Maintenance of Productive Capacity of Forest Ecosystems

W. Keith Moser, Patrick D. Miles, Aimee Stephens, Dale D. Gormanson, Stephen R. Shifley, David N. Wear, Robert J. Huggett, Jr., Ruhong Li

Introduction

THIS CHAPTER REPORTS projected changes in forest area, age, volume, biomass, number of trees, and removals from 2010 to 2060 for alternative scenarios that bracket a range of possible future socioeconomic and climate conditions in the Northern United States, which consists of 20 central and northeastern States (see Fig. 1.1). As described in Chapter 2, the scenarios incorporate different assumptions about population growth, economic development, land-use change, carbon emissions, and climate change. Changes in forest attributes over time for each scenario were estimated using the Forest Dynamics Model (Wear et al. 2013). The information presented in this chapter, more than any other, is directly derived from projections of changing forest conditions for each scenario as modeled by the Forest Dynamics Model.

Several alternative scenarios were used that cover a range of different assumptions about the economy, population, climate and other driving forces. The assumptions were incorporated into analytical models that estimate how northern forests are likely to change under each alternative scenario. The seven scenarios (A1B-C, A1B-BIO, A2-C, A2-BIO, A2-EAB, B2-C, and B2-BIO) are based on a storyline and storyline variation. They are labeled by their storyline identifier (A1B, A2, or B2) followed by a hyphen and the storyline variation (C, BIO, or EAB).

The storylines were developed by the Intergovernmental Panel on Climate Change (IPCC 2007, Chapter 2): A1B assumes moderate gains in population growth with large gains in income and energy consumption—but with a balanced renewable/fossil fuel portfolio; A2 assumes large gains in population growth and energy consumption with moderate gains in income; and B2 assumes moderate gains in population growth, income, and energy consumption. All projections are estimated using two versions of a single global circulation model, the CGCM 3.1 (Canadian Centre for Climate Modelling and Analysis 2012a) for A1B and A2 and the CGCM 2.0 (Canadian Centre for Climate Modelling and Analysis 2012b) for B2.

Key Findings

- If harvesting rates observed in the recent past continue into the future, differences in projections of forest conditions in the northern region would be small.
- Under all projections, the trend of steadily increasing live wood volume that characterized northern forests in the past century would level off from 2010 to 2050; after 2050, volume is projected to decrease if harvesting increases to satisfy demand for bioenergy.
- The levels of increased biomass harvesting for energy assumed in three scenarios appear to be too large to be sustainable through 2060; lower levels of harvesting for energy or projections that include wood-energy plantations could have different outcomes.
- Forest area by age class is concentrated in the 40- to 80-year age category, resulting in a lack of structural forest diversity that would take decades to alter.
- Under a projection of large gains in population and energy consumption and moderate gains in income, total ash mortality within the expanding infestation forecasted for the emerald ash borer forest conditions would have little effect on total volume, area by species group, or area by age class in northern forests.
- Under all projections for the North, the area of the maple-beech-birch forest-type group would increase and the area of nearly all other forest-type groups would decrease; projections are mixed for the white-red-jack forest-type group.
- For the North as a whole, projected forest removals resulting from land-use changes are likely to average about 13 percent of total removals, with the remainder resulting from harvesting; in populous eastern States—including Massachusetts, Maryland, New Jersey, and Rhode Island—removals resulting from land-use changes would be >50 percent in some decades.
- Under all projections for northern forests, the growth-to-removals ratio would be <1.0 (indicating an unsustainable situation over the long term) from 2035 to 2055; by 2060, the ratio would increase to 1.2 if harvesting rates observed in the recent past (2003 to 2008) continue into the future.
- The large increases in harvesting northern forests required to satisfy a robust demand for bioenergy would not be sustainable over the long term because it would result in decreasing forest volume after 2050; this does not suggest that lower rates of bioenergy harvesting would be unsustainable.

The three storyline variations are as follows:

- C—the standard variation continuing recent removals trends
- BIO—increased harvest and utilization of woody biomass for energy
- EAB—potential impact of continued spread of the emerald ash borer (EAB) (*Agrilus planipennis*) with associated mortality of all ash trees in the affected areas.

A baseline assessment (Shifley et al. 2012) characterized the North as the most densely forested and most densely populated region of the country—a place where people and forests meet and mingle. The past influences of this juxtaposition of people, forests, and associated interactions have culminated in the forests of today, and expectations about future interactions strongly shape projections of forest conditions. Over the next 50 years, population is expected to increase across all three storylines (Chapter 2) resulting in an increase in urban areas at the expense of all other land uses (Chapter 10).

FOREST AREA

Over Time

The anticipated decreases in forest area reverse the long-term trend of increasing forest area in the region (Fig. 4.1). Over the next 50 years, forest land area is projected to decrease from an estimated 174 million acres in 2010 to 163 million acres (-6.4 percent) in 2060 under A1B; to 165 million acres (-5.4 percent) under A2; and to 168 million acres (-3.5 percent) under B2. Although decreasing by about 1 percent per decade across all scenarios, the anticipated losses would still be relatively small compared to the cumulative increase in forest area since the start of the 20th century. However, the anticipated loss paired with the expected increases in population would mean a substantial decrease in forest area per capita (Appendix Chapter 2). Northern forests will have to work harder to meet the needs of a growing population, which is expected to increase by somewhere between 15 and 50 million people from 2010 to 2060 (Chapter 2).

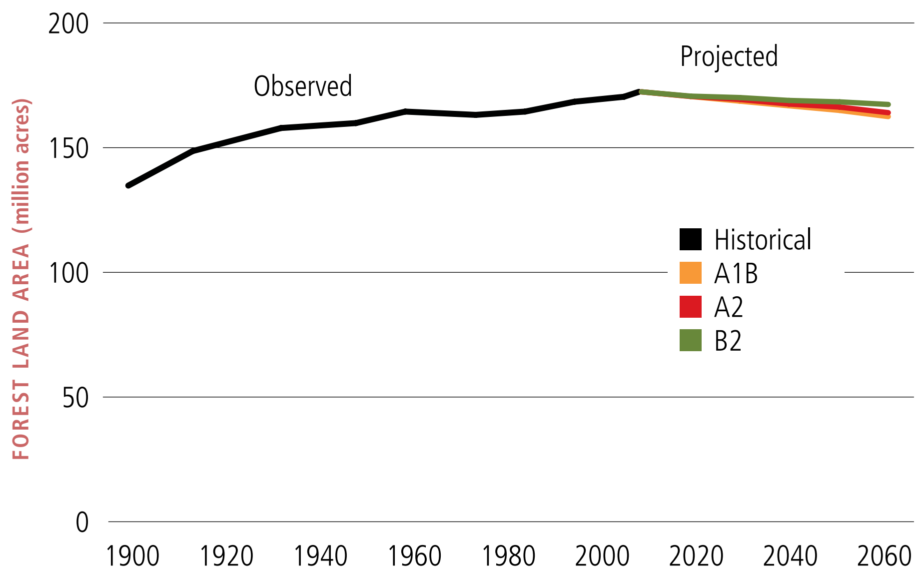


FIGURE 4.1

Forest area in the North under historical conditions (Smith et al. 2009) and projected from 2010 to 2060 under three greenhouse gas storylines (IPCC 2007)—A1B assumes moderate greenhouse gas emissions, moderate gains in population, and large gains in income and energy consumption (but with a balanced renewable/fossil fuel portfolio); A2 assumes high greenhouse gas emissions, large gains in population and energy consumption, and moderate gains in income; and B2 assumes low greenhouse gas emissions with moderate gains in population, income, and energy consumption. Forest area in 1630 has been estimated at about 300 million acres.

Projected population increases are expected to occur in and around existing urban centers (Chapter 2). Consequential losses in forest area are expected to follow a similar pattern (Chapter 3). As a result, forest land losses would be concentrated in the more densely populated States along the Atlantic seaboard (Fig. 4.2). With the loss of forest land and with the clustering of losses around urban areas would come additional concerns about fragmentation and parcellation, the consequences of which could outweigh the relatively small percentage loss in total forest area (Chapter 3).

By Forest-type Group

The current distribution of forest area by forest-type groups is spatially depicted in Figure 4.3 and displayed in Figure 4.4. Under all three scenarios the oak-hickory (*Quercus* spp.–*Carya* spp.) and maple-beech-birch (*Acer* spp.–*Fagus* spp.–*Betula* spp.) groups would continue to dominate through 2060. These two types, which together comprised 62 percent of the total forest area in 2010, are projected to account for about 64 percent of total forest area under all scenarios in 2060 (Appendix Chapter 4).

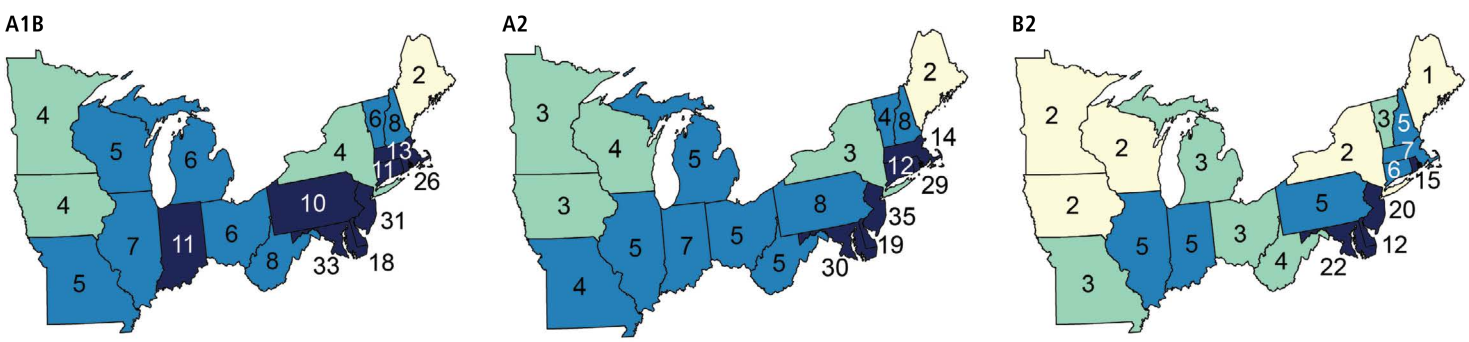
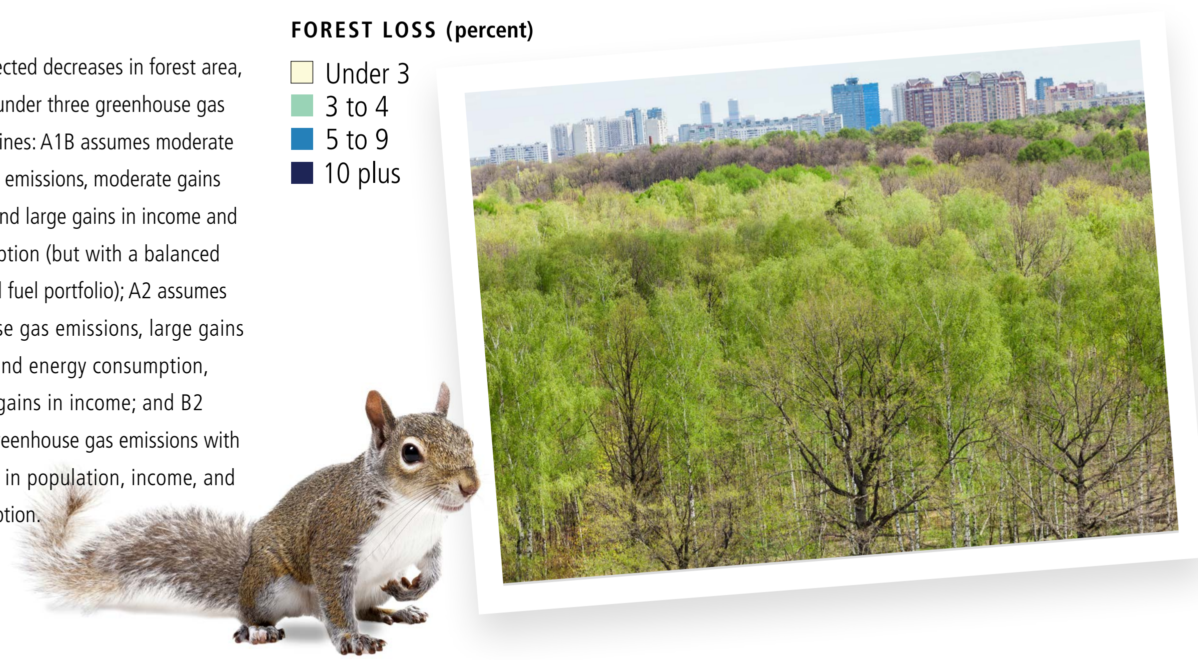


FIGURE 4.2

State-level projected decreases in forest area, 2010 to 2060, under three greenhouse gas emissions storylines: A1B assumes moderate greenhouse gas emissions, moderate gains in population, and large gains in income and energy consumption (but with a balanced renewable/fossil fuel portfolio); A2 assumes high greenhouse gas emissions, large gains in population and energy consumption, and moderate gains in income; and B2 assumes low greenhouse gas emissions with moderate gains in population, income, and energy consumption.

