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William H. McWilliams
Brett J. Butler
Lawrence E. Caldwell
Douglas M. Griffith
Michael L. Hoppus
Kenneth M. Laustsen
Andrew J. Lister
Tonya W. Lister
Jake Metzler

Randall S. Morin
Steven A. Sader
Lucretia B. Stewart
James R. Steinman
James A. Westfall
David A. Williams
Andrew Whitman
Christopher W. Woodall

Northeastern
Research Station

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Abstract

In 1999, the Maine Forest Service (MFS) and USDA Forest Service's Forest Inventory and Analysis (FIA) program implemented a new system for inventorying and monitoring Maine's forests. A salient feature of the new inventory process is a nearly threefold improvement in timeliness as full inventories are completed every 5 years. The 2003 results represent the first full set of annual inventory and growth data since the end of the extreme spruce-budworm epidemic (SBE) of the 1970's and 1980's. The effects of the SBE continue to affect the composition, structure, and distribution of Maine's forested ecosystems. Insight into current forest dynamics will help stakeholders plan for potential future disturbances like SBE. The area of forest land in Maine has remained stable since the 1970's. Although relatively small acreages of forest are converted to other land uses these conversions often remove highly valued forests such as white pine. The total inventory volume of live trees increased slightly, indicating the beginning of a response of Maine's forest to the tremendous devastation from SBE. The spatial distribution of sapling-size spruce and fir across the State reveals a general abundance of regeneration, foretelling waves of merchantable wood in coming years.

The Authors

WILLIAM H. MCWILLIAMS, BRETT J. BUTLER, DOUGLAS M. GRIFFITH, MICHAEL L. HOPPUS, ANDREW J. LISTER, TONYA W. LISTER, RANDALL S. MORIN, LUCRETIA B. STEWART, and JAMES A. WESTFALL are foresters with the Northeastern Research Station's Forest Inventory and Analysis unit in Newtown Square, PA. JAMES STEINMAN is a forester with Northeastern Area State and Private Forestry. CHRISTOPHER W. WOODALL is a research forester with the North Central Research Station's Forest Inventory and Analysis unit in St. Paul, MN. LAURENCE E. CALDWELL is a private forestry consultant, Turner, ME. KENNETH M. LAUSTSEN is biometrician with the Maine Forest Service, Augusta, ME. STEVEN A. SADER is a professor of forest resources and JAKE METZLER is graduate student, with a University of Maine, School of Forest College of Natural Sciences, Forestry, and Wildlife, Orono, ME. DAVID W. WILLIAMS is an entomologist with the USDA Animal and Plant Health Inspection Service, Otis ANGB, MA. ANDREW WHITMAN is research scientist with Manomet Center for Conservation Sciences, Brunswick, ME.

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Scott Barnes
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Joshua Brown
Bob Chandler
Aaron Clark

Everett Cram
Ronna Coleman
Mike Devine
Jamie Dow
Kristen Dubord
Melanie Duffy
Dan Edgecomb
Matthew Gallucci
Jeff Harriman
John Hoyt
Allison Kanoti

Keith Kanoti
Catherine Kropp
Jeff Martin
Brian McAuthur
Jason Morrison
Kathy Murray
Stephen Pawlowski
Alexander Peacock
Dan Peers
Scott Peterson
Brian Reader

Mike Skinner
Grayln Smith
Christina Stacey
Eric Therriault
Jonathan Tyler
Jeff Wazenegger
Charles Willette

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Brief

In 1999, the Maine Forest Service (MFS) and the USDA Forest Service's Forest Inventory and Analysis (FIA) program implemented a new system for inventorying and monitoring Maine's forest resources. The most salient benefit of the new system is a nearly threefold improvement in timeliness. The extension of the sample includes a broader range of measurements that will help analysts understand the relationships between resource change and underlying ecological variables. The following is a summary of resource conditions, a prospective future outlook, and policy implications related to the principal findings of this report:

Resource Conditions

- With 17.7 million acres of forest land, Maine is the most heavily forested state in the Nation at 90 percent. The State's forest has been essentially stable for the last several decades (Fig. 1).
- There have been multiple shifts in acreage among owner groups during the last 45 years. Public ownership has steadily increased yet it constitutes a small portion of Maine's forest land. The ownership of Maine's large private forests is changing. Over the last several decades, industrial owners have reduced their holdings while a new category of investor owners that includes timber investment management organizations, real estate investment trusts, and limited liability corporations have increased their holdings (Fig. 2).
- Unlike forests in other timber-producing states, most of Maine's forests are naturally regenerated stands that are managed extensively (Fig. 3). These stands comprise 44 commercial tree species. Species with the most trees 1 inch or larger in diameter in breast

height (d.b.h.) are balsam fir (35 percent), red maple (12); red, white, and black spruce (11), and sugar maple, yellow birch, and American beech (11). This indicates these stands are diverse and closely resemble “natural” forests. The small portion of Maine’s forest that is managed intensively include plantation, precommercial thinning (spacing), and conifer release (Fig. 4).

- Maine’s underlying forest habitat is 38 percent hardwood and 62 percent softwood types (Fig. 5), but this acreage currently is occupied by 59 percent hardwood and 41 percent softwood forest types. This is an artifact of mixed-wood stands and recovery following spruce budworm outbreaks, and reflects the difference between FIA estimates of existing vegetative cover and habitat classification that represents potential natural vegetation of a site.
- The volume of timber on Maine’s forests is nearly double that in 1952 (Fig. 6). Current estimates of growth and harvest are essentially equal (0.35 cord/acre/year).
- Regenerating forest stands in Maine generally is not a concern as natural regeneration typically results in as many as tens of thousands of seedlings/acre within several years of a disturbance. Over the long-term, the vegetative composition of these stands reflect the underlying habitat type.
- The major groupings and the current distribution of Maine’s timberland by stand diameter class reveal that one-fourth of Maine’s timberland is in sapling-size stands (Fig. 7). Poletimber and sawtimber-size stands account for 43 and 30 percent, respectively. Large sawtimber comprises only 9 percent of the timberland.
- The major groupings and the current distribution of Maine’s timberlands by stocking region is shown in Figure 8. Stocking regions are categories related to stand development

guides. About one-third of Maine's timberland is in the optimal class. The sub-optimal and overstocked classes account for 23 and 21 percent, respectively.

- Currently, timber is harvested on nearly 562,000 acres/year. Most of this activity consists of partial harvesting or shelterwood cutting (Fig. 9).
- Eastern white pine and six major hardwood species (sugar maple, red maple, yellow and white birch, aspen, and northern red oak) consistently account for 90 percent of the sawtimber volume usually graded for quality, and volumes of sawtimber have increased steadily over the 45-year inventory period (Fig. 10).
- White pine has shown a small but steady increase in the average size of sawtimber trees over the inventory period, peaking at 14.8 inches during the last 8 years (Fig. 11). The average diameter of the major hardwoods declined slightly but then recovered during the same period. The current average, 14.4 inches, and has remained stable over the last 8 years.
- Volume of sawtimber per acre of timberland is a measure used to assess trends. Both white pine (73 percent) and the major hardwoods (93 percent) have shown steady increases over the inventory period (Fig. 12).
- The stocking and distribution of large trees (at least 16 inches d.b.h.) greatly affect wildlife habitat, biodiversity, and stand structure. The relative distribution of large trees in Maine's forests is shown in Figure 13.
- The distribution of sawtimber volume by tree grade (quality) for the two most recent inventories shows improvement for sugar and red maple, yellow and white birch, and aspen. This improvement is apparent from the increase in the percentage of grade 1 and 2 material. When all sawtimber size classes are considered, the quality of white pine

decreased while northern red oak showed little change. However, the distribution is influenced heavily by tree size. When only trees at least 15 inches d.b.h. are considered, white pine shows little change while northern red oak improves slightly (Fig. 14).

- Certain species of lichens occur only on older trees. The distribution of those species is shown in Figure 15.
- Terminal harvests constitute a large share of total harvests for white pine and northern red oak--24 percent and 38 percent, respectively, of total annual removal.
- The continued vigor of beech is at risk due to factors such as drought and disease. Areas with the greatest impact are shown in dark red in Figure 16.
- To date in Maine, assessments of forest health by FIA have not revealed ozone-related plant damage.
- FIA data indicate that Maine's forests have a low diversity of shrub/vine species. Only 30 percent of the plots samples contain more than four of the species tallied, most of which are deciduous shrubs. Many deciduous shrub species have tremendous value to wildlife.
- Maine's forests have high fuel loads and, therefore, an extremely high fire risk at long intervals associated with prolonged drought. These conditions occur when organic material in soils dries to the point that it becomes flammable.

Outlook

- If growth and harvest rates are maintained at current levels, timber volumes will remain stable and then likely increase as stands recovering from spruce budworm outbreaks grow to merchantable size.

- The long-term implications are of the increased frequency of harvesting Maine’s forest resources are unclear. Timber harvesting has increased from nearly 250,000 to more than 500,000 acres annually, and has shifted from clearcutting to largely “partial harvesting.”
- It is not known how long the reversion of agricultural land throughout the state will continue to balance the amount of land converted to development (mostly in southern Maine).
- That harvests from site conversions account for 24 and 38 percent of the annual harvest for white pine and red oak, respectively, has implications for the future supply of these species.
- With respect to the timber supply, the importance of small nonindustrial private forest-land owners is increasing. Because of the large number of these owners, the fragmented spatial distribution of their forests, and a perceived reluctance to harvest, it is difficult for resource planners to coordinate management strategies.
- It is not known how changes in land ownership in Maine (e.g., number of small ownerships and shift from the forest industry owners to investors) will affect long-term timber management and availability.
- Invasive exotic pests likely will pose a greater threat in the future. For example:
 - Balsam woolly adelgid, which in the past has been limited to the coastal area of Maine, has expanded to inland areas and is causing significant mortality of balsam fir.

- Hemlock woolly adelgid is now established in extreme southern Maine and is expanding northward.
- Maine's forests could be threatened by the emerald ash borer, which is expanding from Michigan, and *Phytophthora ramorum*, which causes sudden oak death. The latter is expanding from nursery stock in California, but it is not known whether *P. ramorum* can survive in Maine's climate.
- If current trends continue, there will be declining inventories of species such as beech (largely because of bark scale disease) and aspen. At the same time, there will be increased inventories of species such as sugar maple, white ash, northern red oak, and yellow birch. These changes will influence wildlife habitats and other resource values.
- With respect to changes in stand structure on an acreage basis, the impact of the spruce-budworm epidemic in Maine rivals that of other forest disturbances in the Eastern United States over the last century. Merchantable-size stands will reemerge over the next 25 years as waves of young spruce-fir mature. The result will be a large block of acreage in a relatively even-age condition, much like the condition of spruce-fir early in the last century.
- Because the most recent FIA data have not been modeled, we cannot accurately predict when the new sapling-size stands of spruce-fir in areas affected by spruce budworm mortality or salvage harvests will grow to merchantable size for harvesting.

Policy Implications

- The annual inventories of Maine’s forest resource have been extremely valuable and will continue to provide information needed for informed decisionmaking on forestry issues. The diversity of the underlying forest stands and associated issues elevate the importance and complexity of these inventories. The data generated are particularly important in addressing both timber and nontimber values, for example, assessing wildlife habitat conditions and biodiversity and predicting the vulnerability of Maine’s forests to invasive exotic pests.
- Monitoring growth and harvest levels and predicting future growth rates will require careful attention, particularly for species like white pine and red oak, which account for a large portion of the harvest due to site conversion.
- Growth and yield modeling and modeling of future forest conditions at the stand level are needed so that we can:
 - Predict when sapling-sized spruce-fir stands will grow to merchantable size.
 - Monitor species-specific inventory gains and declines and their effect on the timber supply, quality trends, wildlife habitat, and other ecosystem values.
 - Increase timber yields from Maine’s forests through improved utilization and more intensive management.
 - Improve our understanding of the trends in the quality of timber for Maine’s forest- products industry.

- Planning for wildfire suppression in Maine should take into account that, at long intervals, the threat of fire is extremely high when soil organic matter dries to the point that it can burn.
- There is a need to evaluate the implications for timber supplies and other forest values of increasing the amount of acreage harvested annually, as well as the effect of shifting from clearcutting to partial harvesting.
- The potential threat from invasive exotic pests will require increased monitoring.
- There is a need to evaluate the impact on timber supply and other forest values from declining inventories of species such as beech and aspen, increasing inventories of species such as sugar maple, white ash, northern red oak, and yellow birch, and the reliance on timber volumes from site conversion for white pine and red oak.
- There is a need to evaluate the effect of changes in ownership (e.g., number of small landowners and shift from industry owners to investors) on timber supply/availability and the stability of the land base managed actively for forestry.
- The conversion of forest land to other uses threatens future sustainability in the southern portion of the State. Monitoring and evaluation of this trend should continue.
- The structural characteristics of forest land in Maine have undergone major changes. Currently, there are large blocks of forest in the early stages of succession; other areas contain one-, two-, and multistory stands. This more complex structure benefits certain nontimber values and may require new harvest and management strategies.

- Management planners must consider whether the abundance of balsam fir in the next forest (currently more than two-thirds of sapling-size trees) could make Maine's forests vulnerable to another spruce budworm epidemic as they mature.
- As Maine's young forest grows, considerable spruce-fir acreage will offer opportunities for intensive management, including precommercial thinning in stands less than 20 years old and commercial thinning in older stands. These activities can increase yields while reducing risk and mortality.
- Maine's spruce-fir forests tend to dominate management and policy discussions because of the importance of this type (e.g., special value in papermaking). However, there are many other forested ecosystems with important values and complex issues. For example, recent increases in demand for hardwoods for both pulp and sawlogs have created opportunities for managing and developing deciduous forests. Hemlock woolly adelgid could destroy hemlock across its range and the decline of beech affects the major source of hard mast for fauna.
- Public concerns for nontimber resources such as noteworthy plant and wildlife habitats, sensitive areas, water quality, biodiversity, and providing public access and recreation opportunities likely will continue to be high-profile forest policy issues for the foreseeable future.

