Evidence for Increasing Red Maple Abundance in the Eastern United States

Songlin Fei and Kim C. Steiner

Abstract: Red maple (*Acer rubrum* L.) is widely believed to be increasing in abundance in eastern North America, but most evidence is anecdotal or localized. In this article we present analyses of FIA data sets designed to formally quantify changes in abundance of red maple in the eastern United States during the period of 1980 to 2005. The results indicate that recent increases in red maple abundance are almost ubiquitous on a state-by-state basis throughout the species' natural range and generally greatest in the western portions of the range. No states experienced a significant decrease in red maple abundance during this period. There is evidence that the species has naturalized into areas west of its putative pre-Columbian distribution. Red maple had an inverse "J" population structure, and density of red maple trees has increased in all diameter classes across the region. The trend of increasing red maple abundance will continue unless the circumstances that cause this phenomenon are changed. FOR. SCI. 53(4):473–477.

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RED MAPLE (*ACER RUBRUM* L.) has recently come to a level of abundance in some parts of eastern North America that appears to be unprecedented in history (Lorimer 1984, Heiligmann et al. 1985, US FS 1995, Abrams 1998). In the northeastern United States, growing stock of red maple has shown extraordinary increase when compared to several other species (Alderman et al. 2005). The reasons for this apparently novel phenomenon presumably involve large-scale, exogenous, and unprecedented factors such as new fire regimes, introduced species, climate change, and/or modern wildlife and forest management practices. However, the precise causes are unclear and probably complex.

Although the increase of red maple in recent decades is widely acknowledged, our knowledge of the phenomenon is based largely on anecdote and localized evidence. Increases in red maple abundance have been reported in the northeastern (Lorimer 1984, Heiligmann et al. 1985, Alderman et al. 2005), north-central (Larsen 1959, Host et al. 1987, Zaczek et al. 2002), and southern (Arthur et al. 1998, McDonald et al. 2002, Galbraith and Martin 2005) portions of the United States. However, we lack a comprehensive and quantitative description of the phenomenon, and we do not even know necessarily whether it is still continuing. In this study, we use US Forest Service Forest Inventory and Analysis (FIA) data (US FS 2006) to describe changes in abundance and size class structure of red maple during the period 1980–2005 throughout its natural distribution in the eastern United States.

Materials and Methods

The FIA database is a long-term record of information on the status and trends of America's forest resources based on field samples distributed across the landscape with approximately one sample location every 6,000 ac. Before the year 2000 most states were inventoried periodically, but at irregular and asynchronous intervals. Since 2000 most states have been inventoried annually, but only partially. For this study, we used Forest Inventory Mapmaker 2.1 (Miles 2006) to capture county-level information on the total number and volume of all live trees for all species on timberland within the natural range of red maple (Little 1971). For most states we obtained data from two or more completed inventories, beginning with the first available measurement after 1980. The first inventories were all periodic surveys conducted between 1980 and 1995, depending on the state. The second inventory was defined as the latest available periodic survey or full-cycle, annual survey (all plots) as of January 2006. Completed second inventories were not available for six states (Arkansas, Kentucky, Louisiana, New York, Ohio, and Texas), so for these we used partial-cycle annual survey data as the second measurement. The interval between the two inventories ranged from 7 to 19 years, with an average of 12.4. Data were also retrieved for counties located near but outside the western boundary of the red maple range (Little 1971). In total, we used data from 2,391 counties in 37 states (32 states covered by the documented range of red maple, and five states outside of but close to its documented range; Figure 1).

Importance value (IV) was used to describe relative abundance of red maple for each state for each inventory. IV was calculated as the mean of relative density (total number of red maple/total number of all live trees · 100) of all trees with a diameter of at least 1.0 in. and relative dominance (total growing stock volume of red maple/total growing stock volume of all live trees · 100). For states that are only partially within the natural range of the species, only data from counties within the range were used to calculate IVs.

