CHAPTER 7.

Standing Dead Tree Resources in Forests of the United States

Christopher W. Woodall,[1]
Karen L. Waddell,
Christopher M. Oswalt,
and James E. Smith

INTRODUCTION

Given the importance of standing dead trees to numerous forest ecosystem attributes/processes such as fuel loadings and wildlife habitat, the Forest Inventory and Analysis (FIA) Program of the Forest Service, U.S. Department of Agriculture, initiated a consistent nationwide inventory of standing dead trees in 1999. As the first cycle of annual standing dead tree inventories nears full national implementation, the goal of this study was to conduct one of the first empirical assessments of the Nation's standing dead tree resources. Results indicate that there are a substantial number of standing dead trees in forests across the United States, exceeding 10 billion nationwide and consisting of mostly small-sized trees (< 30 cm d.b.h.). Forests in the Rocky Mountains and Pacific Northwest have some of the largest mean biomass of standing dead trees per unit of forest land (+3 Mg/ha), whereas Plains States had the least. The species composition of standing dead trees is quite diverse with over 130 species having more than 1 million Mg each nationwide, but is dominated by western tree species (e.g., Douglas-fir, +200 million Mg). Given the emerging role of standing dead trees in biomass/bioenergy economies and carbon cycling, continued monitoring of this resource is highly warranted.

Standing dead trees, sometimes referred to as snags, may be defined as remnants of once living trees that are still upright, self-supported, and lean less than 45° from vertical (USDA Forest Service 2006). Standing dead trees are an integral component of forest ecosystems, enhancing the structural diversity of forests of all ages. They have many roles such as providing wildlife habitat, storing carbon, and contributing to the overall fire hazard in a stand. Numerous wildlife species depend on standing dead trees for shelter, nesting sites, and food, including a variety of avian (Raphael and White 1984) and forest invertebrate species (Harmon and others 1986). Analysis of forest carbon pools have become an important component of national resource assessments. The United Nations 1992 Framework Convention on Climate Change (United Nations 1992) called for yearly reporting of the carbon mass stored as dead wood, of which standing dead trees are a considerable component, in forests among all signatory nations (EPA 2004).

When the total biomass of standing dead trees in a forest becomes excessive (Kirby and others 1998), the standing dead trees themselves may constitute a substantial fire hazard. Dead trees of different heights can potentially act as a fuel ladder to live tree crowns (Stephens 1998) and may help predict the amount of down woody debris through fuel succession models (Schimmel and Granstrom 1997). Overall, dead tree information has been used to assess a variety of forest stand attributes/processes such as growing stock mortality, wildlife habitat, wildfire hazards, or biomass/carbon.

There has been a dearth of information regarding standing dead wood resources across the United States. In the past, most standing dead tree analyses were at local/regional scales (Cline and others 1980, Goodburn and Lorimer 1998,

[1]Research Forester, U.S. Department of Agriculture Forest Service, Northern Research Station, St. Paul, MN 55108.

Healy and others 1989, Ohmann and Waddell 2002), while national-scale forest resource analyses omitted dead tree attributes entirely (Smith and others 2004). The lack of published national standing dead tree resource estimates can be attributed to the absence of a nationally consistent standing dead tree inventory. Standing dead trees were not consistently inventoried in all States during FIA periodic forest inventories (prior to 2000). The extent of sampling ranged from a minimum necessary to determine rates of mortality to measurement of all standing dead trees sufficient for population level estimates (similar to current annual inventories). To address the growing need for consistent and timely standing dead tree resource information, the FIA program initiated annual inventories of standing dead trees at the onset of the 21st century. Woodall and others (2009) provided an initial examination of a partial inventory of the U.S. forests with data measured from 2000 to 2005. Since then, a more complete and vetted national standing dead wood database with new volume models (Heath and others 2009) has become available. Subsequently, estimates of standing dead tree attributes have been generated and national-scale analysis is now possible. The goal of this study was to summarize the current standing dead tree resource in forests of the United States with emphasis on the following attributes: size distribution, species composition, State-level biomass, and change estimates.

