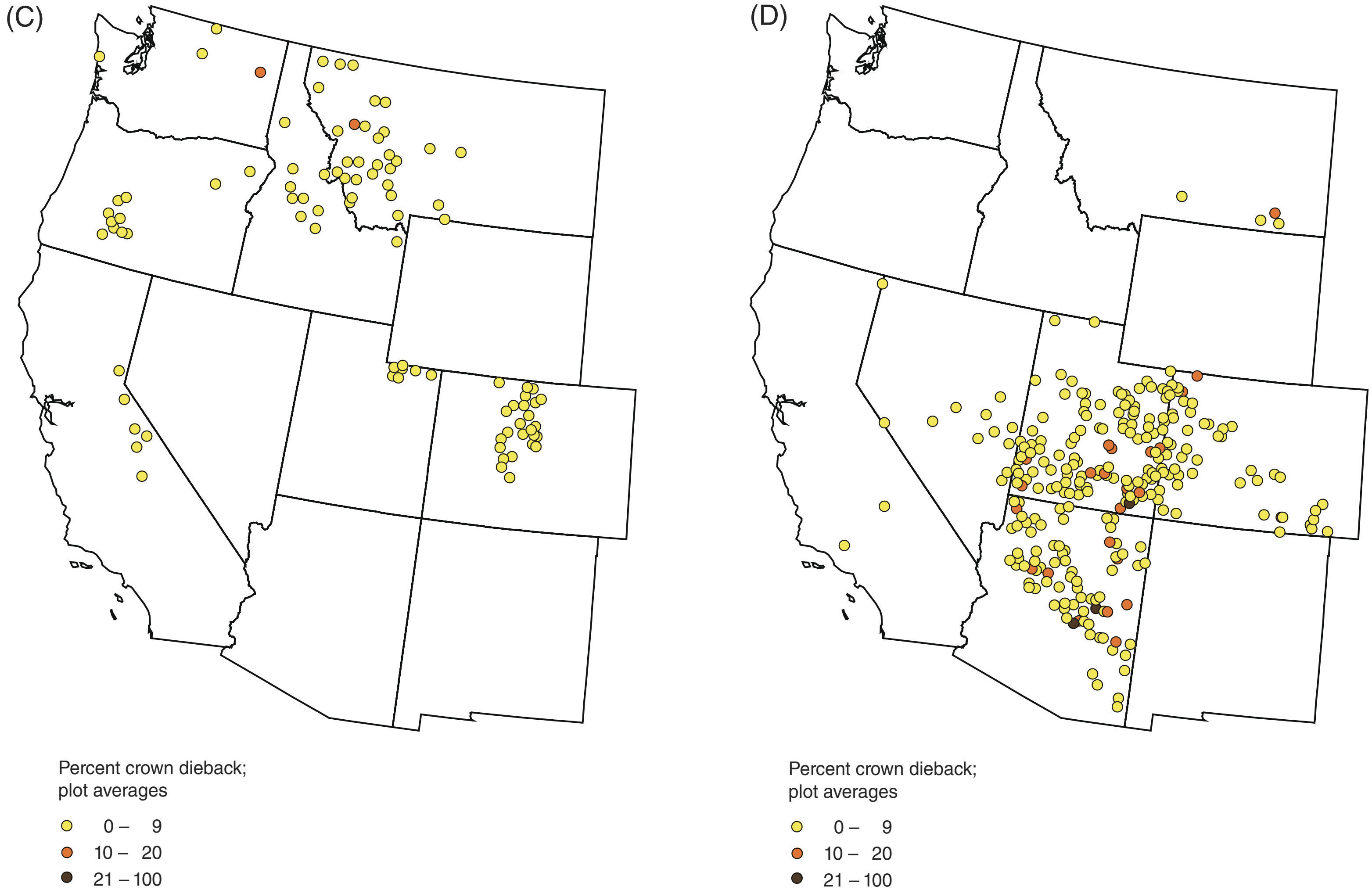
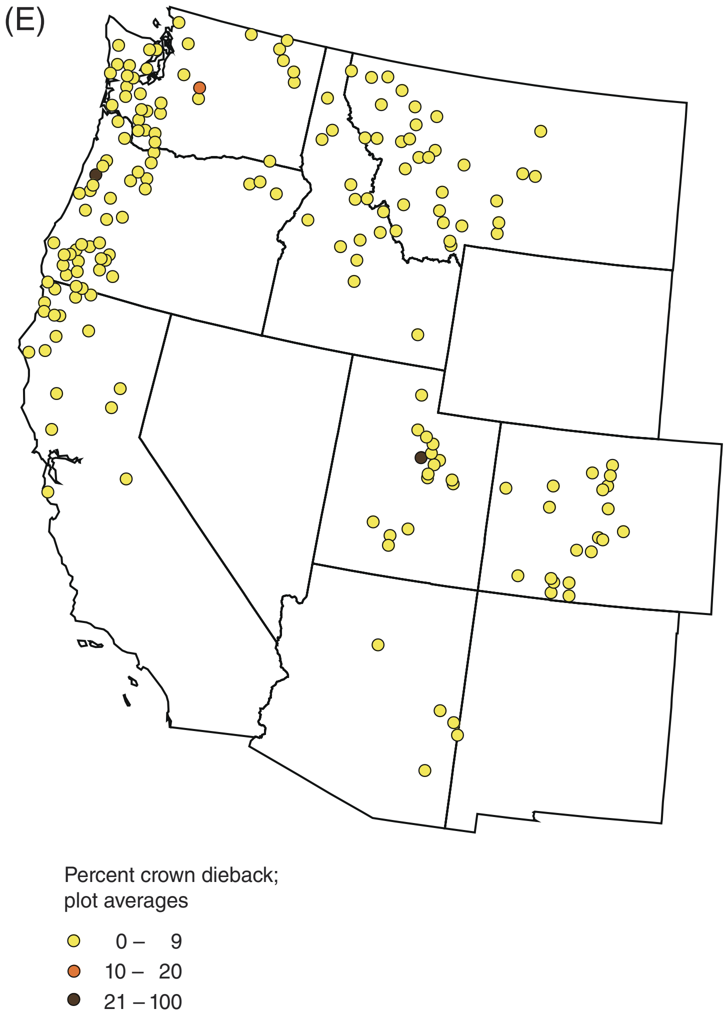


Figure 8.2 (continued)—Crown dieback plot averages for major softwood species of the Western United States: (A) true fir, (B) Englemann spruce and other spruces, (C) lodgepole pine, (D) pinyon pine and juniper, (E) Douglas-fir, and (F) ponderosa and Jeffrey pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)



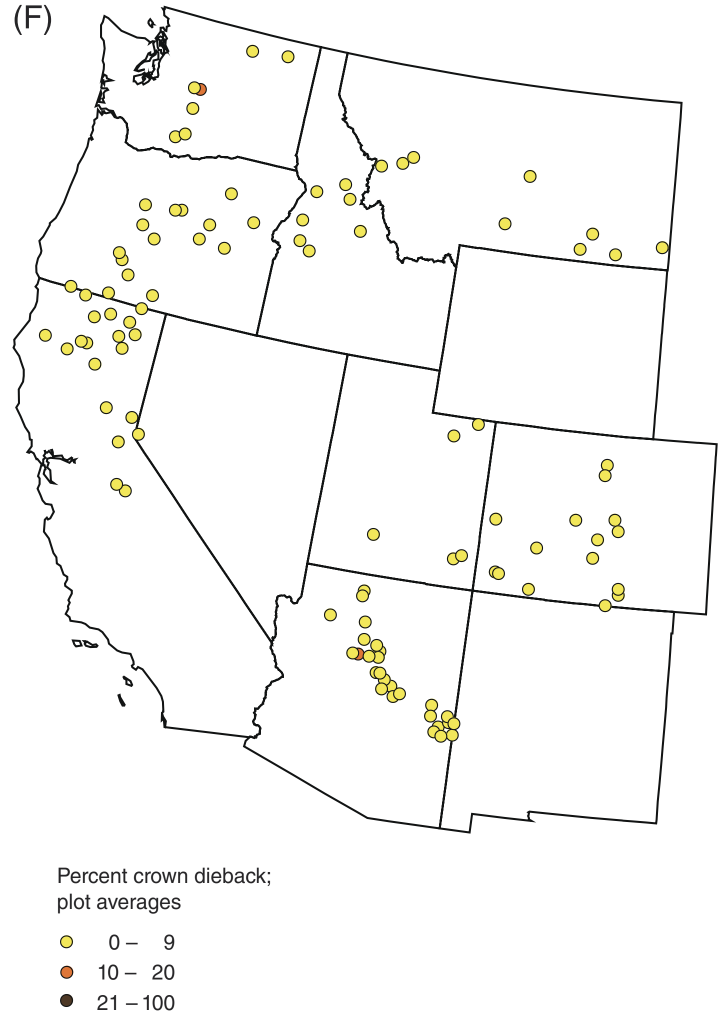
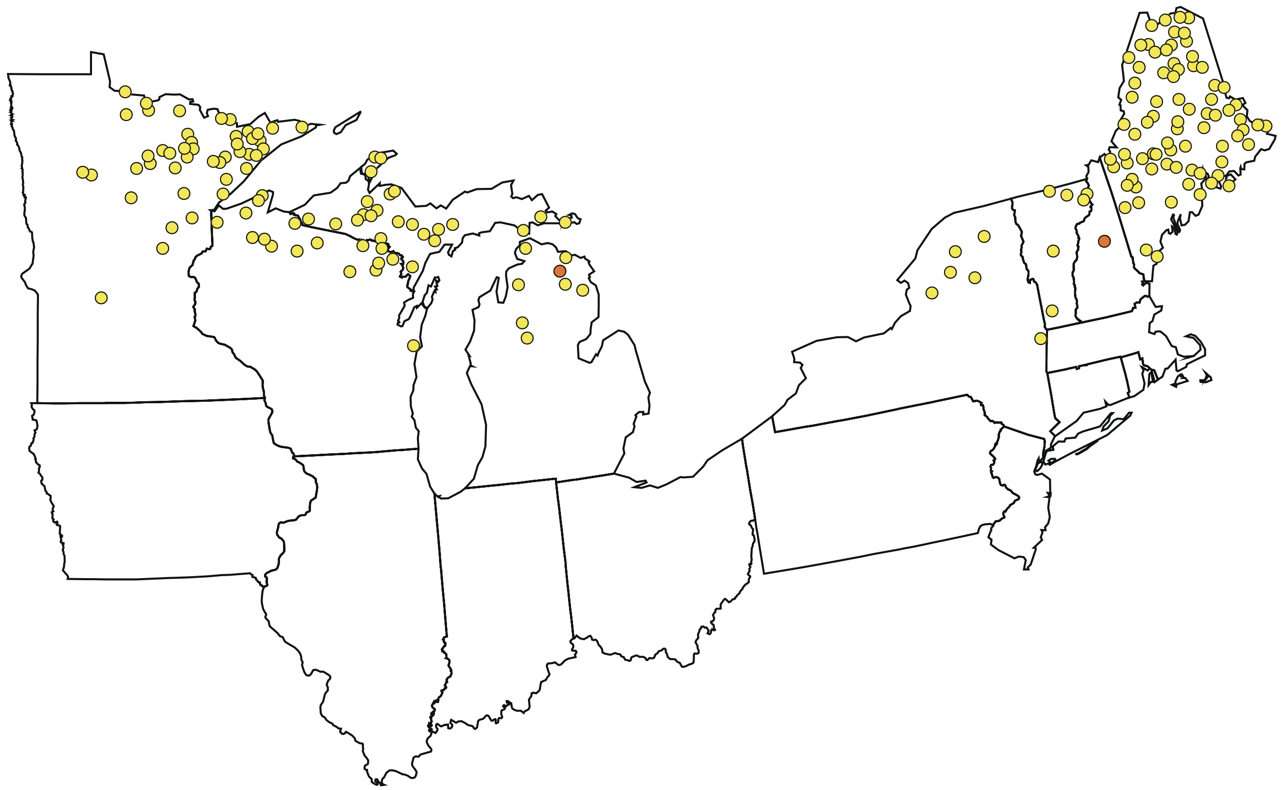


Figure 8.2 (continued)—Crown dieback plot averages for major softwood species of the Western United States: (A) true fir, (B) Englemann spruce and other spruces, (C) lodgepole pine, (D) pinyon pine and juniper, (E) Douglas-fir, and (F) ponderosa and Jeffrey pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program)

Species-specific plot averages in the East (fig. 8.3) indicated that levels of crown dieback were relatively high for northern white-cedar, particularly in parts of Maine and Michigan. Plot averages for northern white-cedar ranged from 0.0 to 32.9 percent dieback; 16.0 percent of the plots had dieback averages >10 percent (fig. 8.3C. In an evaluation of forest health conditions between 1993 and 2002, Steinman (2004) mapped the percent of basal area with unhealthy crowns by county for several individual species in the Northeastern United States. Trees were said to have unhealthy crowns if any of the following conditions were met: at least 25 percent crown dieback, at least 30 percent foliage transparency, and <35 percent crown density. Clusters of plots with elevated dieback in northern white-cedar (fig. 8.3C) generally correspond to counties Steinman identified as having high percentages of northern white-cedar basal area with unhealthy crowns. Reasons why a relatively high proportion of plots have elevated levels of dieback are unclear although Johnston (1990) notes that unfavorable winter weather, deicing salts, and drought are common agents that may cause foliage discoloration and lead to severe damage or death of the tree. Maine experienced one of the worst droughts in its history between 1999 and 2002 (Lombard 2004), and dry conditions also occurred between 1998 and 2002 in the Upper Peninsula and northern Lower Peninsula of Michigan (Steinman 2004). Drought is a potential explanation, but further investigation is warranted.

Softwood crown density plot averages varied across the country (fig. 8.1B). The areas with the densest crowns corresponded to the pinyon-juniper and spruce-fir species groups in the West and East, respectively, whereas the areas with less dense crowns were dominated primarily by pine species (figs. 8.4A through 8.4F and 8.5A through 8.5F). These averages show that some species tend to have denser crowns than others (Randolph 2006, Zarnoch and others 2004). Ongoing research is aimed at identifying the crown conditions that are normal for various species so that healthy and unhealthy crown conditions can be quantified more accurately.

(A)



Percent crown dieback;
plot averages

- 0 – 9
- 10 – 20
- 21 – 100

Figure 8.3—Crown dieback plot averages for major softwood species of the Eastern United States: (A) spruce and balsam fir, (B) eastern white pine and red pine, (C) northern white-cedar, (D) loblolly and shortleaf pine, (E) Virginia pine, and (F) longleaf and slash pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)

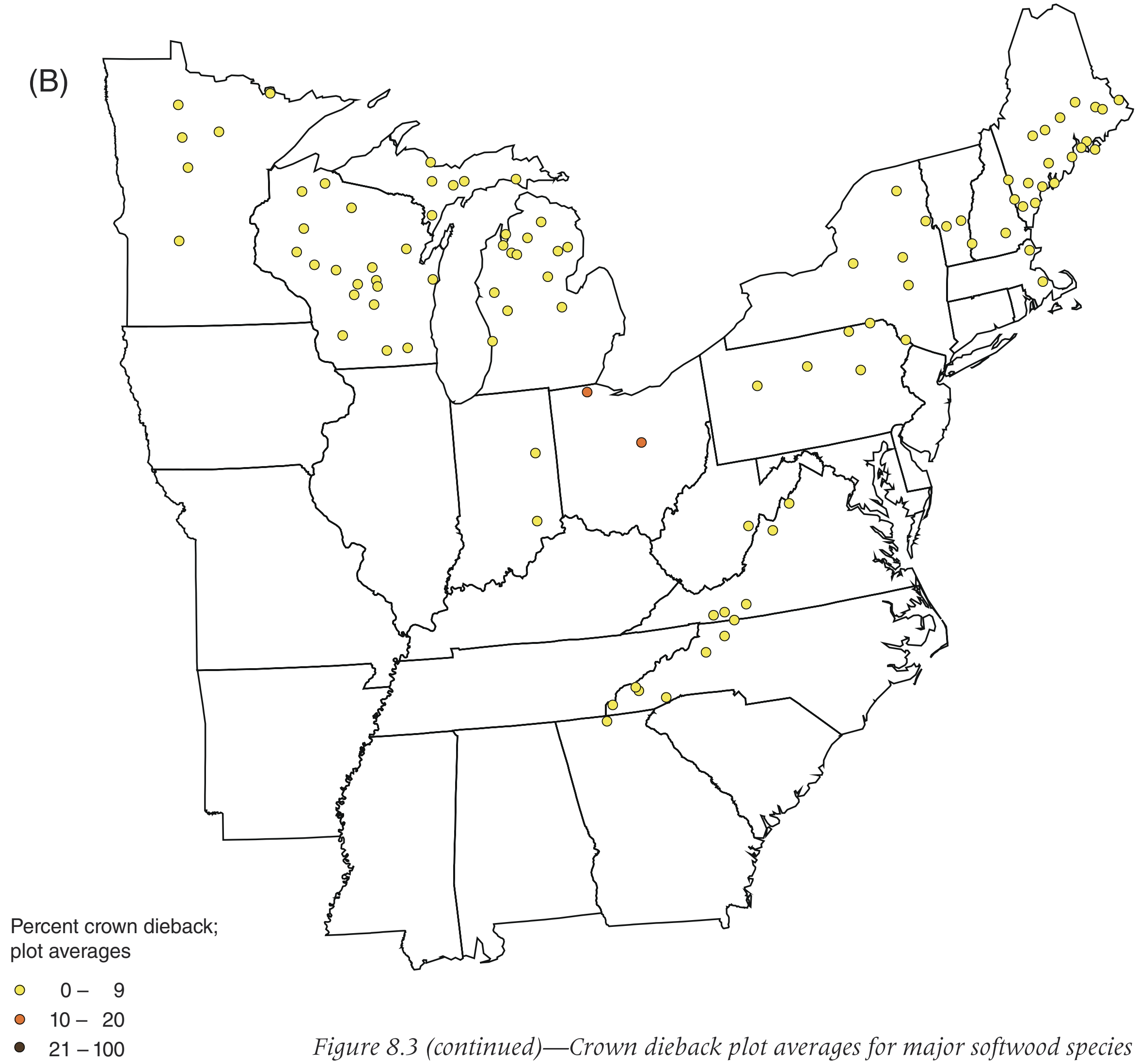


Figure 8.3 (continued)—Crown dieback plot averages for major softwood species of the Eastern United States: (A) spruce and balsam fir, (B) eastern white pine and red pine, (C) northern white-cedar, (D) loblolly and shortleaf pine, (E) Virginia pine, and (F) longleaf and slash pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) *(continued to next page)*