Introduction

In this bulletin we analyze forest vitality (health) based on data from the first full annual inventory of Maine's forest resources conducted by FIA and the MFS. Previous annual reports have been published since the new annual inventory system was implemented in 1999 (MFS 2000; Griffith and Laustsen 2001; Laustsen and Griffith 2002; Laustsen and others 2003). Past periodic inventories were published in 1959 (Ferguson and Longwood 1960), 1971 (Ferguson and Kingsley 1972), 1982 (Powell and Dickson 1984), and 1995 (Griffith 1996). This first full report includes data collected over the first 5 years following the implementation of the new FIA annual inventory system. For simplicity, the 5-year inventory date is referred to as 2003.

Perhaps the most compelling objective of this report was to work toward merging FIA's national inventory protocols with the specific issues and needs of Maine's stakeholders. The degree to which this report serves the forestry community is a measure of success in meeting this objective. The process of customizing the inventory and analysis to the needs of Maine's clients is an ongoing process. Policy discussions aimed at improving the FIA inventory system began in earnest following the 1995 inventory of Maine. It was clear that periodic inventories with cycle lengths exceeding 10 years did not address the needs of the State's stakeholders. Both federal and State legislation of the late 1990's resulted in a federal mandate to conduct annual inventories across the US and a state mandate for Maine. The results of these early deliberations provided considerable input for developing improved analytical constructs for the new system.

A draft outline for this report was developed using the improved constructs and comments that emerged from discussions of previous annual reports. Then in the spring of 2004, two stakeholder listening sessions were held to solicit further suggestions. It was agreed that this

report should focus on the salient findings of the FIA inventory but also incorporate closely related data that clarify or extend the utility of the findings. For example, Bureau of Census population data provide information on the urbanization of forest land. The intent is to focus on basic findings of the inventory and avoid specialized analyses that are better addressed in separate studies. In some cases, it is recognized that existing FIA data may not fully quantify the required variables for a specific analysis. For example, the information on change components (net growth, removals, and mortality) will not be based on a full remeasurement of sample plots until the second 5-year cycle is completed. FIA indicators are presented as a geo-spatially where possible to gain insight into Maine's current forest condition, recent changes, and prospective future trends. The intent is to provide timely and relevant analyses for wise-use policies affecting the forest land base.

Spruce Budworm

The impact of the eastern spruce budworm underlies resource changes in Maine's forests. Two major outbreaks occurred in the past century. The most recent spruce budworm epidemic (SBE) began in the late 1960's and was a major force through the mid-1980's, devastating stands containing spruce and especially balsam fir (Brann and others 1985, Trial 1989). Salvage harvests began during the mid-1970's and harvesting remained heavy through the 1990's. As a result, removals have exceeded growth. High levels of fir and spruce mortality associated with harvest activity reduced the inventory (Ireland and McWilliams 1997). A map for outbreaks covering the SBE years clearly shows the significance of Maine's outbreaks (Fig. 17) as it depicts the frequency of occurrence of aurally detectable defoliation over the years 1954 to 1988. The severity of budworm activity varied considerably from stand to stand in a given year. Stands containing significant stocking of balsam fir were impacted most severely. The most extensive and severe damage from SBE in Eastern North America occurred over a large area of Aroostook County and New Brunswick, Canada. The effect of SBE on the ecology and management of Maine's spruce-fir forests has rivaled similar landscape-level disturbances in the Eastern United States by gypsy moth, southern pine beetle, and the large-scale conversion of natural pine stands to plantations across the Coastal Plain of the eastern United States. Throughout this report, such impacts are reflected in changes in the major habitat types, stand-diameter classes, and stocking levels; as well as inventory volume, net growth, removals, and mortality.

The Annual Inventory: Results from the First 5 Years

Forest Land

Location and Trends

Forests cover 17.7 million acres or 90 percent of the land area of Maine (Fig. 18; Appendix Table A1). Maine has the highest proportion of forest land of any state. The other primary land uses are agriculture (3 percent) and “other” (7 percent). All but 3 percent of the forested acreage is classified as timberland or forest land capable of producing commercial crops of wood and not restricted from harvest. Forest land includes reserved forest land in Baxter Park and other public holdings, unproductive forest land, and other lands that meet the FIA definition of forest but are not available for timber harvest.

At the time of European settlement around 1630, the estimated area of forest land in what is now Maine was 18.2 million acres (Smith and others 2001). As settlement increased, the area in forest land decreased (Irland 1999) (Fig. 19). This trend continued in Maine until the early 1900’s. The area of forest in the State peaked around 1971 and has been stable since then. The current estimate of forest land is not significantly different from the 1982 or 1995 estimates.

The use of inventory regions facilitates analysis of areas that are relatively homogeneous for variables such as physiography, climate, ownership, and management regimes. It is difficult to combine Maine’s counties into analysis regions because of their size and latitudinal breadth. For

example, Penobscot County spans well over a degree of latitude and includes both organized and unorganized territories. To overcome this difficulty, Maine’s inventory regions were combined into four megaregions (Fig. 20). Even these regions do not fully delineate the north-south differences in resource conditions.

Current estimates for the four megaregions confirm the stability of Maine’s forest-land base. No region is experiencing a great loss of forest land (Fig. 21). These changes in acreage are the net result of acreage entering and leaving forest land. Of the total FIA sample, only 37 samples representing about 220,000 acres shifted either to or from forest land. The distribution of those plots is:

| <u>Land Use</u> | <u>Additions to Forest</u> | <u>Diversions from Forest</u> |
|-------------------------|----------------------------|-------------------------------|
| Agriculture | 9 | 0 |
| Urban/other | 7 | 8 |
| Wet/water | 8 | 2 |
| Denied Access/hazardous | - | 3 |

Note: Denied access/hazardous samples are not measured, so it is not known whether the location is forested.

This does not minimize the importance of forest-land conversion that is occurring in populated (e.g. southern Maine) and other areas, nor its impact on wood availability.

Biophysical Regions and Watersheds

A complex mix of biotic and abiotic factors determines forest composition, structure, and function. Traditional geopolitical boundaries such as the FIA inventory regions are not always correlated with these natural phenomena. To place FIA data in an ecological context, they have been summarized by biophysical region and watershed.

Maine's diverse landscape can be mapped into logical reporting units using biological and physical characteristics. McMahon (1990) developed 15 biophysical regions for Maine (Fig. 22). McMahon (1998) refined the regions and harmonized Maine's regions with those of other eastern states (Keys and others 1995), increasing biophysical regions in Maine to 19. The earlier work of McMahon was used to overcome the statistical limitation of a small sample size associated with smaller polygons (Table 1).

Because there has been considerable interest in forest-inventory summaries by watershed, FIA samples were further summarized by U.S. Geological Survey hydrologic units at a level that maintains an adequate number of samples (Watermolen 2002)(Figure 23 and Table 2).

The biophysical regions and watershed summaries are examples of how FIA data can be used beyond traditional timber assessments. Other in-depth analyses could be conducted for specific

issues of interest. For example, a survey of tree-species diversity by watershed could add to current research related to the larger issue of biodiversity.

----- **END OF SIDEBAR 1** -----

Urbanization

Urban forests include trees and associated vegetation within urban, suburban, and industrial settings. These forests often differ from their rural counterparts in forest structure and function as they can be exposed to unique abiotic and biotic pressures associated with their proximity to cities (Zipperer and Pouyat 1995). Urban forests offer environmental benefits such as habitat for wildlife, aesthetic enjoyment, visual barriers, climate control, water improvement, and air and noise pollution abatement.

FIA has published estimates of urban forest area in previous statistical reports. These estimates are based on a visual inspection of the land uses surrounding each inventory plot. Forested sample locations that are bordered by developed land on three sides are designated as urban forest locations. Because of the subjective nature of this field-call for urban forest and the small number of plot locations sampled, the error associated with state- and county-level estimates of urban forest area is high. The FIA field classification is useful for local analyses but an alternative method for calculating urban forest area has been developed that identifies areas of forest within a state that fall in U.S. Census-designated urban areas or in areas of high population density. Urban forest statistics were calculated using data on forest-land distribution from satellite derived land-cover maps (Vogelman and others 2001) and urban area and population

data from the 2000 Census. For areas not officially classified as urban by the Census, population-density classes are displayed based on census tracts. Multi-Resolution Land Cover (MRLC) data are somewhat dated (1992) but allow a useful baseline estimate for comparison with a newer classification of 2002 data that is under development.

Less than 0.5 percent of Maine's forests is in urban areas designated by the U.S. Bureau of Census (Fig. 24). Cumberland County has the highest percentage of heavily populated urban forest with 16 percent. Most of Maine's counties have little forest land within densely populated areas (Table 3), particularly counties in the unorganized territories. This does not minimize the potential effect of urbanization on the availability of traditional resources from forests in an urban setting in some areas of Maine (Wear and others 1999).

Forest Land Ownership

FIA conducts the National Woodland Owner Survey (NWOS) as a social survey complementing the forest inventory. Data presented here are based on survey responses from 189 families and individuals who own forest-land in Maine. As with the base FIA program, the NWOS is implemented on an annual basis and estimates will improve as responses from additional forest-land owners are received. The NWOS website offers additional information:

www.fs.fed.us/woodlandowners.

Forest land in Maine is distributed evenly among families and individuals, forest industry, and other private groups (Fig. 25). Forest industry and other forest-management companies own the majority of forest land in the northern portion of the state, while families and individuals own a majority of the forest land in southern Maine (Fig. 26). Six percent of forest land is under the stewardship of public agencies. The State, primarily under the Bureau of Parks and Lands, is the dominant public owner and controls an estimated 743,000 acres of forest land (Table 4).

Private ownership of Maine's forest lands has been dynamic over the last 2 decades. Initially, millions of acres of forest land were transferred among forest industry firms as they merged and realigned landholdings. Eventually, a number of these companies became less inclined to own forest land and more willing to rely on wood procured on the open market. This more recent shift in corporate philosophy is driven by market forces and the desire to reduce debt and realign assets to concentrate on core businesses. Despite this shift in philosophy, forest-industry landholdings in the State are substantial.

As the landholdings of forest industry decreased, the area of forest land owned by other private entities increased. Between 1995 and 2003, the area of forest land in Maine owned by other corporate private owners increased by approximately 60 percent. The majority, 78 percent of this land came from forest industry with the remainder acquired from families and individuals. These other corporate private entities include institutional investors such as pension funds, and land acquired on the behalf of individuals; most of these lands are managed by private companies, including timberland investment management organizations.

As for nonindustrial owners, results from the NWOS indicate that an estimated 222,000 families and individuals own 5.7 million acres of forest land in Maine. They are the dominant land-ownership group in the southeast and south-central portions of the State. While three out of five of these owners own fewer than 10 acres of forest land (Table 5), the majority of the family and individual forest land is owned by people with landholdings of 50 to 500 acres (Fig. 27). Large parcels are common in the unorganized territories (Fig. 28).

The families and individuals have diverse ownership and forest management objectives. The most common reasons for owning forest land are related to aesthetics and privacy and/or the fact that the land is a part of a family legacy. Other common reasons for ownership include recreational opportunities, including hunting and fishing, land investment, and timber production (Table 6).

While about one-third of family and individual owners have harvested trees from their land in the past 5 years (Table 7), less than 5 percent have a written management plan (Table 8). A higher proportion of owners, 14 percent, have sought management advice. As the size of an owner's landholdings increases, so does the likelihood that he/she has a written management plan and has sought management advice. Property taxes and the ability to maintain the land within the family are the greatest concerns of these owners. Such concerns may be related to the finding that 9 percent of the forest land is owned by people who plan to sell their land or pass it on to their heirs in the next 5 years (Tables 9-10).

Forest Type, Habitat Type, Stand-Diameter Class, and Stocking

Maine’s forests have experienced tremendous change over the last three decades. Understanding this change requires measures of forest composition and structure. Composition is often addressed by classifying forest land according to the makeup of “existing” or “potential natural” tree vegetation. Two such measures are examined in this report: the traditional FIA forest type and habitat type. Measures of structure typically describe the relative size of and degree of site occupancy by trees. A diameter-based size class that uses basal area per acre as a measure of site occupancy is presented herein.

The FIA forest-type and stand-size class variables are calculated using a national algorithm that provides consistent classification of dominant tree-species composition for all states and regions of the country¹. The resulting information can be compared across large forested landscapes and provides input to national and international resource studies. Changes to the algorithm have caused FIA to modify estimates for the 1982 and 1995 inventories based on the latest classification scheme. To overcome this, the previous three inventories were re-processed using the latest approach. The results are summarized by ownership class in Table 11. To illustrate the utility of the FIA forest-type groups for large-scale analysis, Maine’s spruce/fir forest land is compared to other leading spruce/fir states:

| | <u>Thousand Acres</u> |
|-------|-----------------------|
| Maine | 5,829.9 |

¹ Arner, Stanford L.; Woudenberg, S; Waters, S.; Vissage, J.; MaClean, C.; Thompson, M. 2000. National algorithm for determining stocking class, stand size class, and forest type for forest inventory and analysis plots. On file with the Northeastern Research Station, Forest Inventory and Analysis, 11 Campus Blvd., Suite 200, Newtown Square, PA 19073

| | |
|-----------|---------|
| Minnesota | 3,777.3 |
| Michigan | 2,684.9 |
| Wisconsin | 1,300.9 |

As shown, Maine continues to lead the nation in terms of total spruce/fir forest land. The re-processed forest type information is presented in more detail in the Appendix. (Note: the information in the Appendix is for timberland acreage only.)

