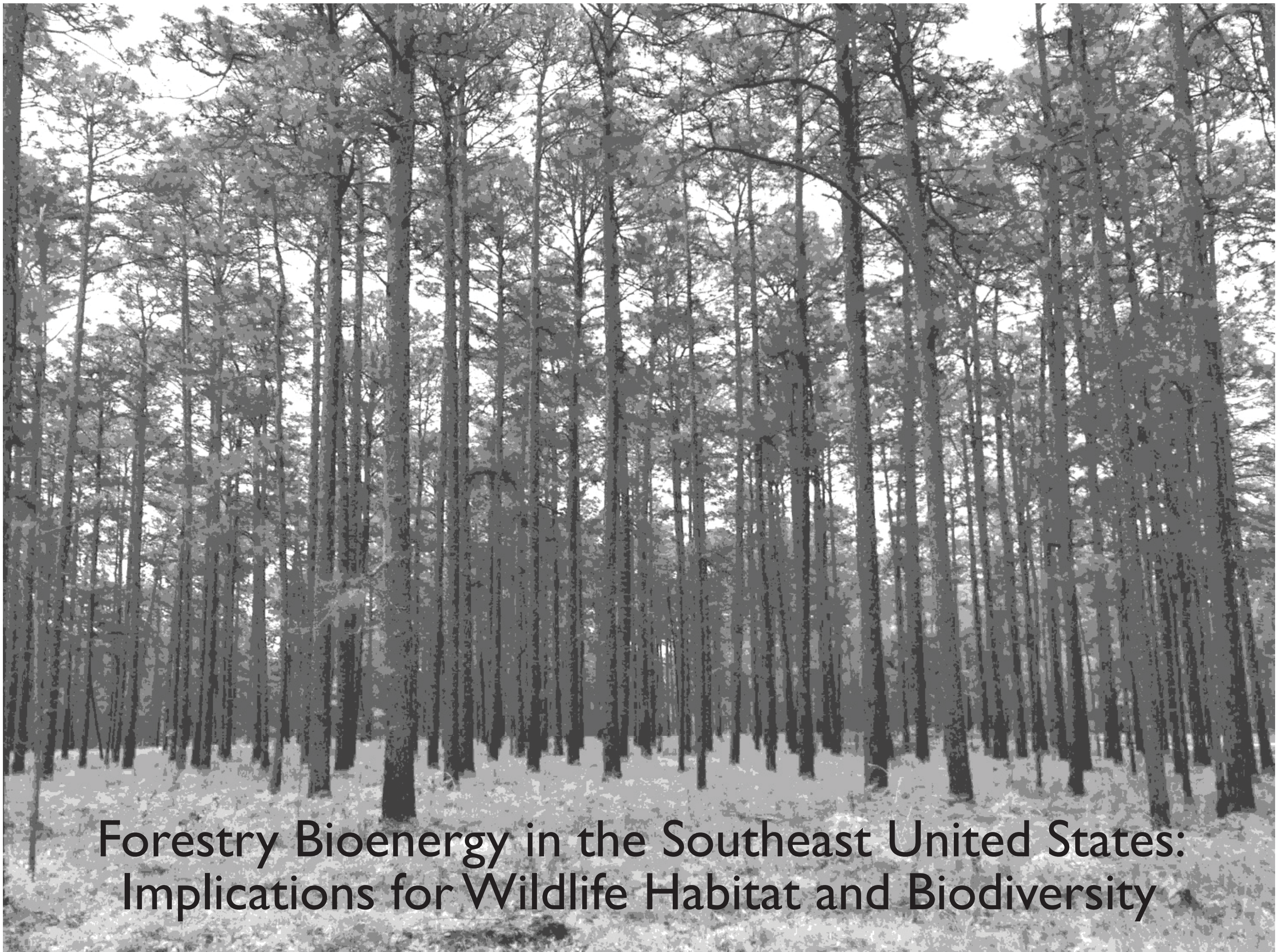

Forestry Bioenergy in the Southeast United States: Implications for Wildlife Habitat and Biodiversity

Final Report DRAFT
December 5, 2013

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Research for this project was conducted through a collaborative effort between faculty and graduate student researchers at the University of Georgia, University of Florida, and Virginia Polytechnic Institute and State University (a.k.a., Virginia Tech University). Chapter 2, authored by Daniel Geller (University of Georgia, College of Engineering) and Jason M. Evans (University of Georgia, Carl Vinson Institute of Government), provides an overview of facilities chosen for the study's focus. Chapter 3, authored by Divya Vasudev, Miguel Acevedo, and Robert J. Fletcher, Jr. (all from University of Florida, Department of Wildlife Ecology and Conservation), provides a presentation of conservation analysis methods and identification of indicator species. Chapter 4, authored by Jason M. Evans, provides a technical explanation of spatial modeling methods employed for the facility case studies. Chapters 5-10, authored by Jason M. Evans, Alison L. Smith (University of Georgia, College of Environment and Design), Daniel Geller, Jon Calabria (University of Georgia, College of Environment and Design), Robert J. Fletcher, Jr., and Janaki Alavalapati (Virginia Tech University, Department of Forest Resources and Environmental Conservation) provide the results and discussion of facility case study analyses. Chapter 11, authored by Pankaj Lal (Montclair State University, Department of Earth and Environmental Studies), Thakur Upadhyay (Virginia Tech University, Department of Forest Resources and Environmental Conservation) and Janaki Alavalapati, provides an overview of forestry biomass energy policies within state, federal, and international contexts, as well as the increasing policy attention to biodiversity concerns. Chapter 12, co-authored by all investigators, synthesizes the results of the report into a series of suggestions for policy consideration and future research studies. Executive Summary and Final Report layout completed by Alison L. Smith.

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Cover photo credit: Tiffany Williams Woods

TABLE OF CONTENTS

LIST OF FIGURES
PLACEHOLDER

LIST OF FIGURES
PLACEHOLDER

List of Acronyms

AF&PA - American Forest and Paper Association
ATFS – American Tree Farm System
BCF - Biomass Conversion Facility
BCAP - Biomass Crop Assistance Program
BMP – Best Management Practice
CoC- Chain of Custody
DWM – Downed Woody Matter
EA - Environmental Assessment
FMP – Forest Management Plan
FNP - Forests No Pasture*
G1 – Critically Imperilled (Nature Serve Classification)
G2 - Imperiled (Nature Serve Classification)
G3 - Vulnerable (Nature Serve Classification)
FSA - Farm Services Agency
FONSI - Finding of no Significant Impact
FNW – Forests no Wetlands*
FOR – Forests*
FSC - Forest Stewardship Council
FSP – Forest Stewardship Program
GAP – National Gap Analysis Program
GHG – Greenhouse Gas
GIS – Geographic Information Systems
HAO – Harvest Area Objective
HNW - Hardwood No Wetlands*
HWD – All Hardwood*
MCE – Multi-Criteria Evaluation
MOLA - Multiple Objective Land Allocation
NEPA - National Environmental Policy Act
NIPF - Nonindustrial Private Forest
PDP - Plantation, Disturbed and Pasture*
PEFC - Programme on the Endorsement of Forest Certification
PNP - Plantation and Disturbed, No Pasture*
PO – Plantation Only*
RPS - Renewable Portfolio Standards
SE – Southeastern (US)
SFI - Sustainable Forestry Initiative
SFM - Sustainable Forest Management
SHARP - Sustainable Harvesting and Resource Professional
SMZ - Streamside Management Zone
SWAP – State Wildlife Action Plan
UPL – Uplands*
WLC – Weighted Linear Combination

*Land Cover Sourcing Screen

I. INTRODUCTION

Spanning across the low-lying and sandy soils of the Coastal Plain, the gentle slopes and clay soils of the Piedmont, and the steep sloping terrains of the southern Appalachian Mountains, the forests of the southeastern (SE) U.S. are widely recognized for their high biodiversity. Differentiated across the region by various terrains, precipitation patterns, annual temperature ranges, and dominant tree species, SE forests broadly share a wet and humid climate with mild winters that produce minimal to no persistent snow cover in even the coldest locations. These favorable climate conditions support high primary forest productivity as compared to most other U.S. forest regions and similar temperate latitudes across the world. This high productivity and terrain heterogeneity together support the wide diversity of ecological associations and wildlife habitats found throughout the SE region.

Land cover change and management factors have prompted significant population and range area declines for a number of native forest-dependent plants and animals throughout the SE over the past two centuries. Specific factors that have served as primary stressors to native forest biodiversity in the SE region include: 1) historic logging of virtually all original primary forests; 2) large-scale clearing of primary and naturally regenerated forests for conversion into agriculture, plantation pine forestry, and suburban development; 3) long-term suppression of fire from forest ecosystems dependent on this disturbance; and 4) establishment and spread of various invasive plants, animals, and pathogens (see, e.g., Martin 1993; Griffith et al. 2003). But despite these direct habitat stressors and additional secondary effects from large-scale habitat fragmentation, today's SE forest landscape still contains large areas of high quality habitat that together support the vast majority of native plant and wildlife species originally found in the region at the time of European discovery (Trani 2002).

This study was commissioned jointly by the National Wildlife Federation and Southern Environmental Law Center for the purpose of developing and discussing scenario-based assessments of wildlife habitat risks from the woody biomass to bioenergy industry in the SE U.S. The rationale behind the study that the SE U.S. forest region – which the U.S. Forest Service defines as including the forested areas of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma South Carolina, Tennessee, Texas, and Virginia – is currently experiencing what is perhaps the world's most rapid growth in the development of woody biomass production facilities (Mendell and Lang 2012). According to recent estimates by Forisk Consulting (2013), U.S. wood pellet production may exceed 13.7 million tons in 2014, representing an 87% increase from 2012 and with most of this production likely being supplied by forests of the SE U.S. Due mostly to ongoing renewable energy mandates in the EU being implemented under the Kyoto Accord, some analysts expect similar demand increases for SE wood pellets to continue through 2020 and beyond (Goh et al. 2013).

Opportunities and Risks

Expansion of the bioenergy industry is prompting wide-ranging discussion about opportunities and risks that new biomass energy demands may have on SE forest lands. Available research suggests that evaluation of woody biomass energy is highly complex, and that many kinds of environmental tradeoffs are implied by biomass utilization scenarios. These tradeoffs can be expected to vary significantly across different contexts of place, spatio-temporal scale, and intensity of resource utilization (see, e.g., Talbot and Ackerman 2009).

This makes any generalizations about future impact difficult to impossible across a region as large and diverse as the SE U.S. However, a summary of such tradeoffs under an opportunities and risk framework is useful for summarizing the complexity of discussions regarding the ongoing development of this industry, and the variety of ways that these discussions specifically interplay with concerns about biodiversity conservation.

Opportunities

It has been widely argued that emergence of a new energy market for lower quality biomass material may incentivize wider implementation of management practices generally viewed as beneficial to the forest landscape and associated ecological systems. For example, new energy users have been suggested as a potential market for deadwood and understory overgrowth materials that pose high risks for catastrophic wildfire, but are otherwise uneconomical to remove (Evans and Finkral 2009; Susaeta et al. 2009). Research suggests that regular thinning of many SE plantation forest landscapes, particularly when coupled with prescribed burning interventions, can result in rapid positive responses for a wide variety native taxa, including many species of conservation concern (Hedman et al. 2000; Miller et al. 2009). Direction of undesirable and invasive plant material to biomass energy facilities is also sometimes noted as a potential catalyst in support of large-scale ecosystem restoration and wildlife enhancement objectives (Eisenbees et al. 2009; Evans 2010; Spears 2012).

From a broader environmental standpoint, even the most intensive SE forestry systems require relatively small human energy inputs in the form of fertilizer, pesticides, herbicides, and fuel as compared to common agricultural bioenergy feedstocks such as corn, sugarcane, and soy beans (Evans and Cohen 2009; Daystar et al. 2012; Dwivedi et al. 2012). By extension, comparative analyses generally show significant ecosystem service advantages for forestry biomass in terms of long-term carbon cycling, nutrient processing, water quality protection, and water quantity regulation as compared to traditional agricultural feedstocks (Dwivedi et al. 2009; Hsu et al. 2010; Lippke et al. 2011). A variety of research indicates that site-level biodiversity values from intensive plantation forestry land covers in the SE U.S. are generally higher than those associated with other human-modified landscapes (Brockerhoff et al. 2008; Miller et al. 2009), including first generation agricultural bioenergy feedstocks (Fletcher et al. 2010).

Risks

Recent literature lists several ways that large-scale woody bioenergy development has the potential to impact ecological systems in adverse ways. First, there is increasing recognition that rapid scale-up of bioenergy facilities in the SE forest landscape likely implies a level of demand that greatly exceeds the feasible supply of lower quality and/or waste materials (Galik et al. 2009), which were once regarded as a primary available source (e.g., Perlack et al. 2005). By extension, it is worried that such a large new demand, particularly when placed on top of existing demands for the traditional forest products industries, may imply levels of woody biomass extraction that could threaten the long-term functioning and sustainability of SE forest habitats already under stress from multiple factors.

Additional expansion of southern plantation pine forests, which are composed of dense row-based plantings of loblolly (*Pinus taeda*) or slash (*Pinus elliottii*) pines, is often cited as one potential near-term result of increased bioenergy demand in the Coastal Plain and Piedmont provinces (Zhang and Polyakov 2010; Davis et al. 2012). Conversion of extant native ecosystems into production landscapes dedicated to intensive feedstock production is widely recognized as a major risk factor associated with increased bioenergy demands (Fargione et al. 2008; U.S. Environmental Protection Agency 2011), and plantation pines are specifically regarded as a primary factor in the loss of many natural stands of SE forests over the latter half of the twentieth century (Allen et al. 1996). At a stand level, intensive biomass harvest of small diameter and residual woody materials may in some cases have the potential to increase sediment and nutrient loads to adjacent water bodies, particularly in the context of highly sloped, riparian, and wetland forestry contexts (Janowiak and Webster 2010). Increased tree planting densities, which are often recommended for southern pine plantation systems optimized for bioenergy production, may also have the potential to reduce net watershed flows into regional streams, lakes, and groundwater systems due to higher net landscape evapo-transpiration (Evans and Cohen 2010; McLaughlin et al. 2013).

In local woodshed areas that lack high pine plantation production potential and/or have specific facility demands for hardwood-based bioenergy, woody biomass will necessarily be sourced from primary and/or residual biomass obtained from natural forest stands for at least the near-term. This is because there currently is very little plantation-grown hardwood capacity in the SE U.S. (Merkle and Cunningham 2011). Specific concerns with hardwood biomass harvest in the Appalachian Mountains and, to an arguably lesser extent, the Piedmont include increased opening of closed canopy conditions and/or substantial removal of "downed woody matter" (DWM), both of which may lead to habitat loss for interior forest species (Vanderberg et al. 2012). In the Coastal Plain, hardwood based biomass sourcing may in many cases be preferentially sourced from floodplain and basin wetland forests, which are generally the most productive hardwood sites (Kline and Coleman 2010). Increased stream sedimentation, alteration of hydrologic regimes, changes in water chemistry, and different thermal profiles that can effect local fish, water birds, and aquatic invertebrates are post-harvest concerns when sourcing wood from riparian bottomland forests in the SE Coastal Plain (Ensign and Mallin 2001; Hutchens et al. 2004).

Study Goals and Questions

Biodiversity conservation is widely recognized as a pillar of sustainability assessments at local, state, national and international levels. Because bioenergy development is specifically linked to governmental and international policy frameworks designed to promote climate change mitigation and other sustainability goals, detailed assessments of wildlife habitat risks associated with current bioenergy scale-ups in SE forests is clearly appropriate and necessary for informing adaptive policy development at this time.

While this report represents an objective effort to assess biodiversity opportunities and risks from forestry biomass energy, we caution that wildlife responses to bioenergy development are fundamentally nested within, and further contribute to, a highly complex suite of variables that include many future uncertainties and unknowns. Because of this, it is important to note that formal consideration of all – or even most – potential habitat change factors, scenarios, and associated ecosystem and species responses was neither possible nor intended.

Goals
The overarching goals of this study were fourfold.

1. To develop spatial analyses that provide specific information about the likely land cover base for long-term feedstock sourcing for six woody biomass facilities.
2. To analyze potential effects of biomass sourcing scenarios on a selection of native wildlife species identified as having high conservation concern.
3. To review state, national, and international policies related to deployment of biomass-based energy, with specific focus on sustainable sourcing criteria that pertain to wildlife habitat and biodiversity maintenance.
4. To synthesize the land cover analyses, wildlife assessments, and policy review as a guide for future research focus and associated policy development.

Facilities
To operationalize the technical research goals (1 & 2 above), we applied a case study approach that focuses on six forestry-based bioenergy facilities located across the SE. These case study facilities are:

1. Georgia Biomass, LLC, a wood pellet manufacturing facility located near Waycross, GA in the lower Atlantic Coastal Plain.
2. Enviva Pellets Ahoskie, a wood pellet manufacturing facility located in Ahoskie, NC in the upper Atlantic Coastal Plain.
3. Piedmont Green Power, a biomass fired electrical generating unit located near Barnesville, GA in the southern reaches of the Piedmont province.
4. South Boston Energy, a biomass fired electrical generating unit located in South Boston, VA and in the northern reaches of the Piedmont province.
5. Carolina Wood Pellets, a wood pellet manufacturing facility located in Otto, NC and in the southern Appalachian mountains.
6. Virginia Hybrid Energy Center, a co-fired coal and biomass electrical generating unit located in St. Paul, VA and in the southern Appalachian mountains.

These facilities were selected because they together provide a wide cross-sampling of SE forest types and feedstock sourcing practices, thus giving opportunity for comparisons across a high diversity of habitats and impact factors. The specific spatial modeling approaches and findings are applied and presented in such a way that they can be utilized and refined for similar future assessments of other regional bioenergy facilities.

Research questions

In developing the case studies, we used literature review and spatial analysis methods to address a series of specific research questions for each facility:

1. What woodshed ecosystems are most at risk of biomass harvest and/or land

cover conversion over the lifetime of each case study facility?

2. What habitats of critically imperiled (G1), imperiled (G2), or vulnerable (G3) status occur within potential woodshed sourcing areas?
3. How might different biomass sourcing and harvesting practices be expected to affect native forest habitats and wildlife species of high conservation value and concern?
4. What policies and practices are available to mitigate and/or address conservation concerns associated with increased biomass energy extraction from SE forests?

Technical Approach

To address research question 1), we first utilized facility biomass demands and local forestry productivity assumptions to calculate landscape area sourcing requirements for each facility. These sourcing requirements models were then used to develop spatially explicit sourcing models.

These sourcing models take into account two primary spatio-economic factors: 1) Road transport distance of biomass material from the forest to the facility; and 2) Competition with other woody biomass consumers in the woodshed sourcing area. Sourcing models assumed that facilities will preferentially source from woodshed areas that minimize costs through less road transport distance, while also minimizing bid pressure from competing biomass facilities. For softwood sourcing, additional modeling consideration was given to soil type, elevation, slope, and distance to road factors that influence land owner decisions for establishing plantation pine across the landscape.

A series of customized "scenario screens" were run for each facility to simulate sourcing under different sets of sourcing constraints that reflect various protocols for sustainable forest management criteria. Woodshed areas with public ownership status or conservation easements that exclude extractive timber harvests were removed from consideration for all sourcing model scenarios. Land cover information for all sourcing models was based on the United States Geological Survey's 2011 Gap Analysis Program (GAP) National Land Cover dataset (USGS 2011). This dataset is designed for use in conservation planning and assessments, which can include large-scale evaluations of biomass and renewable energy sourcing from forest ecosystems.

Sourcing models were run across a standard set of harvest intensity and biomass allocation assumptions for each facility. Results for sourcing models based on each of these biomass allocation assumptions were translated into maps of relative landscape risk for biomass harvest. Five risk classes were defined through this approach: 1) High; 2) Moderately high; 3) Moderate; 4) Moderately low; and 5) Low. Higher risk in this context is technically defined as having a higher relative suitability for biomass sourcing based on model factors, and does not necessarily imply vulnerability to an adverse biodiversity impact from this sourcing.

The spatially explicit integration of these disparate factors and constraints into biomass sourcing models is a novel research contribution provided by this study. Specifics of the modeling scenario development and workflow integration are developed in full detail in Chapter 4.

Softwood sourcing

For plantation pine-based biomass, a series of five scenario screens were applied for softwood sourcing on private lands. These ranged from the most permissive criterion of allowing conversion of any upland land cover with the exception of row crops and developed areas, to the most restrictive of only sourcing biomass from existing plantation pine forestry land covers.

Ecosystem and wildlife habitat overlap assessments for softwood sourcing were performed a subset of two intermediate scenario screens: 1) a permissive scenario that allowed for conversion of natural upland forest stands into plantation pine based on landscape factors, while assuming no conversion of agricultural (i.e., row crop and pasture), developed lands, or wetland areas into plantation pine; and 2) a restrictive scenario that limited the resource base of softwood sourcing to existing plantation pine and other disturbed lands (i.e., harvested, cleared, and ruderal succession) that are presumed to form the existing resource base for extractive softwood forestry.

Hardwood sourcing

Two scenario screens were applied for hardwood sourcing on private lands. The permissive screen for hardwood forestry assumed no restriction against sourcing from wetland and riparian forests. A more restrictive screen limited all sourcing to upland hardwood forests, and thus allowed no sourcing from forested wetlands. All hardwood sourcing screens excluded agricultural (including pasture and row crop) and developed land covers from the forestry biomass resource base. In two woodsheds with large areas of land held publicly by the U.S. Forest Service, an additional screen that allowed for sourcing from all non-Wilderness National Forest lands was compared to a scenario screen that prohibited all sourcing from National Forests.

At risk (G1-G3) ecological associations

Research question 2) was addressed through a partnership with NatureServe, whose analysts conducted detailed overlay analyses of woodshed areas to identify element occurrences of G1 (critically imperiled), G2 (imperiled), and G3 (vulnerable) ecological associations. Identification of such at risk (G1-G3) associations for the purpose of avoiding adverse impacts on forest ecosystems of high conservation value is a component of most sustainable forest management certifications. Intersection analyses of G1-G3 datasets maintained by NatureServe were performed for each facility woodshed as defined by a 75-mile road network analysis. Known conservation areas were excluded from consideration in these intersection analyses.

