Chapter 27
United States of America (USA)

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27.1 Introduction

27.1.1 Descriptive Statistics

In the United States of America (USA), forest land is defined with respect to four criteria: (1) minimum area of 0.4 ha, (2) minimum crown cover of 10%, (3) minimum width of 36.6 m, and (4) forest use. Total forest land currently exceeds 310 million ha and has generally been increasing since the 1920s, despite a near tripling of the human population. Currently, more than 30% of the country is characterized as forest land with 58% of it in various categories of private ownership. Unlike in many European countries, private forest land owners in the USA have considerable freedom to convert their land from forest to non-forest uses and vice-versa in response to varying commodity prices and other factors. This feature of private land ownership at least partially explains substantially varying local forest areas over time.

The Nation's many topographic and climatic zones define a large number and great variety of forest biomes ranging from boreal in the north to tropical in the southeast. In the eastern half of the country, the oak-history forest type group represents 34% of forest land and dominates in the central part of the region, pine groups represent 17% and dominate in the southeast, and the maple-beech-birch group with 13% and aspen-birch group with 4% dominate in the north. In the western part of the country, coniferous species dominate with Douglas fir representing 18%, pinyon-juniper representing 15%, fir-spruce representing 14%, and Ponderosa pine representing 11% of forest land. In Alaska, the fir-spruce forest type group is the largest and represents 34% of forest land.

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The forest land use category Forest Available for Wood Supply (FAWS) is not commonly used in the USA, although the concept is prevalent. In particular, the definition of the American land use category Timberland includes the specification that the land must not be withdrawn from timber utilization. Thus, all timberland is in the FAWS land use category. More than 200 million ha of forest land are classified as timberland, meaning that they are capable of producing 0.57 m^3 of industrial wood products annually, are not legally reserved from timber harvest, and are similar to what is known elsewhere as productive forest land. Nearly 70% of timberland is privately owned (Oswalt et al. 2014). In contrast to timberland, the land use category Reserved Forest Land is defined to be land where management for production of wood products is explicitly prohibited. Reserved Forest Land constitutes 7–10% of forest land, includes mostly state and federal parks and wilderness areas, has doubled in area since the early 1950s, and is concentrated in western States.

27.1.2 Wood Resources and Their Uses

Wood resources are generally available for use on all private, non-reserved forest land and most public non-reserved forest land. Local exceptions include buffer zones established for aesthetic purposes and for filtering purposes such as near water sources. Net growing stock volume on timberland, one measure of wood resources, totals nearly 30 billion m^3 and has increased by more than 50% since 1953, mostly in the eastern USA (Oswalt et al. 2014). Over the past 50 years, growth has generally exceeded removals throughout the country. Although removal levels have stabilized in recent years, the source of removals has shifted decidedly from public land in the West to private land in the East. In 1996, coniferous removals in the South exceeded growth for the first time since 1952 when data were first reported. Between 2007 and 2012, the southern region of the country had 63% of American removals (Oswalt et al. 2014), hence the characterization of this region as the "woodbasket of the country." Nation-wide in 2011, timber harvested for industrial products and fuelwood totaled more than 360 million m^3 of which saw logs accounted for 39%; the combination of pulpwood and composite panel outputs accounted for 39%; fuelwood accounted for 14%; veneer production accounted for 5%; and poles, posts, and mulch accounted for 2%.

27.2 The National Forest Inventory

The Forest Inventory and Analysis (FIA) program of the U.S. Forest Service conducts the National Forest Inventory (NFI) of the USA for purposes of estimating the area of forest land; the volume, growth, and removal of resources; and the health of the forest (McRoberts et al. 2010). The FIA program and its predecessors have continuously assessed the Nation's forest resources since 1928. The current form of the inventory was initiated in the early 1990s and is consistent across the entire country with respect to major features such as plot configuration, sampling design, core variables, measurement protocols, and reporting requirements. The inventory is conducted in three phases. In Phase 1, remotely sensed data in the form of aerial photographs and satellite imagery are used for intial assessments of all plots and to stratify the area of interest in support of stratified estimation for purposes of increasing the precision of estimators. In Phase 2, field crews visit plot locations that include forest land, and observe or measure a broad array of site and mensurational variables. Phase 3 consists of more intense measurements of a subset of Phase 2 plots for purposes of assessing a suite of variables related to forest health, ground vegetation, and soils. Additional components of the FIA program include a survey of woodland owners, an emerging urban forest survey, and a mill survey using questionnaires designed to determine the locations, sizes, and types of mills; the volume of roundwood received by product, species and geographic origin; and the volume, type and disposition of wood residues generated during primary processing.

The FIA sampling design is based on a tesselation of the entire country into 2400 ha hexagons with a plot established at a randomly selected location in each hexagon. In the eastern USA, 14% of the plots are measured each year, and in the western USA where growth is slower, 10% of the plots are measured each year. An interpenetrating panel design is used whereby the plots measured in any particular year constitute a complete sample of each state. Each year, approximately 50,000 plots are assessed of which more than 17,000 are on forest land and are measured by field crews.