The traditional FIA forest type classification presents a challenge to resource analysts attempting to track composition shifts in Maine. The large amount of disturbance that has occurred over the period since the 1982 inventory makes it difficult to assess when, where, and how changes in forest habitat are affecting forest conditions in Maine. The FIA forest-type variable assesses existing vegetation based on the dominant overstory at the time of measurement. A prime example of the difficulty of interpreting FIA types occurs in heavily disturbed spruce/fir acreage. Transitional deciduous species often occupy these sites temporarily and have a major impact on the forest-type classification and resultant shifts over time. Another issue with the FIA forest type is that the naming scheme was designed to address regional and national needs rather than nomenclature typically used in Maine. To overcome these issues, an alternative approach was used. The approach considers potential natural vegetation, termed “habitat type,” to estimate the most likely long-term composition for a given site. Habitat types indicate the probable climax or late-successional species composition that is determined by biophysical relationships relating to site quality. Habitat types are based on the work of Leak (1982) and are used in the FIBER model (Solomon and others 1995). The same approach for

classifying forest land has been used to project future timber supplies and silvicultural priorities (Gadzik and others 1998, Wagner and others 2003).

Table 12 shows the distribution of forest land by habitat type and ownership class for comparison with the FIA forest-type group results. The basic difference between philosophies is well exemplified by comparing estimates for spruce/fir using the two approaches. The spruce/fir forest-type group was estimated to be 5,829.9 thousand acres compared to 7,523.2 thousand acres of spruce/fir habitat type. The larger acreage for the spruce/fir habitat type is due to the inclusion of forest land that is currently dominated by transitional species, typically intolerant hardwoods. The habitat-type assignment considered other information besides just the current dominance by hardwoods. The classification takes into consideration previous forest composition, soil conditions, and whether there are spruce or fir seedlings sampled.

The standard FIA measure of stand size gives a general indication of stage of stand development and is referred to as “stand-size class.” Each sampled condition is assigned to one of three stand-size classes based on the class that accounts for the most stocking of live trees per acre: sapling/seedling, poletimber, and sawtimber (see Definition of Terms). In this report, the stand-size class variable was modified to provide three improvements that were deemed useful in Maine. The sawtimber-size class was divided into large and small sawtimber to provide more detail. The traditional minimum breakpoints for the sawtimber class of 9.0- and 11.0-inches diameter at breast height (d.b.h.) for softwood and hardwood, respectively, were changed to a single 10-inch breakpoint for all species. Lastly, basal area per acre was used as the importance value for calculating the predominant size of sampled trees. The modified variable will be

referred to as “stand-diameter class” to avoid confusion with the standard FIA stand-size class variable (see Appendix Tables for information on FIA stand-size).

Stocking provides a measure of site occupancy that can be used in conjunction with other variables to analyze prospective management options and policy implications. Relative stocking is a term describing existing stocking in relation to stocking guidelines. Relative stocking is calculated for individual species using existing equations in the literature. In many cases, research has been completed for the major “timber” species; however, some species still lack specific equations and are assigned to the most logical equation possible. To overcome this limitation, simplify the understanding of the term “stocking,” and provide a measure more specific to Maine’s habitat types; stocking was assigned using stocking charts from the FIBER model (Solomon and others 1995) which are referred to as stocking regions (see Definition of Terms).

The new habitat type, stand-diameter class, and stocking approaches were used to reprocess the 1982, 1995, and 2003 inventory data. This provides a consistent set of results for the three inventory dates. The detailed results of the reprocessing are shown in Tables 13 to 15.

Generalized distribution surfaces for the habitat types are shown in Figure 29. These surfaces were derived from the FIA inventory data using geostatistical techniques to provide continuous surfaces that represent the most probable distribution for a given type (see Appendix for more detail). The resulting “surface” represents habitat types and should not be confused with individual species distribution maps described later in this report. The reason for including both

products is to provide a more complete analysis of species occurrence in Maine. For example, spruce species are split between habitat types, but are combined in the species distribution map. The surfaces provide a graphic depiction for habitat types that are often scattered geographically.

Beech/red maple habitat is scattered across Maine with the highest confidence of occurrence in the southern portion of the State. Cedar/black spruce habitat is also dispersed, most commonly found in wet areas. The occurrence of hemlock/red spruce is concentrated in a band across southern Maine. Oak/white pine habitat predominates in southwestern Maine and along the coast. Spruce/fir is heavily concentrated in the unorganized territories, the western mountains, and the eastern coastal region. Sugar maple/ash is very common in all but southwestern Maine and Downeast.

Changes in the distribution of forest land by habitat type for the last three inventories are shown in Figure 30. As would be expected, changes in the distribution are less drastic than changes in FIA forest-type groups. Spruce/fir is the most prevalent habitat, accounting for 42 percent of Maine's forest land. The impact of SBE and harvesting caused a decrease in spruce/fir of about half a million acres between the 1982 and 1995 inventories. Restocking of spruce/fir acreage is reflected in the subsequent increase of 342.9 thousand acres between 1995 and 2003. Other habitat types containing spruce and fir also experienced decreases. The oak/white pine habitat type increased steadily and now totals 1,492.4 thousand acres. The beech/red maple increased dramatically between 1982 and 1995, but has decreased since then. This change occurred as young red maple flourished due to the opening up of stands to sunlight, but was subsequently classified as spruce/fir and other types as these species out-competed red maple for space and

sunlight. The sugar maple/ash habitat type remained stable over the period and now totals 2,658.6 thousand acres.

The distribution surfaces for stand-diameter classes are shown in Figure 31. Today's sapling stands are heavily concentrated in the unorganized territories and Downeast. Poletimber stands are found across ME, but have highest occurrence in the southern half of the State. Small and large sawtimber are also dispersed widely, although large sawtimber stands are relatively uncommon.

Changes in the distribution of forest land by stand-diameter class reflect increases in sapling-size acreage as poletimber stands were decreasing due primarily to disturbance effects (Fig. 32).

Sapling stands increased by 1,435.5 thousand acres between 1982 and 2003. A corresponding decrease in poletimber of 2,710.5 thousand acres also occurred. Poletimber stands containing significant stocking of balsam fir were often impacted by SBE and related salvage harvesting. Not all of the poletimber stands were converted to younger sapling stands however, as some poletimber stands grew to small sawtimber size. The current distribution of forest land by stand-diameter class is 24 percent sapling, 42 percent poletimber, 20 percent small sawtimber, and 9 percent large sawtimber.

Isolating the changes in the spruce/fir habitat type clarifies the major role this habitat plays in the structural changes that have occurred across Maine's forested landscape (Fig. 33). As would be expected, the characteristic decline in poletimber and increase in sapling acreage is more dramatic for spruce/fir and the megaregions covering the unorganized territories (Fig. 34). The

Southern region had an increase in poletimber and both small and large sawtimber classes. The most dramatic examples of the dominant trend is apparent on forest industry forest land located mostly in the unorganized territories (Fig. 35). Nonindustrial private acreage has seen an increase in poletimber, small sawtimber, and large sawtimber since the 1995 inventory.

The oak/white pine habitat type exhibits trends that are quite different than spruce/fir (Fig. 36). Oak/white pine has had steady decreases in sapling acreage and increases in the larger stand-diameter classes. This foretells an aging resource with little recruitment into younger age classes.

The findings for changes in the distribution of forest land by stocking level indicate some encouraging trends and general improvements (Fig. 37). Although the understocked and sub-optimal class had increases, there were more dramatic improvements in the other classes. The acreage in the optimal stocking region decreased by 839.4 thousand acres between 1982 and 1995, but then increased by 1,510.8.0 thousand acres since 1995--a net gain of 671.4 thousand acres. Another positive trend was the 3,011.4 thousand acres decrease in the acreage of overstocked forest land. This decrease followed an increase between 1982 and 1995. As with other changes in composition and structure, the spruce/fir habitat type has driven trends at the state level (Fig. 38).

Stand Structure.

The distribution of forest land by stand structure class helps to explain the current mix of conditions across Maine (Table 16). This information is useful for crafting management strategies for the various habitat types in the State. Each forested condition that is encountered is assigned to one of the following: single-story, two-story, multi-story, or mosaic, e.g. a condition that is characterized by two distinct canopy layers is assigned to the two-story class. A common example would be a mature overstory with an understory of sapling-size trees. The management options for this condition are different than for single-story condition. Currently, the bulk of Maine's forest land is either single story (45 percent) or two-story (42 percent).

Low-basal area conditions.

Since the 1995 inventory, there have been two statewide referenda and other proposed legislation concerning forest-management practices. These initiatives focused on the frequency and size of clearcutting, the need to balance periodic growth and harvests, and the impact of liquidation harvesting. The continuing interest in policy development related to practices that create stands with low basal area provides the basis for the analysis that follows.

Each sample condition was assigned to one of seven classes based on basal area per acre of all tallied live trees 1 inch or larger in d.b.h. The lowest basal-area class represents stocking of 0 to 49 square feet per acre. This class comprises more than 3 million acres of timberland (17 percent of total), a substantial increase of 450,000 acres since 1995. Current status of the low-basal area class is examined by ownership, megaregion, and stand-diameter class.

For the most part, these acres have potential; 47 percent of all acres in this basal-area class are in the sapling-seedling stand-diameter class (Table 17, superscript a). Appropriate silvicultural practices are needed to enhance the growth potential of this acreage.

Statewide, forest industry owns 36 percent of these low basal-area acres; 51 percent are in the sapling class (Table 17, Superscript b). Proper management of this acreage and its composition through practices such as precommercial thinning; and the prompt return of this land to merchantable size will enhance the productivity of Maine's forests.

Another concern is combination of low/no basal area and sawtimber stand-diameter classes that are currently classed as being low/no basal area or understocked. This grouping accounts for only 10 percent of the acres in lowest basal-area class, however, 58 percent of the 320,000 acres are held by nonindustrial private landowners (Table 17, Superscript c).

The northern region accounts for 56 percent of the acres in the low basal-area class. Again, there are forest management opportunities here as 65 percent of these acres are classed as sapling and are at least fully stocked (Table 18, northern region gray shadings). The share of low/no basal-area acreage in the southern and western regions, at 82 and 81 percent, respectively, is troubling because the bulk of these acres are in poletimber-size stands, for which there are fewer management opportunities (southern and western gray shadings).

Harvest Disturbance

The MFS has conducted censuses of harvest activity in Maine since 1982 (the period from 1982 to 1986 is a single average). Harvest trends of the 1980's and 1990's clearly reflect increased cutting (in acres) over the period (Figs 39-40). The average annual harvest from 1982 to 1989 totaled 286,600 acres compared to 449,200 acres from 1990 to 1994. Since then, the average acreage harvested increased to 531,000 acres. Trends also indicate a dramatic shift from clearcutting to partial cutting, e.g. partial and shelterwood, beginning in the early 1990's. Partial cutting now dominates harvesting in Maine. Other MFS data indicate that natural extensive management practices dominate Maine's forestry practices. Statewide, planting, precommercial thinning, and conifer release activities occur on only about 5 percent of the timberland.

FIA data allow one to evaluate the degree to which forest land in Maine has been impacted by harvesting. The distribution of timberland by cutting intensity reflects the current character of timberland. Cutting intensity is defined as the basal area of cut trees divided by total basal area prior to harvest expressed as a percentage. The results reflect harvest activity over the recent inventory period, from 1995 to 2003. The acreage of timberland with no trees removed was 84 percent. This estimate is based on the limited remeasurement sample of the first 5 years of annual inventory. The estimate compares to a MFS estimate of 75 percent from 1995 to 2002 (MFS 1986 to 2003). As additional remeasurement data emerges, detailed analyses of harvesting (by diameter and species) can be completed.

Numbers of Trees

The forest land of Maine is frequently referred to as the “Acadian Forest” because of its unique location between Boreal Forests to the north and Central Hardwood Forests to the south. This transition zone provides a rich mixture of commercial species. This diversity is reflected in the variety of tree species tallied, which include 15 commercial softwood species, 30 commercial hardwood species, and 20 noncommercial hardwood species. Tree-species diversity is shown in Figure 41. Each pixel is highlighted according to modeled numbers of species tallied.

Balsam fir represents 35 percent of all live trees that are greater than 1.0 inch d.b.h., followed by red maple (12 percent), red spruce (9), noncommercial hardwoods (8), and paper birch (6). The high proportion of pioneer species reflects the sapling share of forest land (24 percent).

Shifting focus to abundance only on the timberland base and merchantable size trees (at least 5.0 inches d.b.h.), balsam fir remains the most abundant species with a 15-percent share, followed by red maple (13 percent), red spruce (13), northern white-cedar (10), and then paper birch (6).

Maine’s softwood resource has a higher proportion of sawlog quality trees than the hardwood resource (Fig. 42). Sawtimber-size trees (at least 9 and 11 inches for softwoods and hardwoods, respectively) represent 27 percent of all softwood stems. The bulk of softwoods are classified as growing-stock trees; 67 percent of live trees at least 5.0-inches d.b.d. are of acceptable sawlog quality but these trees do not meet the minimum size (9 inches d.b.h.). Poor-quality softwoods include rough (poor form) trees (4 percent) and rotten (excessive defect) trees (2 percent).

Sawtimber-size hardwood trees represent 14 percent of live hardwoods. Most of the live merchantable-size hardwoods are growing stock trees, 73 percent of which are of acceptable sawlog quality but too small for sawtimber. Poor-quality hardwood trees include rough trees (10 percent) and rotten trees (3 percent).

Over the last 45 years, the periodic inventory of Maine's forest resources provides an interesting perspective of stand development and dynamics in reaction to natural and forest-management interventions (Fig. 43). The per-acre average for timberland in 1959 was 813 sapling-size, 144 poletimber-size, and 15 sawtimber-size trees. The 1971 periodic inventory revealed the rapid stand development across the State during this interval. On the average acre, saplings decreased to 617, poletimber trees increased moderately to 179, and sawtimber trees increased substantially to 43. Over the next decade or so, stand dynamics were in apparent equilibrium. The 1982 inventory estimated continuing minor decreases in saplings (589) and poletimber (174) and a continuing minor maturation to sawtimber trees (46). Concurrent with part of this period is the SBE and the beginning of salvage harvesting.

Both of these impacts are very apparent in the inventory period of 1982 to 1995. The 1995 inventory showed a major shift in the distribution of trees by size. The trees present on the average acre increased to 785 saplings; poletimber had a major decrease to 135 trees that was attributed to both SBE-induced mortality of small suppressed/intermediate trees and salvage harvests; while sawtimber had a minor decrease to 42 trees.