METHODS

The FIA program conducts a three-phase inventory of forest attributes in the United States (Bechtold and Patterson 2005). The FIA sampling design is based on a tessellation of the United States into hexagons that are approximately 2428-ha in size and have at least one permanent plot established inside each hexagon. In phase 1, the population of interest is stratified and plots are assigned to individual stratum, such as forest, nonforest, and forest-edge, to increase the precision of estimates. In phase 2, tree and site attributes are measured in forested conditions for field plots established in the 2428-ha hexagons. Phase 2 plots consist of four 7.32-m fixed-radius subplots or 17.95-m macroplots on which standing dead trees ≥ 12.7 cm d.b.h. are inventoried. Individual tree variables include species, d.b.h., and total height (Bechtold and Patterson 2005, USDA Forest Service 2006).

All standing dead tree estimates were based on empirically sampled forest inventory data from the most current, publicly available inventory, i.e., within the FIA database, for each State (excluding interior Alaska and Hawaii). Inventory data were from annual inventories collected between 1999 and 2008, except for Wyoming (2000) and New Mexico (1999), where periodic inventories were used. The number of FIA plots used in this study where at least one forested condition was observed totaled 87,401.

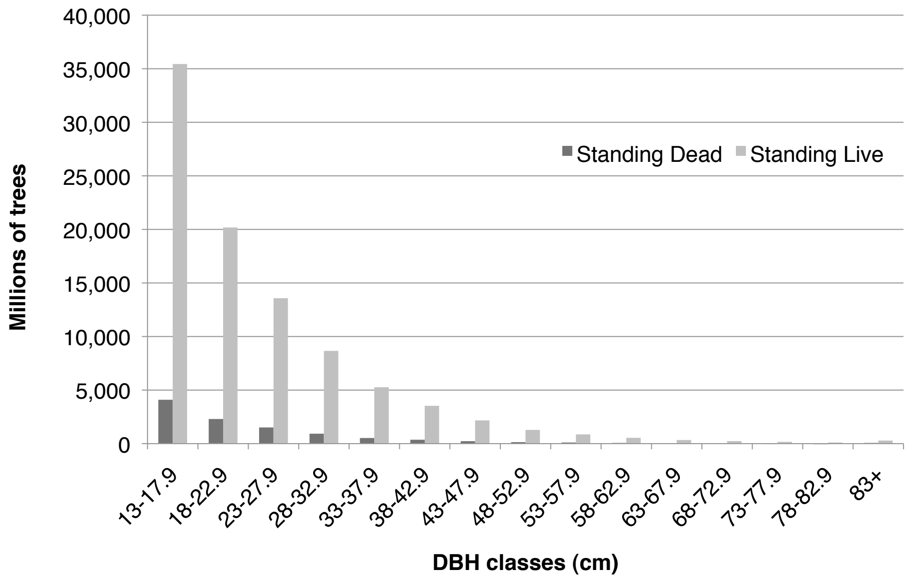


Figure 7.1—Diameter distribution for standing live and dead trees, United States (Note: Sampling error below 100 million trees for all estimates).

The total number of standing dead and live trees was estimated nationwide for 5 cm d.b.h. classes. Nationwide total aboveground dry biomass (Biomass; Mg) was determined for all tree species. Only the top 10 tree species with respect to this population estimate are reported in this analysis. The top and bottom 10 forest types in terms of mean standing dead tree biomass per unit forest land area (Mg/ha) was determined. For each State, the total standing dead tree biomass (Mg), biomass per unit forest land area (Mg/ha), and the ratio of standing dead and live biomass were determined. Finally, in order to estimate change for one contiguous region of the United States, where re-measured data were available, the change in the ratios of standing dead to standing live tree biomass between two points in time (time 1: 1999–2004, time 2: 2004–08) was examined for a selection of North Central States. General FIA population estimation procedures are detailed by Bechtold and Patterson (2005).