FOREST LOSS (percent)

- Under 3
- 3 to 4
- 5 to 9
- 10 plus



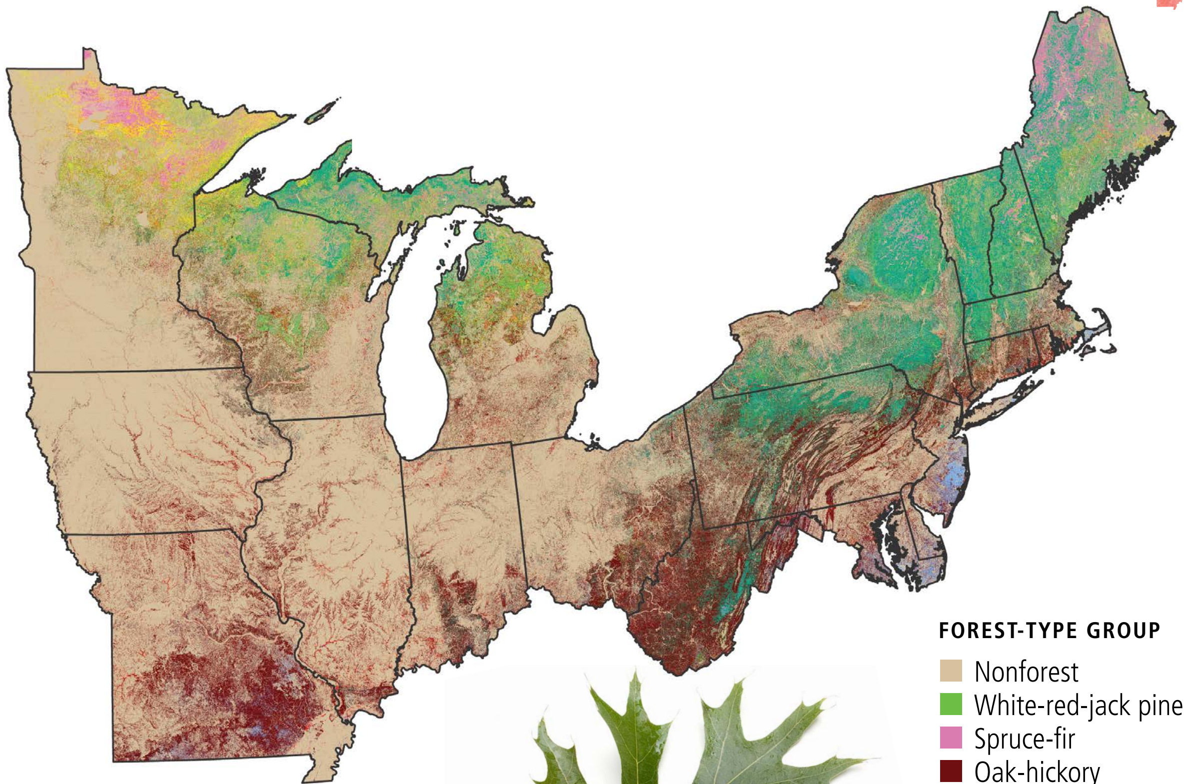


FIGURE 4.3

Forest-type groups in the North (Wilson et al. 2012, Wilson et al. 2013).

Forest area loss will likely be one of the biggest contributors to composition changes in northern forests from 2010 through 2060. Figure 4.5 shows the percent change in forest area by forest-type group. Four of the six groups—spruce-fir (*Picea* spp.—*Abies* spp.), oak-hickory, elm-ash-cottonwood (*Ulmus* spp.–*Fraxinus* spp.–*Populus* spp.), and aspen-birch (*Populus* spp.—*Betula* spp.)— are projected to decrease under all three scenarios. The white-red-jack pine group (*Pinus strobus* – *Pinus resinosa* – *Pinus banksiana*) is expected to increase under some scenarios, and the maple-beech-birch group is expected to increase under all scenarios.

These changes reflect the differential impacts of projected stand development, succession, growth, harvest, and mortality on areas that would remain forested (for example, more maple-beech-birch and less oak-hickory). Also, projected increases in urban areas would affect some groups more than others, in large part reflecting their relative abundance in locations near major population centers.

Only 52 percent of forest area is projected to be in the same forest-type group in 2060 as it was in 2010 (Fig. 4.6), with changes stemming from a variety of causes including succession, harvesting, and diversion to nonforest land uses. For example, only 40 percent of the land that was in the white-red-jack pine group in 2010 is projected to remain in that group in 2060; 21 percent is projected to be converted to the late successional maple-beech-birch group; and 5 percent to nonforest uses (Fig. 4.6). Conversion to nonforest land uses is projected to be highest in the “other” forest-type group (10 percent) and the oak-hickory group (9 percent), both of which are often located in close proximity to urban areas. Conversions to nonforest would be lowest (2 percent) for the spruce-fir group, which is usually located far from large urban areas. The elm-ash-cottonwood group—especially under the emerald ash borer scenario—and the aspen-birch groups would experience the largest percentage decrease (Fig. 4.5).

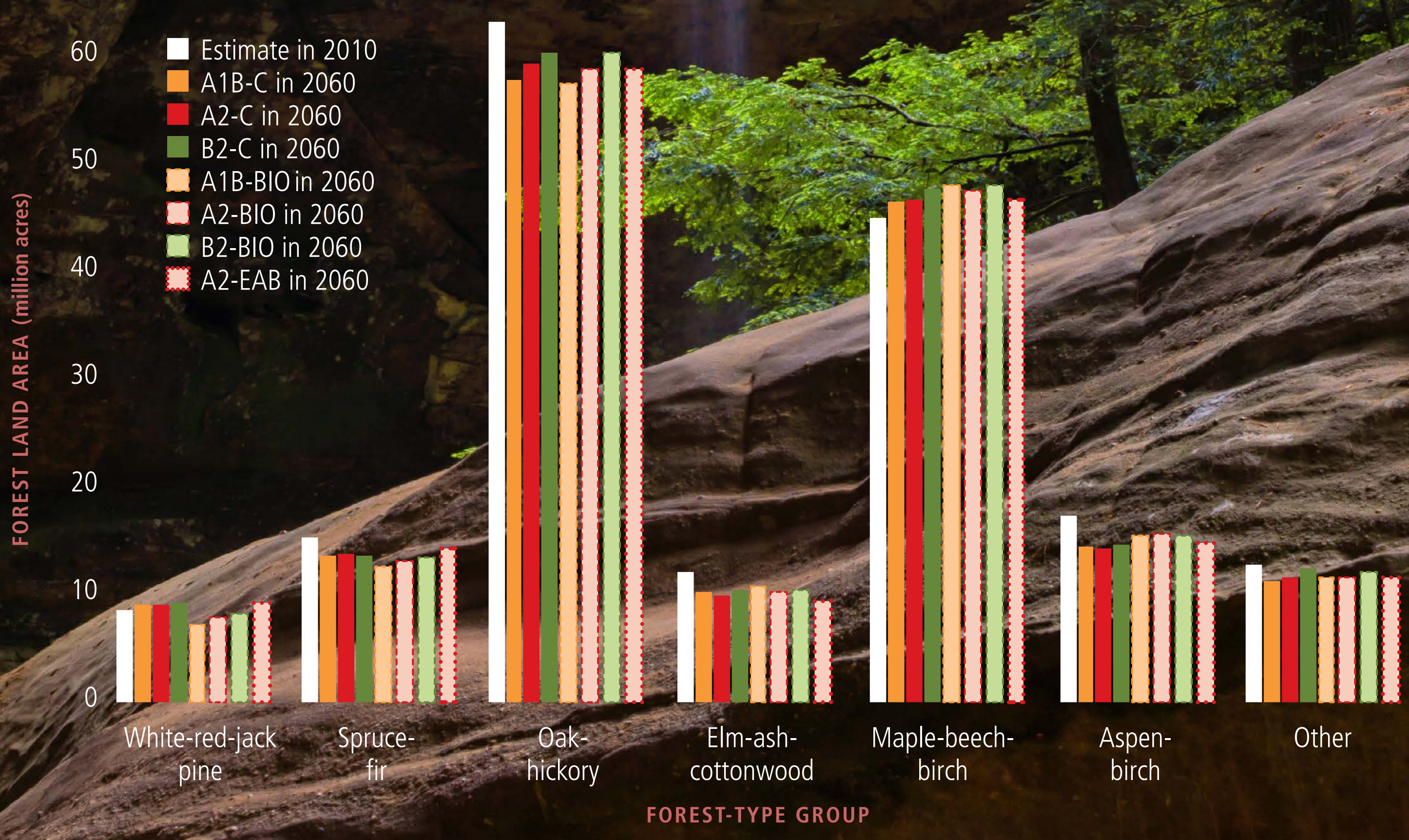
By Age Class

Because of past patterns of natural and human disturbance that occurred in the first half of the 20th century, northern forests are predominantly “middle aged,” with over half of current acres between 40 and 80 years and relatively few acres <20 years or >100 years (Pan et al. 2011) (Fig 4.7). This lack of age-class diversity has implications for biodiversity and wildlife habitat suitability now and into the future (Chapter 3).

In forests undergoing normal patterns of succession without large disturbances, the age-class distribution naturally shifts toward older forests. Certain harvesting practices or severe insect, disease, or fire effects will regenerate forest area and move it to the youngest age class. Over the past five decades, however, rates of forest regeneration have been relatively low, and northern forests have aged.

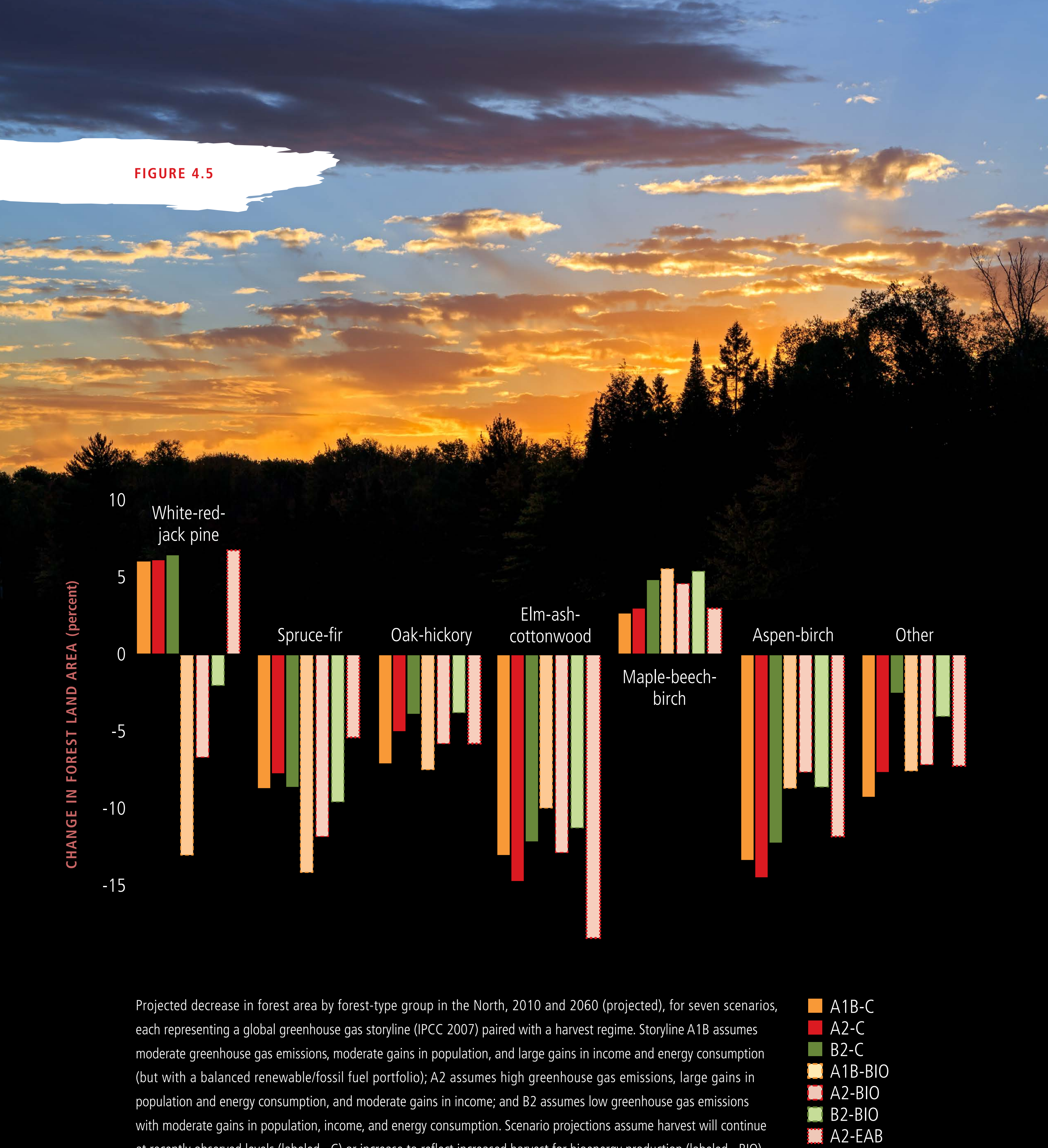
Three of the scenarios (A2-C, A1B-C, and B2-C) assume continuation of the levels of forest harvesting, regeneration, and disturbance that have contributed to the current compressed age-class distribution. As a result, northern forests would continue to age, with the bulk of acres shifting into the 60- to 100-year classes over the next 50 years (Fig 4.7). Chapter 3 reports decreasing potential habitat for species that depend on early successional forest ecosystems, primarily because of changes in forest succession and conversion of forests to nonforest uses. Under A2-EAB, a similar shift in the age-class distribution would occur, despite the assumed loss of ash species to the continued spread of emerald ash borer. For all of these scenarios, forest maturation over the next five decades is expected to decrease the area of forest land <60 years and increase area for older forests (Fig. 4.8). Longer projection periods would likely exacerbate this trend.

FIGURE 4.4



Area of forest land in the North by forest-type group, 2010 and 2060 (projected), for seven scenarios, each representing a global greenhouse gas storyline (IPCC 2007) paired with a harvest regime. Storyline A1B assumes moderate greenhouse gas emissions, moderate gains in population, and large gains in income and energy consumption (but with a balanced renewable/fossil fuel portfolio); A2 assumes high greenhouse gas emissions, large gains in population and energy consumption, and moderate gains in income; and B2 assumes low greenhouse gas emissions with moderate gains in population, income, and energy consumption. Scenario projections assume harvest will continue at recently observed levels (labeled –C) or increase to reflect increased harvest for bioenergy production (labeled –BIO). Scenario A2-EAB is a variation of scenario A2-C that also assumes all ash species will eventually succumb to an expanding zone of infestation by the nonnative emerald ash borer.