Ecosystem and wildlife assessments

To address question 3), we conducted an overlay analysis of detailed forest ecosystem types, as defined by the 2011 GAP Land Cover dataset, with biomass sourcing models. Following work by Fahrig (2003), we interpreted the primary biodiversity impact of concern as direct habitat change risks. These risks were specifically defined through area-based sums of cumulative harvest disturbance and/or land cover conversion potential for extant forest ecosystems over an assumed 50-year facility life time. Available literature and information about facility sourcing practices were utilized to discuss a range of general ecological, biodiversity, and wildlife responses that may be expected under biomass sourcing scenarios.

To supplement these ecosystem/land cover-based discussions, we developed additional overlay analyses of sourcing risk models with spatially explicit GAP distribution datasets for nine wildlife "indicator" species located in some or all of the facility woodsheds. These species included the eastern spotted skunk (*Spilogale putorius*); long-tailed weasel (*Mustela frenata*); northern bobwhite quail (*Colinus virginianus*); Swainson's warbler (*Limnothlypis swainsonii*); brown-headed nuthatch (*Sitta pusilla*); prothonotary warbler (*Protonotaria citrea*); gopher frog (*Lithobates capito*); northern cricket frog (*Acris crepitans*); and timber rattlesnake (*Crotalus horridus*). These species were selected for analysis through an iterative process that included consideration of several criteria: 1) diversity of taxa; 2) regional, rather than highly local, distribution; 3) conservation status concerns that could likely be affected, whether positively or negatively, by biomass extraction practices; and 4) availability of formal GAP distribution data.

Specific methods behind ecosystem criteria and species selection are described in Chapter 3, while overlay methods are described in Chapter 4. Results and interpretations for each case study woodshed are developed in Chapters 5-10.

Policy review

A review was developed for existing sustainable forest management (SFM) certification programs and best management practices (BMPs) for SE U.S. forestry systems. SFM programs include the Forest Stewardship Council (FSC), Sustainable Forestry Initiative (SFI), American Tree Farm System (ATFS), and the Program on the Endorsement of Forest Certification (PEFC), although none of these currently have a standalone biomass to energy certification. New state-level BMPs specific for biomass energy have been developed by the State of South Carolina, and recommendations for implementing biomass forestry BMPs in a manner that may mitigate habitat concerns has been developed by the Forest Guild.

Report Overview

Research for this project was conducted through a collaborative effort between faculty and graduate student researchers at the University of Georgia, University of Florida, and Virginia Polytechnic Institute and State University (a.k.a., Virginia Tech University). Chapter 2, authored by Daniel Geller (University of Georgia, College of Engineering) and Jason M. Evans (University of Georgia, Carl Vinson Institute of Government), provides an overview of facilities chosen for the study's focus. Chapter 3, authored by Divya Vasudev, Miguel Acevedo, and Robert J. Fletcher, Jr. (all from University of Florida, Department of Wildlife Ecology and Conservation), provides a presentation of conservation analysis methods and identification of indicator species. Chapter 4, authored by Jason M. Evans, provides a technical explanation of spatial modeling methods employed for the facility case studies. Chapters 5-10, authored by Jason M. Evans, Alison L. Smith (University of Georgia, College of Environment and Design), Daniel Geller, Jon Calabria (University of Georgia, College of Environment and Design), Robert J. Fletcher, Jr., and Janaki Alavalapati (Virginia Tech University, Department of Forest Resources and Environmental Conservation) provide the results and discussion of facility case study analyses. Chapter 11, authored by Pankaj Lal (Montclair State University, Department of Earth and Environmental Studies), Thakur Upadhyay (Virginia Tech University, Department of Forest Resources and Environmental Conservation) and Janaki Alavalapati, provides an overview of forestry biomass energy policies within state, federal, and international contexts, as well as the increasing policy attention to biodiversity concerns. Chapter 12, co-authored by all investigators, synthesizes the results of the report into a series of suggestions for policy consideration and future research studies.

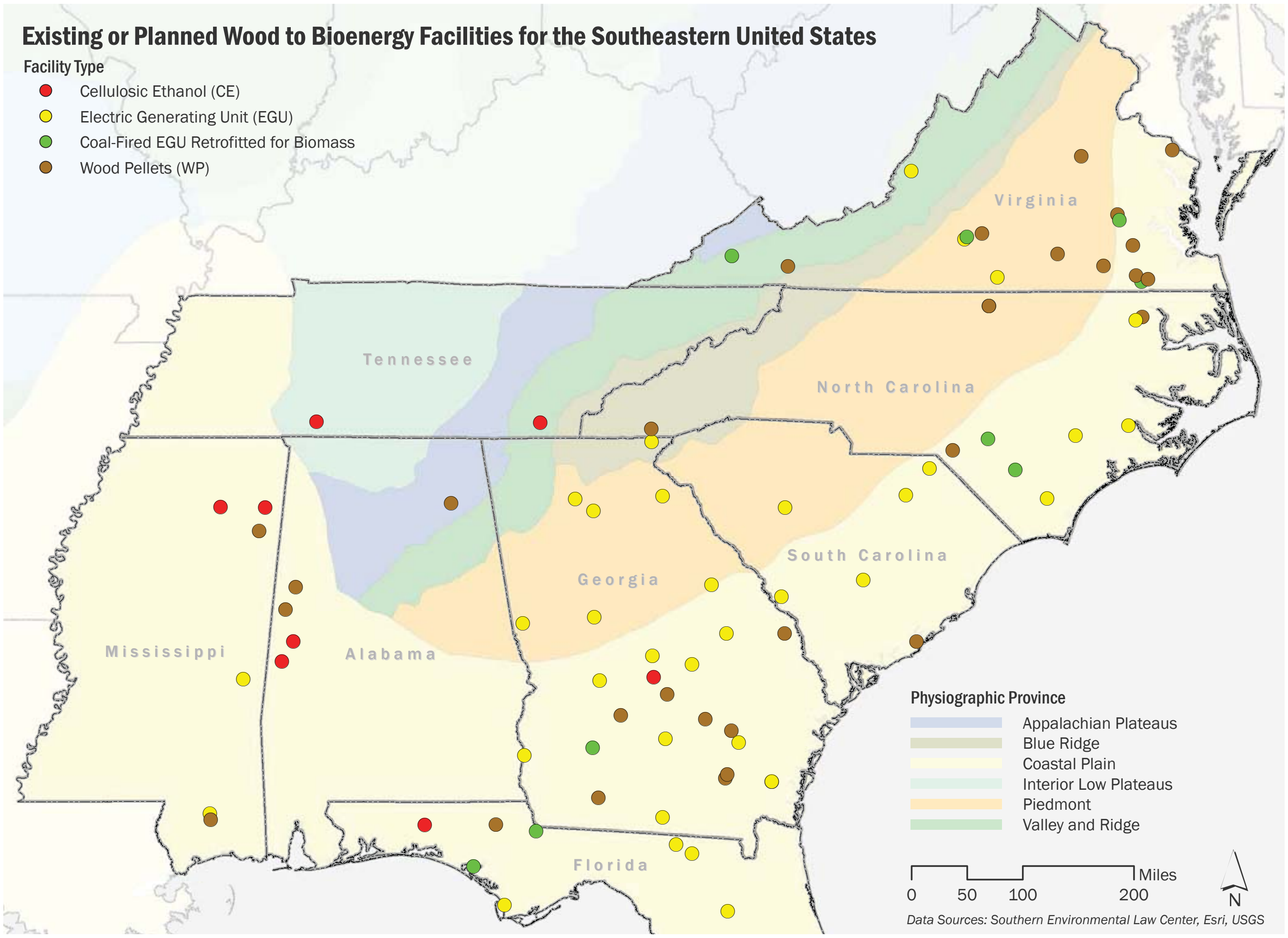
II. FACILITY DESCRIPTIONS

Upon review of existing or planned wood to bioenergy sites identified by Southern Environmental Law Center (2012; summarized in Figure 1) and in consultation with project sponsors, we developed biomass sourcing models and wildlife habitat overlay assessments for six facilities (summarized in Figure 2). To provide a wide degree of geographic diversity for the geospatial and wildlife analyses, we chose purposely two facilities in the Coastal Plain, two in the Piedmont, and two in the Mountain provinces of the SE U.S.

Coastal Plain Facilities

Facility 1: Georgia Biomass, LLC, located near Waycross, Georgia, is a wood pellet facility with an estimated output of 750,000 Mg/yr. This production output, which is based exclusively on softwood from yellow pine, likely makes this facility the single largest wood pellet producer in the world. The facility was built through collaboration between RWE Innogy of Germany and

Figure 1. Existing or planned wood to bioenergy facilities



BMC of Sweden, and is part of a vertically integrated energy production system for export. The main two power plants that originally intended to source from Georgia Biomass are Plant Amer in the Netherlands and Plant Tilbury in the United Kingdom. However, it has been announced that Plant Tilbury will ceased biomass power generation in October 2013. We identified this facility as potentially high impact due to its large size and high demand for biomass.

Facility 2: Enviva Pellets Ahoskie is a wood pellet facility located near Ahoskie, North Carolina. In operation since November 2011, the facility is located at a site that was previously a Georgia Pacific sawmill. Due to this prior usage, the logging worker base and other wood supply logistics for this facility are well-established. The Enviva facility reports a production output of 350,000 Mg/yr using a mix of approximately 80% hardwood and 20% softwood feedstock. The pellets produced at the Ahoskie facility are shipped to European utilities through a supply contracts with E.ON, one of the largest investor owned utilities in the world, and Electrabel, a subsidiary of GDF SUEZ Group. The Ahoskie facility is near the deepwater port of Chesapeake, VA through which their pellets are exported to the European markets.

Figure 2. The six facilities chosen to model land use change and habitat impact risks

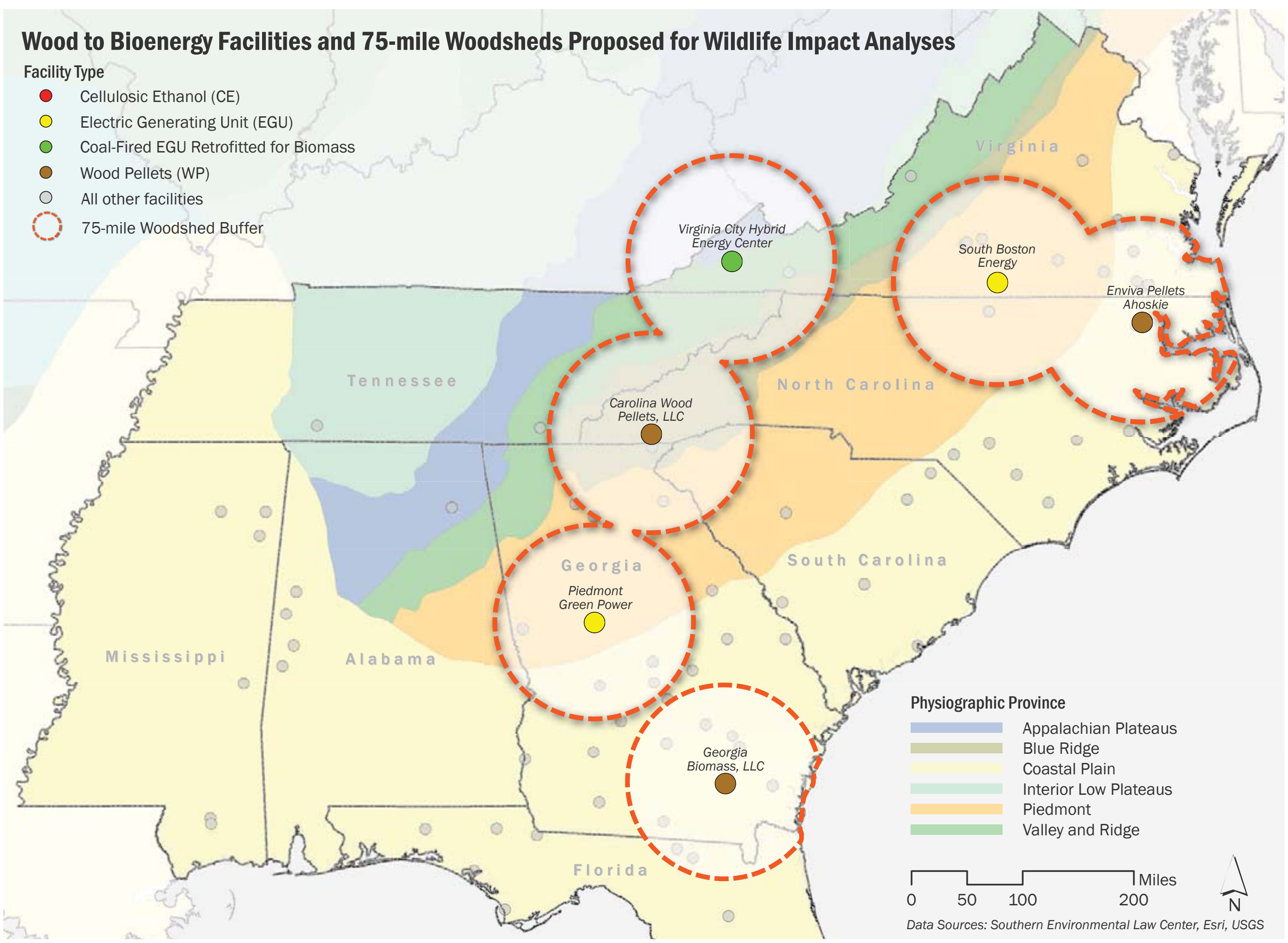


Figure 3. Georgia Biomass, LLC

Figure 4. Enviva Pellets Ahoskie

Figure 5. Piedmont Green Power

Piedmont Facilities

Facility 3: Piedmont Green Power, located near Barnesville, Georgia, is a 60.5 MW electric generating unit, and one of the few proposed or existing wood based facilities in the southern Piedmont province. Catchlight Energy, the parent company of this project has secured a 20 year power purchase agreement with Georgia Power, which will provide the facility with reliable and sustained income. The unit is intended to provide power to approximately 40,000 homes. This facility was identified as potentially high impact due to its large biomass demands and its location in the Piedmont.

Facility 4: South Boston Energy, located near South Boston, Virginia, is a proposed 49.95 MW power facility. Proposed feedstocks include wood wastes, wood chips and slash. This facility is being constructed with funding from a $90 million USDA loan, and the power will be purchased by the Northern Virginia Electric Cooperative (NOVEC) to service approximately 16,000 customers. Current information suggests that this facility will begin operations in the near future. This facility is identified as potentially high impact due to its large biomass demands, as well as being one of the few facilities located within the southeast Piedmont province.

Mountain Facilities

Facility 5: Carolina Wood Pellets, located in Otto, North Carolina, is a wood pellet facility with an estimated production of 68,000 Mg/yr. This facility manufactures hardwood pellets for domestic home stoves, which are bagged and sold on the consumer market. The current feedstock is described as scrap wood from manufacturing, logging and construction sources. At maximum production levels, the facility can produce enough wood pellets to heat 30,000 homes. The facility is an active installation and has been producing pellets since 2009. This facility presents an interesting alternative to the other facilities, as it currently uses hardwood residues as opposed to softwood plantation timber. The facility is selected for analysis because of its location in the southern Mountains, which poses a different set of challenges and constraints as compared to forestry in the Coastal Plain and Piedmont provinces.

Facility 6: Virginia City Hybrid Energy Center, located in St. Paul, Virginia, is a 585 MW electrical generation unit operated by Dominion Virginia Power. This facility is designed to co-fire up to 20% biomass in its coal fuelled electric production facility, although is operationally running on a 10% biomass capacity (~59 MW). This facility is the only co-fired biomass/coal power facility identified for this study. The facility will provide power for 146,000 homes, 14,600 of which will be supplied by biomass. The identified fuel is wood waste in the form of chips. The very large biomass demands of this facility, coupled with a sourcing area located in the southern Mountains, make it potentially high impact.

Figure 6. South Boston Energy

Figure 7. Carolina Wood Pellets

Figure 8. Virginia City Hybrid Energy Center

III. INDICATOR SPECIES SELECTION

Authors: Divya Vasudev, Miguel Acevedo, and Robert J. Fletcher, Jr., Department of Wildlife Ecology and Conservation, University of Florida

Identification of indicator species

We identified indicator mammalian, avian, amphibian and reptilian species for each bioenergy facility based on a three-step process. First, we identified priority species based on State Wildlife Action Plans of Georgia, North Carolina, South Carolina and Virginia (Georgia Department of Natural Resources 2005; South Carolina Department of Natural Resources 2005; North Carolina Wildlife Resources Commission 2005; Virginia Department of Game and Inland Fisheries 2005). Species that were of concern due to their status as a migratory or game species were given special consideration (e.g., game species: Northern bobwhite *Colinus virginianus*; migratory species: Swainson's warbler *Limnothlypis swainsonii*). Second, we obtained range and distribution data of the selected species from the National Gap Analysis Program (GAP) (http://gapanalysis.usgs.gov/).

For this exercise, we only used information on the overall range of the species, while the distribution of the species within its range was utilized for the wildlife habitat modeling (see below). We overlapped the range of the selected species with a 75-mile buffer around each facility considered in this study, thereby identifying those species located within the vicinity of the selected facilities on the basis of GAP data. We preferentially chose taxa that were represented in more than one facility. Lastly, we used multiple databases to obtain additional habitat association and conservation status information on identified indicator species, including Animal Diversity Web hosted by the University of Michigan (http://animaldiversity.ummz.umich.edu), the International Union for the Conservation of Nature and Natural Resources Red List of Threatened Species (http://www.iucnredlist.org), and the Cornell Laboratory of Ornithology (http://www.allaboutbirds.org). We narrowed our search down to approximately 8 candidate species of each taxa, and then had external reviewers critique the list and provide suggestions for finalizing the list of indicator taxa.

Justification for the use of the GAP database

The National Gap Analysis Program (GAP: http://gapanalysis.usgs.gov/) is an initiative of the United States Geological Survey in partnership with a number of federal and state agencies, as well as non-governmental organizations. The GAP database has was developed and has been explicitly applied for the purpose of identifying regions of conservation priority and to assess overall conservation effectiveness (Larson and Sengupta 2004, Rodrigues et al. 2004).

The current GAP database includes a high resolution (30-m) National Land Cover map that uses satellite imagery to define a seamless set of vegetation and ecosystem classifications across the United States (USGS 2011a). The 2011 National GAP Land Cover map is widely recognized as the most detailed national land cover classification dataset that maintains consistent classifications at a national scale. For this reason, it is frequently applied for regional and national analyses of biodiversity protection, land cover change, renewable energy assessments, and climate change adaptation (USGS 2011a).

The GAP database also provides for a large repository of available information on species range, distribution and habitat associations (USGS 2011b). The GAP wildlife database represents an integrated collation of current published and expert knowledge on identified species. High resolution distribution data in the GAP wildlife dataset represent both known and predicted occurrences for a wide range of species at a 30-m resolution. Predictions of species distributions are obtained from information on species habitat associations collated from published literature and expert opinion. Additionally, elevation, wetland inventories and other appropriate information are incorporated into predictions of species distribution. It is important to note that GAP data predicts suitable habitat for species rather than the probability of occurrence for each species.
The GAP wildlife database provides information that is directly comparable across taxa, and is also directly associated with the National GAP Land Cover classification system. Consequently, this approach provides a standardized and detailed method for rapidly assessing potential wildlife vulnerability.

In this study, we used the species distribution models from the GAP database to provide direct, high-resolution assessments of wildlife vulnerability under different sourcing scenarios. Sourcing screen scenarios for biomass conversion or harvest were developed from the GAP National Land Cover dataset, with land cover classes generalized to 100-m (1 hectare) cell sizes. After developing land cover risk assessment models for each sourcing screen scenario, we then obtained distribution data for each selected indicator species from the GAP database. After generalizing wildlife distribution data to 100-m (1 hectare) cell sizes, we then overlaid these GAP distribution data for each species with the areas identified with each sourcing scenario. This approach allowed us to calculate the total area of suitable habitat that would be at risk of biomass harvest using a standardized method with results that are directly comparable.

INDICATOR SPECIES LIST

The following are the mammalian, avian, amphibian and reptilian indicator species that resulted from the iterative selection process (Table 1).

Mammals

1. The **eastern spotted skunk** *Spilogale putorius* is an edge-specialist species, found at forest-grassland ecotones. The species is located in the woodsheds of Georgia Biomass LLC., Piedmont Green Power, Carolina Wood Pellets and the Virginia City Hybrid Energy Center, spanning the states of Georgia, North Carolina and Virginia. The

Figure 9. Eastern spotted skunk *Spilogale putorius* Photo credit: NPS

Table 1. List of indicator species among the six facility woodsheds

Species	Scientific Name	GB	PGP	CWP	VHC	SB	EP
Mammals							
Eastern spotted skunk	*Spilogale putorius*	X	X	X	X	X	
Long-tailed weasel	*Mustela frenata*	X	X	X	X	X	X
Seminole bat	*Lasiurus seminolus*	X	X	X			
Southeastern pocket gopher	*Geomys pinetis*	X	X				
Birds							
Northern bobwhite	*Colinus virginianus*	X	X	X	X	X	X
Swainson's warbler	*Limnothlypis swainsonii*	X	X	X	X	X	X
Brown-headed nuthatch	*Sitta pusilla*	X	X	X		X	X
Prothonotary warbler	*Protonotaria citrea*						X
Amphibians							
Gopher frog	*Lithobates capito*	X	X				
Northern cricket frog	*Acris crepitans*	X	X	X	X	X	X
Mole salamander group	*Ambystoma spp.*	X					X
Slimy salamander group	*Plethodon spp.*		X	X	X	X	
Three-lined salamander	*Eurycea guttolineata*	X	X	X		X	X
Reptiles							
Timber rattlesnake	*Crotalus horridus*	X	X	X	X	X	X
Broad-headed skink	*Plestiodon laticeps*	X	X	X	X	X	X
Common five-lined skink	*Plestiodon fasciatus*	X	X	X	X	X	X

The facility abbreviations are GB: Georgia Biomass, LLC., Georgia; PGP: Piedmont Green Power Facility, Georgia; CWP: Carolina Wood Pellets, North Carolina; VHC: Virginia City Hybrid Energy Center, Virginia; SB: South Boston Energy, Virginia; EP: Enviva Pellets, LP, North Carolina.

