Submitted to an Interagency effort focused on the Montreal Process Criteria and Indicators of Sustainable Forest Management. This manuscript, authored by Linda Heath and Ken Skog, was produced as part of Linda's role as Lead for Criterion 5 (carbon cycle). There are three indicators in Criterion 5. They are being written for the 2003 National Report on Sustainable Forest Management.

Criterion 5, Indicator 28 (DRAFT). Contribution of forest products to the global carbon budget.

Contact: Linda Heath
USDA Forest Service
Northeastern Research Station
PO Box 640
Durham, NH 03824
603-868-7612
Lheath@fs.fed.us

Ken Skog
USDA Forest Service
Forest Products Laboratory
One Gifford Pinchot Dr.
Madison, WI 53711
608-231-9360
kskog@fs.fed.us

I. Analysis

A. What is the rationale and guidance for this indicator?

1. Rationale from the Technical Advisory Committee (TAC) for the Montreal Process, as recorded in the Roundtable Report: This indicator measures the role that forest products play in the sequestration, cycling, or emission of carbon. Harvested wood releases its carbon at rates dependent upon its method of processing, and its end-use: for example, waste wood maybe burned immediately, paper usually decays in up to five years (although landfilling of paper can result in longer-term storage of the carbon and eventual release as methane or carbon dioxide), and lumber decays in up to 100 or more years. Provided the forest is fully regenerated, forest harvesting could result in a net reduction in carbon emissions if the wood that is harvested is used for long-term products such as lumber, and particularly where wood is used as a substitute for higher energy materials. In addition, where wood is used as a substitute for fossil fuels, there can be positive benefits to carbon cycles. There is still scientific uncertainty and debate on accounting methodologies regarding wood products. The default assumption is that all carbon in harvested biomass is oxidized in the removal year. The net change in stocks of forest products should be a better indicator of a net removal of carbon from the atmosphere than the gross amount of forest products produced in a given year. New products with long lifetimes processed from current harvests frequently replace existing product stocks, which are in turn discarded and oxidized.

Interpretation from the Technical Advisory Committee (TAC) for the Montreal Process, as recorded in the Roundtable Report: Net increases or decreases in the sequestration of carbon from the production and use of forest products will have to be determined based on knowledge of changing wood manufacturing technologies and consumption**.**

2. Clarification of the Indicator and additions to rationale.

Reduction of greenhouse gases such as carbon dioxide and methane through quantification, monitoring, and management is the goal of the United Nations Framework Convention on Climate Change (UNFCCC). Many nations are participating in this Convention. The scientific arm of this effort is called the Intergovernmental Panel on Climate Change (IPCC). IPCC has published guidance (http://www.ipcc.ch/pub/guide.htm; IPCC, 1997) on estimation approaches to greenhouse gas inventories, including carbon associated with land use change, and forestry. The TAC expects Indicator 28 to conform to the IPCC Guidelines. Usually, the Guidelines include default values, however, they allow for more appropriate country-specific values to be used. Current Guidelines state that storage of carbon in forest products be included in a national inventory only in the case where a country can document that existing stocks of forest products are increasing. Otherwise, the default method is to assume that all carbon in harvested biomass is emitted in the removal year. The U.S. can provide scientific information that indicates its stocks of forest products are increasing. Thus, the estimates presented in this Indicator conform to the Guidelines.

Forest products, as used in the indicator title, is taken to mean harvested wood that is removed from the forest. The rest of the tree that is cut but left in the forest is considered forest ecosystem carbon and is counted as a pool in Indicator 26 and as a category of net carbon change in Indicator 27. There is little guidance in the IPCC Guidelines on estimating carbon in harvested wood.

One policy issue under debate is how to account for carbon in exported or imported products. Publications that discuss accounting options are Brown and others (1998), Lim and others (1999), and Winjum and others (1998). The three proposed accounting approaches are the stock change approach, the atmospheric flow approach, and the production approach. In terms of results, the main difference in these approaches is how carbon storage in exports and emissions in exports are assigned. If a country has no imports or exports of wood products, then these approaches produce the same results.

B. What data are used in quantifying this indicator?

This indicator reports trends in the contribution of carbon in harvested wood to the global carbon budget. Carbon is presented in terms of megatonnes (Mt) or megatonnes per year (Mt/yr), carbon equivalent. A megatonne equals one million metric ton.