For all plots on forest land, FIA field crews obtain observations and measurements that describe individual trees, site quality, stocking, general land use, ownership, reserved status, and general stand characteristics such as forest type, stand age, and disturbance. For all trees with diameter at breast height (*dbh*, 1.37 m) of at least 12.7 cm, individual tree observations and measurements include species, *dbh*, height, and removals. Tree- and plot-level observations and measurements are used to predict additional variables including tree and plot volume and biomass, growth, and mortality. Following quality checks, plot data are made available via a publicly accessible Internet site.

FIA data are available to forest planners and managers to assist in managing the Nation's forest resources. However, the data are only sufficient for assessing the past and current state of the resource and for estimating trends. Today, forest planners and managers are increasingly expected to manage stands in ways that are ecologically and economically sound; that comply with a diverse array of objectives including criteria related to health and condition, scenic value, wildfire risk, invasive species, insects and pathogens, and biodiversity; and that produce sufficient additional revenue at harvest to justify intermediate treatments. Further, forest planners and managers have little first-hand knowledge or validated guidance regarding how to comply simultaneously with these often competing criteria. Thus, they need more than just data; they need techniques and tools that use the current state of the resource as a starting point for projecting the long-term consequences of alternative management strategies.

27.3 The Forest Vegetation Simulator

27.3.1 Overview

Multiple forest projection systems are used in the USA, depending on the region and the purpose. Of these, the Forest Vegetation Simulator (FVS) is the most widely used, particularly by federal and state government agencies and private landowners. FVS is an empirical, distance-independent, individual-tree forest growth modeling system constructed, maintained and updated by the U.S. Forest Service. The basic spatial analysis unit is a stand, but the system accommodates many thousands of stands simultaneously. Initial conditions for model predictions consist of a summary of current forest conditions, often in the form of a tree list that can be obtained from the FIA database. Minimal input requirements are individual tree species, diameter, height, and expansion factor. Predictions are possible for several hundred years with time steps of 5–10 years. Details of the FVS system are documented in Dixon (2002) and in an excellent review by Crookston and Dixon (2005).

More than 20 geographical FVS variants have been developed to accommodate regional and local conditions in the USA and parts of western Canada (Crookston and Dixon 2005). Extensions of the basic model functions in the forms of integrated modules or separate models that use FVS output files as input have also been developed. These extensions broaden the system to address specific applications such as the effects on forest growth and mortality of insects and pathogens, fire and fuels, and climate change. Additionally, the economic extension aids in the assessment of silvicultural alternatives, and the fire and fuels extension can be used for carbon accounting. The system includes a graphical user interface and post-processing programs that allow stand visualization and that customize output reports to meet user requests. Brief descriptions of the models and some of the extensions follow with additional details available in the Internet-accessible references provided.

27.3.2 Models and Extensions

27.3.2.1 Growth and Mortality Models

The most important components of the system are the large tree diameter increment and mortality models for the regional variants. These models drive much of the system. Overall, FVS has four primary model components: height growth, diameter growth, crown change, and mortality. The first three components consist of separate sub-models for small trees and for large trees. Within a projection cycle, the processing sequence is: large-tree diameter growth, large-tree height growth, small-tree height growth, small-tree diameter growth, mortality, and crown change. The small-tree model is driven by height growth, whereas the large-tree model is driven by diameter growth. This approach is intended to ensure a smooth transition in height growth as tree size increases. Logistic models are used to predict mortality based on a suite of site and tree conditions. Mortality predictions generally reflect typical background level with mortality due to insects, pathogens, and fire accommodated in the extensions. In addition, as stand basal area approaches the site potential, mortality rates increase (Dixon 2002).

27.3.2.2 Regeneration

Natural regeneration is predicted by summarizing species-specific small-tree attributes such as average frequency and height for seedlings and small saplings based on local FIA plot observations. Seedling recruitment is based on relationships with maximum stand density index. Small sapling regeneration is based on distribution patterns characteristic of current stand size class (seedling/sapling, pole, sawtimber) and density conditions. Apportioning the small sapling frequencies according to the observed distribution patterns provides an expected natural regeneration by stand size/density condition or vegetation state (Vandendriesche 2010).

27.3.2.3 Insects and Pathogens

Extensions to FVS have been developed to accommodate the effects of insects and pathogens (Crookston and Dixon 2005). These extensions are in form of modules that are integrated with the base FVS program. They modify the standard growth and mortality predictions to represent insect and pathogen losses and are implemented once per year within a projection cycle. Crookston and Dixon (2005, Table 1) document many of the separate modules that have been developed for individual insects and pathogens.

27.3.2.4 Fire, Fuels and Carbon

The Fire and Fuels Extension supports fuel management and post-fire treatment decisions by simulating fuel dynamics over time. The extension estimates changes in vegetation due to fuel treatments that include prescribed burns, multiple thinning schemes, piled fuel and burning, pile burning, and mastication. The extension evaluates the effectiveness of these treatments with respect to short- and long-term stand dynamics that are important for silviculture, wildlife habitat, and fuel hazards. The extension does not predict the probability of fire or the spread of fire among stands.