FIGURE 4.5



Projected decrease in forest area by forest-type group in the North, 2010 and 2060 (projected), for seven scenarios, each representing a global greenhouse gas storyline (IPCC 2007) paired with a harvest regime. Storyline A1B assumes moderate greenhouse gas emissions, moderate gains in population, and large gains in income and energy consumption (but with a balanced renewable/fossil fuel portfolio); A2 assumes high greenhouse gas emissions, large gains in population and energy consumption, and moderate gains in income; and B2 assumes low greenhouse gas emissions with moderate gains in population, income, and energy consumption. Scenario projections assume harvest will continue at recently observed levels (labeled –C) or increase to reflect increased harvest for bioenergy production (labeled –BIO). Scenario A2-EAB is a variation of scenario A2-C that also assumes all ash species will eventually succumb to an expanding zone of infestation by the nonnative emerald ash borer.

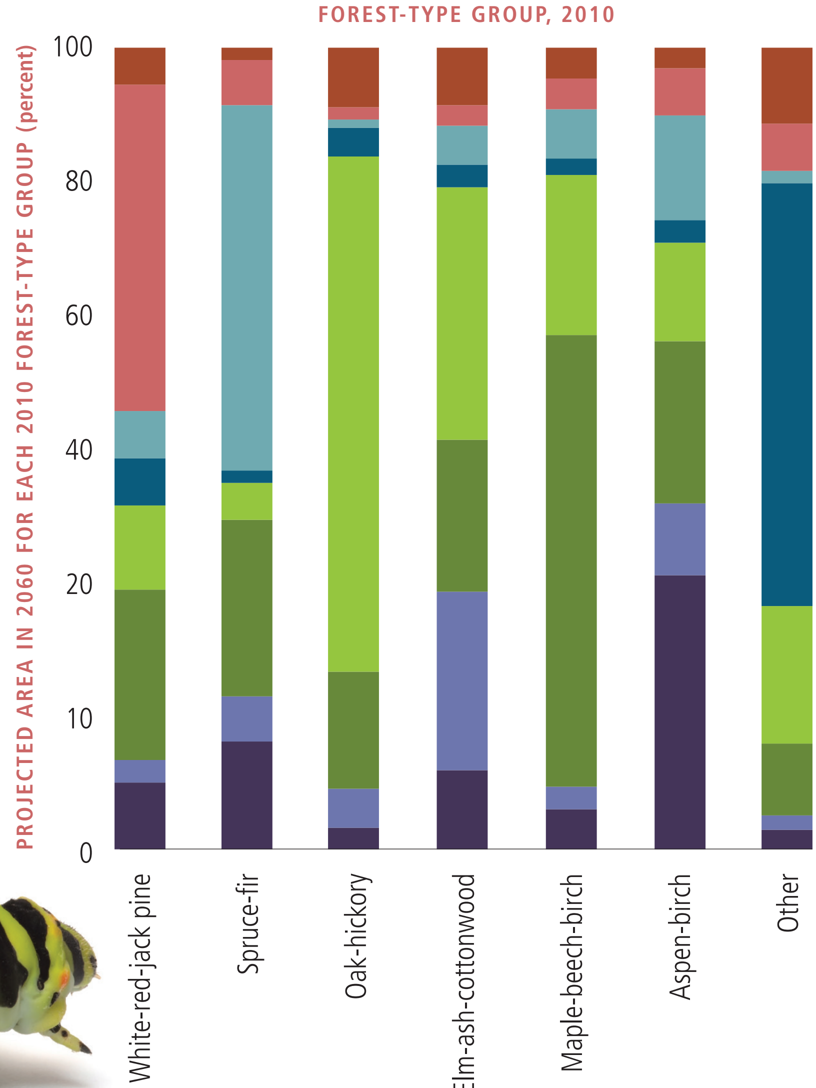


FIGURE 4.6

Projected change in the proportionate distribution of forest-type groups in the North, 2010 to 2060, under scenario A2-C that assumes high greenhouse gas emissions, large gains in population and energy consumption, moderate gains in income, and a continuation of recently observed harvest rates.

The pattern of age-class changes for A2-EAB, which assumes expanding zones of ash mortality, would mirror that of the A2-C scenario. Because ash species are rarely the majority component of forest stands, the loss would not have an effect on the stand age of affected forest acres.

Scenarios with enhanced removals to meet the demand for bioenergy (A1B-BIO, A2-BIO, and B2-BIO) are projected to have the largest impacts on the age structure of northern forests. All three scenarios assume an increase in harvesting that results in regenerated stands.

The projected total forest area would be the same for a paired set of scenarios (for example, A2-C versus A2-BIO), but the proportion of forest area in younger age classes would increase under the one that assumes increased harvesting for bioenergy. The result would be an increase in young (early successional) forests and a shift in distribution toward the younger age classes (Fig. 4.7). Under all scenarios with increased harvesting for bioenergy, forest area in the youngest age class (<20 years) would increase.

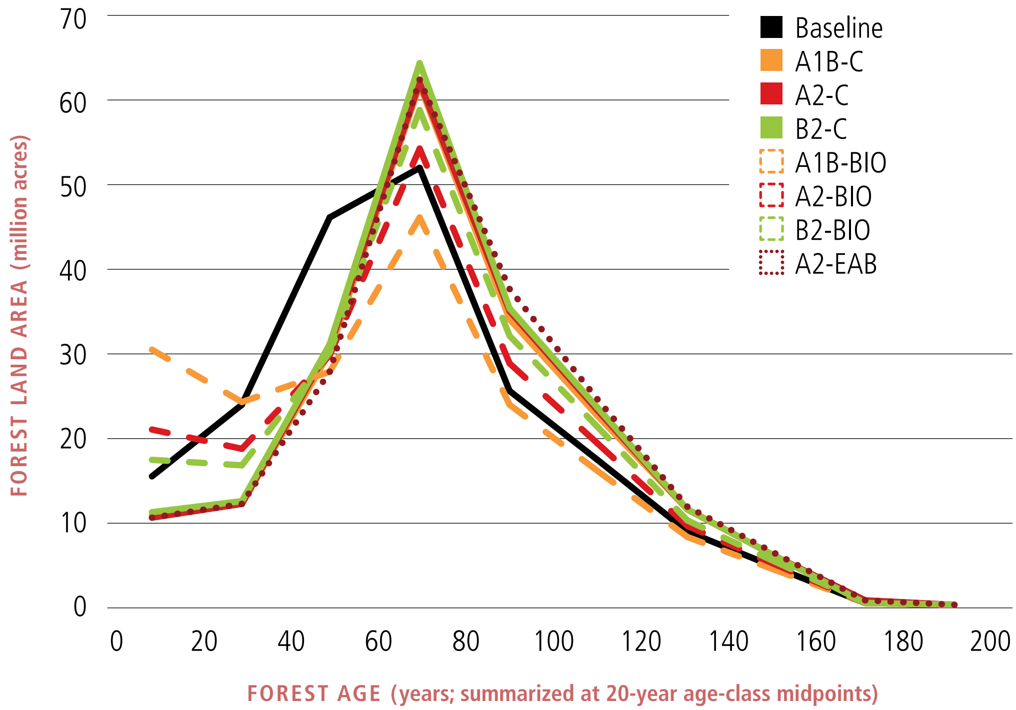


FIGURE 4.7

Forest land area by age class in the North is estimated for 2010 and projected for 2060 under seven scenarios, each representing a global greenhouse gas storyline (IPCC 2007) paired with a harvest regime. Storyline A1B assumes moderate greenhouse gas emissions, moderate gains in population, and large gains in income and energy consumption (but with a balanced renewable/fossil fuel portfolio); A2 assumes high greenhouse gas emissions, large gains in population and energy consumption, and moderate gains in income; and B2 assumes low greenhouse gas emissions with moderate gains in population, income, and energy consumption. Scenario projections assume harvest will continue at recently observed levels (labeled –C) or increase to reflect increased harvest for bioenergy production (labeled –BIO). Scenario A2-EAB is a variation of scenario A2-C that also assumes all ash species will gradually succumb to an expanding zone of infestation by the nonnative emerald ash borer.

Scenario A1B-BIO would result in double the area of young forests by 2060 while also reducing forest area in the 40- to 100-year classes. With increased harvesting, fewer acres would progress into older age classes. Thus, the projected increases for age classes >60 years would be smaller for scenarios with increased biomass harvesting than for no increase in harvesting (Figs. 4.7, 4.8).

All three scenarios with increased harvesting are expected to result in a more even distribution of forest area by age class, most notably for forests <80 years, which would improve both landscape-scale forest structural diversity and habitat diversity (Hunter and Schmiegelow 2011). However, as discussed in later sections of this chapter and in Chapter 5, the rate of harvesting associated with scenarios A1B-BIO, A2-BIO, and B2-BIO has other, less desirable, ramifications.

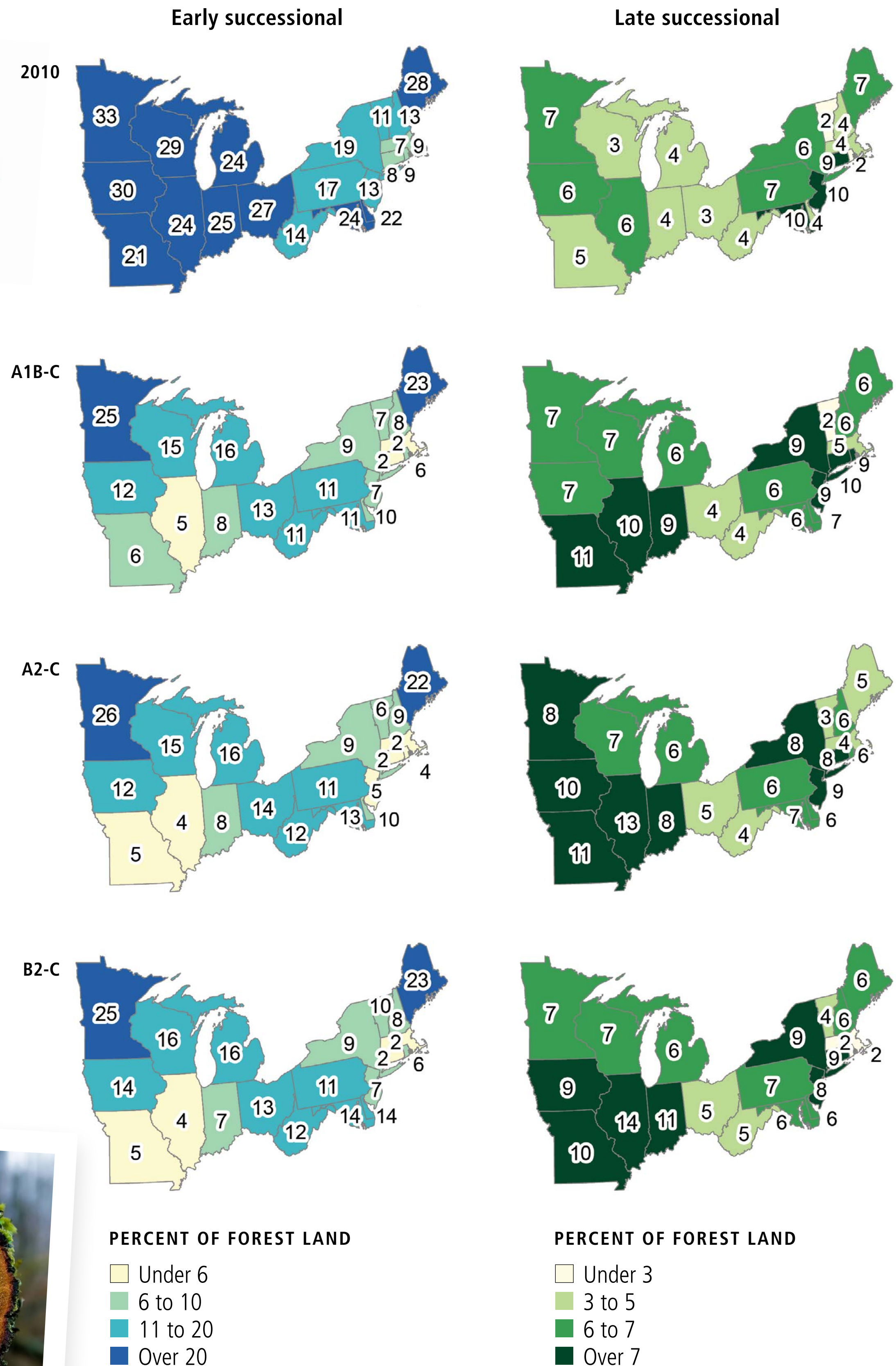


FIGURE 4.8

Proportionate area of early successional forest (aged 40 years or younger) and late successional forest (aged more than 100 years) in the North in 2010 and 2060 (projected) under three scenarios that assume a continuation of recently observed harvest levels. Furthermore, A1B assumes moderate greenhouse gas emissions, moderate gains in population, and large gains in income and energy consumption (but with a balanced renewable/fossil fuel portfolio); A2 assumes high greenhouse gas emissions, large gains in population and energy consumption, and moderate gains in income; and B2 assumes low greenhouse gas emissions with moderate gains in population, income, and energy consumption (IPCC 2007).

Many northern forests currently classified as >100 years will experience gap-phase regeneration and gradually move into an uneven-age structure with multiple age cohorts. Although uneven-aged stands do not fall neatly into a single age class or size class, these forests generally retain a cohort of mature, dominant overstory trees. Consequently, from a biodiversity perspective, uneven-aged stands are considered to be mature forests that are in the understory reinitiation stage of stand development—or as Oliver and Larson (1990) reported, in the old-growth stage of development.