RESULTS AND DISCUSSION

There is 1 standing dead tree for every 10 standing live trees across the United States with a total of 10.6 billion standing dead trees nationwide (fig. 7.1). The diameter distribution is similarly shaped for standing live and dead trees. When tree counts were viewed as a percentage of the total distribution, standing live trees had only slightly higher percentages than standing dead trees for smaller diameter classes (d.b.h. < 53.0 cm) and vice versa for larger-sized trees (table 7.1). Because large-

Table 7.1—Diameter distribution (diameter class count divided by total) for standing live and dead trees and factor (difference between standing live and standing dead trees population counts), United States

D.b.h.[a] (cm)	Live trees (percent)	Dead trees (percent)	Factor
13-17.9	38.3	38.3	8.65
18-22.9	21.8	21.5	8.78
23-27.9	14.7	14.1	8.98
28-32.9	9.3	8.7	9.34
33-37.9	5.7	4.9	10.01
38-42.9	3.8	3.4	9.69
43-47.9	2.3	2.1	9.46
48-52.9	1.4	1.3	9.14
53-57.9	0.9	1.0	8.24
58-62.9	0.6	0.6	8.01
63-67.9	0.4	0.4	7.27
68-72.9	0.3	0.3	6.68
73-77.9	0.2	0.3	5.89
78-82.9	0.1	0.2	5.66
83+	0.3	0.6	4.19

Note: Inventory data were from annual inventories collected between 1999 and 2008, except for Wyoming (2000) and New Mexico (1999), where periodic inventories were used.
[a] d.b.h. = diameter at breast height.

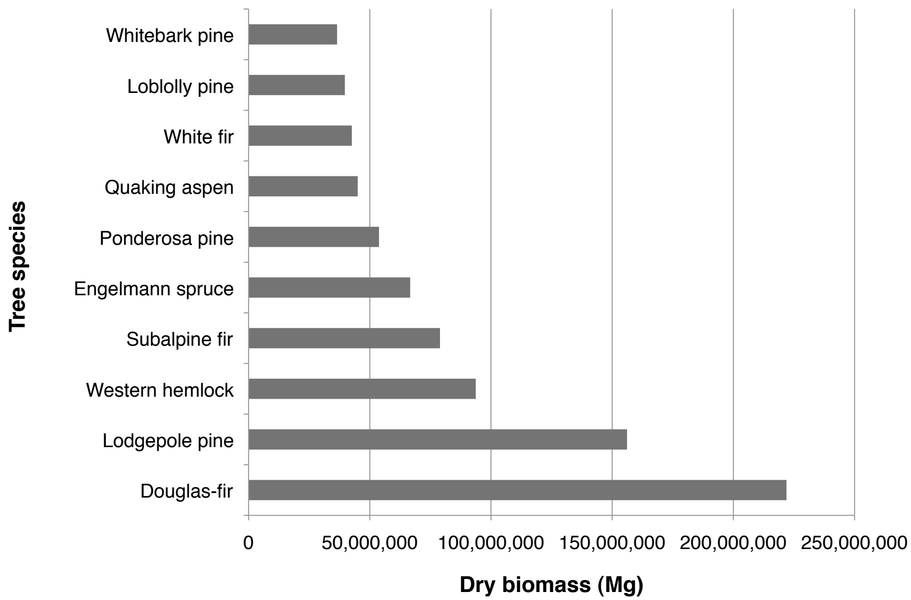


Figure 7.2—Top 10 tree species in terms of total aboveground dry biomass (Mg), United States.

sized standing dead trees are resident in forest ecosystems for longer time periods than rapidly decaying smaller-sized trees, the relative frequency of tree counts is greater in large-sized standing dead trees when compared to standing live trees. Whereas live trees outnumber standing dead trees by a factor of almost 9 to 1 for the smallest trees (d.b.h. 13.0–17.9 cm), this factor was only approximately 4 to 1 for the largest trees (d.b.h. > 83.0 cm) (table 7.1).

