Status and Progress in Large-Scale Assessments of the Productive Capacity of Forest Ecosystems in the United States

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The Montreal Process is a forest sustainability reporting framework adopted by 12 temperate–boreal nations consisting of 7 basic criteria and 64 indicators. This article focuses specifically on criterion 2, maintenance of the productive capacity of forest ecosystems, and its five indicators: area of forestland and net forestland available for timber production; growing stock and annual increment on forest available for timber production; area, percent, and volume in plantations; and annual removals of nonwood forest products (NWFP). We compare historic and current inventory processes, discuss the implications of each, present criterion 2 indicator highlights, and identify gaps in our current knowledge.

In general, the productive capacity of US forests is strong. Forest and timberland areas have been stable for over 50 years, net growth continues to exceed removals, growing stock volume is up 51% since 1953, and planted forests continue to increase in area and provide a larger share of the nation’s annual wood production. NWFPs continue to be difficult to track but progress has been made.

Keywords: forest area, volume, growth, planted forest, timber harvest, nonwood products, annual inventory

As a result of the United Nations Conference on the Environment and Development (UNCED) in Rio de Janeiro, Brazil (UNCED 1992), the Montreal Process criteria and indicators (C&I) for the conservation and sustainable management of temperate and boreal forests were developed and agreed to by the United States and 11 other countries (Argentina, Australia, Canada, Chile, China, Japan, Korea, Mexico, New Zealand, Russian Federation, and Uruguay). This group of nations represents 90% of the world’s temperate and boreal forests, 60% of all forests, 35% of the world’s population, and 45% of world trade in forest products.

Within the C&I framework, the 7 criteria represent broad-level values or general categories of attributes associated with sustainability of forests and 64 indicators are specific measures within these criteria. The Montreal Process criteria include (1) conservation of biological diversity; (2) maintenance of productive capacity of forest ecosystems; (3) maintenance of forest ecosystem health and vitality; (4) conservation and maintenance of soil and water resources; (5) maintenance of forest contribution to global carbon cycles; (6) maintenance and enhancement of long-term multiple socioeconomic benefits to meet the needs of societies; and (7) legal, policy, and institutional framework. Although we will only address criterion 2 in this article, it is important to note that when evaluating overall sustainability of the nation’s forests a synthesis of the information from indicators within and between criteria is essential. More general information on the Montreal Process may be found at www.rinya.maff.go.jp/mpci/ or www.mpci.org, and specific information about the US implementation may be found at the Forest Service sustainability website (US Forest Service 2010).

Montreal Process criterion 2, maintenance of the productive capacity of forest ecosystems, is quantified by five indicators: area and percent of forestland and net area of forestland available for wood production; total growing stock and annual increment of both merchantable and nonmerchantable tree species in forests available for wood production; area, percent, and growing stock of plantations of native and exotic species; annual harvest of wood products by volume and as a percentage of net growth or sustained yield; and annual harvest of nonwood forest products (NWFP). For nearly 70 years, the United States has used a nationwide forest inventory system to document the status and trends in forest distribution, volume, composition, ownership, and use. This article compares historic and current inventory processes, discusses the impli-

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Progress in Indicator Data Acquisition

Forest Inventory

The Forest Inventory and Analysis (FIA) program of the US Forest Service became the world’s fourth continuous nationwide forest inventory with Congress’ passage of the McSweeney-McNary Research Act in 1928. Under the original legislation, the US Forest Service was charged with conducting forest inventories collaboratively with state agencies on a state by state basis with the intent of repeat inventories every 10 years in each state. National assessments were historically compiled by taking the most recent periodic inventory from each state and aggregating them for national reports with data labeled with a nominal report year (e.g., 1953, 1963, 1970, 1977, 1987, 1992, 1997, 2002, and 2007). State inventories were occasionally updated to the assessment year but this was not a general practice. Since the 1997 national assessment, each report includes an appendix showing the actual dates of state inventories used for the nominal assessment date. A brief description of the historic inventory process is available by VanHoozer et al. (1993).

