Chapter 16
Forecasting Forest Type and Age Classes in the Appalachian-Cumberland Subregion of the Central Hardwood Region

David N. Wear and Robert Huggett

Abstract This chapter describes how forest type and age distributions might be expected to change in the Appalachian-Cumberland portions of the Central Hardwood Region over the next 50 years. Forecasting forest conditions requires accounting for a number of biophysical and socioeconomic dynamics within an internally consistent modeling framework. We used the US Forest Assessment System (USFAS) to simulate the evolution of forest inventories in the subregion. The types and ages of forests in the Appalachian-Cumberland portions of the Central Hardwood Region are likely to shift over the next 50 years. Two scenarios bracket a range of forest projections and provide insights into how wood products markets as well as economic, demographic, and climate changes could affect these future forests. Shifts in the future age distributions of forests are dominated by projected harvest regimes that lead to qualitatively different forest conditions. The future area of young forests correlates with change in total forest area—as total forest area declines, so does the area of young forests. However, changes in the area of young forests and forest age class distributions are most directly altered by the extent of harvesting within the Appalachian-Cumberland subregion.

D.N. Wear (✉)
USDA Forest Service, Southern Research Station, Research Triangle Park, NC 27709, USA
e-mail: dwear@fs.fed.us

R. Huggett
Department of Forestry and Environmental Resources, North Carolina State University, Raleigh, NC 27695, USA
e-mail: rhuggett@fs.fed.us

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16.1 Introduction

Because forest conditions change over time, effective management guidelines address not only today's conditions but also the future trajectories of forest conditions. Future forests will be defined by a complex and interacting set of economic, biological and physical driving forces. We describe forecasts of how forest type and age distributions might change in the Appalachian-Cumberland subregion of the Central Hardwood Region over the next 50 years. We 'look forward' to provide a start for managing tomorrow's forests today. Our analysis is based on forest forecasts developed as part of the Southern Forest Futures Project (Wear et al. 2009), a regional assessment of the Southern USA addressing several questions regarding the future of forests and the benefits they provide.

Forecasting forest conditions requires accounting for a number of biophysical and socioeconomic dynamics within an internally consistent modeling framework. Biophysical factors include the influence of climate on species persistence and disturbance patterns along with the demographics of forest aging and mortality. Socioeconomic forces include the influence of population and economic growth on land use choices and associated loss (or gain) of forest area; the effects of timber harvesting patterns driven by demand for wood products; and the relative value of forest stands for providing wood products. Timber supply derives from evolving forest conditions and preferences of forest landowners regarding management of their lands.

Understanding the interrelated complex of change vectors requires a computer simulation framework; we use the US Forest Assessment System (USFAS) to simulate evolution of forest inventories. Forecasts of future forest conditions require a set of assumptions about the future course of climate and economic conditions, packaged as comprehensive scenarios. For our analysis, two scenarios bracket a range of forest age class and forest type projections, and provide insights into how wood products markets could influence availability and condition of early, mid and late successional forest habitats in the Appalachian-Cumberland subregion.

In the following sections of this chapter, we describe the structure of the USFAS and the information contained in its forecasts. We describe the structure of the two future scenarios and their derivation from international and national assessments. Forest forecasts are developed and discussed. We conclude with a discussion of implications as well as potential shortcomings and uncertainties inherent in our approach.

16.2 Methods

Forecasting forest conditions requires an integrated assessment approach that accounts for biological, physical, demographic, and economic changes. We utilized the US Forest Assessment System or USFAS (Wear 2010) developed by the US Forest Service for various national and regional resource assessments. The USFAS

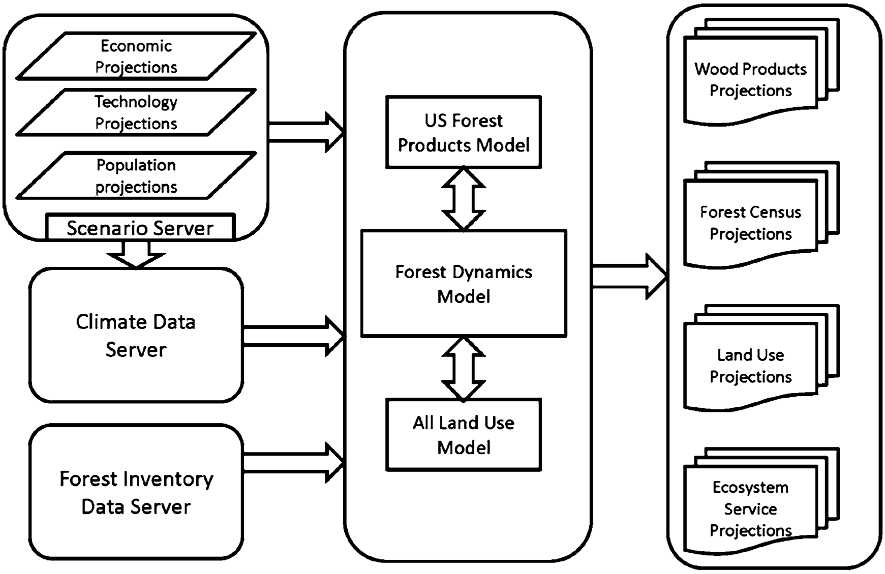

Fig. 16.1 Schematic of the US Forest Assessment System

addresses forest dynamics using scenario analysis to gauge uncertainty inherent in world views and model outputs. The basic inputs to the modeling system include various climate, economic, and demographic projections (Fig. 16.1, column 1) that are inputs to what is labeled a “scenario server”. Most scenarios were constructed from a foundation defined by the International Panel on Climate Change (IPCC) storylines and scenarios. For the RPA national assessment[1] these projections of coupled economic, population, and climate changes were downscaled to a fine-scale for the continental USA. Within the USFAS we consider these data aggregated to the county level.

