# An Assessment of Natural Assets in the Appalachian Region: Forest Resources

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Appalachian Regional Commission
1666 Connecticut Avenue, NW
Suite 700
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**Prepared by:**

**Downstream Strategies**
Fritz Boettner (Project Manager), Jason Clingerman, Rory McIlmoil, Evan Hansen, Laura Hartz, and Anne Hereford

**West Virginia University**
Michael Vanderberg, Kathryn Arano, Jinyang Deng, Jacquelyn Strager, and Michael Strager

**The National Network of Forest Practitioners**
Colin Donohue





Downstream Strategies
West Virginia University
AHC Appalachian Hardwood Center

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# Abbreviations

| | |
|---|---|
| **ARC** | Appalachian Regional Commission |
| **BMP** | best management practice |
| **CP** | compromise programming |
| **DSS** | decision support system |
| **EIA** | Energy Information Administration |
| **EMM** | Electricity Market Module |
| **FIA** | Forest Inventory Analysis |
| **GIS** | geographic information system |
| **MACED** | Mountain Association for Community Economic Development |
| **MCA** | multiple criteria analysis |
| **MW** | megawatt |
| **MWh** | megawatt-hour |
| **NERC** | North American Electric Reliability Corporation |
| **NIDRM** | National Insect and Disease Risk Map |
| **NPCC** | Northeast Power Coordinating Council |
| **NPS** | National Park Service |
| **NRCS** | Natural Resources Conservation Service |
| **ORNL** | Oak Ridge National Laboratory |
| **RFC** | Reliability First Corporation |
| **RPA** | Resources Planning Act |
| **SERC** | Southeast Reliability Corporation |
| **SOLE** | Southern On Line Estimator |
| **TPO** | Timber Product Output |
| **US** | United States |
| **USDA** | United States Department of Agriculture |
| **USEPA** | United States Environmental Protection Agency |
| **USFS** | United States Forest Service |
| **USFWS** | United States Fish and Wildlife Service |
| **VACAR** | Virginia-Carolinas |
| **WAC** | Watershed Agricultural Council |
| **WVU** | West Virginia University |

# EXECUTIVE SUMMARY AND KEY FINDINGS

The Appalachian region consists of approximately 205,000 square miles (131 million acres), covering 420 counties in 13 states (Figure 1). It extends more than 1,000 miles from southwestern New York to northeastern Mississippi and is home to 24.8 million people (ARC, 2009a). Appalachia is the largest forested area east of the Mississippi River; many cities and rural communities within and around the region are dependent upon the wise use, management, and development of Appalachian forests.

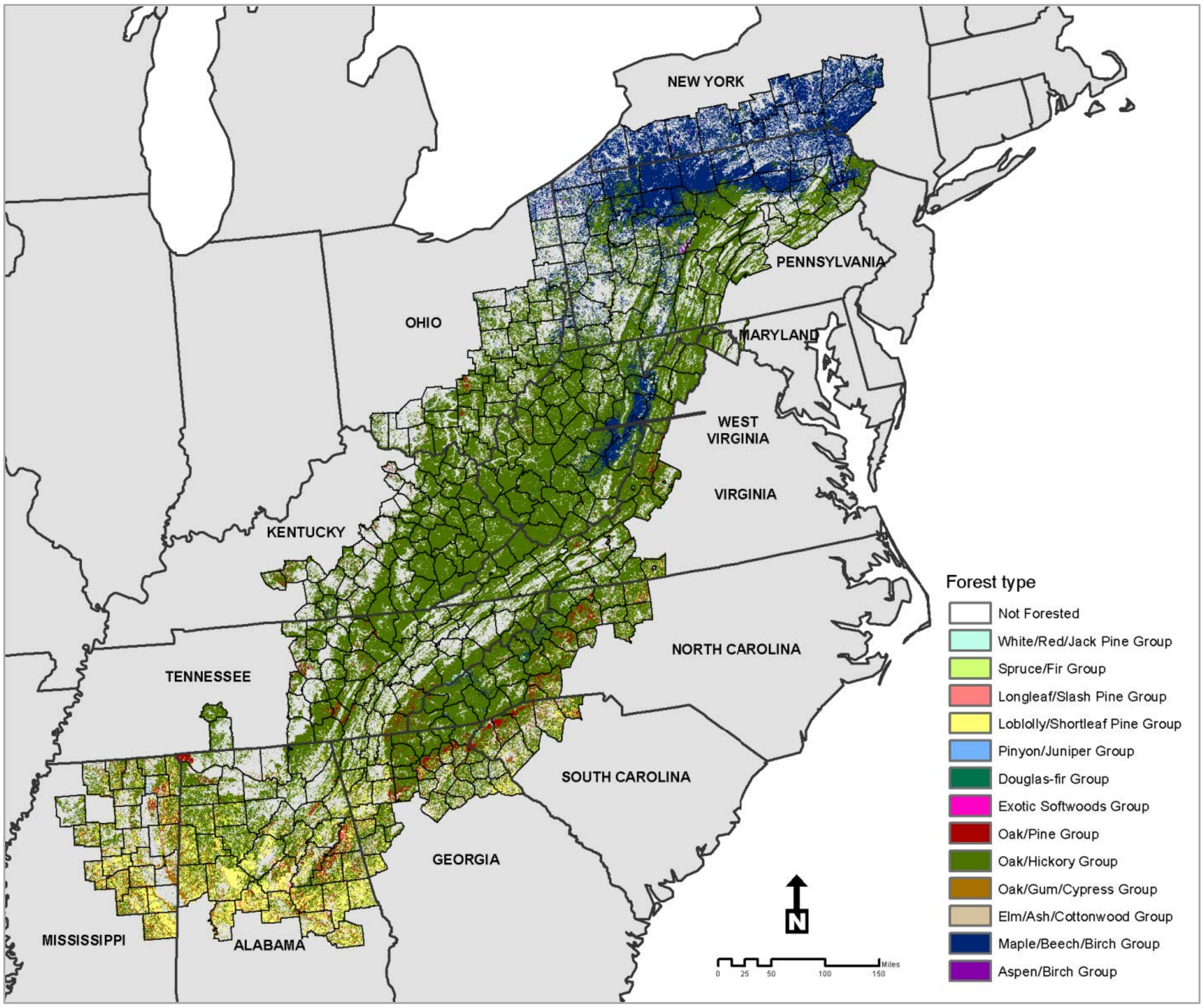



**Figure 1: Forest types in the Appalachian Regional Commission region**

This project was initiated as part of the long-term research objective developed by the Appalachian Regional Commission (ARC) to understand Appalachia's natural assets. The primary goal of this study is to provide information that will encourage the sustainable management of forest assets across the region, which requires developing an inventory of the forest assets, analyzing their value and usage, assessing their potential contribution to economic development of the region, and creating a framework to help plan their best use.

This study describes forest assets in the Appalachian region to facilitate forest management and planning strategies and to provide useful information and tools for decision-makers. It evaluates three aspects of forest resources—***quantity, quality, and value***—using data and information collected for a variety of metrics and indicators (Table 1).

Data collected from various sources were analyzed and mapped at the county level. Many types of forest datasets exist across the United States (US); however, very few are consistent from region-to-region or state-to-state. The exception to this rule is the US Forest Service's (USFS's) Forest Inventory and Analysis (FIA) program, a comprehensive census of America's forests. Forest resources do not always follow political boundaries or adhere to easily manageable units, but based on the FIA dataset, we examined regionally consistent and representative characteristics in order to understand Appalachia's forest resources. For each assessment category, this study lists the specific datasets used, rationale for the methods, and overall results.

The appendices include a discussion of forest carbon payments, an analysis of the feasibility of co-firing forest biomass in coal-fired power plants, an assessment of the climate and biomass resource benefits of improved forest stand health, and the results of a stakeholder survey.

**Table 1: Forest asset categories**

| Quantity | Quality | Market value | Non-market value |
|---|---|---|---|
| Standing timber volume | Stand quality | Wood | Wildlife habitat |
| Woody biomass volume | Growth ratio | Wood product | Watershed services |
| Wood product volume | Stand origin | | Recreation |
| Forest carbon mass | Insect and disease risk | | Cultural |
| Forest area | Housing density change | | |
| | Predicted forest loss | | |
| | Forest disturbance | | |

The **Forest Quantity** category examines the volume (available standing timber and annual forest products output), area, and carbon storage of Appalachia's forests. The **Forest Quality** category is based on impacts to forest resources from a variety of stressors, including recent disturbances, plantation forestry, the risk of insects and disease, increased housing density (the number of homes per unit area) and expansion, as well as tree growth, mortality, and non-merchantable volume. Healthy forests can be an asset for recreational use and industrial growth, both of which can be significant economic drivers. The **Forest Value** category is composed of two categories: market and non-market values. Market values are those that are derived from market exchanges of forest resources—like selling timber. Non-market values capture other uses of forest resources—like providing habitat for wildlife.

## Key findings

The following key findings are organized by asset category.

### Forest quantity

Forest resources have influenced the Appalachian region throughout its recent history. While much of the forestland was harvested for timber during the early twentieth century, forests cover 65% of the land base today.

- Forest quantity was evaluated using five indicators, which represented the relative amounts of **standing timber**, **woody biomass**, **wood products**, **forest carbon**, and **forest area**.
- The Appalachian counties with the highest overall quantity are in the most mountainous areas of the region, while counties with the lowest quantity are concentrated in the southwestern region in Alabama and Mississippi. Many forests of the southwestern region are composed of smaller trees and other species when compared to the forests of the mountainous areas of Appalachia, and this can have a large effect on the overall volume of standing timber, woody biomass, and forest carbon stocks.
- The counties with the highest quantity of forest resources usually contained significant areas of protected land, such as national forests, national parks, national rivers, state forests, or state parks.
- The counties clustered in southwestern Appalachia, despite relatively lower forest quantity scores, generally had the highest wood product output. This pattern suggests that the forest industry in the area may be impacting forest quantity.

### Forest quality

Within a forested area, the quality of the resource has an impact on its potential value. Forest quality can impact the market value—based on selling wood fiber and solid wood products—or the non-market value, based on recreation or other ecosystem services.

- For this study, forest quality was evaluated by assessing five indicators: **stand quality** in terms of health and merchantability, **growth ratio** as a simple measure of tree growth and mortality, **stand origin, projected forest loss** via pressures from housing and insects and disease, and **forest disturbance** due to a variety of natural and artificial factors. In addition, the projected forest loss indicator is broken down into two components, **housing density change** and **insect and disease risk,** for a more detailed analysis.
- The counties with the highest overall forest quality were generally located in Mississippi, Alabama, New York, northern Pennsylvania, Ohio, and West Virginia.
- The counties with the lowest overall forest quality were generally located in Georgia, South Carolina, North Carolina, and Tennessee. These counties are generally near larger cities, which could be experiencing urban growth.
- As reflected in the projected forest loss indicator, the majority of counties are not likely to experience large amounts of deforestation due to housing pressure or tree mortality from insect infestation and disease.
- Currently, forest disturbance does not greatly detract from forest quality, but this trend may change as climate change impacts on temperature and precipitation regimes shift the patterns of forest disturbance over time.

## Forest value

Forests provide significant market value in the form of timber and other wood products and considerable non-market value for their ecosystem services and other benefits.

### Market value

More than 98% of the region's forestland is productive timberland, and Appalachian forests greatly contribute to the core of the nation's high-quality hardwood resource. These values were examined in the market value asset section of this report.

- Market value is based on two indicators—**wood value** and **wood product value**—which reflect observed market prices.
- Counties in North Carolina, Pennsylvania, Georgia, and northern West Virginia had some of the highest forest market values. These counties also had high values for both standing timber volume and wood product value in the forest quality category. This link means that market value follows some components of forest quantity, although this pattern usually depends on other factors as well.
- Counties in Ohio, western Alabama, and southern New York had some of the lowest market values, which reflects lower timber products output in Ohio and lower-density forests in western Alabama.
- High-valued counties also typically produce a greater volume of the high value wood products like veneer, while low-scoring counties typically produce low value products such as pulpwood.
- Notably, the distinction between the Ohio and West Virginia border is very sharp; Ohio's low-value counties are in stark contrast to West Virginia's high value counties, at least on the perimeter. This pattern could be attributed to the significantly higher volume of high-value products coming from fine hardwood species in West Virginia as compared to Ohio.

### Non-market value

Forests have tremendous value that is not reflected in market transactions for forest products like wood composites and veneer. These non-market values, such as cultural values and ecosystem services, are evaluated in the non-market value category.

- Non-market value was evaluated using four categories: **wildlife habitat, watershed services, recreation,** and **cultural**.
- West Virginia counties scored relatively high, compared with counties in other states. West Virginia is the third-most forested state in the country and the most forested in the Appalachian region. Thus, it is not surprising that West Virginia has a high non-market value, since two of the four components of the non-market value assessment category are directly driven by forest acreage
- Like the highest market values across the region, the highest non-market values also follow the forest quantity measurements, with a few exceptions. These results suggest that value can generally be derived directly from forest quantity, but other factors must also be considered in creating value from forests.

# 1. INTRODUCTION

## 1.1 About this study and report

This project was initiated as part of the long-term research objective developed by ARC to understand Appalachia's natural assets. The primary goal of this study is to provide information that will encourage the development and sustainable management of forest resources across the region, which requires developing an inventory of forest assets, analyzing their value and usage, assessing their potential contribution to economic development of the region, and creating a discussion to assist with planning their best use.

In a survey with over 130 forestry professional respondents, 84% believed that forests are important or very important to the surrounding area's economy.

*ARC Forest Asset stakeholders*

"In today's world of 'green' alternatives to all of the world's woes, trees are a renewable, biodegradable, all natural resource. We need to utilize them to our benefit."

*ARC Forest Asset stakeholder*

The project team was comprised of several organizations, including Downstream Strategies—an environmental consulting company from Morgantown, West Virginia—and West Virginia University (WVU). In addition, the National Network of Forest Practitioners' Appalachian Forest Resource Center was a major contributor to the research. Many experts in forest resources and economics were involved throughout this project, providing a well-rounded and representative team.

Often, merging science and policy can be a tremendous challenge. This study attempts to summarize forest resource data in a way that is understandable and relevant to policy makers. To enhance the study and its utility, a geographic information system (GIS) geodatabase was created that contains all of the underlying layers and analysis results. These data can be used in other research or in customized analyses or mapping projects. In addition to the geodatabase, a decision support system (DSS) was created to assist in understanding the results, both spatially and statistically. The DSS is a customized ArcMap GIS software tool that analyzes spatial patterns and creates an environment where the user can weigh various decisions that could support or inhibit economic development. The functionality of this tool and technical details are presented in Appendix D.

Other technical appendices include a discussion of carbon pricing and markets (Appendix A), an analysis of the feasibility of co-firing forest biomass in coal-fired power plants in the region (Appendix B), an assessment of the climate and biomass resource benefits of improved forest stand health (Appendix C), and the results of an Appalachian forest stakeholder survey completed by the Appalachian Forest Resource Center at the National Network of Forest Practitioners (Appendix E).

## 1.2 Implications for policy and research

This study assesses forest assets in the Appalachian region in order to facilitate forest management and planning strategies. It is not an all-encompassing analysis, but it does begin a conversation about forest resource management. There are many positive relationships between forest resources and economic development, including non-transactional or quality-of-life benefits.

Appalachia's economy is dependent on its natural resources, like timber, which are sold in domestic and international markets. In addition to providing for these transactional benefits—also known as the market value of the forests—Appalachia's forests provide a wealth of recreational opportunities and cultural importance to the region's residents and its visitors.

Understanding the relationship between the region's forest resources and its economic development can play many important roles. By clarifying the services that abundant, healthy forests provide, local and state policymakers can make informed decisions on resource use, development strategies, climate policy, and other important issues.

It is also important for private sector leaders to fully appreciate Appalachia's forest resources. When making decisions about locating new businesses, for example, leaders often consider several forest-related factors, including the business's proximity to recreational opportunities and raw materials like fuelwood, timber, or biomass.

This report, and the data that accompany it, can therefore be used by local and state leaders to inform their decisions on new policies related to forest quantity, quality, and access. It can be used by economic development officials to attract new businesses. And, it can be used by the private sector to inform business-location decisions.

## 1.3 How to use the report and data

This report describes the methods and data used to assess the ARC region forest resources. Throughout the document, boxes called "Putting the tool to work" are designed to help the reader identify relevant opportunities, challenges, and actions illuminated by the assessments.

Some of the data are combined or calculated in ways chosen by the research team. However, individuals, agencies, and organizations may want to examine the data without the prescribed calculations. The DSS allows users with access to ArcMap GIS software to apply their own priorities or criteria to the forest asset data, thus reexamining the counties according to locally important factors.

### Putting the tool to work report examples:

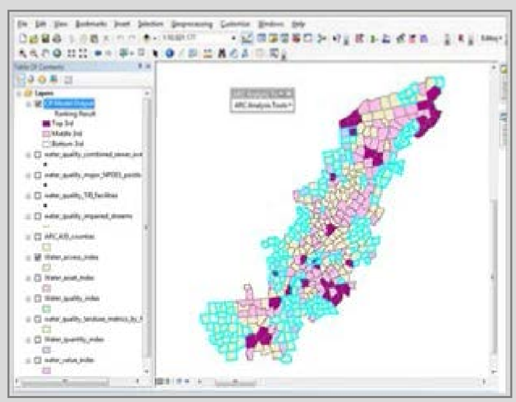
**Throughout the document, boxes called "Putting the tool to work" are designed to help the reader identify relevant opportunities, challenges, and actions illuminated by the indices.**

### Design your own maps using forest and economic data

Project GIS datasets can be downloaded from the Downstream Strategies Web site and used to make maps; examine results; navigate metrics, indicators, and indices; or create additional analyses.

To download data or the decision support tool, documentation, or the GIS-based DSS, contact the Appalachian Regional Commission.

### Create your own scenarios using the GIS Decision Support System



This project provides an interactive, GIS-based decision support tool (DSS) that allows users to prioritize areas for economic development opportunities. The DSS integrates spatial data, user input, and a ranking algorithm.

## 1.4 Data caveats

This study and report were developed to enable practitioners across the region to understand their forest resources and to better plan for the future. It examines many different datasets that vary spatially, temporally, and in their intended application. Despite the inherent difficulties in bringing together such a diverse set of data, this study is the most comprehensive attempt to-date that catalogs and summarizes forest resource data points across Appalachia.

Many types of forest datasets exist across the US; however, very few are consistent from region-to-region or state-to-state. The exception to this rule is the US Forest Service's (USFS's) FIA program. This program contains four key elements: 1) forest monitoring by remote sensing for stratification and field-based sampling of forest extent, cover, growth, mortality, removals, and overall health; 2) ownership questionnaire-based surveys; 3) timber product output questionnaire-based surveys; and 4) utilization studies for forest harvesting operations. The FIA program employs the following operational techniques to assure and improve the quality of data: planning, method documentation, training for data collectors, several checks for data quality, uncertainty analysis for survey data, peer-review of analysis products, and continuous feedback on data collection methods and processing. For more information on this data source, visit the national FIA Web site: http://www.fia.fs.fed.us.

Forest resources do not always follow political boundaries or adhere to easily manageable units, but based on the FIA dataset, we devised a systematic assessment method to examine regionally consistent and representative characteristics in order to understand Appalachia's forest resources. The FIA program is a national census with a standardized regional protocol. Data are updated annually. The primary advantage of the FIA program is the consistent data coverage it provides across states, but its shortcoming is the density of field sampling. Only one sample site for every 6,000 acres of forestland is monitored, and this can lead to high sampling errors in areas where forests are non-contiguous or comprised of forest stands with many different characteristics. This should be kept in mind when viewing the maps in this report. However, the resource specialists on this project maintain that the FIA program is the viable dataset—at the present time—for assessing forest resources across Appalachia.

Most data and results were derived from two sources: (1) the FIA database (Oswalt and Turner, 2009; Straka, 2007; USFS, 2010a); and (2) analysis of FIA Timber Product Output (TPO) data for state-level forest assessments compiled for the 2010 Resources Planning Act (RPA) assessment, which is part of the USFS Forest Inventory and Analysis program (Smith et al., 2009). States that have completed forest assessments and made them available online are listed in Table 2. Case study data for county-level forest residue biomass resources were derived from the National Renewable Energy Laboratory (Milbrandt, 2005), Oak Ridge National Laboratory (ORNL, 1999), and FIA databases. These data sources provide an estimate of necessary forest metrics for index development at the county scale, based on plot-level samples of forest resources. Therefore, the data carry a level of uncertainty or error associated with the estimation procedure. We recognize that no data source is perfect, but consider the sources used in the assessments to be the best available at present due to the FIA's consistency across ARC counties.

**Table 2: Appalachian state forest resource assessments**

| State | Agency | Web address |
|---|---|---|
| Alabama | Alabama Forestry Commission | http://216.226.177.78/PDFs/Forests_at_the_Crossroads-AL-State_Assesement.pdf |
| Georgia | Georgia Forestry Commission | http://www.gfc.state.ga.us/ForestManagement/documents/GAStateAssessment-6-17-10.pdf |
| Kentucky | Commonwealth of Kentucky | http://forestry.ky.gov/LandownerServices/Pages/ForestlandAssessment.aspx |
| Maryland | Maryland Department of Natural Resources Forest Service | http://www.dnr.state.md.us/forests/sas.asp |
| Mississippi | Mississippi Forestry Commission | http://www.mfc.ms.gov/assessment-strategy.php |
| New York | New York State Department of Environmental Conservation | http://www.dec.ny.gov/lands/60829.html |
| North Carolina | North Carolina Division of Forest Resources | http://www.ncforestassessment.com |
| Ohio | Ohio Department of Natural Resources, Division of Forestry | http://ohiodnr.com/tabid/22319/Default.aspx |
| Pennsylvania | Pennsylvania Department of Conservation and Natural Resources | http://www.dcnr.state.pa.us/forestry/farmbill/index.html |
| South Carolina | South Carolina Forestry Commission | http://www.state.sc.us/forest/scfra.htm |
| Tennessee | Tennessee Department of Agriculture, Division of Forestry | http://www.state.tn.us/agriculture/forestry/sustainability.html |
| Virginia | Virginia Department of Forestry | http://www.dof.virginia.gov/info/resources/2010-State-Assessment_( 15_reduced.pdf |
| West Virginia | West Virginia Division of Forestry | http://www.wvforestry.com/events_12022K1.cfm |

## 1.5 Background

The Appalachian region consists of approximately 205,000 square miles (131 million acres), covering 420 counties in 13 states (Figure 1). It extends more than 1,000 miles from southwestern New York to northeastern Mississippi and is home to 24.8 million people (ARC, 2009a).

Many cities and rural communities within and around the region are dependent upon the wise use, management, and development of Appalachia's forests. A downsizing of critical Appalachian industries has led to a decline in traditional agricultural and mining jobs in many rural areas, leading to a large population migration to urban areas over the past 50 years. According to Freudenberg (1992), employment in traditional farming has dropped about 70 percent from the early 1900s and employment in other natural resource–dependent industries, such as mining and forestry, has been cut in half.

However, these macro-level economic and social trends are not uniform across all rural areas; the major factors affecting migration patterns across the rural landscape have changed substantially over the last few decades (Nord and Cromartie, 1997). Those places rich in natural assets are more likely to experience substantial population growth than are areas with fewer natural assets. For instance, Johnson and Beale (2002), in a national study of rural counties, report a significant population rebound during the 1990s, with "recreation counties"—those with high tourism receipts and business activity—leading the way with a 20.2 percent population increase compared to a 10.4 percent increase for all rural counties. The economic and population growth patterns in Appalachia also reflect this reality (ARC, 2009a).

Natural assets are not only linked to population growth, but also to economic restructuring and economic well-being (Johnson and Beale, 2002; Shumway and Otterstrom, 2001). For example, Shumway and Otterstrom (2001) report that counties rich in natural amenities experienced dramatic increases in employment in service sectors such as health care, personal services, recreation and entertainment, and professional services.

Local or regional economic growth is dependent upon natural, social, economic, and political factors. Each factor's contribution to economic growth may vary by county or region. This poses a challenge to researchers: to determine the relative importance of each factor at the county or regional level.

## 1.6 Literature review

The chosen methods, framework, data, and empirical approach used in this report are based on an extensive literature review. The following section highlights regional studies on forest resources as well as methods used in other types of natural asset assessment.

The economic value of forests has been recognized in many market-based forms. For example, trees and woody biomass are extracted for wood products like sawlogs, veneer logs, and pulpwood. Bioenergy production via combustion, co-generation, and combined heat and power also has value in markets. In addition, terrestrial carbon storage, to a limited extent, has a market value.

Forests also have non-market values by providing recreation opportunities, wildlife habitat, and other ecosystems services. Forest-related economic activity plays an essential role in economic development and growth, both locally and regionally.

Forests are the dominant resource on the Appalachian landscape, covering 86 million acres or 65percent of the region and have been increasing, as agricultural lands revert back to forestland (USFS, 2010a). More than 98percent of the region's forestland is considered to be a productive timberland resource (USFS, 2010a).

Because of their importance, forests have been extensively studied in the literature. An exhaustive review of literature on forest resources is beyond the scope of this study; however, selected studies on natural assets including forests are reviewed. When necessary, additional studies on forest quantity, quality, and value are reviewed within their respective sections.

"Forests are a critical natural resource that shaped the Region's history and influenced its culture. Nearly all of the Region's forestland experienced intensive timber harvesting and deforestation during the late 1800s and early 1900s. These resilient forests today cover 86 million acres, providing wildlife habitat and recreation, protecting the Region's waters, and supporting an extensive wood products industry."

*Appalachian Regional Development Initiative Report: Economic Assessment of Appalachia (2010)*

"Trees play an important role in the world's carbon cycle. They act as a sink for carbon, removing it from the atmosphere in terms of $CO_2$ and storing it as cellulose. In this role, forests help mitigate the effect of burning fossil fuels and the resulting global climate change associated with increased levels of $CO_2$ in the atmosphere."

*Forests of the Mountain State (Widmann et al., 2007)*

An assessment of Appalachian forest resources was recently completed by Widmann et al. (unpublished) for ARC. Highlights of this report include:

- Forests are the dominant resource on the landscape of the Appalachian region.
- Appalachian forests contribute to the core of the nation's quality hardwood resource.
- Private landowners own 82percent of the forestland in the region.
- Management of private forests is the key to a sustainable resource in the Appalachian region.
- Forest productivity can be increased by better management of private land.
- The output of timber products is strong and dominated by hardwood products, but is declining in the face of international competition and economic uncertainty.
- Opportunities exist to increase product output with woody biomass utilization while maintaining the health and productivity of the region's forests.
- Non-timber products provide emerging opportunities for sustainable harvest of traditional products.
- Forests provide benefits and services to everyone, even when economic returns are indirect or difficult to quantify.

An economic assessment of Appalachia was recently completed by the Appalachian Regional Development Initiative (2010), which provides an excellent review of economic factors in the region, including forest assets. The main findings from this assessment, directly applicable to forest assets, are:

- Forests in the region provide many benefits, including wildlife habitat, recreation opportunities, and water protection; forests also support an extensive wood products industry.
- The physical characteristics of the region result in diverse and productive forest ecosystems, containing approximately 100 species of hardwood trees and 25 species of softwood trees.
- Many species of trees are essential to the hardwood lumber industry, with the Allegheny Plateau of Pennsylvania and New York containing two-thirds of the nation's black cherry timber volume.
- The region's forests are maturing, with 62percent of stands dominated by large diameter trees.
- Oak, a favorable species, is lagging behind maple in terms of regeneration.
- Woody biomass is poised to be utilized for co-firing with traditional coal-fired energy generation.
- The region produces 13percent of the nation's total TPO volume.
- Recreational, forest-based tourism is important to the region, with many rural areas attracting visitors from larger metropolitan areas who enjoy the outdoors.

Several other studies focus on land-use and economic growth in Appalachia; these studies also present key information on the region's forest assets. One comprehensive study—Southern Appalachian Man and the Biosphere Cooperative (1996)—examines the ecological conditions (i.e., atmospheric, aquatic, and terrestrial) and social, economic, and cultural status in several regions that include: northern Virginia, eastern West Virginia, northwestern South Carolina, northern Georgia, and northern Alabama. The assessment was accomplished through the cooperation of federal and state natural resource agencies within the region.

In terms of the social, economic, and cultural value in the region, this study examined four aspects: (1) communities and human influences, (2) the timber economy, (3) outdoor recreation supply and demand, and (4) roadless and designated wilderness areas. To address changes in population and housing in the region, census data from 1970, 1980, and 1990-91 were analyzed. Other data sources included the Census of Agriculture for the last three decades and US Department of Agriculture (USDA) Economic Research Service data. Maps displayed averages for the counties in the study area as compared to averages for the seven states in which the southern Appalachian counties reside. In addition, surveys were conducted among organizations and residents to understand their attitudes toward natural resources and the environment.

Another study examines land ownership patterns and its impact on the Appalachian community based on a survey of 80 counties (Appalachian Land Ownership Task Force, 1981). The study found that only a few owners control most of the land and minerals in Appalachia: more than half (53 percent) of the total surface area was owned by corporations and government, absentee landowners, and very few of the local population. Of this group, absentee landowners owned the most (75 percent), followed by corporations and government (27percent) and members of the local population (1percent). Almost 40 percent of the land in the sample, and 70percent of the mineral rights, were held by corporations. Additionally, the federal government was the single largest landowner, controlling more than 2 million acres at the time.. Indices were developed to illustrate the concentration of ownership of mineral and surface acres. These patterns of concentration have ripple effects on economic development and the wellbeing of the region.

## 1.7 Stakeholder involvement

We solicited information and feedback from a variety of stakeholders in an effort to coordinate with outside institutions, as well as to ensure our project focus and efforts are aligned with regional objectives and goals. Project staff from the National Network of Forest Practitioners coordinated the stakeholder involvement through an online survey with closed- and open-ended questions, refer to Appendix E for detailed responses.

The survey was sent to 697 recipients across the Appalachian region, including local development districts, conservation districts, resource conservation and development districts, private foresters, federal and state land managers, and the Natural Resources Conservation Service (NRCS). Of those surveyed, 141 participated, yielding a 20 percent response rate. The largest numbers of respondents were from local development districts, conservation districts, conservation organizations, NRCS, and resource conservation and development districts.

In reality, respondents often self-identified with multiple roles such as NRCS staff and hunter/outdoorsman or soil and water conservation district supervisor and logger. Several self-identified as forest landowners. Responses were shared with the project team during various phases of the project to direct and ground the project.

### Comments from survey respondents

*"We have more pressure from housing growth destroying forest areas than from other sources."*

☼ ☼ ☼

*"It seems difficult to get private forest landowners to understand the importance of developing a forest management plan and using sound practices in forest harvest operations to ensure sustainable forest management."*

☼ ☼ ☼

*"In today's world of 'green' alternatives to all of the world's woes, trees are a renewable, biodegradable, all natural resource. We need to utilize them to our benefit."*

☼ ☼ ☼

*"It [increased biomass use] could very well destroy them! Forests are more than wood products. Woodland plants, wildlife, water quality, recreation and aesthetics are but a few examples."*

Highlights from the closed-ended questions include:

- Just over half (53 percent) of respondents felt that forests were poorly managed or very poorly managed.
- Just under half (49 percent) of respondents felt that woody biomass for energy would have a positive or very positive impact on their area's forests.
- Respondents were divided on forest health: 43 percent felt forests were healthy, 36 percent felt they were neither healthy nor unhealthy, and 20 percent felt they were unhealthy.
- At the same time, respondents were significantly concerned about the impacts of insects and disease: 99 percent felt that these issues were somewhat or very threatening to forests.
- The only other issue that received a similar response was invasive plants: 95 percent of respondents felt that invasive plants were somewhat or very threatening to forests in their area.
- 70 percent of respondents felt that over-harvest of timber was somewhat or very threatening. Yet, according to the FIA data, there is substantially more timber growing than is harvested, so this perception may be at odds with the scientific data. With the current decline in harvest due to market depression, it is likely that the issue of over-harvest is more one of perception than fact in most places.