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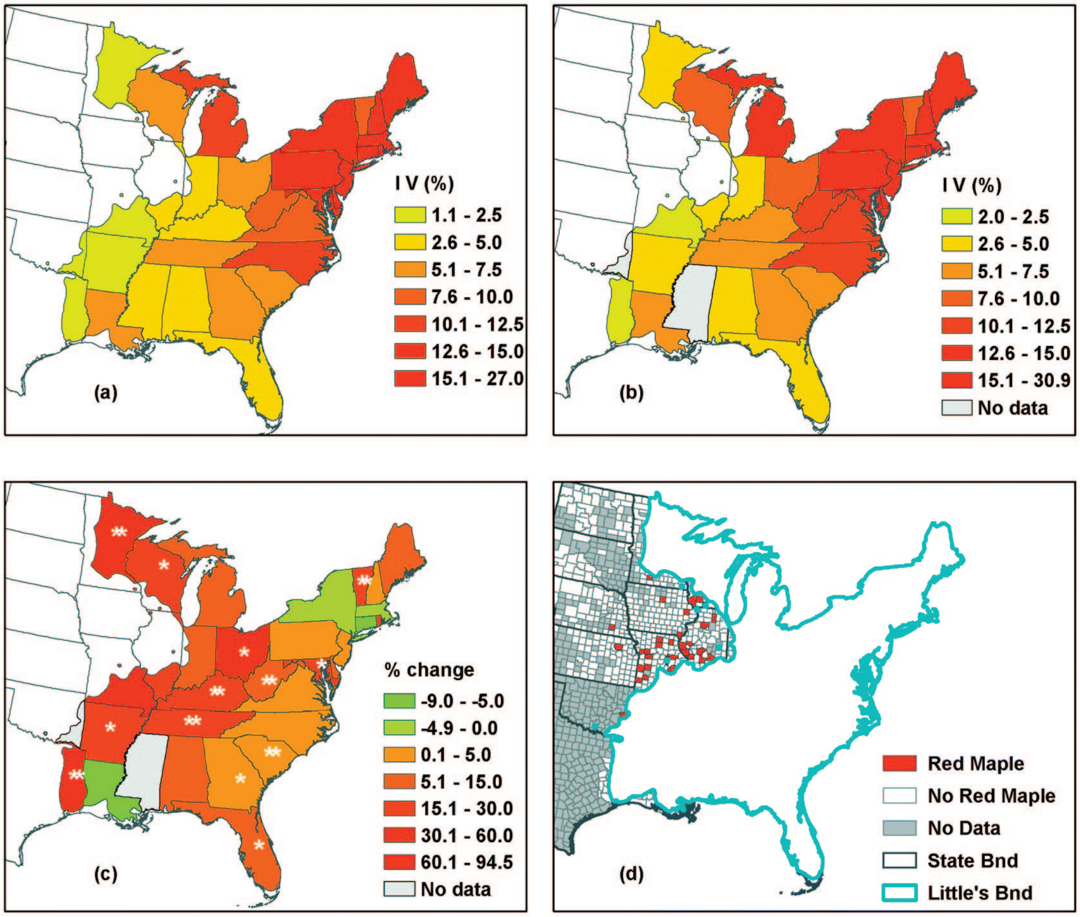

Figure 1. Average red maple IV by state within Little's (1971) range at first measurement (a) and second measurement (b), relative IV change (($IV_2 - IV_1$)/$IV_1 \cdot 100$) between the last two forest inventories (c), and county-level presence of red maple outside of its historical area of occurrence in the United States (d). *, states in which IV change between inventory periods is significant at $P < 0.1$; **, states in which IV change between inventory periods is significant at $P < 0.05$.

For each state, the relative IV change between the two inventories was calculated (($IV_2 - IV_1$)/$IV_1 \cdot 100$), and a paired *t*-test analysis was applied to state mean IVs for each inventory to examine whether the change is significant, using county-level IVs to calculate standard deviations.

Red maple density by diameter class was used to study changes in the population structure of red maple during the period 1980–2005. Red maple density (stems/acre) was calculated by diameter class for each measurement period for all the 32 states within red maple's historical range. Relative density change between the two measurement periods (($density_2 - density_1$)/$density_1 \cdot 100$) was calculated by diameter class for each state except Mississippi and Oklahoma (only one survey was available). Average and standard error of relative density change by diameter class were summarized for all the states to illustrate the overall change of red maple population structure.