For the analysis described in this chapter we consider two future scenarios, both of which have the same economic and demographic growth. In particular, we use the population and economic growth projections from the IPCC’s A1B storyline, which anticipates relatively high economic growth and a moderate level of population growth in the USA (IPCC 2007). In contrast, climate and timber market forecasts vary between the two scenarios. One scenario, labeled High Market, anticipates strong growth in the demand for wood products and applies a projection of climate

[1]The Forest and Rangeland Renewable Resources Planning Act (RPA) (P.L. 93–378, 88 Stat 475, as amended) was enacted in 1974. Section 3 of the Act requires the US Forest Service to provide a national renewable resource assessment to provide reliable information on the status and trends of the Nation’s renewable resources on a 10-year cycle.

from the MIROC General Circulation Model (GCM)[2]. The other scenario, labeled Low Market, anticipates a steady decline in market demand and applies the CSIRO GCM. Change in demand is represented by exogenously imposed timber price trends.

The left column also contains the Forest Inventory and Analysis (FIA) Forest Inventory database (USDA Forest Service 2007), emphasizing that the USFAS simulates the development of detailed FIA inventories through time in response to these drivers. Current forest conditions are defined by the most recent panels of plot measurements in the FIA forest inventory and the condition of each plot is forecast forward based on the scenarios and a set of internal dynamics.

There are three simulation components of the USFAS (Fig. 16.1, middle column). At the top is the US Forest Products Model which links USA regional forest products markets to global market conditions and domestic timber supply conditions. Timber supply is provided by the Forest Dynamics Model which accounts for timber harvesting by public and private landowners and is described below. For the present simulation analysis we replaced the explicit market model with general price assumptions that imposed price trends that reflected expanding or contracting markets within the Appalachian-Cumberland subregion. This seems reasonable given the size of the market considered here and the nature of our analysis, which is to demonstrate a reasonable range of future trajectories. For the High Market scenario we increase timber prices at a compounded 1% per year rate throughout the 50 year forecast period. For the Low Market scenario, we decrease prices by a compounded 1% per year. This has the effect of altering harvest patterns as described below.

The Forest Dynamics Model simulated the evolution of all forested plots in the FIA inventory (Fig. 16.1, column 2). Modeled plot dynamics start with a harvest model that accounts for effects of price levels and forest conditions on propensity of forest owners to harvest their forests; separate models address harvesting by public and private forest ownerships (Polyakov et al. 2010). Harvesting allows for either partial or final harvesting, depending on economic and forest conditions, and is price responsive. That is, more timber is harvested when prices are higher. Plot age is incremented by the simulation time-step for unharvested plots, but is defined using historical patterns of age changes associated with forest plots that receive either a partial or final harvest in the FIA inventories. The broad forest management type of the site (upland hardwood, lowland hardwood, and three pine (*Pinus* spp.) types) is held constant for unharvested forest plots but allowed to change in response to harvesting. Forest planting after harvest is possible, but is tied to historical planting

[2]The emission outputs for various scenarios were used to initialize the atmospheric concentrations of GHG in numerous general circulation models (GCMs) to forecast the effects on climate variables. The RPA Assessment provides a downscaling of climate forecasts to the county level (Coulson et al. 2010) for three scenarios applied to three GCMs. In this analysis we apply the outputs from the MIROC GCM—the Model for Interdisciplinary Research on Climate from the Center for Climate System Research, University of Tokyo—and the CSIRO GCM—the Australian Commonwealth Scientific and Industrial Research Organization Mark 2 Global Climate Model.

frequencies for various forest types. Because planting is rare in the Appalachian-Cumberland subregion, post harvest planting has little influence on the forecasts.

Whole plot imputation, a resampling scheme, defines the future inventory (Wear 2010). Using this approach, a historical plot with comparable climate, forest management type, age, and harvest characteristics is selected to represent conditions for each future plot condition forecasted by the model. When forest management type is held constant, this resampling allows for shifts in the constituent forest types over time. For example, if a site becomes hotter and drier over time, the forest type might shift from yellow-poplar (*Liriodendron tulipifera*) to oak-hickory (*Quercus-Carya*). Forest type transitions are driven largely by changes in climate condition, and become more prevalent in later years of the simulations. Given this statistical approach to constructing future inventories, individual plot forecasts are less informative than summaries of changes in the inventories over large aggregates of plots. Several components of the model, including transitions and imputation schemes are probabilistic defining a stochastic modeling system. We run the models 25 times and then select one run with the greatest central tendencies for this set as a representative inventory for subsequent display and analysis.