Highlights from the open-ended questions include:

- When asked about biomass, 27 percent of respondents specifically mentioned the importance of forest management plans and sustainable harvesting practices, and 31 percent of respondents highlighted the potential economic benefits.
- When asked about opportunities for forest in their area, 37 percent of respondents mentioned the importance of forest management plans.
- Respondents added numerous responses in the "Other" category, including loss of high value markets, impacts of strip mining, oil and gas leasing, lack of forest management plans, loss of species diversity, acid rain, and inadequate removal of logging roads. Problems with regeneration and deer browsing pressure were also mentioned by multiple respondents.

# 2. FOREST QUANTITY

Forest quantity can mean many different things: trees available for wood fiber production or acres available for other ecosystem services and recreation, for example. Much of the region's forestland was harvested for timber during the early twentieth century. Today, forests represent 65 percent of the land base and harvesting continues to support a forest products industry that provides raw materials and an assortment of wood products to both domestic and international markets.

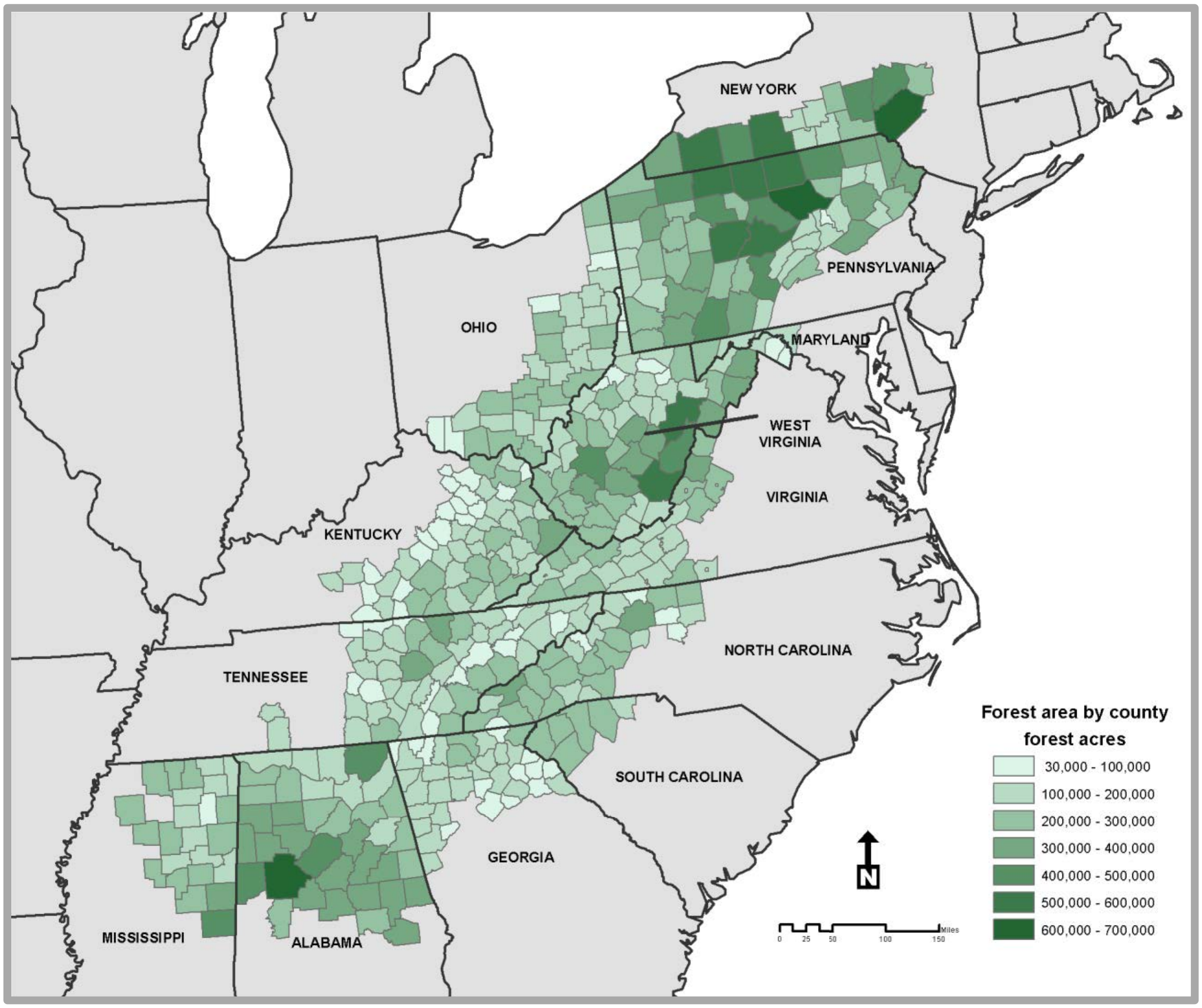



**Figure 2: Forest area by county (acres)**

Based on the FIA data, Forest area, shown in Figure 2, is a simple measure or a "windshield" perspective of forest quantity in a county. Measurements of forest quantity can fluctuate annually, decreasing with the utilization of trees for wood fiber and growth-related mortality, and increasing with tree growth. Furthermore, large alterations in land-use patterns can result in substantial impacts on forest quantity, with afforestation (or reforestation) and deforestation positively and negatively affecting the forest asset, respectively. This chapter presents an assessment of forest quantity across the Appalachian region.

## 2.1 Components and framework

Publicly available data were analyzed to produce five indicators of forest quantity across the Appalachian region. For each indicator, Table 3 lists the metrics used, unit of measurement, and the data source. To understand these data at the county level, each forest quantity indicator—with the exception of percent of county forested—is divided by the forest area of the county. This step allows for better comparisons of forest resources from county to county, ensuring that the size of the county does not weight the results.

1. **Standing timber volume:** Measures the live tree volume in each county suitable for use for traditional forest products, relative to the area of forestland within a county.
2. **Woody biomass volume:** Measures the standing forest resource potentially available for use as forest biomass, relative to the total forest area within a county, whether it is for energy generation or other uses.
3. **Wood product volume:** Measures the production of the forest products industry within a county in terms of raw or primary material output. This indicator is not directly associated with the standing forest.
4. **Forest carbon mass:** Presents the amount of carbon stored in forests, both above- and belowground, relative to the total forest area within a county.
5. **Percent of county forested:** Presents the forested acres divided by total acres in a county, resulting in a ratio of forest area to county area and displayed as a percentage.

**Table 3: Forest quantity assessment components**

| Indicator | Metric | Denominator | Unit of measurement | Data source and date |
|---|---|---|---|---|
| Standing timber volume | • Volume of growing stock trees | Forest acres | Cubic feet of wood | Forest Inventory Analysis, 2009, 2010 |
| Woody biomass volume | • Aboveground live biomass in trees<br>• Aboveground dead biomass in trees | Forest acres | Volume in dry tons | Forest Inventory Analysis, 2009, 2010 |
| Wood product volume | • Sawlog volume<br>• Veneer volume<br>• Composite materials volume<br>• Post, poles, and pilings volume<br>• Fuelwood volume<br>• Pulpwood volume | Forest acres | Cubic feet of wood | Forest Inventory Analysis, 2009, 2010<br><br>Timber Product Output, 2007 |
| Forest carbon mass | • Aboveground live tree carbon<br>• Aboveground understory carbon<br>• Standing dead tree carbon<br>• Downed woody debris carbon<br>• Litter carbon<br>• Soil carbon | Forest acres | Volume in dry tons | Forest Inventory Analysis, 2009, 2010 |
| Percent of county forested | • Acres of forestland | County acres | Acres of forest per county | Forest Inventory Analysis, 2009, 2010 |

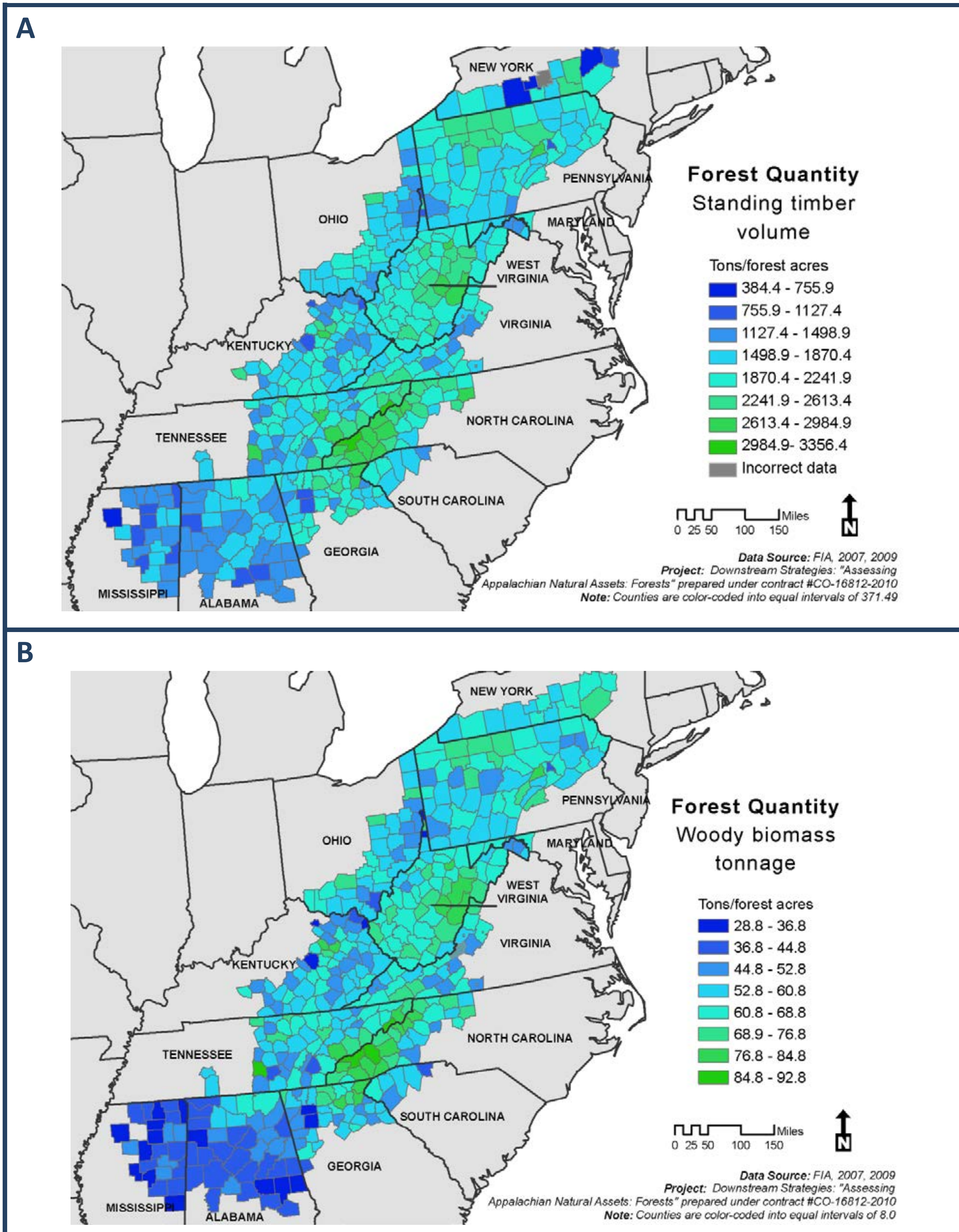



Figure 3: (A) Standing timber volume and (B) woody biomass tonnage

### 2.1.1 *Standing timber volume*

Timber volume is a measure of the amount of growing stock trees[1] in a county. This metric is reported in cubic feet per county and it is the only metric used in the standing timber volume indicator. Standing timber volume is a measure of growing stock trees relative to the forested area of the county.

Panel A in Figure 3 shows the standing timber volume in cubic feet per forested acre for Appalachian counties. Generally, there are higher standing timber volumes towards the more mountainous central Appalachians, while forested areas in southwestern counties (Mississippi and Alabama) show lower volumes per acre. Counties in western North Carolina, West Virginia, eastern Tennessee, and northwestern Pennsylvania generally show the highest standing timber volumes per forested acre. This suggests that the southwestern Appalachian forests have less timber volume than the rest of the region, per forested acre.

Many forests in the southwestern counties are composed of smaller trees compared to counties in the more mountainous areas, and even though the number of trees may be similar, smaller trees result in lower overall volumes of sawtimber. While the trend of lower standing timber volume could be due to greater harvesting intensity in the southwestern and other low-scoring counties, it could also be due to differences in forest type and species composition (e.g., hardwood trees vs. softwood trees) where drier climates create slower-growing and less dense structures due to limitations in growth resources.

**Equation 1: Standing timber volume**

$$\textit{Standing timber volume}_{county\text{"}i\text{"}} = \textit{volume of growing stock trees}_i \,/\, \textit{forest area}_i$$

Overall, the Appalachian forests appear to be relatively well stocked, with only eight counties within the region showing standing timber volumes below 990 cubic feet of wood per forested acre. Tompkins County, New York was removed from the analysis due to irregular data, which showed a standing timber volume that well exceeded the range of the rest of the Appalachian region.

### 2.1.2 *Woody biomass volume*

Woody biomass volume includes aboveground biomass in both dead and live trees and provides a measure of forest biomass that could be used as a resource for traditional forest products or for non-traditional uses such as energy production (Equation 2). Panel B in Figure 3 shows the woody biomass volume for Appalachian counties in tons per forested acre. Generally, there is a higher density of woody biomass volume towards the central Appalachians, with forested areas in southwestern counties (Mississippi and Alabama) showing the lowest relative density of woody biomass volume.

**Equation 2: Woody biomass volume**

$$\textit{Woody biomass volume}_{county\text{"}i\text{"}} = (\textit{aboveground live biomass}_i + \textit{aboveground dead biomass}_i) \,/\, \textit{forest area}_i$$

[1] A growing stock tree is "a live tree of commercial species that meets specified standards of size, quality, and merchantability. [It] excludes rough, rotten and dead trees" (Wisconsin Department of Natural Resources, 2011).

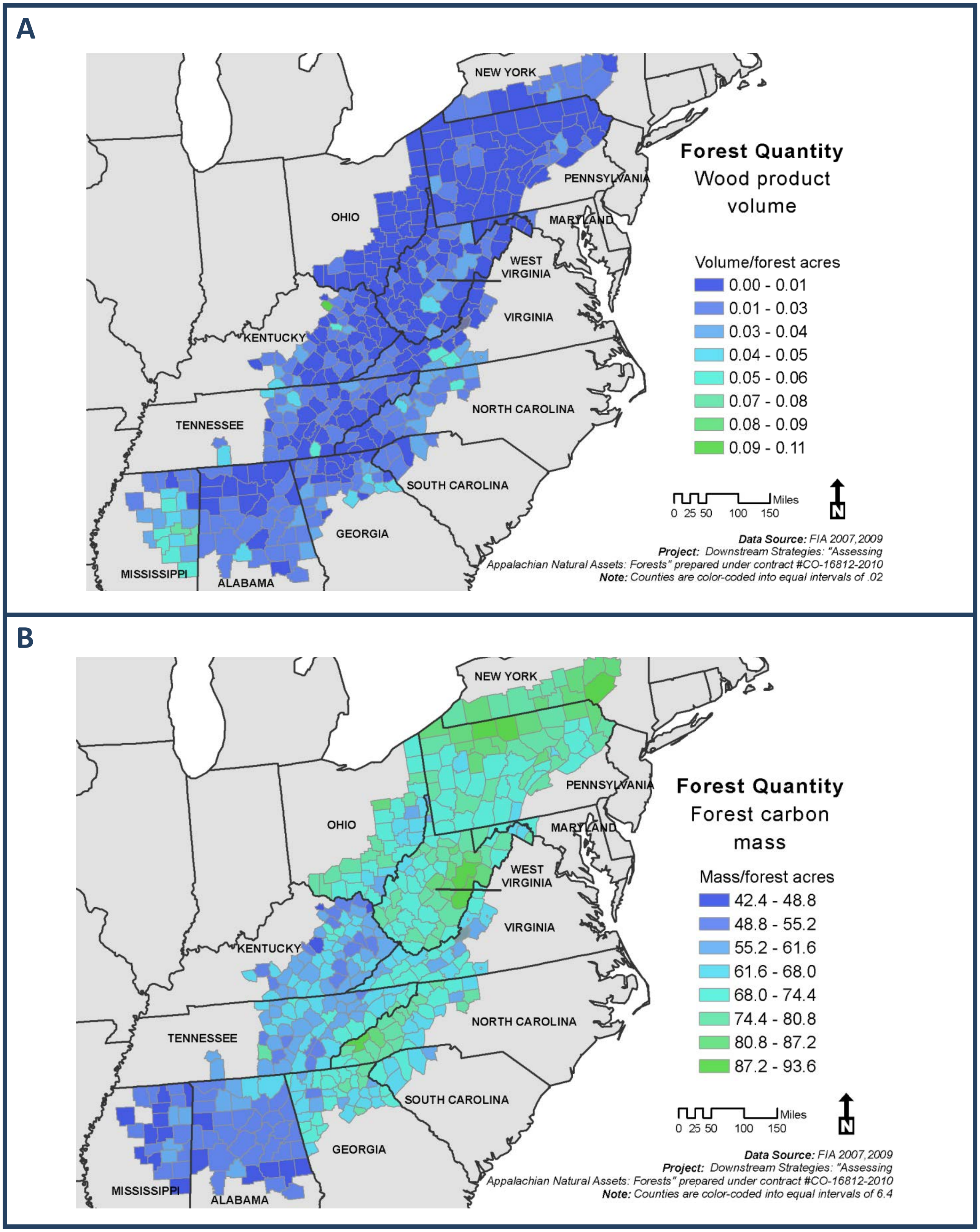



Figure 4: (A) Wood product volume and (B) forest carbon mass

Trends in woody biomass volume are due to forest type, forest age, and forest structure. The woody biomass volume in Mississippi and Alabama forests may be low relative to the rest of the region because of the dominance of the timber industry and plantation forestry in this area. Naturally-occurring forest types of the central hardwood portion of the region contain species that are most valuable when they are large enough to meet sawlog or veneer log specifications, whereas many of the trees in the plantation forests of the southwestern counties are valuable enough when they meet specifications for pulpwood chips or dimension lumber (both are smaller than specifications for hardwood sawlog and veneer).

Similarly, the forests in Mississippi and Alabama may be densely populated with individual trees that are relatively small compared to trees in the central hardwood area of the Appalachian region. Even though there may be a similar or even greater number of trees in Mississippi and Alabama as compared with the central hardwood area, smaller trees will result in a lower overall woody biomass volume. In other words, low-density forests with large trees can easily surpass high-density forests with small trees in terms of woody biomass volume.

Counties in western North Carolina, West Virginia, eastern Tennessee, and northwestern Pennsylvania generally show the highest values. The southwestern Appalachian forests have less woody biomass volume than the rest of the region, per forested acre, which is similar to the trend seen for standing timber. This suggests a greater harvesting intensity and differences in forest types within the southwestern and other low-scoring counties compared to those counties with the highest woody biomass volume per forested acre. Interestingly, the northeastern counties of New York, which show low standing timber volumes, exhibit higher scores in woody biomass volume. This may be due to a greater density of dead trees and downed woody debris from natural disturbance events.

The use of woody biomass as a form of renewable energy has become increasingly popular in the last decade, and the most important part of siting a biomass energy facility is whether a steady and reliable supply of woody biomass can be procured. Example 1 on page 19 (“Degraded forest stands and carbon”) and Example 2 on page 20 (“Forest harvesting residues in co-firing”) showcase the capabilities of the DSS that is a companion to this report. While Example 2 does not specifically show potential biomass energy facility sites, it does provide insight into which counties have the most potential for both “extra” woody biomass supply and current harvesting residues (also a potential source of woody biomass supply).

### 2.1.3 *Wood product volume*

Wood product volume is derived from TPO data, which are sourced from the FIA database and the RPA Assessment (Smith et al., 2009). This indicator is composed of the volume of roundwood products, including fuelwood. Volume harvested for roundwood products includes sawlogs, veneer logs, and pulpwood from both industrial and nonindustrial settings. Sawlogs are usually destined for sawn products such as lumber, whereas pulpwood is usually destined for paper production and other wood fiber uses. Veneer logs are high quality sawlogs destined for use as wood veneer. Fuelwood includes roundwood logs and chips used as fuel in industrial, residential, or institutional situations. Composite products, like oriented strand board and engineered lumber, are also included, as well as post, piling, and pole production.

Panel A in Figure 4 shows the wood product volumes in cubic feet per forested acre for Appalachian counties. Generally, a few Appalachian counties have high wood product volumes relative to the rest of the region. In contrast to standing timber volume and woody biomass volume, some southwestern counties in Mississippi and Alabama exhibit higher wood product volumes compared to the rest of the region, further suggesting that the lower scores for in-forest timber and biomass volumes could be due to increased harvesting intensity in those counties.

**Equation 3: Wood product volume**

$$\textit{Wood product volume}_{county"i"} = (\textit{sawlog volume}_i + \textit{composites volume}_i + \textit{veneer volume}_i + \textit{post-piling-pole volume}_i + \textit{fuelwood volume}_i + \textit{pulpwood volume}_i) \,/\, \textit{forest area}_i$$

The relatively low scores for wood product volume throughout the central and northern Appalachian region contrast with the relatively higher volumes of standing timber and woody biomass, suggesting that there could be opportunities for forest products industry growth in these areas. However, many counties within the region only reported timber product output volumes for some of the TPO data classes. Many counties could therefore have a greater product output than suggested by the wood product volumes shown in Panel A of Figure 4. The data for wood products shows a strong trend towards low volumes, which suggests that a disproportionately large percentage of wood product production comes from relatively few counties within the Appalachian region.

### 2.1.4 *Forest carbon mass*

Forests store carbon terrestrially and emit carbon to the atmosphere in the forest carbon cycle. Forest carbon stocks increase as trees grow and accumulate carbon in woody tissue, and stocks decrease when trees are removed from the forest through harvesting, as well as when trees die and decay or burn during wildfires. Some aboveground forest carbon is transferred belowground during decomposition and can eventually become part of the forest soil. Belowground carbon levels fluctuate much slower than aboveground carbon levels; therefore, aboveground activities such as harvesting, insects, disease, fire, and weather can significantly impact forest carbon stocks.

Over the past several decades, interest has grown in forest carbon, due in large part to the emerging evidence surrounding climate change. Carbon markets, where they exist, place economic value on “additional” carbon stored in tracts of forest. These markets are a new consideration in forest landowner decision-making.

Carbon calculations are based on the biomass equations developed by Jenkins et al. (2003), but are adjusted by a factor of 0.5 to account for the dry mass of carbon contained in wood (approximately 50 percent of dry mass). Live tree carbon consists of aboveground tree carbon and root carbon. Total forest carbon consists of carbon found in live trees, standing dead trees, down dead coarse woody debris, leaf litter, soil, and smaller vegetation (seedlings, shrubs, and bushes). This method allows for the breakout of live trees for comparison to total forest carbon, which is beneficial due to the propensity for live-tree management. This indicator is a sum of these metrics and is reported in tons of carbon per forested acre.

Panel B in Figure 4 shows the total forest carbon mass for Appalachian counties. Southwestern Appalachian counties generally have lower carbon mass than northeastern counties. This could be due, in part, to a greater harvesting intensity in the southwestern counties and shorter-rotation plantation forestry management activities. Differences in forest types also persist as drier forests and lower densities contribute less carbon mass in the southwestern counties, compared to wetter conditions in the central and northeastern counties.

Another factor to consider here is ownership: Non-industrial private landowners dominate the Appalachian region as a whole, while industrial forestry is more common in the southwestern counties.

Panel B in Figure 4 also shows contrasts in carbon mass between West Virginia and Kentucky counties, with Kentucky counties showing lower mass than West Virginia. This trend continues south through Tennessee and further into Alabama and Mississippi. While the lower carbon mass in Alabama and Mississippi can be partially explained by harvest intensity and plantation forestry, the difference in carbon mass in Kentucky and Tennessee is due mostly to fewer changes in forest types and a drier climate, which contributes to fewer down and dead trees, less forest litter depth, and lower amounts of soil carbon compared to forested areas in West Virginia, North Carolina, and Ohio.

**Equation 4: Forest carbon mass**

$$Carbon_{county"x"} = (\text{aboveground live tree } C_x + \text{aboveground understory } C_x + \text{standing dead tree } C_x + \text{down woody debris } C_x + \text{litter } C_x + \text{soil } C_x + \text{root } C_x + \text{belowground understory } C_x) / \text{forest area}_x$$

The shift towards valuing carbon may incentivize a change in management activity in forests that show low forest carbon mass, but in order to store “additional” carbon, changes in management activity may be required in all counties. The challenge for increasing carbon stocks in Appalachian forests is developing management strategies that utilize the forest resource for both carbon and economic value, while maintaining healthy and resilient working forests.

### 2.1.5 *Percent of county forested*

Forest area is a simple measure of the quantity of forestland relative to the total land area in the county. The area of a forest resource is important for all forest values, including recreation and other ecosystem measures such as wildlife habitat and watershed services. In simple terms, the higher the forest area score, the greater potential benefit to a county.

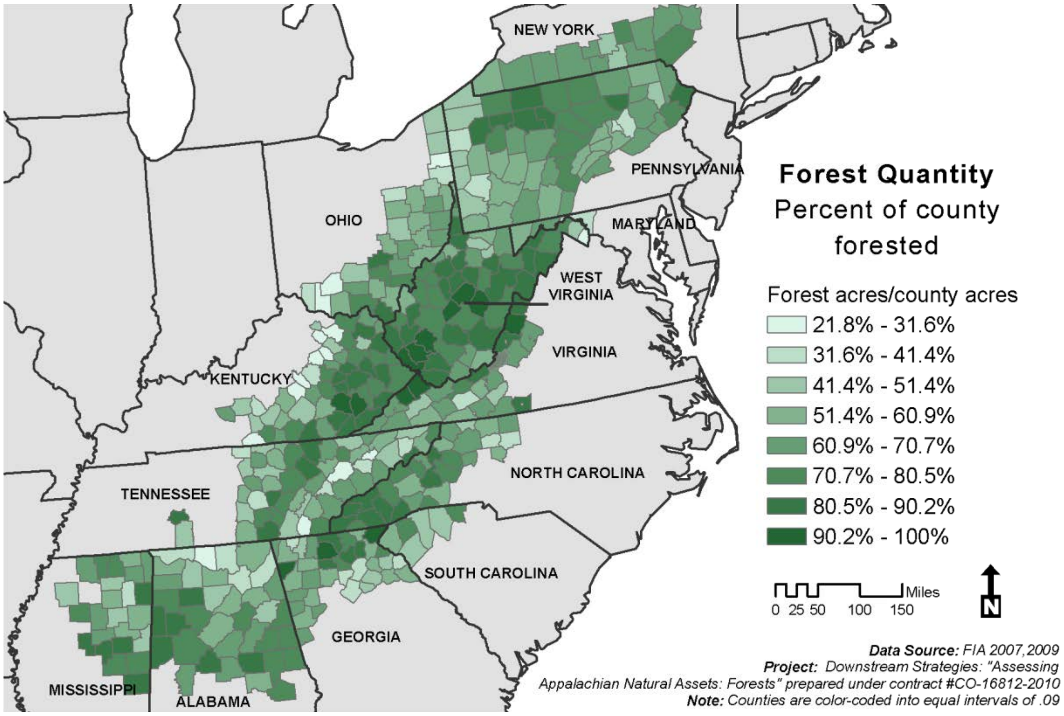
Panel A in Figure 5 on the following page shows the percent forest for Appalachian counties. A large cluster of highly forested counties are found across West Virginia and eastern Kentucky. A greater portion of these central Appalachian counties are forested compared with counties in the surrounding states of Ohio, Pennsylvania, Maryland, Virginia, and Tennessee. New York exhibits almost entirely low scores, as does South Carolina. The southwestern states of Mississippi, Alabama, and Georgia show a mix of high and low percentages, but overall these states trend towards lower percentages. The western counties of North Carolina show more relative forest area than eastern counties, and although Pennsylvania exhibits lower percentages overall compared to its southern neighbor, West Virginia, it does show a cluster of high-percentage counties in the northern part of the state.

## 2.2 Discussion

In terms of quantity, Appalachian forests are generally in good condition. Standing timber volume and woody biomass tonnage are many times higher in counties near national forests and other public lands. For example, both standing timber volume and woody biomass tonnage are high in counties that contain the Monongahela, George Washington, and Jefferson National Forests in West Virginia and Virginia, as well as in the Pisgah, Cherokee, Nantahala, and Chattahoochee National Forests in Tennessee, North Carolina, and Georgia. To the north, Pennsylvania shows similar trends, with higher standing timber and woody biomass volumes in counties containing the Allegheny National Forest and the Elk, Moshannon, and Susquehannock State Forests. New York continues the trend in counties containing Allegheny State Park and Catskill Park.

Lower levels of standing timber volume and woody biomass tonnage are found in the southwesternmost counties of Alabama and Mississippi, but that is to be expected given the differences in forest type and climate.

A

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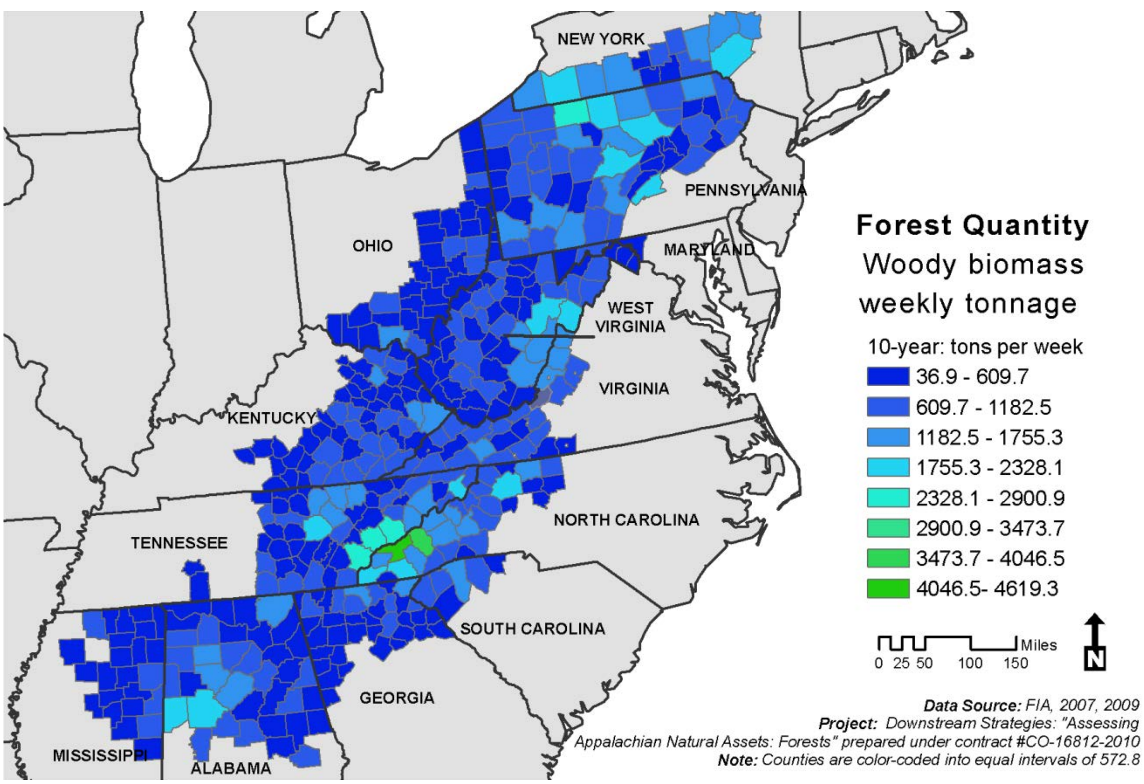



**Figure 5: (A) Forest area by county area and (B) woody biomass supply over a 10-year timeline**

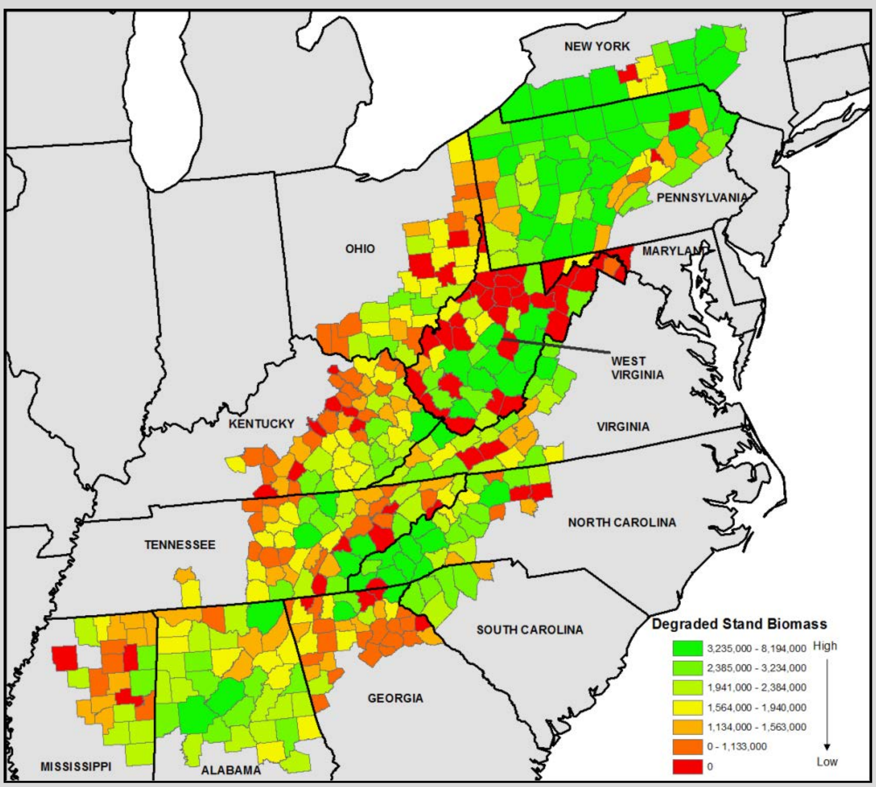
Appalachian counties generally have low wood product output, which is to be expected given the nature of wood processing and wood product manufacturing. Woody material is generally sourced from surrounding counties to supply the demand for processing facilities. The southwestern counties of the region show greater wood product output, and this is due to the more intensive forestry practices in the area and the type of wood products being produced, such as dimension lumber and plywood. Most of the Appalachian region does not support plantation forestry as well as the southwestern states. Non-plantation forests are more likely to have longer rotations and partial harvests to produce larger logs for fine hardwood lumber and veneer.