NUMBER OF TREES

The number of trees in the region is projected to decrease by 12 to 20 billion, or roughly 10 to 17 percent, from 2010 to 2060 (Fig. 4.9). As forests age, fewer but larger trees are the expected outcome. The largest decrease would occur under the A2-EAB scenario, in which the emerald ash borer infestation would permanently reduce the total number of ash trees. The growing space released by dying ash trees is presumed to be captured by adjacent trees of other species rather than by new reproduction. This projected outcome—the long-lasting reduction in the total number of trees—is one of the most notable results from the A2-EAB scenario.

VOLUME

Live Tree Volume

The total volume of all live trees is a measure of historical productivity because it represents the wood volume that has accumulated up to the year of measurement. It is a function of site factors (productivity of the soil and availability of soil moisture), climatic factors (growing season length, averages and variations in temperature and rainfall), ecological factors (competing species and disturbances), and stand history (forest age, past management actions, and past disturbances). The estimates of all live volume include the volume from cull trees and noncommercial tree species, which are excluded in estimates of growing-stock volume discussed in the next section. Typically, estimates of all live volume are highly correlated with aboveground tree biomass, even though they exclude tree stumps, tops, branches, and bark, all considered part of the aboveground biomass pool.

The projected total live tree volume for the northern forests is somewhat similar across all scenarios until 2050 (Appendix Chapter 2, Fig. 4.10). The scenarios with increased biomass harvesting (A1B-BIO, A2-BIO, and B2-BIO) or increased mortality attributed to emerald ash borer (A2-EAB) would have less volume than those assuming no changes in harvesting (A1B-C, A2-C, and B2-C), but the trends for all scenarios would follow a similar pattern.

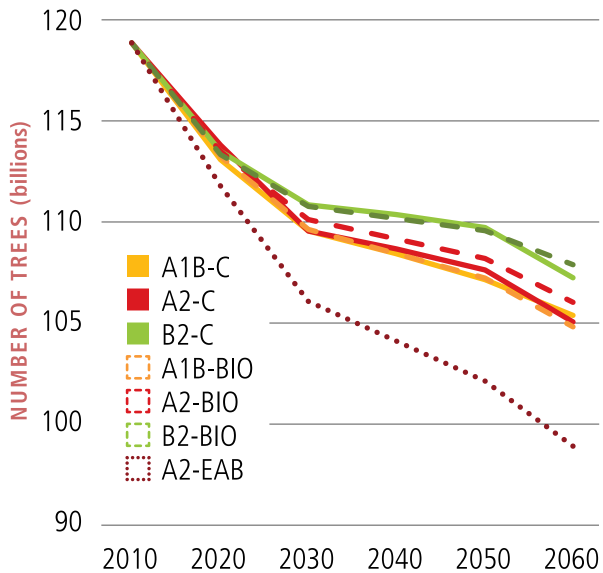


FIGURE 4.9

Projected number of trees in forests of the North, 2010 to 2060, under seven scenarios, each representing a global greenhouse gas storyline (IPCC 2007) paired with a harvest regime.

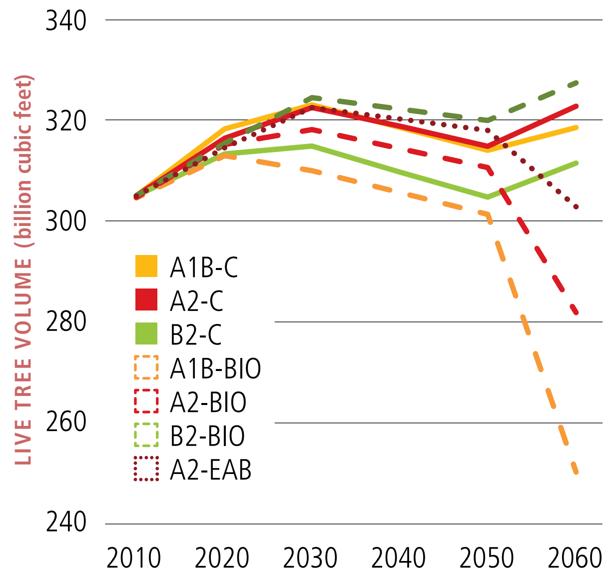


FIGURE 4.10

Projected live tree volume in forests of the North, 2010 to 2060, under seven scenarios, each representing a global greenhouse gas storyline (IPCC 2007) paired with a harvest regime.

Storyline A1B assumes moderate greenhouse gas emissions, moderate gains in population, and large gains in income and energy consumption (but with a balanced renewable/fossil fuel portfolio); A2 assumes high greenhouse gas emissions, large gains in population and energy consumption, and moderate gains in income; and B2 assumes low greenhouse gas emissions with moderate gains in population, income, and energy consumption. Scenario projections assume harvest will continue at recently observed levels (labeled –C) or increase to reflect increased harvest for bioenergy production (labeled –BIO). Scenario A2-EAB is a variation of scenario A2-C that also assumes all ash species will gradually succumb to an expanding zone of infestation by the nonnative emerald ash borer.

Starting in 2050, however, biomass removals would increase rapidly under scenarios A1B-BIO, A2-BIO, and B2-BIO with a corresponding decrease in volume. For those scenarios, bioenergy demand would exceed what can be provided by alternative sources such as residues from wood production and agriculture, and require that harvesting increase dramatically (Ince et al. 2011a,b; Chapter 2).

Only scenarios with increased biomass harvesting (A1B-BIO and A2-BIO and B2-BIO) projected a net decrease in live tree volume from 2010 to 2060. But as illustrated in the following section on growing-stock volume, even the scenarios that project volume increases estimate that the rate of increase would be lower than the rate observed over the previous five decades.

Live tree volume projections are markedly different across the region, with most of the States in western areas increasing in volume and most of the States farther east experiencing smaller increases or even decreases (Fig. 4.11). Many of the eastern States that are expected to experience losses are the same States expected to lose forest area to urbanization. Projected differences vary greatly by State under A1B-C, A2-C, and B2-C (based on historical removals by product class from 2003 to 2008) versus scenarios with increased biomass utilization. Examples are Minnesota and Wisconsin, both heavily forested and both expected to experience significant volume decreases under the biomass scenarios, particularly A1B-BIO, and increases under the other scenarios. Under all enhanced biomass scenarios, heavily forested States where current harvesting rates are high are projected to supply most of the additional biomass. This outcome is in part due to model assumptions about future biomass harvesting that are based on historical rates of harvest removals and land use. A simple scaling function is used to increase removals under the biomass scenarios (Chapter 2).

Differences in projected volume among forest-type groups are illustrated by comparing A2-C with corresponding scenarios that assume enhanced biomass utilization (A2-BIO) and expanding emerald ash borer impact (A2-EAB). Volume differences among these scenarios were generally <10 percent by 2060 (Fig. 4.12) and proportional to volumes in 2010. As expected, scenarios with increased biomass harvesting or increased ash mortality predict less live volume than A2-C.

Further comparisons by major species group indicated that under A2-EAB, ash trees would essentially disappear from northern forests by 2040 (Fig. 4.13), but the loss of ash volume would be partially offset by volume increases in other species (Chapter 5).

Growing-stock Volume on Timberland

In the North, 95 percent of forest land is classified as timberland (forest land that maintains a minimum potential for growth of 20 cubic feet per acre per year and is not restricted from active forest management by statute or regulation); and 92 percent of the timber on timberland is classified as growing stock (merchantable timber volume, or all live volume reduced by defect and nonmerchantable species). Consequently, patterns and trends observed for growing-stock volume on timberland are usually similar to corresponding measures of total volume of all live trees, albeit with lower volume totals.

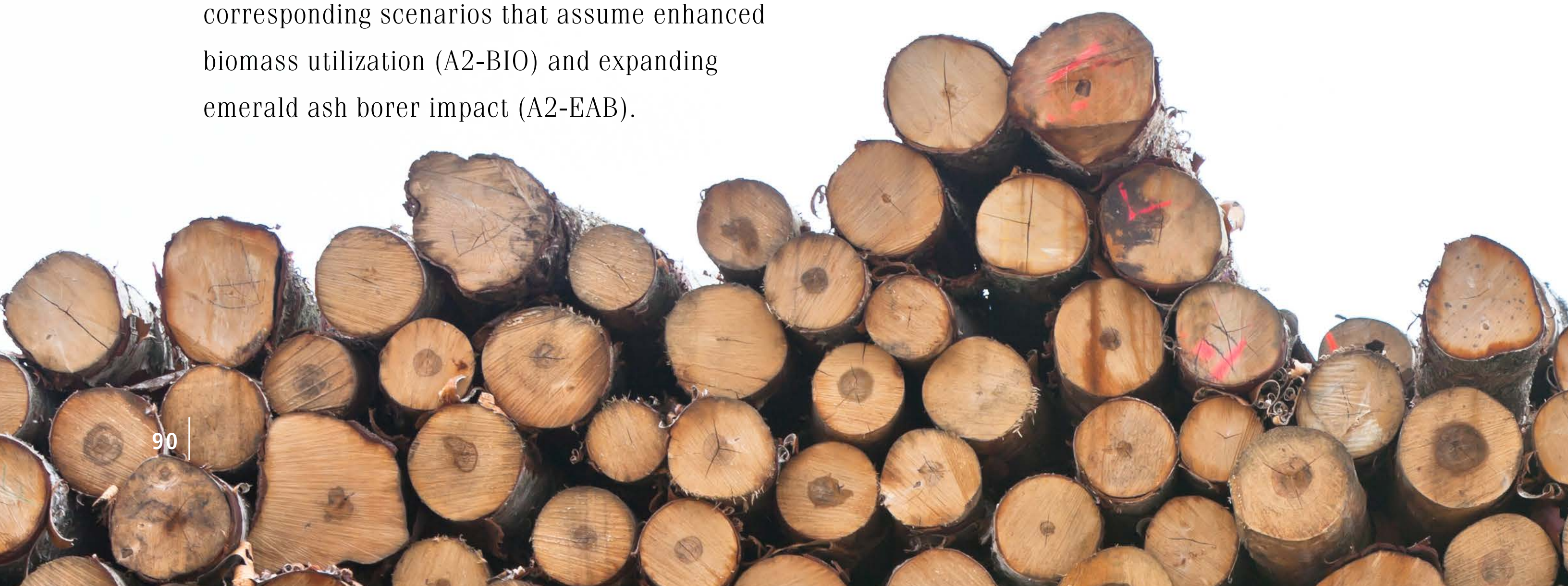
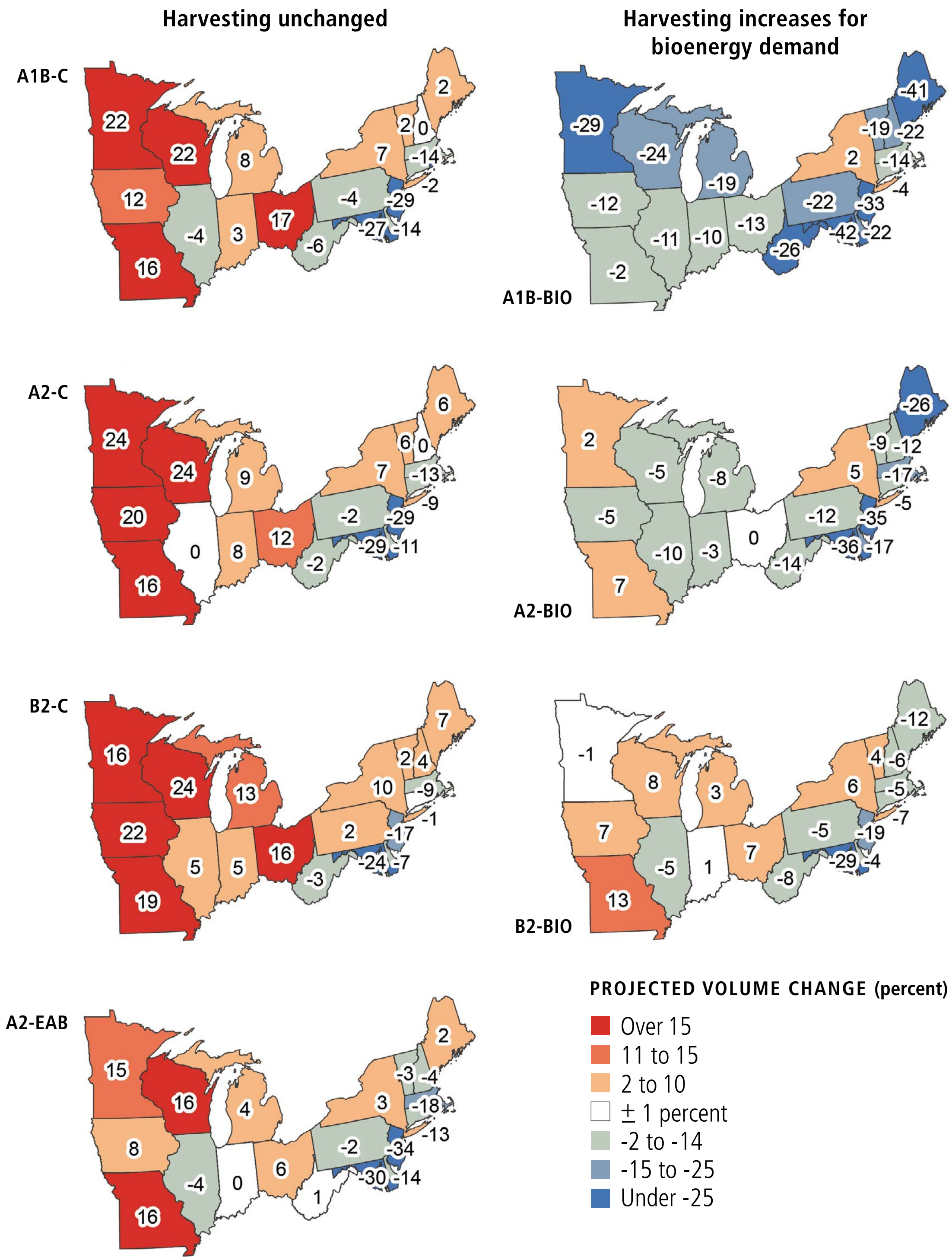


FIGURE 4.11

Projected change in live tree volume in forests of the North, 2010 to 2060, under seven scenarios, each representing a global greenhouse gas storyline (IPCC 2007) paired with a harvest regime. Storyline A1B assumes moderate greenhouse gas emissions, moderate gains in population, and large gains in income and energy consumption (but with a balanced renewable/fossil fuel portfolio); A2 assumes high greenhouse gas emissions, large gains in population and energy consumption, and moderate gains in income; and B2 assumes low greenhouse gas emissions with moderate gains in population, income, and energy consumption. Scenario projections assume harvest will continue at recently observed levels (labeled –C) or increase to reflect increased harvest for bioenergy production (labeled –BIO). Scenario A2-EAB is a variation of scenario A2-C that also assumes all ash species will gradually succumb to an expanding zone of infestation by the nonnative emerald ash borer.