A third component is the All Land Use Model (Fig. 16.1 middle column). This component simulates effects of population and economic growth on the distribution of land uses in each county in the Appalachian-Cumberland subregion. It starts by predicting effects of population and income growth on the amount of urban or developed land uses in the county. It then predicts changes to rural land uses, including forest, crops, range, and pasture land uses, in response to urbanization, timber prices, and average crop returns within the county. For this analysis, timber prices differ between the two scenarios (High Market and Low Market) by assumption, and crop returns are assumed to remain constant over time. Population and income changes are comparable across the two scenarios and reflect the growth modeled for the RPA/IPCC A1B storyline. Forecasts of land use changes at the county level are used to shrink or expand the "area expansion factor" proportionally for all plots within the county. These factors define the area represented by each plot in the inventory.

Outputs from the USFAS (Fig. 16.1, Column 3) include forecasts of complete inventories and detailed forest conditions that can be derived from inventory records, forecasts of land uses at the county level, and forecasts of forest removals determined by timber harvesting and land use changes. The modeling framework is stochastic and is used to generate multiple realizations of future inventories and examine uncertainty inherent in the modeled elements of the system. For this analysis, we focus on what we call the "representative inventory" which is the inventory simulation with the greatest central tendency defined as the minimum total percentage deviation from mean values for a vector of modeled variables (it is also possible to examine the variances associated with each forecasted variable by examining the full set of simulations). As described in Fig. 16.1, subsequent analysis of various ecosystem services and conditions can be supported by these forecasts; for example, our analysis of change in successional stage habitats.

For the present analysis of age class projections, we defined three age classes. The Early-Age class is defined as forests aged 0–20 years. Middle-Age class forests are between 21 and 70 years old. And the Old-Age class forests are greater than 70 years old. Other age breakdowns were possible, but we felt that the larger age bins (>15 years) provided the best accounting of broad trends in age class distributions. We summarized age class distributions of the various forest type groups using these age class breakdowns.

16.3 Study Area and Data

The simulated study area was the Appalachian-Cumberland subregion evaluated in the Southern Forest Futures Project (Wear et al. 2009). This subregion (Fig. 16.2) reflected a broad variety of geophysical and ecological conditions represented by Blue Ridge, Northern and Southern Ridge and Valley, Cumberland Plateau and Mountain and Interior Low Plateau ecological sections (Fig. 16.1; also see McNab, Chap. 2), but was limited Virginia, Kentucky, Tennessee, North Carolina, Alabama and Georgia. Although the boundaries generally followed standard ecophysiographic lines, their final definition was determined by a team of specialists working on various components of the project.

Our forecasts started with the most recent (2007–2009) forest inventories available for each state in the subregion. We link each to their immediate previous forest inventory to estimate the harvest /transition models for various ownership groups and forest types in each state (see Polyakov et al. 2010). Because of data limitations, the Tennessee harvest model was applied to Kentucky's plots.

Simulations generate forecasts of forest conditions across a number of variables. In this analysis, we focused on forecasts of change in area of various forest type groupings and their age classes. We started by examining the five forest management types used by FIA to aggregate forest types in the South: Naturally Regenerated Pine, Planted Pine, Mixed Pine-Hardwood, Upland Hardwood and Lowland Hardwood. The Appalachian-Cumberland subregion is dominated by the Upland Hardwood group (McNab, Chap. 2) and we focused most of our analysis on this broad group split out into four sub groups: Oak-Hickory, Yellow-Poplar, Maple-Beech-Birch, and Other Hardwoods. These groups are aggregates of forest types defined by FIA using dominant and associated tree species assemblages. We started with the Forest Type Groups defined by FIA but then modified our groupings to match the setting. We used FIA's definition of Oak-Hickory where generally all of these forest types have oak dominants (USDA Forest Service 2007). We separated types with Yellow-Poplar dominants from FIA's Oak-Hickory group to define a separate Yellow-Poplar group. These are generally found on moist soils (McNab, Chap. 2). We used FIA's definition of the Maple-Beech-Birch group which includes sugar maple (*Acer saccharum*), black cherry (*Prunus serotina*), hard maple, and red maple (*A. rubrum*) dominants. The Other Hardwoods group is dominated by FIA's mixed upland hardwood type which includes a variety of species without a clear species dominance to place the plot in one of the other types. FIA notes that these types are generally on upland sites.