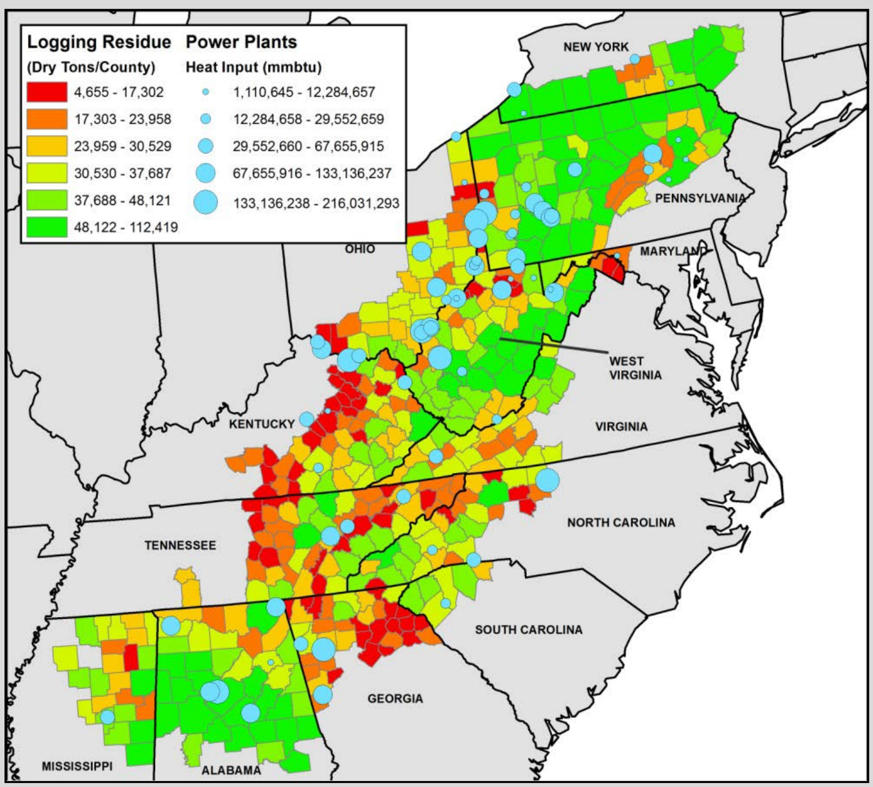
The forestry practices employed by the southwestern Appalachian counties compared to the rest of the region also have some influence on forest carbon. The smaller trees and shorter rotations in the southwestern counties can lead to less carbon mass, while larger trees and longer rotations store more carbon over time. However, other important factors in forest carbon storage include forest type and climate. The general trend of the Appalachian region is decreasing carbon from the northeast to the southwest.

The forests of Appalachia are plentiful; however, counties vary based on the amount of forested land and the level of industry and infrastructure. In terms of standing timber volume, woody biomass volume, and forest carbon mass, the Appalachian region is doing very well. The standout indicator related to quantity is the amount of wood product volume produced by each county in the region. Clearly, the forest resource could allow for more wood product production, but the economics of doing so require innovation to be competitive in the current market.

### 2.2.1 *Supply for a biomass energy facility*

Dead standing biomass (dead tree) volume in tons was used to determine a maximum potential weekly biomass supply over a 10-year timeline (see Panel B in Figure 5). Ten years is most likely the minimum supply agreement for a potential biomass energy facility, with 15 to 20-year supply being more attractive. This is a very simple analysis that assumes all dead standing biomass is available for use. A more detailed analysis of a potential supply area would have to include ownership and accessibility and would need to consider post-harvest woody biomass retention guidelines. However, this analysis does outline potential multi-county areas that may be more suitable for a biomass energy facility, if standing dead trees could be salvaged as a biomass supply resource. As shown in Panel B in Figure 5 areas in southwestern Alabama, eastern Tennessee, western North Carolina, eastern West Virginia, and north-central Pennsylvania have the most standing dead tree biomass. Large volumes of standing dead trees could be a sign of recent disturbance or a forest with its health in decline, which may also mean the forest is in need of some active management activity.


NEW YORK
PENNSYLVANIA
OHIO
MARYLAND
WEST
VIRGINIA
KENTUCKY
VIRGINIA
NORTH CAROLINA
TENNESSEE
SOUTH CAROLINA
GEORGIA
MISSISSIPPI
ALABAMA
Degraded Stand Biomass
3,235,000 - 8,194,000
2,385,000 - 3,234,000
1,941,000 - 2,384,000
1,564,000 - 1,940,000
1,134,000 - 1,563,000
0 - 1,133,000
0
High
Low


Logging Residue
(Dry Tons/County)
4,655 - 17,302
17,303 - 23,958
23,959 - 30,529
30,530 - 37,687
37,688 - 48,121
48,122 - 112,419
Power Plants
Heat Input (mmbtu)
1,110,645 - 12,284,657
12,284,658 - 29,552,659
29,552,660 - 67,655,915
67,655,916 - 133,136,237
133,136,238 - 216,031,293
NEW YORK
PENNSYLVANIA
OHIO
MARYLAND
WEST VIRGINIA
VIRGINIA
KENTUCKY
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TENNESSEE
SOUTH CAROLINA
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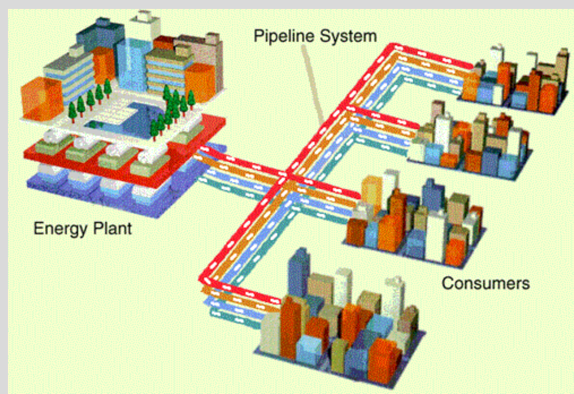
Pipeline System
Energy Plant
Consumers

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# 3. FOREST QUALITY

## 3.1 Introduction

The quality of a forest impacts its market value because higher-quality forests can produce higher-value wood fiber and solid wood products. Similarly, higher-quality forests can produce higher non-market values for recreation or other ecosystem services.

The market value of timber is impacted by tree grade, species, and available volume, which in turn can be affected by site productivity, disturbance events, and forest condition. The aesthetic quality of a forest can be a major factor in the non-market value placed on a recreation experience, while a healthy forest ecosystem promotes the value of common-good services such as water transport and flood mitigation, wildlife habitat, and photosynthesis. This chapter provides a comprehensive regional assessment of forest quality and a framework to assess how forest quality factors into economic conditions and development.

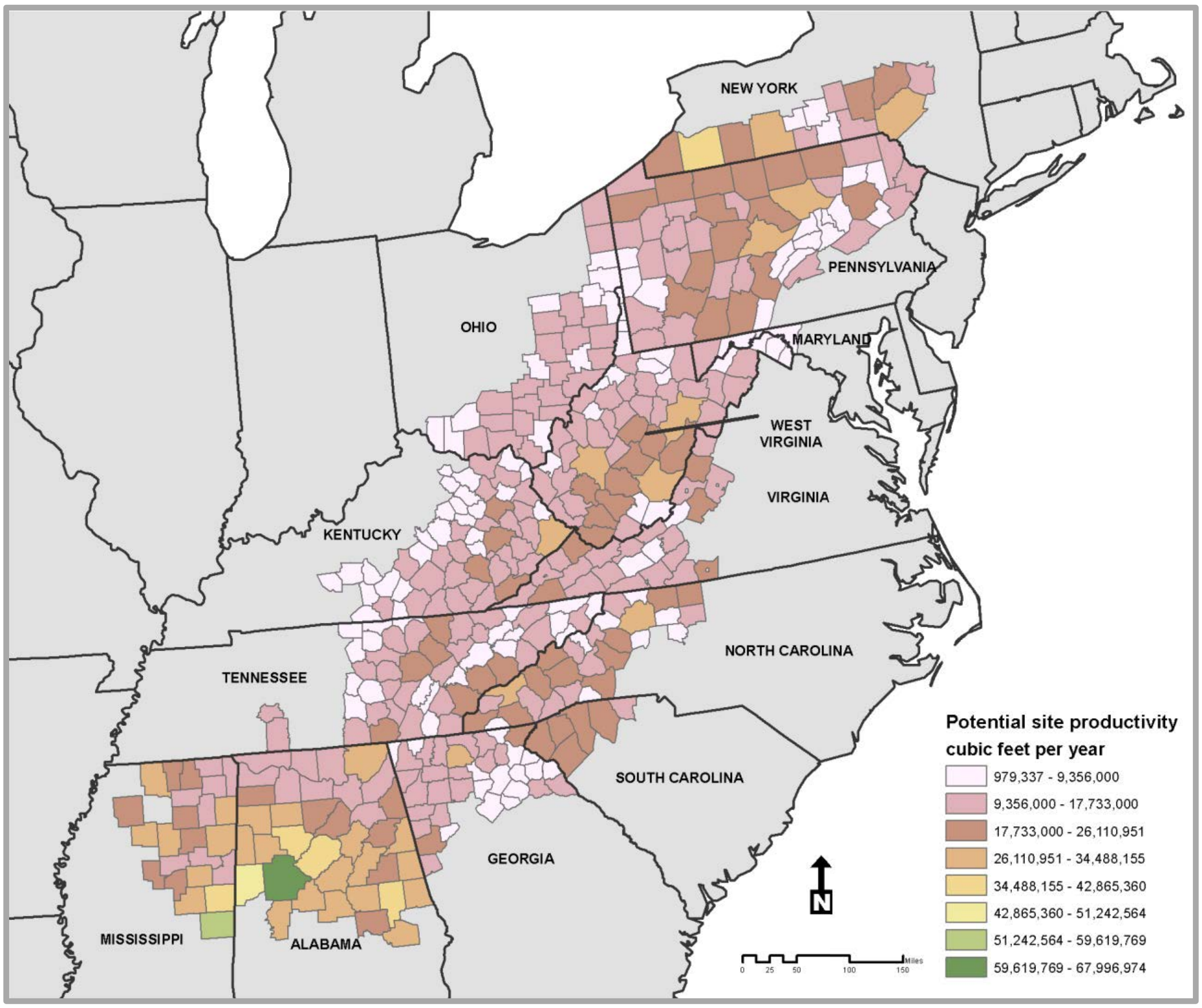



**Figure 9: Potential site productivity (cubic feet per year, source: FIA 2009/2010)**

## 3.2 Components and framework

Assessing the quality of a county's forest resource requires the examination of many different datasets. Forest quality metrics were procured from publicly available sources and used to create five forest quality indicators. As shown in Table 4, these five indicators include:

1. **Stand quality**: Measures the potential productivity of forests as the forest cull volume (i.e., un-merchantable volume due to decay or substandard grade), weighted by the percentage of naturally regenerated forestland within a county.
2. **Growth ratio:** Provides a simple measure of forest health by dividing annual growth of standing timber volume by the annual volume of standing timber lost to natural mortality.
3. **Stand origin:** Measures how a forest stand was last regenerated. This indictor divides the acres of naturally regenerated forestland by the total acres of forestland.
4. **Projected forest loss**: Represents the forecasted loss of forest acreage due to housing pressure and insects and disease.
5. **Forest disturbance**: Quantifies the current amount of forest affected by abiotic factors such as hurricanes and floods, biotic factors such as animal disturbance, and silviculture.

**Table 4: Forest quality assessment components**

| Indicator | Metric | Denominator | Unit of measurement | Data source and date |
|---|---|---|---|---|
| Stand quality | • Volume of growing stock trees<br>• Cull volume | None | None (ratio) | Forest Inventory Analysis, 2009, 2010 |
| Growth ratio | • Annual growth<br>• Annual mortality | None | None (ratio) | Forest Inventory Analysis, 2009, 2010 |
| Stand origin | • Acres of naturally regenerated forest | None | Percent | Forest Inventory Analysis, 2009, 2010 |
| Projected forest loss | • Risk of basal area loss due to insect and/or disease infestation<br>• Future housing density | None | Percent | National Insect & Disease Risk Map (NIDRM) – USFS, 2011<br>Forests on the Edge – USFS, 2005 |
| Forest disturbance | • Biotic disturbance<br>• Abiotic disturbance<br>• Silviculture | None | Acres | Forest Inventory Analysis, 2009, 2010 |

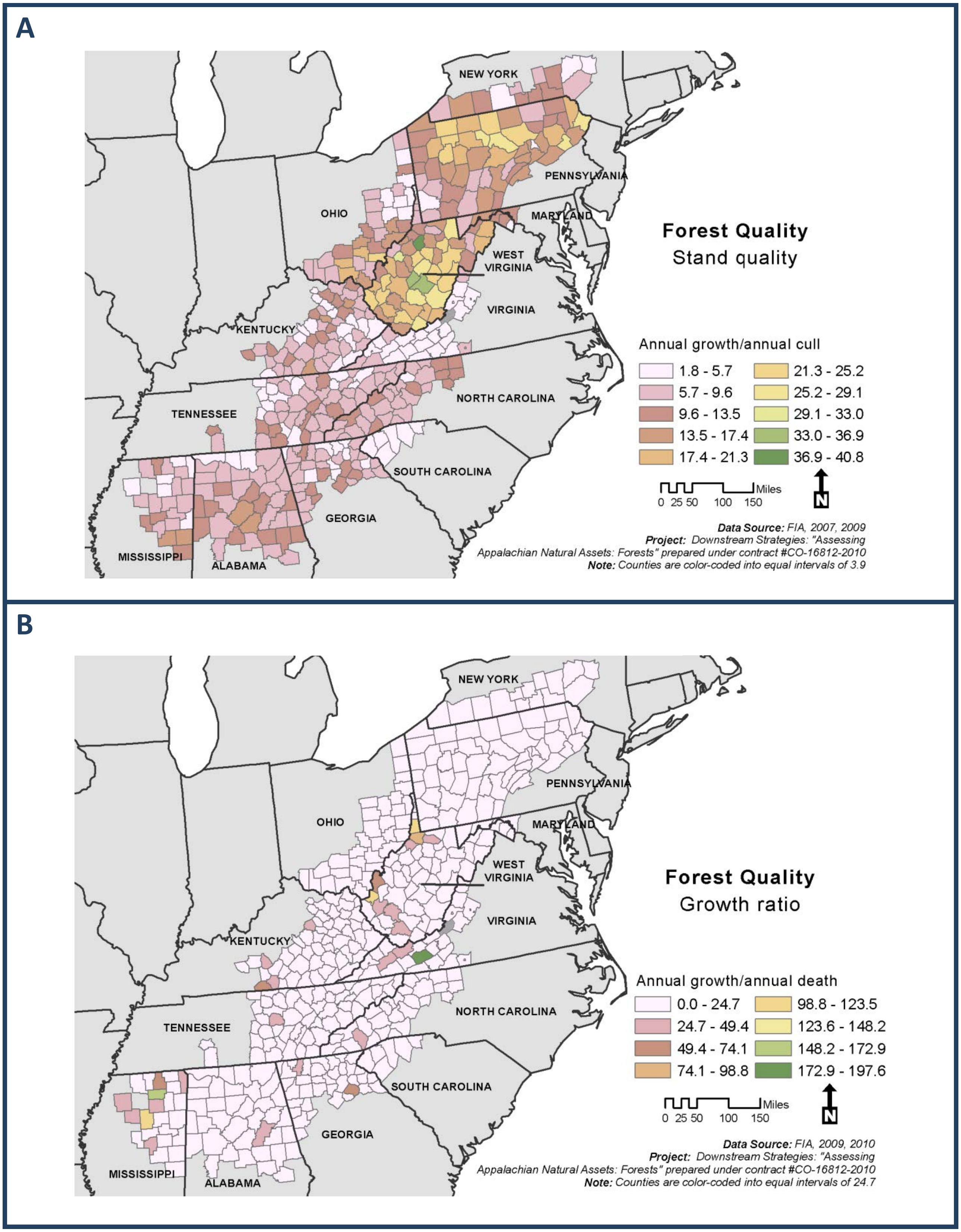



Figure 10: (A) Stand quality and (B) growth ratio

### 3.2.1 *Stand quality*

Stand quality measures the forest condition. This indicator is the ratio of standing timber volume to the volume of rough and rotten cull trees (Equation 5). The result is a measure that relates the merchantable amount of tree volume within a county's forest with the non-merchantable tree volume. Higher values suggest healthier, more favorable forest conditions, while lower values suggest the potential for improvement. Both metrics within the stand quality indicator originate from the FIA dataset.

**Equation 5: Stand quality**

$$\textit{Stand quality}_{county\text{“}i\text{”}} = \textit{volume of growing stock trees}_i \,/\, \textit{cull volume}_i$$

Panel A in Figure 10 shows the stand quality for Appalachian counties. Generally, all counties in the Appalachian region showed good stand quality, with the majority of counties showing at least 1.8 times more standing timber volume (i.e., volume of growing stock trees) than cull volume. For stand quality, higher values represent a more productive forest with trees of good form and merchantability. Much of West Virginia and northern Pennsylvania show higher stand quality scores than the rest of the Appalachian region. These areas are known for their fine hardwoods (such as red oak, white oak, and black cherry) and yellow-poplar veneer, and active forest management in these areas is already a primary objective to capture the value of fine hardwood species. Active management helps to create a healthy forest with timber of good size and quality.

The lower stand quality ratios found throughout the southwestern Appalachian region can be misleading. Forests in this area are still of relatively high quality; however, primary products in the region rely more on trees for pulp and paper, dimension lumber, and composite wood products as opposed to fine hardwood lumber. In addition, cull volume does not play as important a role as it does in the fine hardwood region of the central Appalachians because tree form and grade are less critical to producing pulp, paper, and composite wood products.

### 3.2.2 *Growth ratio*

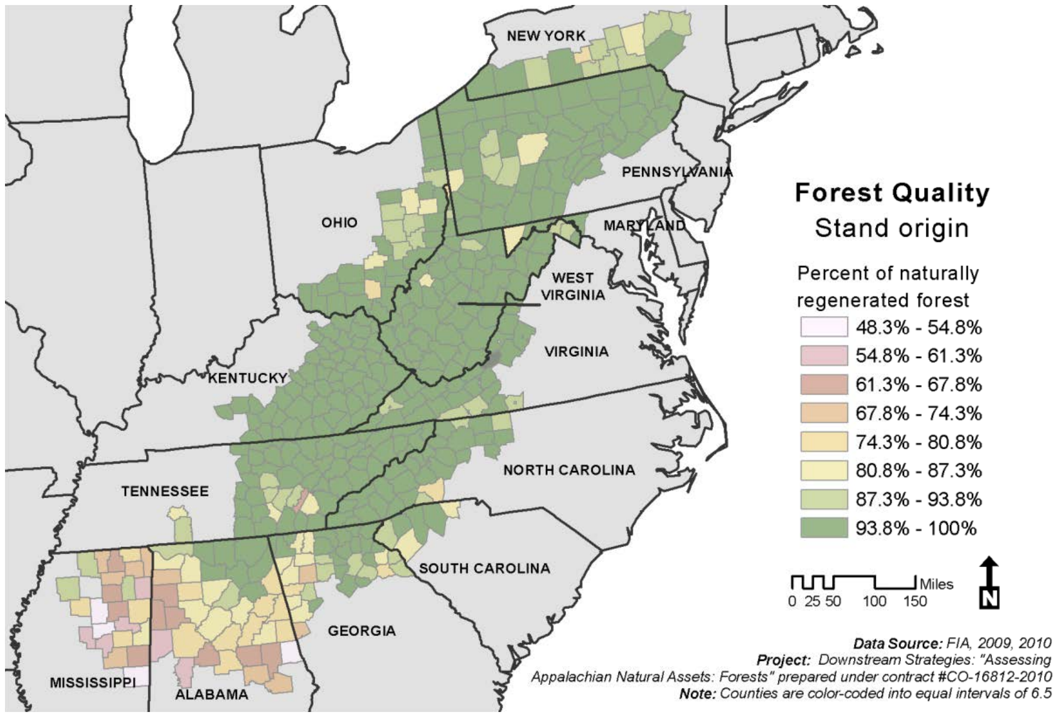
Growth ratio is the annual growth of standing timber volume divided by the annual volume of standing timber lost to natural mortality (Equation 6). A growth ratio greater than one means that natural mortality is less than natural growth, while a ratio less than one means that net growth is negative because mortality volume is greater than growth volume. Growth ratio is one of the simplest measures of forest health. A forest with a low or decreasing growth ratio may be experiencing a decline in forest health due to various factors, and it may be worth improving the forest stand.

**Equation 6: Growth ratio**

$$\textit{Growth ratio}_{county\text{“}i\text{”}} = \textit{annual growth}_i \,/\, \textit{annual mortality}_i$$

As shown in Panel B in Figure 10, forests in most Appalachian counties have a relatively low growth ratio. The lowest category ranges from about 25 times more growth than mortality down to a point where growth is less than mortality (a rare occurrence). If counties have a growth ratio exceeding one, growth is exceeding mortality. Only a few counties in the region have higher growth ratios; most of these counties are in Mississippi. These forest stands typically undergo intensive plantation forestry practices and can exhibit large growth ratios with virtually no mortality. As for the rest of the region, although most growth ratio scores are relatively low, all but approximately 7 percent are greater than one. Exploring options to increase the growth ratio may be worthwhile in low-scoring forests, such as management activities geared towards improving forest health.

A




B

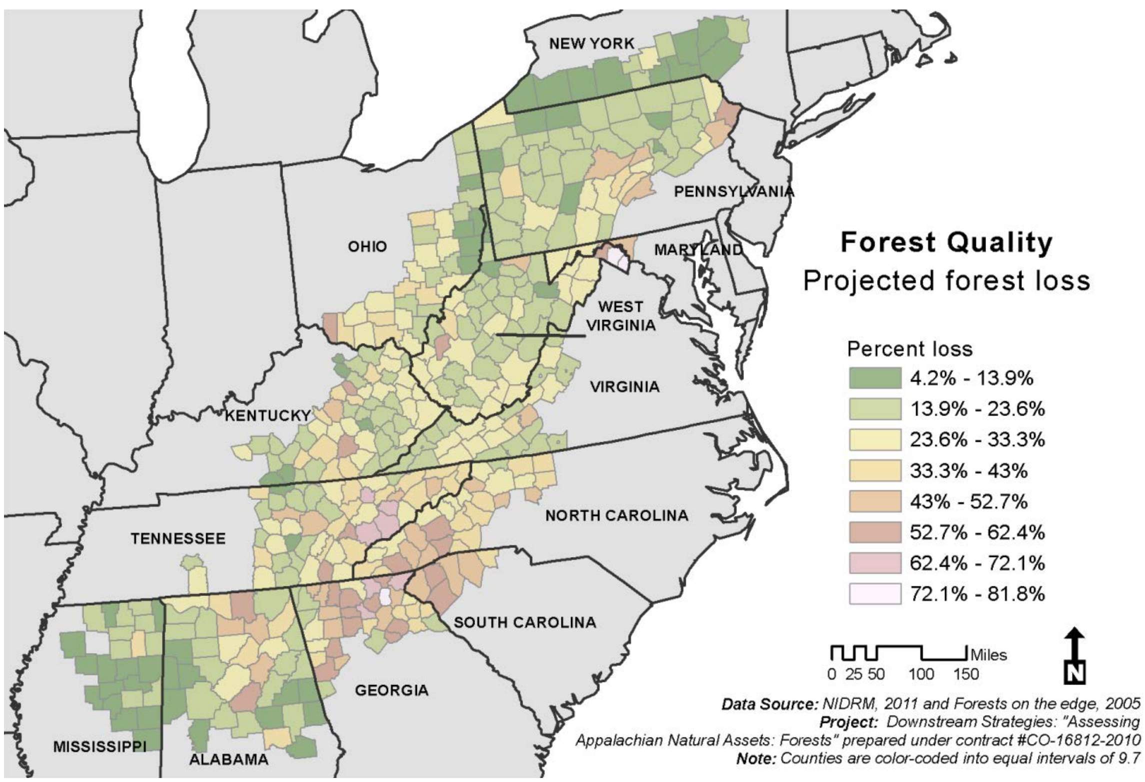



Figure 11: (A) Forest stand origin and (B) projected forest loss

### 3.2.3 *Stand origin*

Stand origin is a measure of how a forest stand was last regenerated. There are two main types of regeneration methods employed in the Appalachian forest region: natural and artificial regeneration. Stand origin was calculated by dividing the acres of naturally regenerated forestland by the total acres of forestland, and then multiplying by 100 to get a percentage of naturally regenerated forestland.

The natural regeneration method allows for the seeds of trees once found on the site to become established and counts on forest succession and silvicultural techniques to develop the stand into a healthy, desired forest structure and composition. Artificial regeneration can be as simple as planting desired native species on sites to speed up or bypass natural succession, or as intensive as planting non-native species at very high initial densities, pre-commercial thinning, and using fertilizer and pesticides to control for competing vegetation and resources. Natural regeneration is the preferred method for the long-term, as it is usually much less intensive in terms of site preparation and chemical fertilizer and pesticide application, while favoring the maintenance of species composition, structure, and diversity. However, there are benefits to both types of forest stand origins.

**Equation 7: Stand origin**

$$\textit{Stand origin}_{county\text{“}i\text{”}} = \textit{acres of natural regenerated stands}_i \,/\, \textit{forest acres}_i$$

Panel A in Figure 11 shows that most of the Appalachian region is highly dependent on natural regeneration. Some counties in Mississippi and Alabama rely more on artificial regeneration compared to the rest of the region. However, even in these counties, no more than approximately 40 percent of the forest area is artificially regenerated. This suggests that the forests of the Appalachians, in general, rely heavily on natural regeneration.

### 3.2.4 *Projected forest loss*

Projected forest loss is composed of two metrics: the projected percent of forest loss due to change in housing density and the projected percent of basal area loss due to insect and disease damage. These percentages are combined to form the risk of total projected forest loss (Equation 8).

Nationally, forests are at risk of encroachment, fragmentation, and forest area loss due to increasing pressures from housing developments. Projections of future housing density increases were used to approximate future development within the ARC region. The Forests on the Edge study by USFS (Stein et al., 2005) produced maps of predicted housing density changes on private lands (including private forestlands), available by decade from 1940-2030. Housing density categories mapped include undeveloped, rural (16 or fewer housing units/square mile), exurban (16-64 units/square mile), urban (64 units or more/square mile), and commercial/industrial. Comparisons between decades allow for assessment of conversion from less developed to more developed land uses by county. Public lands, which include local-, state-, and federally owned land from the Protected Areas Database (DellaSala et al., 2001), were excluded from the analysis.

**Equation 8: Projected forest loss**

$$\textit{Projected forest loss}_{county\text{“}x\text{”}} = \textit{housing density risk}_x + \textit{insect and disease risk}_x$$

Following Stein et al. (2005), a change in housing density was defined as a change from rural to exurban, or from rural or exurban to urban. Changes in housing density were calculated using Forests on the Edge data from 2000 (based on the 2000 Census) and projections for 2030. Data for 2000 and 2030 were used to determine the areas with housing density changes. The overall housing density change for each county was found by determining the change in total percentage for each county between 2000 and 2030.

To account for risks to forests from insect damage and disease, we summarized data from the National Insect and Disease Risk Map (NIDRM) project (USFS, 2011). Specifically, we compiled average percent basal area loss predictions by county from the NIDRM maps. The NIDRM maps are composites of 188 individual models designed to predict responses to common insect and disease tree mortality agents (including gypsy moth, emerald ash borer, and southern pine beetle) for 57 tree species, with the final results being maps of percent basal area loss over the next 15 years (Krist et al., 2007). Percent basal area loss was modeled for one-square kilometer cells by calculating the total loss from all agents and host species as a percentage of total standing live volume of trees greater than one inch in diameter (USFS, 2011).

Panel B in Figure 11 shows the percentage of projected forest loss for Appalachian counties. Counties with the greatest projected loss dominate Georgia, South Carolina, and western North Carolina near the greater Atlanta metropolitan area. In these three states, the housing metric drives the high percentage of projected forest loss, meaning that forests are at greater risk from housing pressure than insects and disease; this is not generally the case in the rest of the region. Other counties with high percentages of projected forest loss are found near the eastern panhandle of West Virginia and Maryland near the fast-growing city of Martinsburg, West Virginia, and also in central and eastern Pennsylvania areas closer to larger cities. Low percentages of projected forest loss dominate the counties of Mississippi and New York, whereas most other states exhibit a mix of high and low percentages for projected forest loss, depending on the proximity of larger, faster-growing cities or metropolitan areas.

Across the Appalachian region, the trend suggests that the majority of counties are not likely to experience large amounts of deforestation due to housing pressure or tree mortality from insect infestation and disease. Furthermore, in order to show the impact, discussed above, of either potential future housing density changes or insect and disease infestation on the forests of Appalachia, the projected forest loss indicator can be broken down into two base maps (Panels A and B in Figure 12). These figures clarify that the projected housing density metric drives the potential forest loss values in the states of Georgia, Alabama, and South Carolina, while the combination of the risk of insect and disease and projected housing density impacts potential forest loss in North Carolina.

It is interesting to note the potential impact of insect and disease risk on the future of forests in the state of West Virginia (Panel A in Figure 12). The impact is lost when combined in the overall projected forest loss map (Panel B in Figure 12) due to the magnitude of percent change in housing density across the region. However, the risk of insect and disease infestation does appear to be an indicator worth tracking in the future in West Virginia, as well as in other states such as central Pennsylvania, southern Ohio, western Maryland, and eastern Kentucky.