The 2003 estimate continues to reflect the rapid development of young saplings, currently representing 1,051 trees per acre of timberland, along with continued minor decreases in the number of poletimber and sawtimber trees at 131 and 41, respectively.

Since one-quarter of Maine's timberland is classed as sapling stand-diameter class, these submerchantable trees warrant closer examination to understand the future prospects of Maine's forest resources. Between 1995 and 2003 there was a 52-percent increase in softwood saplings, while hardwood saplings have increased only by 17 percent (Fig. 44). Further, the increases follow a reverse J-shaped distribution, with the bulk of the increase occurring in the 1-inch d.b.h. class and dropping rapidly off to the 4-inch d.b.h. class (Fig. 45). From a statistical standpoint, all of these sapling increases within each d.b.h. class represent a significant change since the 1995 estimate.

The spatial distribution of the expected increase in saplings is important to certain forest product industries and reflects progressive stand development following extensive harvest over the last 25 years (Figs 46-47). Examining the distribution of larger to smaller diameter classes provides a general representation of where and when waves of spruce and fir forest will attain merchantable size. There are three areas with relatively high concentrations of 4-inch saplings; northern Piscataquis County, a localized area in the southern part of the Aroostook Lowlands, and a band along the Eastern Coastal region. The concentration of 3-inch saplings is highest in a band encompassing portions of the biophysical regions of the Western Foothills, Central Mountains, Aroostook Hills, and the Aroostook Lowlands. Concentrations of 2- and 1-inch trees are highest in the Downeast and Aroostook Hills regions.

Standing Dead Trees

Unutilized dead trees represent a loss in the productivity of the land for forest products; however, dead trees contribute to a forest's biodiversity by providing den sites for cavity-nesting birds and as the future source of down woody material. Both the frequency and size of dead trees are important characteristics in determining these and other nontimber attributes.

Salvable dead trees are defined as at least 5.0-inches d.b.h., have recently died, and still retain an intact bark structure. The numbers of these trees have remained fairly constant since 1982.

Current estimates of nonsalvable dead trees show a substantial decrease since 1995, especially in softwoods and particularly balsam fir and red spruce. This is an indication that nonsalvable dead trees tallied in 1995 are no longer standing and are probably part of the current down woody material estimates (Tables A17, B11, and C11).

Standing dead trees are further characterized by diameter class (5.0 to 10.9 inches d.b.h., 11.0 to 14.9 inches, and 15 inches and larger) and by tree condition class (intact top or broken top).

Dead trees in the largest class are of primary interest because of their expected longevity within the existing stand structure. The current distribution for this size class is 18.1 million trees, an average of 1.1 per acre of timberland. Trees in this class in 1995 averaged 0.9 per acre of timberland.

Down Woody Material

Down woody material (DWM) is defined as dead material on the ground in various stages of decay. DWM is an important component of forest ecosystems because it affects the: quality and structure of wildlife habitats, structural diversity, fuel loading and fire behavior, carbon sequestration, and the storage and cycling of water (USDA For. Serv. 2002b). Components measured include coarse woody debris (CWD), fine woody debris (FWD), duff, litter, herbs/shrubs, and fuelbed depth. CWD is dead wood 3 inches or larger in diameter (1000-hour fuels); FWD is dead wood 0.1 to 2.9 inches in diameter (1-, 10-, and 100-hour fuels). Litter is defined as the loose plant material on top of the forest floor where little decomposition has occurred. Duff is the layer just below the litter and consists of decomposing leaves and other organic material. CWD and FWD are sampled using line intersect sampling methodologies. DWM sample transects begin at each subplot center extending 24 feet to the subplot border. CWD and FWD are sampled only along transects in accessible forestland.

It should be noted that the analysis and interpretation of Maine's DWM data is based only on 2 years of data (2001 and 2002). As additional data are available and as analysis techniques are refined, DWM inventory analyses will be more extensive. With regard to estimates of fuel loading, Maine's fuel profile matches what might be expected for a landscape dominated by northern boreal/mixed hardwood forests. There is a tremendous amount of duff due to slow decay rates, but the amounts of FWD and CWD are relatively minimal. The shrub/herb fuel depths are low, indicating relatively little development of nontree vegetation that might serve as ladder fuels during a wildfire. Compared to western states, Maine's fire hazard is low.

However, given the presence of fuels in all size classes and the large amounts of duff and standing timber across Maine, the fire hazard in Maine's forests could be great during extended periods of drought.

CWD creates numerous ecological niches and serves as habitat for plants, animals, protists, bacteria, and fungi (Harmon and others 1986). Most of Maine's habitat type groups contain an appreciable amount of CWD that provides a diversity of habitat (Table 19). The spruce/fir and sugar maple/ash habitat types have the largest mean amount of CWD mass at over 4 tons/acre. The cedar/black spruce and oak/white pine habitat types have the least amount of CWD mass at less than 2 tons/acre. In Maine, one might expect low mortality of individual trees and subsequent CWD recruitment. The loadings of CWD appear adequate for maintaining habitat diversity across Maine, but most of Maine's CWD pieces are dominated by small diameters (< 7.9 inches in transect diameter) (Fig. 48) in advanced stages of decay (decay classes 4 and 5) (Fig. 49). Generally, the most desirable CWD habitat needed to accommodate a diversity of species is represented by a diversity of tree sizes and decay classes. Only an estimated 11 percent of Maine's CWD was characterized as freshly fallen or within several years of recruitment.

With respect to stand size class, the mean volume of CWD is greater in stands containing large- and medium-size trees (Fig. 50). Because it may take several decades for stand to recruit CWD through stand development-induced, individual-tree mortality, it is logical that stands with large size trees would have more CWD volume than those with smaller size trees. The amount of small FWD was significantly greater in stands with small size trees (Fig. 51). Because FWD is

recruited through the development and death of fine tree-crown branches and saplings, it stands to reason that the ratio of fine branches to overall crown volume is greater in small trees.

Therefore, a stand of small trees may have more FWD (1-hour) than those with large and medium size trees. The increase in FWD cannot be solely attributed to fine branch material.

The spatial distribution of DWM attributes can be examined in a cursory manner by spatial interpolation of individual plot values (Fig. 52). CWD levels were significantly lower in the southern half of Maine. The spatial distributions of duff and litter weights apparently are distributed randomly.

Distribution of Tree Species

Displaying the spatial distribution of forest attributes enhances our ability to address the “where” part of the overall challenge of looking at prospective future developments in species composition. The purpose of these distribution surfaces is to display the current spatial distribution of species across Maine’s forested landscape. Compositional patterns depend on a complex mix of factors. Broad geophysical and biophysical features are apparent; however, local site conditions and factors affecting trends in their composition are beyond these distributions; hence, the use of surfaces rather than “maps.” Figure 53 shows species-distribution surfaces for select softwood and hardwood species using basal area of the species of interest as a percentage of total basal area per acre. Major species are shown to stay within the limits of statistical techniques used.

The concentration of red spruce in the Central and Western Mountains is evident, as is the medium abundance of this species in St. Johns Uplands, Aroostook Hills, and Eastern Lowlands. Red maple is scattered across Maine with the highest concentration in the Southwest interior and South Coastal. Balsam fir is common from the Central Interior northward. High concentrations of fir occur in pockets to the north and west of Mount Katahdin. The association of eastern white pine with coastal Maine is evident as is the occurrence of this species in the central, southern, and coastal regions. Northern white-cedar is common across the State and follows a predictable pattern through low-lying wet areas. Sugar maple is most common from the Interior regions northward. The distribution of eastern hemlock nearly mirrors that of sugar maple, with localized high concentrations in Washington County and in the southwestern portion of the State. Aspen is found in medium concentrations in central and northern Maine. Paper birch is prevalent in Mountain and other upland regions, particularly the higher elevation Central and Western Mountains. The distribution of yellow birch mimics sugar maple but with more diffuse occurrence. Beech is found throughout the State with patchy occurrence in mountain regions. Northern red oak is most common in the warmer regions in the southwest.

Shrubs and Vines

The FIA tally of shrubs and vines includes deciduous, evergreen, and dwarf shrubs, and vines; with as many as 96 unique species or groupings of species. Shrubs and vines are tallied on a milacre plot concentric to the 1/300 acre microplot that is used to tally seedlings and saplings. For each condition class, as many as 99 individuals can be tallied for each species grouping.

For the 2003 inventory, 75 species groups were tallied in Maine; 87 percent of the forested plots had shrubs and vines of some nature. Of the 2,759 forested plots, deciduous shrubs occurred on 75 percent, dwarf shrubs were present on 56 percent, evergreen shrubs on 11 percent, and vines on 3 percent.

Figure 54 depicts only forested plots on which shrubs and vines were recorded and the frequency distribution of plots with unique species counts (species richness). Slightly more than 77 percent of the plots from the five panels had four or fewer shrub and vine species. Only 1.5 percent would be characterized as having a high diversity, i.e. 10 or more shrub and vine species.

The most frequently occurring shrub or vine species are the bunchberry dwarf shrub, found on more than half of the plots, *Rhubus* species (raspberry), tallied on 40 percent, and blueberry and twinflower (20 percent each) (Table 20).

Because of the nature of the FIA inventory, there is less opportunity for finding and recording species that occupy areas of diverse biotic edges or species that are classified as exotic/invasive. The frequency of species of concern, e.g. buckthorn, barberry, and honeysuckle, is relatively low in Maine.

Biomass

Biomass provides the most inclusive accounting of tree-fiber resources from Maine's forest. Biomass information can be used to address a host of issues, e.g. residue availability, which could be captured as part of current harvesting practices and be reasonably transported, processed, and utilized for new products or as alternative fuels and energy sources. FIA partitions the biomass of growing stock trees into four major components: growing stock (the traditional bole portion), branches, foliage, and stumps and roots (Appendix Tables A41, A44, and A45). An inclusive estimate for FIA rough and rotten trees is included. The bole portion comprises the bulk of total biomass. The total from this table (total timber) is carried forward to biomass summary tables that also include saplings, dead trees, and shrubs (Appendix Tables A40, A42, and A43).

The current total biomass estimate on timberland is 980 million dry tons, a 13-percent increase since 1995 (Wharton and Griffith 1995). Probability surfaces for softwood, hardwood, and total aboveground biomass are shown in Figure 55.

The sapling-component estimate reflects a 22-percent increase followed by the timber component (+11 percent). These increased estimates complement increases in volume discussed elsewhere.

Estimates of overall change in biomass capsulize the effects of land-use change, harvesting, and regrowth. Figure 56 reflects changes in biomass per acre that occurred between 1991 and 2000 by town. The classification of forest land is based on the ability of Landsat Thematic Mapper imagery to detect change. Much of Maine's forest land has not changed much in terms of biomass. The yellow areas show where biomass is increasing due to increases in forest land area or regrowth. By far, most of the yellow areas represent regrowth, as they occur in areas with little increase of forest land, mainly in the unorganized territories in the northern half of Maine. The red areas of the map depict where either forest land is being lost, harvesting has occurred, or some other factor is decreasing biomass per acre. Most of the red areas are in the southern half of the State.

-----**START OF SIDEBAR 2**-----

Estimates of forest carbon are derived from biomass estimates and reflect carbon dioxide (CO₂) fluxes in greenhouse-gas accounting. In 2003, Maine enacted legislation that requires the Department of Environmental Protection, Bureau of Air Quality, to produce a statewide Greenhouse Gas (GHG) emission inventory annually.

The Environmental Protection Agency, through its contractor, and with input from the USDA Forest Service, developed a spreadsheet program to assist individual states in compiling GHG inventories. The program includes default inventory data, with an option for users to input their own data to improve prediction accuracy. Maine's 1995 FIA inventory was used to estimate

forested conditions for the 2000 ending base year. It was estimated that the Land Use Change and Forestry (LUCF) account provided 15 percent of the CO₂ emissions (Fig. 57). The magnitude and direction (emission vs. sequestration) did not agree with recent annual inventory reports by MFS that estimated that forest land and biomass increased from 1995 to 2002 (Laustsen and others 2003).

Additional investigation determined that the carbon component of soils represented nearly 60 percent of predicted emissions in the total forest carbon flux. For the initial base estimate, the 1990 Forest Carbon Flux uses revised estimates of Maine's 1982 FIA periodic inventory as reported in the 1987 Resource Planning Act Assessment (RPA). The ending base estimates a 2000 Forest Carbon Flux using Maine's 1995 periodic inventory as reported in the 1997 RPA. The inconsistent treatment and updating of the base estimates was further compounded with additional changes in classification techniques, sampling design, and the FORCARB models.

After incorporating these improvements and land-use change information, it was found that the GHG accounting and inventory estimated that the LUCF account became a minor sequestration source from 1990 to 2000. The challenge is how forest management can improve the ability of Maine's expansive forest resource to become a larger and more effective sink for carbon.

----- **END OF SIDEBAR 2** -----

Inventory Volume

During the analysis of the new annual inventory data and results, it became apparent that the 1995 tree volumes needed to be reviewed due to discrepancies in measured tree bole and sawlog lengths. A new model for estimating tree height was developed and implemented for this report (Westfall and Laustsen in press). As shown in Figure 58, the new estimates of 1982 and 1995 growing-stock volume correlate well with trends in basal area--an indication that tree heights are now in line.