Trends and projections of volume—Historical data from Smith et al. (2009) show that volume increases of growing stock have been steady, doubling from about 125 billion cubic feet in the early 1960s to current levels of 263 billion cubic feet. This trend is projected to level off by 2050 (Fig. 4.14), when differences in assumptions would result in decreases under the scenarios with accelerated biomass harvesting and modest increases under the other scenarios. Even under the scenarios that project the largest increases in growing-stock volume, the rate of increase would be much smaller than that observed in previous decades. Projected growing-stock volume in 2060 would be 6 percent larger than the 2010 estimate under A1B-C, 7 percent larger under A2-C, and 9 percent larger under B2-C. Decreases in growing stock volume from 2010 to 2060 under scenarios that assume accelerated biomass removals would be 0.2 percent (B2-BIO), 8 percent (A2-BIO) and 19 percent (A1B-BIO); clearly A2-BIO and A1B-BIO would be unsustainable in the long run.

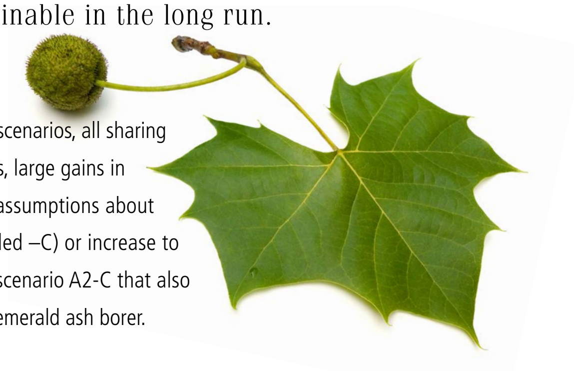
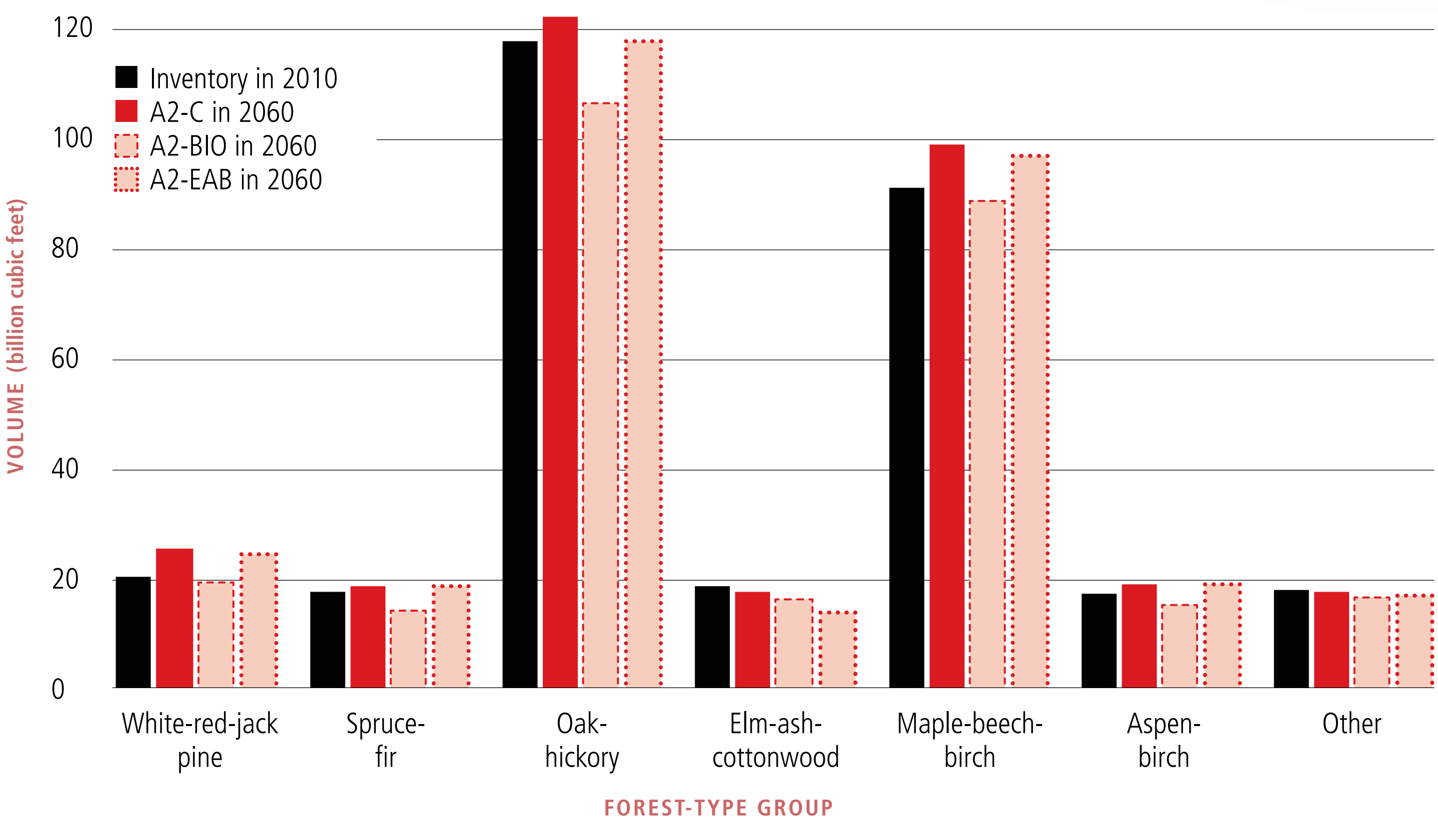


FIGURE 4.12

Live tree volume on forests in the North estimated for 2010 and projected through 2060 under three scenarios, all sharing one greenhouse gas emission storyline, A2, that assumes large increases in greenhouse gas emissions, large gains in population and energy consumption, and moderate gains in income (IPCC 2007), but with varying assumptions about future removals. Scenario projections assume harvest will continue at recently observed levels (labeled –C) or increase to reflect increased harvest for bioenergy production (labeled –BIO). Scenario A2-EAB is a variation of scenario A2-C that also assumes all ash species will gradually succumb to an expanding zone of infestation by the nonnative emerald ash borer.



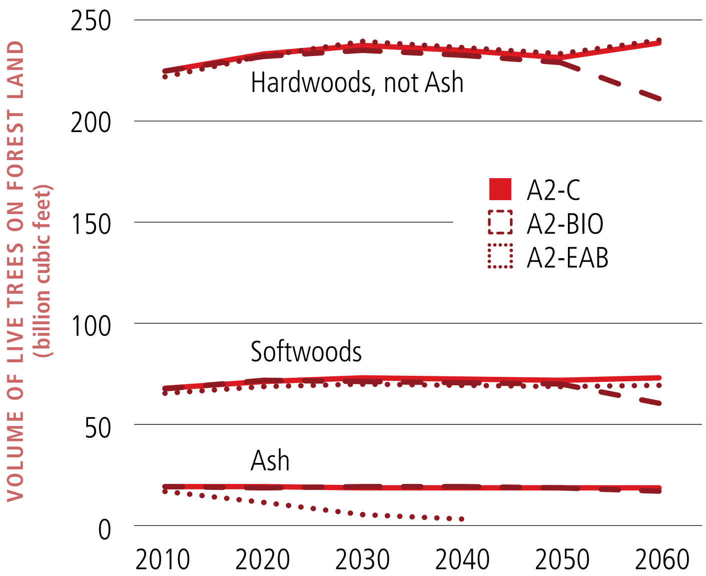


FIGURE 4.13

Projected change in live tree volume of ash, other hardwoods, and softwoods in the North under three scenarios, all sharing one greenhouse gas emission storyline, A2, that assumes large increases in greenhouse gas emissions, large gains in population and energy consumption, and moderate gains in income (IPCC 2007); but with varying assumptions about future removals. Scenario projections assume harvest will continue at recently observed levels (labeled –C) or increase to reflect increased harvest for bioenergy production (labeled –BIO). Scenario A2-EAB is a variation of scenario A2-C that also assumes all ash species will gradually succumb to an expanding zone of infestation by the nonnative emerald ash borer.

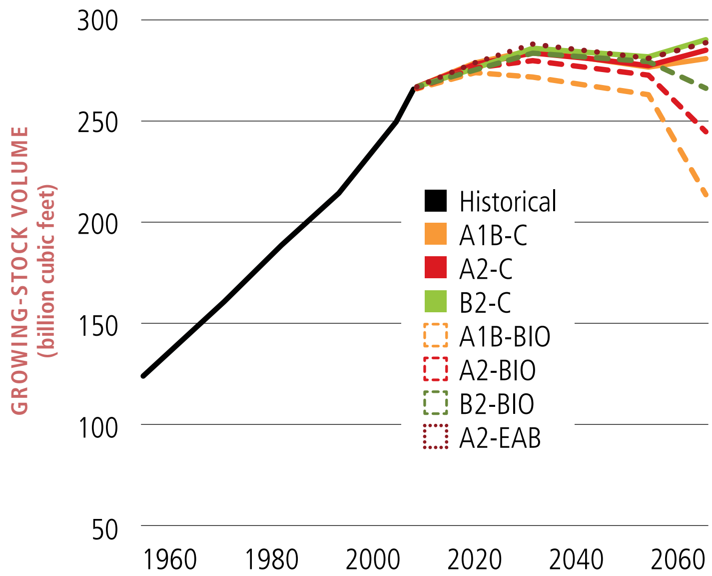


FIGURE 4.14

Net volume of growing stock on timberland in the North, both historical (back to 1963) and projected through 2060 under seven scenarios, each representing a global greenhouse gas storyline (IPCC 2007) paired with a harvest regime. Storyline A1B assumes moderate greenhouse gas emissions, moderate gains in population, and large gains in income and energy consumption (but with a balanced renewable/fossil fuel portfolio); A2 assumes high greenhouse gas emissions, large gains in population and energy consumption, and moderate gains in income; and B2 assumes low greenhouse gas emissions with moderate gains in population, income, and energy consumption. Scenario projections assume harvest will continue at recently observed levels (labeled –C) or increase to reflect increased harvest for bioenergy production (labeled –BIO). Scenario A2-EAB is a variation of scenario A2-C that also assumes all ash species will gradually succumb to an expanding zone of infestation by the nonnative emerald ash borer.

Despite the expected impact of emerald ash borer upon ash species, regional growing-stock volumes in 2060 projected under A2-EAB would increase by 8 percent over the 2010 estimates and would mirror projections for A2-C.

The change from a historical trend of rapidly increasing growing-stock volume to a projected trend of nearly constant growing-stock volume can be attributed to the combined effects of (1) an aging forest resource with a normal decrease in the annual rate of volume growth; and (2) an accelerated conversion of forest to urban land with a corresponding loss of timberland area and associated losses in timberland volume.

Net volume growth predictions—Collectively, the annual rates of volume growth, mortality, and removals determine the net change in total growing-stock volume as illustrated in Figure 4.14. When net growing-stock volume (gross growth less mortality) exceeds growing-stock removals, the result is an overall increase in growing-stock volume. Likewise, a high rate of mortality or of removals can result in a decrease in total volume, for example, under A1B-BIO (Fig.4.15).

This section reports net growth of growing-stock volume, which has been adjusted to exclude volume losses not associated with harvesting or land-use removals (harvesting and land-use removals are addressed in subsequent sections). Net growth is usually a positive value; a negative value would indicate abnormally high mortality attributed to insect infestations, disease outbreaks, weather events, wildfire, or other severe disturbances.