Table 1. Indicator Species List

species is associated with woodland habitats, such as oak and pine forests, as well as grassland vegetation, such as agricultural and pastural lands. The eastern spotted skunk is a species of conservation concern in the states of North Carolina and Virginia (North Carolina Wildlife Resources Commission 2005; Virginia Department of Game and Inland Fisheries 2005). In addition, we chose this species for their association with ecotones, as well as their representation in four of the six chosen facilities. GAP distribution data are available for this species, and formal spatial overlays were therefore performed for those facility woodsheds in which the eastern spotted skunk occurs.

2. The **long-tailed weasel** *Mustela frenata* is a widespread species found in all woodsheds chosen in this study. They are a generalist species associated with a wide variety of habitats and moderately susceptible to land-use change and habitat fragmentation (Reid & Helgen 2008). Habitats that the long-tailed weasel inhabits include hardwood and coniferous forests, pocosin shrublands, cypress swamps and herbaceous wetlands, grasslands, and urban areas.

Figure 10. Long-tailed weasel *Mustela frenata*
Photo credit: http://www.flickr.com/photos/will-wilson/4429071190/

Though widespread, they are a species of concern in North Carolina, in particular associated with spruce-fir forests and hardwood forests (North Carolina Wildlife Resources Commission 2005). GAP distribution data are available for this species, and formal spatial overlays were therefore performed for all facility woodsheds.

3. The **southeastern pocket gopher** *Geomys pinetis* is located in the state of Georgia, and is found in the woodsheds of Georgia Biomass LLC, and the Piedmont Green Power. The pocket gopher is a species of high conservation priority in the state of Georgia (Georgia Department of Natural Resources 2005). In addition, pocket gophers are considered to be ecosystem engineers, with multiple species utilizing burrows excavated by the species (Riechman & Seabloom 2002). The southeastern pocket gopher is found associated with pine forests, pine-oak mixed forests and upland hammock habitats (Lindzey & Hammerson 2008). GAP distribution data are not currently available for this species, and therefore formal spatial overlays were not performed.

4. The **seminole bat** *Lasiurus seminolus* inhabits the states of Georgia, South Carolina and North Carolina is found in three of the six six facility woodsheds considered in this study: Georgia Biomass LLC., Piedmont Green Power, and Carolina Wood Pellets. The Seminole bat is listed as a species of conservation concern, especially associated with woodland habitat in the state of North Carolina (North Carolina Wildlife Resources Commission 2005). These insectivorous species can be found roosting in pine trees, particu-

larly hosting Spanish moss *Tillandsia usneoides*. GAP distribution data are not currently available for this species, and therefore formal spatial overlays were not performed.

Birds

1. The **northern bobwhite quail** *Colinus virginianus* is located in all six facility woodsheds. It is a popular game species, and as such, listed as a high priority species in the wildlife action plans of the states of Georgia, North Carolina, South Carolina and Virginia (Georgia Department of Natural Resources; South Carolina Department of Natural Resources 2005; North Carolina Wildlife Resources Commission 2005; Virginia Department of Game and Inland Fisheries 2005). The species is found in pine and xeric woodlands, deciduous forests and agricultural lands. GAP distribution data are available for northern bobwhite quail, and formal spatial overlays were therefore performed for all facility woodsheds.

Figure 11. Bobwhite Quail *Colinus virginianus*. Photo credit: Tom Wright UF/IFAS

2. The **Swainson's warbler** *Limnothlypis swainsonii* is a migratory species, whose seasonal range overlaps with all facility woodsheds. This insectivore is associated with forested habitats with thick undergrowth (Graves 2002). These include oak and mixed bottomland forests, swamp forests, mesic hardwood forests and Appalachian hemlock hardwood forests. The Swainson's warbler is a species of conservation concern in the states of South Carolina, North Carolina and Georgia (Georgia Department of Natural Resources; South Carolina Department of Natural Resources 2005; North Carolina Wildlife Resources Commission 2005). GAP distribution data are available for this species, and formal spatial overlays were therefore performed for all facility woodsheds.

3. The **brown-headed nuthatch** *Sitta pusilla* is a pine-forest dwelling songbird found in all woodsheds. The species is associated with pine forest and savanna and mixed pine-oak forests, and in addition, floodplain forests, cypress swamps and xeric woodlands. The species is of conservation concern in the states of Virginia, South Carolina and North Carolina (South Carolina Department

Figure 12. Swanson's warbler *Limnothlypis swainsonii***.** Photo credit: http://www.flickr.com/photos/juliom/7158750123/

of Natural Resources 2005; North Carolina Wildlife Resources Commission 2005; Virginia Department of Game and Inland Fisheries 2005). GAP distribution data are available for this species, and formal spatial overlays were therefore performed for all facility woodsheds.

Figure 13. Brown-headed nuthatch *Sitta pusilla.* Photo credit: http://www.flickr.com/photos/vickisnature/3297971410/

4. The **prothonotary warbler** *Protonotaria citrea* is a migratory songbird found throughout wooded swamps of southeastern United States of America. This species is associated with floodplain forests and other bottomland forests. Successful breeding is contingent on the presence of water bodies, and trees with nesting cavities. GAP distribution data are available for this species, and formal spatial overlays were performed for the Enviva Pellets woodshed.

Amphibians

1. The **gopher frog** *Lithobates capito* is a species endemic to the Southeastern United States of America. At least two states list the gopher frog as a species of conservation concern (Georgia Department of Natural Resources 2005; South Carolina Department of Natural Resources 2005). Habitat associations include longleaf pine and turkey oak forests and pine flatwoods, where the species uses pocket gopher and gopher tortoise *Gopherus polyphemus* burrows (Bihovde 2006). Egg masses are laid in water, and hence permanent water bodies are essential breeding habitat. GAP distribution data are available for

Figure 14. Prothonotary warbler *Colinus virginianus.* Photo credit: Jeff Lewis

Figure 15. Gopher frog *Lithobates capito.* Photo credit: Steve A. Johnson.

this species, and formal spatial overlays were performed for the Georgia Biomass and Piedmont Green Power woodsheds.

2. The **northern cricket frog** *Acris crepitans* requires permanent water bodies for their persistence. The distribution of the species encompasses all facility woodsheds considered in this study, with the exception of the Virginia City Hybrid Energy Center. The species is of moderate conservation priority in South Carolina (South Carolina Department of Natural Resources 2005). This species was chosen for its requirement for permanent water bodies, such as ponds, marshes and reservoirs, and its use of pine woodlands as dispersal habitat. GAP distribution data are available for this species, and formal spatial overlays were therefore performed for all facility woodsheds.

3. We include the white-spotted slimy salamander *Plethodon cylindraceus*, the northern slimy salamander *P. glutinosus* and the South Carolina slimy salamander *P. variolatus* in the **slimy salamander** group of indicator species. Taken together, the group is found inhabiting areas in the woodsheds of Piedmont Green Power, South Boston Energy, Carolina Wood Pellets, Virginia City Hybird Energy Center and Enviva Pellets LP. The northern slimy salamander is listed as a priority species in North Carolina (North Carolina Wildlife Resources Commission 2005). These salamanders are found in moist woodlands and upland forests. GAP distribution data are not currently available for these species, and therefore formal spatial overlays were not performed.

4. **Mole salamanders** *Ambystoma spp.*, of interest in our study include the eastern tiger salamander *Ambystoma tigrinum*, found in the Georgia Biomass woodshed, and the Mabee's salamander *Ambystoma mabeei*, found in the Enviva Pellets woodshed. The eastern tiger salamander is a high priority species in the state of South Carolina (South Carolina Department of Natural Resources 2005), while the Mabee's salamander is of priority in the state of North Carolina (North Carolina Wildlife Resources Commission 2005). The species group was identified as an indicator species as it requires for its survival breeding ponds and upland woodland habitat (Madison & Farrand 1998). Bottomland forests, cypress swamp and floodplain forests include habitat the species inhabits. GAP distribution data are not currently available for these species, and therefore formal spatial overlays were not performed.

5. The **three-lined salamander** *Eurycea guttolineata* is located in all facility wood-

Figure 16. Northern cricket frog *Acris crepitans*. Photo credit: http://www.flickr.com/photos/pcoin/369987905/

sheds considered in this study except for the Virginia City Hybrid Energy Center. The species is of conservation concern in the state of North Carolina (North Carolina Wildlife Resources Commission 2005). The species can be found in forested floodplains and moist woodland habitats (Hammerson 2004). Thus, emergent vegetation, bottomland forests, floodplain forests, streamhead swamps, and wet shrublands form habitat for the species. GAP distribution data are not currently available for these species, and therefore formal spatial overlays were not performed

Reptiles

1. The **timber rattlesnake** *Crotalus horridus* is found in all facility woodsheds. The species is of conservation concern in the states of South Carolina, North Carolina and Virginia (South Carolina Department of Natural Resources 2005; North Carolina Wildlife Resources Commission 2005; Virginia Department of Game and Inland Fisheries 2005). As its name suggests, this snake is found inhabiting woodland regions, including deciduous, coniferous, and upland forests (Hammerson 2007). GAP distribution data are available for this species, and formal spatial overlays were therefore performed for all facility woodsheds.

2. The **broad-headed skink** *Plestiodon laticeps* is distributed extensively in the states of Georgia, North Carolina, South Carolina and Virginia, and is found in all facilities chosen for this study. The state of North Carolina lists this skink as a reptilian species of high priority (North Carolina Wildlife Resources Commission 2005). The species is found inhabiting mature pine and mixed hardwood forests. GAP distribution data are not currently available for these species, and therefore formal spatial overlays were not performed.

3. The **common five-lined skink** *Plestiodon fasciatus* is also distributed throughout all facility woodsheds considered for this study. These rather common species is found in woodland areas throughout their range, including pine forests, swamps, floodplain forests, wet shrublands and mixed oak forests. GAP distribution data are not currently available for these species, and therefore formal spatial overlays were not performed.

Figure 17. Timber rattlesnake *Crotalus horridus*.
Photo credit: Steve A. Johnson

IV. SPATIAL MODELING METHODOLOGY

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The land cover risk modeling in this project is based upon a multi-criteria evaluation (MCE) decision support framework, as applied with the IDRISI Selva software platform (Eastman 2012). The MCE process is based on an integrated assessment of landscape suitability for achieving a given objective (e.g., biomass harvest) through consideration of what are referred to as "constraints" and "factors."

Constraints are defined in the IDRISI MCE process as a Boolean (0, 1) raster input map variable that has the effect of either allowing or not allowing the given objective to be sourced from any particular area in the landscape. For example, input maps of public conservation lands that are managed in a way that biomass harvest is prohibited take the form of a constraint. More specifically, any areas that are known to be in public conservation land would be classified as unavailable (Boolean value=0), while other areas would be classified as potentially available (Boolean value=1).

Factors in the IDRISI MCE process are defined as map variables that have a continuous effect on landscape suitability for achieving the given objective. For example, travel distances from a biomass facility is modeled as having a continuous effect on suitability, as shorter distances can be expected to entail less travel cost for biomass procurement. Although factor variables may be entered into the IDRISI program utilizing any range of continuous numbers, the MCE process requires normalization of all factor variables into an integer range of 0-255. Values of 0 are generally classified as "Least suitable," while values of 255 are equivalent to "Most suitable."

In this project, the final MCE integration of constraints and factors was applied using a Weighted Linear Combination (WLC) procedure. The WLC requires applying percentage weights to each normalized factor map, with the total weighted percentage for factors equaling 100%. While any cell with a value of 0 for any constraint is masked as 0, factor values for all other cells are weighted and summed to produce a final MCE output. Using the WLC on a cell by cell basis, the MCE is calculated as:

$MCE = \Sigma (W_i * R_i)$, where
W = Weight % for Factor i; and
R = Raster cell value for Factor i

Constraint Development

A series of three primary constraint factors were defined for the land cover models across all facilities: 1) woodshed delineation (0 = areas further than 75 miles network distance; 1 = areas less than 75 miles network distance); 2) conservation lands (0 = conservation; 1 = not identified as conservation); and 3) land cover sourcing screens (0 = land covers assumed as unavailable; 1 = land covers assumed as available). Cell resolution for all raster constraint datasets was set at 100 meters.

Woodshed delineation

The woodshed delineation constraint was developed through Network Analyst tool in ArcGIS10.1. Using the Roads dataset, a 75-mile Service Area boundary shapefile (Woodshed Delineation) was developed based on the input point coordinates for modeled bioenergy facility (see detail below in *Travel distance* factor). These 75-mile Service Areas were then transformed into a Boolean raster datasets (0 = outside of service area, 1 = inside service area) that cover rectangular extents defined by the most extreme latitudes (north-south Y boundary coordinates) and longitudes (east-west X boundary coordinates) of the service area polygon. This constraint was defined as the Woodshed Delineation.

Conservation lands

A conservation land constraint was developed for each facility through a Union overlay of at least three map inputs: 1) the 75-mile Woodshed Delineation shapefile; 2) the Federal Lands shapefile as clipped to the Woodshed Delineation shapefile; and 3) all state level conservation shapefiles, as clipped to the Woodshed Delineation shapefile, for states with at least some land area located in the 75-mile woodshed area. The output shapefile from this Union procedure is described as Conservation Mask. A new attribute column was added into the Conservation Mask and given the name Raster. All areas located in a defined conservation area assigned the value of 0 for the Raster column, while those not in a defined conservation area were defined as 1. The Conservation Mask shapefile was then transformed into a Boolean raster dataset (0 = conservation land; 1 = not conservation land) at a 100m cell resolution using the values in the Raster column.

Two iterations of conservation land constraint were developed for the Carolina Wood Pellets and Dominion Virginia City Hybrid Energy facilities. The first iteration classified all National Forest lands as unavailable (Boolean value = 0) for sourcing hardwood biomass production. This constraint was given the acronym NNF for "No National Forest." The second iteration classified designated Wilderness areas within National Forests as unavailable for sourcing woody biomass production, but assumed that non-Wilderness areas would be available. This constraint was given the acronym NFA for "National Forest Allowed." All other state and federal conservation lands were assumed as unavailable in both National Forest constraint iterations for Carolina Wood Pellets and Virginia City Hybrid Energy.

Land cover sourcing screens

Land cover classifications within the GAP Land Cover dataset were used as the basis for defining a series of sourcing screen constraints for each facility. To facilitate computation efficiency of spatial models across large sourcing areas, the GAP Land Cover data classes, which have an original cell resolution of 30 meters, were generalized to a cell resolution of 100 meters. The land cover classification of each generalized cell was defined as the most frequent land cover class of original resolution contained within the new raster cell area.

Two facilities were modeled based on an assumption of the dominant feedstock being provided by pine plantation biomass: Georgia Biomass and Piedmont Green Power. In addition, the South Boston Energy and Enviva facilities were modeled as sourcing some softwood, as well as hardwood. For the softwood sourcing associated with these four facilities, a series of five land cover sourcing constraint scenarios (i.e., screens) were developed.

- **Softwood Screen 1**: Define GAP land cover class as "Evergreen Plantation or Managed Pine" as Boolean = 1. All other land cover classes are defined as Boolean = 0. This screen was given the acronym "PO" for "Plantation Only."
- **Softwood Screen 2**: GAP land cover classes "Evergreen Plantation or Managed Pine," "Harvested Forest – Grass/Forb Regeneration," "Harvested Forest – Shrub Regeneration," "Disturbed/Successional – Grass/Forb Regeneration," "Disturbed Successional – Shrub Regeneration," and "Undifferentiated Barren Land" classified as Boolean = 1. All other land cover classes are defined as Boolean = 0. This screen was given the acronym "PNP" for "Plantation and Disturbed, No Pasture."
- **Softwood Screen 3**: Include Pasture/Hay as Boolean = 1, in addition to all Boolean = 1 classes defined in Screen 2. This screen was given the acronym "PDP" for "Plantation, Disturbed and Pasture."
- **Softwood Screen 4**: This screen defines all upland forests and disturbed forest ecosystems as Boolean = 1, in addition to all Boolean = 1 classes defined in Screen 2. Pasture/Hay and all other land covers are classified as Boolean = 0. This screen was given the acronym "FNP" for "Forests No Pasture."
- **Softwood Screen 5**: This screen is similar to sourcing Screen 4, with the exception of defining Pasture/Hay as Boolean = 1. This screen was given the acronym of "UPL" for "Uplands."

All softwood screens were based on the hard assumption that existing row crop lands, developed lands, and wetlands are unavailable for conversion. While some conversion among these land use types into plantation pine may be expected to occur in any woodshed, previous analyses suggest that these land covers are far less likely to convert into plantation pine than upland forests or low intensity pastures (Zhang and Polyakov 2010). Because detailed statistical modeling of transitional probabilities at the ecosystem scale was beyond the scope of this study, the most parsimonious assumption was to restrict the land cover analysis to identified upland forests and non-prime agricultural lands (i.e., pasture/hay).

Three facilities were modeled as having a dedicated hardwood feedstock supply: Enviva (80% hardwood), South Boston Energy (50% hardwood), and Carolina Wood Pellets (100% hardwood). For these facilities, two scenario constraints were modeled for hardwood sourcing:

- **Hardwood Screen 1**: Includes all forests and disturbed forests in which hardwood trees may be present as Boolean = 1. Forest types with GAP NVC_MACRO classifications of "Longleaf Pine & Sand Pine Woodland," "Southeastern North American Ruderal Forest & Plantation," and "Wet Longleaf Pine & Southern Flatwoods" were assumed as unsuitable for sourcing hardwood biomass, and thus were classified as Boolean = 0. This screen was given the acronym "HDW" for "Hardwood."
- **Hardwood Screen 2**: Similar to Hardwood Screen 1, except that all wetland and riparian forest are also defined as Boolean = 0. This screen was given the acronym "HNW" for "Hardwood No Wetland."

The Virginia City Hybrid Energy facility was modeled similarly to the hardwood screens, and the high percentage of hardwood forest types in the woodshed makes it likely that hardwoods will serve as the dominant feedstock. However, because the combustion process may presumably accept available softwood material, no hard percentages were set for hardwood to softwood biomass. Natural forest regeneration to levels of harvestable biomass was further assumed to extend beyond the assumed 50-year lifetime of the facility, such that the non-forested Pasture/Hay land cover was excluded from all sourcing screens.

- **Virginia City Hybrid Energy Forestry Screen 1**: Defines all natural, plantation, and disturbed forest ecosystems, including riparian and bottomland forests, as Boolean = 1. All other land covers are defined as Boolean = 0. This screen was given the acronym "FOR" for "Forests."
- **Virginia City Hybrid Energy Forestry Screen 2**: Similar to Virginia City Hybrid Energy Forestry Screen 2, except that all wetland and riparian forest are defined as Boolean = 0. This screen was given the acronym "FNW" for "Forests No Wetlands."

Factor Development

Two primary factors are known to determine the economic viability for bioenergy facilities to source woody biomass from particular forestry locations across the landscape: 1) travel distance for transporting woody biomass from the forestry site to the biomass facility; and 2) the strength of demand competition with other wood users that may also bid for the same given biomass resource. These two factors were modeled using similar spatial analyses for all facilities considered in this study. In addition, a third factor of environmental suitability for conversion into plantation pine forestry was applied for those biomass facilities that are sourcing softwood from plantation pine.

Travel distance factor

The travel distance factor was derived through analyses developed with the Network Analyst tool in ArcGIS10.1. Using the Roads dataset, a Service Area shapefile was defined using the input point coordinates for each modeled bioenergy facility. Break Areas were defined at 1 mile increments from 1 to 75 miles, and output polygons were defined as "Rings." The Service Area polygon for each facility were then transformed into a continuous raster datasets (Range = 1, 75), with the raster value defined from the column attribute defined as "ToBreak." Using this approach, all areas with network distance of 0-1 miles were thus defined as raster=1, 1-2 miles as raster = 2… through 74-75 miles as raster = 75. The output raster dataset was named Travel.