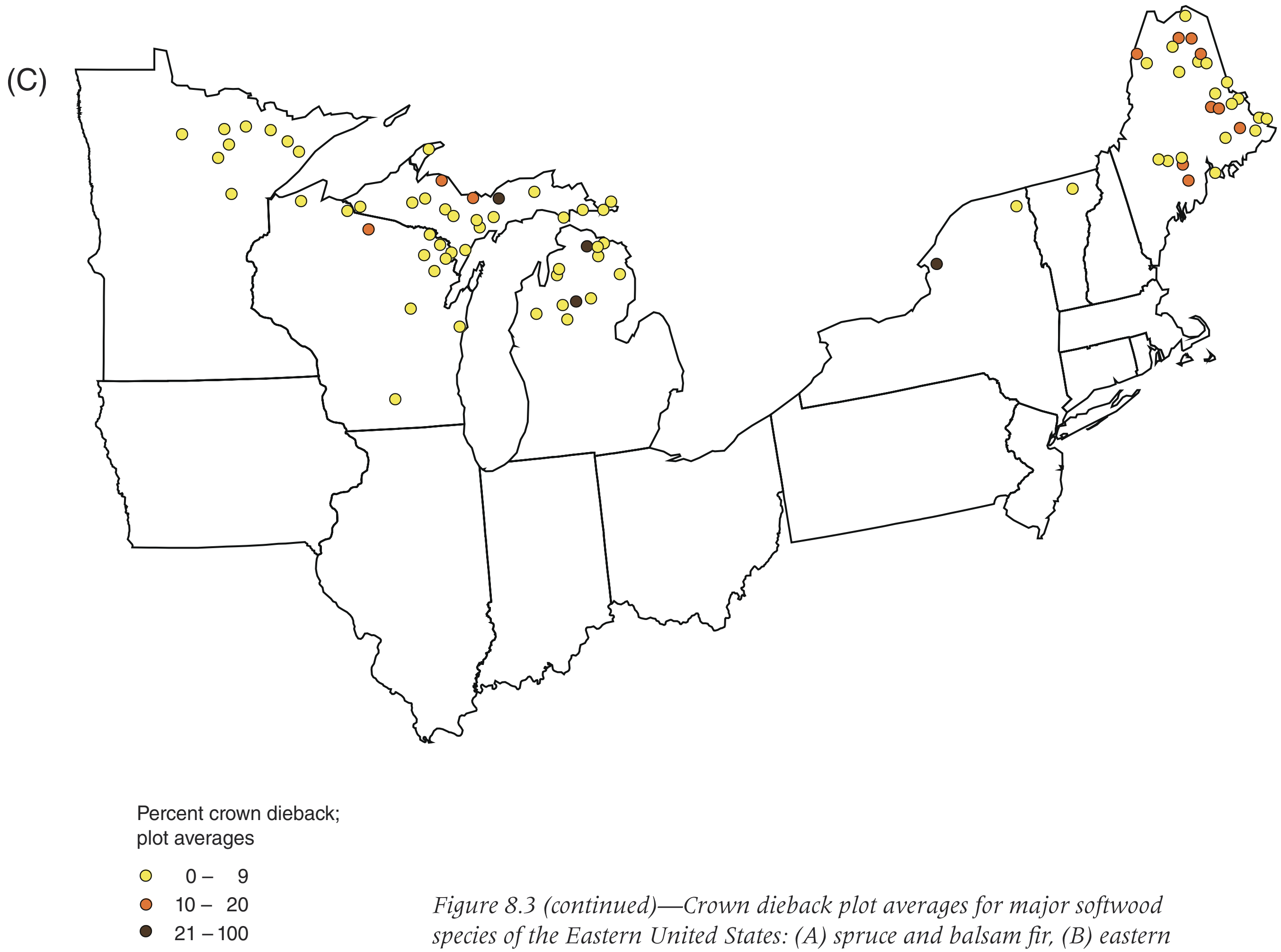


Figure 8.3 (continued)—Crown dieback plot averages for major softwood species of the Eastern United States: (A) spruce and balsam fir, (B) eastern white pine and red pine, (C) northern white-cedar, (D) loblolly and shortleaf pine, (E) Virginia pine, and (F) longleaf and slash pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) *(continued to next page)*

(D)

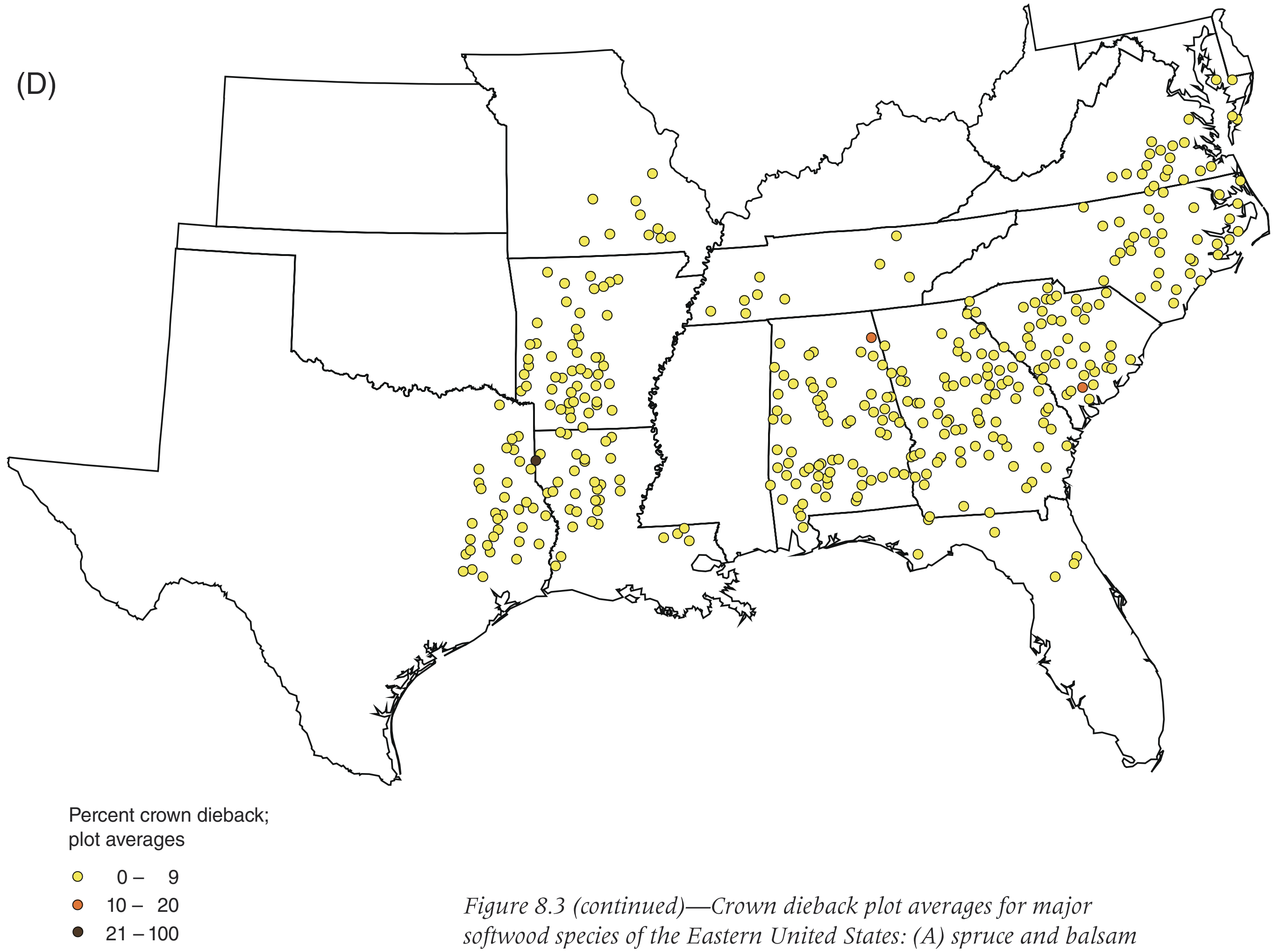


Figure 8.3 (continued)—Crown dieback plot averages for major softwood species of the Eastern United States: (A) spruce and balsam fir, (B) eastern white pine and red pine, (C) northern white-cedar, (D) loblolly and shortleaf pine, (E) Virginia pine, and (F) longleaf and slash pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)

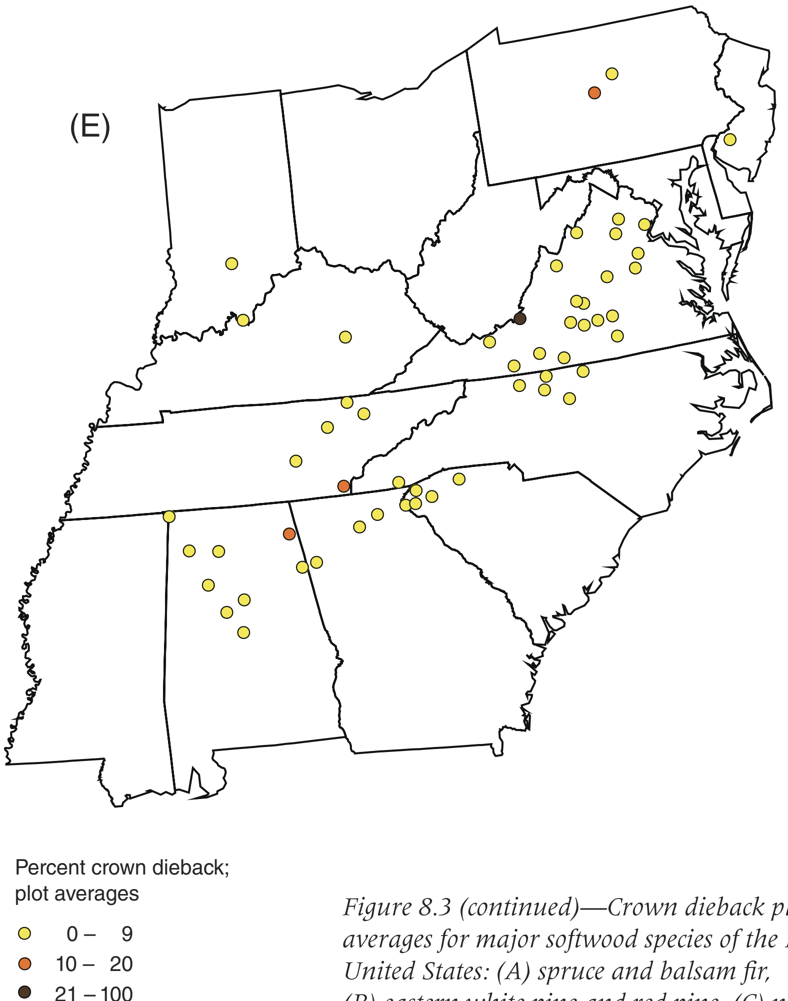


Figure 8.3 (continued)—Crown dieback plot averages for major softwood species of the Eastern United States: (A) spruce and balsam fir, (B) eastern white pine and red pine, (C) northern white-cedar, (D) loblolly and shortleaf pine, (E) Virginia pine, and (F) longleaf and slash pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) *(continued to next page)*

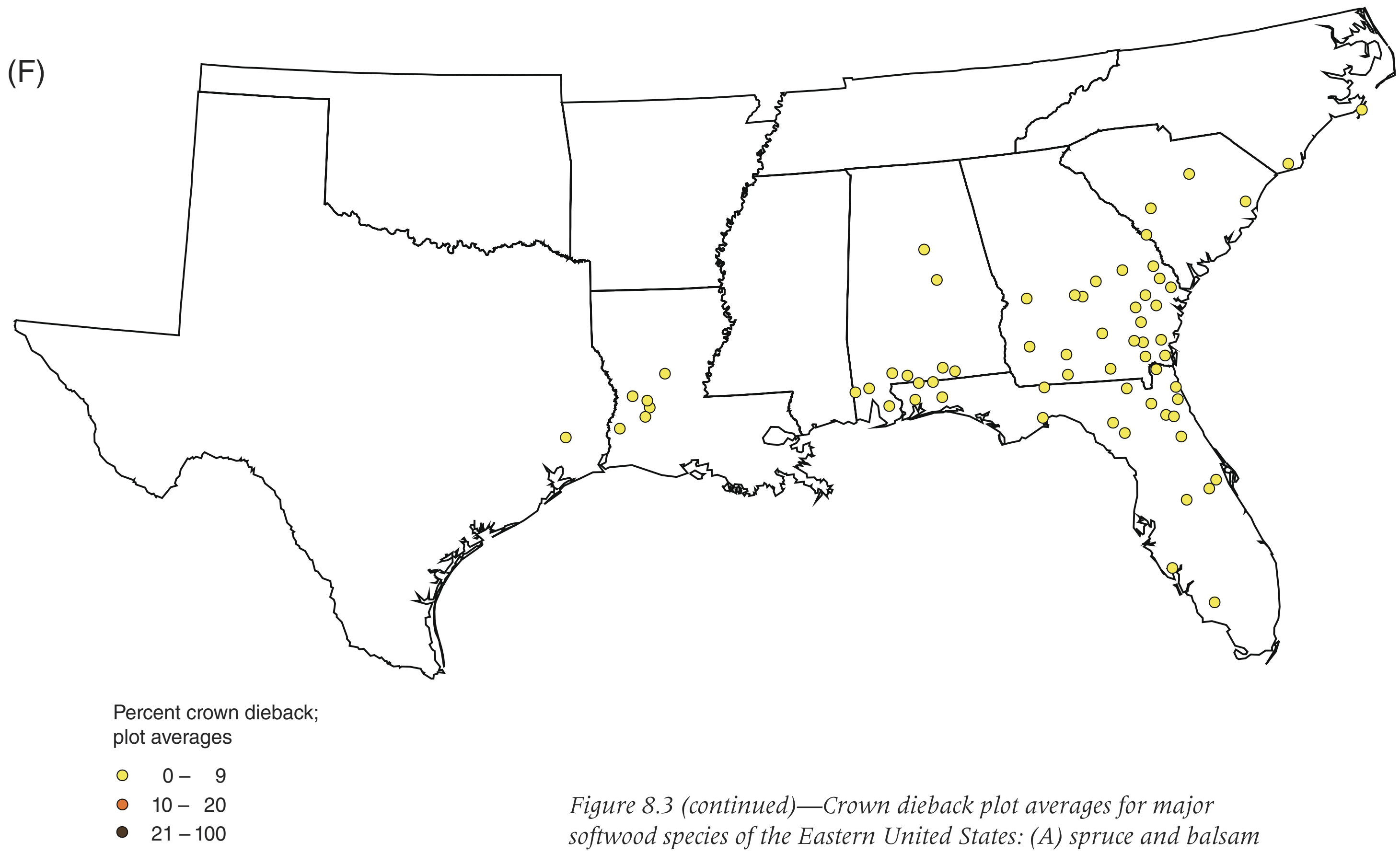


Figure 8.3 (continued)—Crown dieback plot averages for major softwood species of the Eastern United States: (A) spruce and balsam fir, (B) eastern white pine and red pine, (C) northern white-cedar, (D) loblolly and shortleaf pine, (E) Virginia pine, and (F) longleaf and slash pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program)