In 1998, an amendment to the 1978 legislation was included in the Agricultural Research, Extension, and the Education Reform Act (PL 105-185) changed the process of FIA forest inventories in the United States. The amendment requires that states no longer be monitored periodically but rather on an annual basis with a target measurement goal of 20% of all sample plots per state per year (5-year cycle). Currently, congressional funding targets allow for measuring 15% of plots annually (7-year cycle) in the East and 10% of plots annually (10-year cycle) in the West. Most eastern states have augmented congressional funding to measure 20% of plots annually. A description of the current process may be found in a study by Bechtold and Patterson (2005) and in field manuals and other documentation (US Forest Service 2004, 2010).

Timber Removals

Timber harvest affects a low percentage of the standing inventory in the United States annually, generally less than 2% by volume, and field sampling does not provide adequate information for accurate estimates at substate levels. An auxiliary survey method routinely canvasses all the primary wood using mills in the United States to provide more reliable data at smaller scales. This has been done as part of the FIA program since 1947. The general process is described by Blyth and Smith (1979), Smith (1991), and Morgan et al. (2002). Although the annualized inventory will provide estimates based on harvested tree measures, the mill canvass method will likely remain in effect on an annual or biennial basis to allow reliable current reporting at substate levels.

Nonwood Forest Products

Much of this data has only been routinely compiled in the United States since the 1990s and data are not widely available on a national scale. In 2003, estimates of NWFP demand were based primarily on permit sales on public lands in the United States, combined with export data from the US International Trade Commission. Regional and local studies were used as supplemental data. In the US Sustainability Report for 2010 (US Forest Service 2010), the available data appear to be more consistent than in 2003 (US Forest Service 2004) and are available on a yearly basis. The 2010 analysis of NWFP again used permit sales on public lands and permitted harvest quantities were reported. A few new data sources were available, including biannual trade data reporting on the harvest of select medicinal plants and special studies of specific species.

Implications of Changes in Indicator Data Acquisition

Forest Inventory and Timber Removals

The implications of recent changes in the FIA inventory process to annualized inventory have been significant and the 2010 report had current data for 88% of the nation’s timberland compared with 24% for the 2003 report. During historic periodic national assessments, usually about one-half of the states have data less than 5 years old as depicted in Figure 1 for 1997. However, because of the transition from periodic inventories to annualized inventories that began in 1999, the first National Report on Sustainable Forests, dated 2003, was based primarily on older data from periodic state inventories used in the 1997 assessment and close-out periodic inventories after 1997 and thus has a higher percentage of data more than 5 years old.

The annualized inventory will provide more consistent and reliable data, especially when researchers want to look at subnational data in large countries such as the United States. Beginning in 2010, annual-

Figure 1. Age of available inventory data for 1997 National Assessment (Resource Planning Act [RPA]) and the 2003 and 2010 National Reports on Sustainable Forests.
ized data will be collected in all states excluding interior Alaska; thus, by the next national reporting cycle of 2012–2015, current data will be available for nearly all the country. In addition, more frequent primary mill surveys since 1999 have had a similar impact on removals reporting.

Trend data for longer periods will be more reliable than for shorter periods because this tends to even out differences between periodic assessments. Thus, if trends are only viewed between the 2003 and 2010 data in the National Reports on Sustainable Forests, rather than the full span of more than 50 years of available data, the resulting analysis could be misleading. This article will focus on the full span of available data.

**Nonwood Forest Products**

The NWFPs section of the 2010 report was expanded to encompass the new data sources available, and trends were available based on permitted harvest quantities on public lands. Approximations based on contract and permit data were estimates only, because they represent the volume of permitted harvest rather than actual harvest. Data and trends remained incomplete (see Data Gaps section of this article) for NWFPs, despite gains in available data.

**Major Trends in Criterion 2 Indicator Data**

The following discussion is based on the authors’ work for the 2010 National Report on Sustainable Forests and the five indicators of productive capacity. The primary wood availability data for this criterion is timberland variables reported in Smith et al. (2009). Timberland is forestland that is producing or is capable of producing crops of industrial wood with growth in excess of 20 ft³/ac per year and not withdrawn from timber use by statute or administrative regulation, including areas that may currently be inaccessible or inoperable. Timberland excludes reserved forests such as parks and wilderness areas and forests with low growth potential such as juniper, mesquite, scrub oak, or slow-growing forests of interior Alaska.