Competition factor

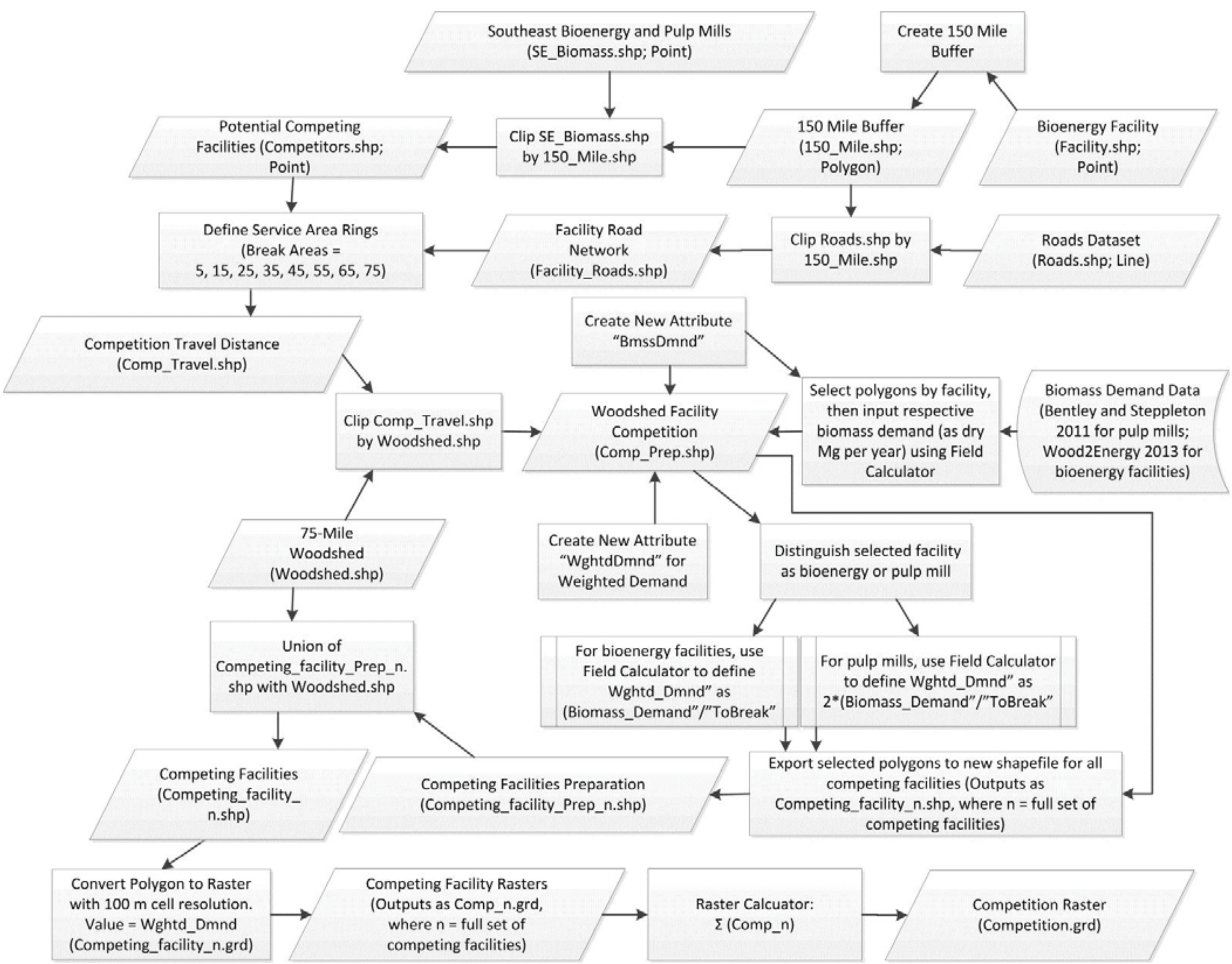
The competition factor was derived through a chain of GIS analyses that take into account relative landscape demands associated with other facilities that may source similar types of woody biomass from within the modeled facility's 75-mile woodshed. These competing facilities were assumed to include other biomass energy facilities (with facility demand from Wood2Energy 2013) and pulp mills (with facility demand data from Bentley and Steppleton 2011). Saw mills were not modeled as potential competitors due to the higher quality wood and associated higher prices associated with the supply of saw timber demand. The full GIS work flow for the competition analysis is described in the Competition Figure 18.

While the GIS procedure for deriving the competition factor involved a complex array of steps, the underlying premise of the resultant competition factor is that other woody biomass facilities exert competitive pressure (C) across the landscape as a direct function of their overall biomass demand (D) and the network travel distance associated with supplying wood to the facility from a particular location (T).

Competitive pressure from each competing bioenergy facility was defined spatially as CBE=D/T, where CBE = competitive pressure from bioenergy; D = Biomass demand (Mg/yr); and T = Network travel distance (miles). The logic of this equation is that competing facilities with larger biomass demand (D) exert greater competitive pressure (C), and that this effect is greater at locations closer to the competing facility and lesser at locations further from the competing facility – as captured by distance (T).

Several recent research studies indicates that extant pulp and paper mills in the southeast United States consistently pay higher prices for delivered woody biomass than bioenergy facilities, and that decisions to locate bioenergy facilities typically include an objective to minimize sourcing competition with pulp and paper mills (Conrad and Bolding 2011; Stasko et al. 2011; Mendell

Figure 18. Competition Figure



and Lang 2012; Guo et al. 2013). Detailed equilibrium modeling provides the most sophisticated method for simulating specific landscape price competition between pulp mills and bioenergy facilities over time, but such modeling was beyond the scope and resources available for this study. Instead, to simulate this assumed effect we applied an additional coefficient when spatially calculating competitive strength for pulp mills:

> CPM = 2*D/T, where CPM = Competitive pressure from pulp mill; 2 = pulp mill competition coefficient; D = Biomass demand (Mg/yr); and T = Network travel distance (miles)

The applied pulp mill competition coefficient is clearly an approximate estimation for simulating the expectation of higher competitive strength of pulp mills as compared to bioenergy facilities of similar size. However, data points by Conrad and Bolding (2011) show delivered pulpwood prices reaching over two times the price of delivered wood fuel chip price on a quarterly basis in Virginia, and recent analyses suggest that southeastern pulp and paper mills can maintain profitability at significantly higher pulpwood prices (e.g., Mendell and Lang 2012; Guo et al. 2013). By contrast, similar analyses of woody bioenergy facilities indicate that operations are generally running at close to a breakeven point at current biomass and bioenergy pricing structures, which currently are supported by a variety of subsidy and tax credit programs (Mendell and Lang 2012; Guo et al. 2013). Thus, the competition coefficient applied here is likely conservative in accounting for the relative competitive strength of an existing pulp and paper industry that remains many times larger than the nascent wood to bioenergy market.

Once C was derived for all bioenergy and pulp mill facilities with overlapping woodshed sourcing areas, the final competition factor map was calculated spatially as:

> Σ C, including all facility values calculated as CBE and CPM

Pine plantation suitability factor

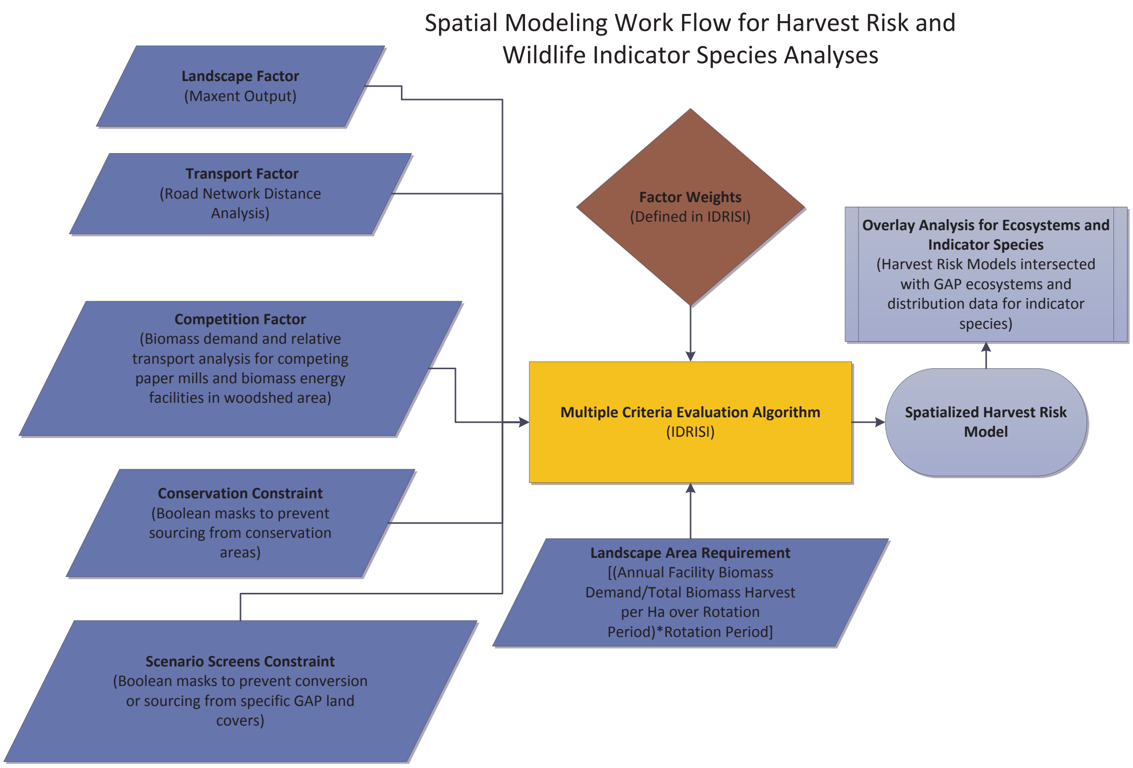
A primary motivating concern behind this study is to better understand impacts of the growing woody biomass energy market as a potential driving factor for increased conversion of native southeastern forests into plantation pine forestry. For those facilities that utilize plantation pine grown forestry as a primary feedstock, environmental suitability for growing plantation was modeled as an additional factor for inclusion in the MCE process using the Maxent (short for Maximum Entropy) species distribution modeling program (Philips and Dudek 2008).

Maxent is a species distribution model that develops suitability predictions based on an iterative analysis of environmental input variables across the landscape of interest (Elith et al. 2006). The Maxent program is generally regarded as among the most reliable and most widely applied species distribution models that use "presence-only" data (Elith et al. 2011). Although Maxent is more typically used to model distributions of non-cultivated species in the natural environment, previous work has demonstrated the validity and efficiency of utilizing presence-only modeling techniques such as Maxent within integrated assessments of potential land use change from the expansion of bioenergy crops at broad landscape scales (Evans et al. 2010).

In this study we developed Maxent models of pine plantation in a simple 75-mile radius around the facilities that are sourcing some or all of their biomass from southern yellow pine (Georgia Biomass, Georgia Piedmont, Enviva, and Plywood Trail). The occurrence data representing pine plantation presence for each facility were obtained through a random sampling of 5,000 points from the GAP land cover dataset for cells classified as "Evergreen Plantation or Managed Pine" within the 75-mile woodshed.

Four types of environmental data were used to fit the occurrence data to a Maxent distribution model at 100 meter cell size resolution: 1) elevation; 2) slope; 3) soil type; and 4) distance to roads. Previous regional models of plantation pine forestry siting patterns in the southeastern U.S. have noted highly significant relationships with each of these four variables (Sohl and Sayer 2008; Yeo and Huang 2012). The importance of elevation in forestry is generally as a proxy for climate variation, although elevations near or below sea level clearly can limit or exclude plantation forestry due to the influence of tidal flooding. The importance of slope is most obvious in high slope areas where planting, maintenance, and logging of plantation forestry may be logistically or economically unsuitable. However, very low slopes may in some areas constrain forestry due to the competitive advantage for alternative uses such as agriculture, or growth yield or logistical issues posed by exceptionally poor drainage. Increased pine planation productivity is clearly associated with specific soil associations, although pine forestry may also be expected to be less prevalent in areas with very high quality soils due to the comparative advantage of more intensive agricultural products (Hamilton 1990). Distance to roads is included as a final variable

Figure 19. Maxent modeling workflow



due to the apparent logistical and efficiency advantage of nearby road access for minimizing loader transport distance. While variability in local temperature, precipitation, and other climate conditions also are known to influence the regional distribution of plantation pine forestry across the southeast (see, e.g., Sohl and Sayer 2008), climate variables were not included in this study due to the expectation that elevation would serve as a dominant proxy/covariate for climate conditions within the more localized (i.e., < 75 mile radius) sourcing areas of bioenergy facilities (Daly 2006).

Elevation (in feet) and slope (as percentage) were derived from the USDA National Elevation Dataset (USDA, NRCS 2001) and entered into the Maxent model as continuous variables. The General Soil Map Unit classification from the STATSGO digital soils map (USDA, NRCS 2006), as generalized from original polygons to 100 meter raster cell size, was entered into the Maxent model as a categorical variable. The distance to roads variable was derived by using the Spatial Analyst tool in ArcGIS 10.1 to apply a 100 meter resolution Euclidean distance analysis from the Roads dataset (ESRI 2010). All of these variables were then clipped to the 75-mile woodshed area. Maxent models were then fit using the occurrence data and four environmental predictor variables for the five facilities sourcing plantation pine forestry.

MCE Decision Parameters

Initial factor parameterization for the MCE was applied through transformation of files using the FUZZY module in IDRISI Selva 17.01 (Table 2). Transport and Competition were transformed through a monotonically

Table 2. Initial factor parameterization using the FUZZY module in IDRISI Selva 17.01

Factor	FUZZY parameters	Softwood weighting	Hardwood weighting
Transport	Function Type = Sigmoidal Function Shape = Monotonically decreasing Control point c = 1 (1 transformed to 255) Control point d = 75 (75 and above transformed to 1)	0.4	0.5
Competition	Function Type = Sigmoidal Function Shape = Monotonically decreasing Control point c = 0 (0 transformed to 255) Control point d = 100,000 (100,000 and above transformed to 1)	0.4	0.5
Maxent	Function Type = Sigmoidal Function Shape = Monotonically increasing Control point a = 0 (0 transformed to 1) Control point b = Maximum value (Maximum value transformed to 255)	0.2	N/A

Table 2. Initial factor parameterization using the FUZZY module

decreasing function, as higher values in the input map are associated with an assumption of lower suitability (e.g., Transport = 1 is more suitable than Transport = 10). Maxent was transformed using a monotonically increasing function, as higher input values correspond to higher suitability. Control points in the MCE refer to the threshold values at which minimum and maximum suitability values are defined, with all values between the control points transformed in a continuous integer scale between 1 - 255. Control points for Transport and Maxent factors simply followed the minimum and maximum values of the input maps.

The control point of 100,000 was applied for setting the lowest suitability Competition factor in all facility MCEs out of the general recognition that there is a geographic threshold point in which competitive exclusion of other wood using facilities can be assumed due to assumed purchasing power (i.e., demand) and procurement travel distance (see, e.g., Huang et al. 2012). A translation of the control point of 100,000 (Mg/mile) used here is that competitive demand pressure reaches a minimum geographic threshold equivalent to the 5-mile travel distance radius of a facility that has 500,000 Mg/yr of woody biomass demand. By setting the Competition control point d to 100,000 in this way, all Competition values of 100,000 or higher were given the suitability value of 1 for the final Competition factor. By contrast, a simple suitability extrapolation that did not include this control point would effectively make the relative suitability entirely dependent on the maximum competition value. For example, if the maximum Competition value was 500,000 (corresponding to demand pressure within a 5-mile radius for a facility with 2,500,000 Mg/yr of biomass consumption), cells with Competition values of 100,000 would be considered ~80% more suitable than those with a value of 500,000 scale – and only ~20% less suitable than those cells with no overlap from competitors (i.e., Competition = 0).

After the FUZZY transformation, factors were then assigned importance weights for input into the final MCE calculation. For the softwood model, Transport and Competition were each weighted at 0.4, while the Maxent suitability model was weighted as 0.2. The higher weights were assigned to Transport and Competition based on numerous studies indicating that the relative distance to a bioenergy facility and lower competition from other wood users are the two most critical economic variables likely to drive landowner decisions to supply bioenergy facilities with woody biomass (Perez-Verdin et al. 2009; Cieszewski et al. 2011; Joshi and Mehmood 2011; Huang et al. 2012; Guo et al. 2013). While the Maxent suitability output does in our judgment provide important information for marginal decision support when all other factors are equal, lower weighting of this factor is justified by at least two factors: 1) potential for silvicultural management practices (e.g., fertilization, genetic improvements, water management, and competition control) to improve production on less environmentally suitable sites (Munsell and Fox 2010); and 2) uncertainty about the relative scalar accuracy of Maxent model predictions, as compared to the much more certain network distance calculations used to develop the Transport and Competition factors. Because environmental suitability for softwood plantation forestry provides no directly relevant information for predicting long-term hardwood sourcing, Maxent models were not included in the hardwood models.

Harvest Area Objectives (HAOs) and Multiple Objective Land Allocation (MOLA)

The next procedure in the multi-criteria decision analysis process was to define a series of harvest area objectives (HAOs) that correspond to land area footprints for biomass sourcing. The HAO values provide an objective land area for selecting a given number of the highest ranking cells as defined by the MCE, thus providing a final map output showing the land area predicted as most suitable for biomass harvest given the MCE criteria.

A series of 10 sequential HAO values were calculated for each facility through the following equation:

> HAO_n = (D/P)/U, where D = Facility wood demand (as dry Mg/yr); P = Net primary production of woody biomass (as dry Mg/yr/ha); U = Biomass utilization assumption (%), calculated as 1/n, where n corresponds to the integer scenario number.

As calculated in this way, HAO_1 represents the minimum land area requirement for sourcing a biomass facility under the condition that all theoretically harvestable biomass from the most suitable lands is allocated to this facility. In practice, however, such a condition of all extracted woody biomass from a given area being allocated to a single biomass consumer is clearly unrealistic. Instead, some allocation to higher value saw timber, unrecoverable residues, and competing facilities must be assumed, even at sites that are most suitable for sourcing a bioenergy facility. Based on both this rationale and the practical interest of reducing computational burdens, we set the minimum area for running suitability models at the HAO_2 level, and then subsequently limited scenario runs and lumped subsequent analyses to the even HAO scenarios (i.e., n = 2, 4, 6, 8, 10). The 50% bioenergy utilization represented by HAO_2 corresponds well to the upper limits of woody biomass to bioenergy that may be expected from southeastern forestry lands given other uses and economic considerations (McClure 2010; Munsell and Fox 2010; Josh and Mehmood 2011). By contrast, the 10% bioenergy utilization represented by HAO_10 generally approximates the amount of land area that would be required if sourced biomass was provided solely through the use of residual material (see, e.g., Bentley 2009; Vanderberg et al. 2012; Abt and Abt 2013).

With the definition of the iterative HAO land areas, the final procedure in the modeling workflow was spatial selection of raster cells most at risk/suitable for softwood and/or hardwood sourcing, as determined by the cumulative MCE ranking, through a multiple objective land allocation (MOLA) tool. For facilities assumed to sole source softwood (i.e., Georgia Biomass and Piedmont Green Power), hardwood (i.e., Carolina Wood Pellets), or undifferentiated forest biomass (i.e., Virginia City Hybrid Energy), iterative MOLA targets were run for HAO_2, HAO_4, HAO_6, HAO_8, and HAO_10 for the one biomass sourcing objective. For facilities with both hardwood and softwood sourcing, the full suite of HAOs was run simultaneously for the two biomass sourcing objectives. Through this procedure, a given piece of land could only be allocated to either softwood or hardwood sourcing. In the case of softwood sourcing, the specific risk factor is land cover maintenance or conversion to plantation forestry in response to bioenergy demand. In the case of hardwoods, the specific risk factor is extraction of primary and/or residual biomass for bioenergy utilization.

In terms of primary interpretation, the HAO_2 scenarios represent the areas predicted to have the highest risk (i.e., suitability) for biomass procurement, while the HAO_10 scenarios represent the much larger area required for sourcing from residuals-only. In order to represent composite risk across a series of sourcing practices, the Boolean raster outputs from HAO scenarios were summed for each facility sourcing objective. Through this summing procedure, maps with an integer scale from 0-5 were produced, with values of 5 representing raster cells selected for all HAO scenarios, values of 4 representing cells selected for four scenarios… to values of 0 representing cells not selected for any HAO scenarios.

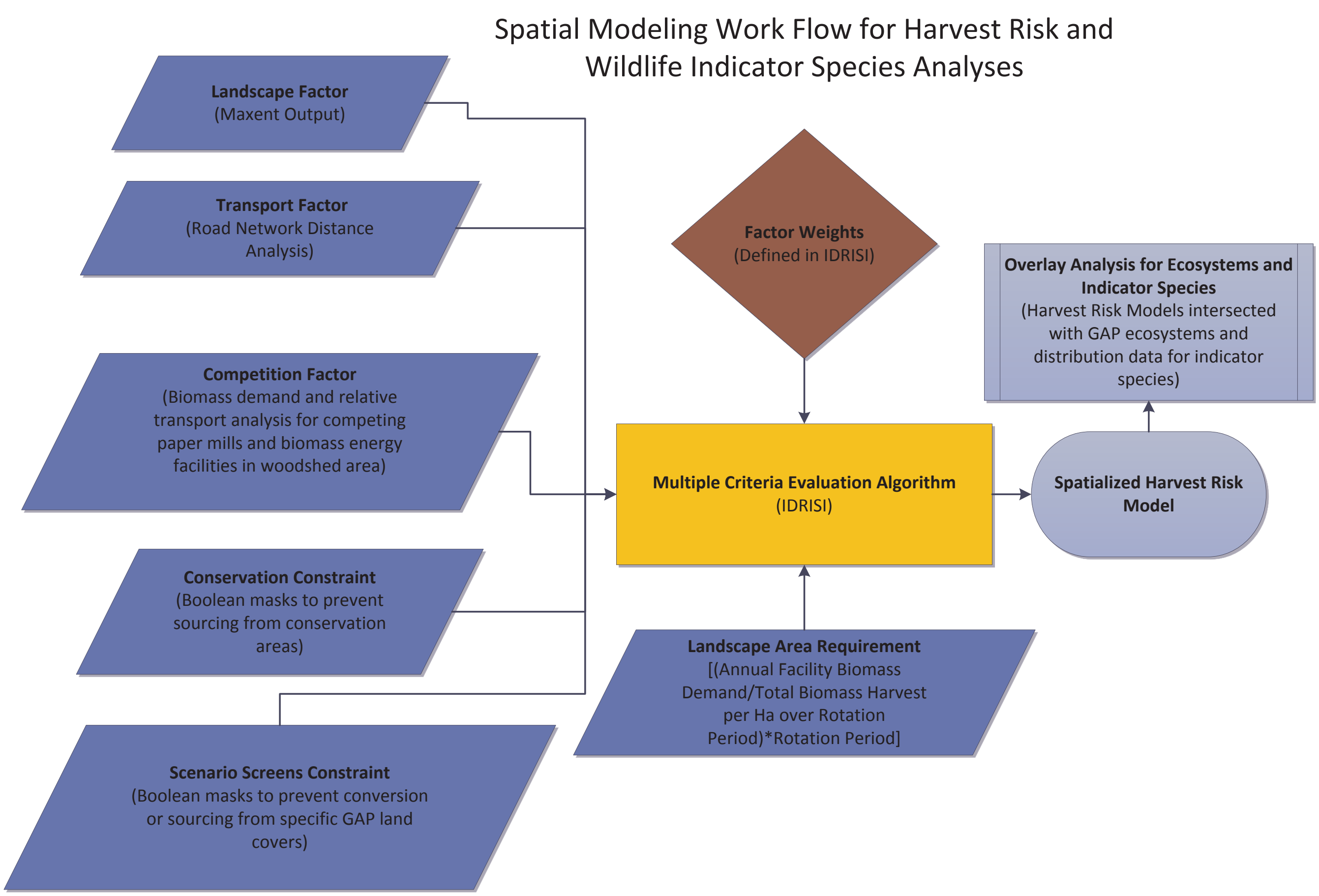
For analysis and visualization purposes, these map integer values were then interpreted into an ordinal risk scale:

5 = High risk
4 = Moderately high risk
3 = Moderate risk
2 = Moderately low risk
1 = Low risk
0 = Not selected in any model run

GAP land cover and wildlife distribution analyses

The next step of the spatial modeling process was to provide an assessment of relative level of risk to extant native ecosystems and wildlife indicator species under sourcing screen scenarios. Following Fahrig

Figure 20. Wildlife impact assessment workflow



(2003), we utilize the risk of forest habitat loss, as implied by the direct replacement of an existing native forest ecosystem with plantation forestry (i.e., softwood sourcing) or introduction of a novel biomass harvest practice within extant forestry systems (i.e., hardwood sourcing), as the dominant variable of interest for interpreting the scale of potential biodiversity impacts from sourcing scenarios.