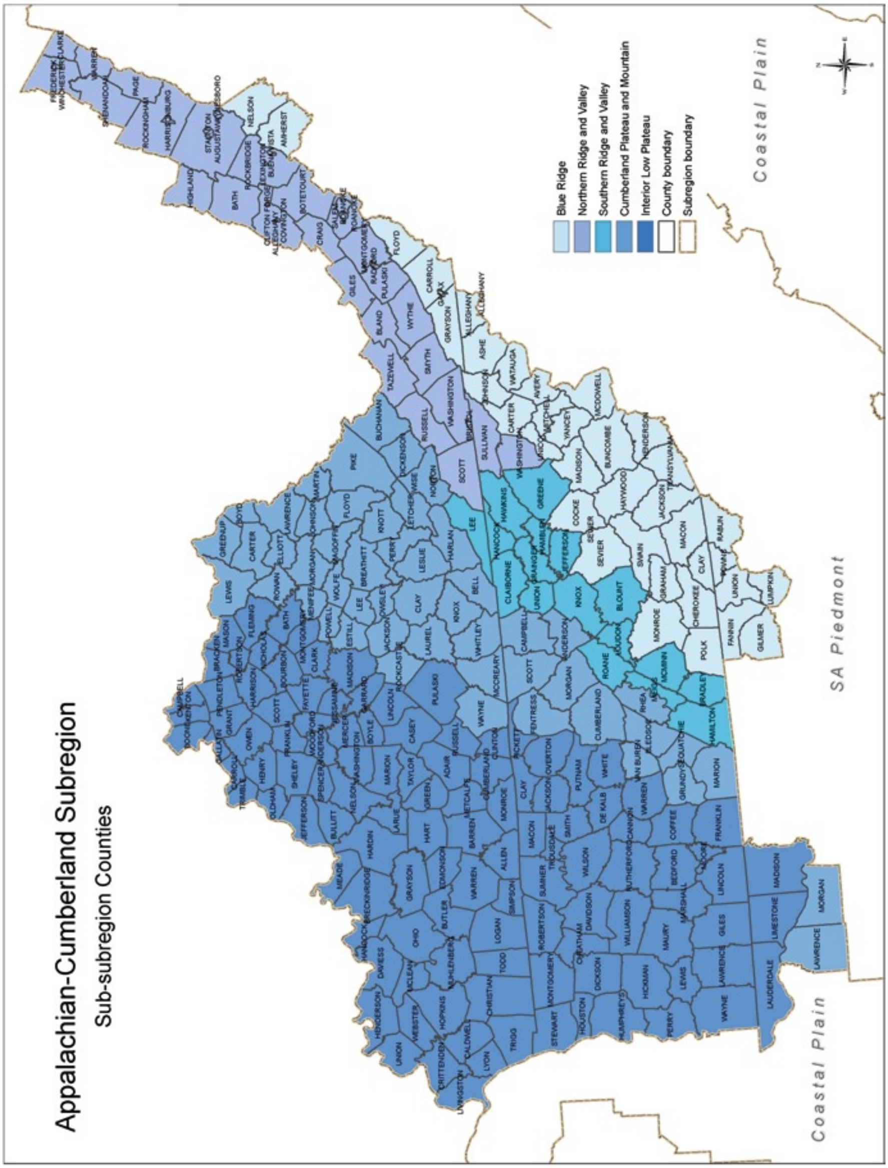

Fig. 16.2 Appalachian-Cumberland subregion, as defined by the Southern Forest Futures Project

16.4 Results

Anticipated population and income growth drive urbanization in the Appalachian-Cumberland subregion. In response, forest area in the subregion was projected to decline by 2.0 million acres under the High Market scenario and by 3.5 million acres under the Low Market scenario (Fig. 16.3). The loss was lower under the High Market scenario because higher prices shift rural land losses toward crops and pasture land rather than forests. Although not displayed here, the highest concentrations of forest losses were around Nashville Tennessee, the triangular area between Louisville, Lexington, and Cincinnati in Kentucky; and the area between Asheville, North Carolina and Knoxville, Tennessee. Little forest loss was projected for eastern Kentucky.

Among the five major forest management types in the South (Upland Hardwoods, Lowland Hardwoods, Natural Pine, Mixed Oak-Pine, and Planted Pine), Upland Hardwoods clearly dominated with 82% of total forest area (Fig. 16.4). Nearly all forest losses between 2010 and 2060 were also contained within this forest management type and we accordingly limited our subsequent analysis to understanding the dynamics of change in Upland Hardwoods.

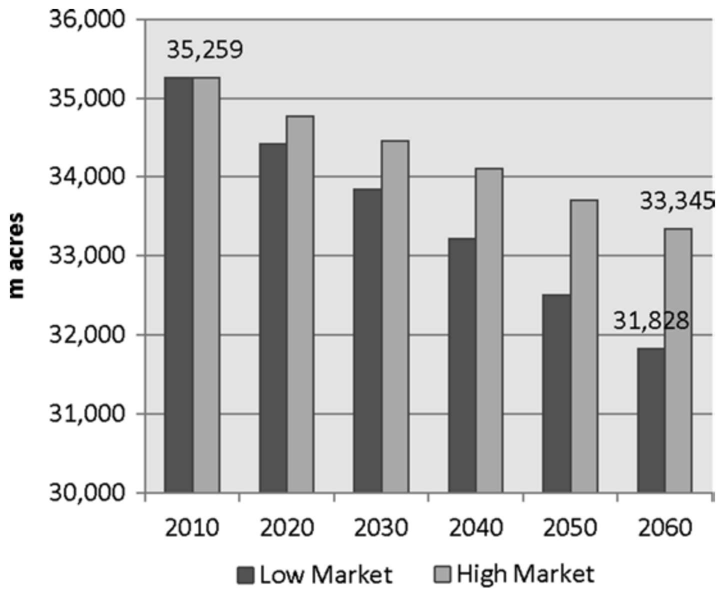

Fig. 16.3 Forecasts of forest area in the Appalachian-Cumberland subregion for High Market and Low Market scenarios, 2010–2060