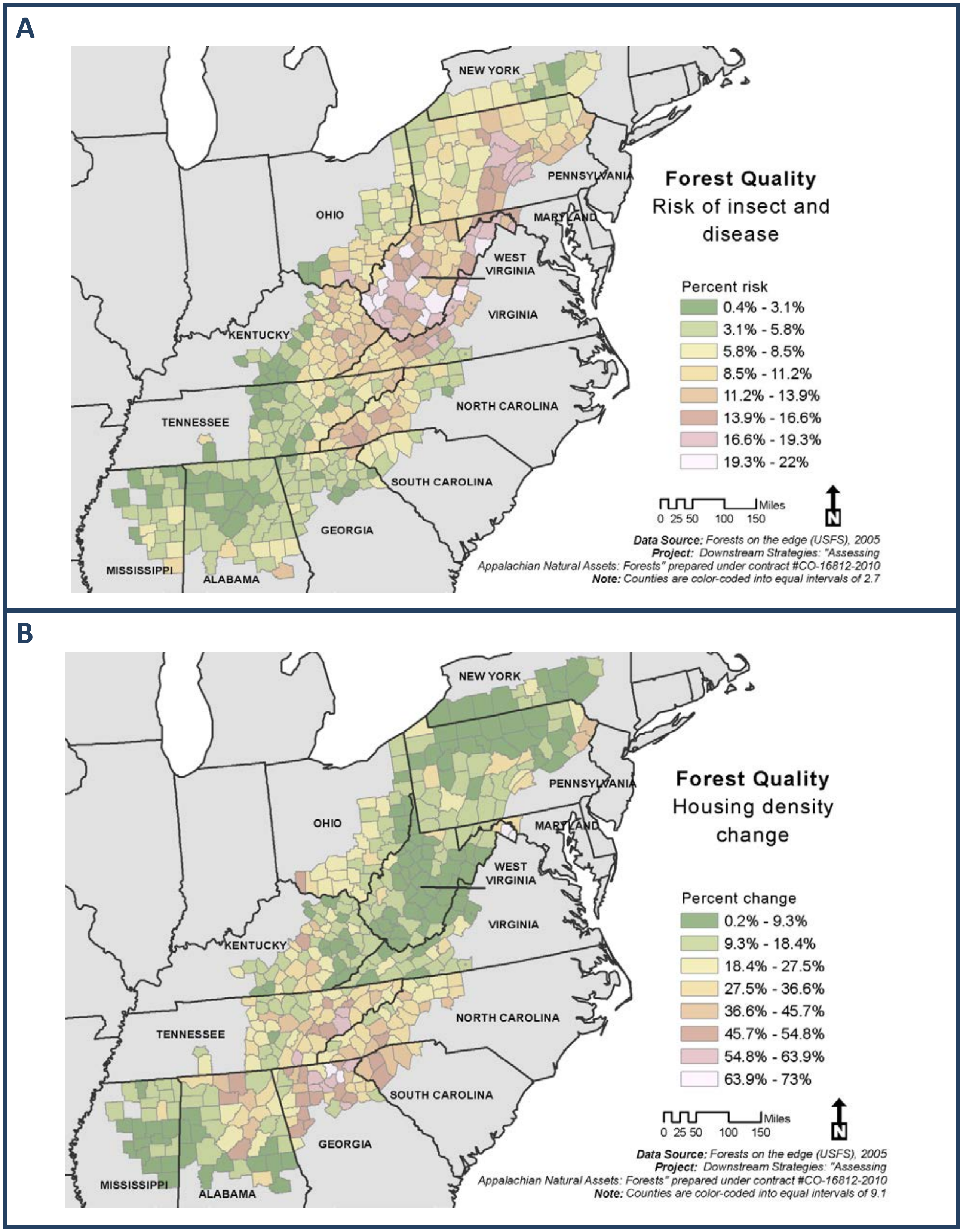



Figure 12: (A) Percent risk of insect infestation and (B) housing density change

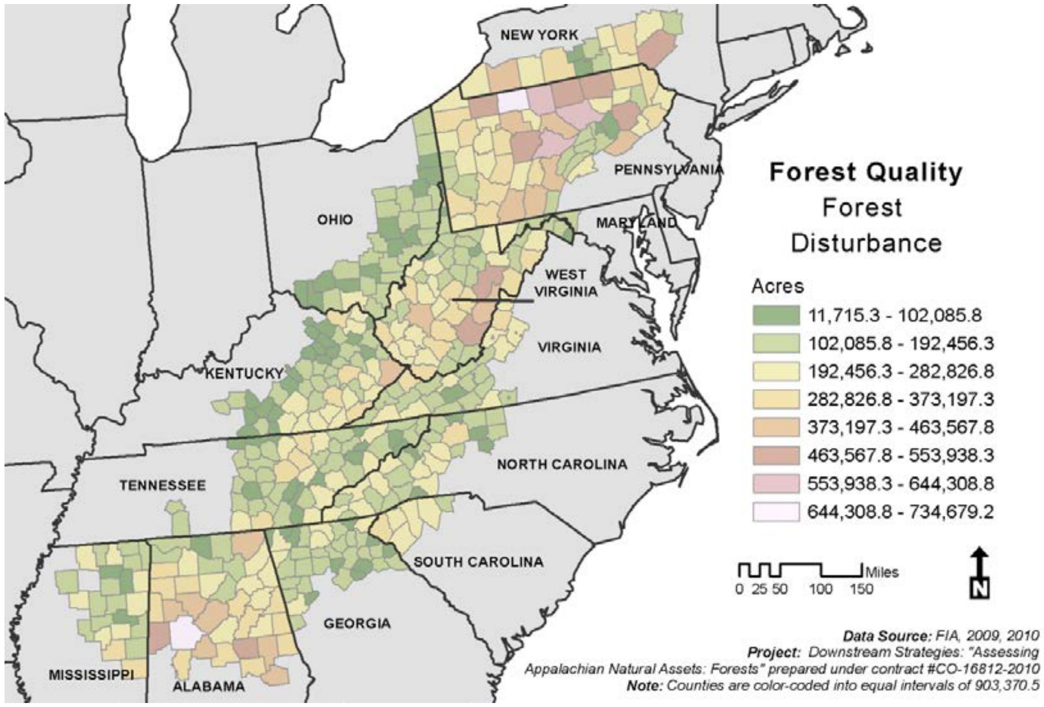
### 3.2.5 *Forest disturbance*

Forest disturbance is a measure of recent forest impacts. Three metrics are used to calculate this indicator: biotic processes, abiotic processes, and silviculture. Biotic factors include invasive vegetation and insect species, as well as other animal and disease disturbances. Abiotic factors include fire- and weather-related disturbances. Silvicultural activities (e.g., forest harvesting and management implementation) are the only human-caused disturbances measured with this indicator. Surface mining activities are included under silviculture acres as a “land-clearing activity” (FIA disturbance code 80). However, no distinction is made between forest management-derived disturbance and surface mining-derived disturbance within code 80. Therefore, the surface-mined acres within this report are not distinguishable from, but included as, forest disturbance. The indicator represents the total acres of disturbed forestland, as a percentage of the total forest area.

**Equation 9: Forest disturbance**

$$\textit{Forest disturbance}_{county\text{“}i\text{”}} = (\textit{biotic acres}_i + \textit{abiotic acres}_i + \textit{silviculture acres}_i) / \textit{forest area}_i$$

A

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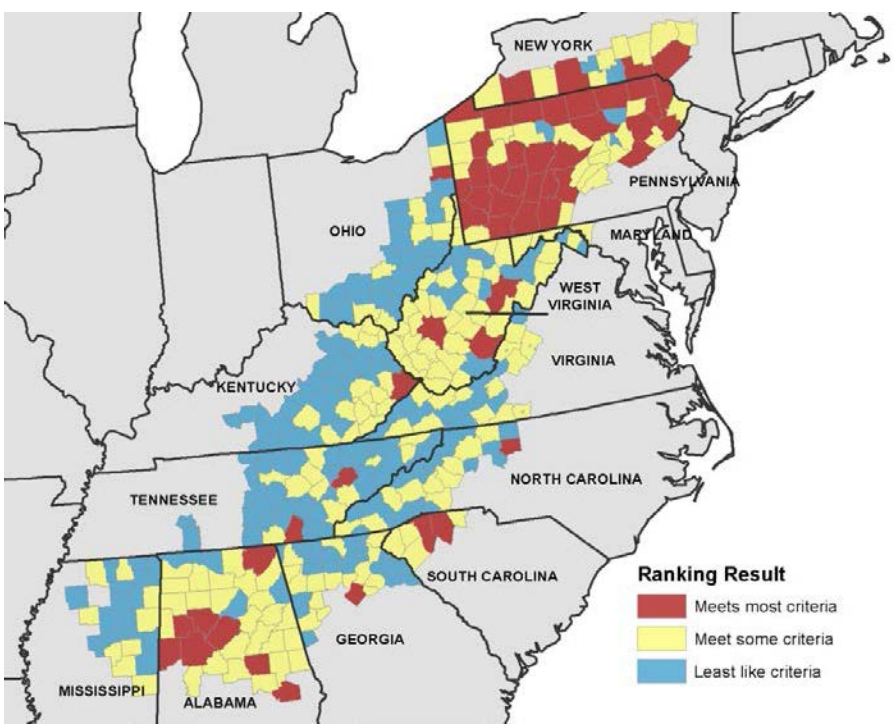



**Figure 13: (A) Forest disturbance and (B) forest quantity case study**

Panel A in Figure 13 shows the forest disturbance acres for Appalachian counties. In general, Mississippi, Georgia, South Carolina, North Carolina, Tennessee, Virginia, Kentucky, Maryland, and Ohio exhibit the lowest amount of disturbed acres within the region. Alabama, West Virginia, Pennsylvania, and New York show a range of disturbed acres within counties from high to low. The higher percentage of disturbed acres in these counties could be due to the increased presence of invasive plant species such as kudzu (*Pueraria Montana* var. *lobata*) or insects such as the hemlock woolly adelgid (*Adelges tsugae*), weather, a greater number of recently-harvested areas for forest management operations, or land clearing for other purposes.

## 3.3 Discussion

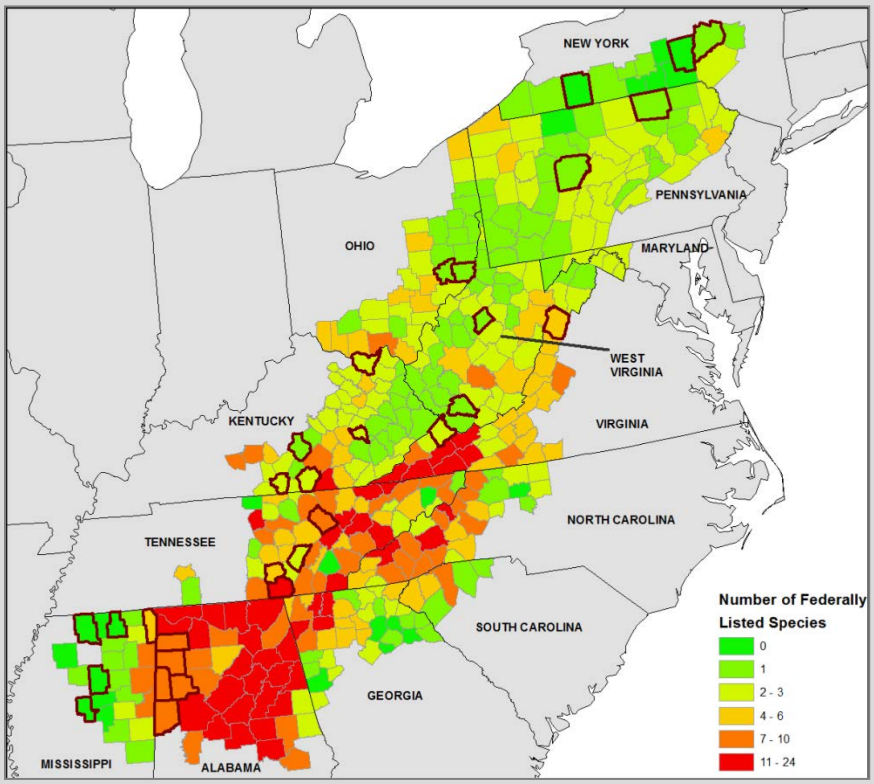
Overall, the Appalachian region is comprised of forests with good quality, and most of the Appalachian region is highly dependent on natural regeneration. The majority of counties show at least 1.8 times more standing timber volume than cull volume, which represents a productive forest with trees of good form and merchantability. Forests in most Appalachian counties have a relatively low growth ratio. However, the lowest category ranges from about 25 times more growth than mortality down to a point where growth is less than mortality. Only a few counties in the region exhibit mortality greater than growth. Exploring options to increase the growth ratio may be worthwhile in some of these forests, including management activities geared towards improving overall forest health.

Projected forest loss is low for most Appalachian counties; counties with higher projected forest loss are generally at greater risk from housing pressure than insects and disease. This is not generally the case in the rest of the region, where the risk of insect and disease infestation tends to have a greater influence on projected forest loss. Across the Appalachian region, the majority of counties are not likely to experience large amounts of deforestation due to housing pressure or tree mortality from insect infestation and disease.

Higher areas of forest disturbance in Appalachian counties tend to be found in Alabama, West Virginia, Pennsylvania, and New York, which could be due to the increased presence of invasive plant species, extreme weather events, active management, or land clearing for other purposes.

### 3.3.1 *Forest disturbance, population, and road density*

Panel B in Figure 13 compares forest disturbance with county population and road density. Road density is the ratio of the length of the county's total road network to the county's land area. The road network includes all roads in the county: motorways, highways, main or national roads, secondary or regional roads, and other urban and rural roads. Using the DSS, high importance was placed on forest disturbance and road density, while a moderate importance weight was applied to population. The map shows counties that best fit the query, with the top third having more roads, more forest disturbance and greater population. These counties in the top third are mostly in a few clusters across the region, and can be crosschecked with the stand quality map (Panel A in Figure 10) to determine counties in the top third that are also of below-average stand quality. These counties may have the most potential for increased active management for healthier forests because disturbance could be contributing to a lower stand quality, and the road infrastructure and potential workforce to successfully manage the forests may already be in place within the county.


NEW YORK
PENNSYLVANIA
MARYLAND
OHIO
WEST VIRGINIA
KENTUCKY
VIRGINIA
NORTH CAROLINA
TENNESSEE
SOUTH CAROLINA
GEORGIA
MISSISSIPPI
ALABAMA
Number of Federally Listed Species
0
1
2 - 3
4 - 6
7 - 10
11 - 24

# 4. FOREST VALUE

## 4.1 Introduction

In this chapter, we consider the value of Appalachia's forests. Economists use a variety of methods to place monetary values on natural resources like forests. These methods include information derived from markets (such as observed market prices) and information estimated from survey data or observed behaviors. This second approach is called non-market valuation and includes techniques such as contingent valuation, property value hedonics, and the travel cost method. It is important to understand and attempt to quantify this value in order to account for the non-transactional economy and to place value on people's perceptions of the worth of forested landscapes.

In this section, the monetary values for forest resources are based on market information for wood and wood products. Non-market values are derived from a meta-analysis conducted by Kreiger (2001), which establishes a value per acre for wildlife habitat, water storage and preservation, recreation, and cultural values. Both the market and non-market values reflect a willingness to pay for the forest resource.

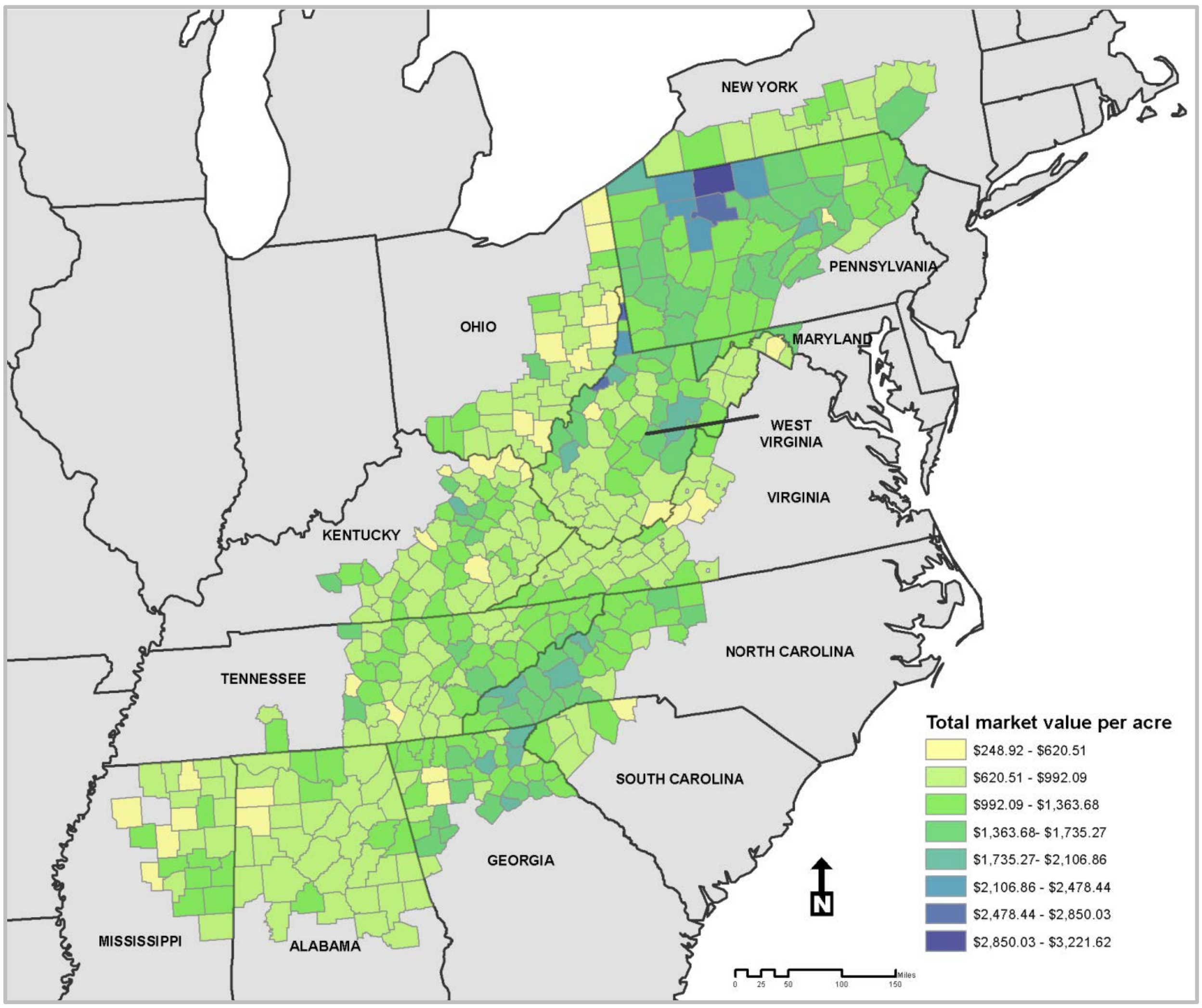



**Figure 15: Total market value per acre**

## 4.2 Components and framework

In this chapter, six indicators were developed to compare forest values across the region. These indicators, and the metrics from which they were derived, are directly associated with forest quantity and quality. For example, quantity metrics are used as inputs in estimating values.

The market and non-market categories are left separate, rather than combining them into a single forest value. This allows readers to discern between these two types of values.

Market values are entirely determined by prices and the quantity of products sold; these data were sourced from FIA and TPO. However, some forest-derived goods demonstrate transactional value on markets but their price and production data are not included in the FIA. For example, non-timber forest products such as mushrooms, ginseng, edible nuts and berries, medicinal herbs, and Christmas trees are becoming an increasingly important source of additional income for rural communities. However, there is a shortage of information with regards to production or harvest data on non-timber forest products, so they were excluded from this report.[2]

**Table 5: Forest quality assessment components**

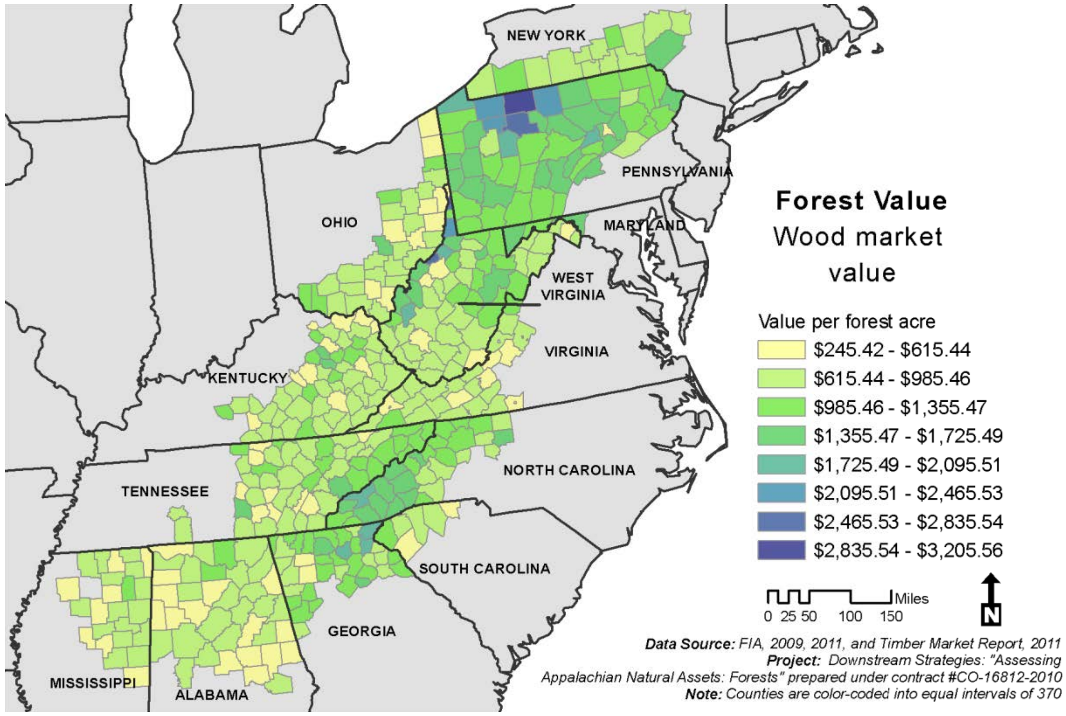
| Indicator | Metric | Denominator | Unit of measurement | Data source and date |
|---|---|---|---|---|
| **Market value** | | | | |
| Wood | • Volume of sawtimber<br>• Value of sawtimber<br>• Tree species | Forest acres | Dollars per acre | Forest Inventory Analysis, 2009, 2010<br>Timber Market Report, 2011 |
| Wood product | • Wood product volume<br>• Wood product value | Forest acres | Dollars per acre | Forest Inventory Analysis, 2009, 2010<br>Timber Market Report, 2011 |
| **Non-market value** | | | | |
| Recreation | • Value of recreation | None | Dollars | Kreiger, 2001 |
| Wildlife habitat | • Value of wildlife habitat benefits | None | Dollars | Kreiger, 2001 |
| Cultural value | • Value of cultural benefits | None | Dollars | Kreiger, 2001 |
| Watershed services | • Value of watershed services | None | Dollars | Kreiger, 2001 |

## 4.3 Market value

In order to calculate the market value of the forest assets in Appalachia, the project team first calculated the market value of wood—notably saw timber. A second indicator captured the value of wood products, including hardwood and softwood veneers, sawlogs, pulp, and fuelwood. The indicators included here are based on FIA and other datasets.

[2] The Appalachian Center for Ethnobotanical Studies provides many resources for the use and cultivation of non-timber forest products. See www.frostburg.edu/aces/.

A

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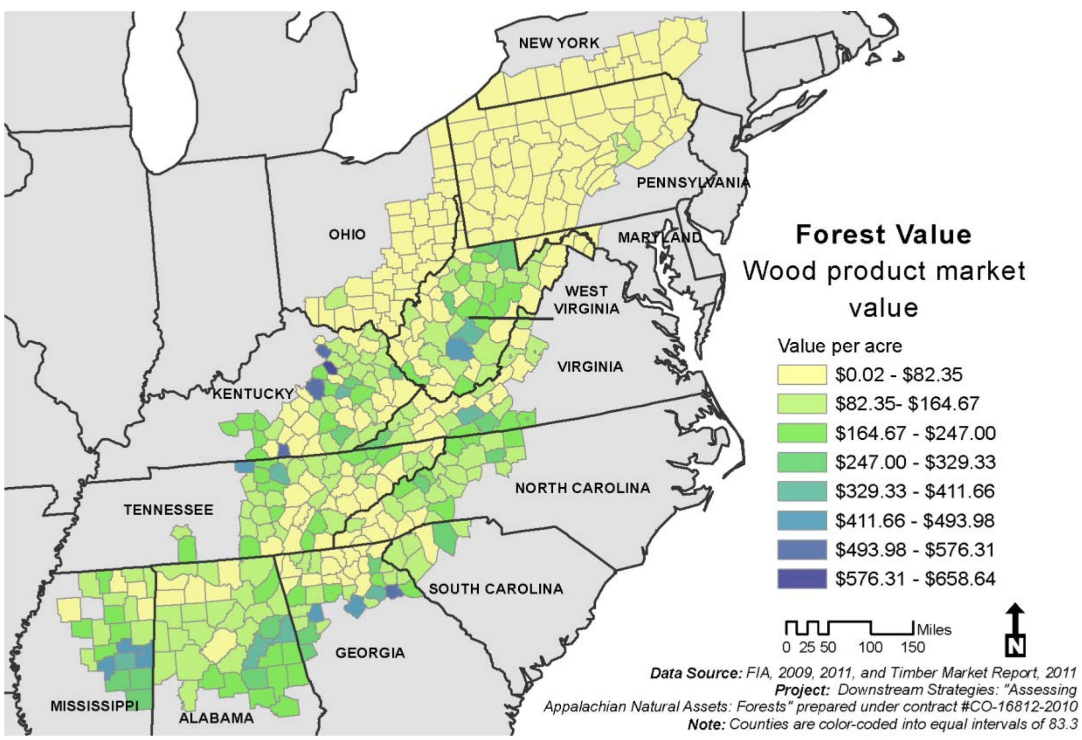



Figure 16: (A) Forest market wood value and (B) forest market wood product value

### 4.3.1 *Wood value*

The value of sawtimber for each county in the Appalachian region was used as a measure of wood value, or value of merchantable standing trees. To calculate the value of sawtimber, the net volume of sawtimber in board feet[3] was collected for each county within the region from the FIA database. Because sawtimber prices were not available for every species, some sawtimber species were grouped into major species categories.

Panel A in Figure 16 shows the value of standing timber for Appalachian counties. Generally, there is a greater timber value in New York, Pennsylvania, Maryland, West Virginia, North Carolina, and Georgia. Other Appalachian counties show a mix of values.

**Equation 10: Wood value**

$$\textit{Wood value}_{county\text{“}i\text{”}} = \textit{Sawtimber value}_i \,/\, \textit{Forested area}_i$$

Many wood values illustrated in Panel A of Figure 16 contrast with standing timber volumes in the quantity section of this report. Generally, it would be expected that counties with greater value have greater volume. However, some counties with high timber volume and lower wood value may have a greater density of lower quality or non-merchantable tree species. It follows that counties with low timber volume and higher wood value may have a greater density of higher quality, merchantable tree species.

### 4.3.2 *Wood product value*

Wood product values for each county were determined by assessing the same wood products from the TPO database used in wood product volume (Equation 11). Panel B in Figure 16 shows the value of wood products for Appalachian counties. Generally, more counties exhibit higher wood product values in the central and southern Appalachian states. Counties in New York, Pennsylvania, Ohio, and Maryland show almost entirely low wood product values, as compared with other Appalachian counties.

The low values in Ohio may be due to relatively young forests that dominate the region. The low values in Pennsylvania, Maryland, and New York are due to low quantities of specific types of wood products that command high market prices, such as veneer. The TPO data show that counties in New York and Ohio have low veneer production compared to the higher value counties. These differences in volume of production by product category (i.e., low-value versus high-value products) can have a significant impact on the final wood product value.

The Appalachian portions of Mississippi, Georgia, and South Carolina show the greatest density of high wood product values, while Alabama, North Carolina, Tennessee, Kentucky, Virginia, and West Virginia all exhibit a mix of high to low wood product values. However, no state in the region has many counties with high to very-high values.

**Equation 11: Wood product value**

$$\textit{Wood product value}_{county\text{“}x\text{”}} = \textit{Sum wood product value}_x \,/\, \textit{Forested area}_x$$

[3] The volume of sawtimber was calculated in board feet by using the International ¼ inch log rule. A board foot is most easily visualized as a piece of wood measuring 12"x12"x1", which equals 144 cubic inches and is the most commonly used volume measurement for sawlogs. The International ¼ inch log rule is the standard log rule used by USFS, and estimates the available board footage in trees based on diameter of the trunk and merchantable tree height.

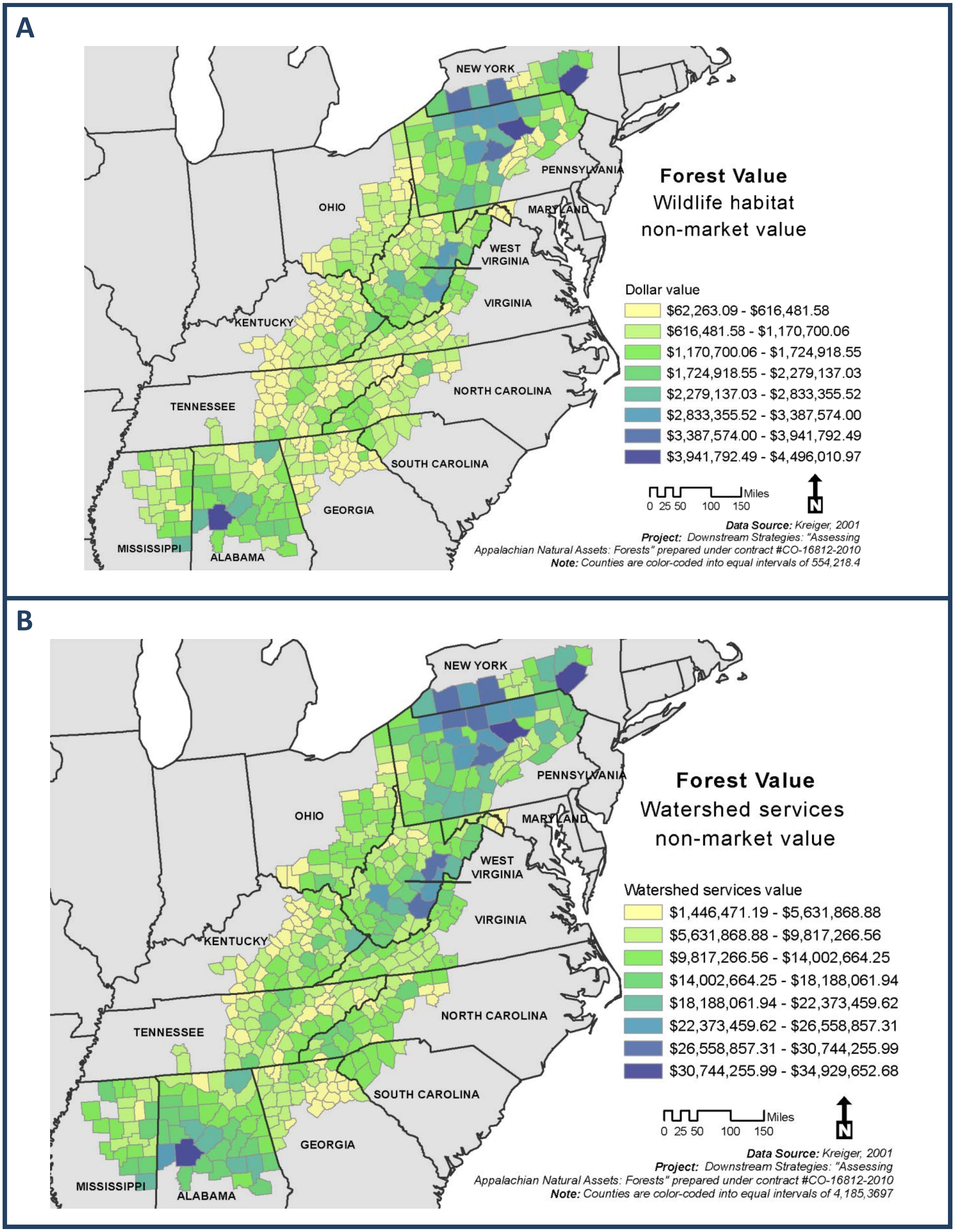



Figure 17: (A) Non-market wildlife habitat value and (B) non-market watershed services value

The map of wood product value in Panel B in Figure 16 shows many counties with values that contrast with the map of wood product volume shown in Panel A in Figure 4 although in general, counties with greater volume also have greater value. Counties with higher output and lower value may be producing products of a lower grade or value (as in the example of veneer, above), while counties with lower output and higher value may be producing products of a higher grade or value. Panel B in Figure 16 suggests that wood product value in the Appalachians is skewed towards lower values. As with wood value, this pattern occurs because a small number of counties have particularly high values in comparison to the majority of counties.