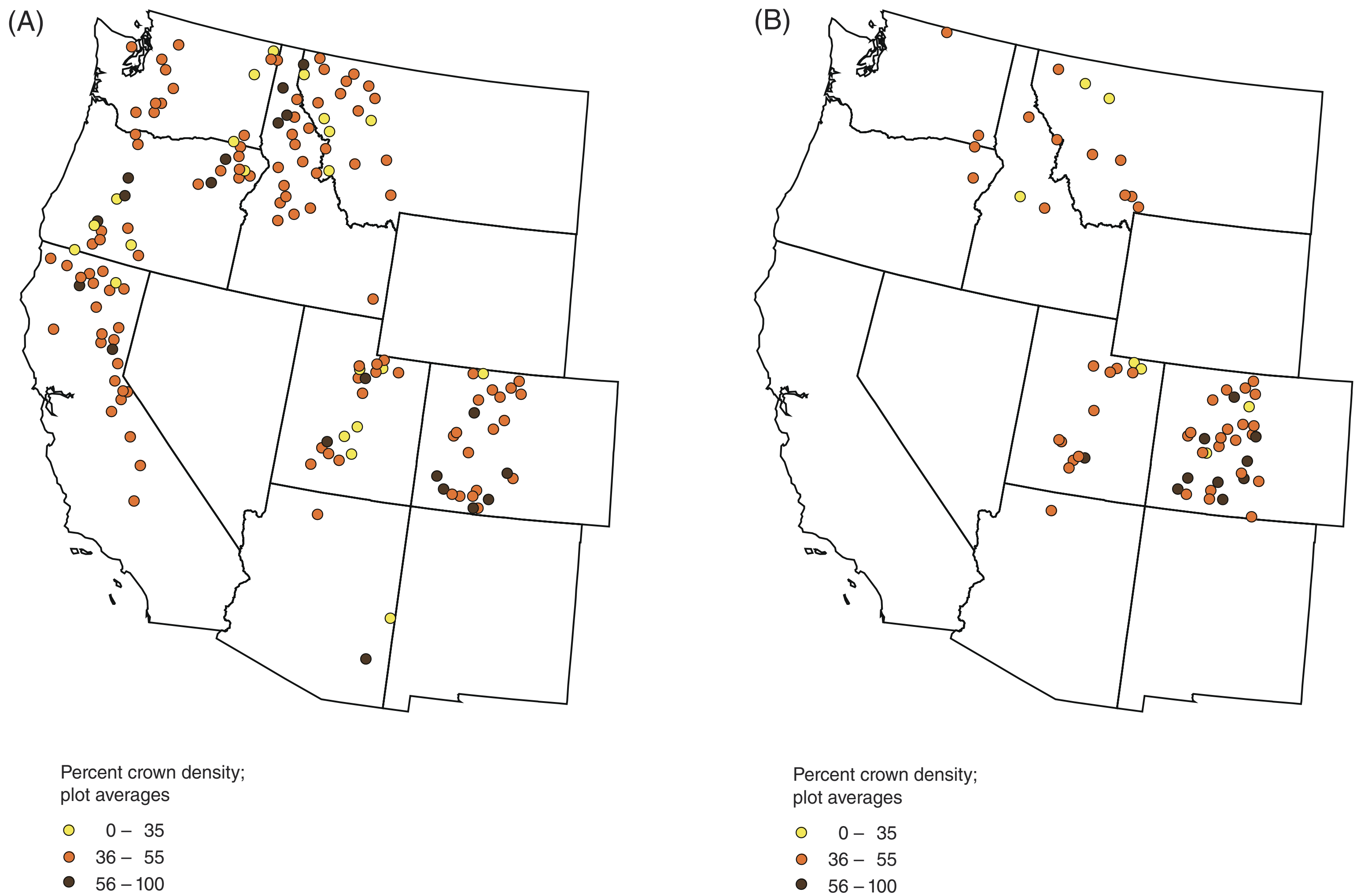
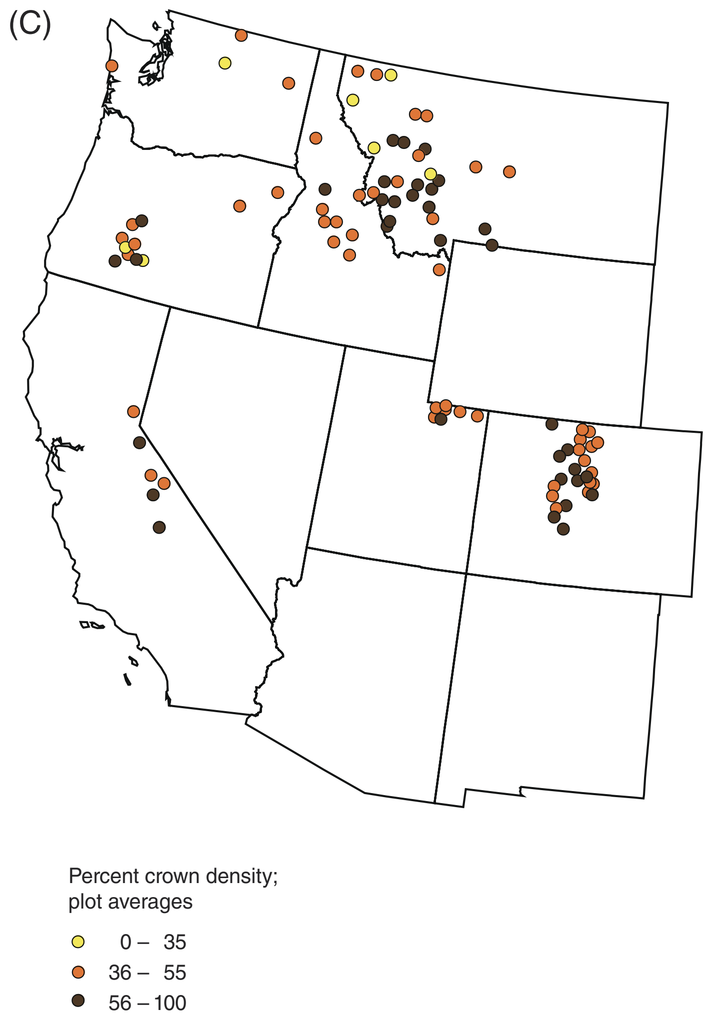


Figure 8.4—Crown density plot averages for major softwood species of the Western United States: (A) true fir, (B) Englemann spruce and other spruces, (C) lodgepole pine, (D) pinyon pine and juniper, (E) Douglas-fir, and (F) ponderosa and Jeffrey pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)



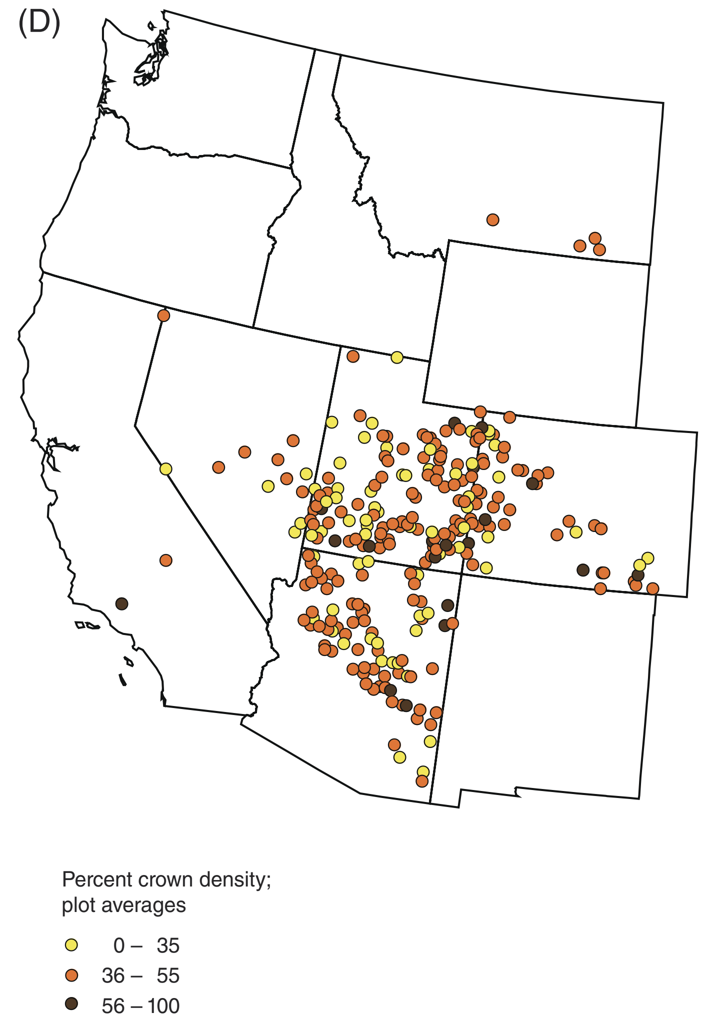
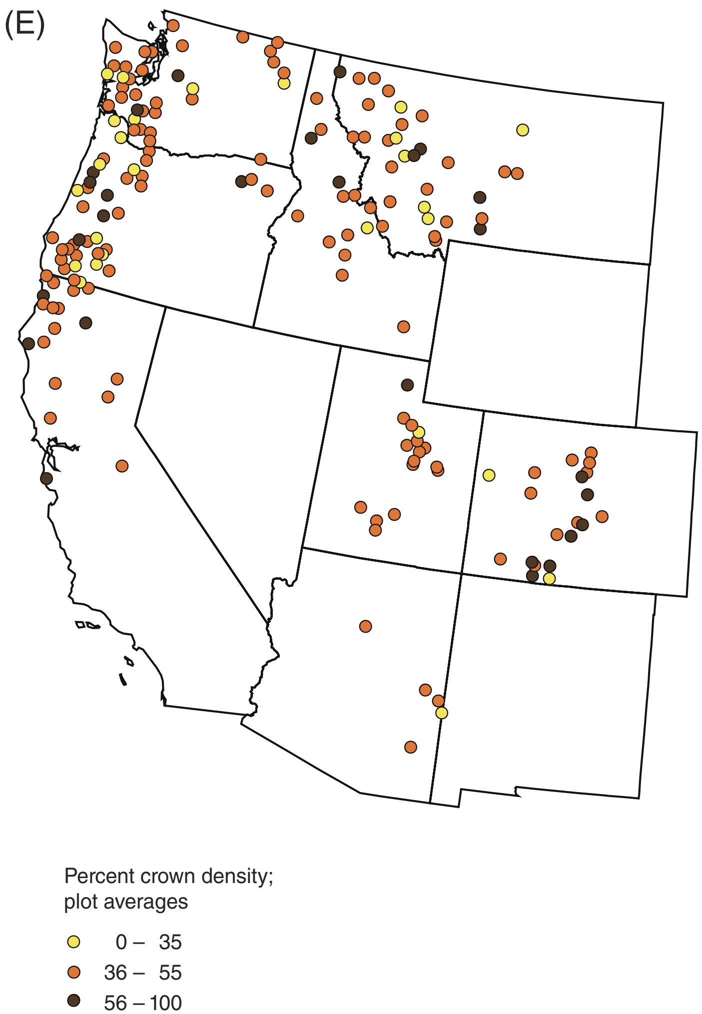


Figure 8.4 (continued)—Crown density plot averages for major softwood species of the Western United States: (A) true fir, (B) Englemann spruce and other spruces, (C) lodgepole pine, (D) pinyon pine and juniper, (E) Douglas-fir, and (F) ponderosa and Jeffrey pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)



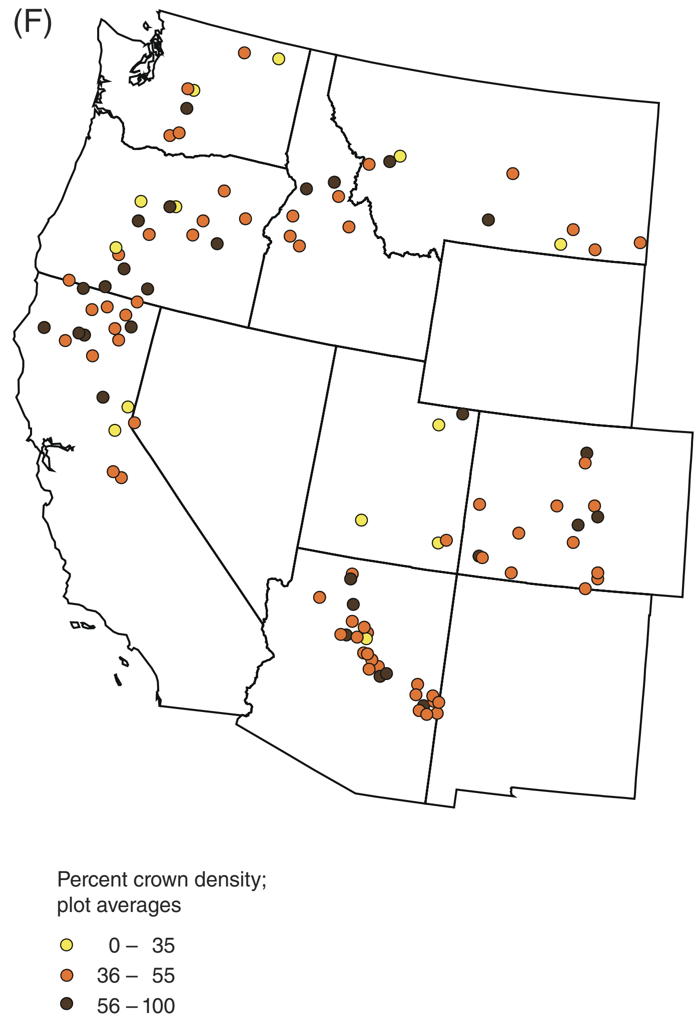
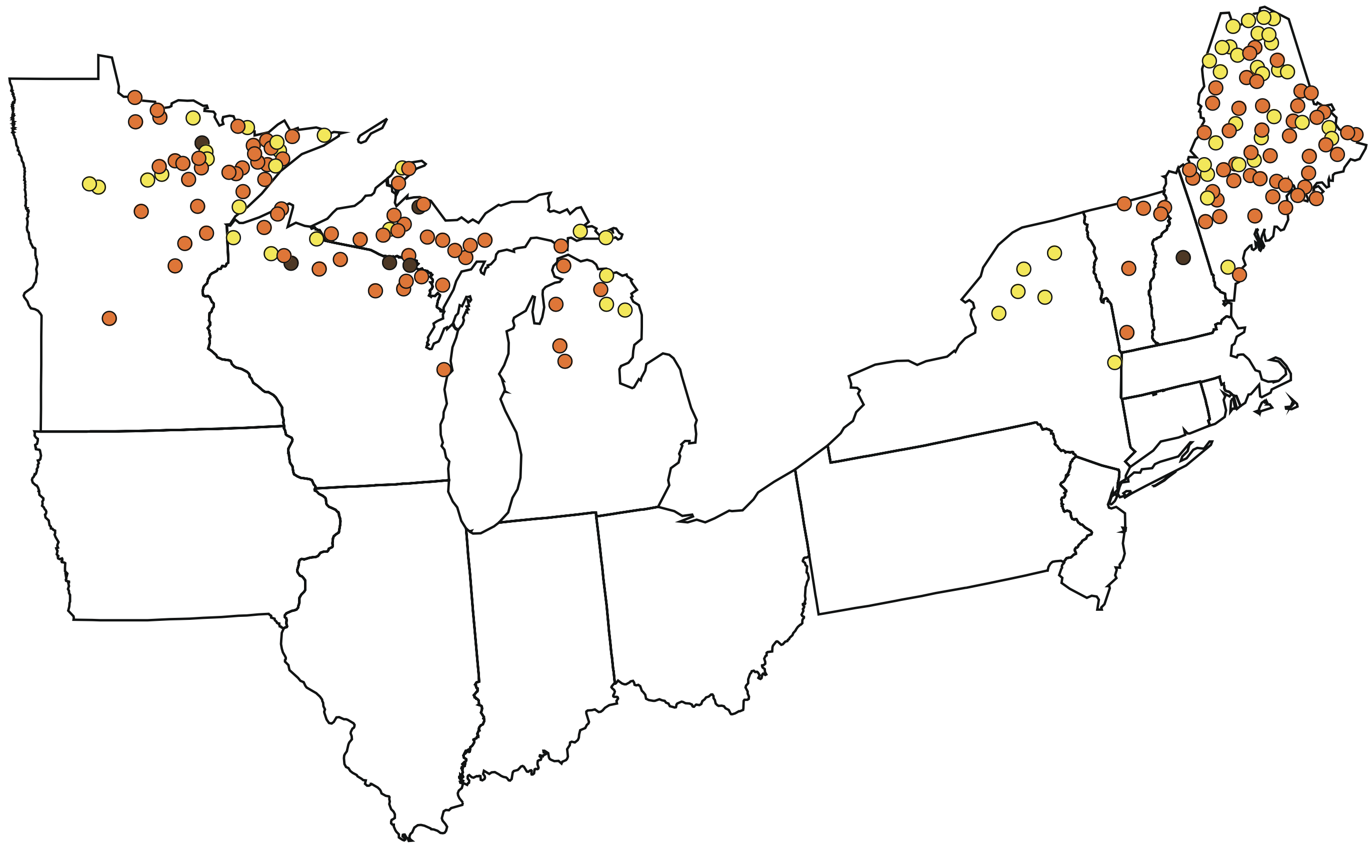


Figure 8.4 (continued)—Crown density plot averages for major softwood species of the Western United States: (A) true fir, (B) Englemann spruce and other spruces, (C) lodgepole pine, (D) pinyon pine and juniper, (E) Douglas-fir, and (F) ponderosa and Jeffrey pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program)

(A)



Percent crown density;
plot averages

- 0 – 35
- 36 – 55
- 56 – 100

Figure 8.5—Crown density plot averages for major softwood species of the Eastern United States: (A) spruce and balsam fir, (B) eastern white pine and red pine, (C) northern white-cedar, (D) loblolly and shortleaf pine, (E) Virginia pine, and (F) longleaf and slash pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)