There are a number of options for discussing inventory volume (see Appendix Table A17, B11, and C11). The following summarizes the distribution of volume (million ft³) for trees at least 5.0-inches d.b.h. on timberland by tree class for the three most recent inventories:

| <u>Tree Class</u> | <u>1982</u> | <u>1995</u> | <u>2003</u> |
|----------------------|-----------------|-----------------|----------------|
| Sawtimber | 12,348.6 | 11,840.8 | 12,616.8 |
| Poletimber | <u>11,760.5</u> | <u>10,145.4</u> | <u>9,796.7</u> |
| Total growing stock | 24,109.1 | 21,986.2 | 22,413.4 |
| Rough | 1,941.7 | 880.4 | 1,132.9 |
| Rotten | <u>898.3</u> | <u>311.5</u> | <u>223.2</u> |
| Total cull | 2,840.0 | 1,191.9 | 1,356.1 |
| Volume of live trees | 26,949.1 | 23,178.1 | 23,769.4 |
| Salvable dead | 535.7 | 409.5 | 449.7 |
| Volume of all trees | 27,484.8 | 23,587.6 | 24,219.2 |

The most traditional measure is growing-stock volume on timberland, which represents the net merchantable volume of the central stem of trees at least 5 inches d.b.h. on acres that are productive, accessible, and not reserved from harvesting (forest land also includes nonproductive

areas). Growing-stock volume currently totals 22.4 million ft³, of which 56 percent is softwood and 44 percent is hardwood. Growing-stock volume excludes the volume of rough and rotten trees. In Maine, the volume of pulpwood quality or better trees on timberland often is discussed because it includes trees that are useable as pulpwood (growing-stock and rough trees, but not rotten trees). The long-term trend in pulpwood or better inventory volume is depicted in Figure 59. The volume of pulpwood or better trees reached a peak that was apparent in the 1982 inventory. Total volume then decreased by 12 percent following the SBE. The pulpwood quality volume was level between 1995 and 2003.

The most inclusive estimates of volume include growing-stock, and rough and rotten trees, or the volume of live trees on forest land. Recent trends in the volume of live trees parallel those for pulpwood-quality trees (Fig. 60). Again, the most striking change in volume occurred between the 1982 and 1995 inventories. It is clear that although hardwood volume decreased slightly, the drop in total live inventory resulted primarily from the decrease in softwood volume as a result of spruce-budworm mortality and related salvage-harvest activities. The latter decrease resulted from major reductions in volume in the 6- to 12-inch diameter classes (Fig. 61) for softwoods, particularly red spruce and balsam fir. As expected, most of the decrease was in the Northern megaregion (Fig. 62). This decrease in volume has been at the center of discussions about the future of Maine's next-generation forest.

The 2003 estimates indicate that the total inventory of live trees on forest land increased by 3 percent since 1995. Figure 63 shows trends in volume for selected species in Maine. Although many species did not change appreciably, there are signs that conditions have improved over the

last 8 years. Trends for red spruce and balsam fir are prime indicators. Between the 1982 and 1995 inventories, the volume of these two species decreased by 49 and 35 percent, respectively. The bulk of these decreases occurred in the 6- to 12-inch diameter classes (Fig. 64). The 2003 results show little change in balsam fir volume and a slight increase in red spruce volume--a sign that Maine's forests are stable. American beech experienced a recent volume decrease of 17 percent, which occurred across a wide range of diameters following an expansion in the volume of 6- to 10-inch trees between 1982 and 1995 (Fig. 65). Other species with significant decreases are northern white-cedar (-4 percent) and aspen (-8 percent). Species with notable positive gains are hemlock (26 percent) and northern red oak (18 percent).

Sawtimber Volume

The volume of sawtimber on timberland represents that portion of the resource capable of being used as traditional veneer logs, sawlogs, bolts, and other sawn products. Sawtimber volume includes the merchantable board-foot volume of the central stem for trees 9 and 11 d.b.h. for softwoods and hardwoods, respectively, that are of sufficient quality to be considered sawtimber. The upper limits of merchantability are 7 and 9 inches top diameter outside bark, respectively. The 2003 results show that the overall sawtimber volume has changed little over the last 2 decades (Fig. 66). Hardwood sawtimber increased slightly between 1995 and 2003, but at a slower rate than between 1982 and 1995. Decreases were apparent in the Northern and Eastern megaregions (Fig. 67).

The results revealed differences in trends for individual species (Fig 68). On the positive side, paper birch increased by 14 percent since 1995 following a slight decrease between 1982 and 1995. Red oak sawtimber expanded by 25 percent since 1995, but this was a slower rate of increase than the 59 percent increase between 1982 and 1995. White spruce and hemlock sawtimber increased steadily over both periods.

On the negative side, sugar maple decreased by 6 percent between 1995 and 2003, a significant reversal of a previous 34-percent increase in sawtimber volume. White pine sawtimber decreased by 3 percent following an increase of 4 percent between 1982 and 1995. Northern white-cedar also experienced the reversal of a positive trend that was evident 1982 and 1995. Both red spruce and balsam fir had minor decreases in sawtimber inventory, though these decreases were minor compared to previous decreases of 26 and 46 percent, respectively.

Figure 69 depicts the current distribution of sawtimber volume on a per acre basis for select species and all species combined. Sawtimber volume is well distributed across Maine but is more common in the Western and Northern megaregions. White pine sawtimber is located primarily in the Southern megaregion. The sawtimber volume of spruce and fir is concentrated heavily in the Western and Northern megaregions, as well as the Downeast area. Red maple is common across Maine but is less common above a latitude of 45 degrees N. Sugar maple, beech, and birch are most abundant in the Western and Northern megaregions. Intolerant hardwoods are most prevalent in a band extending from Oxford County westward to Hancock County, and are scattered in the Northern megaregion.

The distribution of sawtimber volume by tree grade provides an estimate of the relative quality of species in Maine and potential sawtimber products for hardwoods, white pine, spruce, and fir. All growing-stock trees of sawtimber size are assigned a tree grade based on the quality characteristics of the first 16-foot section of the bole. Factors affecting the grade assignment are minimum diameter, length of clear cuttings, and other form and cull defects. The board-foot volume of each tree is ascribed to the tree grade and summed to provide the distribution. Minimum diameter is a critical variable in the tree-grade determination. For example, to be considered for grade 1, the minimum diameter of the graded section is 16.0 inches. Typically, sawmills prefer tree grades one and two for the more desirable lumber products (premium and better for pine; firsts and seconds for hardwoods). Tree grade three is less desirable and the other grade material often is used for products such as pallets, which do not require long sections of clear wood.

The distribution of sawtimber volume by tree grade for all trees for the two most recent inventories shows improvement for sugar maple, red maple, yellow and white birch, and aspen (Fig. 70). The improvement is apparent by the increase in the percentage of grade 1 and 2 material. White pine quality decreased and northern red oak showed little change; however, the distribution is heavily influenced by tree size. When only trees at least 15.0-inches d.b.h. are considered, white pine shows little change and northern red oak shows some improvement (Fig. 71). The reason is that trees with high quality potential are classified as lower grades until they reach the minimum threshold for tree grade 2.

Wood Availability

A complete analysis of wood availability in Maine is beyond the scope of this report. However, a discussion of key concepts that underlie actual wood availability should help clarify current conditions and aid in future studies. Wood availability is dependant on complex interactions among physical, economic, and social constraints. For example, most of the white pine sawtimber is in the southwestern part of the State. Other physical constraints include factors such as slope, distance to a road, and product volume per acre. Figure 72 shows how the inventory of growing-stock volume on timberland is distributed by volume per acre class. About one-fourth of timberland has less than 500 ft³ (less than 6 cords) per acre, though this acreage accounts for only 4 percent of the inventory volume. About half of the volume is in stands with at least 2,000 ft³ (more than 23 cords) per acre, but this volume occurs on less than one-fourth of the timberland. As such, the inventory for stands with enough volume per acre to make harvest feasible is more limited than the total inventory statistics would imply. This phenomenon is most prominent on the current owner group forest-industry (Fig. 73). Conditions are similar for the volume of sawtimber (Fig. 74-75).

Ownership objectives play a strong role in wood availability. For example, as mentioned earlier, the primary reason for holding forest land cited by Maine's family/individual owners are aesthetics, privacy, and family legacy. Add to these factors the relationship between timber supply and demand and it is obvious that wood availability is less than simple inventory metrics imply. Efforts are needed to develop an integrated approach for predicting future wood supplies, similar to previous work (Gadzik and others 1998, Seymour and Lemin 1989). There is an

opportunity to add economic and ecological indicators to the mix of projected parameters (Turner and Caldwell 2001.).

Components of Inventory Volume Change

Changes in the volume of Maine's forests depend on the interrelationship of growth, removals, and mortality, or the components of change. In this section, change components are expressed as growing-stock, live-tree, and sawtimber volume to provide a link to changes occurring in inventory volume. An analysis based on basal area is included as a crosscheck to change in volume. This crosscheck is important in light of recent changes in sample design, the limited remeasurement sample, and the evolution of estimation procedures (see Basal Area Change section). Usually, three terms are used to discuss changes in inventory: gross growth, net growth, and net change:

Gross Growth = Ingrowth (trees achieving merchantable size) + Accretion (survivor growth);

Net Growth = Gross Growth – Mortality;

Net Change = Net Growth - Removals

In the case of growing-stock and sawtimber inventory, the net difference between trees entering the growing-stock class (as cull decrement) and departing the growing-stock class (as cull increment) is added or subtracted to growth as appropriate.

All components are expressed on an average annual basis from the year of the previous plot measurement to the current year of plot measurement. If all sample plots were remeasured, the net change based on change components should match the change based on inventory volume. Currently, these estimates do not match exactly because of the relatively low number of remeasured plots. As each new panel is added, the sample or remeasured plots and trees will increase substantially. For example, more trees were remeasured in the sixth year than in all of the previous 5 years.

Growing Stock

Change components expressed as growing-stock volume on timberland indicate how the manageable portion of Maine's forest inventory is changing over time. Figures 76-77 illustrate the simple but important relationship between specific components for all species and the major species groups. The tight relationship between net growth and removals explains why inventory volume changed little since 1995. This situation will continue until the large inventory of submerchantable stems grows to the 5-inch merchantability limit. At that time, increases in the ingrowth component will boost overall net growth. The large impact of mortality on gross

growth also is well illustrated. Softwood mortality was about one-third of gross growth and one-fourth of hardwood gross growth over the period.

The results for species/species groups show that several species currently have removals in excess of net growth, including red spruce, balsam fir, northern white-cedar, aspen, paper birch, and beech (Fig. 78). Species/species groups with net growth in excess of removals include red maple, white pine, sugar maple, yellow birch, and northern red oak. As discussed previously, information on change components does not always match changes reflected in the inventory. White pine illustrates the statistical mismatch between change in inventory volume and net change based on change components. Although the species had considerable excess of growth over removals, the inventory volume of white pine volume showed little change. The situation for northern white-cedar and beech further illustrate how the various components interact (Fig. 79). The negative net change in the volume of northern white-cedar was caused by a high level of removals, rather than mortality. The decrease in inventory volume of beech was due to high levels of mortality that effectively made net growth be negative (rather than heavy removals). In the case of beech, mortality exceeded removals.

Live Tree

Change components for live trees reflect all tree classes and usually parallel the results for growing-stock volume. The basic difference between them is that live-tree components do not include changes in cull trees so that less volume is subtracted from gross growth in calculating

net growth. As such, the results look slightly better than for growing stock (Fig. 80). The ratio of net growth to removals is useful for summarizing net growth and removals relationships. Ratios less than 1 indicate decreases in volume while ratios greater than 1 indicate increases in volume. As an example of differences between growing-stock and live-tree estimates, the red spruce ratio was 0.64 to 1.0 based on growing-stock trees and 0.94 to 1.0 using live trees (Fig. 81).

Ratios of live-tree growth to removals also are useful for analyzing relationships among megaregions. These ratios were:

| <u>Region</u> | <u>Softwood</u> | <u>Hardwood</u> | <u>All Species</u> |
|---------------|-----------------|-----------------|--------------------|
| Northern | 0.9:1.0 | 0.8:1.0 | 0.9:1.0 |
| Eastern | 1.4:1.0 | 0.8:1.0 | 1.1:1.0 |
| Southern | 1.4:1.0 | 1.4:1.0 | 1.4:1.0 |
| Western | 1.1:1.0 | 1.3:1.0 | 1.2:1.0 |
| State | 1.1:1.0 | 1.0:1.0 | 1.1:1.0 |

Total removals were 2.2 percent of the 1995 estimate of live-tree volume. A noteworthy breakdown of total removal volume is by harvest removal and removal due conversion of forest land to non-forest land uses. Although loss of forest land is not a major issue in Maine, it is important to note that 6 percent of the removal volume was attributed to forest land being converted to other uses. The more important finding is for species located in regions of the State

where conversion is more likely. Prime examples are white pine and red oak for which 24 percent and 38 percent, respectively, of the removal volume was due to conversion (Fig. 82).

Sawtimber

Change components, expressed in board feet, are shown in Figures 83-84. These data are more unreliable than components based on growing stock or live trees because the portion of sawtimber in the overall sample is smaller. In fact, the results for net change in total sawtimber (negative) do not match those for sawtimber inventory volume (positive). The change in inventory volume is more reliable because it is based on a sample of many more trees. These figures should be used with caution and are presented here for completeness.

-----**START OF SIDEBAR 3**-----

Basal Area Change

In the early years of the annual inventory, components of change were evaluated using basal area to overcome limitations of a relatively small remeasurement sample (Laustsen and others 2003; Laustsen and Griffith 2002). The continuation of this analysis provides a link to previous reports and an assessment of trends but more importantly a strong correlation with the volume-based inventory and components of change. The analysis was conducted for growing-stock trees on timberland for 1995 to 2003 (Table 21).

The annualized net change as a percentage of growing stock basal area has improved over the 3-year period. In the third annual report this rate was estimated at -1.3 percent. It improved to -1.1 percent in the fourth report, and again to the current estimate of -0.9 percent. These three estimates continue to track the status in which removals exceed net growth; however, the steady improvement is encouraging.

Estimates of components of change for individual species illustrate past problems and future trends:

- Balsam fir's estimated annual basal-area ingrowth is 20 percent more than accretion, indicating a younger forest beginning to cross the merchantability threshold of 5 inches d.b.h..
- The 1-percent net change for eastern hemlock represents a reversal of the 1995 analysis.
-
- American beech is a species of concern for two reasons. First, the estimate of growing-stock decrement is 200 percent more than the estimate for increment, indicating substantial reductions in quality over the last 8 years. Secondly, the annualized change of -5.3 percent further documents the imbalance in growth, mortality, and removals.
- The major species that are most out of balance in net change are American beech (-5.3 percent), aspen (-2.3), red spruce (-2.3), and balsam fir (-1.9). In the case of red spruce and balsam fir, a positive relationship should occur when small trees begin to reach the 5.0-inch merchantability limit.