**Area and Percent of Forestland and Net Area of Forestland Available for Wood Production**

Forests cover about 751 million ac (nearly one-third of US land area), have been relatively stable for over 50 years, and are nearly equally distributed between East and West. Figure 2 indicates 387 million ac of forestland in the East (combined North and South regions) and 365 million ac in the West (combined Rocky Mountain, Pacific Coast, and Alaska regions). Timberland, likewise, has been stable for over 50 years and comprises the largest overall category of forest with 514 million ac nationally but differs dramatically in distribution compared with all forestland; 368 million ac (72%) of timberland is in the East and 146 million ac (28%) is in the West. This is not surprising considering the lower productive capacity of forestland in the more arid interior West and slower-growing regions of interior Alaska. Timberland currently comprises 68% of all forestland in the United States, 95% of all forestland in the East and 40% of all forestland in the West.

**Total Growing Stock and Annual Increment of Both Merchantable and Nonmerchantable Tree Species in Forests Available for Wood Production**

US forests contain over 800 species of trees. Changing markets and technology dictate species used for wood products; thus, “nonmerchantable” status is difficult to assign any given species except those of very small stature or those with rare, threatened, or endangered status. Generally speaking, about 94% of all live tree volume on timberland in the United States is growing stock or wood capable of being used for commercial products. The remaining 6% of trees on timberland are generally of poor form, small stature, or otherwise unsuited for wood products.

Figure 2. Timberland and nontimberland forest area by region, 1953, 1977, and 2007.

For the most part, growing stock volume has been increasing on timberlands throughout the nation (Figure 3) for the last 50 years. An exception occurs in the Pacific Coast and Alaska where large-tree timber harvests and losses of high volume timberlands to reserves resulted in declines in the 1970s and 1980s, a trend that has reversed with policy changes resulting in sharp reductions in harvesting combined with a slowing of lands set aside as reserved forests in the region.

Since 1953, total growing stock volume in the United States has increased 51% from 616 billion ft³ to 932 billion ft³. Softwood growing stock volume totals 529 billion ft³ or 57% of all growing stock and is concentrated primarily in the West and South. Hardwood volume, at 403 billion ft³, accounts for 43% of all growing stock volume and is concentrated in the North and South (where 90% of all hardwood volume is found). Hardwood volume has risen 118% since 1953 as second- and third-growth hardwood forests continue to mature.

**Area, Percent, and Growing Stock of Plantations of Native and Exotic Species**

For this indicator, the United States adjusted its reporting to include all planted forest and timberland to capture areas where planting has affected forest composition compared with areas of natural regeneration. There are two types of planting in the United States: traditional plantations of intensively managed trees where other vegetation is actively suppressed and planting to augment stocking of naturally regen-
erating forests. The former predominantly occur in the East and the latter predominantly in the West. The United Nations Food and Agriculture Organization (FAO) has made this adjustment from reporting plantations to reporting planted forest as well in the global 2010 Forest Resources Assessment to be released in late 2010. It is likely that the Montreal Process will review a possible revision in this indicator before the next reporting cycle in 2015. From a biodiversity perspective, most of the world’s planted forests consist of nonnative species (FAO 2006, Carle and Holmgren 2008). The United States, countering this norm, contains about 10% of the world’s total planted forests, and 99% of these stands are of native species.

Overall, planted forests account for 8% of all US forestland and 12% of timberland (Figure 4) and are predominately comprised of softwood species. This is significantly up from about 1% of timberland in 1953. In the West, planted forests comprise 12.2 million ac or 19% of all planted timberland with about 95% of western planted acreage occurring in the Pacific Coast region. In the East, planted forests comprise 51 million ac or 80% of all planted timberland nationally. Most eastern planted forests are in the South, which supports 45 million ac (71%) of all planted timberland nationally. Total planted forests have risen from about 5 million ac in 1953 to 63 million ac today.

Over the last 50 years more than 100 million ac of forest have been planted in the United States, including replanting after harvest of previously planted stands, conversion of natural stands, and afforestation of nonforestland. Incentive programs such as the Soil Bank Program in the 1950s (Soil Bank Act of 1956, PL 84-540, Title I) and the Conservation Reserve Program during the 1980s and early 1990s (Food Security Act of 1985, PL. 99-198) resulted in the establishment of millions of acres of planted forest. Although most of these planted forests were established on private land, public funding was often provided as assistance to landowners. Additionally, forest industries have historically leased private forestland or offered management assistance to private landowners to establish or maintain planted forests for future wood supplies. Planted forest acreage continues to rise in the South and accounts for 22% of all timberland in the region. Increases at the current rate are not likely to continue as incentive programs subside and as previously planted stands continue to be harvested and replanted but the new planting rate slows (Smith et al. 2009). Changing ownership patterns will also impact the future of planted forests, as many traditional forest industries have divested their timberlands to Timber Investment Management Organizations and Real Estate Investment Trusts. The full consequences of this major change are still to be fully evaluated. It should be noted that although forest planting is common in the United States, fully two-thirds of all of the average 11 million ac of forest harvested in the United States annually still regenerate by natural means unless converted to nonforest use.