Modeling approach used to estimate Indicator

Similar to the other carbon indicators (Indicators 26 and 27), Indicator 28 is not measured directly. The change in carbon in products is estimated using data on wood and paper products production, and imports and exports over time rather than trying to directly estimate the size of carbon stocks at two points in time. Data are not available to estimate directly carbon in, say, all housing at two points in time, or carbon in products in landfills at two points in time. Change in carbon in products and landfills over time is calculated using factors to convert production, imports, and exports to carbon contents, allotting these products to end uses, retiring them from use based on the end of their use life, transferring some of retired products to landfills, and estimating emissions over time from landfills. We summarize carbon in wood products in four categories: change in carbon in products in use, change in carbon in products in landfills, carbon emissions to the atmosphere from burning where energy was generated for use, carbon emissions to the atmosphere where energy was not captured for use.

For the U.S. estimates begin by tracking harvest and product beginning about 1900. Previous results can be found in Plantinga and Birdsey (1993), Heath and others (1996), Skog and Nicholson (1998). Data on production of lumber, plywood and veneer, pulp and other products, product imports and exports, and fuelwood, in terms of million cubic feet of roundwood equivalent are used as described in Skog and Nicholson (1998), and Skog and Nicholson (2000). A description of the model and associated references is given in Skog and Nicholson (2000). Primary data sources include USDA Forest Service (1964), Ulrich (1989), and Howard (2001). The harvested wood-to-carbon conversion factors are taken from Birdsey (1992). Decay rates of waste wood in landfills, including methane production, and duration rates of carbon in wood and paper are presented in Skog and Nicholson (1998, 2000). Net imports of harvested wood products in the U.S. have historically been small relative to domestic production. Only recently have net imports increased to more than 10% of domestic production (Howard, 2001).

Accounting approaches for reporting carbon in wood products

The three proposed accounting approaches are the stock change approach, the atmospheric flow approach, and the production approach (Brown and others, 1998; Lim and others, 1999; and Winjum and others,1998). The stock change approach measures the annual net change in carbon stored in products in a country. This includes carbon stored in imported products. The atmospheric flow (atmospheric drain) approach measures the annual net drain of carbon from the atmosphere to carbon stored in products in a country. Gross emissions from imported wood appear in the accounts of the importing country. The production approach measures the annual net change in the stock of carbon stored in products including only the carbon harvested in a particular country. This includes storage in products in the home country or in products exported to other countries. Although these approaches sound complex, in terms of results, the main difference in these approaches is to which country carbon storage in exports and emissions in exports is assigned. The atmospheric flow approach accounts for carbon in exported wood products similar to the way carbon in exported oil is handled. The other approaches handle exports differently.

1.Overview

We present estimates using the stock change approach to account for carbon in wood products for 1900 to 2000 in Figure 28-1 and Table 28-1. (That is, we estimate the annual net change in carbon stored in products in the United States, including net imports.) We present estimates using the atmospheric flow approach for 1990 and 2000 in Table 28-2. We currently do not have estimates for the production approach. We do not take a policy position on which approach is more appropriate for the purpose of these Indicators.

In Figure 28-1, note that all categories are shown as positive values, although the emitted and energy categories indicate the amount of carbon released to the atmosphere. Note that the carbon in harvested wood includes only that wood removed from the forest; logging residue left in the forest is not included in these calculations. Early in the period about 70% of the net change in carbon in harvested wood was emitted while being burned for energy in the form of fuelwood, with approximately 20% sequestered in products and 10% emitted without energy production. These net carbon pool change percentages include transfers between categories due to previous use (such as carbon in products being discarded into a landfill), compared to the total amount of carbon harvested during that year. In the middle of the period, only about 45% of the net carbon changes were attributable to carbon emitted while being burned for energy production, less than 20% was in the category of increases in products, and about 10% was due to landfill carbon changes. Net carbon changes in emissions without energy production climbed to 40% of the total harvested in a year, as previous harvested wood was discarded or decomposed or both. By the late 1980's, the pattern changed due to anaerobic landfills in which decay is arrested, and due to more efficient use of waste wood for energy production. Over 50% of the net carbon increases from harvest during one year are in the category wood burned for energy production, about 17% in in-use products, 24% in landfills, and 9% being added to the emissions category.