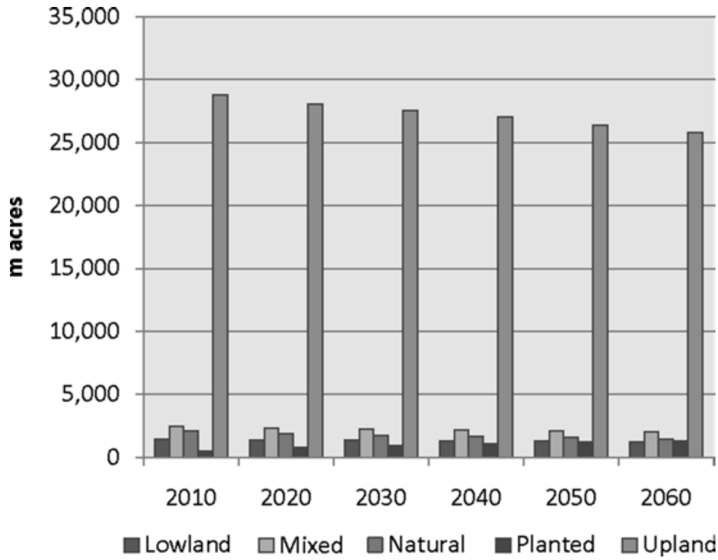

Fig. 16.4 Forecasts of forest area by broad management type for the Low Market scenario, 2010–2060

We defined four subgroups for the Upland Hardwood Forest Management group: Oak-Hickory, Yellow-Poplar, Maple-Beech-Birch, and Other Hardwoods (Fig. 16.5a). Under the Low Market scenario, the greatest change was in Upland Hardwood area (−10%); the Oak-Hickory type changed least, declining by 1% between 2010 and 2060 (Fig. 16.5b). Over the same period, the Maple-Beech-Birch group declined 9%, the Yellow-Poplar 24%, and Other Hardwoods 31%. The patterns of change were different for the High Market scenario where the area of Upland Hardwoods declined by 7% (Fig. 16.6) between 2010 and 2060. Under this scenario, the area of Oak-Hickory declined 5%, the area of Yellow-Poplar declined 12%, and the area of Other Hardwoods declined 17%. Under the High Market scenario, the area of Maple-Beech-Birch increased 8% between 2010 and 2060.

Combining forest area and forest transition dynamics with forest aging and disturbances yielded forecasts of age class distributions of these forests. For the Low Market scenario, area of both Early (0–20 years) and Middle (21–70 years) forest age classes declined. Early-Age class forests declined by 38% from 2.3 to 1.4 million acres and Middle-Age class forests declined by 51% from 18 to 9 million acres. As a result, the area of Old-Age class forests (>71 years) increased substantially between 2010 and 2060, from about 9 million acres to about 16 million acres (+76%) (Fig.16.7).