Nationally, planted forests contain about 75 billion ft³ of growing stock inventory or about 8% of total growing stock (Figure 5). This lower proportion of total inventory relative to the percentage of all timberland planted (12%) is usually caused by the generally younger age class structure of planted forests that are managed and harvested on shorter rotation periods than natural forests. In the South, planted stands are currently providing 43% of the regional softwood removals. The continued increase in planted acres, although at a slower pace, suggests plantations will continue to increase in total harvest share.

Nationally, softwoods such as loblolly pine (Pinus taeda) and shortleaf pine (Pinus echinata) in the East and Ponderosa pine (Pinus ponderosa) and Douglas-fir (Pseudotsuga menziesii) in the West overwhelmingly dominate planted forests. High-value hardwoods such as black walnut (Juglans nigra) and select oaks (Quercus spp.) are also planted.

**Annual Harvest of Wood Products by Volume and as a Percentage of Net Growth or Sustained Yield**

Sustained yield is a difficult value to determine because it depends on the area of timberland available and its ability to remain stable and produce goods and services indefinitely. There is no one set value of sustainability for overall forest production. Overall production depends on the age and composition of the forest and the objectives of millions of forestland owners that constantly alter potential product output. The data presented here merely imply sustainability as a net value where more goods and services are produced than lost over a long period of time. No attempt is made here to evaluate the quality of those goods and services.

Net growing stock growth has exceeded removals on US timberlands for over 50 years (Figure 6) while the area of timberland has remained relatively stable (see Figure 2), resulting in a substantial increase in total growing stock volume. Positive trends in growth on timberland since 1952 are attributable to several factors including positive regrowth and maturation of forests on lands harvested before 1952, investments in fire protection, landowner education, and improved management. Currently, overall growing stock removals are 58% of net annual growing stock growth.

Historically, most harvest occurs on private timberlands in the East and recent data show a further shift of removals from public timberland in the West to private timberland in the East, predominantly the
South, as policies that reduced harvesting on public lands in the West were implemented. Thus, growth has been exceeding removals by a wider margin in the West while the gap has been decreasing in the East. Interpreting growth trend data in the West, particularly on public land, can be complicated by the reductions in harvesting and placement of large areas of public timberland into reserves since the mid-1970s; thus, some of the timberland declines are an artifact of this situation and not a real decline in overall growth.

Although the removals shift from West to East is noteworthy, recent softwood plantings in the South are rapidly reaching commercial size and are expected to improve the softwood growth versus removals situation in that region. Current growth measures in the South may not fully reflect anticipated growth on these planted forests. Currently, 91% of the nation’s total wood output is produced on private lands and 61% comes from private forests in the South.

**Annual Harvest of NWFPs**

The demand for specific NWFPs, if based on the number of public permits requested alone, varies widely from year to year with few distinct directional trends through time. Permit requests and harvest quantities typically follow a supply and demand model, with prices for various products driving pressures on the available resource. Social trends related to health (medicinal plants), diet (edible plants), and décor (arts, crafts, and floral products) also play a role in the demand for particular categories of NWFPs over time.

Harvests of medicinal plants (Figure 7) occur throughout the United States, although the majority of economically important species reported by the American Herbal Products Association (AHPA 2007) are supplied by the temperate forests of the Eastern United States. In addition, although not shown in the top six, saw palmetto (*Serenoa repens*, a medicinal fruit used to relieve stomach irritation) harvests nearly doubled in volume from 2004 to 2005 (the latest available AHPA reporting period) and were nearly five times the reported quantities in 1999.