To develop these assessments, formal overlay risk analyses were performed at the HAO_2, HAO_6, and HAO_10 levels for subsets of screen scenarios that provide particular conservation interest or concern. The basis for ecosystem analyses was the GAP land cover as generalized to a 100 meter cell size and masked to the 75-mile road network woodshed area.

The basis for the indicator species analyses was GAP distribution data for each respective species, also generalized to a 100 meter cell size. A series of tabular tallies show the total areas of potential impacts to woodshed ecosystems and indicator species over a 50-year facility lifetime under the scenarios of interest. From these results, specific interpretations of biodiversity concerns, as well as potential opportunities for mitigating such concerns through sourcing constraints and other landscape management programs, are developed for each case study facility.

Identifying ecological associations of high conservation value

A final spatial modeling exercise, performed in partnership with analysts from NatureServe, was developed to identify ecological associations of high conservation value in facility woodsheds. Raster files representing the 75-mile woodshed areas for each facility, and with conservation areas removed from consideration, were intersected with NatureServe's "element occurrence" dataset. These element occurrence datasets for ecological associations have been assembled by each state's Natural Heritage Program, and contain general spatial information for ecological associations and species of conservation concern. Conservation status listings for ecological associations follow the NatureServe global conservation status ranks of G1 (critically imperiled, or very high risk of extinction), G2 (imperiled, or high risk of extinction), G3 (vulnerable, or vulnerable to extinction), G4 (apparently secure), and G5 (secure).

By intersecting woodshed areas with these element occurrence datasets, a list of ecological associations of high conservation value and total number of known element occurrences for these associations (as contained within the NatureServe database) was assembled for each woodshed. While these lists provide critical information into the types of high conservation value ecological associations known to occur within woodshed areas, it is important to note that the extent of mapping effort, classification terminology, and spatial resolution of element occurrences vary widely among – and even within – different states. Importantly, absence of G1-G3 listings for some woodsheds (e.g., Georgia Biomass and Piedmont Green Power) does not imply that high conservation associations do not occur in these woodsheds. Instead, such absences are much more likely a function of little previous effort to identify and map such associations within these woodshed areas particularly as cross-walked to the NatureServe classification system. Due to such idiosyncratic features of the ecological occurrence datasets, it was not possible to develop confident area calculations or formal comparisons regarding the G1-G3 associations identified within the different woodshed areas considered in this project.

Table 3. Spatial Datasets	
Data Description	**Source Data Set**
Land Cover	USGS. 2011. National Gap Analysis Program Land Cover Data – Version 2. Metadata at http://gapanalysis.usgs.gov/gaplandcover/data/land-cover-metadata/.
Species Distributions	USGS. 2011. USGS Gap Analysis Program Species Distribution Models. Metadata at http://gapanalysis.usgs.gov/species/data/metadata/.
Roads	ESRI. 2010. U.S. and Canada Detailed Streets. Metadata at http://library.duke.edu/data/files/esri/esridm/2010/streetmap_na/streets.html.
Soils	USDA, NRCS. 2006. Digital General Soil Map of U.S. Metadata at http://soildatamart.nrcs.usda.gov/Metadata.aspx?Survey=US.
Elevation	USDA, NRCS. 2001. National Elevation Dataset 30 Meter 1-degree Tiles. Metadata at http://www.alt2is.com/mcwma/ftp/partner/GIS_layers/GIS_Metadata/elevation/ned30m_metadata.html.
Pulp Mills	USDA Forest Service, Southern Research Station, SRS-4851. Mill2005s. Metadata at http://www.srs.fs.usda.gov/econ/data/mills/mill2005s.htm
Woody Bioenergy Facilities	SELC. 2013. Proposed and Existing Woody Biomass Facilities in the Southeastern US. http://www.southernenvironment.org/uploads/fck/biomassfacilities_map&table_2013June26.pdf.
Federal Lands	National Atlas of the United States. 2005. Federal Lands of the United States. Metadata at http://nationalatlas.gov/metadata/fedlanp020.html.
Florida Conservation Lands	Florida Natural Areas Inventory. 2013. Florida Conservation Lands. Metadata at http://www.fnai.org/shapefiles/FLMA_metadata_201306.htm.
Georgia Conservation Lands	University of Georgia NARSAL and Georgia Department of Natural Resources. 2011. State Land Conservation GIS, Georgia Conservation Lands. Available at https://data.georgiaspatial.org/index.asp.
Kentucky Conservation Lands	Kentucky Department of Parks. 2005. Kentucky State Park Boundaries. Metadata at http://kygisserver.ky.gov/geoportal/rest/document?id=%7B4C790098-C3E8-42C6-A4EB-22CA7215911B%7D.
North Carolina Conservation Lands	North Carolina Heritage Program. 2013. Managed Areas in North Carolina. Metadata at http://data.nconemap.com/geoportal/catalog/search/resource/details.page?uuid=%7B2855F163-E809-44BF-92E5-
South Carolina Conservation Lands	USGS and South Carolina Department of Natural Resources. 2009. Public Lands. Available at http://www.dnr.sc.gov/GIS/descMLproject.html.
Tennessee Conservation Lands	Tennessee State Parks Office of GIS. 2011. Tennessee State Parks and Natural Areas Boundaries. Available at http://www.tn.gov/environment/parks/gis/data/.
Virginia Conservation Lands	Virginia Department of Conservation and Recreation. 2013. Conservation Lands Database. Metadata at http://www.dcr.virginia.gov/natural_heritage/documents/conslands.pdf.
West Virginia Conservation Lands	West Virginia State GIS Data Clearinghouse. 2011. Public Lands – Wildlife Management Areas. Available at http://wvgis.wvu.edu/data/data.php.

Table 3. Spatial Datasets

V. CASE STUDY OF GEORGIA BIOMASS, LLC

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Facility overview

Georgia Biomass, LLC is a wood pellet facility located near Waycross, Georgia . The facility has an estimated pellet output of 750,000 Mg/yr (Wood2Energy 2013), which requires an approximate wood demand of 810,000 dry Mg/year. All of this biomass is currently provided by yellow pine, including loblolly and slash pine species. This facility relies on clean chips as a feedstock for production of pellets, and currently uses little to no residual material.

Figure 21. LongLeaf Pine, Photo Credit: Tiffany Williams

Currently, most commercial forests in this region are managed to provide pulpwood to local pulp mills with co-management to grow larger diameter trees for higher value saw timber. Pulpwood management results in approximately 25 year rotations with 2 thinnings during a rotation. The average density in this type of regime is approximately 400-600 trees per acre. Annual average productivity for pulpwood quality biomass is estimated at 9 dry Mg/ha for yellow pine in this coastal plain woodshed (Kline and Coleman 2010). Based on these annual productivity values, rotation regimes, and facility biomass demands, we applied an area of 90,000 hectares in plantation forestry as the minimum sourcing requirement for this facility (i.e., HAO_1) under 100% allocation of harvested biomass.

GAP land cover summary

The 75-mile road network sourcing area (Georgia Biomass Map 1) for Georgia Biomass provides a total land cover base of approximately 3.03 million hectares. The largest land cover type within this woodshed area is plantation pine forestry, which occupies over 661,000 hectares, or approximately 21.8% of the woodshed. Over 544,000 additional hectares, or approximately 18.0% of the woodshed, is classified as recently disturbed, in some stage of ruderal succession, or deciduous plantation forestry. Taken together, the existing plantation pine and disturbed forestry lands account for approximately 39.8% of the woodshed land area.

Figure 22. Planted Pine, Photo Credit: Robinson Schelhas

Cultivated croplands comprise 10.7% of land area in the Georgia Biomass woodshed, and are the next largest single land cover after plantation forestry. Pasture/hay lands comprise 3.8% of additional land, giving a total of about 14.5% of land cover in some form of agricultural usage. Another 6.9% of the woodshed is identified as developed areas that can be expected to provide minimal primary forestry biomass to the facility. Most of the developed areas are contained in or around the small Georgia cities of Waycross, Brunswick, Valdosta, and Jesup. Another 1.5% of the woodshed is composed of open water, fresh and saltwater marshlands, and beach land covers. Together these non-forest land covers encompass approximately 22.9% of the woodshed area.

There are a large number of natural forest ecosystem types located within the Georgia Biomass woodshed. These include a variety of upland and wetland forest associations typical of the SE coastal plain, but also several non-riverine basin wetland forests that are globally unique to the Okefenokee Swamp region. Over 426,000 hectares, or 14.1%, of the natural forests are uplands, with approximately 326,000 hectares (10.8%) classified as longleaf pine (*Pinus palustris*) woodlands and various other native pine tree ecosystem associations. Other native trees commonly found on dry uplands in this woodshed include turkey oak (*Quercus laevis*), and sand live oak (*Quercus geminata*), with more mesic upland forest systems often containing slash pine (*Pinus elliottii*), loblolly pine (*Pinus taedus*), live oak (*Quercus virginiana*), laurel oak (*Quercus hemisphaerica*), water oak (*Quercus nigra*), and sweetbay magnolia (*Magnolia virginiana*). Natural wetland forests of all types occupy approximately 21.8% of the woodshed area, with the most common wetland trees including bald cypress (*Taxodium distichum*), pond cypress (*Taxodium ascendens*), black gum (*Nyssa biflora*), and red maple (*Acer rubrum*). All natural forest lands together occupy over 1 million hectares, or 35.9% of the woodshed.

Public lands databases that include federal landholdings and state conservation lands for Georgia and Florida indicate that 10.4% of the woodshed is under some form of conservation protection. By far the largest public landholdings in the woodshed are contained within the Okefenokee National Wildlife Refuge and adjacent state conservation lands held by Georgia and Florida. Other notable conservation areas include the Bank's Lake National Wildlife Refuge, Paulks Pasture Wildlife Management Area (Georgia DNR), Little Satilla Wildlife Management Area (Georgia DNR), and several Georgia state lands located along the Altamaha River corridor.

Georgia Biomass Table 1 provides a complete summary of ecosystem area coverage in the 75-mile sourcing area for the Georgia Biomass facility, along with associated areas and percentages identified as either being under public ownership or other forms of conservation protection. Georgia Biomass Map 2 provides a visualization of GAP land cover generalized to the macro ecosystem level, as well as outlines of major conservation lands located in the woodshed.

Woodshed competition

The competition overlay and network analysis for the Georgia Biomass pellet plant identified a total of thirteen other facilities that may be expected to compete for woody biomass within at least some portion of the 75-mile woodshed area (Georgia Biomass Map 3). This includes eight active pulp and paper mills, as well as five bioenergy or biopellet facilities active as of April 2013. Most of the pulp and paper facilities that show sourcing overlap with the Georgia Biomass woodshed are located near the Atlantic coast. For this reason, much of the eastern woodshed shows extremely high competitive demand pressure for pulpwood quality feedstock (Georgia Biomass Map 4). By contrast, relatively little competitive demand pressure is shown for much of the western woodshed.

Plantation pine forestry distribution and suitability

A visualization of the Maxent suitability model for plantation pine forestry in the Georgia Biomass woodshed is given in Georgia Biomass Map 5. Distance to road provided the strongest contribution to the Maxent model (43.7%) for the Georgia Biomass woodshed, with soil type (37.8%) and elevation (16.1%) also providing major contributions. Slope was a minor predictor (2.4% contribution) of plantation suitability in this woodshed, likely due to relatively flat slopes found throughout the landscape.

Biomass sourcing models and associated ecosystem risks

The full series of biomass sourcing screen results for the Georgia Biomass facility are presented in Georgia Biomass Maps 6-10. The HAO for each model run and associated suitability classes associated with the color-coding are provided in Georgia Biomass Table 2. A clear feature of these visualizations is that the strong competitive demand pressure from the coastal pulp and paper facilities effectively "pushes" the most favorable sourcing areas into the western woodshed.

The model results indicated insufficient land area for achieving HAO_8 and HAO_10 under the "Pine Plantation Only" (PO) screen (Georgia Biomass Map 6). These results suggest that the Georgia Biomass facility would not be able to source biomass based on the most restrictive criteria of only residual material from existing plantation pine forestry. However, because the manufacturing process requires clean chips derived primarily from main stem pulp wood, it is highly unlikely that the facility would in practice source across the entire land area implied by a residuals-only sourcing demand. The areal requirement for HAO_10 was readily achieved with the PNP screen that allows sourcing from plantation pine and other disturbed forestry lands, while allowing no conversion of existing pasture or native upland forest ecosystems (Georgia Biomass Map 7).

The worst case screen from a biodiversity conservation standpoint for the Georgia Biomass facility is "Forest No Pasture" (FNP). This screen assumes that conversion of upland forests will occur with no restriction and that no existing pastures may serve as a potential donor land cover. A spatial visualization of the predicted risks to upland forest ecosystems under FNP is provided by Georgia Biomass Map 11. Summary tables of the detailed land covers that fall within the High, Moderate, and Low risk scenarios of the FNP are shown in Georgia Biomass Table 3a, 3b, and 3c.

The FNP scenario model for Georgia Biomass identified 43,520 hectares of natural stand forests that show a High conversion risk (Georgia Biomass Table 3a). This includes 34,594 hectares of longleaf and other pine upland forests, as well as 8,566 hectares of native upland or mesic hardwood associations. Additional conversion of remnant longleaf pine stands is likely the most serious conservation concern in this woodshed, as a large number of species of high conservation concern are known to show adverse effects from landscape-scale conversion of longleaf pine to plantation forestry. Examples of such include the federally endangered red-cockaded woodpecker (*Picoides borealis*) and the federally threatened eastern indigo snake (*Dymarchon corais*), as well as several species of special concern including (*Crotalus admananteus*), Bachman's sparrow (*Aimophila aestivales*), SE American kestrel (*Falco spiverius Paulus*), gopher tortoise (*Gopherus polyphemus*), and pocket gopher (Van Lear et al. 2005).

NatureServe analysis of G1-G3 ecological associations

NatureServe analyses found no known occurrences of G1 (critically imperiled), G2 (imperiled), or G3 (vulnerable) ecological associations within the Georgia Biomass woodshed. This result is believed to be an artifact of very limited ecological association mapping in Georgia, and does not indicate that G1-G3 associations are not present in this woodshed. Because of the paucity of available data, detailed identification and protection of G1-G3 ecological associations can be recommended as a near-term need for ensuring that biodiversity conservation can be implemented as part of sustainable biomass energy procurement practices in this woodshed.

Indicator species analysis

Georgia Biomass Tables 4a – 4c provide a summary comparison of indicator species habitat overlay results between the FNP (no forest protection, no pasture conversion) and PNP (pine and disturbed only, no pasture conversion) sourcing screens. With the exception of the northern cricket frog, all analyzed HAO runs for the FNP scenario show higher areas of habitat overlay than similar HAO runs of the PNP scenario.

For all intensity scenarios, the Swainson's warbler is the species with the highest percentage increase in habitat risk under the FNP screen, but also the species with the lowest area and woodshed habitat percentage overlay for any scenario. These results reflect the generally low occupancy of the Swainson's warbler in plantation pine forestry, the bird's preference for riparian and hardwood forests that generally show lower conversion risk than upland pine forests, and a high percentage of Swainson's warbler habitat in the Georgia Biomass woodshed that is held in public or conservation ownership status. Although utilization of plantation pine forestry by Swainson's warblers is known in the SE U.S. (Bassett-Touchell and Stouffer 2006), maintenance of bottomland and mesic hardwood stands is likely to be highly protective of this species in the Georgia Biomass woodshed.

The brown-headed nuthatch is the indicator species with the second highest percentage of habitat overlay risk under both the FNP and PNP screens for all scenarios. Moreover, relative habitat overlay risk is substantially higher for the FNP screen under all scenarios. This result reflects the brown-headed nuthatch's higher general occupancy of native pine land covers as compared to plantation pine forestry, a habitat preference is generally thought to be a function of the higher snag density in natural pine stands (McComb et al. 1986; Land et al. 1989). By extension, conversion of natural pine stands to plantation pine forests can be generally predicted to have negative impacts on brown-headed nuthatch populations. While brown-headed nuthatches show very low utilization of dense plantation pines with high canopy cover, commercial thinning practices that reduce pine canopy, suppress understory hardwoods, and increase herbaceous/shrubby groundcover can result in rapid increases of brown-headed nuthatch utilization at the site scale (Wilson and Watts 1999). From a landscape habitat standpoint, this suggests that bioenergy sourcing practices that promote mid-rotation thinnings, while also excluding any new conversion of extant high quality natural pine stands, may have the potential to provide some benefit to local brown-headed nuthatch populations.

The northern bobwhite shows the second highest total area overlay for all scenarios, a result that directly reflects the wide range of woodland, forestry, and agricultural habitats that this species utilizes (Blank 2013; Janke and Gates 2013). While the FNP screen resulted in more potential habitat overlay for the northern bobwhite quail as compared to the PNP screen for all scenarios, the relative percentage of increase is relatively small (ranging from 2.9 – 3.4%). This result is consistent with work suggesting that northern bobwhite quail populations can be relatively resilient to natural stand conversion into plantation pine (Felix et al. 1986; Dixon et al. 1996), although there is some concern that newer stand-establishment methods may be less conducive for northern bobwhites as compared to historic plantation pine forestry practices (Jones et al. 2010). Work by Hughes et al. (2005) suggests that edge plantings of short-rotation plantation pines along agricultural fields, which has been recommended as an agro-forestry strategy for sustainable bioenergy sourcing, may have some potential for northern bobwhite habitat enhancement in the southern Georgia coastal plain. However, northern bobwhite responses in this and other woodsheds will likely be dependent on the extent to which bioenergy management changes edge dynamics between plantation pines, early successional natural forest stands, pasture/grasslands, and agricultural lands at a broader landscape scale (Seckinger et al. 2008).

The Eastern spotted skunk is the indicator species that shows the highest overall area increase in at-risk habitat, and second highest percentage increase, in comparisons between the FNP and PNP scenarios for the Georgia Biomass facility. While large declines of this species across its range, including in SE Georgia, are well-documented over the past several decades, specific factors behind this decline have long been regarded as unclear (Gompper and Hackett 2005). However, recent work indicates that the Eastern spotted skunks have home ranges that require relatively large patches (~80 ha) of young pine and hardwood forest stands with high structural complexity in both the canopy and understory layers (Lesmeister et al. 2013). Based on these habitat preferences, introduction of heavy understory control in intensive plantation pine forestry may be hypothesized as a potential source of additional degradation for Eastern spotted skunk habitat, particularly in scenarios where extant native hardwood and pine forests with understory structural complexity are converted into plantation pines. For all these reasons, sourcing practices that prohibit conversion of natural forest stands are likely critical for maintenance of suitable Eastern spotted skunk habitat in the Georgia Biomass woodshed. Similar to the northern bobwhite, increased afforestation of young stand age pine forests for bioenergy production along edges with agricultural landscapes may have the potential to enhance habitat for the Eastern spotted skunk. However, such afforestation is likely to have most benefit for Eastern spotted skunks when explicitly designed to increase connectivity with riparian or other hardwood forest corridors.

The long-tailed weasel is the indicator species that shows the highest overall area of overlay impact under all scenarios, a result that reflects both its large home ranges and wide diversity of forest habitat utilization (Simms 1979). Habitat overlay risk is higher for FNP as compared to PNP for all scenarios, although the relative percentage of increased risk is generally small (3.6 – 4.6%). The long-tailed weasel is known to have high behavioral sensitivity to fragmentation of the forest landscape through agricultural clearing (Gehring and Swihart 2004), although little is directly known about the specific impacts to long-tailed weasels that may be associated with conversion of natural forest stands through plantation pine conversion in the SE U.S. However, research in other areas of North America suggests that managed forests with high canopy cover provide long-tailed weasels with connectivity between higher quality natural forest stand habitats (Simms 1979; Gehring and Swihart 2003). In the Georgia Biomass woodshed, it is reasonable to suspect that rotational management regimes that maintain dynamic connectivity corridors between higher stand age plantation pines and natural forest stands may be expected to minimize habitat impacts on long-tailed weasels and other species highly sensitive to discontinuities in forest cover, whether associated with permanent clearing (i.e., agriculture) or multi-year loss of canopy following a forestry clear cut.

The gopher frog is notable for having the highest percentage of woodshed habitat at-risk from the FNP scenario. Listed as a species of conservation concern in Georgia, the gopher frog has high habitat affinity for open understory longleaf pine and pine flatwood ecosystems with intact populations of pocket gophers and/or gopher tortoises (Blihovde 2006; Roznik and Johnson 2009). Although gopher frogs can be found in some pine forestry sites that are managed for more open canopy conditions, conversion of native longleaf pine into plantation pine forestry land covers is widely recognized as a major contributor to large population declines noted in this species over the past several decades (Mitchell et al. 2006). Identified habitat risks for this species may be considered a proxy for larger habitat area risks to more wide-ranging longleaf pine species such as the gopher tortoise (Diemer 1986), and generally provide indication of an "umbrella" conservation benefit provided through sourcing practices that restrict against conversion of extant natural pine forest stands in the Georgia Biomass woodshed.