Between 1990 and 1997 about 60 Mt/yr were added to carbon stocks in landfill and wood-in-use categories. If added to the estimate of carbon sequestration in forest ecosystems (Indicator 27), the estimate for the U.S. forest sector, not including soil carbon, totals approximately 195 Mt/yr for the 1990's.

Estimates of the cumulative fate of carbon in the United State from 1910 to 1997, including net imports, are shown in Figure 28-2. Note that all pools are shown as positive in sign for comparison. Two of the pools, energy and emitted, are cumulative emissions from harvested wood. Thus, this is the amount that has been emitted to the atmosphere over the period. The two pools will never decrease, because once carbon has been emitted, it will not transfer back into the in-use or landfill category except for the small fraction of atmospheric $CO2$ that is taken up by trees, stored in merchantable timber, and eventually harvested for wood products. The total amount of carbon in wood harvested between 1900 and 1997 is approximately 8,650 Mt, with about 2,700 Mt currently stored in products and landfills.

2. Regional trends

It is possible to suggest rough relative contributions of U.S. regions to storage of carbon under the production approach by looking at relative amounts of harvested wood by region as shown in Figure 28-3. The proportions are relatively constant in the middle years, with the proportion of the southern region increasing in the recent years, and the proportion of the Pacific Northwest declining. These proportions are inaccurate to the extent that the life of products and disposal patterns associated with harvest varies by region.

C. How should the data be interpreted relative to the rationale from the TAC?

There are a number of ways to interpret data about storage of carbon in wood products that correspond to the various accounting approaches. These interpretations each meet the intent of the indicator to show the role harvested wood products play in sequestering carbon or limiting carbon emissions for a country or both. These interpretations should be coordinated with interpretations of the effect of carbon storage in forests. In each case the role of the forest is based on a focus on net carbon additions, but the role of products can be viewed differently.

- The role of forests and products in a country in sequestering carbon in given year includes net additions of carbon to forests, plus net additions of carbon to products including net imports (stock change approach).
- The role of forests in a country and products held in a country in draining carbon from the atmosphere includes the net additions of carbon to forests plus the net drain of carbon to products held (including imported) in the country (atmospheric flow approach).
- The role of forests in a country and products originating from harvest in the country in sequestering carbon includes net additions of carbon to forests plus net additions of carbon to products using wood harvested in the country (production approach).

The separate additional information on amount of wood burned for energy also indicates the contribution of wood energy in offsetting carbon emissions from fossil fuel burning. This amount has increased substantially in recent decades particularly due to increased burning of pulping liquor and wood waste in pulp and paper sector and wood waste burning at solidwood product plants. In general, additions to wood products carbon stocks have been increasing in the last 3 decades both in absolute terms and as a proportion of all carbon consumed. The reason for the proportional increase is largely due to increased use of anaerobic landfills and consequent estimated decreases in decay of discarded wood products.

D. Limitations of data provided

The data presented in this indicator are based on a modeling approach that uses data on product production, use life, disposal, and decay. The accuracy of the estimates depends on the validity of the models and the data. The estimates are particularly sensitive to numbers used for the proportion of discarded products going to landfills or dumps, and the degree of decay in landfills and dumps.

A difficulty in estimating stock change for the production approach is determining use life and decay rates for products exported to other countries. Previous estimates of carbon in harvested wood products (Heath and others, 1996) have used the production approach by assuming exports have the same use life, disposal, and decay rates as the U.S. Conversely, estimation of the contribution of individual regions to storage of carbon in wood product is possible in principle for the production approach, but would be complex for the stock change and atmospheric flow approaches. Using the production approach, a region could be associated with carbon stored in any wood harvested in the region. For the other two approaches, each region would need to be viewed as a separate country, because imports to and exports from the region are needed for to make carbon in harvested wood estimates.

E. If current data are not adequate to measure the indicator, what options are available for remedy?

The current estimates are considered a reasonable measure of the indicator. For more accurate and precise estimates, a national-level survey could be adopted to provide estimates of carbon in houses and other end-uses, and landfills. Another option is for additional research to be conducted to validate decay rates and end-use estimates used in the current model.

II. Problems related to scientific, social/political, economic, and institutional concerns.

The TAC expected the estimates in this indicator to match the IPCC Guidelines (1997), and the trade (imports/exports) approach required by the UNFCCC. However, the Guidelines currently have not been developed as much as those for carbon in forests, and a decision has not been made concerning accounting of carbon in imported and exported wood. The information in this indicator may need to be updated in the future once guidelines are available.