Permuted harvests of edible fruits, nuts, berries, and sap on public lands nearly doubled from 1998 through 2007 (Figure 8), as well, reflecting a potential increase in the demand on the resource. Permit issuance for edible plants was highest along the Pacific Coast of the United States, an area where wild-harvesting mushrooms and other fungi are a common activities. Maple syrup production, an important edible NWFP in the Northeastern United States (Figure 9), has remained stable since 1998 in most states except Vermont, which has nearly doubled its production (USDA National Agriculture Statistics Service 2007). Only one-half of 1% of maple taps was permitted taps on public land, suggesting that most maple syrup is produced on privately owned land and exemplifying the need for more information regarding NWFP harvests on private lands.

**Data Gaps and the Path Forward**

**Forest Inventory and Removals**

Beginning in 2010, the FIA annualized inventory is active in 49 of 50 states and coastal Alaska. Thirty-eight states had annualized inventory data for the 2010 National Report on Sustainable Forests, compared with zero states using the annualized system for the 2003 report. Interior Alaska is the remaining area for inclusion in annual inventory and reporting after 2010. Although interior Alaska will likely represent only a minimal portion of the nation’s timberland because of low growth potential, it does represent about 15% of all US forests (over 100 million ac) with significant implications on climate change monitoring, carbon accounting, biodiversity, and other issues.

Because of the need to provide carbon data to the Environmental Protection Agency to report to the Intergovernmental Panel on Climate Change, the FIA is developing a national carbon accounting system to provide data for all major forest carbon pools (trees, understory vegetation, down woody material, litter, and soil carbon). Sampling protocols have been developed and preliminary baseline data have been provided for the entire nation. Additional efforts are focused on improving forest products life-cycle tracking information and annualized accounting of timber products output to assist in full carbon accounting for forests.

**Nonwood Forest Products**

With regard to NWFPs, although some new data were available and some previously available data appeared to be more consis-
tent, some data sources had not been updated from 2003 to 2010. The available data are still largely incomplete with regard to the breadth of NWFPs harvested and used in the United States and do not represent the full range of products on the market. Additionally, the data do not represent the quantity of products harvested without permits, which are often estimated at many times more than that harvested with permits.

A primary difficulty with assessing the sustainability of NWFPs in the United States is the lack of baseline information on each of the products in question, combined with the overall difficulties inherent in monitoring many different products collected on both public and private land. Additionally, biological and ecological knowledge is lacking for many species collected for NWFPs. Therefore, the biggest aid to increasing the sustainability of NWFPs in the United States would be an influx of funding geared toward the study of species lacking data, their habitats, uses, and current and projected markets. NWFP reporting will continue to have tracking challenges that offer many research opportunities.

**Conclusion**

The Montreal Process criterion 2 undoubtedly has the strongest data set available of all the criteria with exception of NWFPs. The FIA program has a long history of consistent definitions and data relative to timberland. Although there have been minor adjustments to the definition of forest over the years, generally related to the percent of tree cover necessary for classification, the impact has primarily been on nontimberland and thus has had little impact on the

![Figure 6. Growth and removals of growing stock on timberland by owner group and region, 1952–2006 (Alaska is included in Pacific Coast for this graphic).](https://academic.oup.com/jof/article-lookup/10.5849/jofv2011-109)

![Figure 7. Quantity of top six wild-harvested dried plants (excluding saw palmetto) for 1999–2005 as reported by the AHPA. (Data source: American Herbal Products Association 2007.)](https://academic.oup.com/jof/article-lookup/10.5849/jofv2011-109)


![Figure 9. Maple syrup production by state(s) and year. (Data source: USDA National Agriculture Statistics Service 2007.)](https://academic.oup.com/jof/article-lookup/10.5849/jofv2011-109)
analysis of criterion 2 in the Montreal Process for the United States. Given that timberland and reserved forests (which would mostly be classified timberland if not preserved) comprise 87% of all forestland in the 48 coterminous states and 79% of forest in all states, the data for trend analysis in criterion 2 is far superior to data available for the other criteria.

Overall, the findings of the Montreal Process criterion 2 for the United States indicate that forest and timberland areas continue to remain stable, overall volume continues to rise as net growth has exceeded removals for over 50 years, and planted forests continue to increase area and provide an increasing share of wood production. NWFPs continue to be a challenge but more data and sources of information are becoming available.

The reader is encouraged to visit the 2010 National Report on Sustainable Forests website for more detailed information and analysis on all of the Montreal Process criteria and indicators for the United States (US Forest Service 2010). The 2010 report is scheduled for publication in late 2010.

Literature Cited