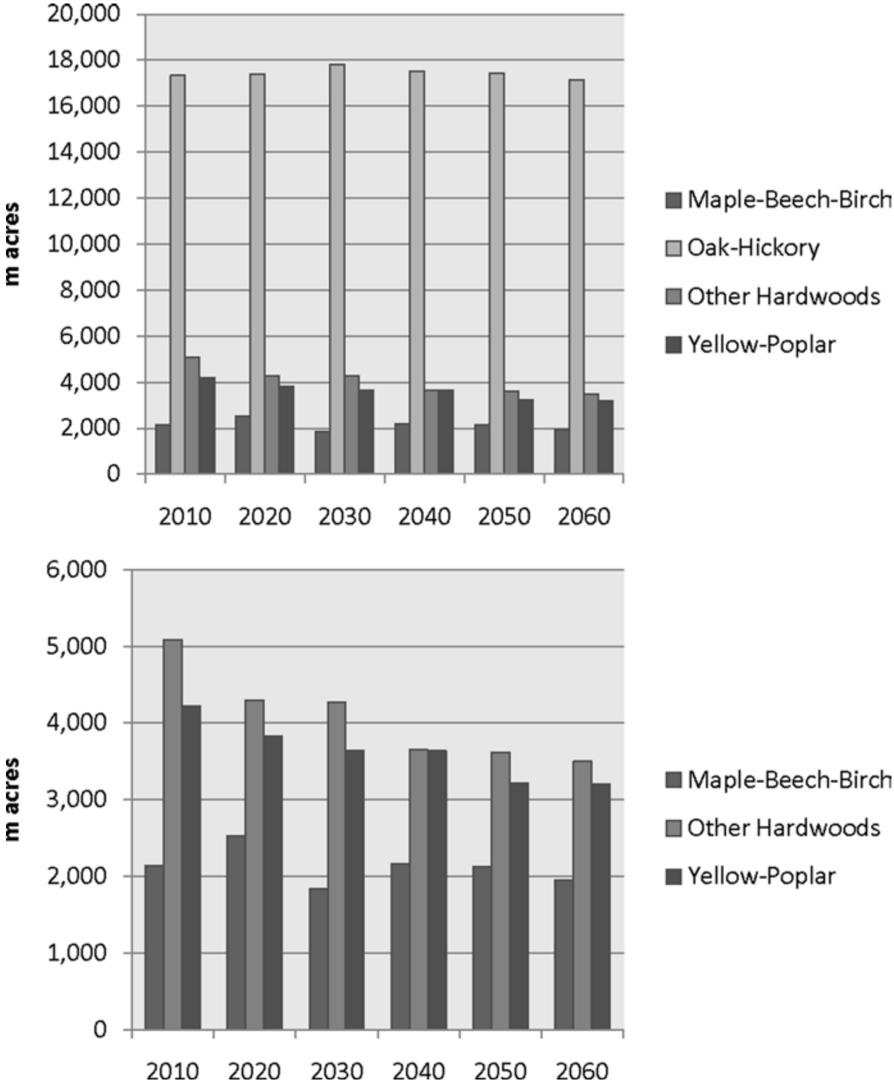

Fig. 16.5 Forecasts of forest area by forest type within the Upland Hardwood Forest Management group for the Low Market scenario, 2010–2060

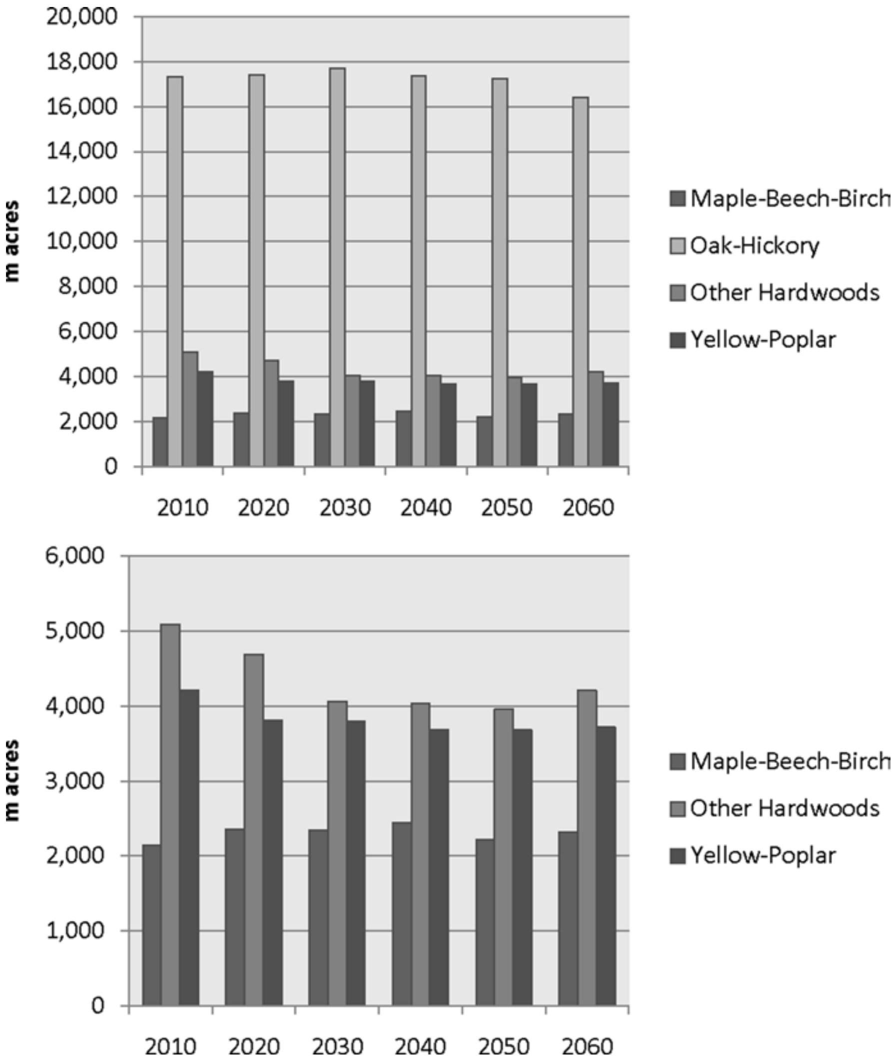

Fig. 16.6 Forecasts of forest area by forest type grouping within the Upland Hardwood Forest Management group for the High Market scenario, 2010–2060

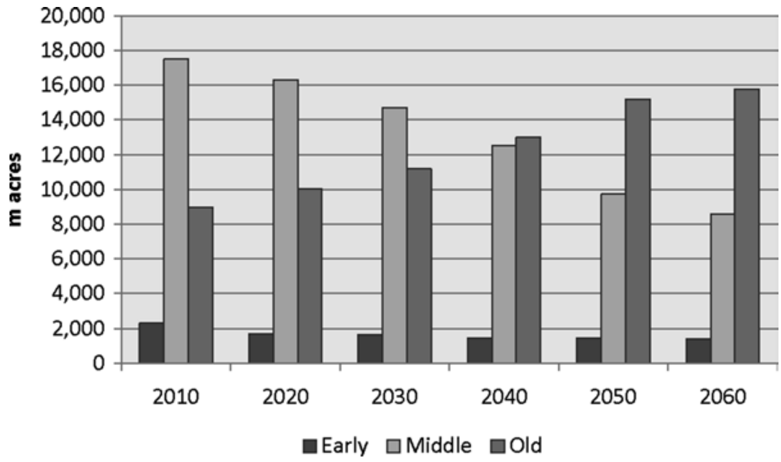

Fig. 16.7 Forecast of Early-, Mid-, and Old-Age class forests in the Appalachian-Cumberland subregion for the Low Market scenario, 2010–2060

Under the High Market scenario, area of Early- and Middle-Age class forests declined, but at a lower rate (Fig. 16.8). Loss of Early-Age class forests was less than one half of that forecasted for the Low Market scenario (–371,000 versus –878,000 acres). Loss of Middle-Age class forests and gain in Old-Age class forests was also dampened with this scenario: Middle-Age class forest area declines by 40% (versus 51% for the Low Market scenario) and Old-Age class forest area increases by 58% (versus 76%).