III. Cross-cutting issues/relationships with other indicators.

This indicator is directly related to the other Criterion 5 indicators, Indicators 26 and 27. Indicator 26 is a measure of forest carbon pools. The live tree pools are significantly affected by the amount of wood harvested in the United States. Net change in forest carbon for Indicator 27 is estimated directly by subtracting forest carbon pools estimated at different times and dividing by the years of difference between the times to produce annual changes in carbon. Changes in harvested wood carbon pools are not considered in Indicator 27. To understand the total benefits of forestry in retaining carbon stocks or reducing emissions or both, both forest and harvested wood components should be considered. See the discussion in section C above on interpretation. Indicators that provide measures of wood removals, such as Indicators 13, 31, and 33, should provide results consistent with the removals used in this Indicator.

IV. Suggested guidance on use of the data.

The underlying data on roundwood production have been collected after the harvested trees have been removed from the forests. Estimates of roundwood harvests based on USDA Forest Service, Forest Inventory & Analysis (FIA) surveys of forests are similar, but not an exact match, to the roundwood production estimates. Thus, the two data sources may provide different estimates of harvested wood. The roundwood production information is used because it is more detailed, and thought to be more accurate. However, estimates from Indicator 26 and 27 are based on FIA surveys. Summing these three Indicators (26, 27, and 28) to produce the total effect of forests on the global carbon cycle may result in some increased uncertainties because of the differences in data.

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Table 28-1 Change in carbon in wood product in use and in landfills, and amounts of carbon emitted from products, with and without energy production, 1910 – 1998, using the carbon stock approach (Mt/yr carbon).

Year	Change in products in use (1)	Change in products in dumps & landfills (2)	Total change in stock of carbon in product (3)=(1)+(2)	Emitted by burning with energy production (4)	Emitted by decay or burning without energy production (5)	Total emissions from products (6)=(4)+(5)	Total wood carbon consumed (7)=(3)+(6)
1910	24.3	1.1	25.4	88.4	10.6	99.0	124.4
1915	21.4	2.0	23.4	88.4	12.5	100.9	124.3
1920	22.9	3.1	26.0	51.9	14.7	66.6	92.6
1925	20.2	3.7	23.9	51.9	16.4	68.3	92.2
1930	12.8	4.1	16.9	44.6	15.5	60.1	77.0
1935	11.3	4.3	15.6	44.6	16.6	61.2	76.8
1940	14.0	5.3	19.3	35.0	20.4	55.4	74.7
1945	14.5	5.9	20.4	36.5	23.2	59.7	80.1
1950	13.6	6.3	19.9	37.4	25.5	62.9	82.8
1955	11.2	6.8	18.0	37.3	28.3	65.6	83.6
1960	9.0	7.1	16.1	34.6	30.6	65.2	81.3
1965	9.9	8.0	17.9	27.3	31.4	58.7	76.6
1970	12.4	9.2	21.6	32.8	35.9	68.7	90.3
1975	7.8	16.9	24.7	37.8	28.7	66.5	91.2
1980	11.8	27.9	39.7	48.1	19.2	67.3	107.0
1985	16.5	32.9	49.4	62.1	13.8	75.9	125.3
1990	26	33.4	59.4	74.4	11.4	85.8	145.2
2000	25	32.5	57.5	88.1	14.3	102.4	159.9