## 4.4 Non-market value

In order to evaluate non-monetary benefits from forests on a county-by-county basis, we estimated the wildlife habitat, watershed services, recreation, and cultural values provided by the forest.[4] All of these value estimates are linked to the area of forest in each county. Wildlife habitat values were estimated using the Wildlife Habitat Benefits Estimation Toolkit developed by the Defenders of Wildlife (2006). The other three indicators used values from Krieger (2001), who established rates of environmental service value per acre (Table 6).

**Table 6: Non-market forest values (dollars per acre)**

| Use sector | 2009 Forest value |
|---|---|
| Watershed services | $50.96 |
| Recreation | $15.52 |
| Cultural | $1.16 |

Note: Values per acre were extracted from Krieger (2001) and adjusted to 2009 dollars. The wildlife habitat value index was derived from Defenders of Wildlife (2006).

### 4.4.1 *Wildlife habitat value*

To estimate the dollar value associated with terrestrial habitat in Appalachian forests, the Wildlife Habitat Benefits Estimation Toolkit developed by the Defenders of Wildlife (2006) was used. This toolkit uses a model that was developed from a meta-analysis of several studies on the different benefits associated with wildlife and habitat. The model lets the user enter values for acres of terrestrial habitat and assumes that the habitat provides for multiple species in addition to open space. Forested acres per county were entered.

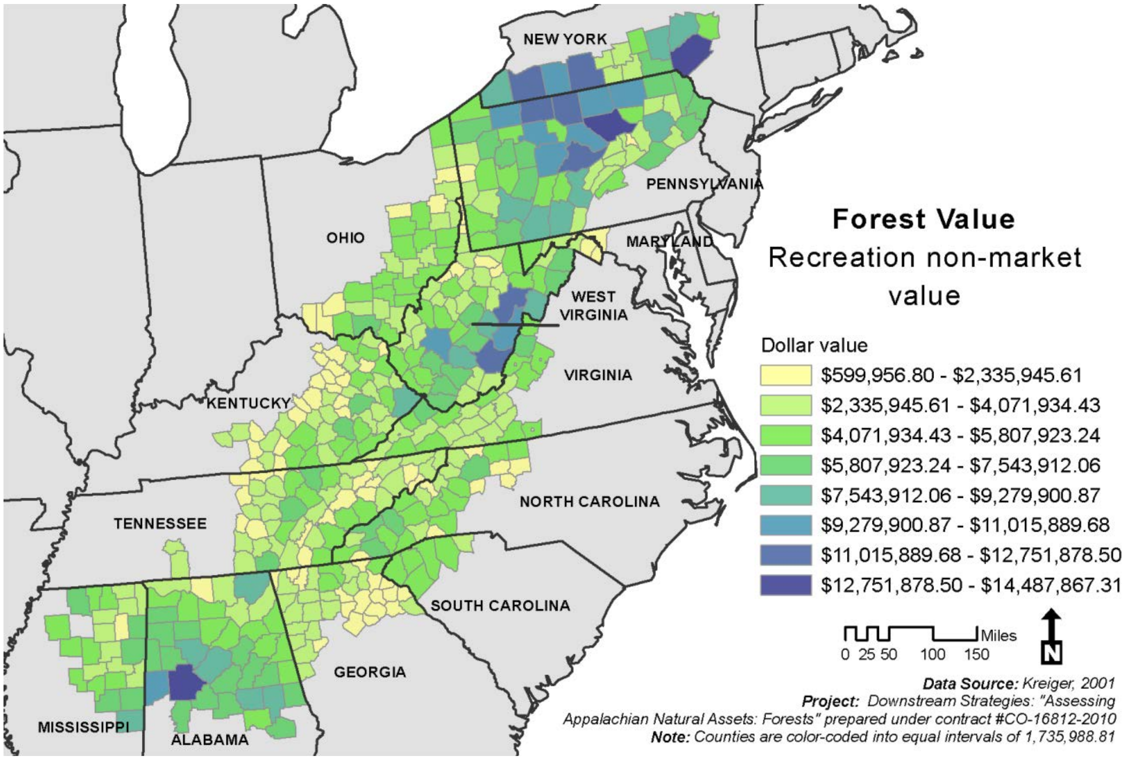
Panel A in Figure 17 shows the value of wildlife habitat for Appalachian counties. While wildlife habitat values were generally skewed toward the low side, high values exist in certain counties in New York, Pennsylvania, West Virginia, and Alabama. This pattern is consistent with the distribution of scores for the other non-market value indicators, because they all use forest area per county as a base parameter.

**Equation 12: Wildlife habitat value**

$$\textit{Wildlife habitat value}_{county\text{“}i\text{”}} = \textit{County forested acres}_i \; i \; \textit{Wildlife habitat value per forested acre}$$

[4] Carbon sequestration as an additional form of ecosystem services is described in Appendix A. The amount of carbon in Appalachia is quantified through the forest carbon mass indicator, which is described in the forest quantity chapter.

A

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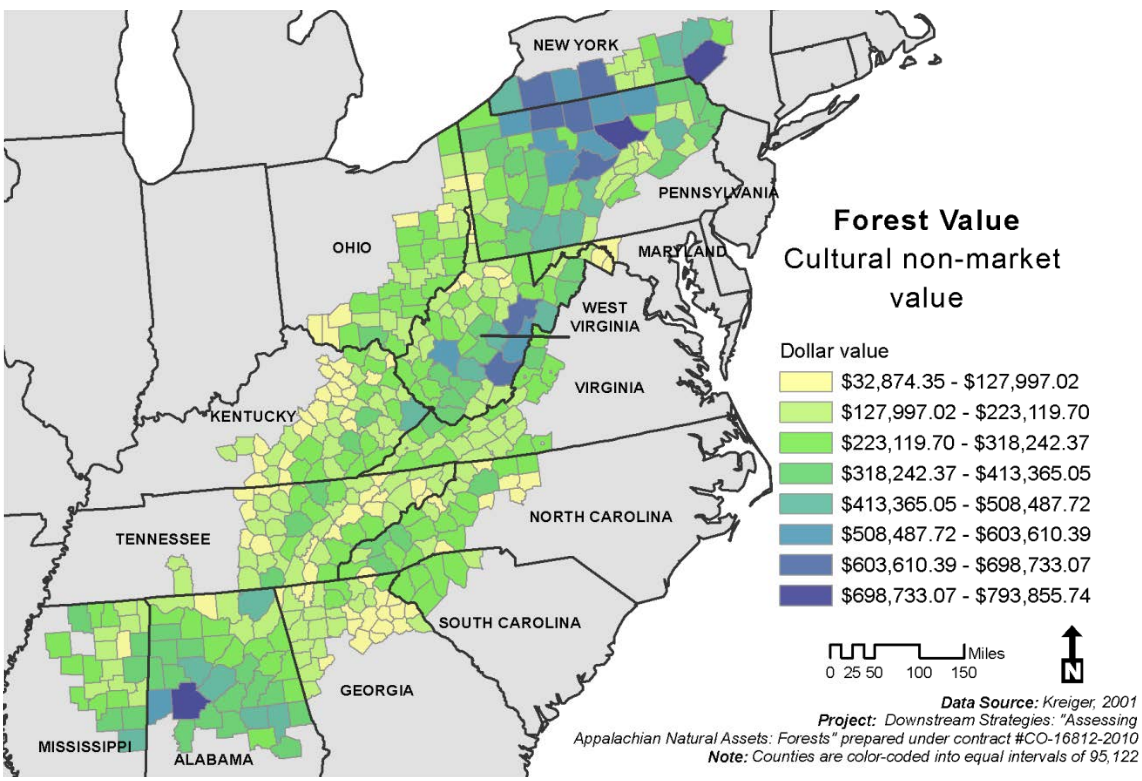


**Figure 18: (A) Non-market recreation value and (B) non-market cultural value**

### 4.4.2 *Watershed services value*

Forested landscapes store and purify water, improving both the quantity and quality of water in the Appalachian region. Forests contribute to water quality by reducing soil erosion and filtering pollutants from water. Clean water from forest ecosystems is particularly important to many municipalities that obtain their water from forested watersheds (Krieger, 2001). Studies have shown a direct linkage between water quality and forest cover (e.g., Freeman et al., 2008). For example, decreased forest cover was significantly related to decreased water quality, and low water quality was related to higher treatment costs. It has also been shown that larger forested areas are linked with better quality of untreated water and lower drinking water prices. To assess the value of watershed services provided by forests, the project team applied a per-acre value from Krieger (2001) to the amount of forested acres within the county (Equation 13). Panel B in Figure 17 shows the value of watershed services for Appalachian counties. Values were highest in certain counties in New York, Pennsylvania, West Virginia, and Alabama. This pattern is consistent with the distribution of scores for the other non-market value indicators, because they all use forest area per county as a base parameter for the calculation.

**Equation 13: Watershed services value**

$$\text{Watershed services value}_{\text{county}``i"} = \text{County forested acres}_i \text{ i watershed services value per forested acre}$$

### 4.4.3 *Recreation value*

Forestlands in the US, both public and private, play an essential role in providing recreational opportunities for the public; over 173 million recreation visits were made to national forests annually since 2005 (USFS, 2010b). Approximately 86 million acres, or 65 percent of the Appalachian region, is forested (Miles, 2010; as cited in Widmann et al., unpublished). Appalachian forests provide substantial opportunities for recreation and tourism for the region’s residents and others. Millions of residents participate in outdoor activities such as hunting and fishing (Widmann et al., unpublished).

The value of recreation for each county in the Appalachian region was calculated by multiplying the per-acre estimate from Krieger (2001) for temperate or boreal forests by the number of forested acres.

**Equation 14: Recreation value**

$$\text{Recreation value}_{\text{county}``x"} = \text{County forested acres}_x \text{ x recreation value per forested acre}$$

Panel A in Figure 18 shows the value of recreation for Appalachian counties. Recreation values were highest in certain counties in New York, Pennsylvania, West Virginia, and Alabama counties. This pattern is consistent with the distribution of scores for the other non-market value indicators, because they all use forest area per county as a base parameter.

### 4.4.4 *Cultural value*

Forests provide a wealth of cultural values, such as aesthetic value, existence value, and cultural heritage value (Krieger, 2001). The cultural value for each county in the Appalachian region was calculated by multiplying the per-acre estimate from Krieger (2001) for temperate or boreal forests by the forested acreage in each county. Panel B Figure 18 shows the cultural value for Appalachian counties. Values were highest in certain counties in New York, Pennsylvania, West Virginia, and Alabama. This pattern closely resembles the other non-market value indicators because this indicator is also based on forest area per county.

**Equation 15: Cultural value**

$$\text{Cultural value}_{\text{county “x”}} = \text{County forested acres}_x \times \text{cultural value per forested acre}$$

## 4.5 Discussion

In terms of market value, counties with greater volumes of standing timber and wood product output generally have greater values. However, counties with higher timber volume and lower wood value may have a greater density of lower quality or non-merchantable tree species, while counties with lower timber volume and higher wood value may have a greater density of high quality, merchantable tree species. Also, counties with higher wood product output and lower value may be producing products of a lower grade or value, while counties with lower output and higher value may be producing products of a higher grade or value. A small number of Appalachian counties have particularly high values in comparison to the majority of counties; therefore, the market value maps show a large number of counties in the categories with relatively lower market values.

In terms of non-market value, counties with higher value are often located in areas with publicly owned forestlands. Examples include the Monongahela National Forest in West Virginia, George Washington National Forest in Virginia, Allegheny National Forest in northern Pennsylvania, and Daniel Boone National Forest in eastern Kentucky.

### 4.5.1 *Poverty and the value of forests*

Using the DSS, a map was created (Figure 19) that compares standing timber value, wood product value, non-market forest value, and poverty levels. High importance—or weight—was placed on poverty and wood product value, while more moderate weights were applied to standing timber volume and non-market value. The map shows counties that best fit the criteria, with the top third generally having greater poverty and forest value. These counties are mostly found in a few clusters across the central and southern Appalachian states.

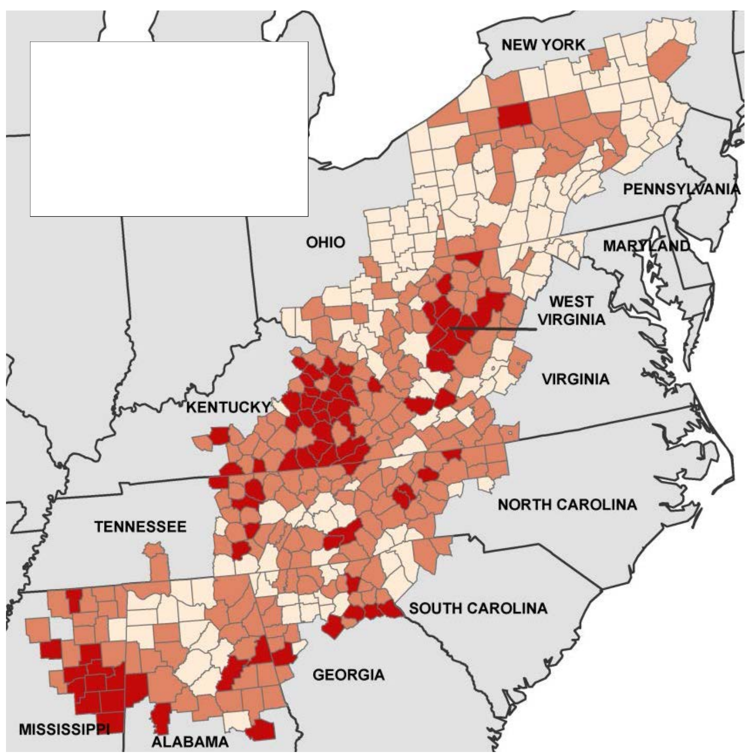


**Figure 19: Decision support system output - value and poverty**


DOLM

# 5. CONCLUSION

Based on a literature review, data compilation, and analysis, this study quantified numerous metrics and indicators that describe forest quality, quantity, and value across all Appalachian counties. These assessments demonstrate one way that forest resources can be quantified and understood—one we hope will help guide conversation and future research, and begin to place an emphasis on determining the true value of our natural resources, both economically and culturally.

In addition, this project provides a GIS Decision Support System, which allows users to capture this dynamic and complicated resource in the context of their understanding of local forests' relationships with economic development or distress.

## 5.1 Recommendations

The forests of Appalachia have long been the fuel for one of the region's premiere natural resource extraction industries; the history and the future of the forests in the region are inextricably tied to the region's economic development. Wise use of the forest resource can aid economic development, especially in the most rural regions. Evaluating the existing forest asset in terms of its quality, quantity, and value is the first step in effectively linking economic development and sustainable use of the resource. The following policy recommendations are possible next steps in this process.

**Promote forest management**
One of the greatest needs identified in the stakeholder surveys was improved forest management. Generally, much timber harvest follows the adage: "cut the best, leave the rest." Forest operators are often paid by timber value and have an incentive to select the most valuable trees to cut. Without a forester involved, timber may be cut without regard to forest reproduction, and stands may be degraded rather than stewarded. Most forestlands cut in Appalachia do not have a forester involved and have no forest management plan. If investment decisions by ARC are going to enhance forest value through time, it is important to prioritize timber harvests from managed lands. In addition to any direct support for communities undertaking forest management promotion initiatives, ARC could score forest-related project proposals higher if they include forest management plans. This would create incentives for partners in local communities to collaborate to improve management in their areas.

Any public dollars that are invested in biomass facilities (be it direct project support, feasibility work, or tax incentives) should be made in ways supportive of improved forest management. Schools applying for support for transition to wood heat should indicate how they plan to source wood from managed lands. Large facilities, such as power plants and biorefineries, should source only from managed lands as their impacts could greatly enhance or degrade forest resources in an area.

**Work towards real-time forest information**
Forest-use project areas should also consider the other competing demands for wood. Future ARC forest indicators work would be well to track the current demands on wood, ideally in real time. "Sourcing circles" for facilities could give project developers an indication of the overlapping demand for forest products, locations of likely over-harvest, and "gaps" where projects would be most useful. Projects in areas of low demand could receive additional points, and projects in high-demand areas would require sustainable sourcing plans.

It would be advisable for future assessments to include process indicators around forest management. As states begin to digitize maps of parcels with forest stewardship plans, those maps could be requested from state foresters. Alternatively, per-county acreages could be used to create an indicator of the percentage of land under forest management plans. Information on forest certification could be added from the Forest Stewardship Council, American Tree Farm System, and Sustainable Forestry Initiative.

**Prioritize future forest data sources**

- **Social indicators.** The National Woodland Owner Survey conducts landowner surveys that include attitudinal questions that investigate why private landowners own their land, their intentions with harvest, and their history of harvest and management practices. While not compiled county-by-county, multi-county clusters could be evaluated to determine the suitability of development approaches to local landowner dynamics. For example, in some areas, forest improvement may be a priority while in others it may not "catch on" with landowners.
- **Timber-related employment.** Currently the TPO is the primary data source available for wood production and employment. This survey only measures primary mills, despite the fact that secondary and tertiary processors provide more employment. Also, the survey may only be conducted every five years. The economic picture for mills can change rapidly. With the current economic decline, a significant portion of the mills in Appalachia have ceased or slowed production relative to the last Timber Production Output (TPO) study.
- **Growth-to-removal ratio.** Growth-to-removal ratio is a fundamental measure of forest health that was excluded from the project because of the lack of consistent data across states. It is imperative to know where more timber is being cut than is growing, or vice versa. It is also important to know the species and grade of timber stands. For example, an annual harvest rate of 30% might be sustainable, but this rate might not be spread equally over all species and grades; an annual harvest rate of 150% for red oak sawlogs is not sustainable. Growth-to-removal ratios would aid decision-makers and prospective investors in identifying "hot spots" of over-harvest for certain species or grades and ideal locations for new timber processing or biomass facilities.

**Link sustainability and employment**

Given the need for employment across Appalachia and the great need for forest improvement practices, ARC could undertake a Forest and Communities Restoration Initiative. Such an initiative could identify important forest areas for ecosystem restoration projects, as well as areas of high unemployment where forests need improvement such as thinning, grape vine removal, or invasive species control. Partnering with USDA and non-governmental organizations could help to develop a collaborative pilot project on job creation through "green forest jobs."

Appalachia has a tremendous forest resource, which provides monetary and societal benefits to millions of people from the region and beyond. The general approach to forests, in the past, has been to treat them as a raw material for extraction and export. Transitioning to a value-added system, and monetizing ecosystem services, has the potential to increase prosperity in the region. Stewardship of the resource needs to be improved and monitoring systems developed to track the extent of forest management and secondary value-added activities, among others.

**Proactively address biomass**

Biomass harvest for energy production has the potential to improve forest management, but unmanaged extraction of biomass has the potential to threaten ecosystem health and diminish forest resources if demand is excessive and standards for biomass harvesting not followed. The scale of US energy demand is such that every stick of wood in the US could be used to generate energy and it would not put a dent in our long-term energy demand. Specific strategies for addressing biomass include:

- Map biomass facilities' demand and sourcing areas, and those of existing wood users, maintaining a map that communities and investors can use to determine demand on a county's forests.
- Commission research and a stakeholder process to develop biomass utilization guidelines for the subregions of Appalachia that maintain ecological functionality, forest health, and raw material supply for traditional markets other than bioenergy generation.
- Tie public funding to procurement of wood from managed lands.
- Partner with state foresters and USFS to increase management of Appalachian forestlands and landowner awareness of options and issues in forest management.

A forester in southern Ohio reminds us of the fate of Vinton County when the iron furnaces' demand for wood for energy cleared the land of trees and fostered widespread erosion: "Just remember what happened last time we used the forests for energy." The challenge of our time is to base our decisions on how best to utilize what the forests have to give over the long term, rather than demanding of them what we want at the present. This forest project is a meaningful step in that direction and should be followed by initiatives to integrate this information into the day-to-day decisions made across Appalachia.

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# APPENDIX A: FOREST CARBON PAYMENTS

## Discussion

Appalachian forests provide a valuable ecosystem service as an active carbon sink. Currently, the volume of annual forest growth in Appalachia exceeds tree removal volume (Widmann, unpublished), suggesting that the region's forests are removing more carbon dioxide from the atmosphere than they release through natural decomposition processes. While much of this trend is the result of a decline in demand for wood products, the fact that the region's forests are largely under-stocked and immature means there is a substantial opportunity for future carbon management aimed at reducing atmospheric carbon dioxide, regardless of whether demand for Appalachian hardwood recovers in the future. Managing the region's forests for carbon storage could provide a new and significant source of income for private landowners, contributing to the diversification of the regional economy.

As described by the creators of the forest carbon index (Deveny et al., 2009), three approaches exist for improving the carbon sequestration potential of forests: (1) avoiding deforestation, (2) growing new forests, and (3) managing existing forests to increase carbon stocks. According to these authors:

> "Avoiding deforestation and forest degradation stops emissions before they happen and maintains the carbon stocks at their existing levels. Growing forests through afforestation (growing new forest) and reforestation (regrowing a cleared forest) helps to recapture carbon dioxide and store it in forests." (Deveny et al., 2009)

Markets for wood products and forest carbon storage occur on opposite cycles; therefore, a declining or struggling market for wood products serves as a perfect time to begin building a market for forest carbon. This is because when forest products markets are strong, there is little incentive for private timber owners to invest in forest carbon management without a strong carbon price. Conversely, when there is little competition for the wood from traditional industries, the carbon price needs only to exceed the cost of implementing and maintaining a forest carbon management program.

In both cases, forest carbon management as an economic opportunity in Appalachia requires a price on carbon or a payment for storing carbon over a 25-year period, at a minimum. Other beneficial components include a strong voluntary carbon market; assistance in designing and implementing forest carbon management programs; the implementation of a cap-and trade program on a state, regional, or national level; or other factors:

> "participation (in voluntary forest carbon management programs) is likely to be determined by factors such as the trading price of carbon dioxide, transaction costs, acceptance of forest carbon credits as equally tradeable with credits from emissions reduction, and the accuracy with which additional forest carbon storage can be estimated and reported." (Richards et al., 2006)

As noted by the Pew Center on Climate Change:

> "Several factors affect estimates of cost: forest species and practices; the value of land for alternative uses; the disposition of biomass, forest and agricultural product prices; methods used to account for carbon flows over time; the discount rate employed; and the policy instruments used." (Stavins and Richards, 2005, p. v)

In its review of eleven previous studies on forest carbon storage, the Center notes that a program size of 300 million tons of annual carbon storage would cost $50 per short ton of carbon. Additionally, a 2007 report by the Congressional Budget Office reported that:

- A carbon dioxide price of $5 per metric ton would bring about changes in forest management that would sequester about 5-250 million metric tons per year, which is up to 4 percent of the nation's 2005 carbon dioxide emissions from human activity; and
- A carbon dioxide price of $50 per metric ton would bring about the full exploitation forest carbon strategies, sequestering more than 60 billion metric tons of carbon dioxide over a century (Congressional Budget Office, 2007).

Other studies have also investigated the impacts of various carbon prices on forest management: "If countries are able to sell credits at the market price of $20 per ton carbon dioxide–equivalent in 2020, they could maximize revenues from forest carbon" (Deveny et al., 2009, p. 51). Also, existing carbon offset projects initiated by the Mountain Association for Community Economic Development (MACED) paid Kentucky landowners a total of $65,000 for the carbon their forests stored in 2007. These landowners represent 5,006 acres of forestland that took in and stored 14,500 metric tons of carbon during 2007. That amounts to an average carbon payment of approximately $4.50 per ton, and an average land payment of approximately $13 per acre (MACED, 2009). Examples such as these provide prices and analytical results that may be useful in making projections for the Appalachian region.

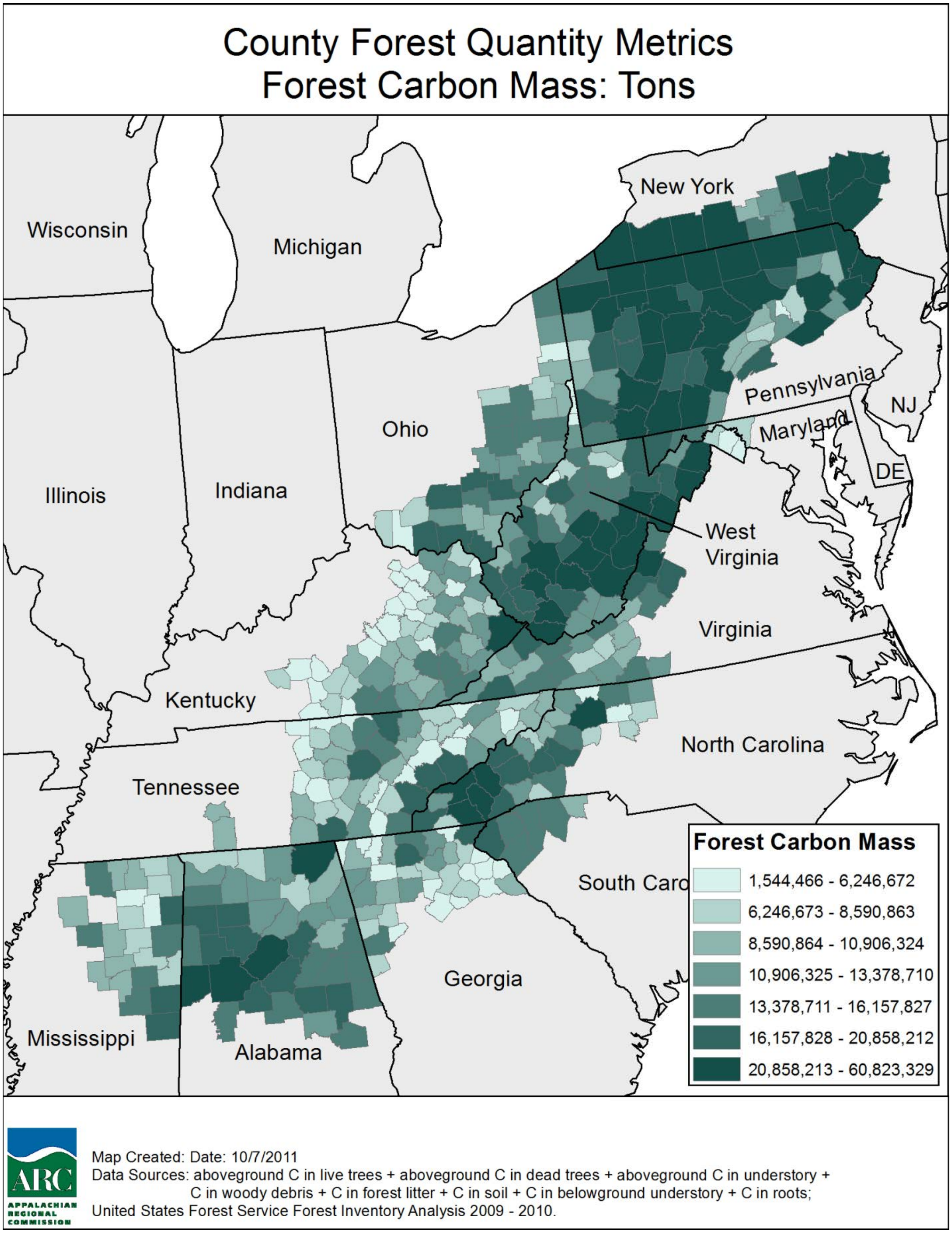
Yet, under a strong voluntary carbon market or a cap-and-trade program, Appalachian policymakers would have to account for the existence of competing uses for forests and how all uses would interact in such a market. In other words:

> "Forest carbon credits will ultimately have to compete with credits generated from all other sectors of climate mitigation in the carbon markets. If offsets generated through energy efficiency projects or methane recapture projects are cheaper than forest carbon offsets, these competing offsets will be preferred in the market." (Deveny et al., 2009, p. 12)

It is imperative to address this issue during the consideration of an Appalachian forest carbon market.

Figure 21 depicts the volume of forest carbon presently stored in forests in the ARC study area. This illustration is a snapshot in time. The map includes carbon that is presently in aboveground live trees, aboveground dead trees, aboveground understory, down woody debris, forest litter, soil, belowground understory, and roots.

**Figure 21: Forest carbon in the Appalachian region**



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# APPENDIX B: CO-FIRING FOREST HARVESTING RESIDUES

## Discussion

Appalachia's vast forest resource offers a variety of opportunities for diversifying the region's economy. One such opportunity that should be better understood for its potential impacts, both positive and negative, is the co-firing of under-utilized forest biomass in coal-fired electric power plants. While an expansion in the use of forest biomass could benefit the region economically, the scale and pace of that expansion could also result in negative changes to the health of the forests or create competition with other wood-using industries. Therefore, it is vital to analyze how demand for these resources will change at varying co-firing rates and over time.

Widmann et al. (unpublished) estimate that Appalachian forests contain approximately 874 million dry tons of *potential* harvest residues such as tree tops and limbs.[5] The same authors also estimate that co-firing biomass with coal for electricity generation in the ARC region's 246 coal-fired boilers would require 25.5 million dry tons of forest biomass each year. Therefore, according to these estimates, the potential harvest residue resource is far greater than what would be required to achieve the region's potential for co-firing with biomass in a single year. The analysis presented below contains a more nuanced analysis, calculating the annual demand for three co-firing scenarios, and comparing these demands against annual—as opposed to total—harvest residues.

The question of whether an expansion in biomass co-firing in Appalachia would impact other wood-using industries must also be addressed. For the purpose of promoting economic diversification and analyzing the degree to which biomass co-firing could contribute to that goal, we aim to determine whether co-firing at different rates would place pressure on existing demand for forest biomass resources, or whether such co-firing rates could be met by using existing and unutilized resources. In this regard, Ray and Ma (2009) estimate that achieving a level where biomass provides 3% of total electricity generation in select Appalachian states would negatively impact other wood-using industries, and that "policies and incentives that promote large-scale wood co-firing of coal-fired power plants (greater than 5 percent) could raise the annual roundwood harvest in the Appalachian states of Maryland, Ohio, Pennsylvania, and West Virginia such that the growth to removals ratio approaches or dips below one" (Ray and Ma, 2009).

On the other hand, "[the] annual positive change in standing inventory coupled with biomass growing in understocked stands and unused harvest and mill residues offers important resources to an emerging woody biomass industry while maintaining current traditional forest products markets" (Widmann et al., unpublished). In other words, because annual forest growth in Appalachia exceeds removals, a substantial percentage of stands are understocked and can be improved with better forest management, and there is a large yet shrinking (Wang et al., 2007) resource in unused harvest and mill residues, the region can support some growth in co-fired generation without competing for resources with other traditional industries.

To determine whether future demand for forest biomass as a feedstock for co-firing with coal can be met with existing and unutilized forest harvest residues, or whether such demand would negatively impact other wood-using industries, we compare estimates of future annual demand with annual harvest residues.[6] However, it should be noted that full utilization of existing residues may also result in negative impacts to forest health due to the ecological benefits the residues provide. We draw no conclusions about what an optimal utilization rate would be for existing residues, but this is an important consideration when

[5] This estimate does not reflect actual harvesting residue volumes generated each year. It only represents the total volume of tree tops and limbs that exist in Appalachian forests.

[6] This analysis focuses only on the use of biomass for co-fired electricity generation. This is due to the substantial impacts that a rapid expansion of co-firing may have on the region's forest resources. However, equally significant impacts may arise from an expanded use of forest biomass for biofuels production and heating purposes.

developing policy that could lead to greater demand for forest biomass resources.