The species composition of standing dead trees is quite diverse with more than 130 species having over 1 million Mg each nationwide, but is dominated by tree species of the Western United States, e.g., Douglas-fir, > 200 million Mg. In terms of total standing dead tree biomass across the United States, western tree species account for nine of the top 10 species with loblolly pine the sole exception (fig.7.2). The combined total nationwide standing dead tree biomass of Douglas-fir and lodgepole pine across the United States is almost equal to the next six species combined. Although western forests possess vast acreage of highly productive monocultures, e.g., Douglas-fir, these estimates may point to a potential forest health and fire hazard challenge facing forest ecosystems in the Western United States. On a per-unit-area basis, western forest types dominate all the top 10 forest types across the United States in terms of biomass per unit forest land area (fig. 7.3A). Western hemlock forest types have over 30 Mg/ha, while the remaining top nine forest types have biomass averaging over 15 Mg/ha. The bottom 10 forest types in terms of mean standing dead biomass per unit forest land area, are represented by woodland species, eastern hardwoods, and southern yellow pines (fig. 7.3B). Woodland tree species are often multi-stemmed and may not attain the same large-diameter sizes of forest land tree species. Because the FIA program only inventories standing dead trees with a d.b.h. in excess of 12.7 cm, many of the smaller-sized woodland tree species stems might be excluded from this analysis where woodland species do not attain large diameters. One reason the southern yellow pine forests have low levels of dead tree biomass may be due to active land managers intentionally capturing anticipated tree mortality through commercial thinning treatments, thereby incurring relatively low levels of tree mortality.

Mirroring the species- and forest type-specific standing dead tree results, western States have a tremendous amount of standing dead tree biomass (fig. 7.4A). The northwestern States of Washington, Oregon, and Idaho have the highest amounts of standing dead tree biomass per hectare in the country, typically in excess of 4 Mg/ha (fig. 7.4B). When ratios of standing dead to standing live biomass are examined, almost all Rocky Mountain States have the highest ratios for the United States (fig. 7.5), possibly due to long-term drought and insect/disease effects (van Mantgem and others 2009).

Due to gradual implementation and remeasurement of standing dead tree plots across the United States, only North Central States were examined for changes in standing dead to live tree biomass ratios (fig. 7.6). Almost all examined States had higher ratios of dead to live tree