The fuel modeling and accounting approach used by the Fires and Fuels Extension can be used to account for stand carbon stocks and carbon in harvested products. With the exception of the litter and duff pools, carbon found in the living and dead biomass is converted to units of carbon by multiplying by 0.5. Stand C stocks are calculated and reported for multiple categories including total aboveground live biomass, standing dead biomass, forest down dead wood, forest floor litter and duff, herbs and shrubs, and belowground live and dead biomass (Rebain et al. 2015).

27.3.2.5 Climate Change

The climate change extension simulates stand-level impacts of climate change via three modifications of model predictors: linking species mortality and regeneration to climate variables that express climatic suitability, linking site index to climate and using it to modify growth rates, and changing growth rates to accommodate climate-induced genetic responses. Growth is affected when climate conditions at a given location change in relation to the optimal climate conditions under which the species is known to grow and thrive. Mortality is affected when the climate becomes inconsistent with the conditions where species are presently known to survive. Regeneration potential is limited by changes that cause an area's climate to become inconsistent with the known conditions where specific species survive; conversely, changes that cause climate characteristics to become more suitable for a species' survival facilitate successful regeneration of the species (Crookston et al. 2010).

27.3.2.6 Economics

The economic ramifications of individual stand prescriptions can be evaluated with any of several independent extensions that do not interact dynamically with FVS but rather run as separate programs using special FVS output files as input. These programs provide additional functionality for specifying rotation lengths, allow for scheduling activities based on economic parameters, and provide for enhanced reporting of revenues based on log dimensions (Dixon 2002 Sect. 8.10).

27.3.3 Uncertainty

Although FVS makes no provision for rigorous uncertainty assessment, random effects are incorporated into several system components. Diameter growth estimates for large-trees consist of the sum of the growth model estimates and random residuals. These residuals are correlated with residuals from the previous growth cycle to mimic the general finding that trees growing rapidly or slowly in the past tend to continue to grow rapidly or slowly, respectively, in the future. In addition, the component of the model that regenerates stands includes random variation in the heights of seedlings, stocking levels and species composition.

Uncertainty assessments are conducted as deemed necessary by external users and are of several forms. First, accuracy assessment consists of comparison of model predictions with ground observations. Russell et al. (2012) found that for the model variants for the northeastern portion of the country and for the region in the vicinity of the Great Lakes, mean deviations between observed and predicted 5-year diameter increments were in the range 0.025–0.625 cm, but that 10% error in diameter predictions produced 25% error in biomass estimates. Second, sensitivity analyses assess the effects of variability in inputs on the variability of outputs. For the Southern region, Vacchiano et al. (2008) found that diameter, site index, and competition-related variables were the most influential predictors of large-tree diameter growth. For the Southern region, Herring (2007) found that large-tree diameter growth predictions were sensitive to variability in only five predictors, whereas the variability in the 25 other predictors contributed less than 5% of total model uncertainty. Third, propagation of error techniques are used to assess the effects of the transmission of statistical uncertainty from sources such as sampling, parameter variances, and model prediction residuals through modelling predictions to the statistical uncertainty of system outputs. For complex models such as large-scale forest projection systems, assessment of the effects of uncertainty from all sources is a daunting task. Thus, assessments frequently focus on individual sources. For Washington State, Gregg and Hummel (2002) used bootstrapping techniques to propagate the uncertainty of in tree-list inputs through to the distribution of variables predicted by FVS. Investigations of the combined effects of uncertainty from all the major FVS sources should be considered.

27.3.4 Applications

The availability of FIA data in FVS-ready format has increased the number of FVS users to the point that it has become the tool of choice for many applications. In addition, FVS is the official tool for stand growth projection on National Forest lands owned and managed by the U.S. Forest Service. Forest managers have also used FVS extensively to summarize current stand conditions, predict future stand conditions under various management alternatives, and update inventory statistics. Crookston and Dixon (2005) document multiple specific applications. FVS was used to analyze the economics and feasibility of alternative timber harvest methods in South Dakota, to optimize management plans for a late successional reserve in Washington, and to develop an optimal forest rotation for reclaimed coal mines in the eastern USA. In response to potential loss of spotted owl habitat, logging in national forests in the Pacific Northwest of the USA was stopped by court order in 1991. FVS was used to identify plant communities in Oregon that would sustain the owl and to produce 300-year yield estimates to support owl habitat in California. Large-scale forest health assessments were conducted using FVS to assess the effects of dwarf mistletoe and root diseases on yield in Oregon and the effects of bark beetles on forest structure in Montana. The feasibility of applications has been further enhanced via linkages between FVS and other software systems, databases, and geographic information systems.

27.4 Conclusions

The FIA program collects information for a broad array of inventory variables using methods that are consistent across the entire country. The data are available to the public in formats that facilitate input to a variety of applications including forest projection systems. FVS is the most widely used forest projection system in the country and is based on integrated diameter growth models, mortality models, and stand regeneration methods. Extensions in the form of integrated modules or separate programs address specific issues such as insects, pathogens, fire, climate change, carbon accounting, and economic considerations. FVS has been successfully used for a wide range of applications including assessment of management alternatives, wildlife habitat analyses, and climate change effects.

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