The northern cricket frog was the only species that showed a higher area habitat overlay with the PNP screen as compared to the FNP screen. This result is explained by the GAP data set predicting heavy northern cricket frog utilization of harvested forest or disturbed/successional lands in a grass/forb state of regeneration along permanent wetland edges, and model runs predicting higher conversion of these grass/forb areas in the PNP screen than in the FNP screen. Because northern cricket frogs are generally known to prefer wetland edges that are free from tall vegetation (Beasley et al. 2005), it is reasonable to expect that heavy edge afforestation around permanent wetlands could indeed have negative impacts on northern cricket frogs in the Georgia Biomass woodshed. More generally, declines in northern cricket frogs may be linked to contamination from herbicides such as atrazine (Reeder et al. 2005). This may be a further concern if plantation pines are established directly adjacent to wetlands containing northern cricket frogs, as a variety of herbicides are commonly used to control understory vegetation across various plantation stand ages (Bullock 2012). Maintenance of herbaceous buffer areas around wetlands containing northern cricket frogs, and particularly minimizing or avoiding use of herbicide control of forestry near these buffers, may be recommended as an approach for increased conservation and protection of this species within a production forestry landscape. The highly localized habitat area predicted for this species, which amounts to under 3% of the total woodshed area and includes many wetland areas unsuitable for plantation pine forestry, broadly suggest that such buffer practices would likely have minimal impact on overall wood supply.

Results for the timber rattlesnake show that the FNP screen pose a large relative (31.4 – 41.2%) increase in habitat overlay risk as compared to the PNP screen. Although timber rattlesnakes are found in both natural and plantation pine stands, they show a high preference for upland and mesic hardwood forests in the Georgia Biomass woodshed. Conversion of such hardwood forests into plantation pine may be generally expected to reduce habitat values for the timber rattlesnake (Garst 2007), while also resulting in significant direct mortality when the poisonous snake is encountered by loggers and other site workers (Reinert et al. 2011). By extension, sourcing practices that restrict against conversion of natural forests, and particularly hardwood forests, into plantation pine are likely to provide very high protective value for the timber rattlesnake. Because there is some evidence that timber rattlesnakes may readily utilize plantation pine and other edges contiguous to hardwood forests independently of the structural diversity in these edges (Anderson and Rosenberg 2011), management inside plantation forests may have little effect on the overall landscape quality of habitat for this species, provided that core forest habitat areas are maintained intact.

Discussion

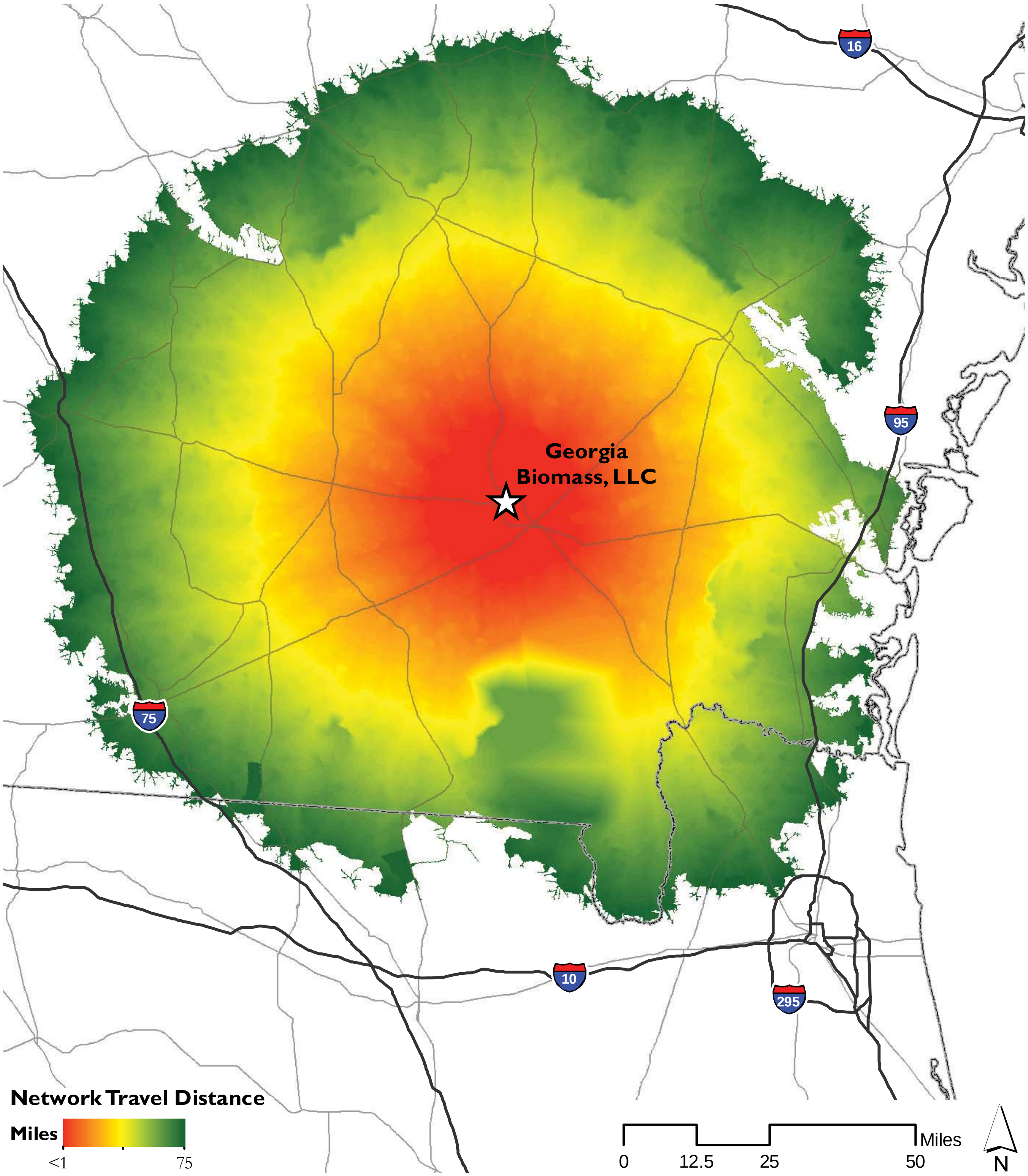
Large-scale conversion to plantation pine over the past several decades is noted as a primary factor in areal declines for all upland ecosystems in the Georgia Biomass woodshed (Allen et al. 1996). Given this historical context, it is reasonable to conclude that biomass sourcing policies that do not restrict against land cover conversion of extant natural forests may put additional areas of remnant longleaf pine, wet flatwoods, and upland hardwood forests at high conversion risk in the Georgia Biomass woodshed. The globally recognized habitat importance of the adjacent Okefenokee National Wildlife Refuge, which contains many species of permanent and migratory wildlife that depend upon habitat in the surrounding forestry matrix (see, e.g., Odum and Turner 1990; Smith et al. 2006; Hoctor et al. 2007), provides a further rationale for sourcing policies that may mitigate conversion risks for remnant longleaf pine ecosystems and other natural forests of high conservation value extant in the private landholdings of this woodshed.

Results from our analyses suggest that the existing land cover base does provide some opportunity for near-term implementation of sourcing policies that are protective of existing natural forest stands in this woodshed. Notably, the tabular summaries in Georgia Biomass Table 3a show that existing plantation forestry and ruderal/disturbed lands provide over 82% of the predicted “High” harvest risk land area base for Georgia Biomass under the worst case FNP screen. As shown in Georgia Biomass Map 7, the sourcing area footprint for

Georgia Biomass under a policy screen of total upland forest protection and a highly conservative assumption of no pasture conversion into plantation forestry appears generally reasonable from a procurement standpoint. Average travel distances are only slightly elevated over the no protection scenario (Georgia Biomass Map 9), while relatively minimal sourcing is required in high competition areas to the east of the facility. This suggests that a sustainable sourcing policy that restricts biomass extraction to existing plantation forestry land and excludes areas currently held in natural forest stands could be implemented with minimal effects on the long-term forestry biomass supplies available for the facility at a woodshed scale.

If a sourcing policy that excludes conversion of remnant longleaf pine and other natural forests with high conservation value is adopted, there appears to be some potential for biomass energy demands to promote increased wildlife habitat values within the existing plantation forestry land base of the Georgia Biomass woodshed. In particular, increased demand for lower quality stemwood may prompt landowners to perform earlier and more frequent thinnings, which can provide for increased maintenance of open habitat conditions that more closely simulates native longleaf and pine flatwood ecosystems (Hartley 2002; VanLear et al. 2005; Mitchell et al. 2006; Miller et al. 2009). Such thinning management may be further implemented in association with prescribed burns, which is currently being recommended as a means of reducing catastrophic fire risk from non-thinned pine plantations in areas surrounding the Okefenokee National Wildlife Refuge (Chesser and Hatten 2008). Integrated thinning and prescribed burn management on plantation forest land is likely to benefit species such as the brown-headed nuthatch, northern bobwhite, gopher frog, gopher tortoise, pocket gopher, eastern indigo snake, and Bachman's sparrow at both stand and landscape scales (Van Lear et al. 2005; Andreu et al. 2012). Further research is needed to understand how such management practices may be implemented in conjunction with long-term bioenergy procurement, as well as sustained maintenance and management of fire-dependent natural stands embedded within the working forestry landscape.

Figure 23. Georgia Biomass Map 1: 75-mile Network Travel Distance and Woodshed Delineation



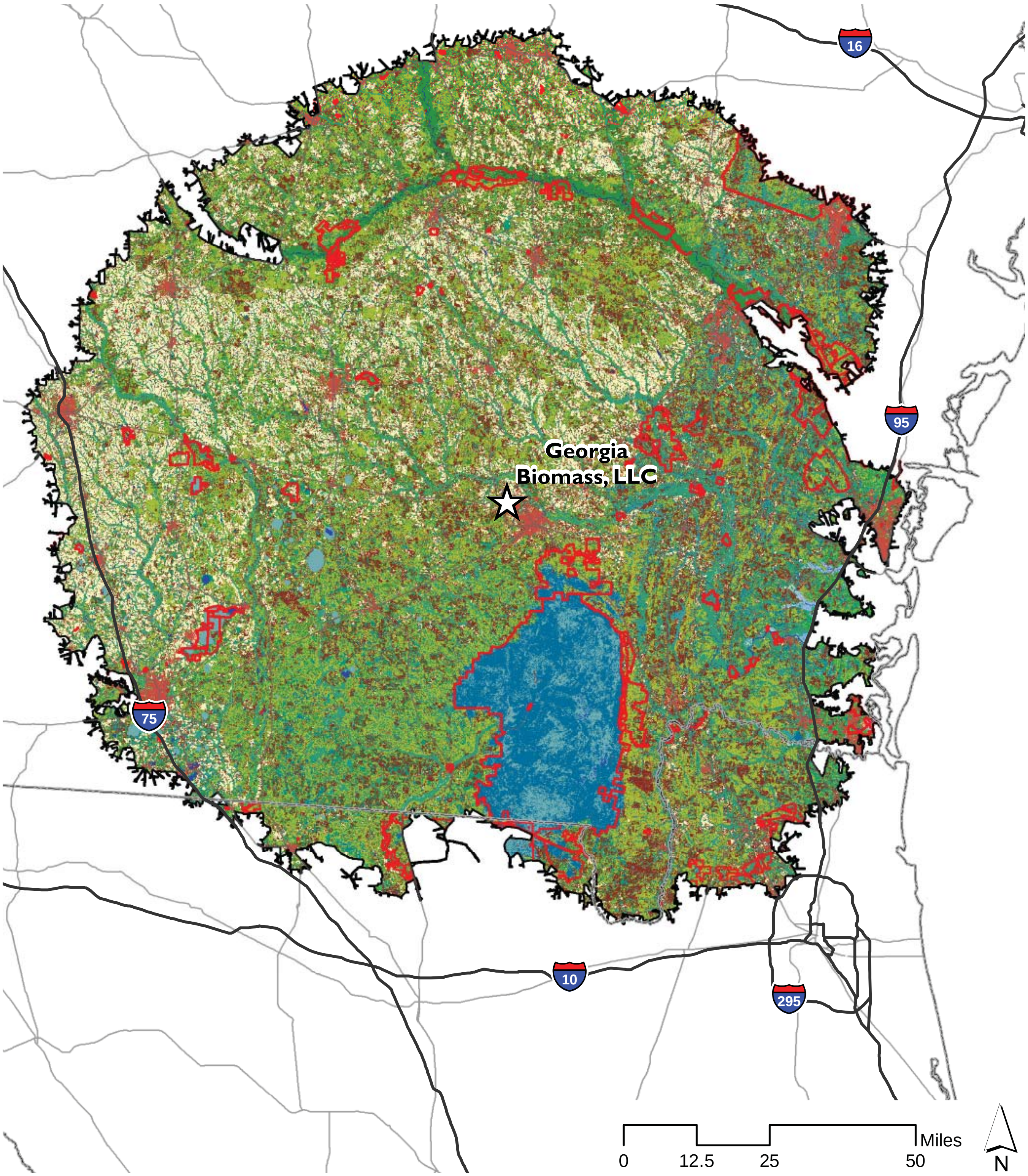
Georgia Biomass Table 1. GAP Detailed Ecosystem Summary for 75-Mile Woodshed Area

GAP Ecosystem	Area	Protected	% Protected
Evergreen Plantation or Managed Pine	661,637	41,071	6.2%
Cultivated Cropland	325,574	5,716	1.8%
Atlantic Coastal Plain Upland Longleaf Pine Woodland	196,321	8,087	4.1%
Disturbed/Successional – Grass/Forb Regeneration	174,112	8,119	4.7%
Developed, Open Space	155,254	5,606	3.6%
Disturbed/Successional – Shrub Regeneration	154,442	8,626	5.6%
Harvested Forest – Grass/Forb Regeneration	118,230	6,046	5.1%
Pasture/Hay	115,580	2,457	2.1%
Atlantic Coastal Plain Small Blackwater River Floodplain Forest	110,597	11,077	10.0%
Southern Coastal Plain Nonriverine Basin Swamp – Okefenokee Taxodium Modifier	99,380	89,137	89.7%
Atlantic Coastal Plain Blackwater Stream Floodplain Forest – Forest Modifier	95,032	5,098	5.4%
Southern Coastal Plain Nonriverine Basin Swamp	90,409	7,052	7.8%
Southern Coastal Plain Nonriverine Cypress Dome	85,007	4,229	5.0%
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland – Open Understory Modifier	74,114	2,728	3.7%
Southern Coastal Plain Hydric Hammock	68,112	4,662	6.8%
Harvested Forest-Shrub Regeneration	65,823	2,708	4.1%
Southern Coastal Plain Blackwater River Floodplain Forest	64,364	2,098	3.3%
Developed, Low Intensity	42,086	554	1.3%
Southern Coastal Plain Nonriverine Basin Swamp – Okefenokee Clethra	41,475	37,087	89.4%
Deciduous Plantations	31,725	1,059	3.3%
West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	28,958	9,050	31.3%
Atlantic Coastal Plain Southern Wet Pine Savanna and Flatwoods	26,534	2,928	11.0%
Southern Coastal Plain Seepage Swamp and Baygall	21,773	1,282	5.9%
Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	19,607	922	4.7%
Open Water (Fresh)	18,834	1,867	9.9%
Southern Coastal Plain Nonriverine Basin Swamp – Okefenokee Bay/Gum Modifier	18,098	17,033	94.1%
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland – Loblolly Modifier	17,127	826	4.8%
Southern Coastal Plain Nonriverine Basin Swamp – Okefenokee Pine Modifier	13,494	11,946	88.5%
Atlantic Coastal Plain Depression Pondshore	13,205	4,083	30.9%
Southern Coastal Plain Oak Dome and Hammock	9,247	341	3.7%
Atlantic Coastal Plain Southern Maritime Forest	8,940	876	9.8%
Atlantic Coastal Plain Xeric River Dune	8,540	587	6.9%
Developed, Medium Intensity	8,187	151	1.8%
Southern Coastal Plain Dry Upland Hardwood Forest	7,355	242	3.3%
Southern Coastal Plain Nonriverine Basin Swamp – Okefenokee Nupea Modifier	7,272	6,304	86.7%
East Gulf Coastal Plain Savanna and Wet Prairie	6,314	560	8.9%

Georgia Biomass Table 1. GAP Detailed Ecosystem Summary for 75-Mile Woodshed Area

Georgia Biomass Table 1. GAP Detailed Ecosystem Summary for 75-Mile Woodshed Area (cont…)			
GAP Ecosystem	**Area**	**Protected**	**% Protected**
Developed, High Intensity	3,772	48	1.3%
Atlantic Coastal Plain Central Salt and Brackish Tidal Marsh	3,189	574	18.0%
Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest -	3,078	90	2.9%
Undifferentiated Barren Land	2,962	186	6.3%
Atlantic Coastal Plain Central Fresh-Oligohaline Tidal Marsh	2,450	165	6.7%
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland – Open	2,235	543	24.3%
Southern Atlantic Coastal Plain Mesic Hardwood Forest	2,081	400	19.2%
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland – Offsite	1,185	62	5.2%
Unconsolidated Shore	927	65	7.0%
East Gulf Coastal Plain Limestone Forest	825	146	17.7%
Atlantic Coastal Plain Clay-Based Carolina Bay Forested Wetland	823	0	0.0%
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland – Offsite	794	119	15.0%
East Gulf Coastal Plain Depression Pondshore	681	166	24.4%
Open Water (Brackish/Salt)	569	110	19.3%
Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest – Oak	458	12	2.6%
Atlantic Coastal Plain Peatland Pocosin	458	16	3.5%
Quarries, Mines, Gravel Pits and Oil Wells	378	33	8.7%
East Gulf Coastal Plain Near-Coast Pine Flatwoods – Open Understory Modifier	253	11	4.3%
Southern Coastal Plain Herbaceous Seepage Bog	244	18	7.4%

Figure 24. Georgia Biomass Map 2: GAP Land Cover and Conservation Lands



Georgia Biomass Map 2: Land Cover Characteristics Legend

Conservation Areas

GAP Ecosystem Class (NVC Macro)

- Longleaf Pine & Sand Pine Woodland
- Southern Mixed Deciduous-Evergreen Broadleaf Forest
- Southeastern North American Ruderal Forest & Plantation
- Southern-Central Oak-Hardwood & Pine Forest
- Central Mesophytic Hardwood Forest
- Southern Floodplain Hardwood Forest
- Southern Coastal Plain Evergreen Hardwood & Conifer Swamp
- Southern Coastal Plain Basin Swamp
- Wet Longleaf Pine & Southern Flatwoods
- Neotropical Coastal Beach Vegetation
- Florida Peninsula Scrub & Herb
- Eastern North American Coastal Grassland & Shrubland
- Atlantic & Gulf Coastal Plain Bog & Fen
- Atlantic & Gulf Coastal Plain Freshwater Tidal Marsh
- Atlantic & Gulf Coastal Plain Pondshore & Wet Meadow
- Eastern North American Atlantic Salt Marsh
- Barren
- Herbaceous Agricultural Vegetation
- Recently Disturbed or Modified
- Open Water
- Quarries, Mines, Gravel Pits and Oil Wells
- Developed & Urban

Figure 25. Georgia Biomass Map 3: Travel Network Analysis & Locations of Competing Bioenergy and Pulp Mill Facilities

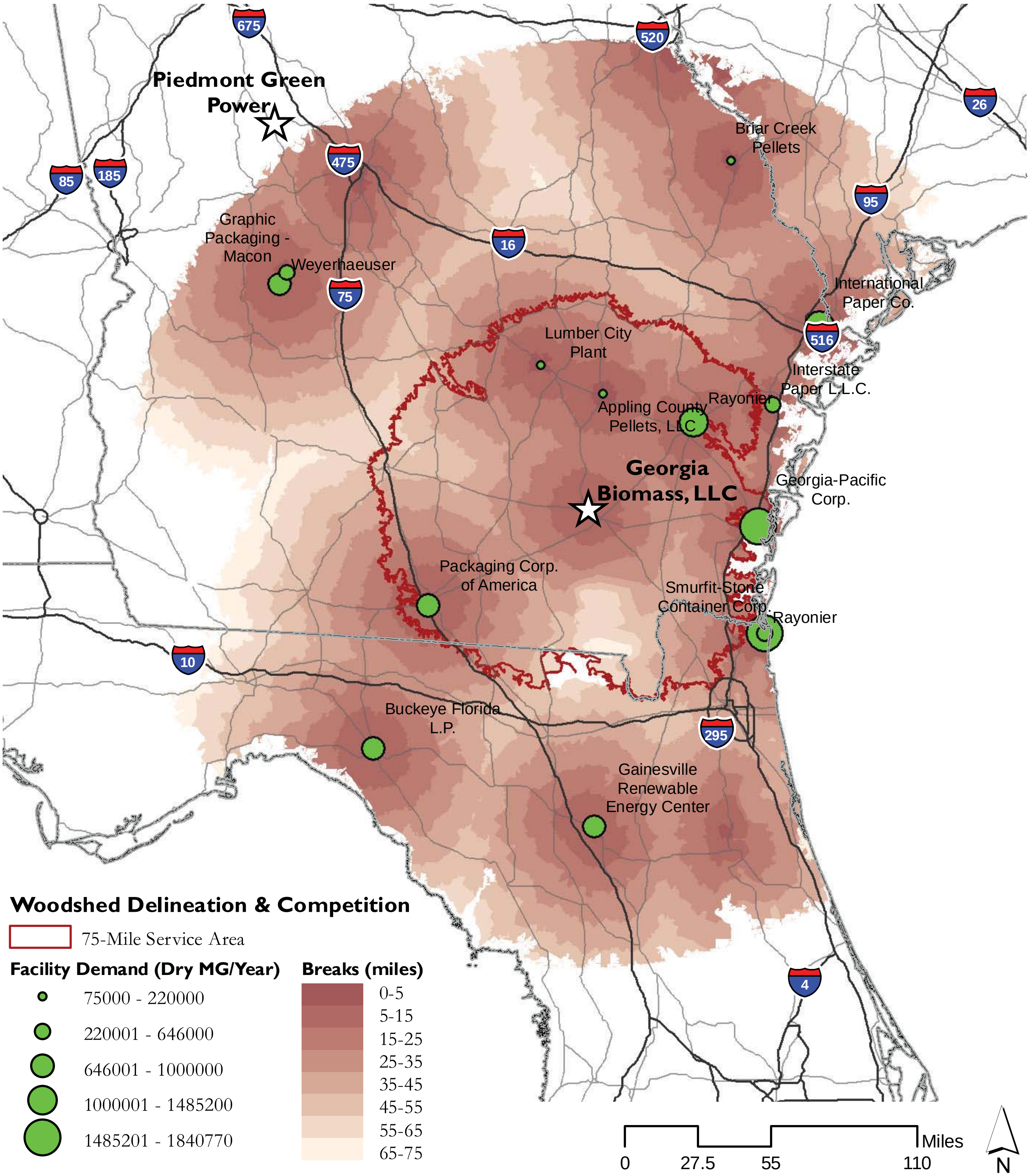


Figure 26. Georgia Biomass Map 4: Competition Demand Strength Analysis, as Annual dry Mg / Network Travel Mile