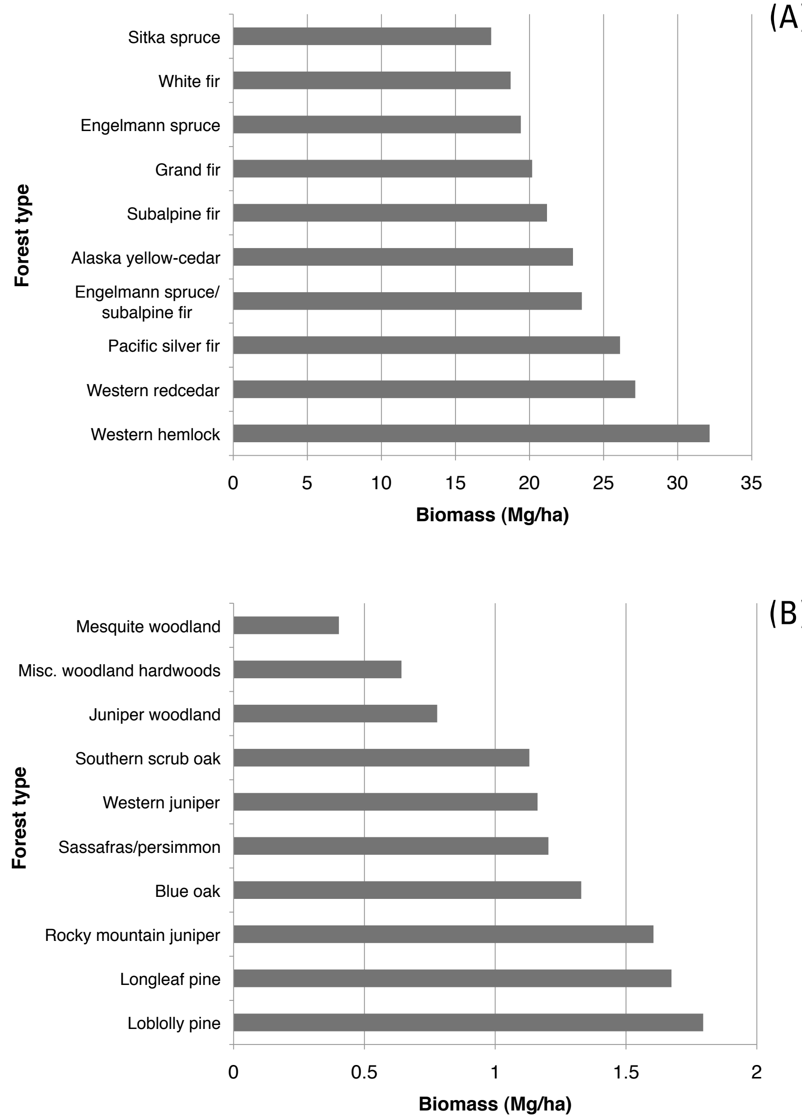
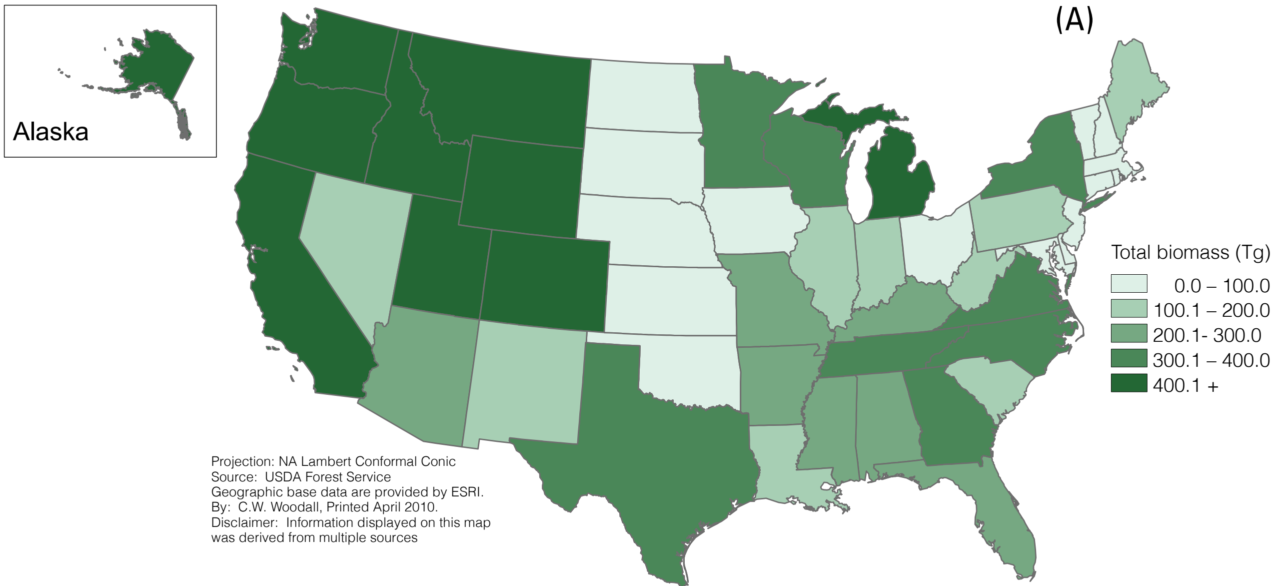


Figure 7.3—Estimates of standing dead tree biomass per unit of forest land area (Mg/ha) for the (A) top 10 and (B) bottom 10 forest types, United States.