Forecasts of change in Early-Age class forests differed across forest types (Figs. 16.9 and 16.10). For the Low Market scenario, Other Hardwoods had the greatest loss in Early-Age forest area (–53%), decreasing substantially between 2010 and 2020 and gradually thereafter. The Other Hardwoods group was largely coincident with Early-Ages and was less frequent for Older-Ages because its species composition is largely indeterminate until later in stand development. Loss of this type would be expected with less forest harvesting over time. After Other Hardwoods, Yellow-Poplar forest types were forecasted to lose the most Early-Age forests (–33%), followed by Maple-Beech-Birch (–28%), and Oak-Hickory forests (–16%).

These patterns of change were different for the High Market scenario (Fig. 16.10). Here Other Hardwoods were also more likely to lose area of Early-Age forest but the difference between 2010 and 2060 was much smaller (–27%). Under this scenario, Oak-Hickory, Yellow-Poplar, and Maple-Beech-Birch forest types showed some oscillation in their Early-Age forest area but departed only slightly from their initial values between 2020 and 2060.

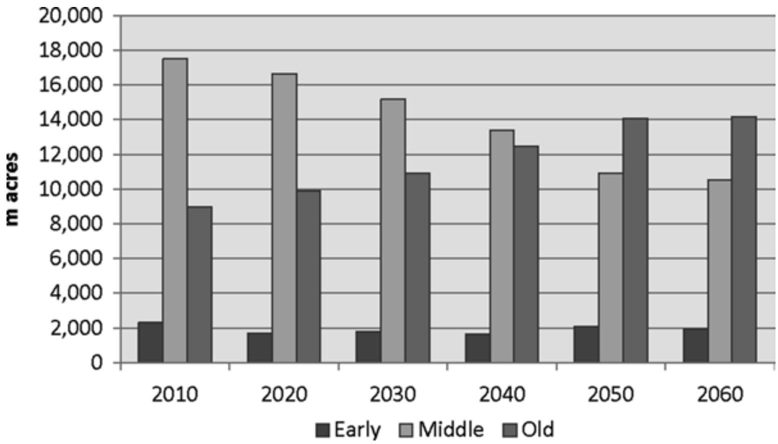

Fig. 16.8 Forecast of Early-, Mid-, and Old-Age class forests in the Appalachian-Cumberland subregion for the High Market scenario, 2010–2060

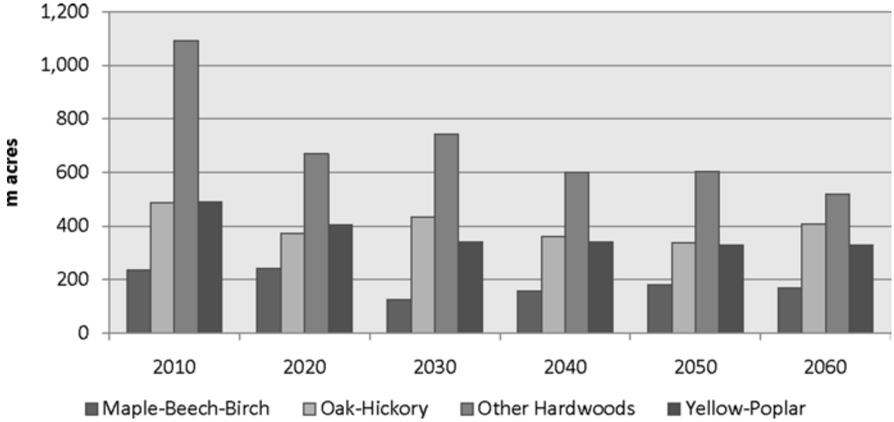

Fig. 16.9 Forecast of Early-Age class forests in the Appalachian-Cumberland subregion for various upland hardwood forest types, 2010–2060, under the Low Market scenario