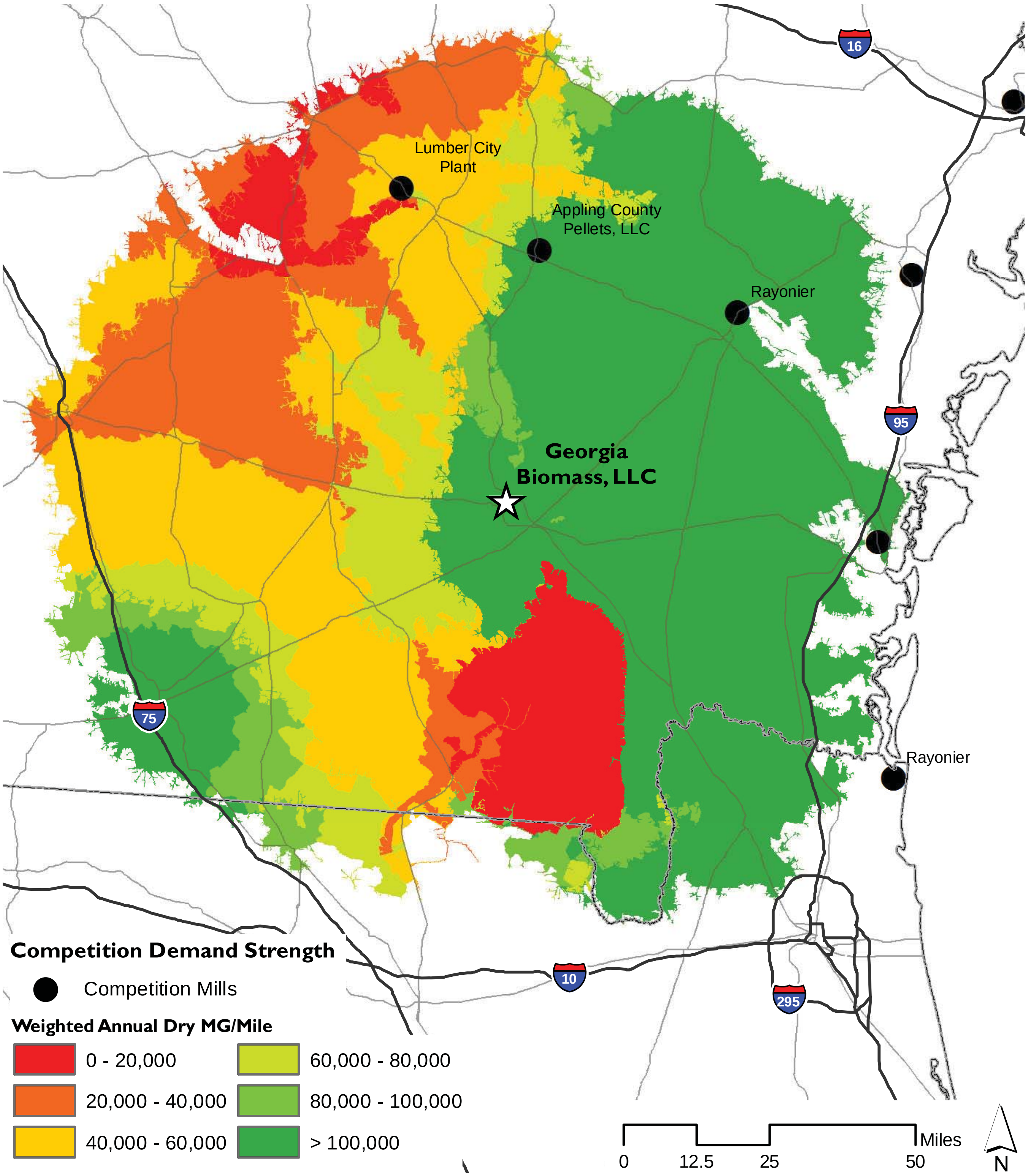


Figure 27. Georgia Biomass Map 5: Maximum Entropy Suitability Model for Pine Plantation

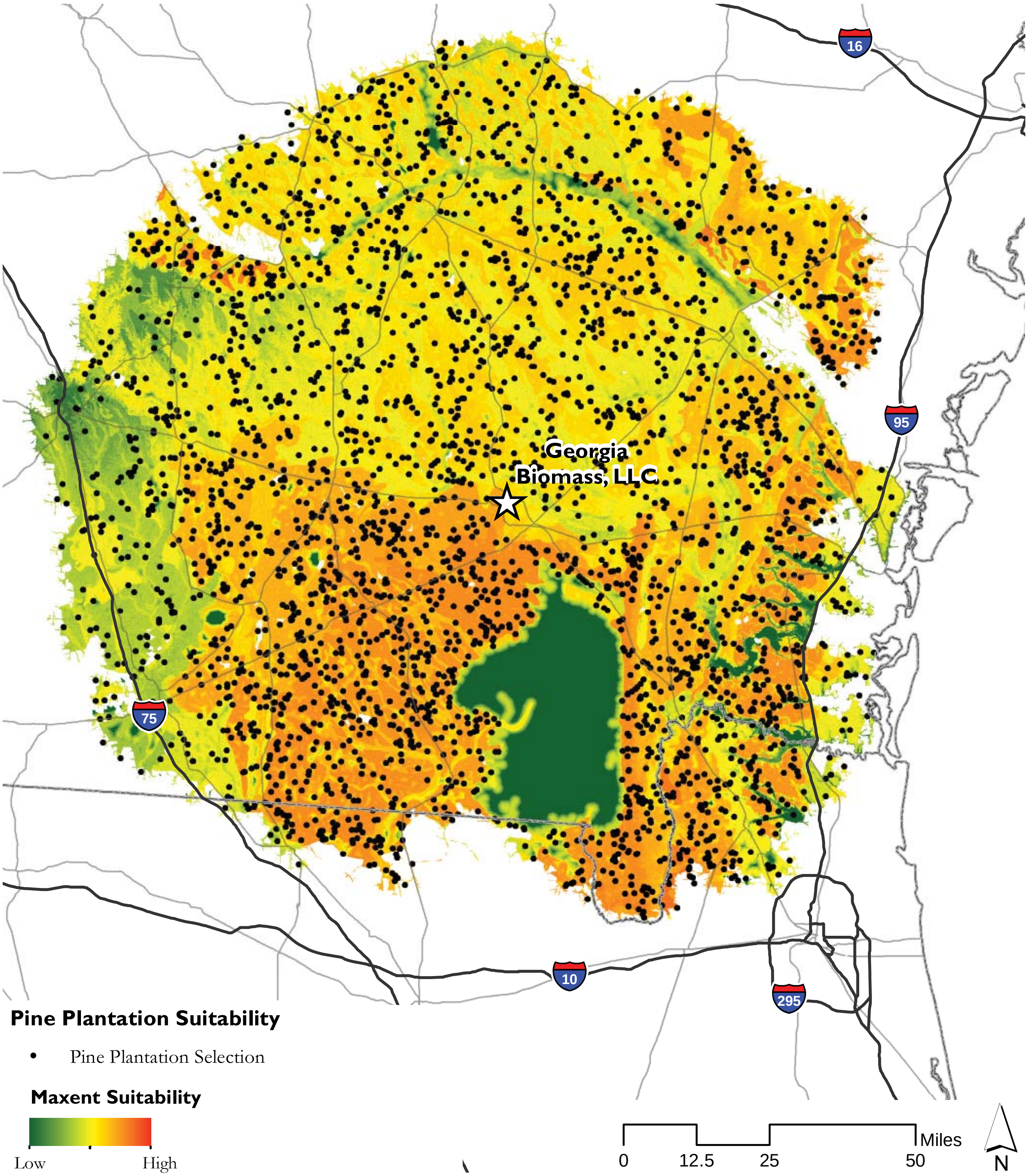


Figure 28. Georgia Biomass Map 6: Composite Model of Pine Plantation Only (PO) Sourcing Model Screen

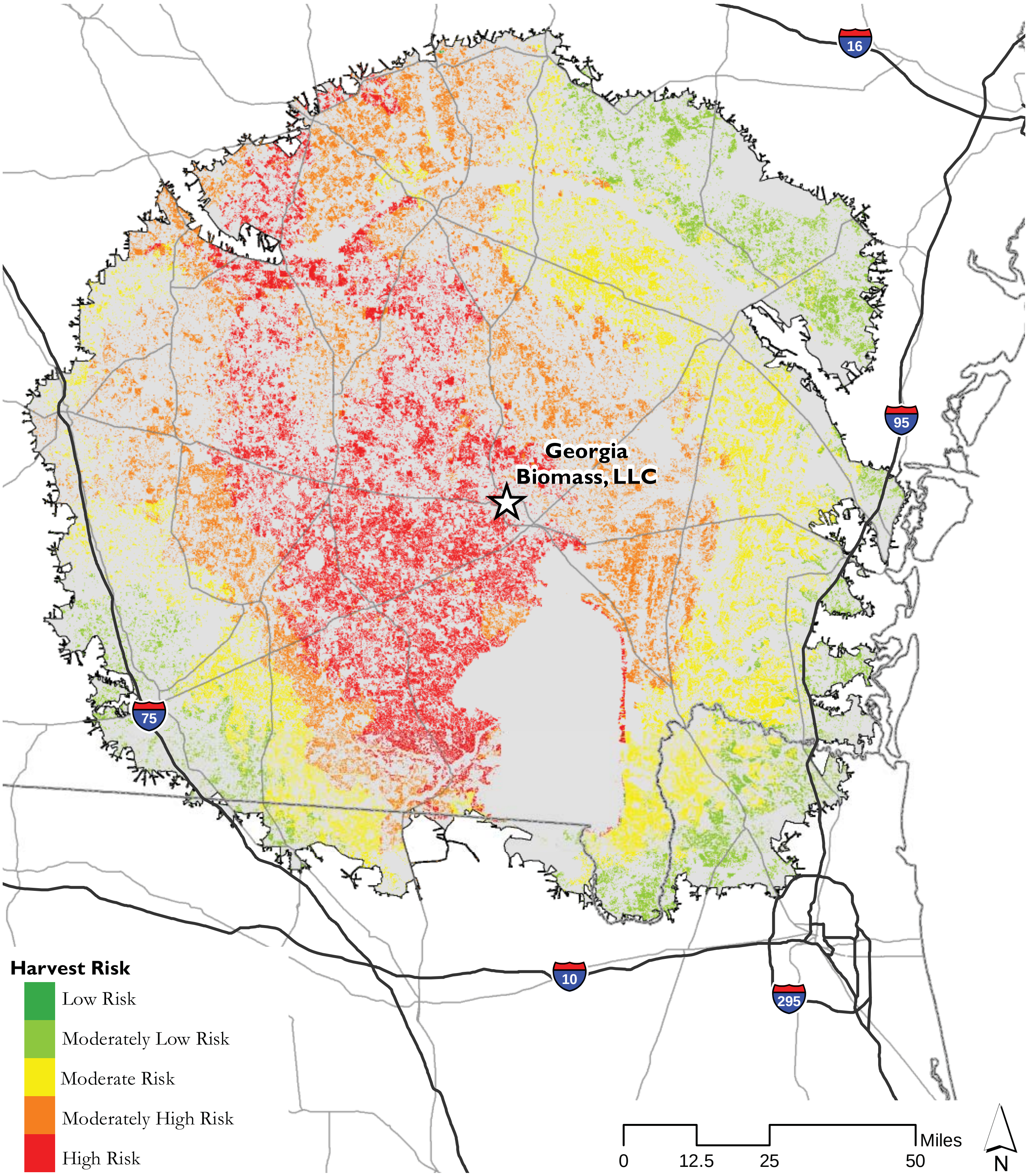


Figure 29. Georgia Biomass Map 7: Composite Model of Pine & Disturbed, No Pasture (PNP) Sourcing Model Screen

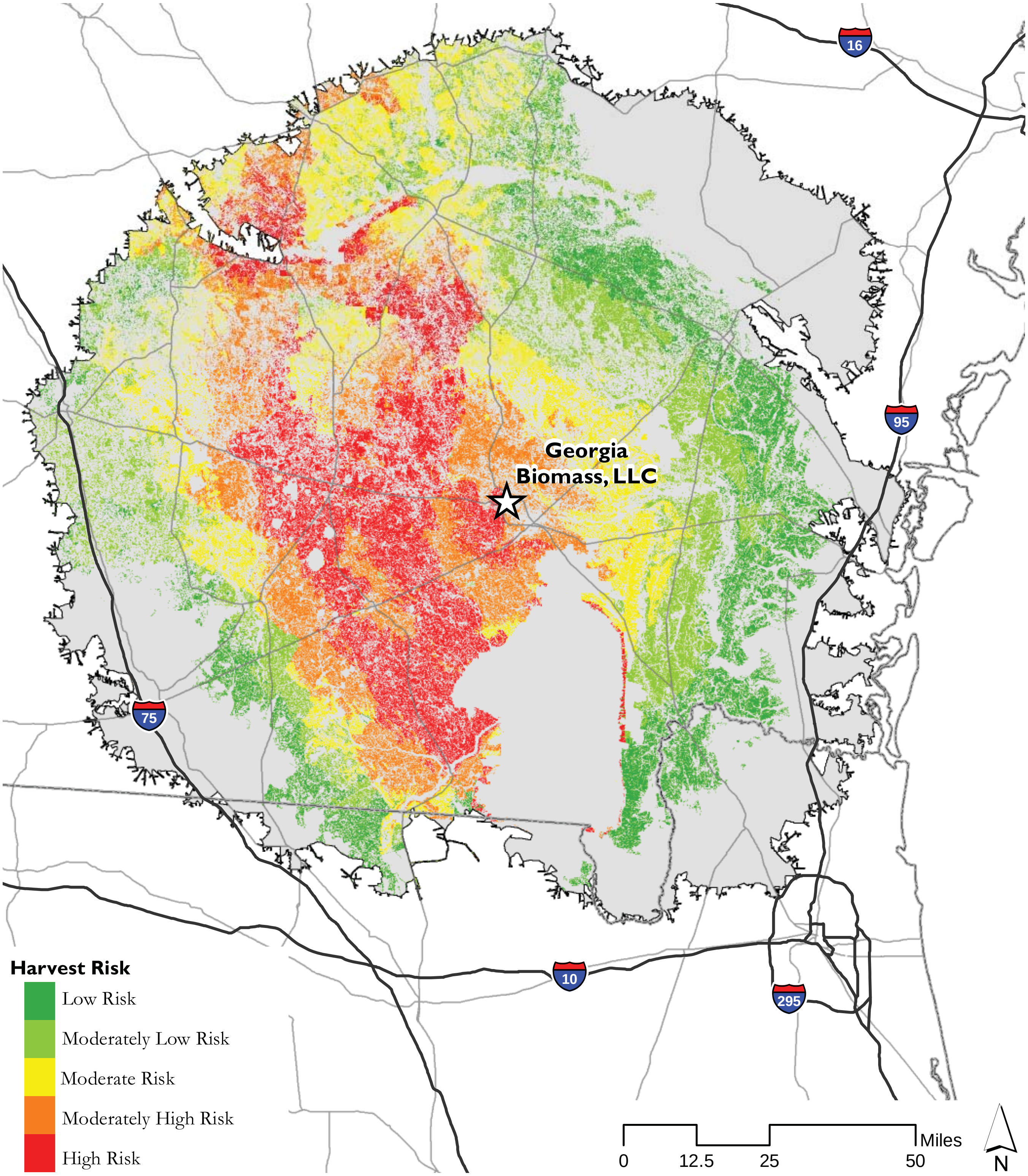


Figure 30. Georgia Biomass Map 8: Composite Model of Pine, Disturbed & Pasture Risk Composite Sourcing Model Screen

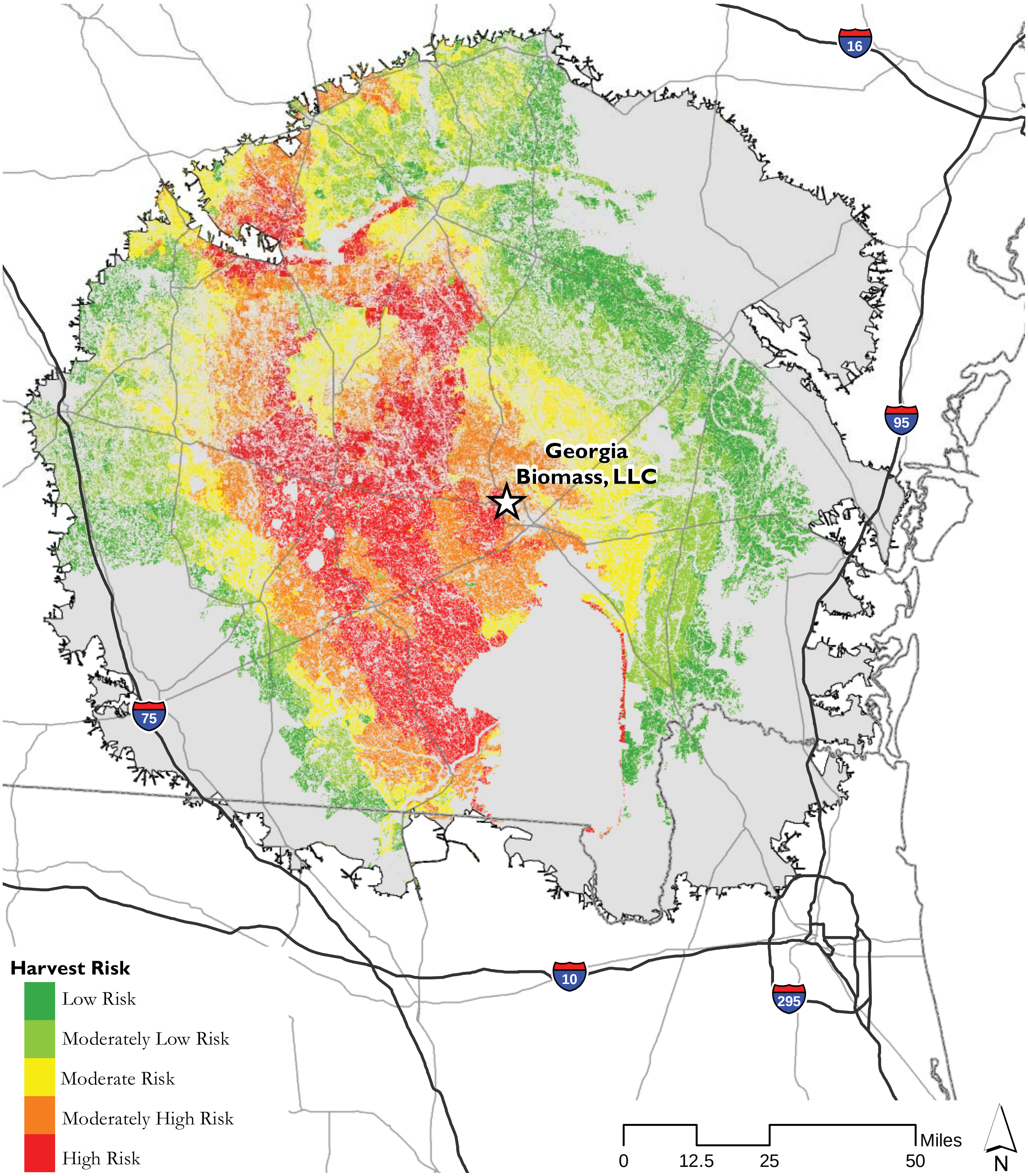


Figure 31. Georgia Biomass Map 9: Composite Model of Upland Forest, No Pasture Risk Composite Sourcing Model Screen