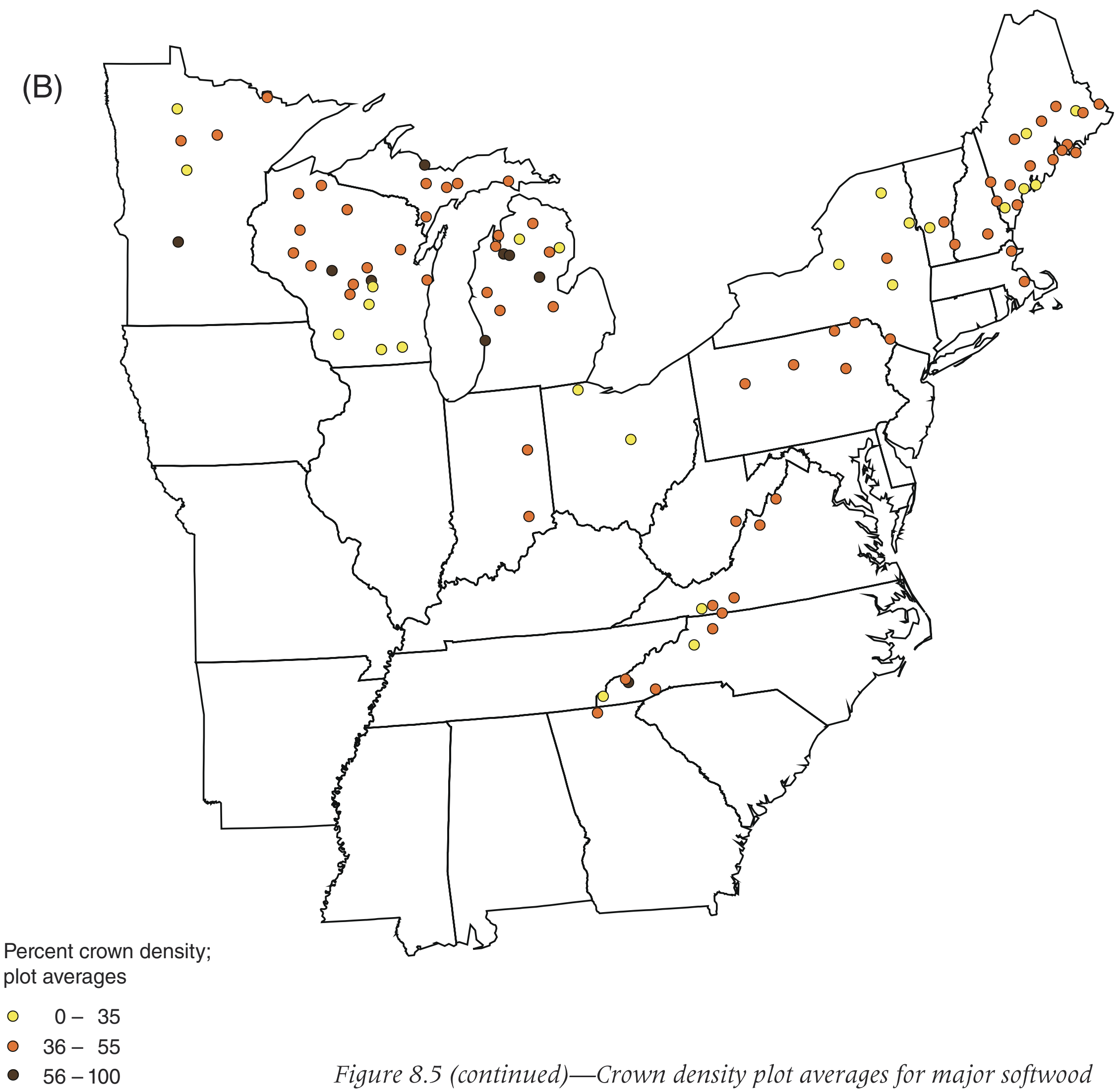


Figure 8.5 (continued)—Crown density plot averages for major softwood species of the Eastern United States: (A) spruce and balsam fir, (B) eastern white pine and red pine, (C) northern white-cedar, (D) loblolly and shortleaf pine, (E) Virginia pine, and (F) longleaf and slash pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) *(continued to next page)*

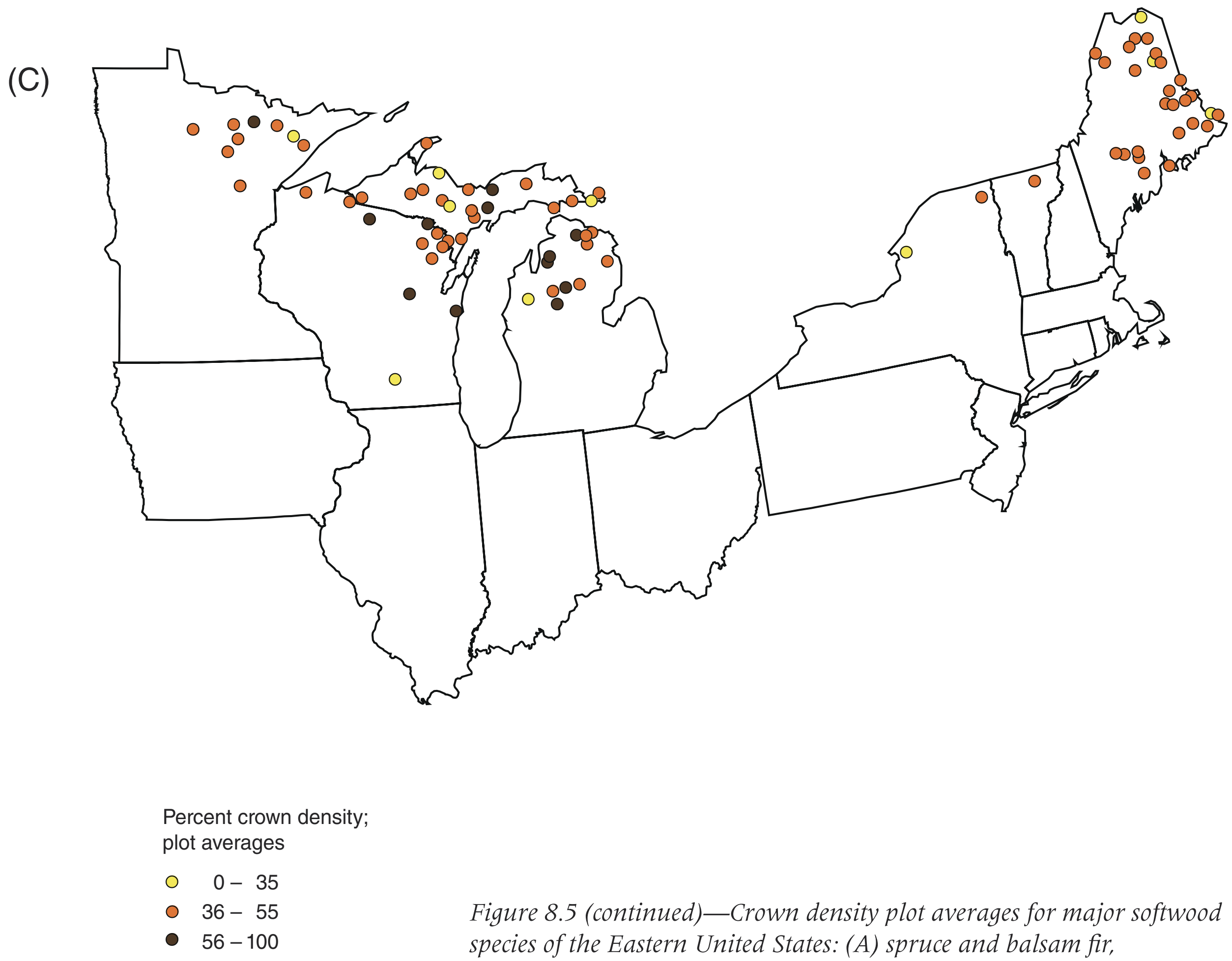


Figure 8.5 (continued)—Crown density plot averages for major softwood species of the Eastern United States: (A) spruce and balsam fir, (B) eastern white pine and red pine, (C) northern white-cedar, (D) loblolly and shortleaf pine, (E) Virginia pine, and (F) longleaf and slash pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)

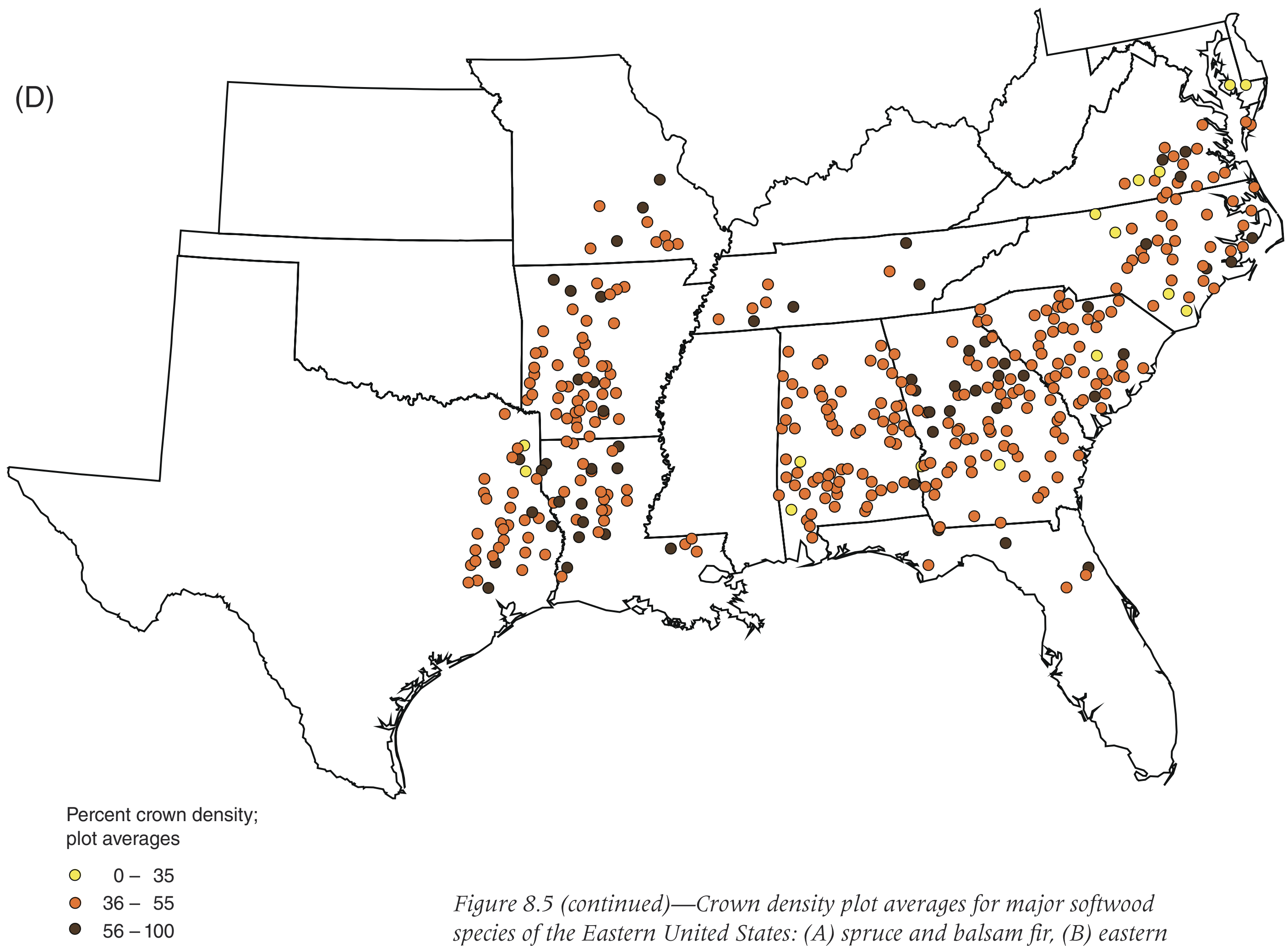
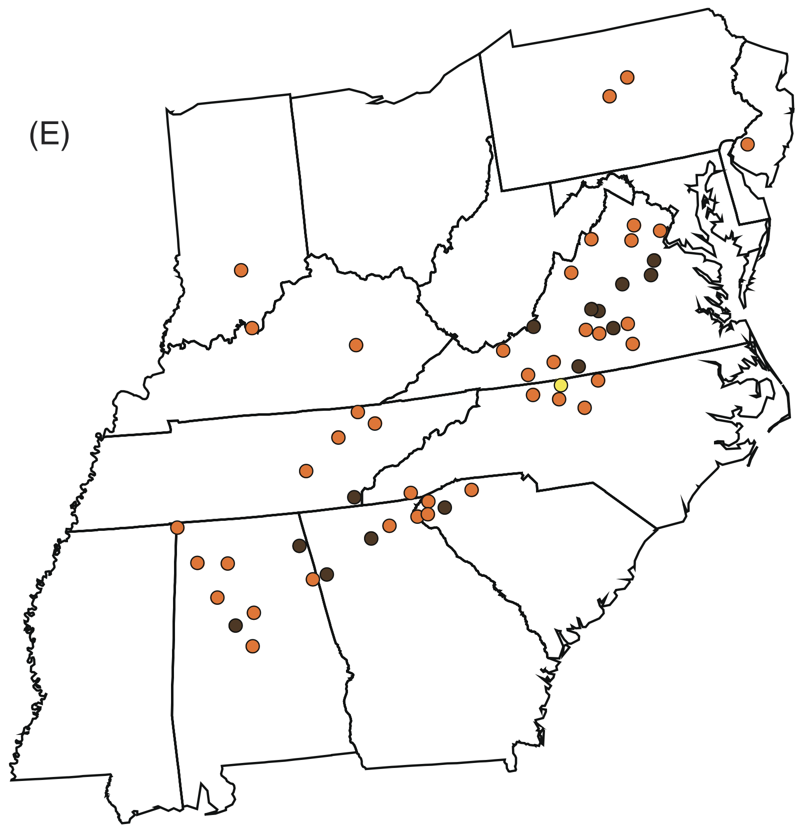


Figure 8.5 (continued)—Crown density plot averages for major softwood species of the Eastern United States: (A) spruce and balsam fir, (B) eastern white pine and red pine, (C) northern white-cedar, (D) loblolly and shortleaf pine, (E) Virginia pine, and (F) longleaf and slash pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)

(E)



Percent crown density;
plot averages

- 0 – 35
- 36 – 55
- 56 – 100

Figure 8.5 (continued)—Crown density plot averages for major softwood species of the Eastern United States: (A) spruce and balsam fir, (B) eastern white pine and red pine, (C) northern white-cedar, (D) loblolly and shortleaf pine, (E) Virginia pine, and (F) longleaf and slash pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)

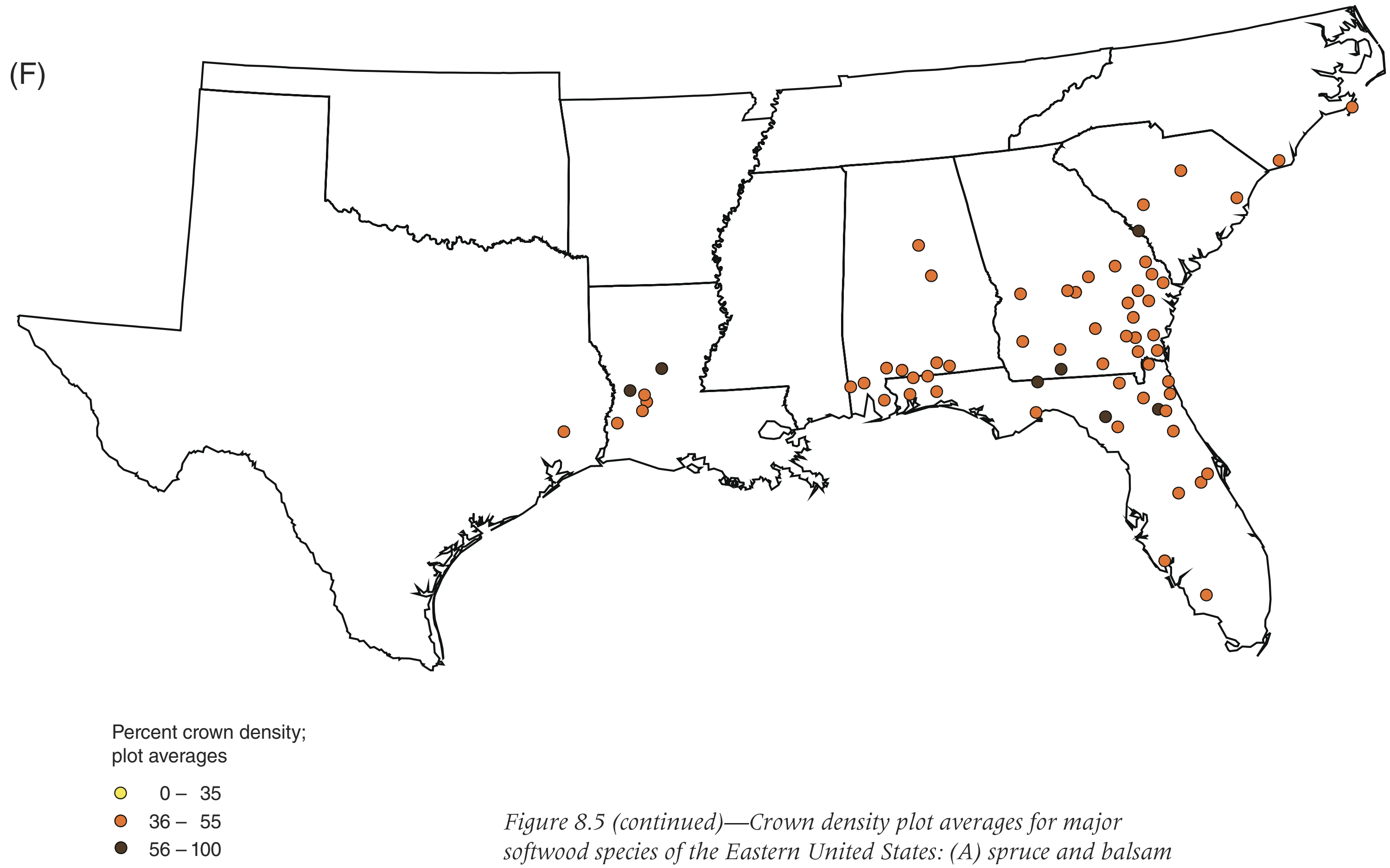


Figure 8.5 (continued)—Crown density plot averages for major softwood species of the Eastern United States: (A) spruce and balsam fir, (B) eastern white pine and red pine, (C) northern white-cedar, (D) loblolly and shortleaf pine, (E) Virginia pine, and (F) longleaf and slash pine. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program)

Hardwoods—Figures 8.6A and 8.6B show plot-level crown dieback and foliage transparency averages across the conterminous United States for the hardwood species group. Plot-level averages for crown dieback were typically <10 percent with only a few scattered plots averaging more than 20 percent dieback. Foliage transparency averages were mostly below 40 percent. Crown dieback averages were relatively high in Arizona and Texas, and foliage transparency averages were relatively high in Texas and northern Minnesota. The high levels of dieback in Arizona and the high levels of dieback and transparency in Texas occurred primarily in a mixture of western woodland species including Arizona white oak, Gambel oak, and silverleaf oak in Arizona and honey mesquite in Texas.