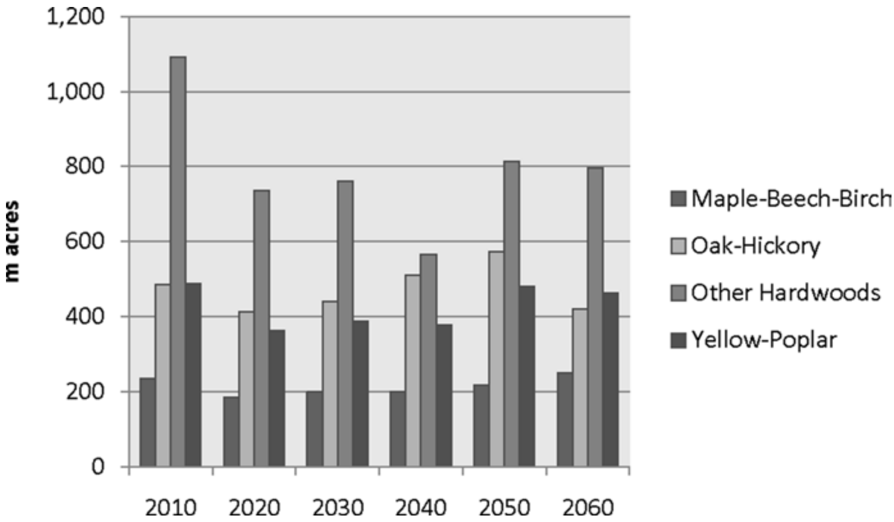

Fig. 16.10 Forecast of Early-Age class forests in the Appalachian-Cumberland subregion for various upland hardwood forest types, 2010–2060, under the High Market scenario

16.5 Discussion and Conclusions

Future forecasts highlighted how socioeconomic forces had a substantial influence on area and structure of forests in the Appalachian-Cumberland subregion of the Central Hardwood Region. These influences were expressed through forecasts of changes in land uses for the subregion, which were largely driven by forecasted increases in populations and incomes. Resulting urbanization drew down the area of rural land uses, primarily forests. For both High Market and Low Market scenarios, forest losses ranged between 2.1 and 3 million acres, or 7–10% of current forest area in the Appalachian-Cumberland subregion.

The area of individual forest types was differentially influenced by these changes in land uses coupled with changes in climate. In this subregion, temperatures increased throughout the projection period and the climate is somewhat drier, shifting growing conditions in important ways. In both scenarios, the Other Hardwoods and Yellow-Poplar forest types lost the highest percentage of their forests. Oak-Hickory, however, lost the lowest percentage of its area, even though it represents the largest share of forests within the subregion. This likely reflected both the location of forecasted urbanization, which could differentially affect the areas of different forest types, and the shift toward warmer and drier site conditions.

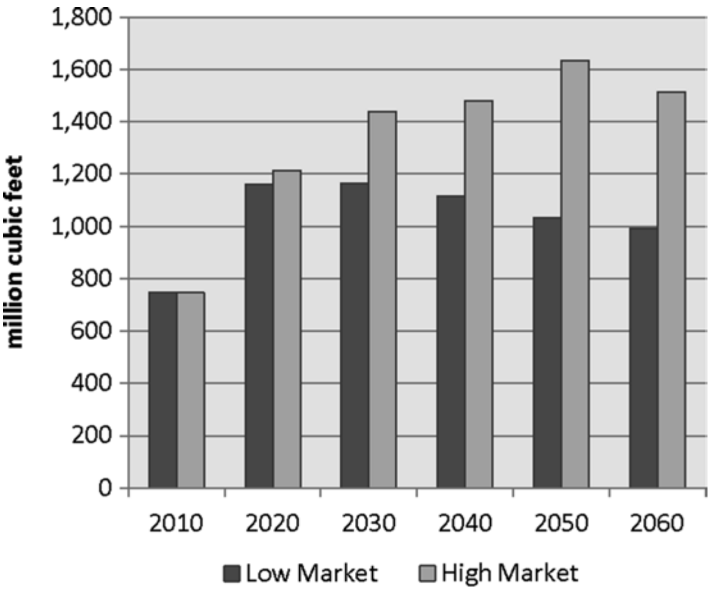

Fig. 16.11 Total hardwood removals forecasts in the Appalachian-Cumberland subregion for High Market and Low Market scenarios

Shifts in the age classes of forests were dominated by the projected harvest regimes. The High Market scenario produced a harvest rate (measured as annual hardwood removals) that was about 58% higher than the Low Market scenario by 2060 (Fig. 16.11). This leads to qualitatively different patterns of change for Early-Age forests. The Low Market scenario leads to a substantial (−38%) loss in Early-Age forests, which strongly favors Other Hardwoods and Yellow-Poplar forest types. The High Market scenario, in contrast, leads to a 16% loss in Early-Age forests over the projection period and favors Other Hardwoods. Changes in Early-Age forest area for all other forest types were forecasted to be minimal over time for the High Market scenario.

Clearly the area of Early-Age forests was scaled by the change in total forest area—as total forest area declined, so did the area of Early-Age forests. However, change in age class distributions of forest types was most directly altered by the extent of harvesting within the subregion. Although the forecasts were unambiguous in showing a decline in Early-Age forest area, comparison of the two scenarios indicated that the area of Early-Age forests was highly variable across what could be considered a moderate range of plausible forest market conditions.

Although the scenarios considered in this analysis are viewed as plausible, in that they reflect seemingly realistic projections of population and income along with the best knowledge regarding future climate and potential forest product prices, they should be viewed as uncertain. We argue that comparisons between the scenarios are the most informative aspect of the analysis, as they highlight the relative importance of vectors of change. Clearly, the future is unknowable, but forecasting models such as the one used here allow for a deliberate and informative consideration of the potential for critical changes in forest conditions.

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