Mortality

Estimates of mortality or the volume of trees that died since the previous inventory are the most important forest-health variable collected by FIA. Mortality reflects a combination of factors that cause tree death. The estimates are intended to describe major disturbances that affect significant acreage or numbers of trees, e.g. affects of ice storms (Irland 1998). Ultimately, tree death creates gaps and openings that result in the establishment of new trees. It should be noted that mortality may be underrepresented because a tree that dies and then is cut is classified as removal because of the difficulty in determining whether it died prior to cutting. At the landscape level, tree mortality was one-third of the gross growth of live trees, which is a proxy for the total productivity of the forest from 1995 to 2003. It is difficult to compare data from different periods, but the estimate of mortality was likely about half of gross growth for 1983 to 1995. Currently, stands at risk of impending mortality represent a prime opportunity to capture live volume and thus maximize stand productivity.

The overall average rate of mortality for the recent inventory period was 1.2 percent of the volume of live trees. Comparing this to rates for the major species/species groups allows a relative assessment. As expected, softwood mortality was above average (Fig. 85). Balsam fir, beech, paper birch, and aspen had above average mortality (Fig. 86). Mortality of red spruce

roughly equaled the state average. Important species with mortality less than the average were white pine, yellow birch, northern white-cedar, red maple, and northern red oak.

The spatial distribution of mortality shows a random patchy pattern across Maine (Fig. 87). Balsam fir mortality is prevalent across the central region of the State and this appears to be a major shift from mortality that was concentrated in northern Maine between 1982 and 1995 (McWilliams and others 1997). Occurrence of other species display more sporadic patterns.

Timber Products Output

The MFS has records and sources of timber products output that date to the early 1900's. These records reflect the harvest of sawlog and pulpwood products for softwoods and hardwoods. The history of Maine's product output for the past century centers on two major production events. The first, a buildup of production, lasted through the first decade of the 1900's (Fig. 88). Overall production peaked in 1909. This was followed by a collapse that reached a low point in the early 1930's due to a combination of the negative impact of the 1910-1920's era spruce budworm outbreak and reduced demand associated with the Great Depression. Production then increased in three steeply cascading surges, each of which was followed by a brief period of level production.

Softwood products, primarily softwood pulpwood, dominate all the major trends in product output (Fig. 89). Production of softwood pulpwood peaked at 2.3 billion cords in 1984. This

was followed by a precipitous decline that continues today. Beginning in the early 1950's, hardwood pulpwood increased steadily until it exceeded softwood production in 1991. The production mix has been roughly two-thirds hardwood and one-third softwood over the last 5 years.

The history of sawlog production reveals more dramatic reversals in periodic production that were driven primarily by three declines in softwood production: from 1910 to 1930, 1950 to 1960, and 1975 to 1985 (Fig. 90). Trends in sawlog output are heavily weighted toward the production of softwood sawlogs. Hardwood sawlog production began to grow in the 1950's and has increased steadily since then. Hardwood sawlogs have contributed more than 20 percent of total sawlog production during the past 5 years.

Forest Health Parameters

The national Forest Health Monitoring (FHM) program was first initiated in New England in 1990 (Brooks and others 1992) in response to increasing concern for the health of the Nation's forests with respect to pollution, insects, diseases, climate change, and other stressors. The objective of the FHM program is to monitor, assess, and report on the long-term status, changes, and trends in forest-health indicators at regional and national scales.

Measurements of FHM indicators are taken in addition to the basic tree measurements collected on Phase 2 plots that are coincident with Phase 3 plots. Indicators are defined as any

environmental component that quantitatively estimates the condition or change in the condition of ecological resources, the magnitude of stress, or the exposure of a biological component to stress. The FHM indicators addressed in this report are tree damage, crown condition, down woody material, ground-level ozone injury, lichens, and vegetation. The data collection method for each indicator is described briefly in each section. The data presented here represent P3 plots that were surveyed at some time in the 1999-2003 period.

Tree Damage

Tree damage and the severity of that damage are assessed for trees at least 1-inch in diameter. As many as three damages can be recorded per tree in the following order: roots, roots and lower bole, lower bole, lower and upper bole, upper bole, crown, stem, and branches (USDA For. Serv. 2002a). The types of damage that are recorded include cankers, decay, wounds, resinosis, cracks, broken bole or roots, brooms, dead roots, vines, dead terminal, dead or broken branches, excessive branching, damaged foliage, and discoloration of foliage. Decay is the most common type of damage encountered. All trees with a damage recorded were considered damaged regardless of the location or the severity of the damage.

A map of the percentage of total basal area at each plot with damage is shown for selected species in Figure 91. For a given species, plots were included only if at least three trees were sampled. The spatial distributions of damage appear to be random for most species. Beech had the highest proportion of plots (71 percent) showing high damage (more than 20 percent of the

basal area). Most of this damage is likely due to the effects of beech bark disease and severe drought. In general, the frequency of high damage was much higher on hardwoods than softwoods.

Crown Conditions

Each measurement of crown condition contains information that can be used individually or in combination with other measurements. Tree-level measurements include vigor class, crown ratio, light exposure, crown position, crown density, crown dieback, and foliage transparency. Factors used to determine the condition of tree crowns are crown dieback, crown density, and foliage transparency. Crown dieback is recent mortality of branches with fine twigs and reflects the severity of recent stresses on a tree. Crown density is defined as the amount of crown branches, foliage, and reproductive structures that block light visibility through the crown. Crown density can serve as an indicator of expected growth in the near future. Foliage transparency is the amount of skylight visible through the live, normally foliated portion of the crown. Changes in foliage transparency also can occur due to defoliation or from reduced foliage resulting from stresses in preceding years. A crown was labeled as poor if crown dieback exceeded 20 percent, crown density was less than 35 percent, or foliage transparency was greater than 35 percent. These thresholds were based on preliminary findings by Steinman (2000) that associated crown ratings with tree mortality.

The percentage of basal area with poor crowns is shown for selected species in Figure 92. The incidence of poor crowns was highest in beech and aspen. Nearly 65 percent of the plots had more than 10 percent basal area with poor crowns. Poor beech crowns would be expected in light of other findings and because the foliage of trees infected with beech bark disease often become sparse (Le Guerrier 2003). Since aspen is relatively short lived (Laidly 1990; Perala 1990), crowns may be poor in trees nearing the end of their normal lifespan. For white pine and balsam fir, nearly 21 percent of the plots had more than 10 percent basal area with poor crowns. Conversely, relatively few sugar maple and spruce species had poor crowns.

Ground-Level Ozone Injury

Ozone (O₃) is a byproduct of industrial development and is found in the lower atmosphere. It forms when nitrogen oxides and volatile organic compounds react in the presence of sunlight (Brace and others 1999). Ground-level O₃ has been known to have a detrimental effect on forest ecosystems. Certain plant species exhibit visible, easily diagnosed foliar symptoms. O₃ stress in a forest environment can be detected and monitored by using these plants as indicators. In the FHM program, these indicator plants monitor changes in air quality across a region and are used to evaluate the relationship between O₃ air quality and the indicators of forest condition (USDA For. Serv. 2002b).

The O₃-induced foliar injury on indicator plants is used to describe the risk of impact within the forest environment using a national system of sites (Smith and others 2003). These sites are not

co-located with FIA samples. O₃ plots are chosen for ease of access and optimal size, species, and plant counts. As such, the plots do not have set boundaries and vary in size. At each plot, 10 to 30 individual plants of three or more indicator species are evaluated for O₃ injury (Table 22). Each plant is rated for the proportion of leaves with O₃ injury and the mean severity of symptoms using break points that correspond to the human eye's ability to distinguish differences. An index is calculated based on amount and severity ratings. The findings for Maine indicate that there is little or no risk of foliar injury due to O₃ across the entire State (Table 23). By contrast, portions of the Mid-Atlantic region are at medium or high risk (Coulston and others 2003).

Lichens

Lichens are composite, symbiotic organisms from as many as three kingdoms. The dominant partner is a fungus. Fungi can produce their own food as parasites or decomposers. The lichen fungi (kingdom Fungi) cultivate partners that manufacture food by photosynthesis. At times, the partners are algae (kingdom Protista) or cyanobacteria (kingdom Monera), formerly called blue-green algae. Some enterprising fungi exploit both at once (Brodo and others 2001).

Monitoring of the lichen community was included in the FHM process to address key issues such as the impact of air pollution on forest resources, and spatial and temporal trends in biodiversity. This long-term monitoring program in the United States dates to 1994 and is currently implemented in 32 states. The objectives of the lichen indicator are to determine the presence and abundance of lichen species on woody plants and collect samples. Lichens are found on

many substrates, e.g. rocks, though sampling was restricted to standing trees or branches/twigs that recently fell to the ground. The samples were sent to lichen experts for species identification.

There is a close relationship between lichen communities and air pollution, particularly sulfur dioxide and acidifying or fertilizing nitrogen- and sulfur-based pollutants. Lichens are highly sensitive to air quality because they rely on atmospheric sources of nutrition. By contrast, it is difficult to separate tree-growth responses specific to air pollution (McCune 2000).

In all, 149 lichen species in 42 genera were sampled on Phase 3 plots (1999-2003) (Table 24). The most common lichen genera, *Parmelia* and *Usnea*, were on 10 percent of the plots. The genera with the most species sampled were *Cladonia* (22 species) and *Usnea* (16).

Species diversity is a combination of the number of species (species richness) in an area and the distribution of individuals among species (evenness). The distribution of species richness for lichens and associated diversity are shown in Figure 93. In general, species richness and diversity are higher in the northern half of Maine. This is a function of the spatial distribution of forest type groups in the State. Mean species richness of the spruce/fir forest type group that makes up most of Maine's northern forest is higher than the type groups that make up the forests in southern region (Table 25). Lichen species richness is similar among stand diameter classes (Table 26). The mean number of lichen species sampled was lowest on large sawtimber plots and highest on small sawtimber-size plots.

Some lichen species are more apt to be found in late successional and old growth (LSOG) forests. Thus they can be used as an indicator of LSOG stands (Selva 1994). The spatial distribution of LSOG lichen species richness is shown in Figure 94. Areas with high numbers of LSOG lichen species exhibit some correspondence to areas with high numbers of trees at least 16.0-inches d.b.h. (Fig. 95). Existing research has shown that forest land with significant numbers of trees 16.0-inches are likely candidates for classification as LSOG (Whitman and Hagan 2004). The twenty-five LSOG lichen species sampled in Maine included:

| | |
|------------------------------|----------------------------------|
| <i>Alectoria sarmentosa</i> | <i>Leptogium tenuissimum</i> |
| <i>Anaptychia palmulata</i> | <i>Lobaria pulmonaria</i> |
| <i>Collema nigrescens</i> | <i>Lobaria quercizans</i> |
| <i>Collema subflaccidum</i> | <i>Menegazzia terebrata</i> |
| <i>Heterodermia speciosa</i> | <i>Myelochroa aurulenta</i> |
| <i>Hypogymnia tabulosa</i> | <i>Nephroma helveticum</i> |
| <i>Leptogium burnetiae</i> | <i>Nephroma resuptinatum</i> |
| <i>Leptogium corticola</i> | <i>Pseudocyphellaria aurata</i> |
| <i>Leptogium cyanescens</i> | <i>Pseudocyphellaria crocata</i> |
| <i>Leptogium laceroides</i> | <i>Pyxine soorediata</i> |
| <i>Leptogium lichenoides</i> | <i>Ramalina thrausta</i> |
| <i>Leptogium miligranum</i> | <i>Usnea longissima</i> |
| <i>Leptogium saturninum</i> | |

Soil Erosion

In general, Maine's forests are associated with low levels of erosion. None of the samples in the four megaregions showed evidence of soil erosion. Preventive forces, such as forest cover, an evenly distributed precipitation regime, and large areas with low slopes account for the State's low erosion levels. This does not mean that management practices should ignore erosion potential as steeper slopes, compacted areas, and lack of vegetation foster erosion.

Vegetation Diversity and Structure

The objectives of the vegetation indicator are to assess forest ecosystem health with respect to diversity, abundance, and rate of change of native and nonnative vascular plant species, and the vertical layering of vegetation within a forest (Stapanian and others 1998). Chronic stressors like discrete site degradation, climate change, and pollution can change the composition of species and lead to the decline or local eradication of sensitive species, as well as increase the number of opportunistic species such as weedy nonnative plants. The abundance and layering of vegetation is a good predictor of wildlife habitat and the severity of damage that might develop when fire occurs. In addition, individual species are important indicators of a site's potential productivity, economic value, and wildlife forage and shelter (USDA For. Serv. 2002b). In Maine, data collection for the vegetation indicator is scheduled to begin in FY2006.

Web Resources

USDA Forest Service, Northeastern Research Station FIA: <http://www.fs.fed.us/ne/fia/>

USDA Forest Service, Forest Inventory Mapmaker: <http://ncrs2.fs.fed.us/4801/fiadb/index.htm>

Maine Department of Conservation, Maine Forest Service:

<http://www.state.me.us/doc/mfs/mfshome.htm>

Department of Maine Inland Fish and Wildlife: <http://www.state.me.us/ifw/index.html>

University of Maine, College of Natural Sciences, Forestry and Agriculture:

<http://www.nsfa.umaine.edu/>

Maine Audubon: <http://www.maineaudubon.org/consERVE/index.shtml>

Manomet Center for Conservation Sciences: <http://www.manomet.org/>

Multi-Resolution Land Characteristics Consortium: <http://www.mrlc.gov/index.asp>

U.S. Census Bureau: <http://www.census.gov/>

U.S. Department of the Interior Geological Survey: <http://www.usgs.gov/>

USDA, National Resource Conservation Service: <http://www.nrcs.usda.gov/>

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APPENDIX

Annual Inventory Design

The annual inventory system combines features of the periodic system with a new systematic grid of sample plots and incorporates measurements from the FHM program. The inventory consists of three phases.