Species-specific plot averages in the East (fig. 8.7) indicated that the trees in the northern Minnesota plots with relatively high foliage transparency averages were primarily cottonwood and aspen species. Plot averages for the cottonwood and aspen trees ranged between 12.9 and 99.0 percent (fig. 8.7D). In Minnesota, 12.7 percent of the cottonwood-aspen plots had averages >40 percent, but only 5.2 percent of the cottonwood-aspen plots outside of Minnesota had foliage transparency averages >40 percent. During the data collection period, the forest tent caterpillar caused heavy defoliation in northern Minnesota forests. This was accompanied by drought and spring frosts at the time of aspen leaf break. These events contributed to aspen mortality and dieback on 50,000 acres across northern Minnesota in 2004 (Minnesota Department of Natural Resources, Division of Forestry; U.S. Department of Agriculture Forest Service 2006), and may help explain the high foliage transparency averages. In addition to these weather and insect events, tree senescence may also be contributing to the high foliage transparency averages. The 2005 annual report of forest health conditions in Minnesota noted that many of the thinly foliated aspen trees were the largest and oldest trees on the sites (Minnesota Department of Natural Resources, Division of Forestry; U.S. Department of Agriculture Forest Service 2006). The ages at which aspens begin to decline are 55 to 60 years for quaking aspen and 50 to 70 years for bigtooth aspen (Laidly 1990, Perala 1990). The highest foliage transparency averages were observed on plots in stands aged 55 to 70 years, though not all plots in this age range had elevated levels of foliage transparency (fig. 8.8).

(A)

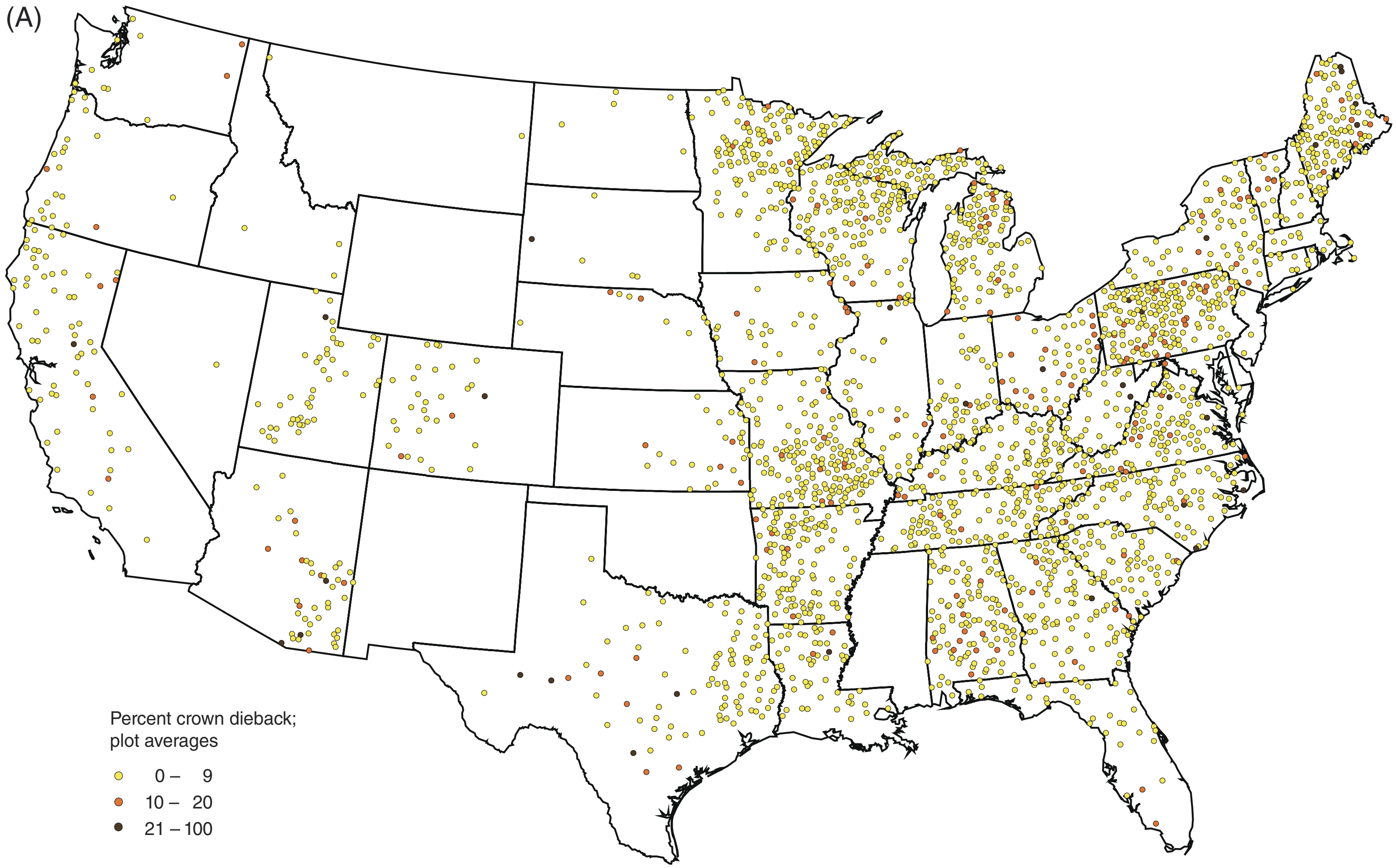


Figure 8.6—Crown dieback (A) and foliage transparency plot (B) averages for hardwood trees in the United States. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) *(continued to next page)*

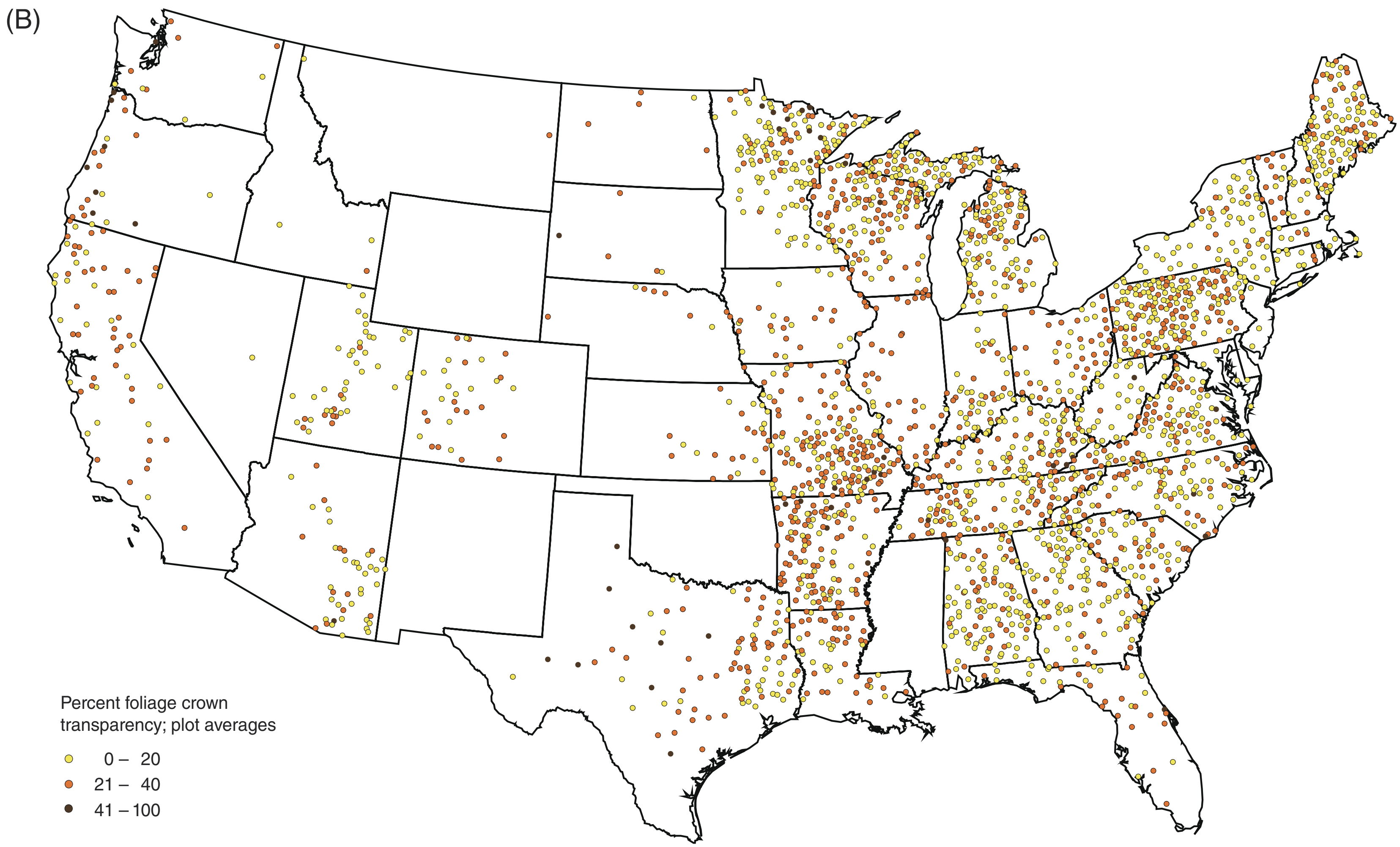


Figure 8.6 (continued)—Crown dieback (A) and foliage transparency plot (B) averages for hardwood trees in the United States. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program)

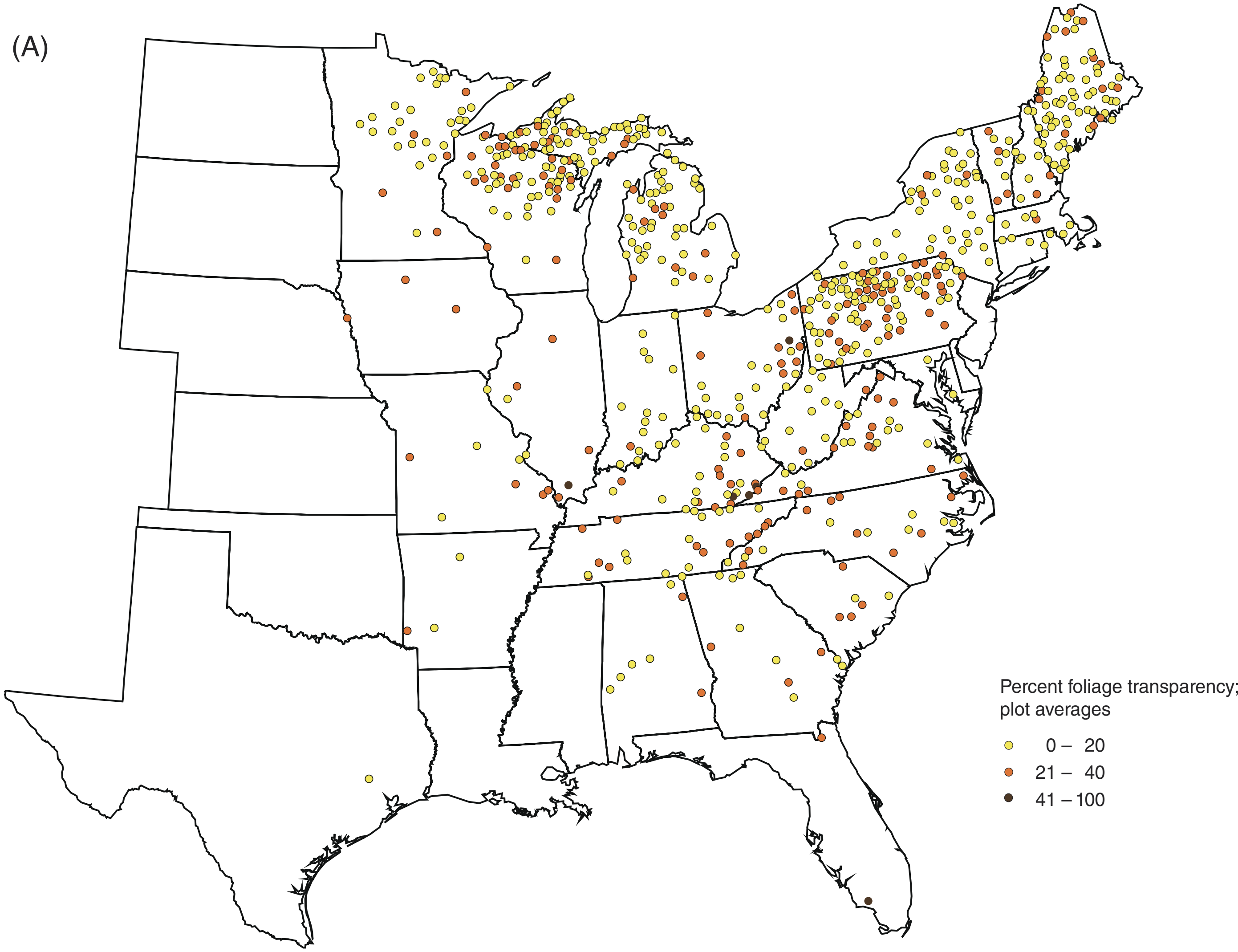


Figure 8.7—Foliage transparency plot averages for major hardwood species of the Eastern United States: (A) maples, (B) hickories, (C) American beech, (D) cottonwood and aspen, (E) red oaks, and (F) white oaks. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)

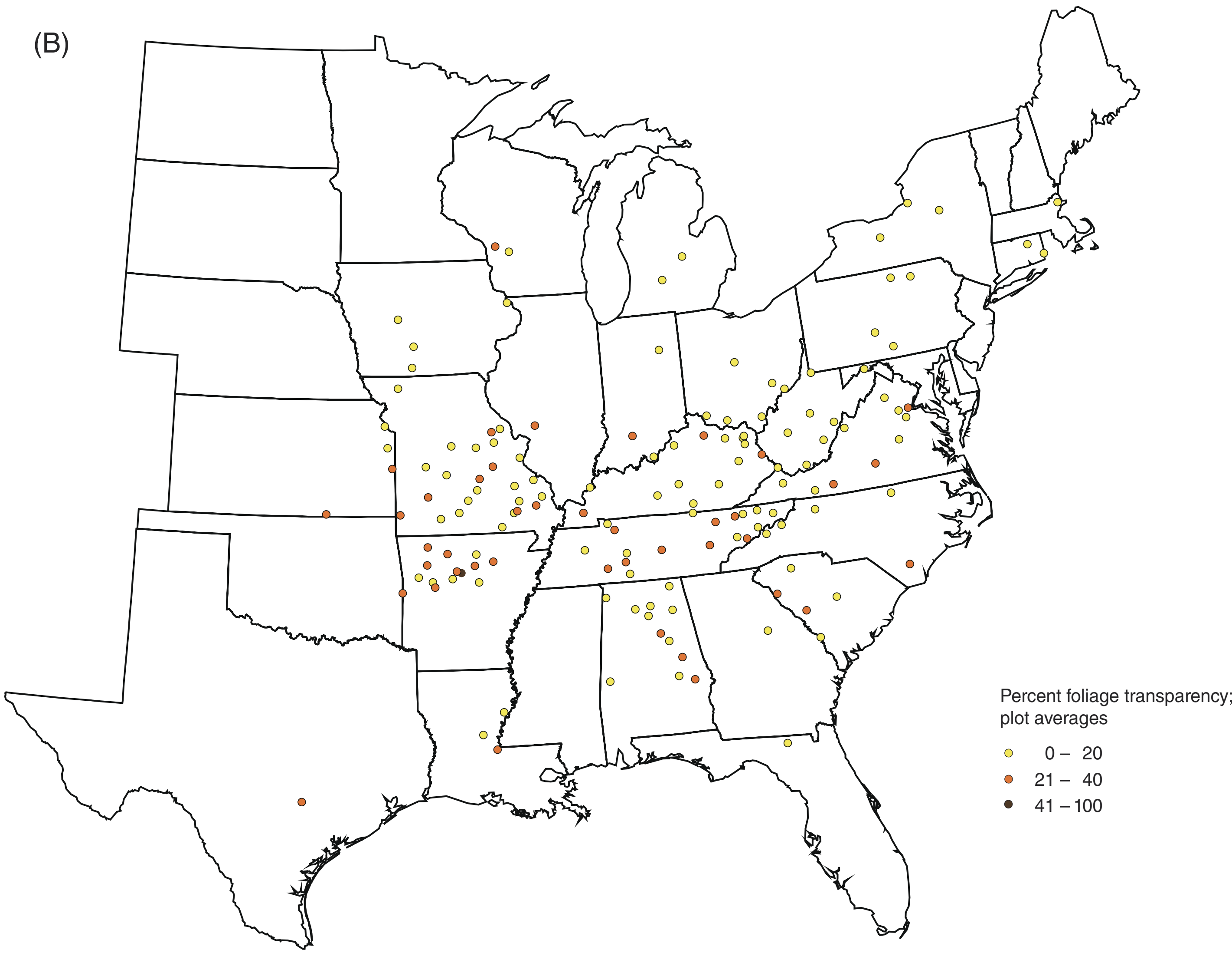


Figure 8.7 (continued)—Foliage transparency plot averages for major hardwood species of the Eastern United States: (A) maples, (B) hickories, (C) American beech, (D) cottonwood and aspen, (E) red oaks, and (F) white oaks. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)