## Data and methodology

We examine three scenarios for the co-firing of biomass with coal in the ARC region. The scenarios are represented by co-firing rates of 2 percent, 5 percent, and 15 percent by heat input, as measured by million British thermal units (mmbtu). The 2 percent co-firing rate was chosen because it is less than the 3 percent rate at which Ray and Ma (2009) estimate that competing wood industries would be impacted. We chose 5 percent because it represents the co-firing rate identified by Ray and Ma (2009) as the limit for select Appalachian states; exceeding this rate would result in annual removals exceeding annual growth. Finally, we chose a 15 percent co-firing rate because it represents a feasible rate that could be achieved with strong policy supports and incentives, but does not exceed the maximum rate at which Bergman and Zerbe (2004) estimate that effective substitution of coal with woody biomass—by heat input—can be achieved. However, others estimate that co-firing at rates greater than 10 percent can reduce the overall efficiency of the coal-fired power plant, but that at the 10 percent rate, the efficiency loss is only about 1 percent (Perlack, 2011; Smith, 2011a).

According to Skone (2012) there are only nine facilities in the US that currently co-fire coal and biomass. These are both utility-owned power plants and pulp and paper mills. Three of these are in the Appalachian region, although all nine are located in the eastern US:

- Stone Container Co. – South Carolina
- Cogeneration South – South Carolina
- Mobile Energy Services Co. – Alabama

Information regarding the co-firing % for the 3 facilities could not be identified, although a 10% biomass to 90% coal rate is used throughout the examples provided in Skone (2012). The purpose of the example in the Forests report is to provide an estimate of what may be achievable under a range of conservative and best-case scenarios (2, 5, and 15%), given the available resources in Appalachia. It is unclear why Skone (2012) chooses a 10% co-firing rate for analysis purposes

The baseline data for heat input from coal is taken from the US Environmental Protection Agency's (USEPA's) Clean Air Markets database, which provides annual boiler unit–level data by state and county for all coal-fired plants. We use 2008 data as our baseline, because it represents the most recent year for which data were available and the US economy was not in a recession. Using conversion rates provided by the federal Energy Information Administration (EIA) and others (Smith, 2011b; Antares Group, Inc. and Parsons Power, 1996), we then estimate the dry tons of forest biomass[7] that would be required, by state and for the region, to achieve the three co-firing levels. In doing so, we present three scenarios for future demand for forest biomass as a feedstock for co-firing with coal for electricity generation.

As a second layer of projection, we use projected rates of change in coal-fired electricity generation through 2020 and 2035 for the seven Electricity Market Module (EMM) regions that cover the thirteen Appalachian states —as published by EIA—to illustrate how our results for biomass demand for the three co-firing scenarios may differ when comparing results based on 2008 coal-fired generation to projected coal-fired generation in 2020 and 2035. Doing so provides a rough idea of how forest biomass demand may change if co-firing rates (e.g. 2 percent) are applied to higher or lower levels of coal-fired generation.

Finally, after generating projections for forest biomass demand for each of our three scenarios, we assess the impact of meeting that demand on the sustainable use of Appalachia's forest assets. We do so by comparing each projection for future demand with estimated volumes of existing harvest residues and with estimated

[7] We assume that the full biomass demand for co-fired electricity generation would be provided by forest biomass.

volumes of total potential harvest residues. This will allow researchers and policy-makers to assess the impact of policies that have been proposed that would influence demand for forest biomass, and/or propose new policy options that would result in the combined benefits of supporting economic development while ensuring the sustainable use of Appalachia's forest assets.

## Estimated forest biomass requirements for co-firing scenarios

This section presents our results for forest biomass feedstock required to achieve a 2 percent, 5 percent and 15 percent rate of co-firing forest biomass with coal—based on heat (energy) input—at coal-fired power plants located within the ARC region. The results are presented in Table 7 by state and for the region. The results represent 228 coal-fired boiler units[8] with a total gross coal-fired electricity generation of approximately 490 million megawatt-hours (MWh) in 2008, which accounted for 25 percent of all coal-fired generation in the US, and 54 percent of all coal-fired generation within the thirteen Appalachian states.[9]

**Table 7: Estimated annual forest biomass requirements for three co-firing rates**

| State | Total heat input, coal (mmbtu) | 2 percent co-firing | | 5 percent co-firing | | 15 percent co-firing | |
|---|---|---|---|---|---|---|---|
| | | Biomass heat input (mmbtu) | Dry tons equivalent | Biomass heat input (mmbtu) | Dry tons equivalent | Biomass heat input (mmbtu) | Dry tons equivalent |
| Alabama | 593,408,195 | 11,868,164 | 690,010 | 29,670,410 | 1,725,024 | 89,011,229 | 5,175,071 |
| Georgia | 376,737,254 | 7,534,745 | 438,067 | 18,836,863 | 1,095,166 | 56,510,588 | 3,285,499 |
| Kentucky | 126,866,780 | 2,537,336 | 147,520 | 6,343,339 | 368,799 | 19,030,017 | 1,106,396 |
| Maryland | 5,142,538 | 102,851 | 5,980 | 257,127 | 14,949 | 771,381 | 44,848 |
| Mississippi | 35,689,277 | 713,786 | 41,499 | 1,784,464 | 103,748 | 5,353,391 | 311,244 |
| N. Carolina | 219,952,337 | 4,399,047 | 255,759 | 10,997,617 | 639,396 | 32,992,851 | 1,918,189 |
| New York | 67,114,559 | 1,342,291 | 78,040 | 3,355,728 | 195,100 | 10,067,184 | 585,301 |
| Ohio | 1,052,107,362 | 21,042,147 | 1,223,381 | 52,605,368 | 3,058,452 | 157,816,104 | 9,175,355 |
| Pennsylvania | 918,990,481 | 18,379,810 | 1,068,594 | 45,949,524 | 2,671,484 | 137,848,572 | 8,014,452 |
| S. Carolina | 13,479,071 | 269,581 | 15,673 | 673,954 | 39,183 | 2,021,861 | 117,550 |
| Tennessee | 199,784,667 | 3,995,693 | 232,308 | 9,989,233 | 580,769 | 29,967,700 | 1,742,308 |
| Virginia | 49,666,024 | 993,320 | 57,751 | 2,483,301 | 144,378 | 7,449,904 | 433,134 |
| W. Virginia | 851,599,413 | 17,031,988 | 990,232 | 42,579,971 | 2,475,580 | 127,739,912 | 7,426,739 |
| **Total** | **4,510,537,958** | **90,210,759** | **5,244,812** | **225,526,898** | **13,112,029** | **676,580,694** | **39,336,087** |

Source: Heat input by state calculated using data from USEPA (2011), and represents the aggregate of heat inputs for all coal-fired boiler units in ARC counties in 2008. Notes: Dry tons equivalent were calculated using conversion factors provided by Smith (2011b) and reported by Antares Group, Inc. and Parsons Power (1996). According to Ma (2011), actual wood demand will be larger than the estimates reported in this table because a fraction of wood energy input would be used for evaporating the moisture remaining in the wood.

As shown in the table, replacing 2 percent of the heat input from coal in the ARC region's coal-fired boilers, at 2008 generation levels, would require an annual forest biomass feedstock (harvesting residues) of 5.2 million dry tons annually, while co-firing rates of 5 percent and 15 percent would require 13.1 million and 39.3 million dry tons per year, respectively.

While the focus of this report is restricted to ARC counties, it is notable that when the same analysis is conducted for all coal-fired boilers located within all counties that make up the thirteen Appalachian states, the required feedstock for each co-firing scenario is approximately 88 percent greater.

## Impact of projected changes in coal-fired generation on future biomass demand

Table 7 presents estimates of the forest biomass requirements for achieving the three co-firing scenarios based on 2008 data. However, significant changes in the relative prices of coal and other fuels for electricity generation, as well as the implementation of more stringent regulation of sulfur dioxide and nitrogen oxide emissions, are expected to alter the fuel mix for US electricity generation. This will have a disproportionate

[8] This number of coal-fired boiler units is slight smaller than the number of units reported by Widmann, et al. (unpublished).

[9] To clarify, the ARC region comprises all or part of thirteen states, but only West Virginia actually lies completely within the ARC region. For the other states, the number of counties lying within the ARC region varies widely.

impact on eastern states, which rely more heavily on coal. Consequently, future demand for forest biomass under the three co-firing scenarios may be higher or lower than estimated in Table 7.

EIA publishes future projections of electricity generation by fuel for various EMM regions,[10] which—for the purpose of conducting more refined projections—reflect subdivisions of the North American Electric Reliability Corporation (NERC) regions. Appalachian states fall wholly or partially within seven EMM regions (see Table 8). Projected electricity generation from coal for each region varies, with some regions—and therefore some Appalachian states—experiencing greater or lesser changes in coal-fired generation over time than others. Table 8 presents the projected rate of change in coal-fired generation, relative to 2008 generation levels, through 2020 and 2035 for each of the seven Appalachian EMM regions.

**Table 8: Projected change in coal-fired generation for Appalachian EMM regions, 2020 and 2035**

| Electricity Market Module region | Appalachian states in region | Percent change in coal-fired electricity generation 2008-2020 | 2008-2035 |
|---|---|---|---|
| NPCC Upstate | New York | -56.7% | -52.4% |
| RFC East | Pennsylvania, Maryland | -2.0% | 6.6% |
| RFC West | Ohio, West Virginia | -3.7% | 13.7% |
| SERC Central | Kentucky, Tennessee | -13.2% | 4.1% |
| SERC VACAR | Virginia, N. Carolina, S. Carolina | -1.1% | 13.8% |
| SERC Southeast | Georgia, Alabama | -9.4% | 7.6% |
| SERC Delta | Mississippi | 16.8% | 15.7% |
| **Total** | | **-5.4%** | **9.5%** |

Source: EIA (2011). Notes: Some states fall within two different EMM regions. For instance, roughly a quarter of the land area of both Maryland and Pennsylvania fall within the RFC West EMM region, while the remaining and greater portion of the two states falls within the RFC East region. For this analysis, we place each state into the dominant EMM region according to proportion of land area, and apply the rate of change in coal-fired generation for that region to the respective state. NPCC = Northeast Power Coordinating Council, RFC = Reliability First Corporation, SERC = Southeast Reliability Corporation, VACAR = Virginia-Carolinas.

As shown in the table, coal-fired electricity generation through 2020 is projected to decline for each of the seven Appalachian EMM regions except SERC Delta. However, as the result of growth in electricity demand—and a projected resurgence in demand for coal-fired electricity—all EMM regions except for Northeast Power Coordinating Council (NPCC) Upstate are expected to experience a net increase in coal-fired generation through 2035 (EIA, 2011). This is also true for the Appalachian region as a whole, and illustrates how demand for Appalachian forest biomass resources may change over time at set co-firing rates.[11] In other words, at each of the three co-firing rates chosen for this study, total Appalachian demand for forest biomass as a feedstock for co-firing with coal may be 5.4%  percent lower than estimated in Table 7 based on projected declines in co-fired generation through 2020, and 9.5 percent higher in 2035.

These rates will be different on the state level. For example, as Kentucky falls within the SERC Central region, it can be estimated that forest biomass demand in Kentucky for co-firing may be 13.2% lower in 2020 than estimated in Table 7, and 4.1 percent higher in 2035. However, it is important to state that significant regulatory changes are likely to occur that have yet to be modeled by EIA, because new regulations were still being drafted when the most recent EIA projections were published. The new regulations are expected to have a significant impact on coal-fired electricity generation (Nelson, 2011), resulting in the retirement of a

[10] The calculations underlying the results in Table 7 use heat input as the basis for calculation, while EIA's projections are reported in billion kilowatt-hours. This is notable because it results in a slight discrepancy when applying projected changes in coal-fired electricity generation over time (measured in kilowatt-hours) to 2008 results for forest biomass demand that were calculated using heat input (measured in btus). Depending on the efficiency of the boiler unit and the quality of the coal being burned, the amount of output—electricity generation—will vary slightly from boiler to boiler and from year to year. However, this would have a negligible impact on our results.
[11] It should also be noted that the projected changes in coal-fired electricity generation represent projected changes for a broad region consisting of more than one state in most cases, and we are applying these regional projections to the ARC portions of states that make up each respective EMM region. This will result in a certain level of error in the analysis, but the EMM projections provide a strong proxy from which to project future changes in coal-fired generation for the boilers located within the ARC portion of the states.

significant amount of coal-fired capacity. Assuming that any new coal-fired capacity developed would fail to equal the retired capacity, this would have a negative impact on coal-fired generation in the region, and therefore the volume of forest biomass required to achieve the three co-firing rates.

## Achievable co-firing rates based on available forest biomass resources

This section analyzes whether existing harvesting residues in Appalachian forests—in other words, tree tops and limbs left behind in the forest following a timber harvest—are sufficient for meeting projected demand for co-firing with coal under each of the three scenarios. To do so, we compare our demand projections with our estimate for current annual volume of harvesting residues as presented in Section 0. Table 9 presents the results of this comparison for each of the three co-firing scenarios based on 2008 levels of co-fired electricity generation. Table 9 also presents the estimated rates of co-firing that are achievable for each state and for the ARC region given existing volumes of harvest residues.

**Table 9: Harvest residues and co-firing demands under three co-firing scenarios, 2008 (dry tons)**

| | | Co-firing demand | | | |
|---|---|---|---|---|---|
| State | Annual harvest residues | 2% co-fire | 5% co-fire | 15% co-fire | Achievable co-firing rate |
| Alabama | 1,788,917 | 690,010 | 1,725,024 | 5,175,071 | 5.2% |
| Georgia | 754,246 | 438,067 | 1,095,166 | 3,285,499 | 3.4% |
| Kentucky | 1,286,753 | 147,520 | 368,799 | 1,106,396 | 17.4% |
| Maryland | 86,555 | 5,980 | 14,949 | 44,848 | 28.9% |
| Mississippi | 863,913 | 41,499 | 103,748 | 311,244 | 41.6% |
| North Carolina | 887,532 | 255,759 | 639,396 | 1,918,189 | 6.9% |
| New York | 800,735 | 78,040 | 195,100 | 585,301 | 20.5% |
| Ohio | 919,536 | 1,223,381 | 3,058,452 | 9,175,355 | 1.5% |
| Pennsylvania | 2,507,563 | 1,068,594 | 2,671,484 | 8,014,452 | 4.7% |
| South Carolina | 221,965 | 15,673 | 39,183 | 117,550 | 28.3% |
| Tennessee | 1,275,330 | 232,308 | 580,769 | 1,742,308 | 11.0% |
| Virginia | 812,849 | 57,751 | 144,378 | 433,134 | 28.2% |
| West Virginia | 1,981,332 | 990,232 | 2,475,580 | 7,426,739 | 4.0% |
| **Total** | 14,187,226 | 5,244,812 | 13,112,029 | 39,336,087 | 5.4% |

Source: Annual harvest are calculated using sources and methods described below in the technical notes to this appendix. Estimates for existing forest harvest residues are conservative as they do not include residues—tree tops and limbs—less than four inches in diameter or less than eight feet long.

As shown in the table, annual forest harvesting residues that exist in the ARC counties within the thirteen Appalachian states are sufficient for achieving at least a 2 percent average rate of co-firing with coal—at coal-fired boilers located within ARC counties—in every state except Ohio (1.5 percent). State-level results vary widely depending on the number and size (heat input capacity) of coal-fired boilers in ARC counties, and on the available harvest residues. On average, however, we conclude that the region as a whole can achieve in excess of a 5 percent rate of co-firing forest biomass with coal using only the existing, unutilized harvest residues, which amount to an estimated 14.2 million dry tons. Any additional demand for co-firing forest biomass with coal would require either additional timber and residue harvesting, or a transfer of woody biomass resources from other wood-using industries.

While the calculations are not shown here, annual harvest residues would be sufficient to achieve exactly a 5 percent rate of co-firing in 2035, using EIA's projections and our calculations of coal-fired electricity generation in ARC states, and assuming that the annual volume of available harvest residues does not change over time. While these assumptions may not occur, the analysis does provide a sense of the volume of forest biomass resources that may be required for co-fired electricity generation in the future.

Figure 7, on page 20 in the main body of the report shows the estimated volume of existing harvesting residues by ARC county, as well as the location and heat input from coal at all coal-fired power plants located in the ARC region in 2008. The map provides an illustration of the proximity—and therefore availability—of forest harvesting residues to the region's coal-fired power plants.

## Conclusions

The US Department of Energy states that the best opportunities for co-firing biomass with coal for electricity generation occur when coal prices are high and annual coal usage is significant (Hayter et al., 2004). Appalachian coal prices, and subsequently the delivered price of coal to power plants across the region, have increased significantly since 2000, resulting in rising electricity costs and greater investment in alternative sources of coal, fuel, and electricity generation (McIlmoil and Hansen, 2010). Additionally, many Appalachian states rely heavily on coal for electricity generation. Therefore, while numerous alternatives to coal exist, greater attention has been paid to biomass in recent years, particularly when the implementation of a national renewable electricity standard appeared likely. Recent political developments have quieted those discussions; however, rising prices for traditional fuels and the prospect of stronger regulation of air emissions from coal-fired power plants may reignite interest in biomass co-firing.

While it is still uncertain whether forest biomass will be used for electricity generation in Appalachia, it is important to understand the potential impacts of expanding the co-firing of forest biomass resources with coal. An expansion in any use of forest biomass could benefit the region economically, but the scale and pace of that expansion could result in negative impacts on forest health and create competition with existing wood-using industries.

This study estimates the volume of forest harvesting residues that would be required to achieve three possible co-firing levels at coal-fired boilers in the ARC region. These volumes are useful for comparing with estimates of existing harvest residues in order to determine the co-firing rates at which existing residues are sufficient for meeting the required demand, both now and in the future, or whether additional harvesting will be required to achieve a target co-firing rate. In doing so, we are able to inform public policy aimed at supporting the expansion of co-firing biomass with coal for meeting renewable energy standards or for achieving targeted emissions reductions. We are also able to determine whether expanding biomass co-firing to certain levels will result in competition for resources with existing wood-using industries—which could hinder rather than promote economic diversification.

Our analysis concludes that achieving a 2 percent co-firing rate at all coal-fired power plants across the ARC region would require 5.2 million dry tons of forest harvest residues annually, while achieving 5 percent and 15percent co-firing rates would require 13.1 and 39.3 million dry tons per year, respectively. With an estimated 14.2 million dry tons of harvest residues available each year, the 2 percent scenario appears to be feasible. The 5 percent scenario is marginal: demand is very close to the estimated annual harvest residues. The 15 percent scenario is not feasible, because it would place demands on the region's forests that clearly exceed their annual production of harvest residues.

Ray and Ma (2009) reached a consistent conclusion; they note that a 5 percent rate of co-firing "could raise the annual roundwood harvest in the Appalachian states of Maryland, Ohio, Pennsylvania, and West Virginia such that the growth to removals ratio approaches or dips below one."

It should be noted that Ray and Ma use a different methodology and a broader area of analysis, focusing on all coal-fired generation and forest biomass for each Appalachian state they studied rather than just the ARC portion of those states. Therefore, we cannot make a direct comparison of the two studies. Despite this, the results of both studies support an important conclusion: that any expansion of co-firing forest biomass with coal beyond the level where unutilized resources are sufficient for meeting the increased demand will have undesirable outcomes, namely increased harvesting beyond a sustainable level or competition for resources with existing wood-using industries. Equally important is the fact that utilizing all existing forest harvesting residues may have undesirable ecological impacts, as harvesting residue provides refuge and foraging habitat for many species of wildlife, is a source of soil nutrients, and supports forest regeneration following natural or man-made disturbances (Grushecky et al., 1998).

These conclusions raise some important questions, particularly in considering how energy policy is structured with the goal of supporting an increase in renewable energy, a reduction of coal-related air emissions, or both. Sample enumerates these questions appropriately, in asking:

> "What is the optimal combination of these technologies that will maximize the contribution of woody biomass to the nation's renewable energy goals, most efficiently utilize wood resources, and ensure that forests continue to be sustainably managed for a range of public values? How will we realign the framework of federal, state, and local policies, mandates, and incentives such that rational economic decisions will result in private capital investment that will produce this outcome?" (Sample, 2010, p. 1)

Sample further points out that "The useful life of a power plant may be 30+ yrs, so the decisions made today will affect the region's communities and forests, and potentially limit other options, for many decades into the future" (Sample, 2010, p. 21). Given these considerations, any expansion of co-firing forest biomass with coal in the ARC region or elsewhere must be limited to a level where growth continues to exceed removals, where existing wood-using industries are not negatively impacted, and where resource demand and consumption do not negatively impact the health and regeneration of forests. As noted by Widmann et al. (unpublished), these goals may be achieved through maximizing the use of available underutilized resources and by improving the productivity of forests and the health of forest stands through improved forest management practices. These approaches should be pursued before promoting the use of forest resources such as forest harvesting residues as a feedstock for co-firing with coal at levels that negatively impact the health of Appalachia's forests or traditional wood-using industries.

## Technical notes

### Conversion of million btus of heat input to dry tons of forest biomass required to achieve a given co-firing rate

Estimates of the heat content of forest biomass vary. However, a conversion rate of 17.2 mmbtu of heating potential per dry ton of forest biomass was provided by EIA (Smith, 2011b) and reported by Antares Group, Inc. and Parsons Power (1996). This is the conversion rate chosen for this study.

The calculation for estimating the dry tons of biomass required to achieve a given co-firing rate is structured as follows:

> Dry tons of forest biomass = mmbtu of heat input x target co-firing rate / 17.2 mmbtu per dry ton

The heating value depends on the species of tree; however, we use an average heating value of woody biomass and apply that value to our calculations for the Appalachian region. A more refined analysis would estimate potential forest biomass demand by using state- or forest-specific average heating values.

### Estimating changes in coal-fired electricity generation in Appalachian states through 2020 and 2035

EIA publishes annual reports titled *Annual Energy Outlook* that, among other things, provide projections of annual coal-fired electricity generation through 2035 for each EIA-defined EMM region. The EMM regions represent sub-divisions of the larger NERC regions. A map of the EMM regions modeled by EIA can be found here: www.eia.gov/forecasts/aeo/pdf/f2.pdf.

There are seven EMM regions that include or are wholly comprised of Appalachian states. Some states fall within two different EMM regions. For instance, less than half of the land area of both Maryland and Pennsylvania fall within the Reliability First Corporation (RFC) West EMM region, while the greater portion of the two states falls within the RFC East region. For our analysis, we place each state into the dominant EMM region according to proportion of land area, and apply the rate of change in coal-fired generation for that region to the respective state. This provides an estimate of how coal-fired electricity generation may grow or decline for each of the thirteen Appalachian states.

To estimate future demand for forest harvesting residue under our three co-firing scenarios, we apply the projected rates of change in coal-fired electricity generation for each state to total 2008 heat input from coal in the ARC region's coal-fired boilers and produce aggregated values for coal-based heat input. These values are used in the analysis to estimate future demand for forest biomass by state. Doing so relies on a few assumptions that are important to note:

1. that the EMM region chosen for states that fall within the boundaries of more than one EMM region is appropriate, meaning the chosen EMM region overlaps with the ARC portion of the state;
2. that each state that falls within a certain EMM region will experience the same rate of change in coal-fired electricity generation over time as the EMM region does on average;
3. that the state-level estimates for changes in coal-fired electricity generation over time apply to the ARC portions of the respective state—in other words, we apply the state-level rate of change to the coal-fired boilers located within the boundary of the ARC region; and that the average heat content of coal burned at coal-fired boilers within each state will not change over time.

## Estimating annual forest harvesting residues by county

FIA does not report harvesting residues; however, given the growth in wood-using industries and the expansion in demand for historically underutilized forest biomass resources, there is a strong need for better data on county-level harvesting residues. For this study, we generate our own estimates for the average volume of harvest residues that remained in Appalachian forests following timber harvest in 2009 and 2010. To estimate the existing harvest residues by county and state in the ARC region, we:

1. determined the average acres of timberland in the Appalachian region in 2009 and 2010, using data obtained from FIA;
2. applied a 2 percent annual harvest rate to the total area of timberland to estimate the acreage of harvested timberland for 2009 and 2010; and
3. applied an average forest harvesting residual per acre harvested of 8.2 tons per acre. Multiplying 8.2 tons per acre by the estimated acreage of timber harvest resulted in an estimated volume for annual harvest residual. This calculation was performed for each ARC county, and the results are illustrated in Figure 7.

The 2 percent harvest rate used in the calculation represents an average harvest rate as presented by Grushecky (2009) for West Virginia. As other similar studies are not available for determining a state-specific average harvest rate for all ARC states, we apply this rate to all ARC counties.

Similarly, the lack of available research on forest harvesting residuals in other ARC states required us to use the best available information. Therefore, the multiplier used in this study of 8.2 tons of harvest residue per acre harvested was drawn from the same analysis, which was conducted for West Virginia forests in 2007 (Grushecky, 2009). This is slightly smaller than a previous estimate of 8.4 tons per acre reported for West Virginia based on harvests in 1993 and 1994 (Grushecky et al., 1998). A later study focusing only on the southern counties of West Virginia found an even higher density of harvest residues at 10.4 tons per acre

(Grushecky et al., 2006). Each of these estimates are considered to be conservative since they were generated without measuring residues less than 4 inches in diameter or less than 4 feet in length.

Grushecky et al. (2006) report wide variability in forest harvesting residue density among different species—ranging from 0.1 (cherry and softwoods) to 5.0 (oak) dry tons per acre—as well as among individual counties. For instance, the average density of harvest residues in Boone County, West Virginia is reported as 12.7 tons per acre, while that for Logan County is reported as 7.1 tons per acre. These examples of variability in post-harvest residue density illustrate the need for better county-level data for harvest residues, as harvesting rate, harvest practices, species composition, and other factors may result in under- or overestimates of residues. However, for this study we used the best available research and information.

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# APPENDIX C: FOREST HEALTH AND BIOMASS

## Evaluating degraded stands and management opportunities for improving forest health and increasing woody biomass availability in the Appalachian region

### Discussion

Degraded hardwood forest stands in Appalachia contain trees that are of poor form, unsound, or diseased; are of non-merchantable species; or have residual damage from harvesting operations and corresponding lower growth rates compared to healthy forests. Degraded stands may also have low stocking densities or patches of low stocking, and may lack advanced regeneration of desirable species. As a result of previous management or harvesting practices, these degraded stands do not contain adequate densities or volumes of merchantable growing stock trees, which presents both challenges and opportunities for future management of such forest resources.

A study on the effects of harvesting practices on West Virginia's wood supply (Fajvan et al., 1998) showed that 25 percent of the sites harvested during the study year had the majority of residual trees classified as ungraded growing stock, but still carried a basal area density of 70 square feet per acre. Stands are usually not considered to be seriously degraded unless they contain less than 50 square feet per acre of acceptable growing stock trees (Clatterbuck, 2006). Therefore, the stands considered in this analysis do not contain sufficient numbers of acceptable growing stock trees, and can be considered to be seriously degraded residual stands that can benefit from some type of management activity for improving forest health.

Seriously degraded stands should be regenerated, as they simply do not contain enough acceptable growing stock to successfully be improved through rehabilitation practices. Regeneration methods usually require the removal of most trees, while leaving the understory seedlings and saplings intact and void of their larger competition. Depending on the species composition and size of the understory, the desired forest structure and composition can be influenced by proper understory management techniques in the years immediately following a regeneration harvest.

The immediate benefits of degraded stand management to the forest are minimal and the trees removed are usually of low quality. However, even low quality trees can be utilized as a raw woody material. The long-term benefits to the forest are greater, and include the regeneration of merchantable tree species of good form and vigor, improved aesthetics, greater resiliency to disturbances such as insects and fire, and greater potential for terrestrial carbon storage by decreasing the risk of carbon loss and increasing forest growth (Ryan et al., 2010).

### Data and methods

This analysis reports the estimated annual volume of woody biomass available from seriously degraded residual stands, with the assumption that all stands could benefit from a regeneration harvest to improve forest health. Woody biomass availability is the focus of the analysis because the research of Fajvan et al. (1998) classified degraded stands as having wood fiber potential, which suggests a low quality material ideally utilized as feedstock for biomass-related energy enterprises.

FIA data were compiled for Appalachian counties. To calculate the annual potential volume of available woody biomass from degraded residual stands, the net volume of live trees and the annual harvest rate in terms of cubic feet of wood volume removed were queried from the FIA database. The forestland area subject to annual harvest was assumed to be 2 percent of the total forestland area within each county, and harvested areas with the majority of residual trees classified as ungraded growing stock were assumed to be

25 percent of the total annual harvest area (Fajvan et al., 1998). The calculation of the volume of woody biomass available from degraded stands was formulated as:

$$V_{degraded\_stands} = (v_{average} * a_{harvest}) * \%_{degraded}$$

Where:

| | |
|---|---|
| $v_{average}$ = | average cubic foot per acre of county forested area minus annual removal volume |
| $a_{harvest}$ = | acres of forested area subject to harvest within county |
| $\%_{degraded}$ = | percentage of harvested forest area classified as degraded stands |

## Results

Applying the results from the Fajvan et al. (1998) study suggests that upwards of 788 million cubic feet of post-harvest residual live tree volume could be available for utilization from approximately 430,000 acres of degraded stands in the Appalachian forest region. Degraded stand areas ranged from 140 acres in Hancock County, West Virginia to greater than 3,400 acres in Delaware County, New York. The average area of degraded stands across the Appalachian forest region was approximately 1,000 acres per county.

Because it was concluded that all degraded stands in this region could benefit from a regeneration harvest, and that the focus was to utilize the harvested trees as woody biomass feedstock, a conversion to dry mass is necessary. We assume an average specific gravity of 0.50 for green wood equates to an average dry wood density of 31.2 pounds per cubic foot (Forest Products Laboratory, 1999). This yields approximately 12 million dry tons of woody biomass at 100 percent utilization. Hardwood species account for 90 percent of the biomass potential, whereas softwood species comprise the rest. However, complete utilization of the woody material is virtually impossible to achieve even with recent forest harvesting and chipping technology, and therefore a more realistic utilization level would be less than 12 million dry tons. Results of potential woody biomass volume ranged from approximately 27,000 tons in the western counties of Maryland to 2.4 million tons in the Appalachian counties of Pennsylvania (Table 10). County estimates appear to be greatest in the central Appalachian forest region and generally taper in the counties closer to the regional edge (Figure 22).