Phase 1

Phase 1 procedures reduce variance associated with estimates of forest-land area. A statistical estimation technique is used to classify digital satellite imagery and stratify the land base as forest or nonforest to assign a representative acreage to each sample plot. Source data are from Landsat Thematic Mapper (30-m resolution) imagery that ranged from 1999 to 2001. An image filtering technique is used to classify individual pixels using the 5- by 5-pixel region that surrounds each pixel that contains the sample plot. The resulting 26 classes are collapsed for each estimation unit (county or supercounty; the latter is a combination of small counties). Stratified estimation is applied by assigning each plot to one of these collapsed strata and by calculating the area of each collapsed stratum in each estimation unit. Stratified estimation produces more precise estimates than simple random sampling.

Phase 2

Field measurements are conducted at sample locations distributed systematically about every 3 miles across the landscape. Sample locations are situated within individual cells of a national hexagonal grid laid across the State of Maine. Each Phase 2 sample represents about 6,000 acres depending on the Phase 1 stratification of forest land. The new national design also incorporates a change to a four-subplot cluster (USDA For. Serv. 2002a). At each location, a suite of variables is measured that characterizes the land and trees associated with the sample (Fig. 96). Each year, 20 percent of the sample locations are measured, that is, it takes 5 years to complete the inventory. Each year's sample is referred to as an "inventory panel." The overall design is referred to as an "interpenetrating design" because no two cells are adjacent to one another within each inventory panel. As a result, each panel provides an unbiased representation of conditions across the State. Each completed panel is combined with existing panels to produce the most precise estimates possible. This report is based on the first five panels measured in Maine using the new annual inventory protocols. After the next panel is complete, the set of panels used for estimation "moves" to the most recent five panels (2nd through 6th year). The moving average approach ensures that the most current and complete inventory data are used.

Phase 3

More extensive forest-health measurements are collected during a 10-week period in summer on a subset of Phase 2 sample locations. The measurements are grouped into six general categories of indicators: crown condition, understory vegetation, down woody material, soil condition, lichen communities, and ozone damage. The intensity of the Phase 3 sample is one sample location per 96,000 acres of land. The relatively small number of Phase 3 samples does not

provide detailed analyses in some cases. For example, breaking down tree damage for a particular species by region reduces the number of samples and yields a high sampling error (SE).

Ensuring Consistency with Previous Inventories

Compiling and reporting results for the first five panels of the annual inventory required additional work to ensure comparisons were valid in light of changing procedures, definitions, and estimation methods. Three areas of concern were addressed for the 1982 and 1995 inventories because existing digital inventory data could be recompiled to current standards. Comparisons to published inventory information prior to 1982 should be used with caution to ensure valid comparisons.

The first concern involved consistency in the estimate of total forest land in Maine. In previous annual reports, analyses were limited to the timberland portion of the forest land base. This approach has adequately addressed wood-supply issues, but more holistic analyses cover the entire forest-land base. This has required incorporating of “other forest land” in a consistent manner for the previous two periodic inventories.

Also, as part of the nationalization of the FIA program, all statistical estimation and compilation systems are being reviewed for consistency among regional FIA units. The intent is to have a national system with comparable data and information across state and regional boundaries. This

resulted in modifications to the procedures and algorithms for compiling data on stocking, forest-type, and stand-size class that were used in development of information for this report. The algorithm used to classify these variables has undergone significant modifications, so estimates in older publications are not comparable with current ones. To overcome this limitation, the latest national approach was used to recompute stocking, forest type, and stand-size class for the current and two most recent inventories. Comparisons of these variables now can be analyzed using a temporally consistent classification system (Appendix Tables A2, A3, A28, A31, A32, A35, A36, A37, A38, A39, B3, B4, B14, C3, C4, and C14). A supplemental approach for developing forest-habitat types was implemented because this variable is preferred as a measure of composition in Maine (see Gadzik and others 1998). A more detailed measure of stand-size class--stand-diameter class--was developed to divide the sawtimber class into small and large sizes. Also, stocking levels were assigned using the FIBER model (see Definition of Terms).

The third concern involved the estimation of individual tree volumes that are used to develop trend data for inventory volume. Due to continuing difficulties in estimating tree bole and sawlog lengths over time, a procedure that predicts previous merchantable lengths by assigning an average length by species group and diameter class has been used in the past. An improved procedure that uses nonlinear regression were developed (Westfall and Laustsen in press). New tree-section lengths have been used to recompute all individual tree volumes for the 1982 and 1995 inventories. These new estimates improve the ability to estimate change components (net growth, removals, and mortality), but does not solve the problematic lack of remeasurement of all sample locations and trees in the sample during the first 5-year inventory cycle. When the new sample grid was put in place, half of the sample locations were new. On the roughly 50

percent of sample locations that were remeasured, only trees on the central 24-foot, circular-radius fixed plot centered over the previously used 52.7-foot, circular-radius fixed plot (1/5-acre) were remeasured. Thus, only 12-percent of the sample trees measured in 1995 were remeasured in the first 5-year cycle. During the second cycle of inventory measurements, all sample locations and trees will be remeasured on forested samples. It is interesting to note that the first panel to be remeasured will capture a remeasured sample of trees that exceeds the entire first 5 years. As a result, the second cycle of inventory is expected to provide consistency between change in inventory volume and the net difference between net growth and removals estimates.

To overcome inconsistencies in previous publications, all of the 1982 and 1995 data have been recompiled to current standards. A set of reconciled tables is included in the Appendix.

Statistical Significance

This report contains a wealth of statistical estimates that are compared over time and among numerous variables. Changes in estimates are discussed in terms of direction and magnitude. All mention of “significant” changes are based on comparing 67-percent confidence intervals for the various estimates. If confidence intervals overlap, there has been no real change in a statistical sense. When confidence intervals do not overlap, significant change has occurred. This approach was used throughout the report, though no attempt was made to include all of the statistical tests of significance. Sampling errors are provided in the Appendix Tables. To approximate 95-percent confidence intervals, multiply the SE’s by 2.

Benefits: More Rapid and Complete Resource Analyses

Perhaps the most salient benefit of the new inventory system will be the nearly threefold improvement in timeliness. A complete new inventory will be available at the end of each 5-year cycle with updates on conditions available yearly. The installation of a single remeasured sample design across the State will greatly improve the quality of information on change in resource extent, status, and condition. The use of this national sample design will facilitate resource assessments that straddle traditional regional and state boundaries to include Maine's results within the New England region, as well as national and international assessments. The FIA website can be used to download data and make specific tabular queries for any state in the nation: <http://ncrs2.fs.fed.us/4801/fiadb/index.htm>.

The extension of the sample to include a broader range of measurements will help analysts better understand the relationships between resource change and underlying ecological variables. The implementation of a suite of forest health variables (Phase 3) will foster a more complete understanding of conditions on Phase 2 plots.

The hiring of permanent field crews is a significant advantage over the use of temporary crews. Under the new design, crew members are visiting sample locations within their region year after year, enhancing their ability to locate samples, obtain permission from landowners, identify local

species, evaluate tree quality, understand forest composition and management activities, and measure the forces affecting resource change in their region.

Although not a direct benefit of the annual inventory, new developments in geospatial analysis allow the use of the FIA grid samples to produce spatial surfaces that represent indicators of interest in Maine. A suite of mapped products is presented. The mapped surfaces were developed using modeling techniques or in some cases, a simple display of sample locations. In the case of kriging and other modeling, the Phase 1 forest-land base map is used to highlight variables of interest on 30-m pixels. The techniques selected take the best advantage of the spatial variability of the FIA data. Each approach provides a “mapped surface” that expresses this variability for the variable of interest. The intent of these products is not attempt to actually map each 30-m pixel but to display the area according to confidence of occurrence classes based on the FIA samples. One concern is determining how many sample plots are needed to provide a reasonable depiction of the spatial variability. In many cases, the FIA data are rich enough to utilize kriging. Another issue involves the neighbor-search routines used by kriging and the caution of displaying averages that reflect a wide range of values. For example, high-basal area plots that are averaged with low basal-area plots result in medium values assigned to pixels.

Definition of Terms

Accretion. The estimated net growth on trees that were measured during the previous inventory (divided by the number of growing seasons between surveys to produce average annual accretion).

It does not include the growth on trees that were cut during the period, nor those trees that died.

This component uses the incremental change in volume between two inventories.

Basal area . The cross-sectional area of a tree stem at breast height, expressed in square feet.

Board foot. A unit of lumber measurement 1 foot long, 1 foot wide, and 1 inch thick, or its equivalent. International ¼ inch rule is used as the USDA Forest Service standard log rule in the Eastern United States.

Commercial species. Tree species currently or prospectively suitable for industrial wood products; excludes species of typically small size, poor form, or inferior quality, e.g., hawthorn and sumac.

Condition. A delineation of a land area based on land use, forest type, stand size, regeneration status, reserved status, tree density, and owner class.

Cropland. Land that currently supports agricultural crops including silage and feed grains, bare farm fields resulting from cultivation or harvest, and maintained orchards. Includes cropland used for cover crops and soil improvement.

Cull decrement. The net volume of rough or rotten trees in the previous inventory that are classified as growing-stock trees in the current inventory (divided by the number of growing seasons between inventories to compute average annual cull decrement).

Cull increment. The net volume of growing-stock trees in the previous inventory that are classified as rough or rotten trees in the current inventory (divided by the number of growing seasons between inventories to compute average annual cull increment).

Cull tree. A rough tree or a rotten tree.

Diameter at breast height (d.b.h.). The diameter outside bark of a standing tree measured at 4-1/2 feet above the ground.

Dry ton. A unit of measure of dry weight equivalent to 2,000 pounds or 907.1848 kilograms.

Dry weight. The weight of wood and bark as it would be if it had been oven dried; usually expressed in pounds or tons.

Forest land. Land that is at least 10 percent stocked with trees of any size, or that formerly had such tree cover and is not currently developed for a nonforest use. The minimum area for classification of forest land is 1 acre. The components that make up forest land are timberland and all noncommercial forest land.

Forest type. A classification of forest land based on the species that form a plurality of live-tree stocking.

Forest-type group. A combination of forest types that share closely associated species or site requirements are combined into forest-type groups.

Gross growth. The sum of accretion and ingrowth.

Growing-stock trees. Live trees of commercial species classified as sawtimber, or poletimber; that is, all live trees of commercial species except rough and rotten trees.

Growing-stock volume. Net volume, in cubic feet, of growing-stock trees 5.0 inches and larger in from a 1-foot stump to a minimum 4.0-inch top diameter outside bark of the central stem, or to the point where the central stem breaks into limbs. Net volume equals gross volume less deduction for cull.

Habitat type. A classification of forest land that uses existing trees to classify conditions according to “potential natural” tree communities. These ecological habitat types are intended to describe communities that are stable over time as opposed to traditional FIA forest types that describe only the existing vegetation. The FIBER model is used to classify sample plot conditions using habitats that are determined by soil-site relationships that change slowly (Solomon and others 1995; Leak 1982). Habitat types used for Maine are beech/red maple, cedar/black spruce, hemlock/red spruce, oak/white pine, spruce/fir, and sugar maple/ash.

Harvest disturbance.

- a) Partial harvest. Harvest by which trees are removed individually or in small patches (fewer than 5 acres in size), sometimes referred to as selection cutting.
- b) Shelterwood. Harvest of mature trees from a forest site in two or more stages. The first stage removes only a portion of the trees to allow establishment of regeneration before the remaining trees are removed in a subsequent harvest.
- c) Clearcut. Harvest on a site more than 5 acres in size that results in a residual basal area of acceptable growing-stock trees more than 4.5-inches d.b.h. and less than 30 square feet per acre, unless after harvesting the site has a well-distributed stand of acceptable growing-stock trees at least 3.0 and 5.0 feet tall for softwoods and hardwoods, respectively.
- d) Change of land use. Harvest conducted to convert forest land to another land use, such as house lots, farm pastures, and other uses.

Hardwoods. Dicotyledonous trees, usually broad-leaved and deciduous.

Ingrowth. The estimated net volume of trees that became 5.0 inches or larger in d.b.h. during the period between inventories (divided by the number of growing seasons between surveys to produce average annual ingrowth). Also, the estimated net volume of trees 5.0 inches and larger in d.b.h. that are growing on land that was reclassified from noncommercial forest land or nonforest land to timberland.

International 1/4-inch rule. A log rule or formula for estimating the board-foot volume of logs. The mathematical formula is:

$$\text{Board-foot volume} = (0.22D^2 - 0.71D)(0.904762)$$

for 4-foot sections, where D=diameter inside bark at the small end of the log section. This rule is used as the USDA Forest Service standard log rule in the Eastern United States.

Land area. (a) Bureau of Census: The area of dry land and land temporarily or partly covered by water, such as marshes, swamps, and river flood plains; streams, sloughs, estuaries, and canals less than 200 feet wide; and lakes, reservoirs, and ponds less than 4.5 acres in area; (b) Forest Inventory and Analysis: same as (a) except that the minimum width of streams, etc. is 120 feet, and the minimum size of lakes, etc. is 1 acre.

Land use. A classification of land that indicates the primary use at the time of inventory. Major categories are forest land and nonforest land.

Live tree. Growing-stock, rough, and rotten trees of any size. Live trees at least 1.0-inches d.b.h. and larger are the commonly referred to.

Merchantable stem. The main stem of the tree between a 1-foot stump height and a 4-inch top diameter (outside the bark), including the wood and bark.

Mortality. The estimated net volume of trees at the previous inventory that died from natural causes before the current inventory (divided by the number of growing seasons between surveys to produce average annual mortality).