(C)

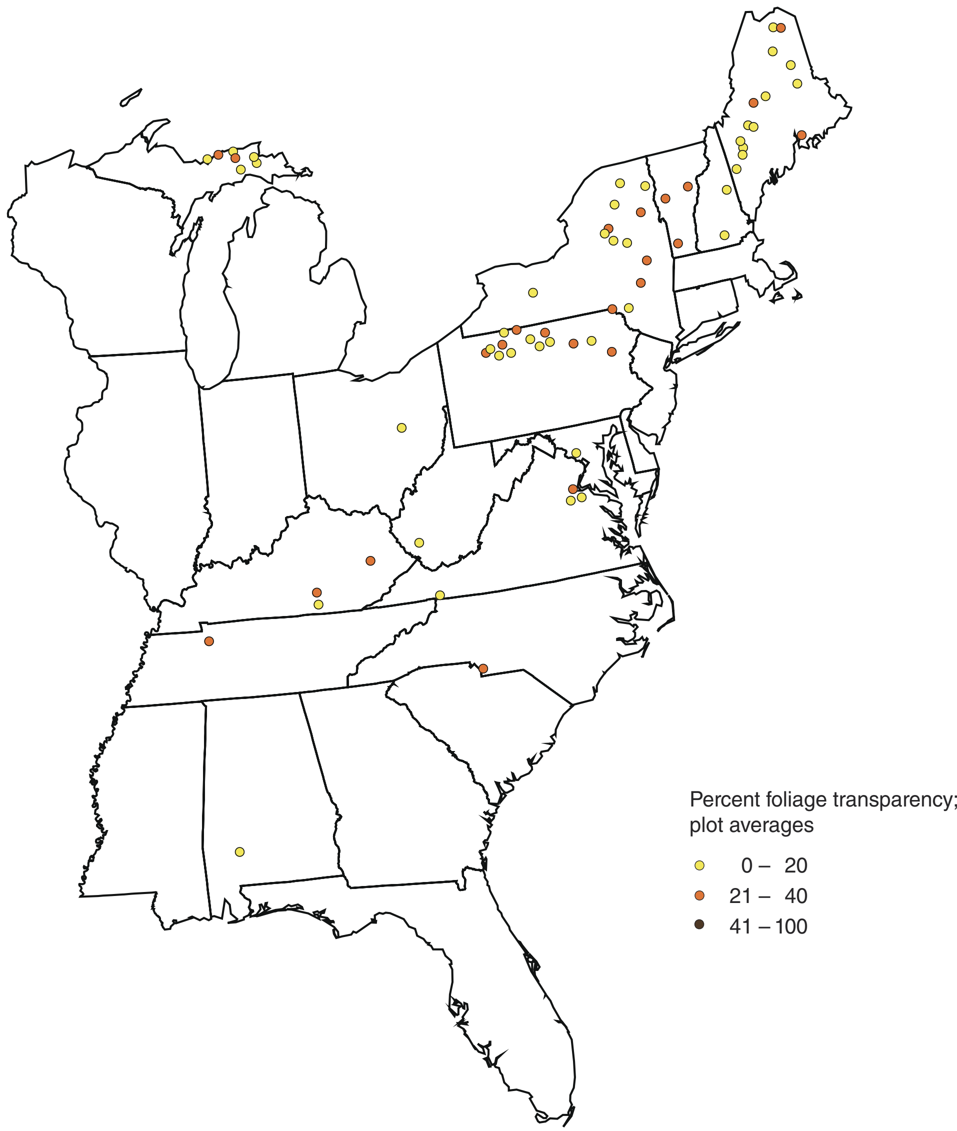
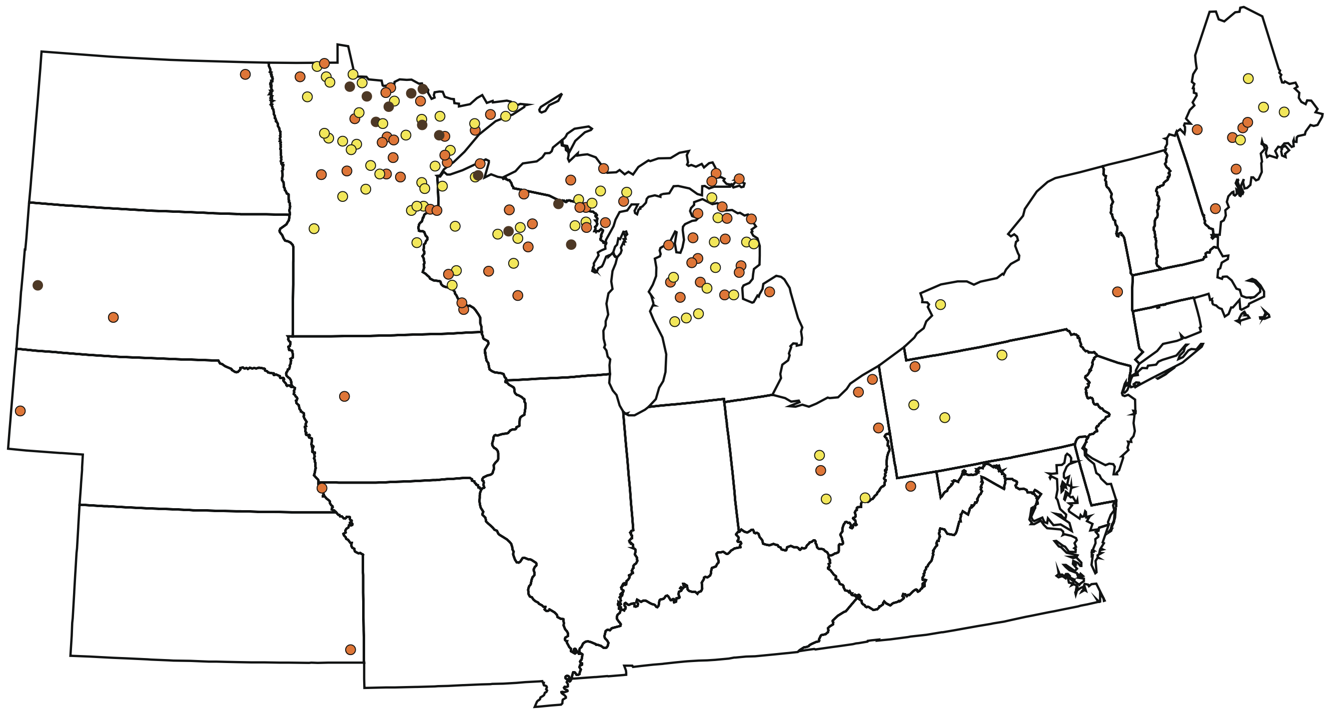


Figure 8.7 (continued)—Foliage transparency plot averages for major hardwood species of the Eastern United States: (A) maples, (B) hickories, (C) American beech, (D) cottonwood and aspen, (E) red oaks, and (F) white oaks. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)

(D)



Percent foliage transparency; plot averages

- 0 – 20
- 21 – 40
- 41 – 100

Figure 8.7 (continued)—Foliage transparency plot averages for major hardwood species of the Eastern United States: (A) maples, (B) hickories, (C) American beech, (D) cottonwood and aspen, (E) red oaks, and (F) white oaks. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)

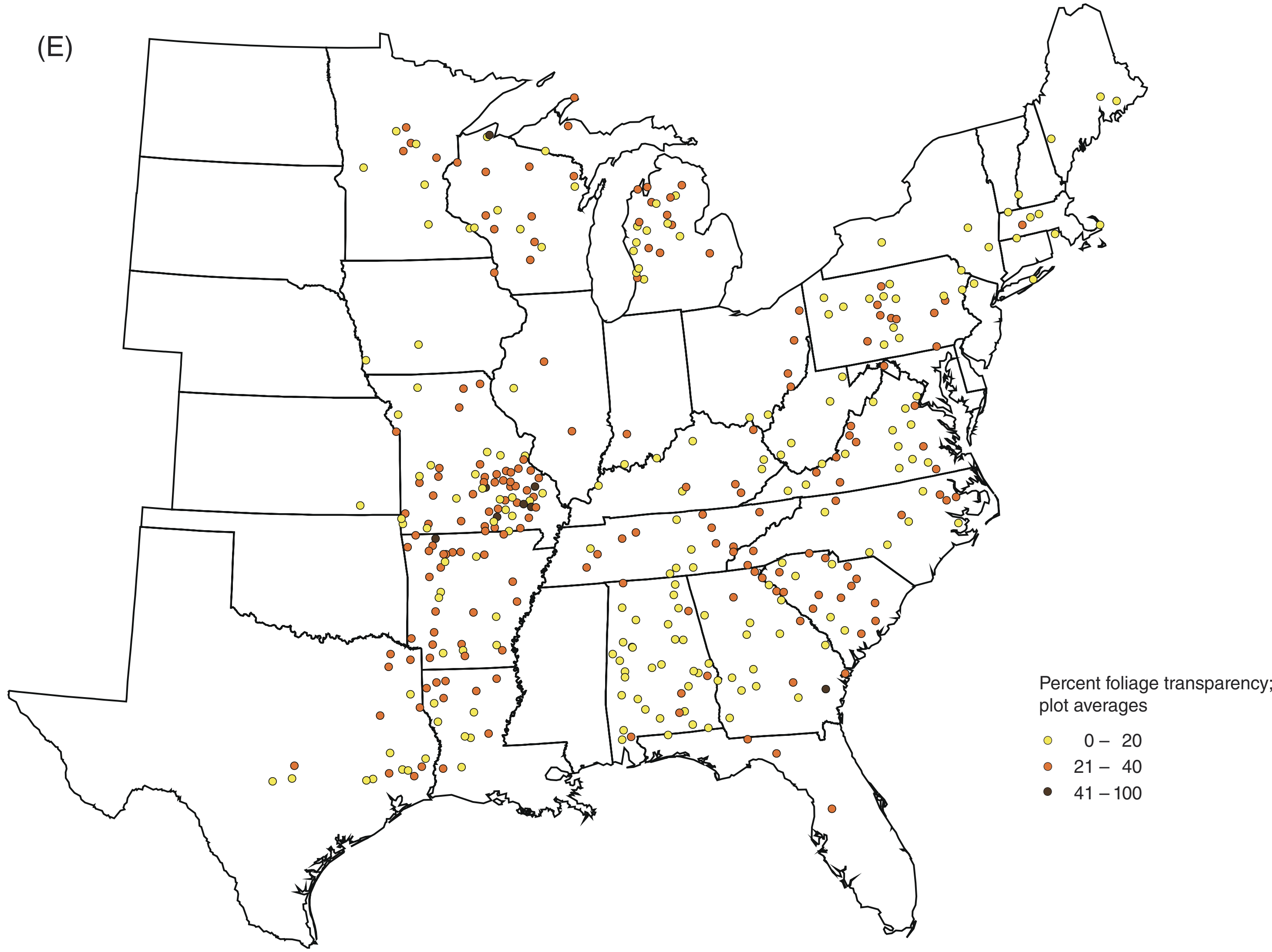


Figure 8.7 (continued)—Foliage transparency plot averages for major hardwood species of the Eastern United States: (A) maples, (B) hickories, (C) American beech, (D) cottonwood and aspen, (E) red oaks, and (F) white oaks. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)

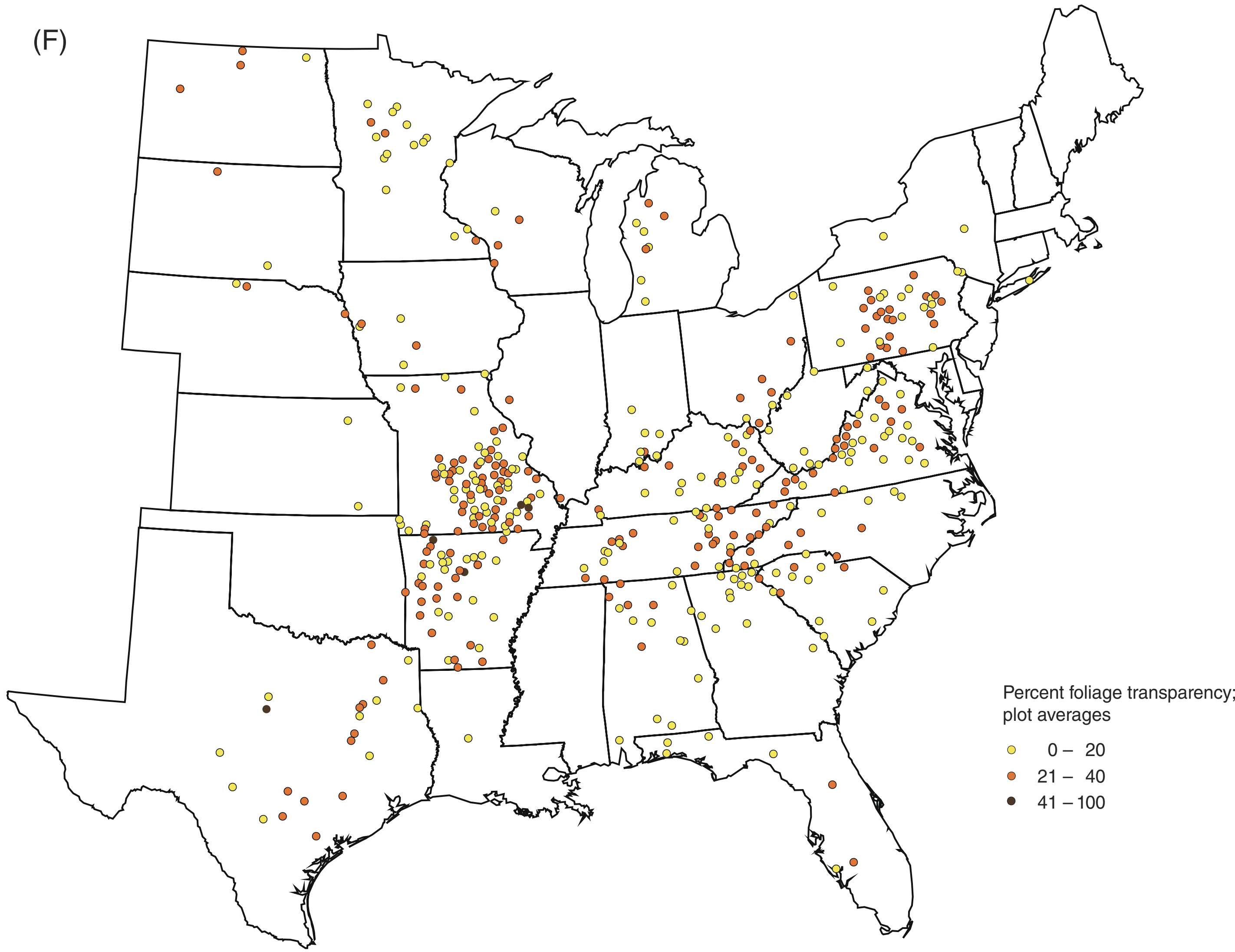


Figure 8.7 (continued)—Foliage transparency plot averages for major hardwood species of the Eastern United States: (A) maples, (B) hickories, (C) American beech, (D) cottonwood and aspen, (E) red oaks, and (F) white oaks. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program)

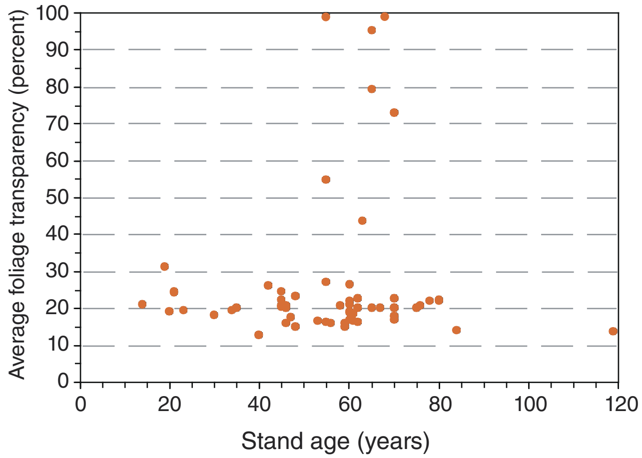


Figure 8.8—Foliage transparency plot averages by stand age for the cottonwood-aspen species group in Minnesota. (Data source: U.S. Department of Agriculture Forest Service, FIA Program)

Other Eastern species groups exhibited spatial clusterings of elevated average dieback (fig. 8.9) and transparency (fig. 8.7). Relatively high levels of red oak (see appendix table A.1), foliage transparency, and crown dieback were clustered in Missouri (figs. 8.7E and 8.9E). There was also a clustering of high dieback levels for maple in eastern Maine (fig. 8.9A), for American beech in New England (fig. 8.9C) and for white oaks (see appendix table A.1) in Pennsylvania and Virginia (fig. 8.9F). There were no outstanding spatial patterns of relatively poor crown condition in hardwoods in the Western United States (figs. 8.10 and 8.11).