Predicted net annual volume growth for growing stock on timberland would be essentially the same under A1B-C, A2-C, B2-C, and A2-EAB (Fig. 4.16) for the entire projection period. Conversely, the scenarios with increased biomass harvesting (A1B-BIO, A2-BIO, B2-BIO) projected much higher increases in volume growth from 2030 to 2060, primarily because increased harvesting intensity regenerates new, young forest areas that typically have more trees,

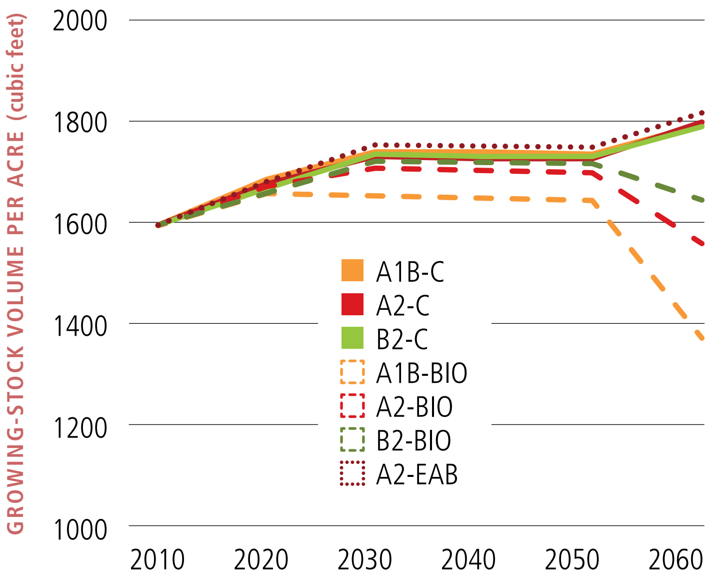


FIGURE 4.15

Projected change in per-acre growing stock in the North, 2010 to 2060, under seven scenarios, each representing a global greenhouse gas storyline (IPCC 2007) paired with a harvest regime. Storyline A1B assumes moderate greenhouse gas emissions, moderate gains in population, and large gains in income and energy consumption (but with a balanced renewable/fossil fuel portfolio); A2 assumes high greenhouse gas emissions, large gains in population and energy consumption, and moderate gains in income; and B2 assumes low greenhouse gas emissions with moderate gains in population, income, and energy consumption. Scenario projections assume harvest will continue at recently observed levels (labeled –C) or increase to reflect increased harvest for bioenergy production (labeled –BIO). Scenario A2-EAB is a variation of scenario A2-C that also assumes all ash species will gradually succumb to an expanding zone of infestation by the nonnative emerald ash borer.

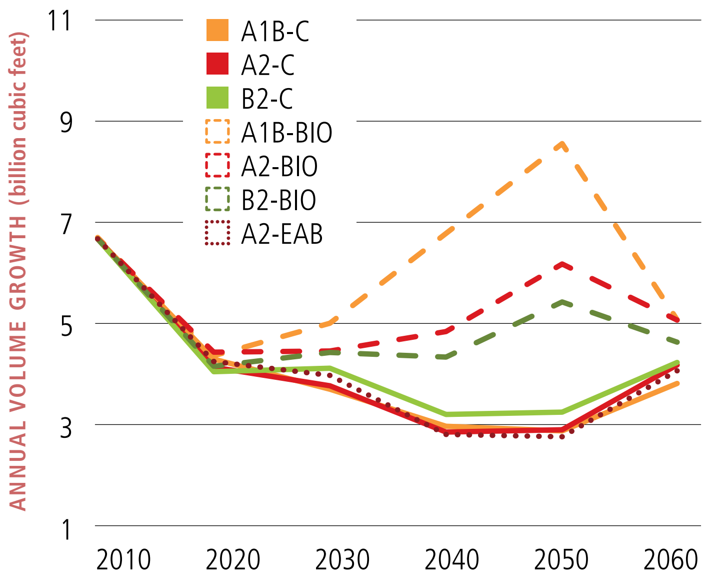


FIGURE 4.16

Projected average annual increase in growing-stock volume for the North, 2010 to 2060, under seven scenarios, each representing a global greenhouse gas storyline (IPCC 2007) paired with a harvest regime. Storyline A1B assumes moderate greenhouse gas emissions, moderate gains in population, and large gains in income and energy consumption (but with a balanced renewable/fossil fuel portfolio); A2 assumes high greenhouse gas emissions, large gains in population and energy consumption, and moderate gains in income; and B2 assumes low greenhouse gas emissions with moderate gains in population, income, and energy consumption. Scenario projections assume harvest will continue at recently observed levels (labeled –C) or increase to reflect increased harvest for bioenergy production (labeled –BIO). Scenario A2-EAB is a variation of scenario A2-C that also assumes all ash species will gradually succumb to an expanding zone of infestation by the nonnative emerald ash borer.

smaller trees, and less volume per acre—but a faster rate of volume increase—than the mature forest they replace. Thus, the enhanced biomass scenarios would create a temporary bubble of growth related to the intensity of the harvesting removals. As shown in subsequent sections, much of this accelerated growth would be offset by the accelerated removals, resulting in little net change in volume.

REMOVALS

Volume removals occur when trees are harvested or when land is converted to urban or other uses. In the northern forests, partial harvesting of the overstory can accelerate the growth of the remaining trees. Harvesting that removes much or all of the forest overstory usually regnerates land back to young forest. Thus, harvesting mature forest can sometimes stimulate increased rates of volume growth in the residual or replacement forests. However, land that is converted to urban use is almost always permanently lost from the forest resource base, and its associated wood volume no longer contributes to the timberland volume total. In contrast, land-use conversions between timberland and agricultural land are more likely to be bidirectional; for example, abandoned agricultural land in one location often reverts to timberland through natural succession at the same time that forests are cleared for agriculture elsewhere.

Removals, whether by harvesting or by conversion of forests to another use, were modeled in 5-year intervals and then summarized by decade from 2020 to 2060 (Appendix Chapter 4). As described in Chapter 2, removals predictions were based on assumptions that the patterns of harvesting removals observed in the recent past will continue into the future (A1B-C, A2-C, B2-C, A2-EAB) or will increase to meet bioenergy demand (A1B-BIO, A2-BIO, B2-BIO).

Procedurally, the volume of removals attributable to land-use change for a given period was calculated as acreage converted to nonforest use multiplied by average volume per acre. Removals attributable to harvesting were then calculated by subtracting estimated land-use removals from the total removals projected by the Forest Dynamics Model (Chapter 2). The following sections separately discuss the projected volume changes for both types of removals.

Harvesting

Annual removals in northern forests are projected to double or triple from 2010 to 2060 under the enhanced biomass utilization scenarios, with increases ranging from 2.9 to 6.8 billion cubic feet (Appendix Chapter 4, Fig. 4.17).

In contrast, annual removals would be essentially flat and nearly identical under the other four scenarios, rising slightly from 3.09 billion cubic feet in 2010 to 3.33 billion cubic feet under A1B-C, 3.39 billion cubic feet under A2-C, 3.12 billion cubic feet under B2-C, and 3.58 billion cubic feet under A2-EAB by 2060.

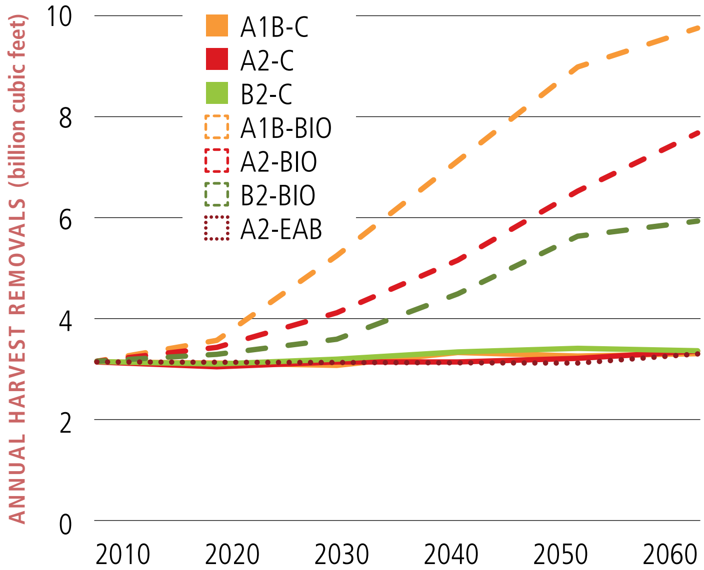


FIGURE 4.17

Annual harvest volumes for the North for 2010 and projected through 2060, under seven scenarios, each representing a global greenhouse gas storyline (IPCC 2007) paired with a harvest regime. Storyline A1B assumes moderate greenhouse gas emissions, moderate gains in population, and large gains in income and energy consumption (but with a balanced renewable/fossil fuel portfolio); A2 assumes high greenhouse gas emissions, large gains in population and energy consumption, and moderate gains in income; and B2 assumes low greenhouse gas emissions with moderate gains in population, income, and energy consumption. Scenario projections assume harvest will continue at recently observed levels (labeled –C) or increase to reflect increased harvest for bioenergy production (labeled –BIO). Scenario A2-EAB is a variation of scenario A2-C that also assumes all ash species will gradually succumb to an expanding zone of infestation by the nonnative emerald ash borer.

With the exception of the densely populated areas on the Atlantic seaboard, projected removals are expected to increase or stay relatively constant at the State level, as shown for A2-C in Figure 4.18. An example is Maine, which had the highest projected removals of any Northern State based on removals that increased by <5 percent from 2010 to 2060. The other heavily forested States of Michigan, Minnesota, and Wisconsin also are projected to have increases, as is the less heavily forested Indiana, and Pennsylvania is expected to remain about the same. With the exception of Rhode Island, decreases in volume harvested are projected for the States along the Atlantic seaboard.

Modeling the extent of salvage harvesting that would accompany ash mortality was beyond the scope of this chapter; doing so would likely have produced noticeable increases in projected removals under the A2-EAB scenario.

Conversion to Nonforest Land Uses

Land-use change removals are those volume losses solely attributable to a decrease in forest area when forest land is converted to urban or agricultural uses. The woody material on converted lands may or may not be harvested, but the assumption is that the entire volume is lost from the forest inventory. Projections of land-use removals were driven by assumptions about loss of forest land under the greenhouse gas emissions storylines; scenarios with accelerated biomass harvesting or expanding emerald ash borer mortality were very similar to the analogous scenarios that projected a continuation of past harvesting rates (Appendix Chapter 4, Fig. 4.19). The only appreciable exception is A1B-BIO/A1B comparison: the volumes removed under the enhanced biomass removal assumptions would be so large that they would reduce the metric—average standing volume per acre—used to calculate land-use change removals.

Land-use removals are projected to increase for all variations of the A1B and A2 scenarios and are projected to decrease for the B2-C and B2-BIO scenarios (Fig. 4.19). Removals would primarily come from hardwood stands, reflecting the composition of forests in the counties that would be most impacted by the loss of forest land.

For the northern forests as a whole, removals resulting from land-use change would be a small component (about 12 percent in 2010) of total removals (Fig. 4.20); the exception would be six States along the Atlantic seaboard (Fig. 4.21) where land-use change would be a large—or even the largest—source of removals. Compared to the midwestern States, most of the States farther east would have higher percentages of total removals resulting from land-use change (examples include New Hampshire, Massachusetts, and Pennsylvania but not Maine) with the highest among them being the small States along the Atlantic seaboard. Situated along the Interstate-95 corridor, this highly urbanized area is more likely to lose forest land to population growth and associated development; harvesting is expected to be comparatively minimal because ownerships are small and the value of ecosystem services from forests is relatively high. In Iowa and Illinois, land-use removals are predicted to be high in the first decade of the projection period, but then decrease rapidly in subsequent decades.

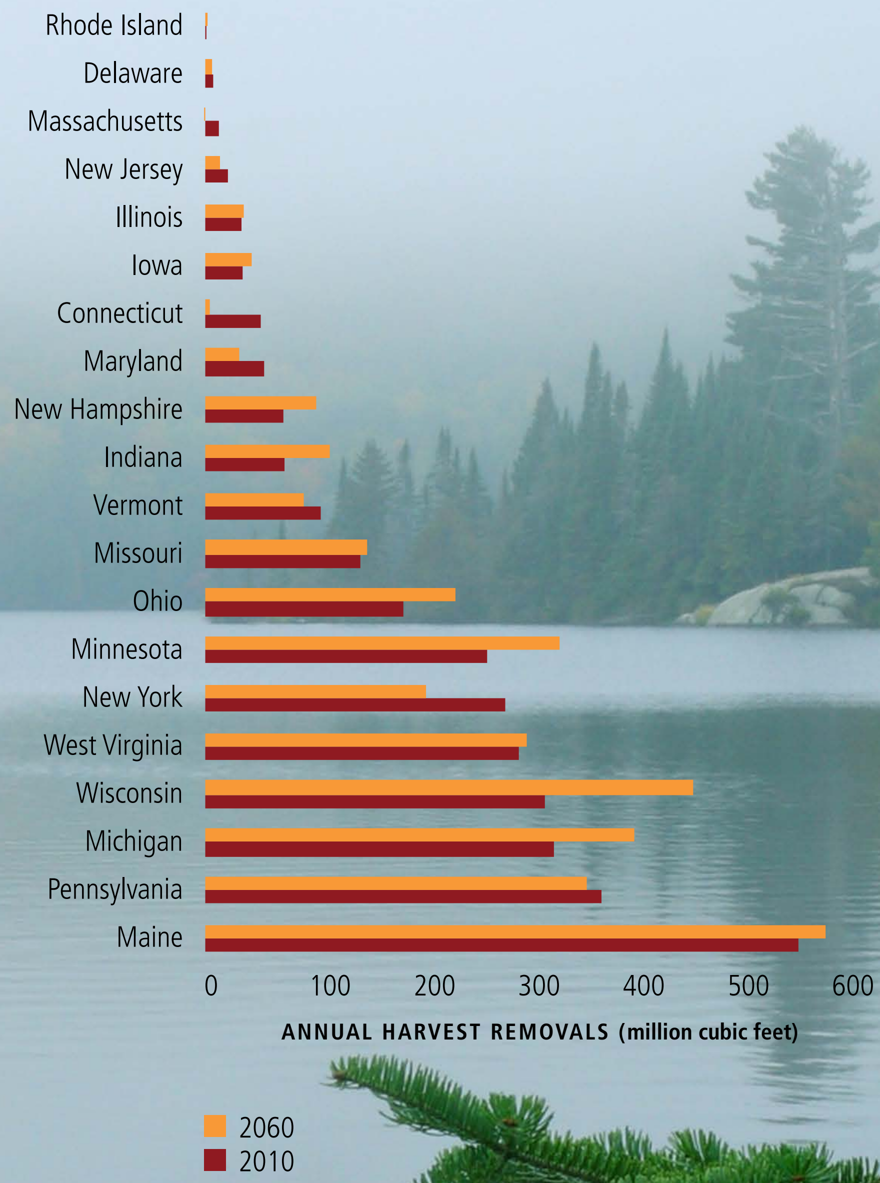


FIGURE 4.18

State-level harvest volume in forests of the North in 2010 and projected for 2060 under scenario A2-C that assumes high greenhouse gas emissions, large gains in population and energy consumption, moderate gains in income, and a continuation of recently observed harvest rates.