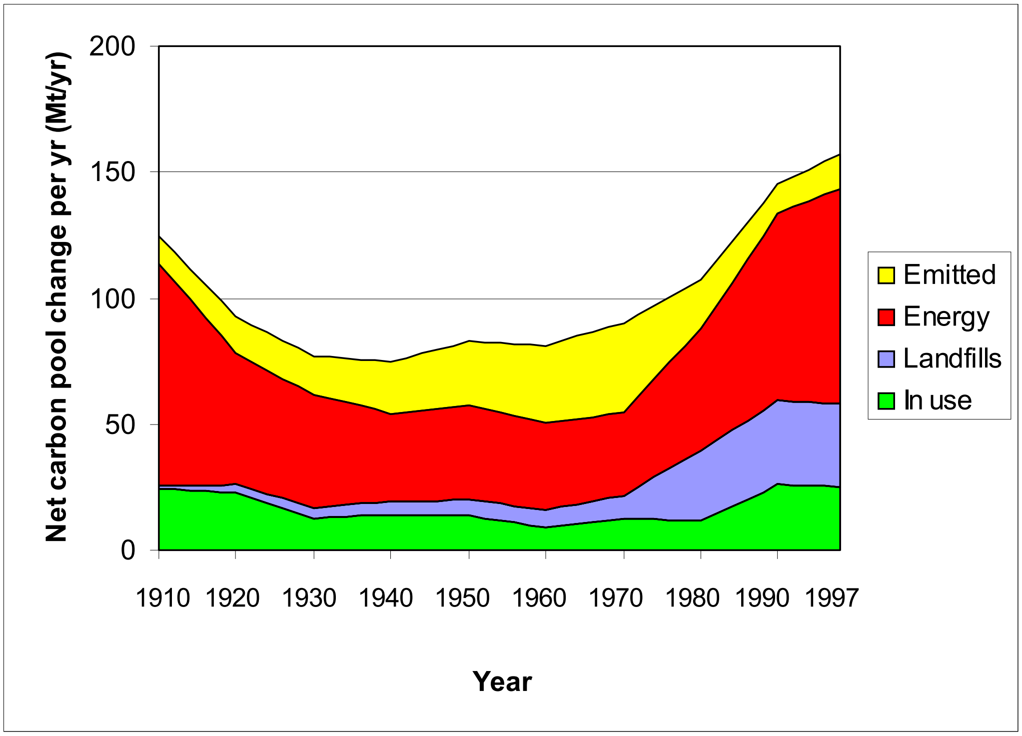
Source: (Skog and Nicholson, 2000)

Table 28-2 Removal of carbon from the atmosphere to wood products, using the atmospheric-flow approach (Mt/yr carbon).

Year	Change in products in use (1)	Change in products in dumps & landfills (2)	Total change in stock of carbon in products (3)=(1) + (2)	Net imports of wood products (4)	Removal of carbon from atmosphere to wood products (5)=(3)-(4)
1990	26.0	33.4	59.4	2.3	57.1
2000	25.0	32.5	57.5	3.3	54.2

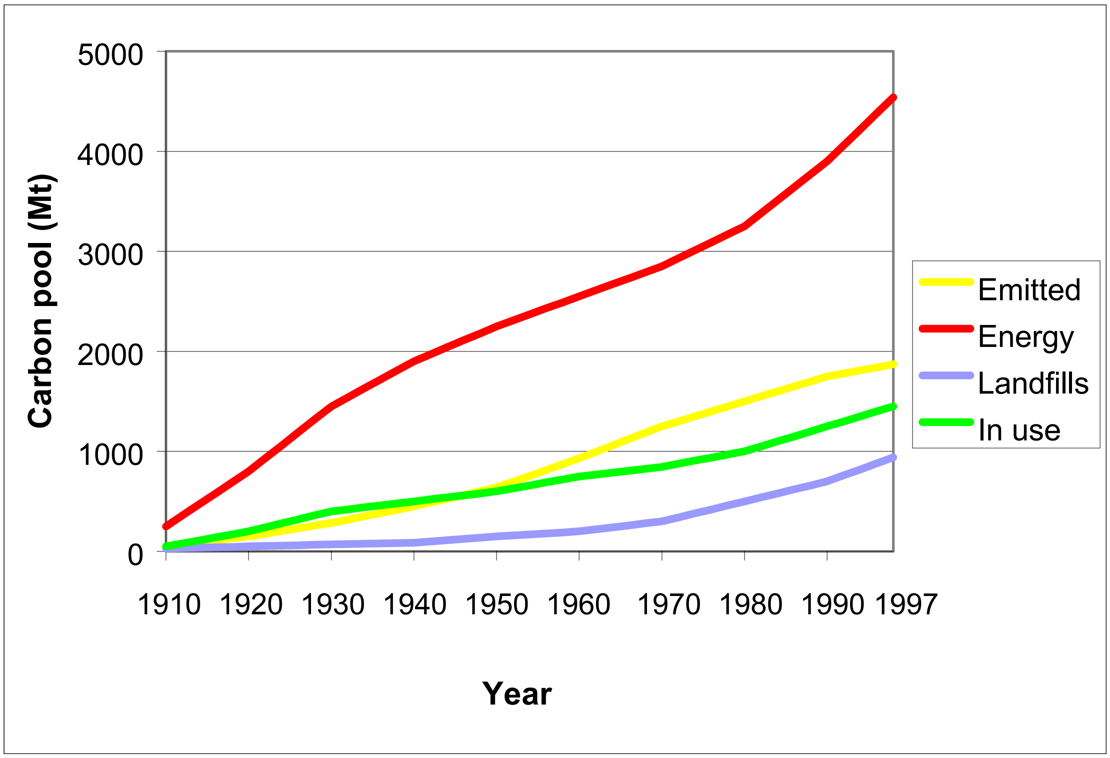
Source: (Skog and Nicholson 2000)