The relatively poor condition of red oak crowns in Missouri is likely related to the documented ongoing decline of red oak stands across much of the State (U.S. Department of Agriculture Forest Service 2006). Drought conditions, increasing tree ages, high stand densities, and the red oak borer have contributed to the decline (U.S. Department of Agriculture Forest Service 2003, 2004) and may partially explain the poor crown conditions seen in red oaks.

Relatively high levels of dieback in white oaks in Pennsylvania and Virginia may be the result of gypsy moth defoliation and weather events. A major gypsy moth outbreak occurred in central and southern Pennsylvania during 2000. Defoliation was heavy in both Pennsylvania and Virginia in 2000 and 2001 (U.S. Department

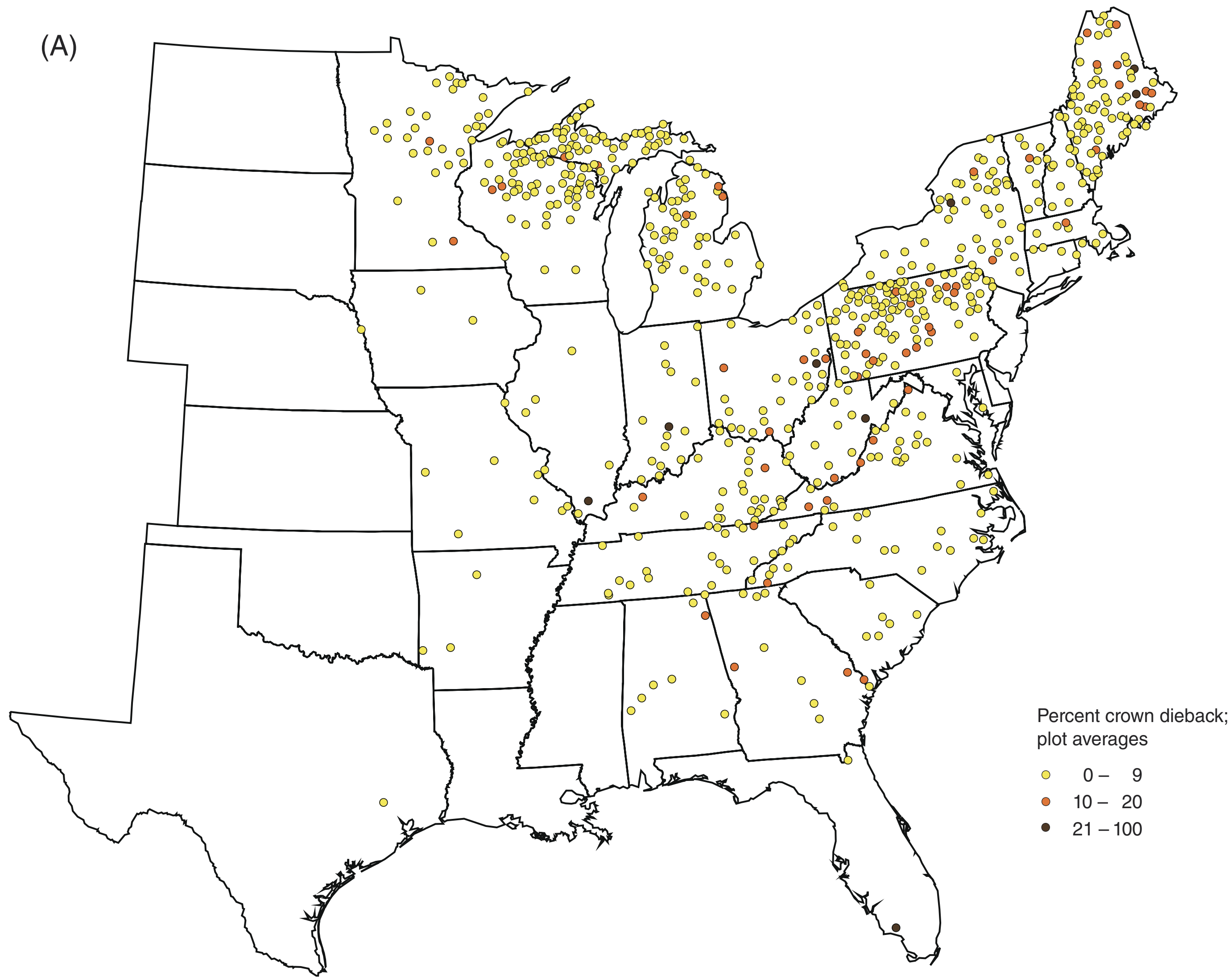


Figure 8.9—Crown dieback plot averages for major hardwood species of the Eastern United States: (A) maples, (B) hickories, (C) American beech, (D) cottonwood and aspen, (E) red oaks, and (F) white oaks. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) *(continued to next page)*

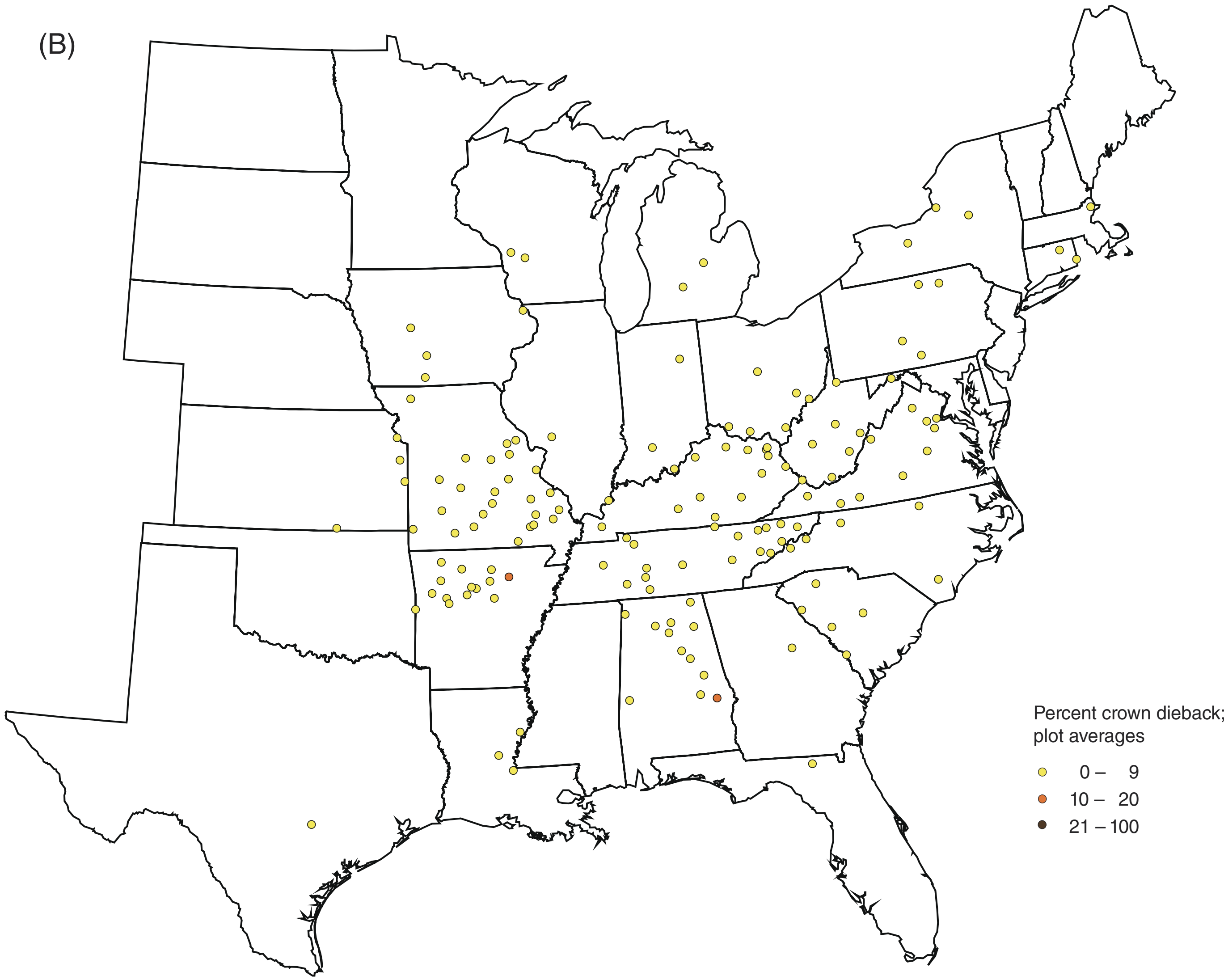


Figure 8.9 (continued)—Crown dieback plot averages for major hardwood species of the Eastern United States: (A) maples, (B) hickories, (C) American beech, (D) cottonwood and aspen, (E) red oaks, and (F) white oaks. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)

(C)

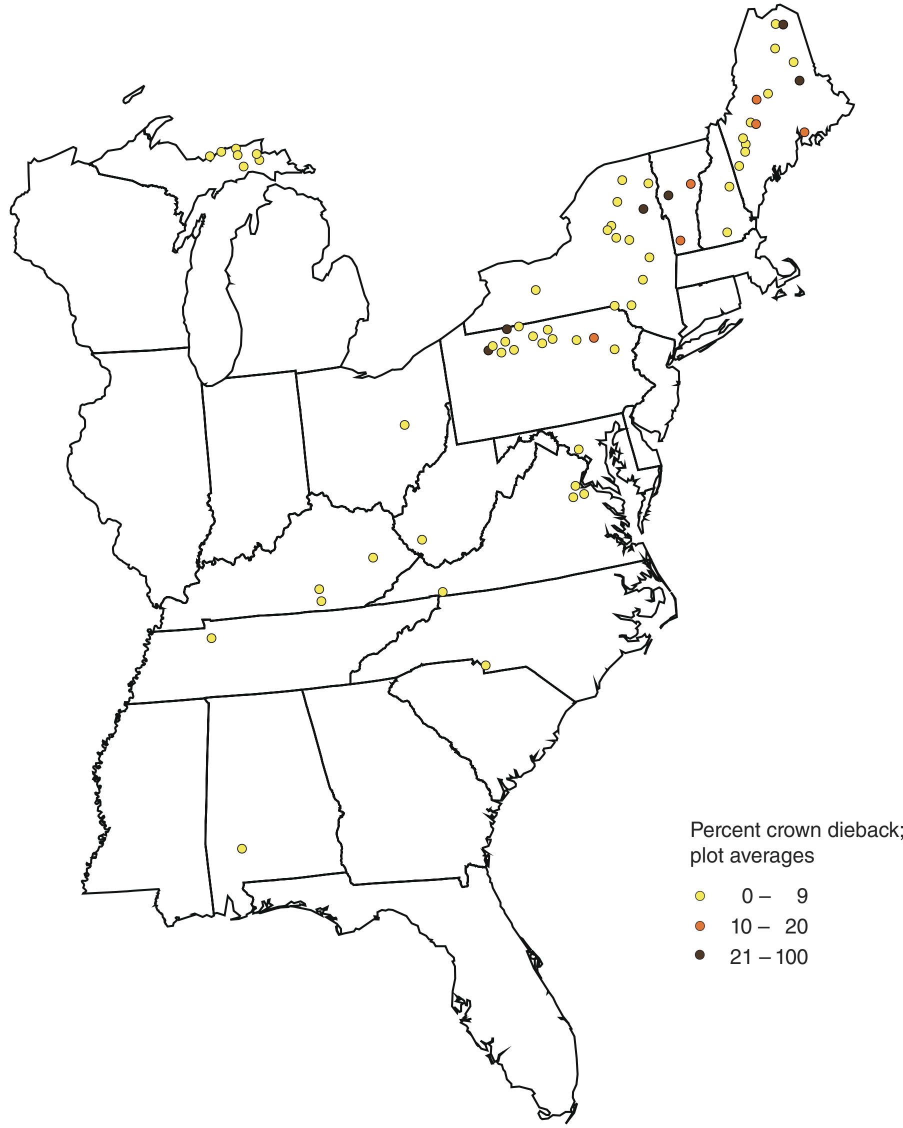


Figure 8.9 (continued)—Crown dieback plot averages for major hardwood species of the Eastern United States: (A) maples, (B) hickories, (C) American beech, (D) cottonwood and aspen, (E) red oaks, and (F) white oaks. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)

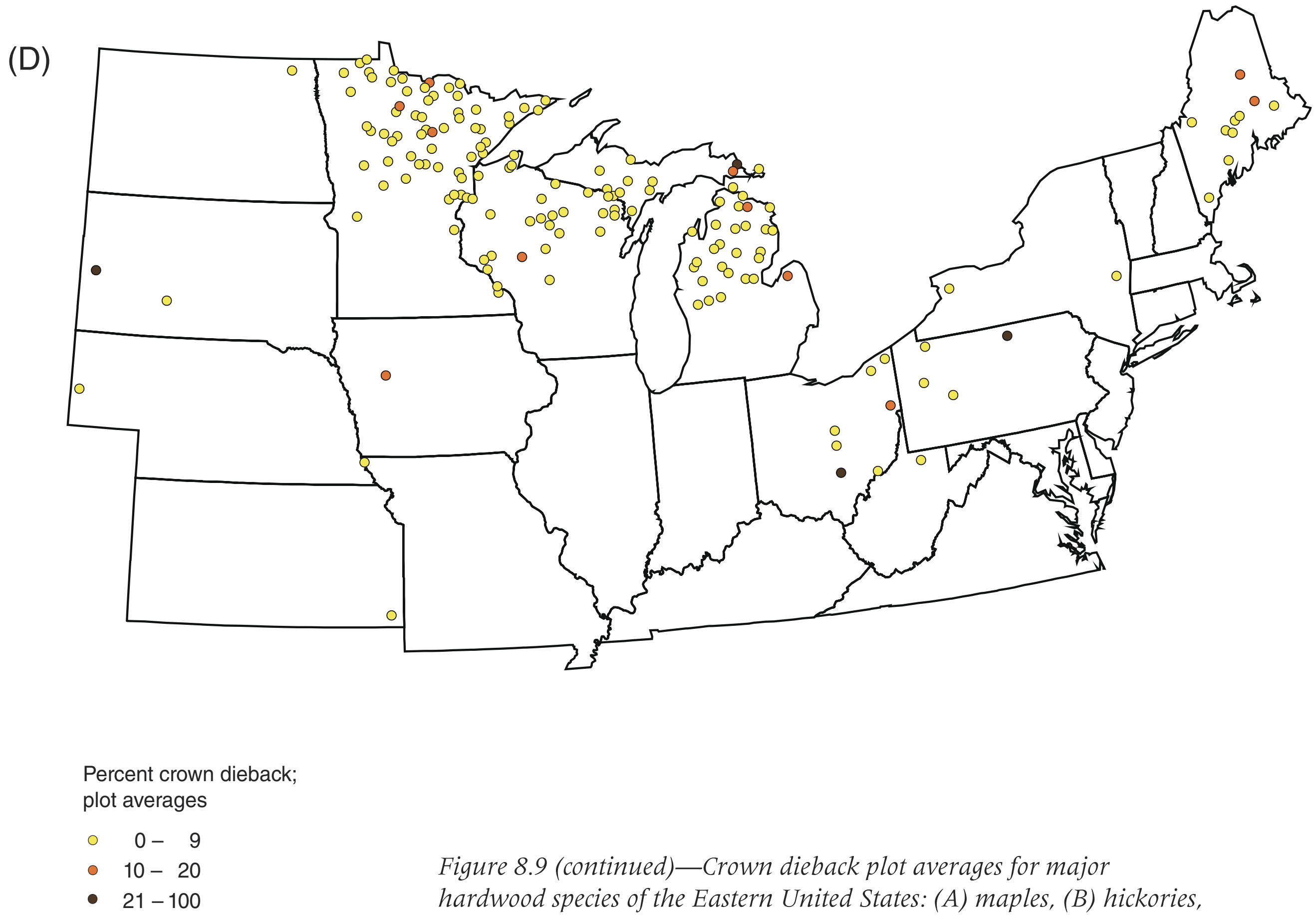


Figure 8.9 (continued)—Crown dieback plot averages for major hardwood species of the Eastern United States: (A) maples, (B) hickories, (C) American beech, (D) cottonwood and aspen, (E) red oaks, and (F) white oaks. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)