Results

The regional distribution of red maple abundance for first and second inventories, and percentage changes in abundance between inventories, are shown in Figure 1a–c. For both inventories, red maple was more abundant in states in the northeastern United States and in Michigan than in other parts of the range. In the first measurement period, state mean IVs for red maple varied from 1.1% (Missouri) to 27.0% (Connecticut), and had an average of 9.6%. Thirty eight percent of the states had an IV greater than 10.0%, and 22% of the states had IVs greater than 15.0%. In the second measurement period, state mean IVs varied from 2.0% (Texas) to 30.9% (Rhode Island), and had an average of 10.8%. Fifty percent of the states had red maple IV greater than 10.0%, and 30% of the states had IV greater than 15.0%. Red maple IV increased for most of the states in the natural range from the first to the second inventory (Figure 1c). Red maple IV increased in 26 states (13 statistically significant at $P < 0.10$) and decreased in only four (no significant change). The overall trend is that red maple abundance increased in almost every portion of its range during the period 1980–2005 represented by the last two FIA inventories in each state. The percentage increases in abundance were especially large in the western portion of the historical range (Figure 1c).

In addition to an increase in abundance of red maple within its natural distribution, recent inventory data suggest that the species has naturalized beyond its documented historical range (Figure 1d). In total, 32 counties located beyond the western boundary of the species' range as identified by Little (1971) were recorded to have red maple on their timberland in the FIA database. The major area of apparent red maple range expansion occurred in the states of Missouri (13 counties) and Illinois (nine counties) within 100–200 miles of the western edge of the documented range. Red maple was recorded in forest inventories even on the timberland in Pottawatomie County, Kansas, and Saline County, Nebraska.

Contemporary red maple population structure based on diameter class had an inverse "J" distribution for each state (Figure 2). Red maple density for all size classes ranged from 13.9 to 170.6 trees per acre, depending on the state. Sapling-size trees (<5.0 in. dbh) composed a majority of the red maple population (64.3–94.8%, depending on the state), poletimber-size trees (5.0–10.9 in.) always less (4.7–28.1%), and sawtimber-size trees (≥11.0 in.) least (0.5–8.1%). States in the Northeast had relatively higher density and a larger proportion of red maple trees in the larger size classes compared to other states, especially those in the western portion of the species' range. In Arkansas and Missouri, 92.2–94.7% of all red maple trees were saplings (<5.0 in.) in the most recent survey.

Changes of density by diameter class between the two inventories show that red maple increased both its density and size for all states combined (Figure 3). Density increased in all diameter classes, but trees in the ≥15.0 in. diameter class had the highest relative density increase (54.6% on average), and trees in the 5.0–6.9 in. class had the lowest relative density increase (3.9% on average). The overall trend is that small size red maple was recruited and large size red maple was accumulated.