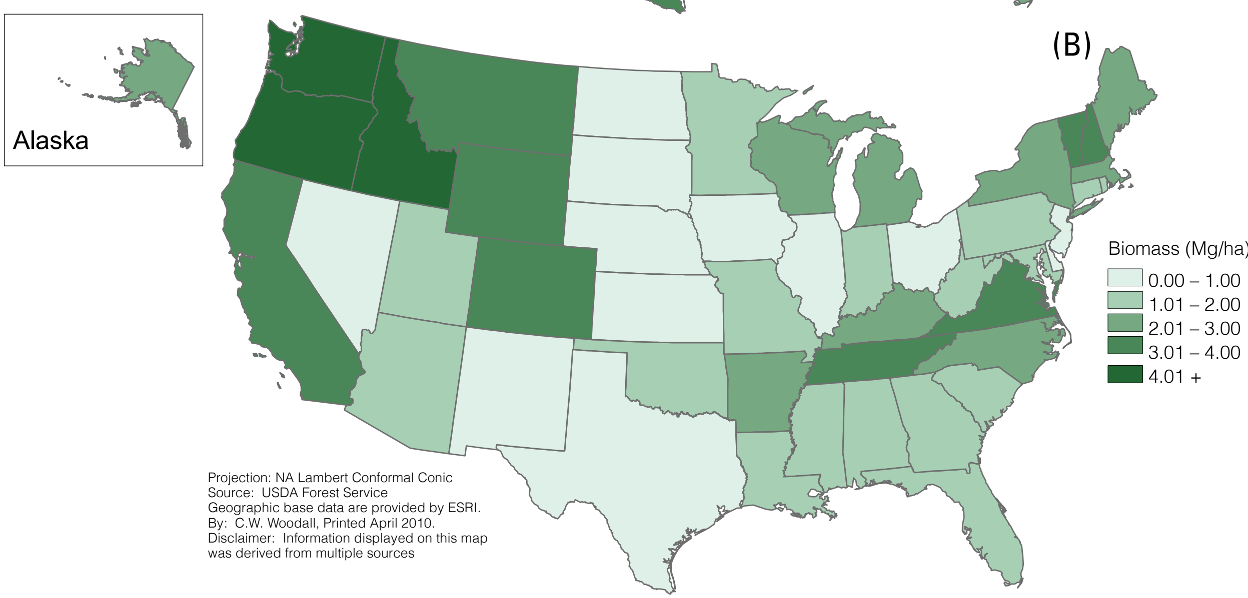


Figure 7.4—Estimates of (A) total biomass (Tg) and (B) biomass per unit forest land area (Mg/ha) of standing dead trees in States (excluding Hawaii and interior Alaska). Note: Alaska is not shown to scale with map of the conterminous United States.

biomass at remeasurement, although differences were within associated sampling errors indicating a lack of statistical difference across this relatively short remeasurement period. Changes in this ratio may serve as an indicator of advanced stages of stand development, e.g., stem-exclusion, or forest health concerns, e.g., such mortality events as pest outbreaks.

Overall, standing dead trees are a sizeable component of forest ecosystems across the United States, but still pale in comparison to live tree resources (in terms of both frequency and biomass). The highly productive West Coast forests retain the greatest amount of biomass in standing dead trees compared to other States across the Nation. In particular, Rocky Mountain States have a high ratio of standing dead to standing live biomass of 0.12 or larger, while most other States in the Nation have ratios below 0.09. Standing dead trees play divergent roles in forest ecosystems of the United States. While they may serve as an indicator of imminent forest health threats such as wildfire, they also serve as critical habitat, a potential bioenergy source, and an important element of the carbon storage capacity of forests across the country. The continued monitoring of this forest resource will ensure the varied roles of standing dead trees are elucidated during forest management and policy decisions.