Figure 28-1. Net changes in carbon in harvested wood products pools (Mt/yr) for the U.S., including carbon in net imports, from 1910 to 1997. Note that all categories are shown as positive values, although the emitted and energy categories indicate the amount of carbon released to the atmosphere.



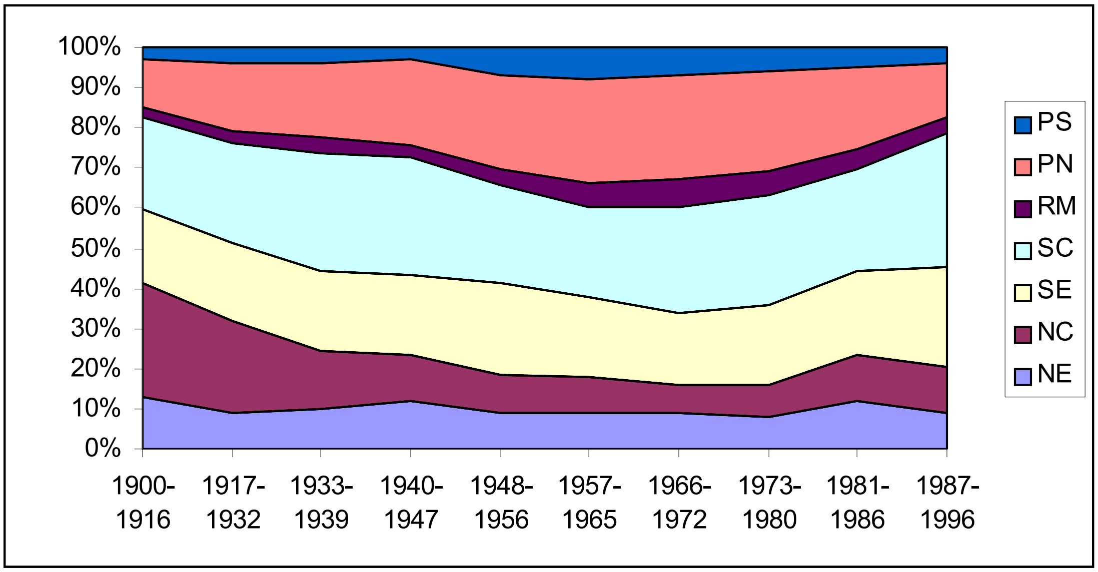
SOURCE: Skog and Nicholson, 1998.
NOTE: Emitted refers to emissions produced from harvested wood without capture of energy produced, and Energy refers to emissions produced from harvested wood with capture of energy produced.

Figure 28-2. Cumulative disposition of carbon in harvested wood products pools (Mt) for the U.S., including carbon in net imports, from 1910 to 1997. Note that the two emissions categories, emitted and energy, are shown as pools of positive value for comparison purposes to carbon in in-use and landfills categories.



SOURCE: Skog and Nicholson, 1998.
NOTE: Emitted refers to emissions produced from harvested wood without capture of energy produced, and Energy refers to emissions produced from harvested wood with capture of energy produced.

Figure 28-3. Proportion of roundwood products harvest in each region, relative to total roundwood products harvest for the conterminous United States. Although the data were collected only periodically for one specific year, they are being applied to every year of the period between data collection and the previous year of data collected.



Regions: NE=Northeast, NC=North Central, PN=Pacific Northwest, PS=Pacific Southwest, RM=Rocky Mountain, SE=Southeast, SC=South Central. Regions follow the regions in Smith and others (2001), with the exception that the Great Plains States are compiled with the NC region.