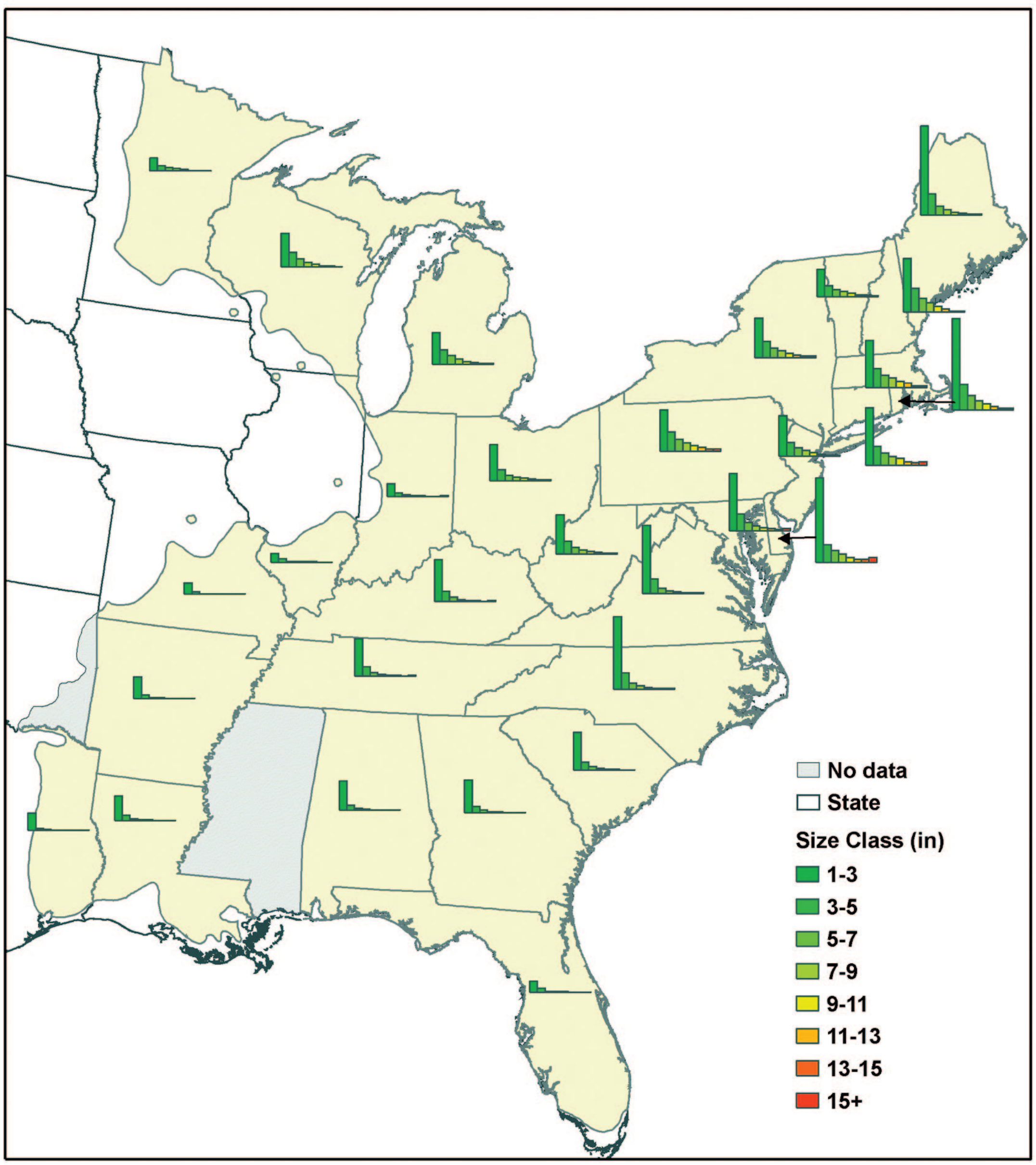

Figure 2. Diameter distribution of live red maple trees by state for the most recent FIA survey; height of the bars is proportional to the statewide average density in each diameter class, where the maximum average density is 101 stems per acre in the 1–3 in. diameter class in Rhode Island.

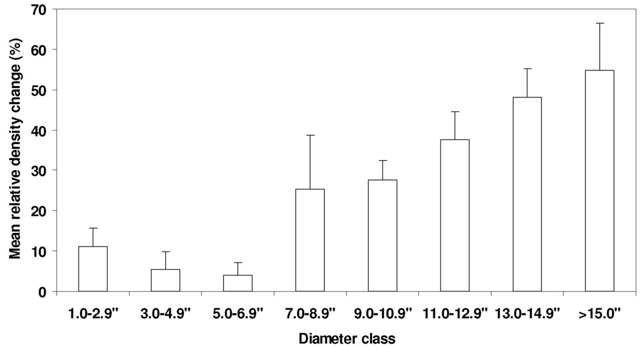

Figure 3. Mean and standard error of relative density change ((density$_2$ − density$_1$)/density$_1$ · 100) of red maple by diameter class for 30 states within red maple's historical range (not including Mississippi and Oklahoma) between the last two forest inventories.