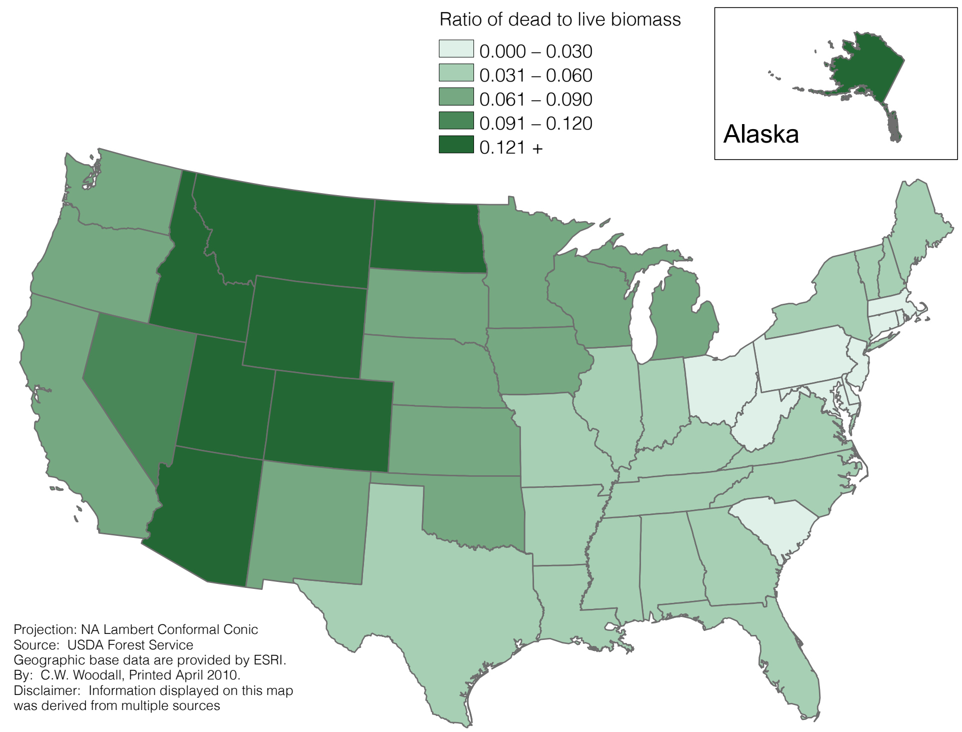


Figure 7.5—Ratio of standing dead tree biomass to standing live tree biomass for all States (excluding Hawaii and interior Alaska). Note: Alaska is not shown to scale with map of the conterminous United States.

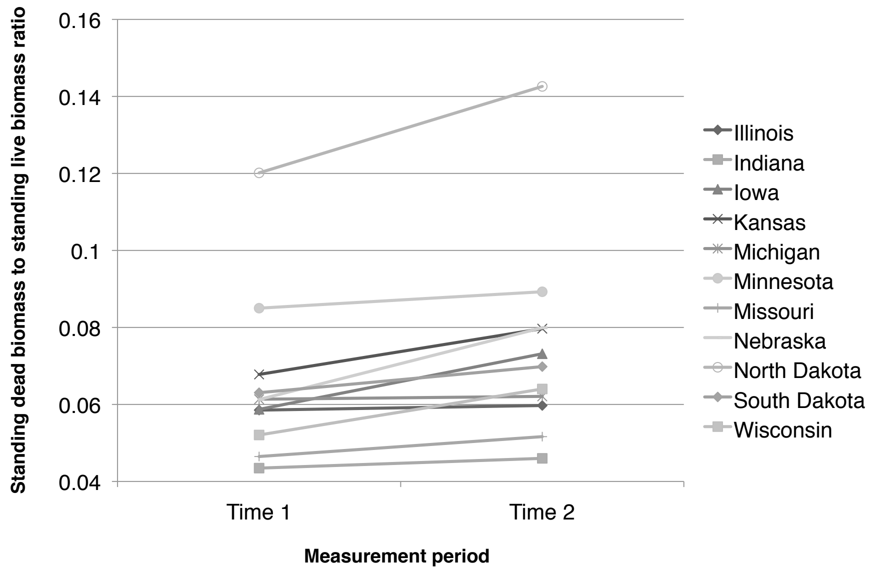


Figure 7.6—Changes in ratio of standing dead tree biomass to standing live tree biomass for North Central States between two measurement periods (1999–2004 to 2004–2008).

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