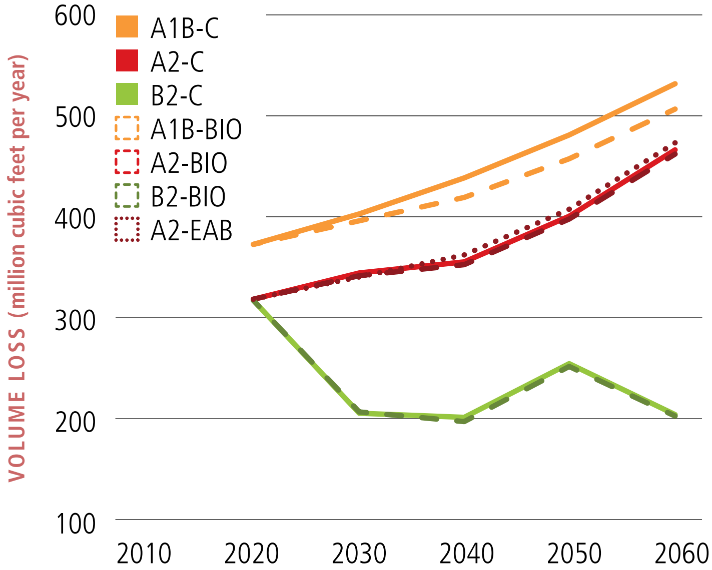


FIGURE 4.19

Projected annual volume losses resulting from land-use changes in forests of the North, 2010 to 2060, under seven scenarios, each representing a global greenhouse gas storyline (IPCC 2007) paired with a harvest regime. Storyline A1B assumes moderate greenhouse gas emissions, moderate gains in population, and large gains in income and energy consumption (but with a balanced renewable/fossil fuel portfolio); A2 assumes high greenhouse gas emissions, large gains in population and energy consumption, and moderate gains in income; and B2 assumes low greenhouse gas emissions with moderate gains in population, income, and energy consumption. Scenario projections assume harvest will continue at recently observed levels (labeled –C) or increase to reflect increased harvest for bioenergy production (labeled –BIO). Scenario A2-EAB is a variation of scenario A2-C that also assumes all ash species will gradually succumb to an expanding zone of infestation by the nonnative emerald ash borer.

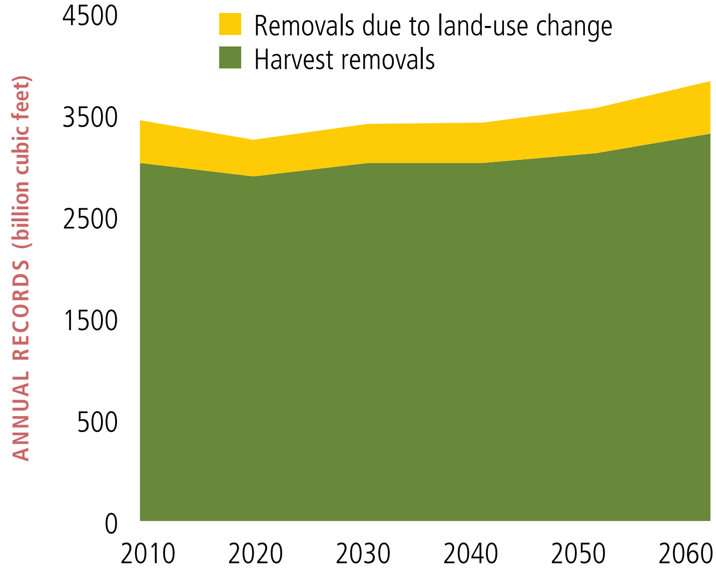
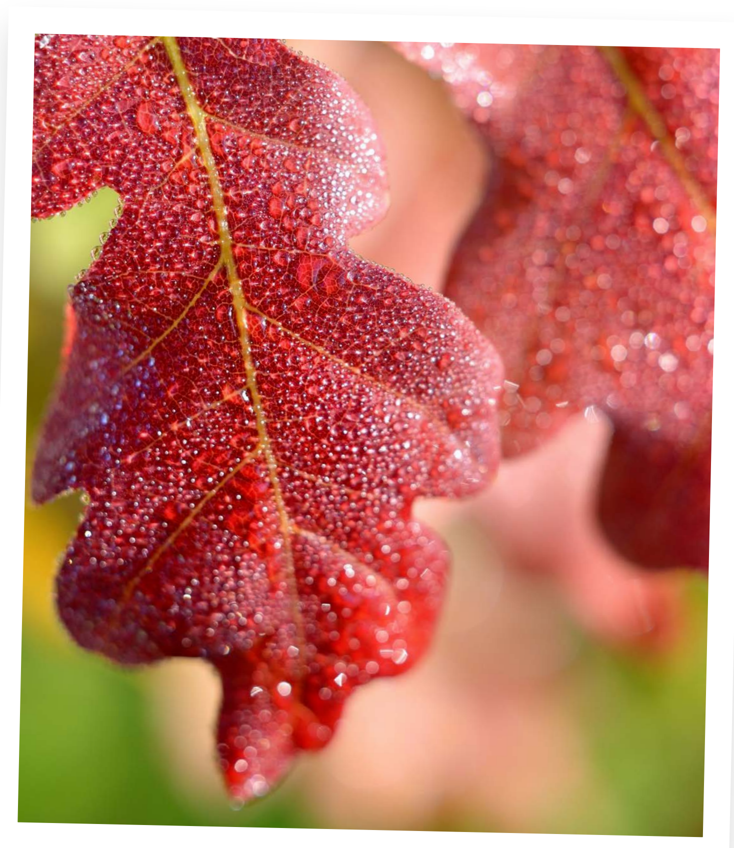
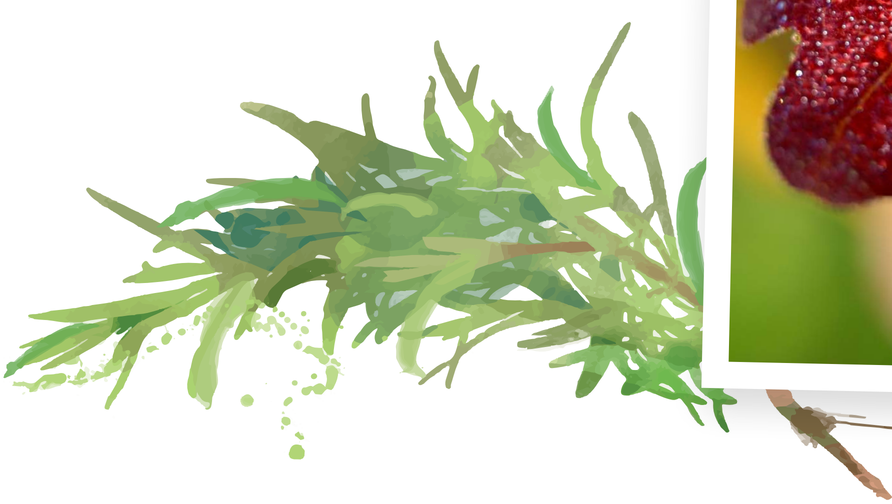
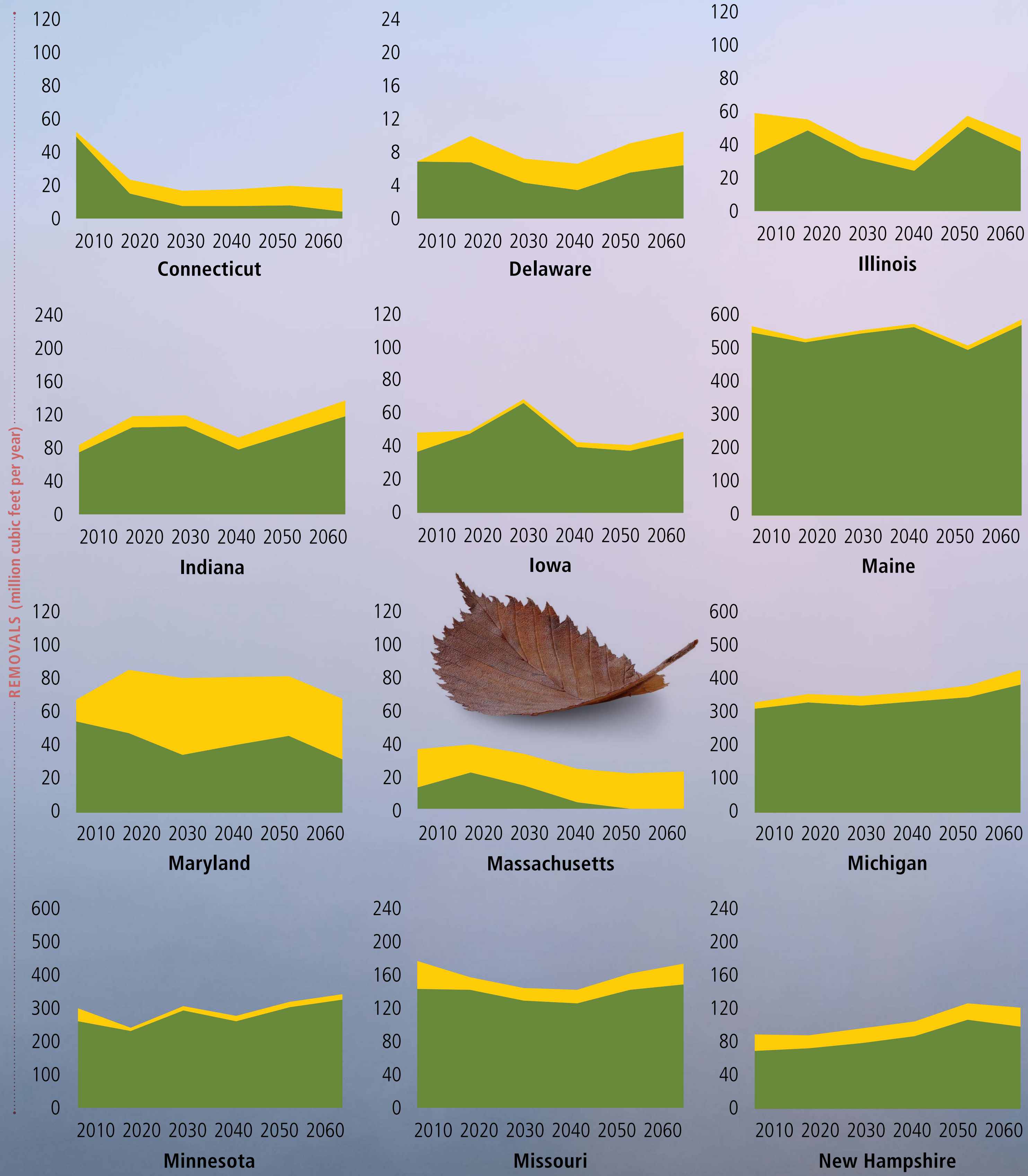


FIGURE 4.20

Comparison of projected volume losses resulting from harvesting and land-use changes in the North, 2010 to 2060, under scenario A2-C that assumes high greenhouse gas emissions, large gains in population and energy consumption, moderate gains in income, and a continuation of recently observed harvest rates.






REMOVALS (million cubic feet per year)
Connecticut
Delaware
Illinois
Indiana
Iowa
Maine
Maryland
Massachusetts
Michigan
Minnesota
Missouri
New Hampshire
2010 2020 2030 2040 2050 2060
0 20 40 60 80 100 120
0 4 8 12 16 20 24
0 40 80 120 160 200 240
0 100 200 300 400 500 600

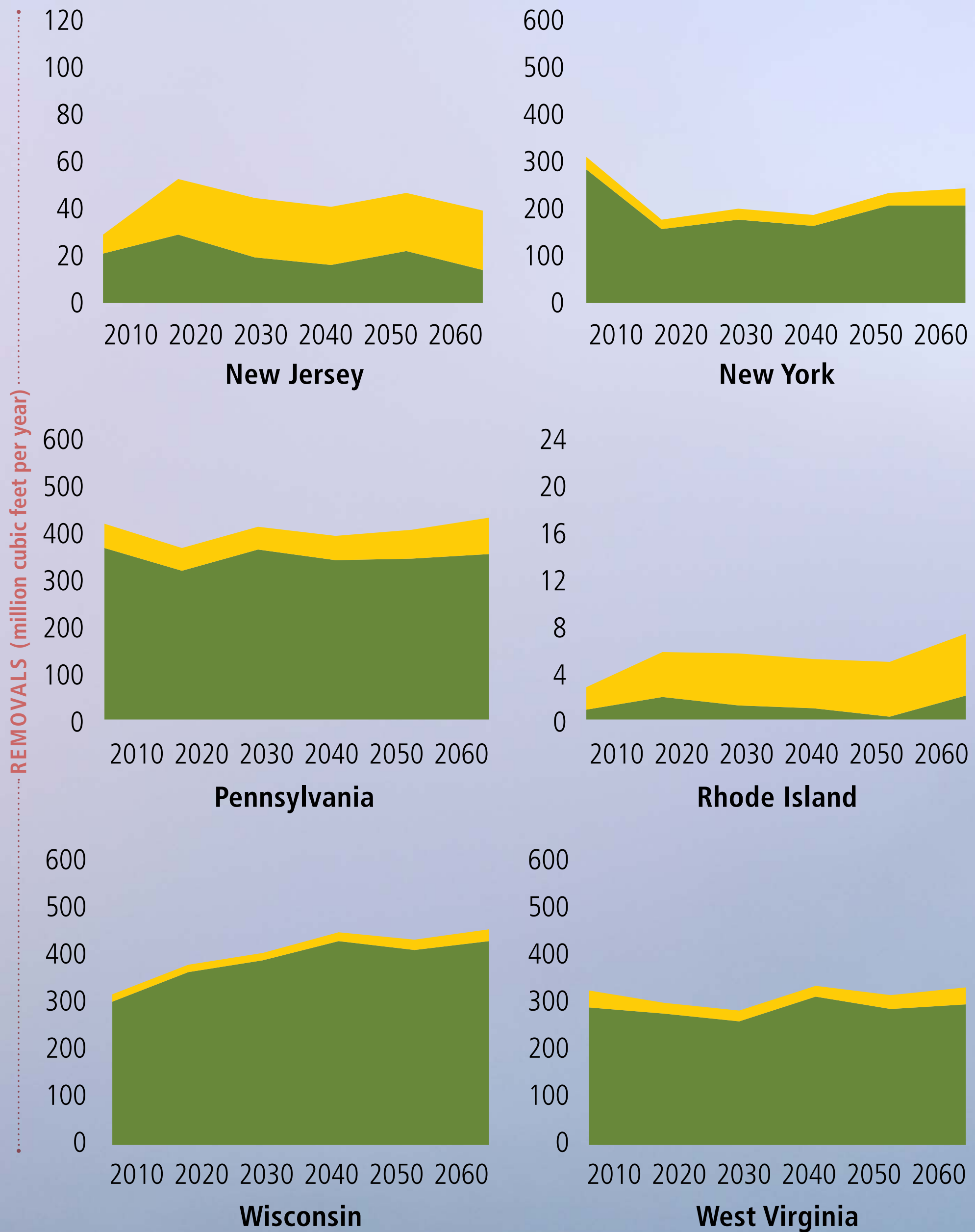


FIGURE 4.21

Removals due to land-use change
Harvest removals

State-level comparison of projected volume losses resulting from harvesting and land-use changes in the North, 2010 to 2060, under scenario A2-C that assumes high greenhouse gas emissions, large gains in population and energy consumption, moderate gains in income, and a continuation of recently observed harvest rates.