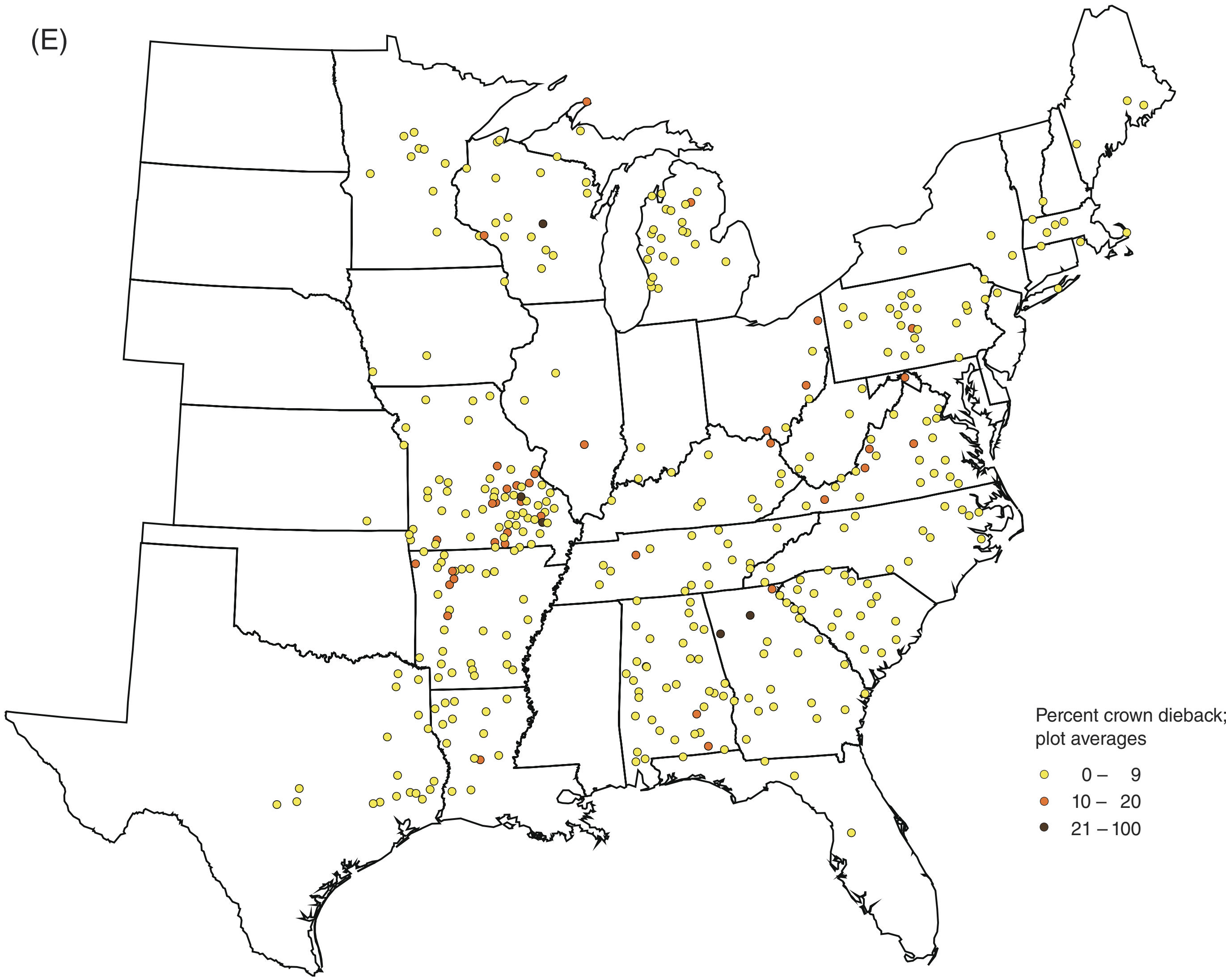


Figure 8.9 (continued)—Crown dieback plot averages for major hardwood species of the Eastern United States: (A) maples, (B) hickories, (C) American beech, (D) cottonwood and aspen, (E) red oaks, and (F) white oaks. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program) (continued to next page)

(F)

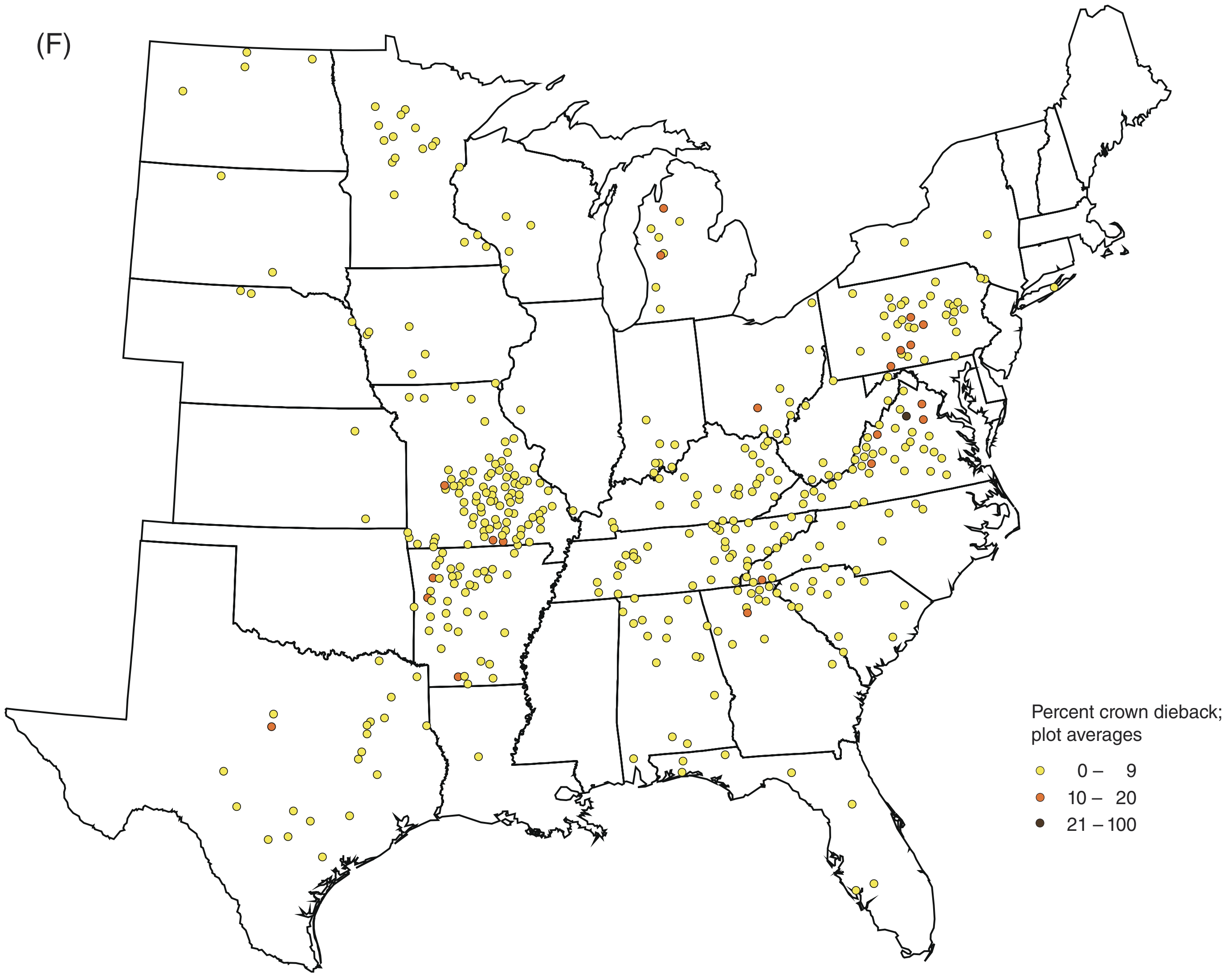
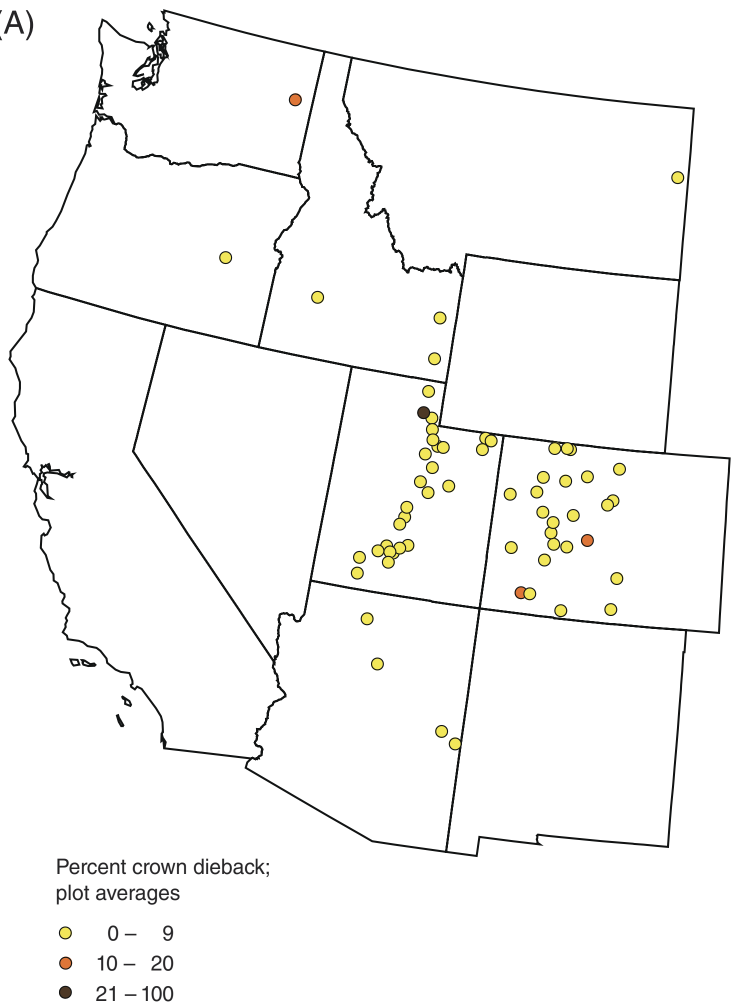


Figure 8.9 (continued)—Crown dieback plot averages for major hardwood species of the Eastern United States: (A) maples, (B) hickories, (C) American beech, (D) cottonwood and aspen, (E) red oaks, and (F) white oaks. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program)

(A)



(B)

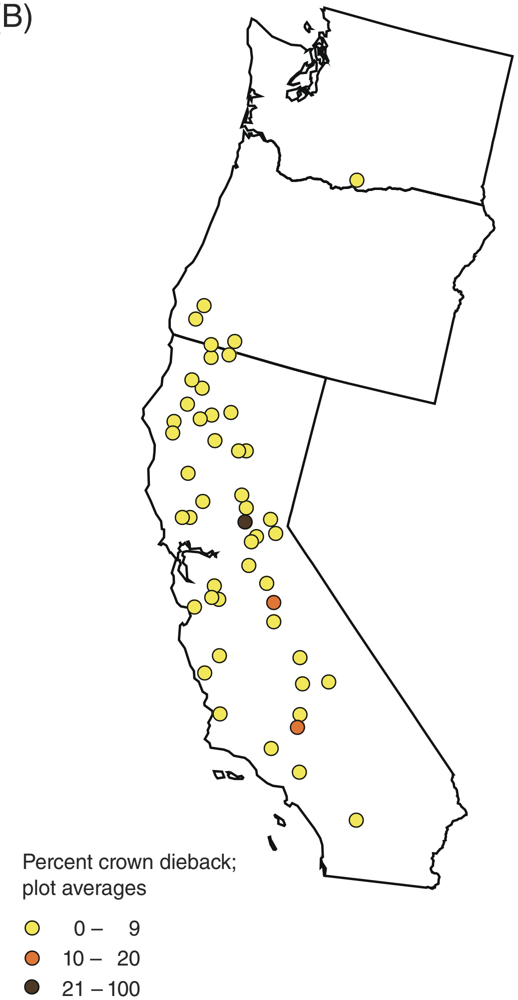


Figure 8.10—Crown dieback plot averages for major hardwood species of the Western United States: (A) cottonwood and aspen, and (B) oaks. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program)

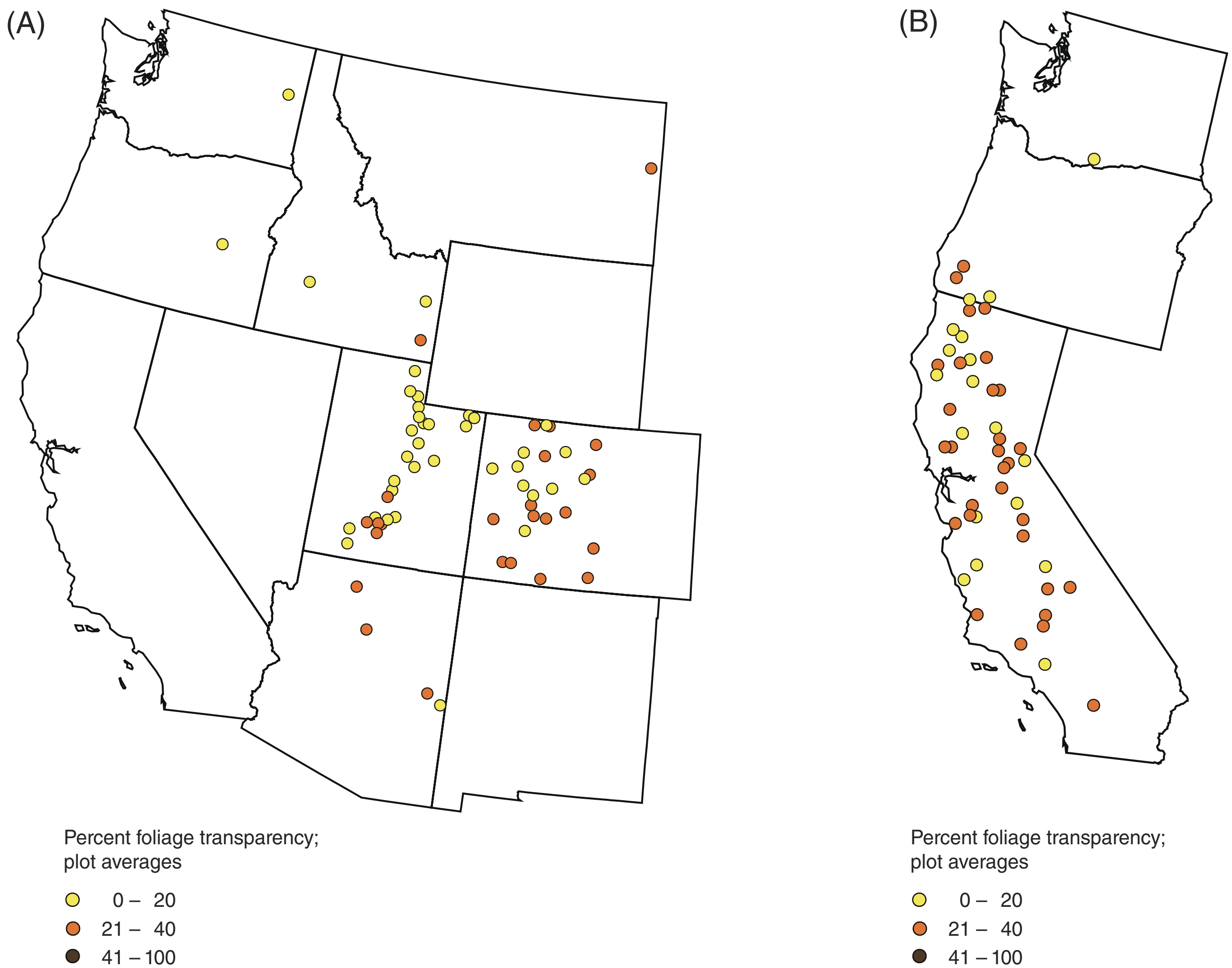


Figure 8.11—Foliage transparency plot averages for major hardwood species of the Western United States: (A) cottonwood and aspen, and (B) oaks. Plot locations are approximate. (Data source: U.S. Department of Agriculture Forest Service, FIA Program)

of Agriculture Forest Service 2002) (U.S. Department of Agriculture Forest Service; Pennsylvania Department of Conservation and Natural Resources, Bureau of Forestry 2001), and in Pennsylvania, the effects of the gypsy moth may have been exacerbated by droughty conditions between 1998 and 2002 (U.S. Department of Agriculture Forest Service; Pennsylvania Department of Conservation and Natural Resources, Bureau of Forestry 2001, 2003).

High plot-level average dieback for American beech in New England is likely the result of beech bark disease. Beech bark disease is an insect-fungus complex consisting of the beech scale insect and two species of *Neonectria* fungi (*N. faginata* and *N. ditissima*). Trees infected with these organisms often exhibit dieback and thin crowns before succumbing to mortality (Houston and O'Brien 1983). Beech bark disease complex has spread throughout New England (Morin and others 2003) and has been described as a chronic problem in Maine (U.S. Department of Agriculture Forest Service; Maine Forest Service 2004). Lingering effects of the 1998 ice storm that crossed Maine, New Hampshire, Vermont, and New York may also be evident in the high dieback averages. Though the ice storm caused considerable crown damage among all species, American beech was the most uniformly impacted (Miller-Weeks and others 1999). Most species quickly rebuilt their crowns in the years following the storm, but American beech had shown little recovery by 2002 (U.S. Department of Agriculture Forest Service; Maine Forest Service 2003).

Possible explanations for the elevated levels of maple dieback in eastern Maine are less obvious. The maple plots with the highest dieback levels were dominated by red maple. Throughout most of Maine, large amounts of red maple basal area were in trees with unhealthy crowns between 1993 and 2002 (Steinman 2004). Red maple had poorer crowns than most other species included in Steinman's (2004) analysis. Factors that may be contributing to the high levels of dieback include the 1998 ice storm, from which red maples have been slow to recover (U.S. Department of Agriculture Forest Service; Maine Forest Service 2003), natural or silviculturally induced stand dynamics, and the 1999–2002 drought.

Conclusions

Spatial clusters of high dieback, high transparency, and low crown density were identified for individual species groups in both the Western and Eastern United States. Most of these clusters were located within regions experiencing stress from known agents such as weather events, insect outbreaks, and disease occurrences. Further investigation will be required to identify the stress agents acting upon the few species with relatively poor crown conditions for which no cause is apparent. In addition to answering specific questions such as this, ongoing research is seeking to develop the full utility of the FIA crown condition indicator. Questions about the application of the crown condition indicator to problems such as early detection of declining forest health, growth and mortality prediction models, biomass estimation, and wildlife habitat modeling are being considered. Efforts are being made to determine how "normal" crown condition varies among species and to improve data collection, analysis, and reporting processes in order to increase the usefulness of the crown condition indicator.

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