Discussion

Although not *every* state in which red maple occurs naturally has registered an increase in the abundance of the species, the exceptions were few, and nearly half of all states showed a statistically significant increase. In general, the states with statistically significant increases had relatively little red maple in the first inventory period, and those that began with a high abundance of red maple have shown smaller increases or statistically nonsignificant decreases. Because only partial-cycle sets of annual survey data were available for the second inventory in six states (Arkansas, Kentucky, Louisiana, New York, Ohio, and Texas), some caution is needed in interpreting the trend for those states, but there is no reason to suppose that those incomplete inventories are biased with respect to red maple abundance. A further, and perhaps more important, caution in comparing trends for different states is that sample sizes (and hence the reliability of state means) vary greatly between large and small states. In addition, the time interval between the first and second inventories differed among states, and different states were inventoried in different years.

Nevertheless, a general trend of growing abundance of red maple throughout most parts of its natural distribution in the United States is clear, and this observation is consistent with local reports of red maple expansion (Heitzman 2003, Rentch and Hicks 2005, McWilliams et al. 2002). Even in states where the increase in red maple abundance over the last two FIA inventories was small and not statistically significant, a look at changes that have occurred through a longer period of time reveals a continuing trend. In Pennsylvania, for example, red maple IV increased from 17.0% in the 1978 inventory (Considine and Powell 1980) to 17.8% in the 1989 inventory, and to 18.3% in the 2004 inventory, which is consistent with the findings of McWilliams et al. (2002) that percentage of growing stock contributed by red maple has increased steadily from about 12% in 1955 to 19% in 2001. Although these changes appear small when expressed as percentages, they are large in absolute terms in such a heavily forested state, and they are particularly important given that red maple was already abundant. Even the rather small IV change from 1978 and 1989 was nevertheless large enough that red maple supplanted northern red oak during that period as the principal sawtimber species (by volume) in Pennsylvania (Alerich 1993).

Not only has red maple increased in importance throughout most of its range, there is also compelling evidence that it has expanded its range into portions of the midwestern United States that it did not formerly occupy (Figure 1d). These data, which were previously published by Prasad and Iverson (2003), show an apparent natural extension of the red maple distribution into the prairie regions west of the documented range, particularly in Illinois and Missouri. The natural distribution delimited by Little (1971) is the putative pre-Columbian distribution based on herbarium records, field notes, previously published information, and similar sources. Although Little's maps are not infallible, they are remarkably accurate in countless small particulars as observed by the junior author in 30 years of travel and study with an intimate knowledge of Little's maps. It is extremely unlikely that numerous occurrences of red maple in forests west of the known range (Figure 1d) would have been missed by the sources consulted by Little but picked up in the low-density sampling regime used to generate FIA data. Thus, these occurrences of the species are most likely of recent origin (late 20th century). It is interesting that the apparent expansion of the range is occurring only in a geographical lacuna within the distribution, an anomaly of red maple that is not shared by any other tree species that ranges throughout the eastern and midwestern United States. This lacuna conforms closely to the former Prairie Peninsula (Transeau 1935), and the almost ubiquitous conversion of those lands to agriculture and nonsavanna woodlots might have favored the naturalization of red maple. Red maple is not known to be used for reforestation plantings in this region, and state forest nurseries in the region are not currently offering red maple for sale (M. Coggeshall and R. Overton, University of Missouri Department of Forestry, pers. comm., April 2006). However, red maple is very widely planted for amenity purposes, and it is possible that offspring from ornamental plantings in residential and commercial areas are escaping into the wild.

Red maple had a persistent inverse "J" population structure (Figure 2). Sapling size red maple contributed over two-thirds of its population for most states. Small red maples in mature stands sometimes have been suppressed since stand initiation and may never grow into the canopy (Oliver and Stephens 1977). Nevertheless, the high density and continuing recruitment of small red maples augers for an even greater dominance of red maple in the future as many of these trees grow into poletimber and sawtimber size classes, as data from the last two surveys show is indeed occurring (Figure 3). As Lorimer (1984) concluded, red maple is not an opportunistic, short-lifespan, early successional species that only grows in the understory, and rather, it will eventually dominate the overstory on reasonably moist sites. The trend documented here will not stop soon.

In conclusion, red maple abundance has increased in the last few decades, especially in the western portion of its range. The species appears also to have expanded its region of natural occurrence compared to documented historical occurrence thought to represent pre-Columbian conditions. The species has a persistent population structure with high recruitment rate. With current land use and forest management practices, the continued expansion of red maple seems inevitable.

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