Net change. The difference between the current and previous inventory estimates of volume (divided by the number of growing seasons between surveys to produce average annual net change). Components of net change are ingrowth plus accretion, minus mortality, minus cull increment, plus cull decrement, minus removals.

Net dry weight. The dry weight of woody material less the weight of all unsound (rotten) material.

Net growth. The change, resulting from natural causes, in volume during the period between surveys (divided by the number of growing seasons to produce average annual net growth). Components of net growth are ingrowth plus accretion, minus mortality, minus cull increment, plus cull decrement.

Noncensus water. Streams/ivers 120 to 200 feet wide and bodies of water 1 to 4.5 acres in size.

The Bureau of the Census classifies such water as land.

Noncommercial species. Tree of typically small size, poor form, or inferior quality that usually are unsuitable for industrial wood products.

Nonforest land. Land that has never supported forests, or land formerly forested but now in nonforest use, e.g., cropland, pasture, residential areas, marshes, swamps, highways, industrial or commercial sites, or noncensus water.

Nonsalvable dead tree. A dead tree with most or all of its bark missing that is at least 5.0 inches d.b.h. and at least 4.5 feet tall.

Nonstocked area. A stand-size class of forest land that is less than 10 percent stocked with live trees.

Owner class. A classification land into categories of ownership:

a) Forest industry. Land owned by companies or individuals that operate wood-using plants.

b) Nonindustrial private . Land owned by companies, nongovernmental organizations (such as timber investment management organizations), or individuals that do not operate wood-using plants.

c) Public. Land owned by federal, state, municipal, or county government.

Pasture land. Includes pasture land other than cropland and woodland pasture. It can include lands that have had lime fertilizer or seed applied, or that had been improved by irrigation, drainage, or control of weeds and brush.

Poletimber stand. A stand-size class of forest land that is at least 10 percent stocked with live trees of which half or more of such stocking is in poletimber or sawtimber trees or both, and in which the

stocking of poletimber exceeds that of sawtimber. This term also applies to the stand-diameter class variable that is based on basal area per acre.

Poletimber tree. A live tree of commercial species meeting regional specifications of soundness and form and at least 5.0 inches in d.b.h., but smaller than a sawtimber tree (9.0 inches d.b.h. for softwoods and 11.0 inches d.b.h. for hardwoods)

Potential sawtimber tree (sawlog quality). A commercial tree species that is field coded as a growing stock tree but is below the minimum diameter for sawtimber (9.0 inches d.b.h. for softwoods and 11.0 inches d.b.h. for hardwoods).

Pulpwood quality tree. A commercial tree species that is field coded as a growing-stock tree or as a rough cull tree.

Relative stand density. A stocking classification procedure that reflects species, stage of development, and the characteristics of the trees present in a stand.

Removals. The net volume harvested or killed in logging, cultural operations (such as timber stand improvement) or land clearing, and the net volume neither harvested nor killed but now growing on land that was reclassified from timberland to noncommercial forest land or nonforest land during the period between surveys. This volume is divided by the number of growing seasons to produce average annual removals.

Reserved productive forest land. Forest land sufficiently productive to qualify as timberland but withdrawn from timber utilization through statute or administrative designation; land exclusively used for Christmas tree production.

Rotten tree. A live tree of commercial species that does not contain at least one 12-foot sawlog or two noncontiguous sawlogs, each 8 feet or longer, now or prospectively, and does not meet regional specifications for freedom from defect primarily because of rot; that is, more than 50 percent of the cull volume in the tree is rotten.

Rough tree. The same as a rotten tree except that a rough tree does not meet regional specifications for freedom from defect primarily because of roughness or poor form; also a live tree of noncommercial species.

Salvable dead tree. A tree at least 5.0 inches d.b.h. that has died recently and still has intact bark; may be standing, fallen, windthrown, knocked down, or broken off.

Sampling error. A measure of the reliability of an estimate, expressed as a percentage of the estimate. The sampling errors given in this report correspond to one standard error and are calculated as the square root of the variance, divided by the estimate, and multiplied by 100. Indicated in statistical tables as “SE”.

Sapling. All live trees 1.0 to 4.9 inches d.b.h.

Sapling/seedling stand. A stand-size class of forest land that is at least 10 percent stocked with live trees of which half or more of such stocking is in saplings or seedlings or both.

Sawlog. A log meeting regional standards of diameter, length, and freedom from defect, including a minimum 8-foot length and a minimum top diameter inside bark of 6 inches for softwoods and 8 inches for hardwoods. (See specifications under Tree-Grade Classification.)

Sawlog portion. That part of the bole of a sawtimber tree between the stump and the sawlog top.

Sawlog top. The point on the bole of a sawtimber tree above which a sawlog cannot be produced. The minimum sawlog top is 7.0 inches diameter outside bark (d.o.b.) for softwoods and 9.0 inches d.o.b. for hardwoods.

Sawtimber stand. A stand-size class of forest land that is at least 10 percent stocked with live trees of which half or more of such stocking is in poletimber or sawtimber trees or both, and in which the stocking of sawtimber is at least equal to that of poletimber. This term also applies to the stand-diameter class variable that is based on basal area per acre.

Sawtimber tree. A live tree of commercial species at least 9.0 inches d.b.h. for softwoods or 11.0 inches d.b.h. for hardwoods, containing at least one 12-foot sawlog or two noncontiguous 8-foot sawlogs, and meeting regional specifications for freedom from defect.

Sawtimber volume. Net volume in board feet, by the International 1/4-inch rule, of sawlogs in sawtimber trees. Net volume equals gross volume less deductions for rot, sweep, and other defects that affect use for lumber.

SE. See Sampling error.

Seedling. A live tree at least 1 foot tall but less than 1.0 inch d.b.h.

Snag. Standing dead tree with most or all of its bark missing that is at least 5.0 inches d.b.h. and at least 4.5 feet tall (does not include salvable dead).

Softwoods. Coniferous trees, usually evergreen and having needles or scalelike leaves.

Sound-Wood Volume. Tree volume of the central stem from a 1-foot stump to a minimum top diameter outside bark or a point where the stem breaks into limbs. Sound cull portions are included. Rotten cull portions are excluded. Most often expressed in cubic feet for live trees.

Species Group. Species groups referred to in some tables and figures are as follows:

a) Balsam Fir.

b) Spruces. white spruce, red spruce, and black spruce.

c) Eastern white pine. eastern white pine

d) Northern white-cedar.

e) Hemlock. eastern hemlock

f) Other miscellaneous softwoods. These merchantable sized (5.0 inches and larger in d.b.h.) species were tallied in 1999, 2000, 2001, or 2002: plantation larch, tamarack, norway spruce, jack pine, red pine, pitch pine, pond pine, and scotch pine.

g) Red maple.

h) Sugar maple/beech/yellow birch. sugar maple, American beech, and yellow birch.

i) Intolerant hardwoods. paper birch, cottonwood species, balsam poplar, eastern cottonwood, bigtooth aspen, quaking aspen

j) Other miscellaneous commercial hardwoods . These merchantable sized (5.0inches and larger in d.b.h.) species were tallied in 1999, 2000, 2001, or 2002: silver maple, norway maple, Ohio buckeye, sweet birch, shagbark hickory, white ash, black ash, green ash, butternut, black cherry, white oak, scarlet oak, northern red oak, black oak, black willow, basswood species, American basswood, elm species, and American elm.

j) Noncommercial hardwoods. These merchantable sized (5.0 inches and larger in d.b.h.) species were tallied in 1999, 2000, 2001, or 2002: maple species, striped maple, mountain maple, serviceberry, birch species, gray birch, american hornbeam, osage-orange, apple species, eastern hophornbeam, pin cherry, chokecherry, willow species, and American mountain-ash.

All unknown species – Tree species that are unknown or not listed.

Stand. A group of forest trees growing on forest land.

Stand origin. An indication of how the measured stand originated: 100 percent natural, 100 percent artificial, or a combination of both.

Stand-diameter class. A classification of forest land based on the plurality of basal area per acre of live trees sampled on each condition: sapling (1.0 to 4.9 inches d.b.h.), poletimber (5.0 to 10.0 inches d.b.h.), small sawtimber (10.0 to 14.9-inches d.b.h.), and large sawtimber (15.0 inches and larger in d.b.h.). The classification requires at least 5.0 square feet of basal area per acre in trees that are of intermediate, co-dominant, or dominant crown position. Conditions with less than 5.0 square feet are classified as low/no basal area. This classification is an alternative to the traditional FIA stand-size class and is used only for Maine.

Stand-size class. A classification of forest land based on the size class (that is, seedlings, saplings, poletimber, or sawtimber) of the stocking of all live trees in the area.

State lands. Lands owned by the state or leased to the state for 50 years or more.

Stocking. The degree of occupancy of land by trees relative to the growth potential utilized by a site. It is expressed as a percent of the “normal” value presented in yield tables and stocking guides. Two categories of stocking are traditionally used in FIA reports: all live trees and growing-stock trees. The relationships between the classes and the percentage of the stocking standard are: nonstocked (0 to 9); poorly stocked (10 to 34); moderately stocked (35 to 59); fully stocked (60 to 100); and overstocked (100+).

In this report, stocking regions were developed using the FIBER model (Solomon and others 1995) to classify forest land as understocked, sub-optimal, optimal, or overstocked. Stocking regions describe the site’s degree of stocking in relation to management opportunities, e.g., suboptimal stands typically require 10 years before stocking would be sufficient for management activity. Stocking regions relate directly to thresholds depicted by FIBER stocking charts. Understocked acreage is below the “C-line.” Sub-optimal acreage is between the C-line and “B-line.” Optimal acreage is between the B-line and the “A-line.” Overstocked acreage is above the A-line.

Stump. The main stem of a tree from ground level to 1 foot above ground level, including the wood and bark.

Timberland. Forest land producing or capable of producing crops of industrial wood (more than 20 cubic feet per acre per year) and not withdrawn from timber utilization by statute (Acadia National Park and Appalachian Trail Corridor) or administrative designation (Baxter State Park and Bureau of Parks and Lands Ecological Reserve). The statutes and designations apply to publicly owned land only. Timberland was formerly known as commercial forest land. Timberland may be

“nonstocked” so long as no natural condition, or human activity prevents or inhibits the establishment of tree seedlings.

Timberland includes the following components:

a) Rural. The historical and traditional acreage classified as timberland in previous inventories.

b) Other forest land. Defines a subset of forest land that is producing, or capable of producing, crops of industrial wood, but is associated with or part of a nonforest land use. In the past, these areas would have been treated as inclusions in the nonforest land use because they were considered part of a development. The minimum area for classification as Other Forest Land is 1 acre. These strips of timber must have a crown width of at least 120 feet. Examples of land that could be classified as Other Forest Land are forested portions of city parks, forested land in highway medians and rights-of-way, forested areas between ski runs, and forested areas within golf courses. Generally, although surrounded by nonforest development, these areas have not been developed and exhibit natural, undisturbed understories.

c) Urban timberland. A subset of forest land that now is grouped into timberland. Include land that except for its location would be classified as rural timberland. This land is nearly (surrounded on three sides) or completely surrounded by urban development, whether commercial, industrial, or residential. This land meets all the criteria for timberland, that is, at least 1 acre capable of producing at least 20 cubic feet per acre per year of industrial wood, is not developed for other than timber production, and is not reserved by a public agency. It is highly

unlikely that such land would be used for timber products on a continuing basis. Such land may be held for future development, or scheduled for development. (The timber that is present may be utilized only at the time of development.) The land may be undeveloped due to periodic flooding, low wet sites, steep slopes, or their proximity to industrial facilities that are unsuitable for residential development. Forested areas within city parks are not urban forest land; it may be Other Forest Land if all requirements are met. City parks cannot be classified as urban timberland as it is currently defined.

Timber products. Roundwood (round timber) products and manufacturing plant by-products harvested from growing-stock trees on timberland, from other sources, e.g., cull trees, salvable dead trees, limbs, tops, and saplings, and from trees on noncommercial forest and nonforest lands.

Timber removals. The growing-stock or sawtimber volume of trees removed from the inventory for roundwood products, plus logging residues, volume destroyed during land clearing, and volume of standing trees on land that was reclassified from timberland to noncommercial forest land.

Top. The wood and bark of a tree above the merchantable height (or above the point on the stem 4.0 inches in diameter outside bark); generally includes the uppermost stem, branches, and twigs of the tree, but not the foliage.

Tree class. A classification of the quality or condition of trees for sawlog production. Tree class for sawtimber trees is based on current condition. Tree class for poletimber trees is a prospective

determination--a forecast of potential quality when they reach sawtimber size (11.0 inches d.b.h. for hardwoods, 9.0 inches d.b.h. for softwoods).

Tree grade. A classification of sawtimber quality based on guidelines for tree grades for hardwoods, white pine, and southern pine. (Note: Red pine was graded using the guidelines for southern pine.)

Trees. Woody plants that have well-developed stems and that usually are more than 12 feet tall at maturity.

Unproductive forest land. Forest land that is incapable of producing 20 cubic feet per acre per year of industrial wood under natural conditions due to of adverse site conditions.

Upper-stem portion. That part of the main stem or fork of a sawtimber tree above the sawlog top to a diameter of 4.0 inches outside bark, or the point where the main stem or fork breaks into limbs.

Veneer log or bolt. A roundwood product from which veneer is sliced or sawn that usually meets certain minimum standards of diameter, length, and defect.

Volume suitable for pulpwood. The net volume (only rotten cull excluded) of growing-stock and rough trees.

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In 1999, the Maine Forest Service and USDA Forest Service's Forest Inventory and Analysis program implemented a new system for inventorying and monitoring Maine's forests. The effects of the spruce budworm epidemic continue to affect the composition, structure, and distribution of Maine's forested ecosystems. The area of forest land in Maine has remained stable since the 1970's. Although relatively small acreages of forest are converted to other land uses, these conversions often remove highly valued forests such as white pine. The total inventory volume of live trees increased slightly, indicating the beginning of a response of Maine's forest to the tremendous devastation from spruce budworm.

Keywords: forest composition; forest vitality; sustainability; timber volume; ingrowth.