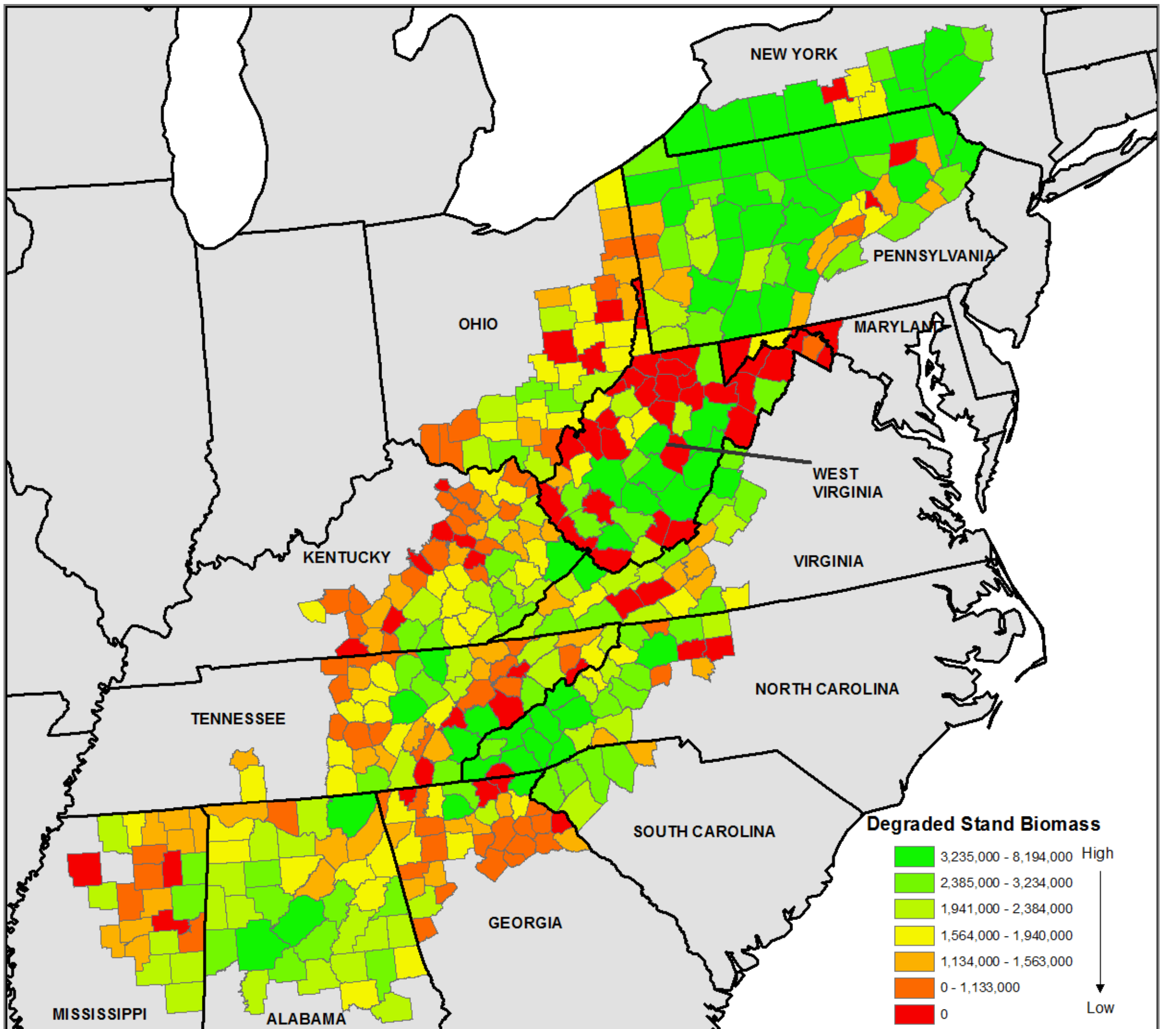
**Table 10: Available volume of woody biomass via regeneration of degraded stands**

| | Hardwood | | Softwood | | |
|---|---|---|---|---|---|
| State | Tons | Percent | Tons | Percent | Total |
| Alabama | 862,580 | 66% | 444,871 | 34% | 1,307,451 |
| Georgia | 549,936 | 77% | 163,372 | 23% | 713,308 |
| Kentucky | 1,112,175 | 98% | 26,428 | 2% | 1,138,603 |
| Maryland | 25,884 | 95% | 1,261 | 5% | 27,145 |
| Mississippi | 312,996 | 59% | 216,337 | 41% | 529,333 |
| New York | 715,711 | 88% | 95,448 | 12% | 811,159 |
| North Carolina | 1,015,009 | 92% | 90,661 | 8% | 1,105,670 |
| Ohio | 725,809 | 97% | 18,827 | 3% | 744,636 |
| Pennsylvania | 2,368,637 | 96% | 94,817 | 4% | 2,463,454 |
| South Carolina | 168,889 | 79% | 44,909 | 21% | 213,798 |
| Tennessee | 1,173,047 | 93% | 83,917 | 7% | 1,256,964 |
| Virginia | 758,246 | 93% | 53,302 | 7% | 811,548 |
| West Virginia | 1,153,200 | 98% | 17,749 | 2% | 1,170,949 |
| **Total** | **10,942,119** | **89%** | **1,351,899** | **11%** | **12,294,018** |

## Conclusion

Regenerating degraded forest stands through active forest management can contribute a substantial amount of woody biomass for utilization within the Appalachian forest region. The regeneration of these stands will also decrease the susceptibility to insect and disease disturbances by improving forest health, therefore mitigating the risk of carbon loss associated with the increased mortality from such disturbances. Furthermore, a healthy regenerated stand will grow more quickly and thus increase the carbon uptake in trees. Increasing carbon uptake and decreasing the risk of carbon loss will yield greater terrestrial carbon stocks in the future, as well as provide a healthier forest overall.

**Figure 22: Available woody biomass in degraded stands**




**Map Title:** County Forest Degraded Stand Biomass

*Date: 10/3/2011*

***Map Note:*** *On the map, counties with predictors of high degraded forest biomass are colored green; those with lower predictors degraded forest biomass are colored red*

***Data Source:*** *US Department of Agriculture, Forest Service National Forest Inventory and Analysis (2009/2010)*

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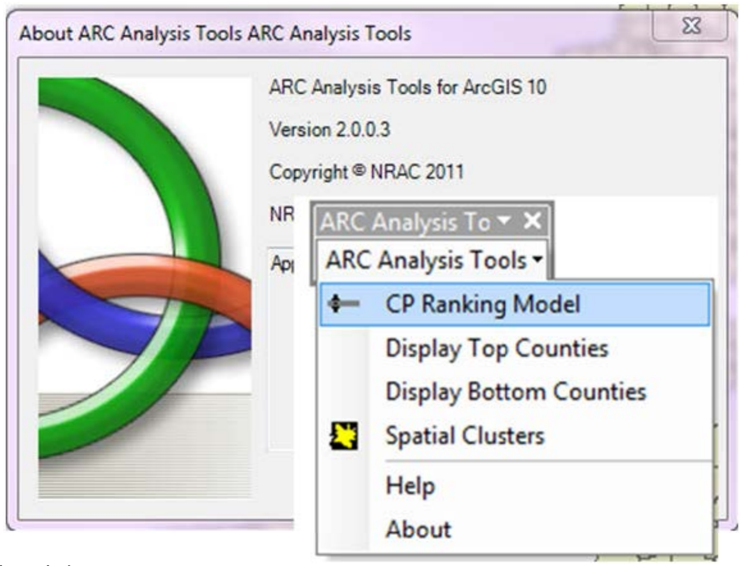
# APPENDIX D: DECISION SUPPORT SYSTEM

## Integrated GIS tool

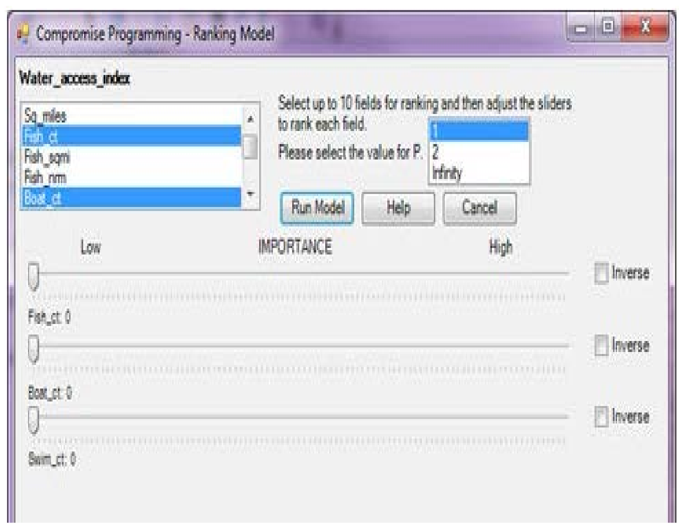
One of the important aspects of any applied research project is the method of communicating results to decision-makers. The output of our study includes an interactive GIS-based DSS (Figure 23) that allows resource managers to evaluate inputs and results of this study, understanding the true spatial nature and relationships of these natural assets. This system integrates spatial data, user input, and a ranking algorithm within a multiple criteria analysis (MCA) framework. The goal of this framework is to provide a tool to integrate spatial data with a MCA-solving algorithm called compromise programming (CP), which allows users to quickly and interactively explore and analyze county-level data.

**Figure 23: Decision support system**




MCA is an alternative approach to traditional economic evaluation techniques. The basic idea behind MCA is to provide a framework for analyzing choices with multiple criteria and conflicting objectives (Malczewski, 1999). A spatial MCA approach aids in the identification of the most suitable management solution for a given purpose. The approach also allows users to examine the effects of alternative options and presents options in a variety of forms such as monetary units, physical units, and qualitative judgments. This makes it possible to analyze tradeoffs between different objectives and address potential conflicts at an early stage, thereby providing the ability to analyze the sensitivity and robustness of different choices.

**Figure 24: Screenshot of tool interface**

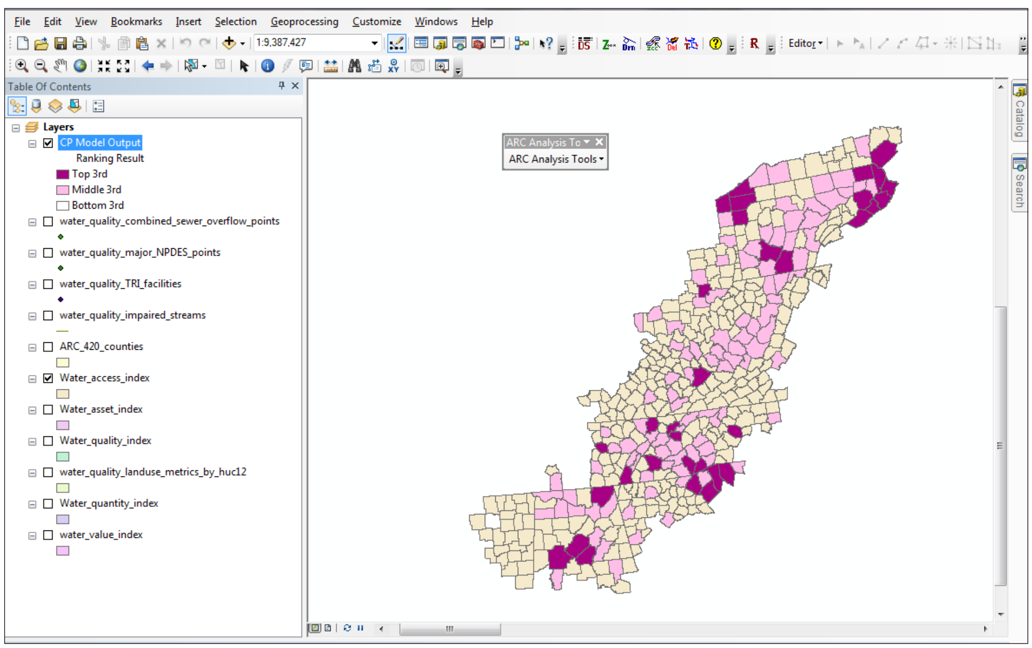



The CP ranking algorithm was chosen because it allows a more theoretically significant ranking of alternatives as compared to a linear weighted model. It also allows the user to integrate sensitivity analysis by altering weights and parameter values to highlight the concern of the decision-maker over the degree of separation or difference from the ideal criteria score. The highest ranked results are those that are closest to the ideal or furthest from the least preferred alternatives. CP algorithms have been used in many different MCA applications including ranking of irrigation technologies (Tecle and Yitayew, 1990), planning water resource systems (Duckstein and Opricovic, 1980; Gershon and Duckstein, 1983), developing forest watershed management schemes (Tecle et al., 1988a), selecting wastewater management alternatives (Tecle et al., 1988b), defining hydropower operations (Duckstein et al., 1989), and performing river basin planning (Hobbs, 1983).

The tool compares allows the decision-maker to assign a weight (or importance value) to each individual criterion and then combine all criteria together for a comprehensive overall result. End users can combine and map the various factors for ranking economic development and forest resources in the ARC region. The final spatial model uses an extension to ESRI's ArcGIS software. The extension consists of a graphical interface designed to guide the user through the process of interactively specifying weights and viewing results Figure 24. This model also provides the ability to display the top- and bottom-ranked counties and to map spatial clusters.

The CP ranking model requires that the user first highlight or make active a shapefile in the table of contents that contains attributes the user wishes to use for the ranking (Figure 25). It is assumed that the user already calculated or added the needed fields to the table in order to use the ranking model. All of the criteria are normalized by the program, so the user does not have to worry about non-commensurate data. All that is required is the direction of value influence. For example, if a higher value for an attribute is desired, then nothing has to be altered in the CP interface; this is the default. However, if the user feels that a lower value is preferred, the inverse button should be selected.

**Figure 25: Selecting a shapefile to be used in the ranking**



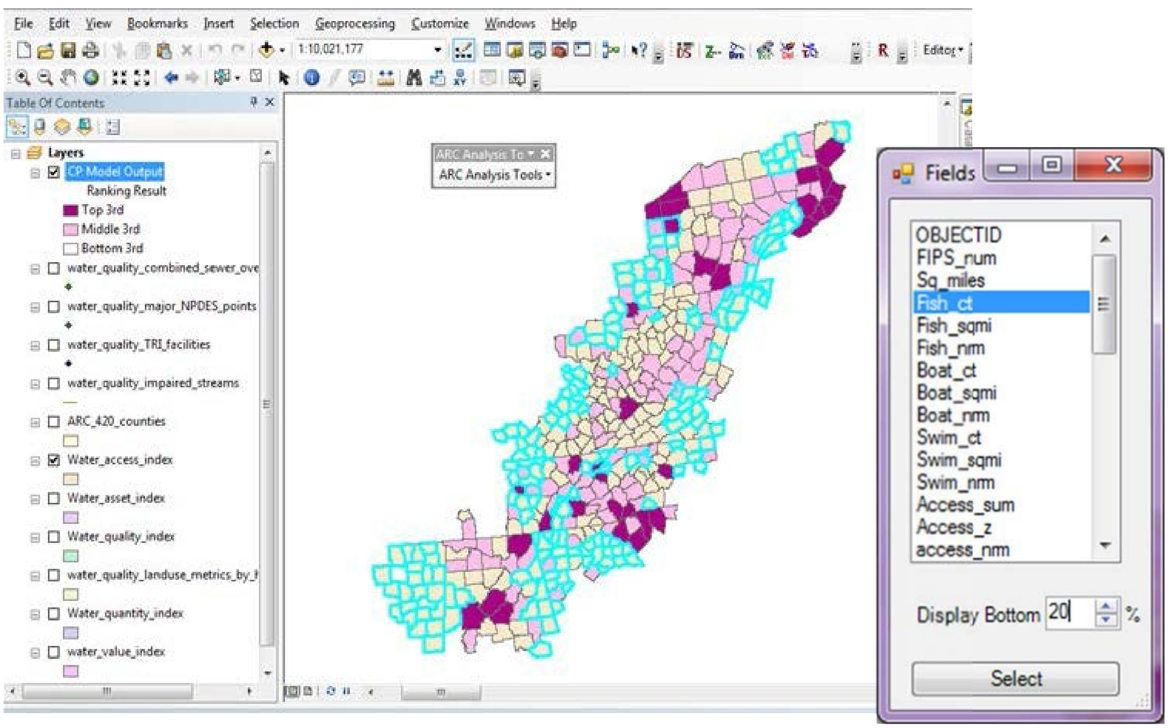

The parameter values of *P* indicate the concern of the decision-maker over the deviation from the ideal values. These values represent the concern of the decision-maker over the maximum deviation (Tecle and Yitayew, 1990; Duckstein and Opricovic, 1980). The larger the value of *P*, the greater the concern. For *P* = 1, all weighted deviations are assumed to compensate each other perfectly. For *P* = 2, each weighted deviation is accounted for in direct proportion to its size. As *P* approaches infinity, the alternative with the largest deviation receives more weight and importance (the largest of the deviations completely dominates) (Zeleny, 1982). To solve the multi-criteria problem using the CP algorithm, the vectors of ideal point values and worst values are determined and then used to compute the values distances from the ideal points. The preferred alternative has the minimum *Lp* distance value for each *P* and weight set that may be used. Thus, the alternative (county, in our example) with the lowest value for the metric will be the best compromise solution because it is the nearest solution with respect to the ideal point. The parameter *P* acts as a weight attached to the deviations according to their magnitudes. Similar weights for various deviations signify the relative importance of each criterion (Romero and Rehman, 1989).

The result of the model run is the addition of a new field to the shapefile—the CP metric. Lower values are preferred and a legend is produced automatically for the user. This legend can always be altered to show a different display of the ranked counties. The true utility of the tool is in the ability to quickly run different scenarios and test the spatial sensitivity of results.

## Finding the top or bottom percentages

Some of the other tools available for the user include the ability to find the top or bottom percentage of ranked features. This was designed to highlight the counties that meet certain threshold requirements in regard to the rankings (Figure 26).

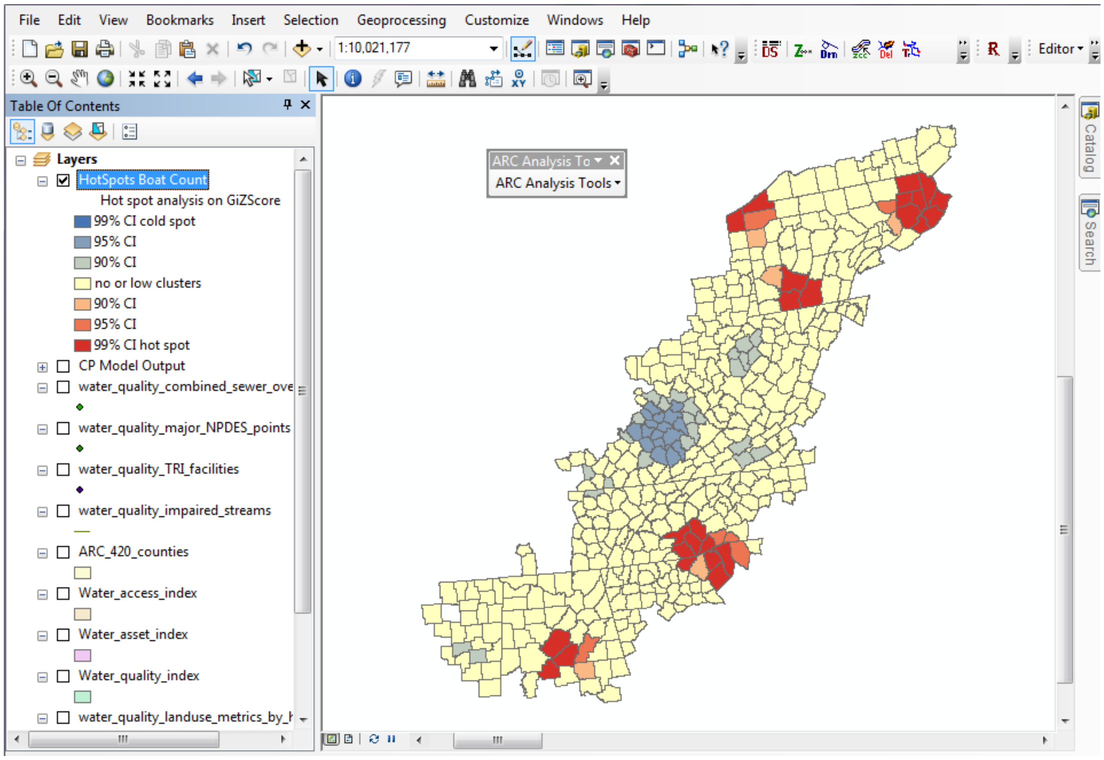
**Figure 26: Percentage queries for the highest and lowest percentages**




## Spatial clusters

The Spatial Clusters Tool is based on a hot spot analysis. This is a spatial statistical calculation that takes into account the spatial position of features and their attributes. The purpose of using the tool is to find areas with high values surrounded by other high values (hot spot) or low values surrounded by other areas with low values (cold spot) that are statistically significant. Figure 27 shows spatial clusters for a sample indicator, which include both hot and cold spots.

**Figure 27: Hot and cold spots**




It is important to carefully select the analysis field. The *Z*-scores and *P*-values are measures of statistical significance, which tell users whether or not to reject the null hypothesis, feature by feature. In effect, they indicate whether the observed spatial clustering of high or low values is more pronounced than one would expect in a random distribution of those same values.

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# APPENDIX E: STAKEHOLDER RESPONSES

## Appalachian forest assessment stakeholder survey

The Appalachian Region Forest Stakeholder Survey was conducted as an online survey gathering input for the Forest Assessment from several categories of stakeholders involved in forest resource management, community economic development, and economic and recreational uses of the forest. The survey was conducted and analyzed by the National Network of Forest Practitioners' Appalachian Forest Resource Center.

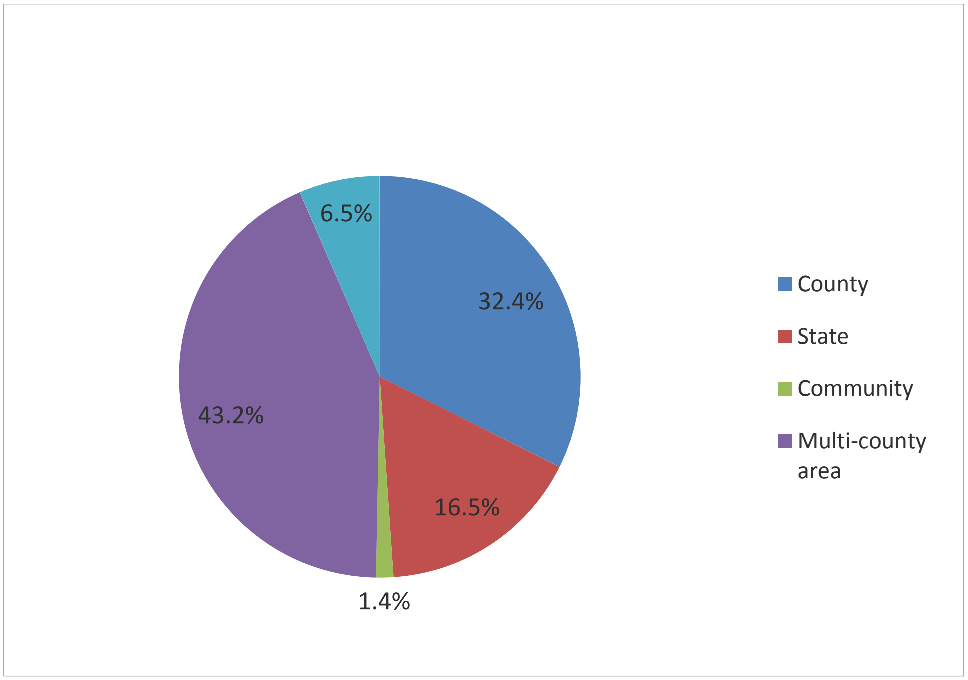
## Respondent role and scale

The survey was sent to 697 recipients across the Appalachian region, including local development districts, conservation districts, resource conservation and development districts (RC&Ds), private foresters, federal and state land managers, and Natural Resources Conservation Service (NRCS) staff. 141 of those surveyed participated, yielding a 20% response rate. Of the respondents, the largest numbers were local development districts, conservation districts, conservation organizations, NRCS foresters, and RC&Ds.

Respondents answered from multiple perspectives. While we included them in surveys because of their formal roles in the region, they often self-identified with multiple roles (NRCS staff and "Hunter/Outdoorsman" or soil and water conservation district supervisor and logger). Several others self-identified as forest landowners. The results are richer for this pattern, but the ability to define differences in results between respondent groups is limited by their identification with multiple stakeholder roles.

**Figure 28: Stakeholder roles**

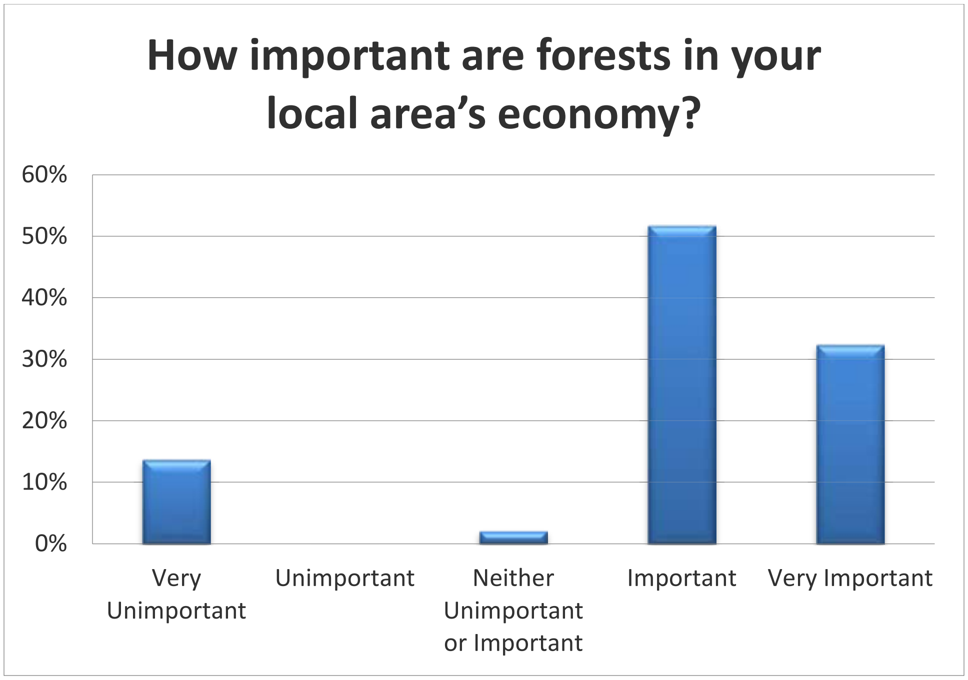
**Figure 29: Scale of work**




## Closed-ended questions

The following questions were assigned a rating on a five-point scale. The bars on each chart are ordered from a rating of one (Very Unimportant) to a rating of (Very Important).

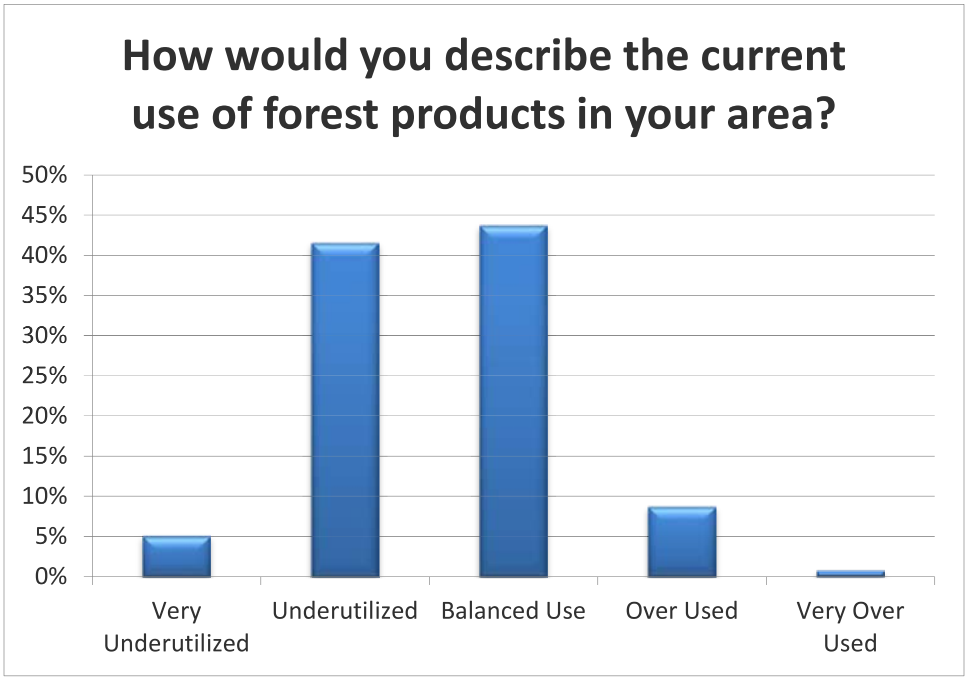
**Figure 30: Economic importance**




Note: The average score was 3.89.

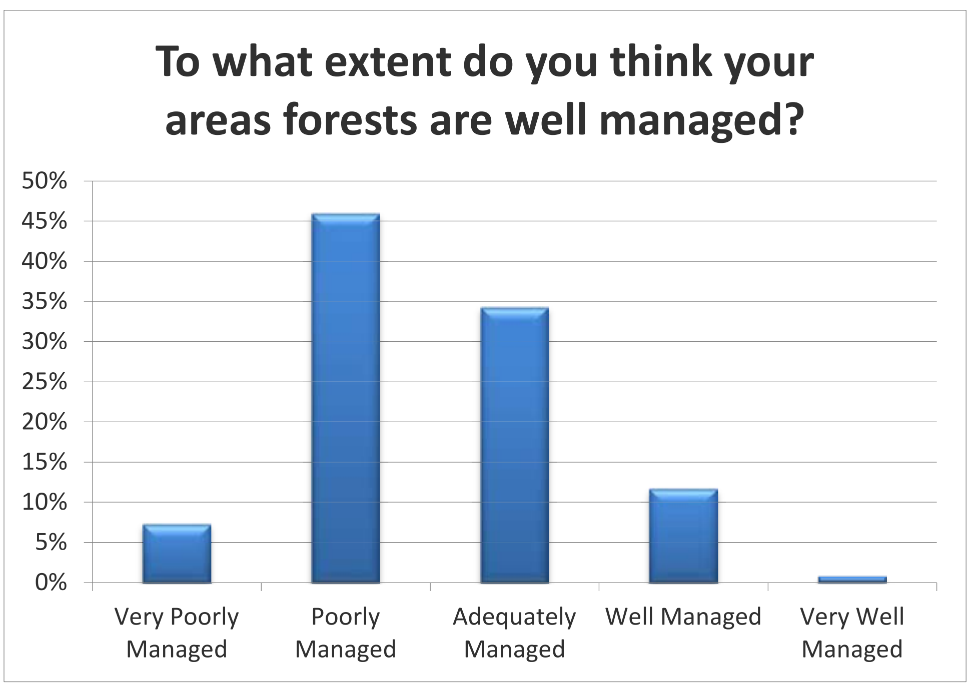
Respondents generally felt forests were economically important in their areas. 52 percent rated forests as "Important" to their areas economy, and 32percent characterized them as "Very Important." 14 percent rated them "Very Unimportant" to their area's economy.

**Figure 31: Forest products utilization**



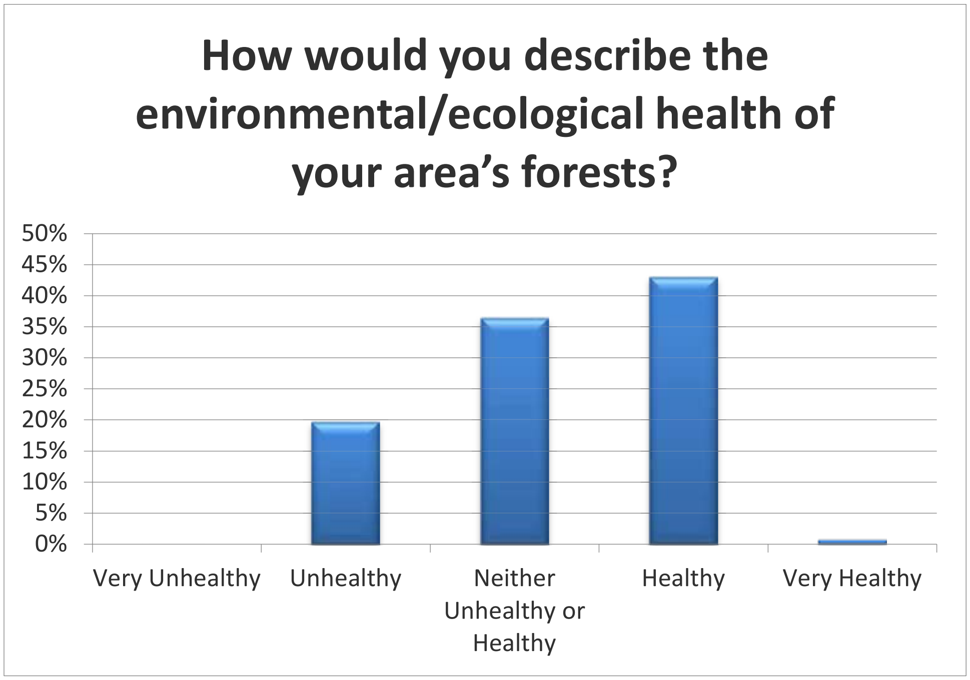

Note: The average score was 2.58.