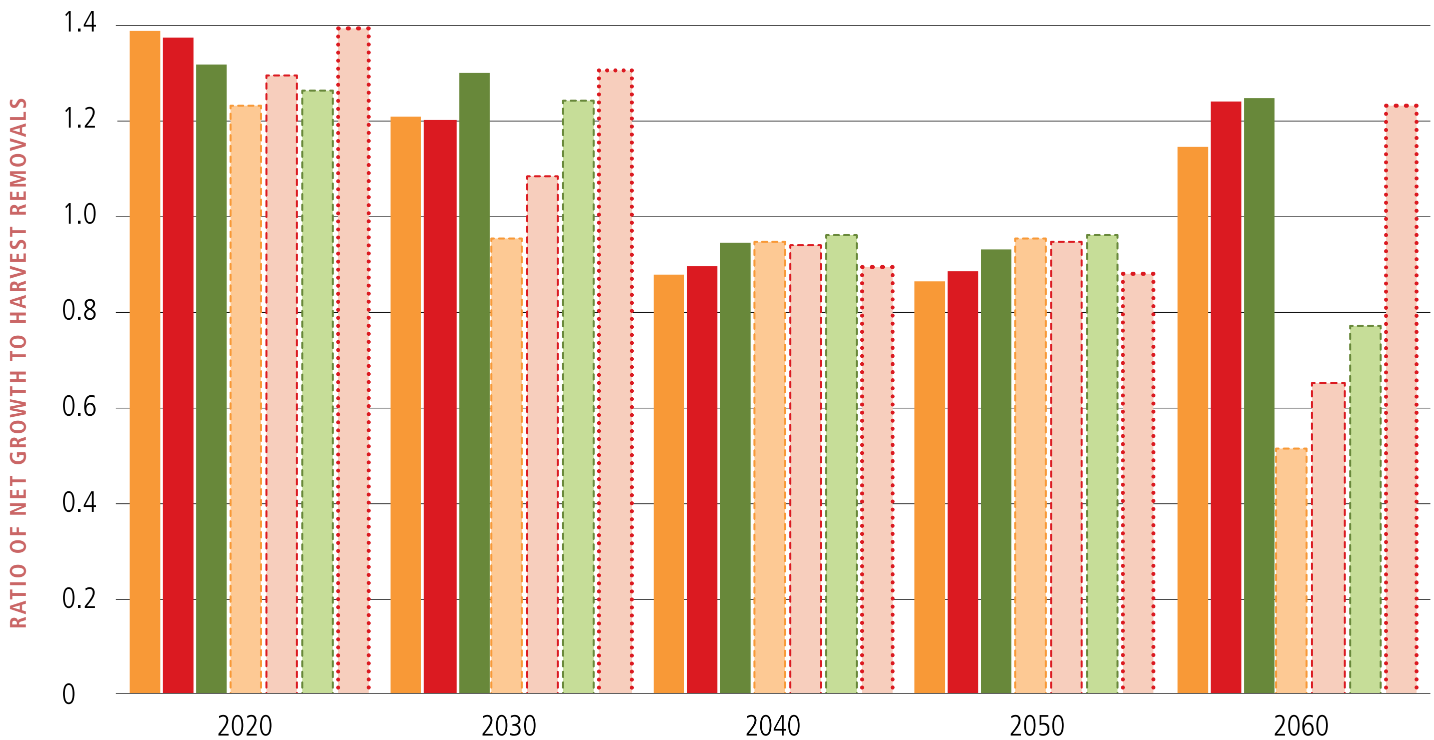
RATIO OF NET GROWTH TO REMOVALS

The ratio of net volume growth to harvest removals is an important indicator of forest sustainability (Fig. 4.22). For periods when the ratio is >1.0, wood volume is accumulating faster than it is being harvested, and total live volume on timberland is increasing. Ratios <1.0 indicate periods when harvest removals exceed net growth and total live volume on timberland is being depleted; over the long run, such ratios are not sustainable.

Figure 4.22 shows ratios predicted for harvesting removals but excludes removals that would result from the land-use changes discussed above. Thus, in some situations where the ratio of growth to harvest removals is >1.0 and volume per acre is increasing, total volume for a State or region could still decrease if large areas of forest are converted to urban or agricultural uses and the trees on the converted land no longer contribute to estimates of total volume.

FIGURE 4.22

Ratio comparing projected average annual net cubic foot volume growth to harvest, by decade, under seven scenarios, each representing a global greenhouse gas storyline (IPCC 2007) paired with a harvest regime. Storyline A1B assumes moderate greenhouse gas emissions, moderate gains in population, and large gains in income and energy consumption (but with a balanced renewable/fossil fuel portfolio); A2 assumes high greenhouse gas emissions, large gains in population and energy consumption, and moderate gains in income; and B2 assumes low greenhouse gas emissions with moderate gains in population, income, and energy consumption. Scenario projections assume harvest will continue at recently observed levels (labeled –C) or increase to reflect increased harvest for bioenergy production (labeled –BIO). Scenario A2-EAB is a variation of scenario A2-C that also assumes all ash species will gradually succumb to an expanding zone of infestation by the nonnative emerald ash borer.



Total volume is projected to increase from 2010 to 2030, decrease slightly until 2050, and then increase from 2050 to 2060 under A1B-C, A2-C, B2-C, and A2-EAB (Fig. 4.14). The decrease is attributable in part to conversion of forest land to other uses and in part to a reduced rate of growth associated with an aging forest resource. As forests age, the annual rate of volume growth typically decreases even though total volume per acre may increase gradually. When coupled with constant or increasing harvesting (Fig. 4.17), the outcome would be a decreasing growth-to-removals ratio from 2020 to 2040 (Fig. 4.22). The projected ratio in 2030 would be <1.0 for all scenarios, with harvesting exceeding growth for a decade or more.

By 2060, the growth-to-removals ratio would increase to about 1.2 under scenarios A1B-C, A2-C, B2-C, and A2-EAB. In contrast, the ratio would continue to decrease for the scenarios with accelerated biomass removals, both for hardwoods and softwoods, with decreases reaching precipitous levels by 2060. These results suggest that the modeled harvesting levels associated with scenarios A1B-BIO, A2-BIO, and B2-BIO are not sustainable over the long term. This is not to suggest that in all situations and at all levels of removal, increased harvesting of biomass for energy is unsustainable, but simply that it is not sustainable at the rate assumed in the modeled scenarios over the long term.

CONCLUSIONS

Differences among projected forest conditions from 2010 to 2060 are small under A1B-C, A2-C, and B2-C. Although these scenarios are based on different assumptions—population growth, land-use change, greenhouse gas emissions, and climate response (see Chapter 2)—their projections of forest area, species composition, volume, volume growth, and removals are most notable for their similarities. The projected outcomes for A2-EAB, which models the elimination of ash species from northern forests as a consequence of the expanding range of emerald ash borer, are similar to those for A2-C in most other respects. Despite the anticipated impacts from conversion of forest land to urban uses, forest land area is projected to decrease by only about 5 percent over the next 50 years.

The models predict that existing forests will get older and removals resulting from harvesting will remain nearly constant under scenarios A1B-C, A2-C, B2-C, and A2-EAB. The consequence for the region as a whole is that forest growth and succession rather than climate change or land conversion would be the primary forces driving forest changes. This is not to suggest that stability will prevail in all locales. For example, forests that adjoin urban areas will certainly be impacted more than rural forests, and tree species at the edge of their natural ranges would be the most vulnerable to changes in climate.

Scenarios with accelerated biomass harvesting stand in sharp contrast, because the greatly accelerated rates of harvesting would dominate projected future changes in volume, volume growth, and age-class diversity.

Two other highly consequential outcomes emerge from these projections. First, the normal aging of northern forests over the next 30 to 40 years will likely end the rapid increase in standing volume that has characterized the past 50 years. As forests mature, the rate of volume increase slows. When this dynamic is coupled with small but persistent losses of forest land to land-use changes, the result would be wood volumes that remain relatively constant from 2010 to 2050. This appears to be the outcome under all scenarios, although larger distinctions among alternative scenarios would emerge after 2050. The potential consequences of this trend are far reaching, and they are discussed further in Chapter 11.

The second consequence, as illustrated by the scenarios with accelerated biomass harvesting, is potential for human intervention—through harvesting—to transform future outcomes over the long run. Changes in harvesting rates could take decades to alter the northern forest landscape; but eventually as new patterns of disturbance (increased biomass harvesting) accumulate over time, they can create substantial shifts in standing volume, volume growth rates, and the regional age-class structure. Thus, the future condition that is deemed desirable for northern forests may well require intensive management intervention over many decades to markedly alter the trajectories of change from the status quo. Implicit in the scenario projections are opportunities for improving forest vitality and diversity, supplying large quantities of wood to forest industries, and still sustaining a stable volume of wood.

Literature Cited

Canadian Centre for Climate Modelling and Analysis. 2012a. CGCM2-coupled global climate model, medium resolution (T47). Ottawa, ON, Canada: Environment Canada. http://www.cccma.bc.ec.gc.ca/models/cgcm2.shtml (accessed August 20, 2014).

Canadian Centre for Climate Modelling and Analysis. 2012b. CGCM3.1-coupled global climate model (CGCM3), medium resolution (T47). Ottawa, ON, Canada: Environment Canada. http://www.cccma.bc.ec.gc.ca/models/cgcm3.shtml (accessed August 20, 2014).

Hunter, M.L., Jr.; Schmiegelow, F.K.A. 2011. Wildlife, forests and forestry. New York: Prentice Hall. 259 p.

Ince, P.J.; Kramp, A.D.; Skog, K.E.; Spelter, H.N.; Wear, D.N. 2011a. U.S. Forest Products module: a technical document supporting the Forest Service 2010 RPA assessment. Res. Pap. FPL–RP-662. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 61 p.

Ince, P.J.; Kramp, A.D.; Skog, K.E.; Yoo, D.; Sample, V.A. 2011b. Modeling future U.S. forest sector market and trade impacts of expansion in wood energy consumption. Journal of Forest Economics. 17(2): 142-156.

Intergovernmental Panel on Climate Change [IPCC]. 2007. Climate change 2007: synthesis report. Contribution of working groups I, II and III to the fourth assessment report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: Intergovernmental Panel on Climate Change. 104 p. http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm (accessed August 19, 2014).

Oliver, C.D.; Larson, B.C. 1990. Forest stand dynamics. New York: McGraw-Hill. 467 p.

Pan, Y.; Chen, J.M.; Birdsey, R.; McCullough, K.; He, L.; Deng, F. 2011. Age structure and disturbance legacy of North American forests. Biogeosciences. 8: 715-732.

Shifley, S.R.; Aguilar, F.X.; Song, N. [et al.]. 2012. Forests of the Northern United States. Gen. Tech. Rep. NRS-90. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 202 p.

Smith, W.B.; Miles, P.D.; Perry, C.H.; Pugh, S.A. 2009. Forest resources of the United States, 2007. Gen. Tech. Rep. WO-78. Washington, DC: U.S. Department of Agriculture, Forest Service. 336 p.

Wear, D.N.; Huggett, R.; Li, R.; Perryman, B.; Liu, S. 2013. Forecasts of forest conditions in regions of the United States under future scenarios: a technical document supporting the Forest Service 2012 RPA assessment. Gen. Tech. Rep. SRS–GTR-170. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 101 p.

Wilson, B.T.; Lister, A.J.; Riemann, R.I. 2012. A nearest-neighbor imputation approach to mapping tree species over large areas using forest inventory plots and moderate resolution raster data. Forest Ecology and Management. 271: 182-198.

Wilson, B.T.; Lister, A.J.; Riemann, R.I.; Griffith, D.M. 2013. Live tree species basal area of the contiguous United States (2000-2009). Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. http://dx.doi.org/10.2737/RDS–2013–0013 (accessed September 23, 2013).