**Figure 32: Management**



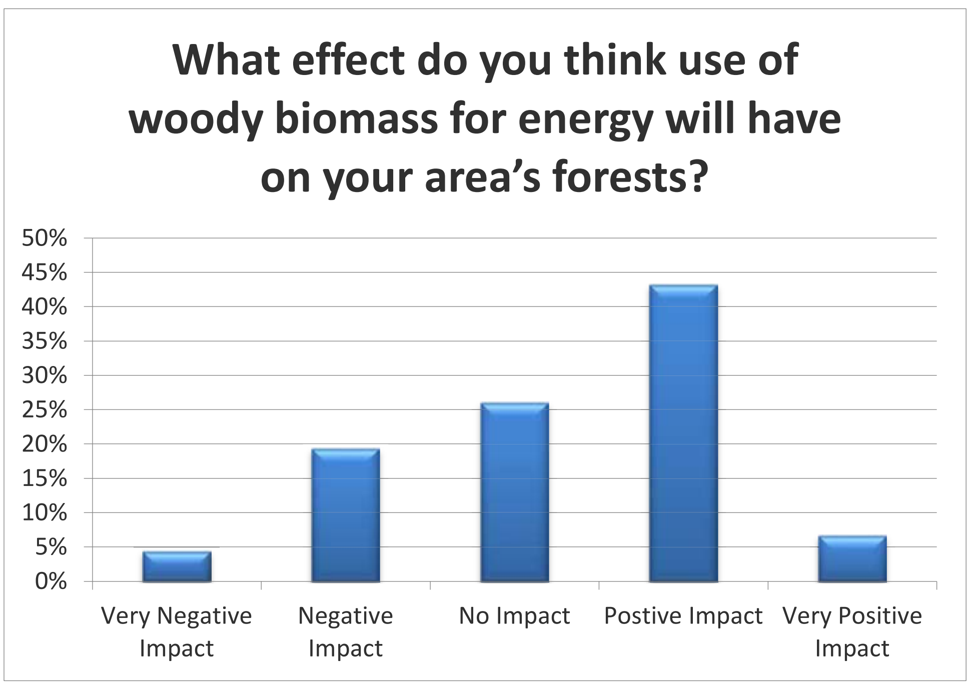

Note: The average score was 2.51.

**Figure 33: Forest health**




Note: The average score was 3.17.

**Figure 34: Biomass**




Note: The average score was 3.34.

When asked to explain their answers ("In what ways will the use of woody biomass for energy impact your area's forests?"), many respondents said there could be negative or positive impacts depending on whether harvesting was done in accordance with management plans and best management practices.

The topics brought up in the open-ended answers broke out into three primary categories with some individuals mentioning multiple categories:

1. Potential economic benefits of biomass utilization (despite the fact that the question focused on forests- this may have biased results as respondents focused on community benefit rather than answering about how it would impact the forests).
2. The importance of management plans and harvesting practices in influencing the impact of biomass (again, this was unsolicited, so a large percentage probably agree with this).
3. Comments that indicated concern about negative impacts on soils, regeneration, diversity, soil fertility, and biomass demand could lead to increase erosion, and conversion from diverse forests to less diverse stands. There was concern that the additional demand could result in over-harvest:
   - *It is a poor idea that will lead to forests being stripped and land destroyed affecting the overall soil and water conditions.*
   - *I am concerned that landowners would not follow BMPs on our Highly Erodible soils*
   - *It could very well destroy them! Forests are more than wood products. Woodland plants, wildlife, water quality, recreation and aesthetics are but a few examples.*

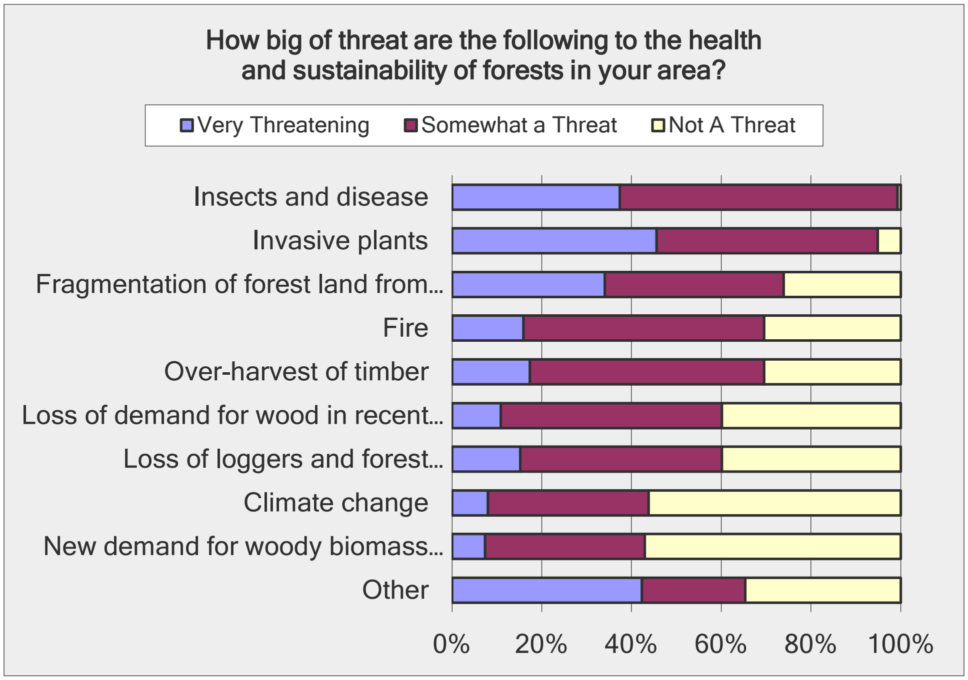
Interestingly, some of the strongest comments were not from environmental or conservation groups but from soil scientists, forestry technicians, and others actually involved in forest science.

The first statement (perhaps the strongest) was from a conservation district member who identified his stakeholder role as a logger (he was answering based on his perspective as a logger more than conservation district member).

These results are surprising as one might expect environmental groups to say things like "it may destroy the forest" but having a local logger say that is surprising. His rationale was that removal of the slash (small downed wood like treetops) would remove protection for the saplings and greatly damage regeneration. Given the general concern with regeneration and deer browse, his perspective fits with some other stakeholder concerns. He also mentioned concerns about soils.

Given the history of clearing and cropping on Appalachia's soils it is probably reasonable to be concerned about the impact of removing the biomass that otherwise cycles into organic matter in the soil. Research has also shown that the lack of coarse woody debris (sticks and logs on the forest floor) can have significant impacts on forest ecology.

**Figure 35: Forest threats**




**Insects and disease**

Overwhelmingly respondents felt that insects and disease problems posed a threat to the forests in their areas.

**Invasive plants**

The only category that participants felt was “Very Threatening” more than insects and disease was Invasive Plants.

**Fragmentation/Development**

Likely there is geographic skew to these responses. Some areas in Appalachia are experiencing greater levels of land development while in other places it really is less of a threat.

**Over-harvest**

Over two thirds of respondents felt timber harvest was a threat. However, in the FIA data, there is substantially more timber growing than is harvested, so this perception may be at odds with the scientific data. But in some areas certain grades or species are often harvested faster than they grow, and in certain areas harvest is greater. New demand for biomass will likely increase wood removals, but it is uncertain if how much they will drive harvest on additional acres. With the current decline in harvest due to market depression, it is likely that the issue of over-harvest is more one of perception than fact in most places. This perception is very important to be aware of and to include in regional planning and communication.

**Other**

Interestingly, climate change showed up as being considered by more than half of respondents to be “Not a Threat.” There is significant scientific evidence that climate change will impact forests significantly, and it is likely that the severity of insect, disease, and invasive plant problems in US forests is exacerbated by climate change, or will be in the future. There appears to be a disconnect between the current science and perceptions in the region around this issue.

The loss of forest workforce was not seen as an issue by over a third of the respondents. In many areas a significant percentage of the workforce (loggers, etc.) has been lost during the recent collapse of timber markets. In addition to the recent losses from the market disruption, the overall age of loggers in many parts of the region is very high, and the next generation is often not as interested in taking on that occupation. This is anticipated to result in a reduced ability to conduct forest management practices until a new workforce is developed. The knowledge and skills of the workforce will also be lost.

Respondents added numerous responses in the "Other" category, including loss of high value markets, impacts of strip mining, oil and gas leasing, lack of forest management plans, loss of species diversity, acid rain, and inadequate removal of logging roads. Problems with regeneration and deer browsing pressure were also mentioned by multiple respondents.

## Open-ended questions

A number of open-ended questions were posed in the second half of the survey which produced several thousands of responses which we coded into categories based on the number of responses. For responses that included more than one answer (e.g., suggesting three important threats or opportunities) we coded each of the answers, so the total percentages are the percentage of all participants that included a certain response.

The coding of open-ended responses is not a precise as tabulation of answers where participants select from a defined set of choices, so the numerical values should be taken with a grain of salt. The richness of open-ended questions is in the range of replies produced by stakeholders.

**7. In what way will the use of woody biomass for energy impact your area's forests?**

See details in the section above, but in general respondents indicated that they believed that biomass markets could:

- + Contribute to better management and more awareness of forest management. (25 percent)
- - Lead to over-harvest, and remove nutrients from already depleted forest ecosystems. (25 percent)
- + Help create jobs and create markets for low quality wood that could help pay for forest restoration efforts. (31percent)

Several respondents felt biomass harvest could be positive if the right elements were in place (27 percent) such as:

- Biomass harvesting guidelines utilized consistently
- Use of BMPs by landowners and loggers
- Low impact harvesting methods
- Management plans for harvested lands

Generally the sense was that if biomass is harvested as part of a management plan, following appropriate guidelines it could be good. If proper care is not taken biomass could have a negative impact on soils and forest health. Some people believed that it would be deterministically good or bad, but most seemed to feel like it depends.

Several respondents indicating significant alarm and fear of the potential negative impacts of biomass harvest. Surprisingly, those were not the environmental respondents but included forestry professionals and a logger.

**Figure 36: Forest threats**

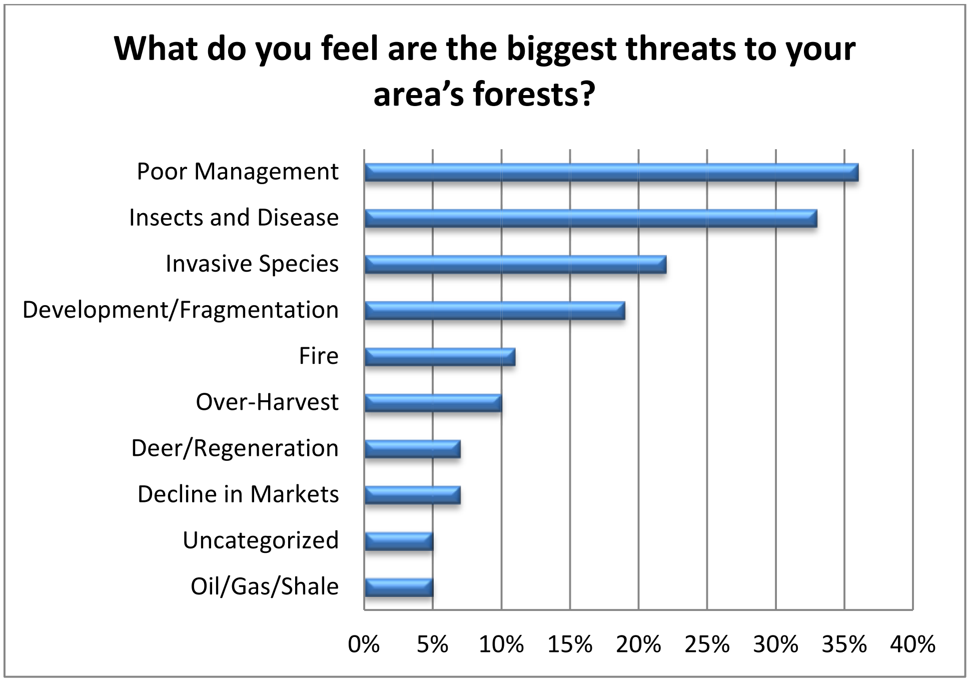
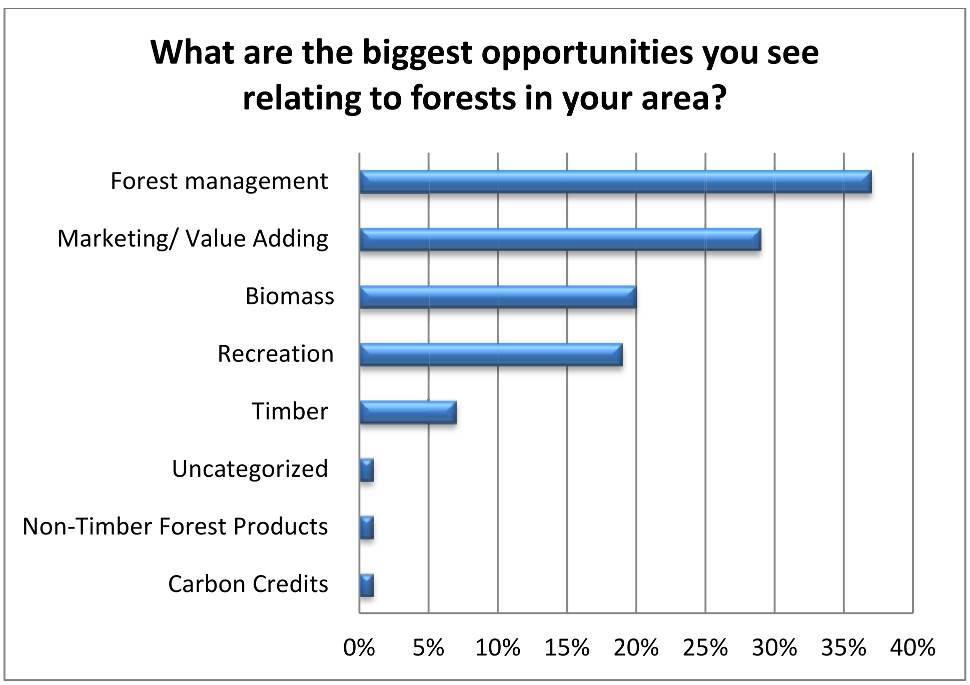



**Figure 37: Forest opportunities**




**Forest management.** This included increase in use stewardship/ forest management plans by landowners, improved management practices, certification, ecological restoration, and resources for management plans and practices. Harvesting on steep slopes without causing erosion was an issue of note. The general sentiment was that there was an opportunity in improving timber and forest resources, benefitting economically and ecologically. Some programs exist, but even current ones operate with a backlog "state agency is understaffed and often have to tell a woodland owner it may be 6-8 months before they can meet with them to develop a management plan" (waits are even longer in some areas, though this was not mentioned by survey respondents).

**Marketing/ Value adding.** Increasing the secondary/value adding to wood (e.g., furniture making rather than just shipping out raw lumber) was a major emphasis, as was helping local wood producers capture markets (green building, specialty markets etc).

**Biomass.** Most responses were general, though the use of biomass markets to improve forest management (and remove material that needs to be removed in improved management) was highlighted. This was seen as compatible with existing timber production (but relies upon management choices to that end)

**Recreation.** Most responses were general with an emphasis on hunting and tourism. Some mentioned infrastructure needs (horse, mountain bike, and hiking trails as well as camping) as well as increasing open/public lands (undoubtedly in certain areas but not others). Nature based/eco-tourism was also mentioned by multiple respondents.

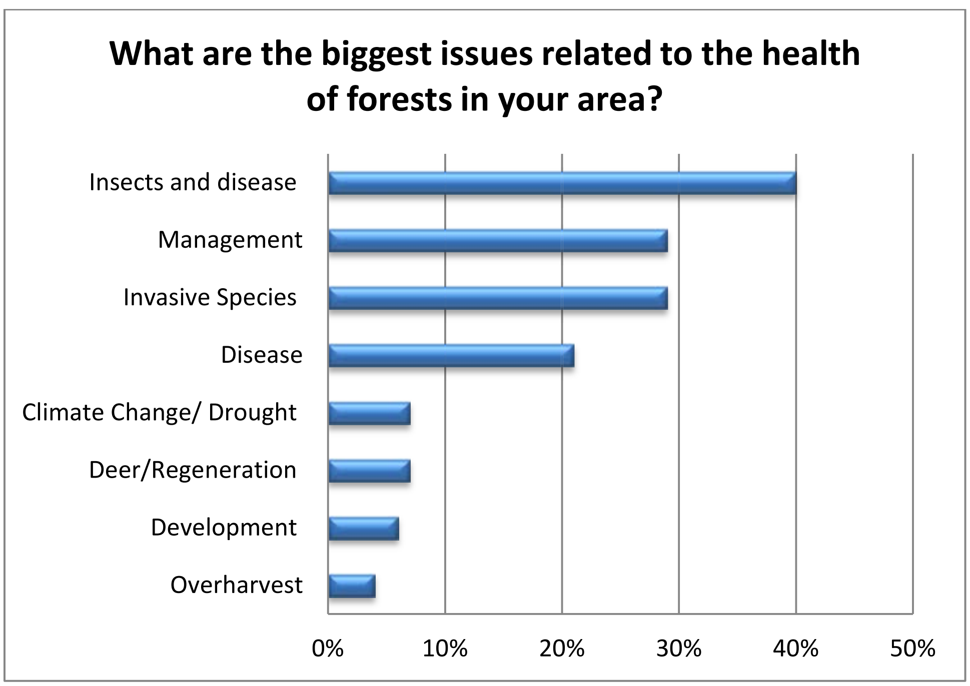
**Timber.** Timber was widely viewed as a resource. For some it was also an "opportunity" based on rebounding markets, "careful" harvest, Etc.

**Carbon credits.** It is likely that two years ago this would have been higher, but with carbon trading markets collapsed only two people mentioned this. If cap and trade legislation happens or carbon otherwise monetized in a consistent way interest will likely be much greater.

**Non-timber forest products.** Ginseng, mushrooms, and other products.

**Uncategorized.** Urbanization was mentioned. Without more description it is unclear if this relates to markets for wood, recreation or something else. One respondent indicated "There just aren't opportunities." This may be a wider-spread attitude that would need to be addressed before much happens in some areas.

**Figure 38: Forest health**



**Insects and disease.** Details in other question

**Invasive species.** This largely referred to invasive plants, Ailanthus in particular.

**Management.** This referred both to management and landowner knowledge about management. High-grading (harvesting of the most commercially desirable grades and species leaving stands degraded) was a big issue, though "lack of management," "no management," and "lack of active management" were at least as common answers.

**Disease.** Details in other question

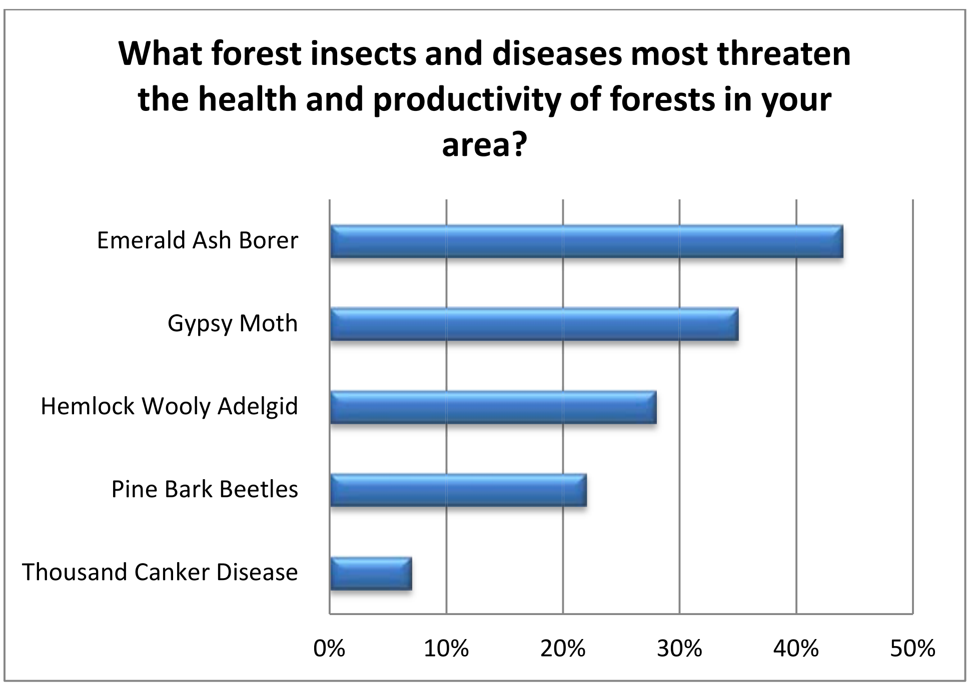
**Deer/Regeneration.** Deer overpopulation is a big issue in some parts of the region. It is probably one of the biggest threats in certain areas, with "nice looking" stands but no regeneration.

**Climate change/Drought.** Both drought and climate change were mentioned. These were grouped together as climate factors. Likely droughts and over-wintering of species because of unusually warm winters will exacerbate many of the other problems forests face. Interestingly pollution was not mentioned often, despite great impacts on high elevation forests in the region.

**Development.** Development and fragmentation was clearly a big issue for many respondents but they seemed to focus on it less when asked about issues related to forest health. Many of the other issues (invasive plants etc.) are impacted by this, however.

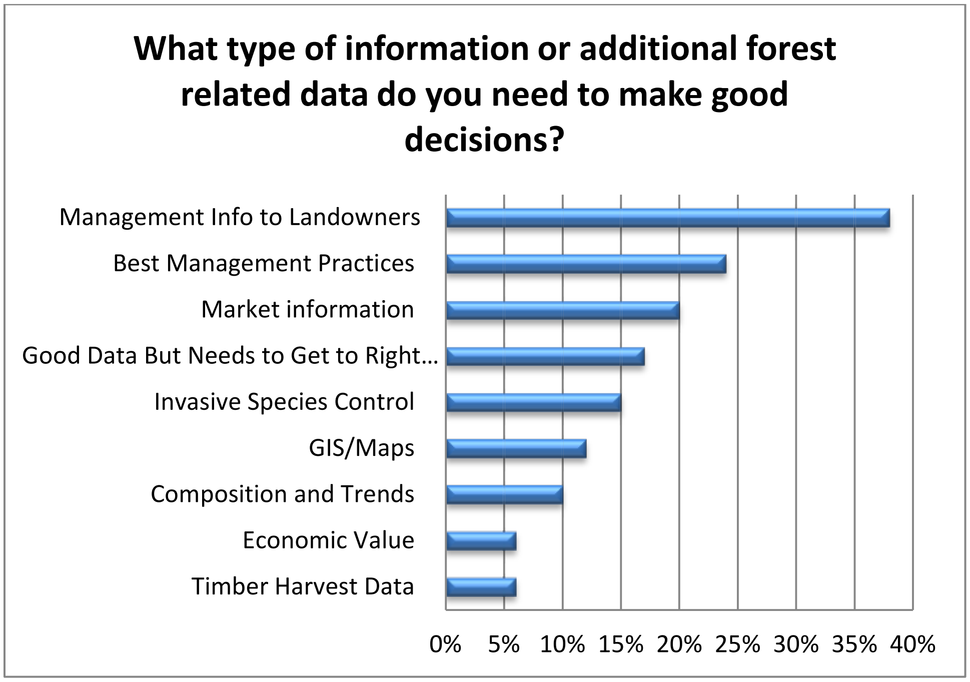
**Over-harvest.** As referenced earlier, the region is not overharvested. Some places, some species, some grades may be over-harvested.

**Figure 39: Forest insects and diseases**




Note: Answers to this question were mostly to inform the indicator development process. Different subregions experience different threats.

**Figure 40: Information or data needed**




**Management Information to Landowners.** This overlaps some with other information such as BMPs

**BMPs.** This was not the BMPs already established for harvesting operations but best practices broadly: management of small parcels, construction of trails, sustainable biomass production, invasive species control, results of new scientific research, forest' role in stormwater runoff, reducing livestock impacts on forests, and decision support tool for small landowners.

**Market information.** This included current and historical timber pricing, where to market timber (a list of mills that is updated often and easily available was suggested). Market trends and projections were also mentioned.

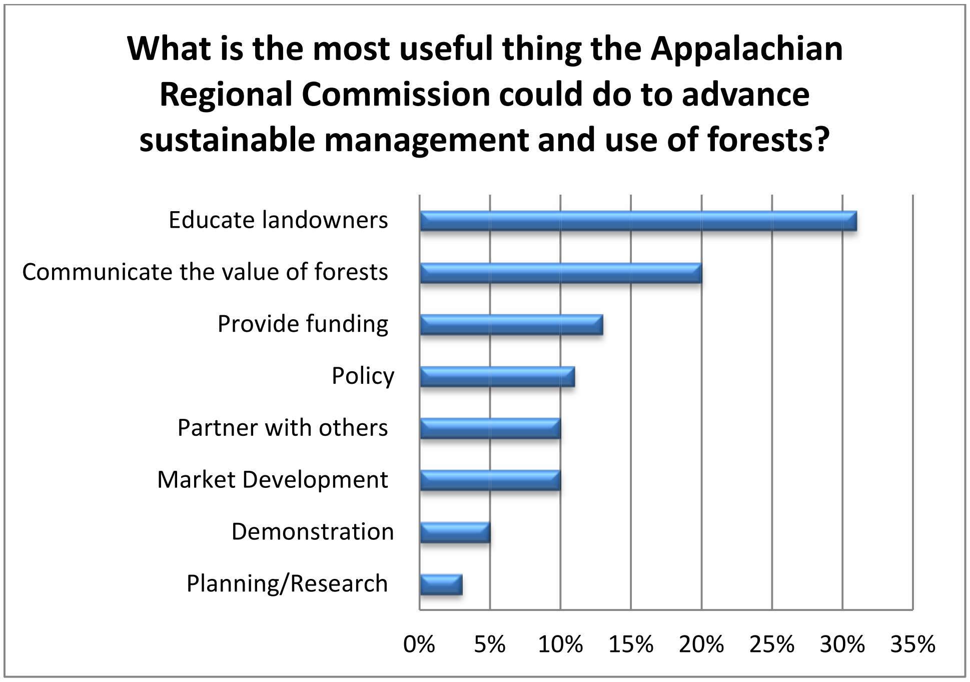
**Good data but…** Good scientific/technical information exists, but it needs to get to the right people (primarily landowners).

**Invasive species control.** Current information and new research.

**GIS/maps.** Current and historical information as well as ecologically oriented GIS layer.

**Economic value.** This included value of timber as well as standing trees, and economically preferable biomass species.

**Figure 41: The most useful thing the Appalachian Regional Commission could do**




While many participants were not sure of ARC's role, the following were the suggestions for what could be done by ARC to advance sustainable management and use of forests:

**Educate landowners.** This area, overlapping some with the next, focused on encouraging landowners to get management plans, encouraging the use of a professional forester, and providing information through publications and trainings. Some was routine information and some was about improved practices "Develop and disseminate best practice information." Overall this cluster of answers reinforced the sentiment of focusing on improved forest management as a key to sustainable use of forests and broader economic benefit.

**Communicate the value of forests.** There was a broad feeling that greater public awareness of the benefits of the region's forests was important. "Outreach- people need to know how important our forest resource is." "Market both tangible and non-tangible values." "Serve as a catalyst for community engagement in defining the future uses of forests." "Educate forest landowners of the benefits to implementing forest management plans." Some of the emphasis was landowner awareness but the majority was broader: "Educate the public!"

**Provide funding.** Funding has been cut in many forestry divisions across the region. Whether it is through advocating for more funding for forestry programs or providing direct funding for specific activities, a number of respondents pointed to this role for ARC. Ideas for ARC's role focused mostly on reinforcing/supporting/deepening efforts to reach landowners with information on management, but also included incentives for restoration and improved stewardship, support for organizations "leading the way with sustainable forest products," support for industrial parks, and training for loggers.

**Policy.** Tax issues and active management of public lands were mentioned twice each. Other suggestions were largely single responses. Laws mandating use of Best Management Practices (voluntary in many states) were suggested, as was additional funding for landowner incentives for management. Recognition of ecosystem services and monetization of these services was also mentioned.

**Market development.** Promotion of the region's wood products was mentioned (particularly as a green/renewable material) as was promotion of non-timber products from the region (ginseng, mushrooms, etc.). Improved market information was mentioned, as was assistance in expanding woody biomass use.

**Partner with others.** While the percentage of respondents who mentioned this was low, the emphasis was very clear and it is probably a sentiment shared by others. "Don't recreate the wheel, it wastes money," "Don't reinvent the wheel."

**Demonstration.** Suggested demonstrations included biomass pilot projects, demonstrations of the benefits of forest management, Low Impact Development and Green Infrastructure (mentioned twice), and a conference sharing best practices currently being demonstrated.

**Planning/Research.** Ideas included a comprehensive study of Eastern WV forests to encourage proper management techniques for forest health, sustainable design of highways and roadways, and greater understanding of the region's soils (and their potentials and limitations)

Respondents also provided additional comments ("If there is anything else you feel we missed that you would like to comment on about the role of forests in your area, please do so here.")

*"Timber harvest is a once in a lifetime thing for most landowners and they need help in deciding how to do that harvest to ensure a good future harvest some day."*

*"Forests control erosion on our steep slopes…Fisheries are suffering real damage due to lack of enforcement of BMPs on log roads and harvesting practices…Drive through (Webster and Randolph counties) in the winter and observe the number of uncovered dirt log roads silting our streams. It is saddening. Look at the number of cuts on one hillside. Do roads really need to be cut every 150 to 200 feet on a mountain side? Permanent roads that are properly drained and gravel paved can benefit logging companies along with other BMPs via saving future recutting, reclamation, and maintenance."*

*"Wayne NF [National Forest] can play a role of modeling landscape level oak-hickory restoration. However, we have low capacity for outreach."*

*"We have more pressure from housing growth destroying forest areas than from other sources."*

*"It seems difficult to get private forest landowners to understand the importance of developing a forest management plan and using sound practices in forest harvest operations to ensure sustainable forest management."*

*"In today's world of "green" alternatives to all of the world's woes, trees are a renewable, biodegradable, all natural resource. We need to utilize them to our benefit."*

*"WV relies on the forestscape for tourism. Maybe the State should offer incentives to maintain the forest. ARC should work to develop the infrastructure to establish finish use industry here in the region and not allow our raw material to be sent oversees for processing. Jobs in WV."*

## Conclusions and recommendations

Many of the results are self-explanatory and will not be discussed. But in the interests of providing some highlights and insights from the report this section will provide some additional commentary.

While much of ARC's emphasis has been on infrastructure and entrepreneurship, there was a clear indication from stakeholders that they felt there were opportunities in addressing how the forest resource was managed.

With as many as 90% of landowners harvesting timber without a forester involved and more than 90% in some areas not having any management plan for their forests, there is a great loss of current and future benefits.

Timber stands in the region are generally neglected and often just treated as a "savings account" where landowners will liquidate valuable timber when they need cash for medical, inheritance, or other expenses. The economic benefits could be greatly increased if deliberate forest management takes place. Landowners would benefit from increased timber income, wood users such as mills would benefit from greater quantity and quality of merchantable lumber, and communities would benefit from increased value-adding and greater profitability from milling of higher quality timber.

But forest management is a long-term process. ARC would have to be committed to investing in the region rather than looking just for immediate job creation or income benefits. Forests are an asset that will appreciate over time and which will generate income and wealth over the long haul if invested in.

The benefits of improved management are not just greater timber revenue. Forests can be healthier and more resilient and can sequester greater quantities of carbon dioxide.

Development strategies that create jobs and income now from "high-grading" existing timber will reduce long-term prosperity. Approaches that involve improved forest management will result in greater long-term forest health, timber abundance, and prosperity.

Nowhere is this more true than the demand for biomass. Respondents felt good about the potential for biomass to create economic opportunities and maintain or improve forest management. But this is likely to be true only if timber is well managed.

Highly concentrated demand (for example that of biorefineries or large scale electricity generation which require supply in the millions of tons) would likely have distorting impacts if not harvested from lands under management. Areas close to facilities would likely be over-harvested or liquidated (with some amount of valuable sawlog and veneer growing stock being diverted to low-value biomass use) while remote areas would be little impacted.

Pairing biomass development with incentives for forest management can clear out a lot of "junk" from the woods, improving growing stock and long-term production of valuable sawlogs and veneer. Without that incentive for management the opportunity for using biomass markets to improve our forest will largely be missed, and in some areas the harvest will have negative impacts.