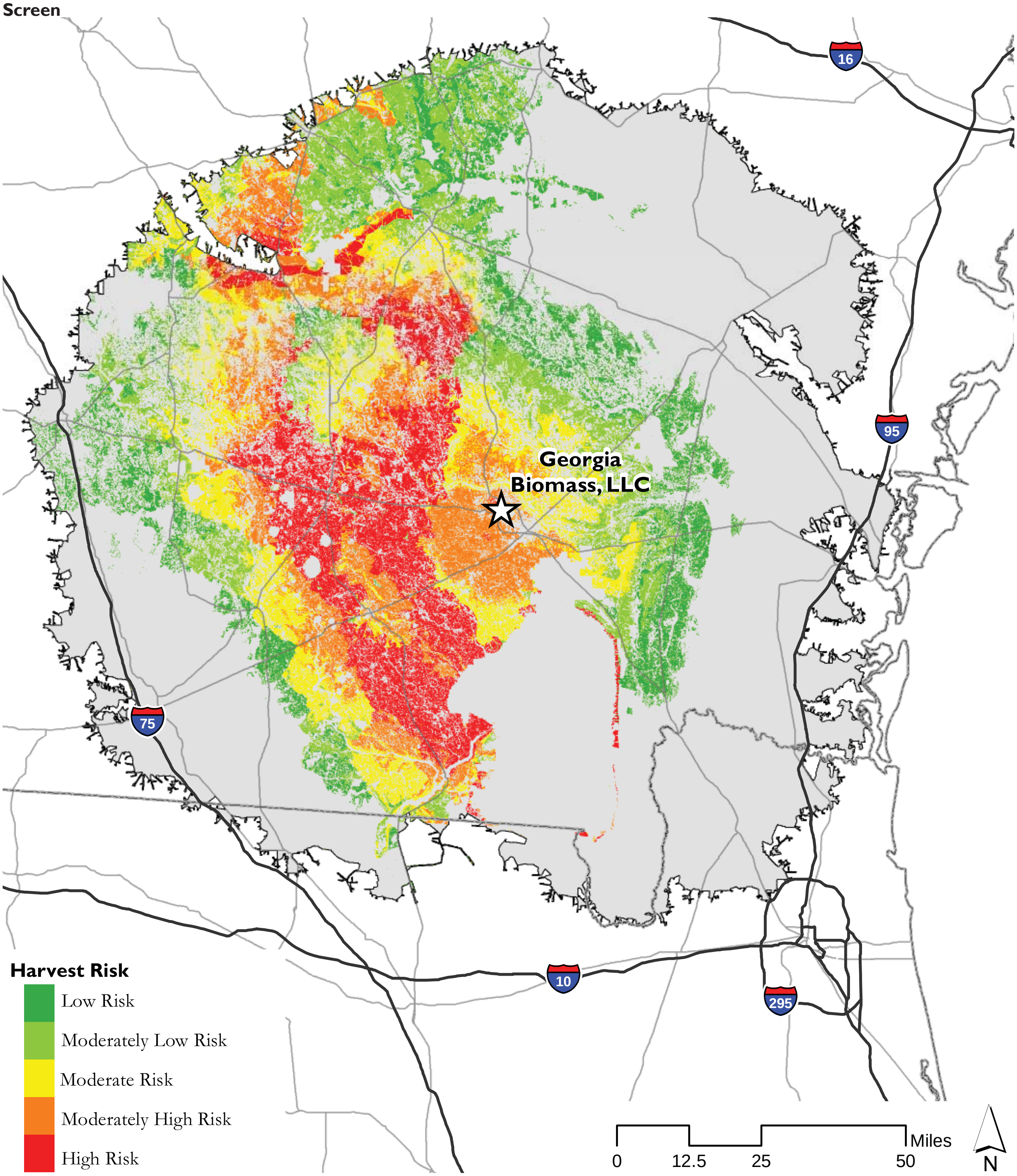
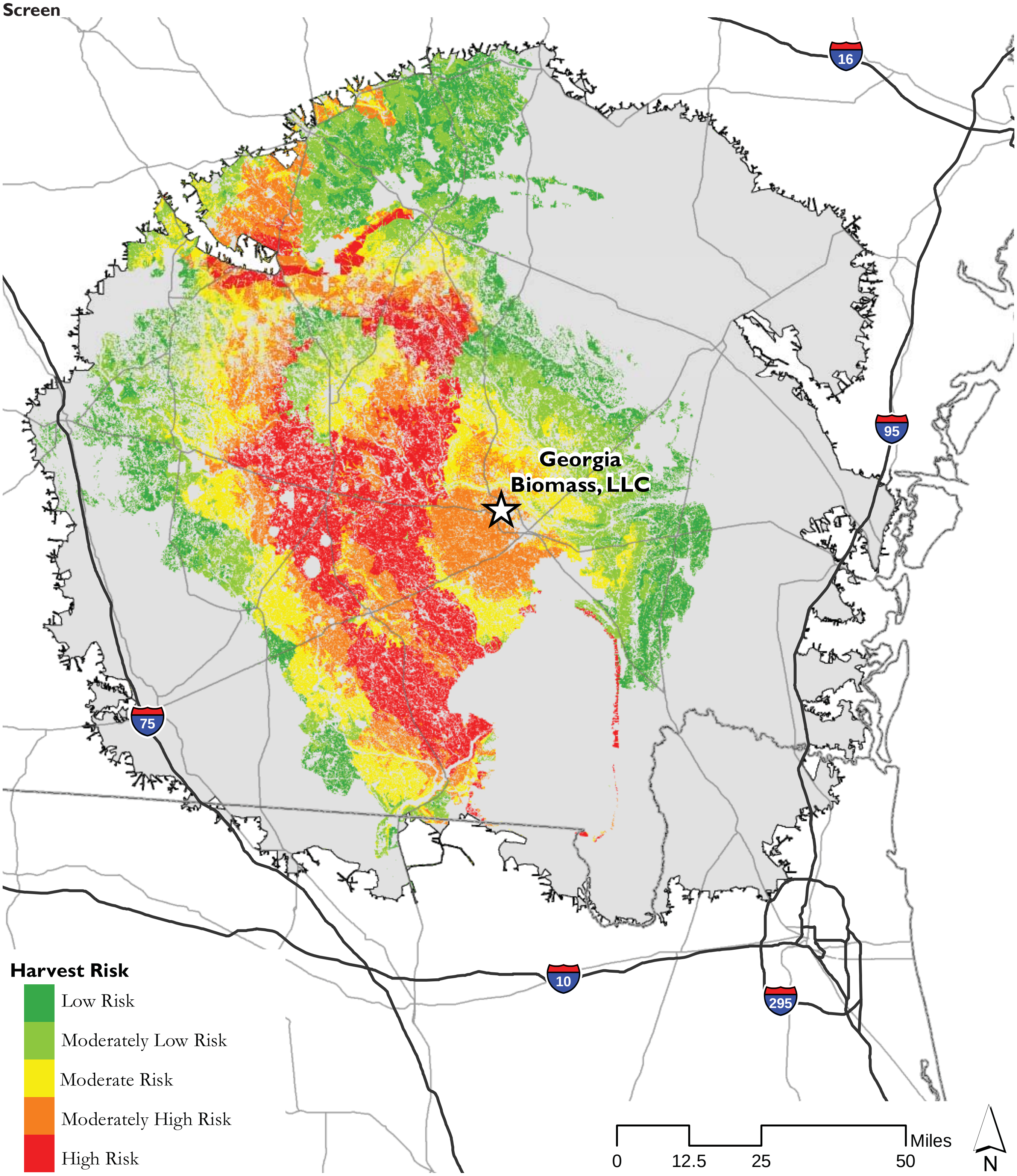


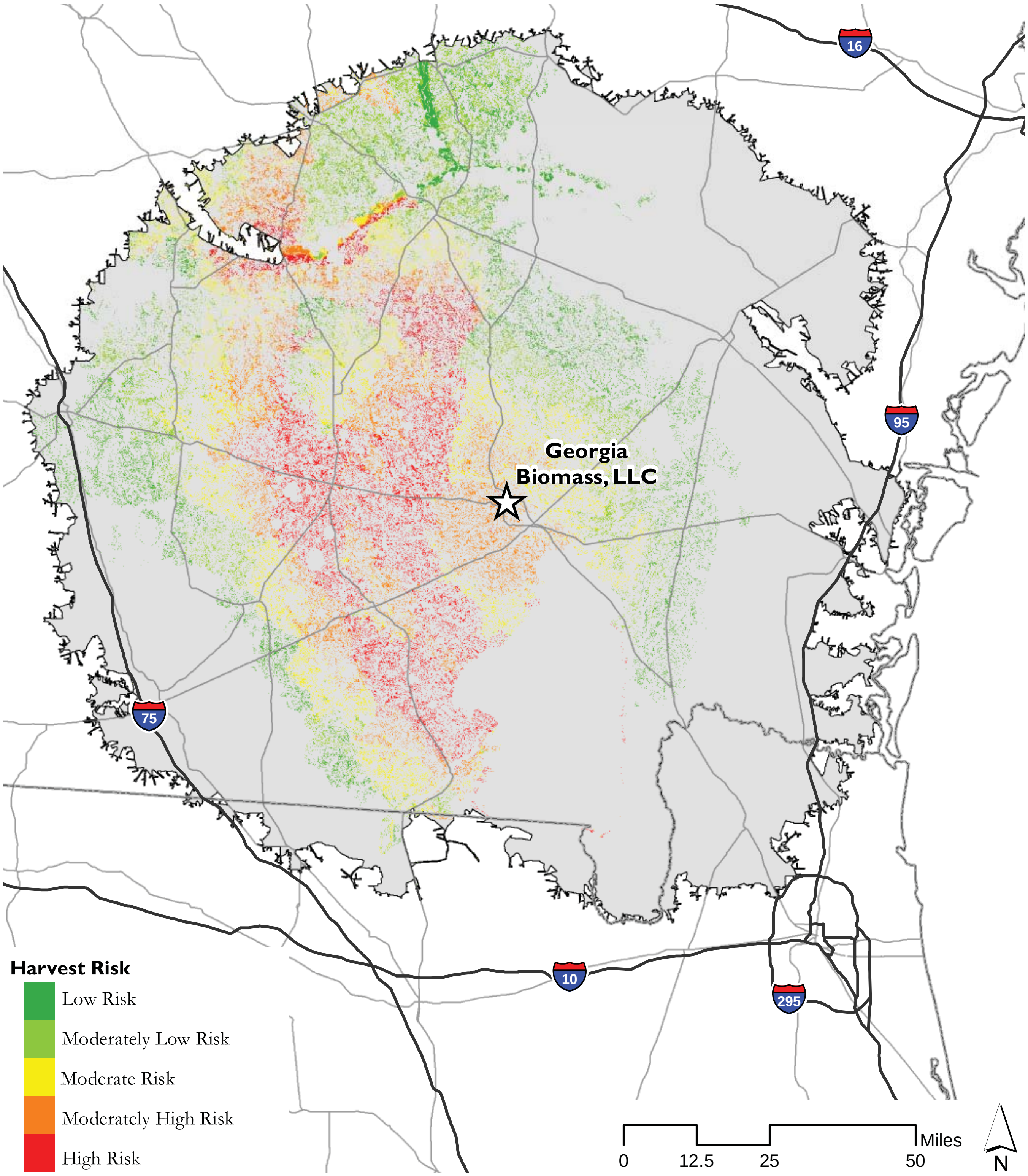
Figure 32. Georgia Biomass Map 10: Composite Model of Upland Forest & Pasture Risk Composite Sourcing Model Screen



Georgia Biomass Table 2. Harvest area objectives (HAO) and associated risk classes for spatial modeling			
HAO	**Softwood (Ha)**	**Demand Intensity (Mg/ha/yr)**	**Harvest/ Conversion Risk Class**
1	90,000	9.00	High
2	180,000	4.50	
3	270,000	3.00	Moderately High
4	360,000	2.25	
5	450,000	1.80	Moderate
6	540,000	1.50	
7	630,000	1.29	Moderately Low
8	720,000	1.13	
9	810,000	1.00	Low
10	900,000	0.90	

Georgia Biomass Table 2. Harvest area objectives and associated risk classes for spatial modeling

Figure 33. Georgia Biomass Map 11: Composite Plantation Pine Conversion Risk for Natural Forest Stands



Georgia Biomass Table 3a. GAP ecosystem overlay for softwood biomass sourcing without forest protection (FNP screen) and high biomass removal intensity (HAO_2)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Offsite Hardwood	52	128	0.0%
Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	629	1,554	0.3%
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Open Understory	178	440	0.1%
Atlantic Coastal Plain Southern Wet Pine Savanna and Flatwoods	464	1,146	0.3%
Atlantic Coastal Plain Upland Longleaf Pine Woodland	15,202	37,549	8.4%
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Loblolly Modifier	2,775	6,854	1.5%
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Open Understory Modifier	15,664	38,690	8.7%
Southern Atlantic Coastal Plain Mesic Hardwood Forest	135	333	0.1%
Southern Coastal Plain Dry Upland Hardwood Forest	851	2,102	0.5%
Southern Coastal Plain Hydric Hammock	5,173	12,777	2.9%
Southern Coastal Plain Oak Dome and Hammock	1,778	4,392	1.0%
West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	619	1,529	0.3%
Deciduous Plantations	3,140	7,756	1.7%
Disturbed/Successional - Grass/Forb Regeneration	13,128	32,426	7.3%
Disturbed/Successional - Shrub Regeneration	15,933	39,355	8.9%
Evergreen Plantation or Managed Pine	83,624	206,551	46.5%
Harvested Forest - Grass/Forb Regeneration	12,728	31,438	7.1%
Harvested Forest-Shrub Regeneration	7,922	19,567	4.4%

Georgia Biomass Table 3a. GAP ecosystem overlay for softwood biomass sourcing without FNP screen and HAO_2

Georgia Biomass Table 3b. GAP ecosystem overlay for softwood biomass sourcing without forest protection (FNP screen) and moderate biomass removal intensity (HAO_6)

GAP Ecosystem	Hectares	Acres	Sourcing %
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Offsite Hardwood	87	215	0.0%
Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	3,216	7,944	0.6%
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Open Understory	435	1,074	0.1%
Atlantic Coastal Plain Southern Wet Pine Savanna and Flatwoods	1,503	3,712	0.3%
Atlantic Coastal Plain Upland Longleaf Pine Woodland	63,158	156,000	11.7%
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Loblolly Modifier	6,872	16,974	1.3%
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Open Understory Modifier	38,083	94,065	7.1%
Southern Atlantic Coastal Plain Mesic Hardwood Forest	282	697	0.1%
Southern Coastal Plain Dry Upland Hardwood Forest	1,490	3,680	0.3%
Southern Coastal Plain Hydric Hammock	14,160	34,975	2.6%
Southern Coastal Plain Oak Dome and Hammock	3,910	9,658	0.7%
West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	3,499	8,643	0.6%
Deciduous Plantations	10,510	25,960	1.9%
Disturbed/Successional - Grass/Forb Regeneration	48,171	118,982	8.9%
Disturbed/Successional - Shrub Regeneration	46,871	115,771	8.7%
Evergreen Plantation or Managed Pine	235,119	580,744	43.5%
Harvested Forest - Grass/Forb Regeneration	39,219	96,871	7.3%
Harvested Forest-Shrub Regeneration	23,401	57,800	4.3%

Georgia Biomass Table 3b. GAP ecosystem overlay for softwood biomass sourcing without FNP screen and HAO_6

Georgia Biomass Table 3c. GAP ecosystem overlay for softwood biomass sourcing without forest protection (FNP screen) and low biomass removal intensity (HAO_10)

GAP Ecosystem	Hectares	Acres	Sourcing %
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Offsite Hardwood	486	1,200	0.1%
Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	8,856	21,874	1.0%
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Open Understory	1,270	3,137	0.1%
Atlantic Coastal Plain Southern Wet Pine Savanna and Flatwoods	4,896	12,093	0.5%
Atlantic Coastal Plain Upland Longleaf Pine Woodland	122,916	303,603	13.7%
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Loblolly Modifier	9,989	24,673	1.1%
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Open Understory Modifier	47,628	117,641	5.3%
Southern Atlantic Coastal Plain Mesic Hardwood Forest	1,124	2,776	0.1%
Southern Coastal Plain Dry Upland Hardwood Forest	2,313	5,713	0.3%
Southern Coastal Plain Hydric Hammock	26,061	64,371	2.9%
Southern Coastal Plain Oak Dome and Hammock	5,690	14,054	0.6%
West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	9,502	23,470	1.1%
Deciduous Plantations	19,425	47,980	2.2%
Disturbed/Successional - Grass/Forb Regeneration	90,651	223,908	10.1%
Disturbed/Successional - Shrub Regeneration	82,412	203,558	9.2%
Evergreen Plantation or Managed Pine	370,017	913,942	41.1%
Harvested Forest - Grass/Forb Regeneration	60,168	148,615	6.7%
Harvested Forest-Shrub Regeneration	36,366	89,824	4.0%

Georgia Biomass Table 3c. GAP ecosystem overlay for softwood biomass sourcing without FNP screen and HAO_10

Georgia Biomass Table 4a. GAP species distribution overlay comparison for sourcing with no natural forest stand protection (FNP screen) versus sourcing only from plantation or disturbed forestry lands (PNP screen) with high biomass removal intensity (HAO_2)

Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with FNP screen (% of woodshed habitat)	Hectares of habitat overlay with PNP screen (% of woodshed habitat)	Hectares of increased habitat overlay with FNP	% Increase in habitat overlay with FNP
Brown-headed Nuthatch	450,839	32,964 (7.3%)	28,768 (6.4%)	4,196	14.6%
Northern Bobwhite	1,668,657	109,606 (6.6%)	106,504 (6.4%)	3,102	2.9%
Swainson's Warbler	113,794	551 (0.5%)	66 (0.1%)	485	734.8%
Eastern Spotted Skunk	686,720	24,507 (3.6%)	14,939 (2.2%)	9,568	64.0%
Long-tailed Weasel	1,808,734	133,848 (7.4%)	129,085 (7.1%)	4,763	3.7%
Northern Cricket Frog	86,629	3,019 (3.5%)	3,441 (4.0%)	-422	-12.3%
Gopher Frog	207,251	17,199 (8.3%)	12,465 (6.0%)	4,734	38.0%
Timber Rattlesnake	410,891	15,124 (3.7%)	10,812 (2.6%)	4,312	39.9%

Georgia Biomass Table 4a. GAP species distribution overlay comparison for sourcing with no FNP screen versus sourcing only from PNP screen with HAO_2

Georgia Biomass Table 4b. GAP species distribution overlay comparison for sourcing with no natural forest stand protection (FNP screen) versus sourcing only from plantation or disturbed forestry lands (PNP screen) with moderate biomass removal intensity (HAO_6)

Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with FNP screen (% of woodshed habitat)	Hectares of habitat overlay with PNP screen (% of woodshed habitat)	Hectares of increased habitat overlay with FNP	% Increase in habitat overlay with FNP
Brown-headed Nuthatch	450,839	104,517 (23.2%)	89,718 (19.9%)	14,799	16.5%
Northern Bobwhite	1,668,657	341,609 (20.5%)	330,339 (19.8%)	11,270	3.4%
Swainson's Warbler	113,794	1,720 (1.5%)	166 (0.1%)	1,554	936.1%
Eastern Spotted Skunk	686,720	88,493 (12.9%)	55,798 (8.1%)	32,695	58.6%
Long-tailed Weasel	1,808,734	408,431 (22.6%)	394,127 (21.8%)	14,304	3.6%
Northern Cricket Frog	86,629	10,342 (11.9%)	10,816 (12.5%)	-474	-4.4%
Gopher Frog	207,251	55,789 (26.9%)	39,017 (18.8%)	16,772	43.0%
Timber Rattlesnake	410,891	44,706 (10.9%)	34,014 (8.3%)	10,692	31.4%

Georgia Biomass Table 4b. GAP species distribution overlay comparison for sourcing with no FNP screen versus sourcing only from PNP screen with HAO_6

Georgia Biomass Table 4c. GAP species distribution overlay comparison for sourcing with no natural forest stand protection (FNP screen) versus sourcing only from plantation or disturbed forestry lands (PNP screen) with low biomass removal intensity (HAO_10)					
Species	**Total woodshed habitat, as hectares**	**Hectares of habitat overlay with FNP screen (% of woodshed habitat)**	**Hectares of habitat overlay with PNP screen (% of woodshed habitat)**	**Hectares of increased habitat overlay with FNP**	**% Increase in habitat overlay with FNP**
Brown-headed Nuthatch	450,839	175,096 (38.8%)	143,221 (31.8%)	31,875	22.3%
Northern Bobwhite	1,668,657	573,856 (34.4%)	556,713 (33.4%)	17,143	3.1%
Swainson's Warbler	113,794	8,007 (7.0%)	333 (0.2%)	7,674	2304.5%
Eastern Spotted Skunk	686,720	160,068 (23.3%)	79,295 (11.5%)	36,730	101.9%
Long-tailed Weasel	1,808,734	686,024 (37.9%)	655,592 (36.3%)	30,072	4.6%
Northern Cricket Frog	86,629	18,906 (21.8%)	21,639 (25.0%)	-2,733	-12.6%
Gopher Frog	207,251	94,037 (45.4%)	57,307 (27.7%)	24,042	64.1%
Timber Rattlesnake	410,891	82,452 (20.1%)	58,410 (14.2%)	80,773	41.2%

Georgia Biomass Table 4c. GAP species distribution overlay comparison for sourcing with no FNP screen versus sourcing only from PNP screen with HAO_10

VI. CASE STUDY OF ENVIVA PELLETS AHOSKIE

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Facility description

Enviva Pellets Ahoskie is a wood pellet facility located near Ahoskie, North Carolina. The Enviva Ahoskie facility reports a pellet production output of 350,000 dry Mg/yr (Wood2Energy 2013), which requires a wood supply of approximately 378,000 dry Mg/yr. This current pellet process utilizes 80% hardwood and 20% softwood feedstock. This suggests that hardwood demand amounts to approximately 302,400 dry Mg/year, while approximate softwood demand amounts to 75,600 dry Mg/year.

For hardwoods, we applied a biomass harvest removal rate of 265 Mg/ha for energy production (Gower et al. 1985). This results in a minimum sourcing area (HAO_1) of 57,000 hectares assuming 100% of harvested biomass allocation to the facility across an assumed 50 year facility life span. Such a biomass removal rate assumes a primary productivity of at least 5.3 Mg/ha/yr to maintain a growth/drain ratio equal to or

Figure 34. Atlantic Coastal Plain Blackwater Stream Floodplain Forest, Photo Credit: Derb Carter

greater than 1 across the lands being directly sourced over the facility's operational life. Primary productivity measurements on bottomland hardwood sites in the southeastern coastal plain indicate woody biomass production ranges on the order of 5-8 dry Mg/ha/yr depending on soil quality, hydrologic regimes, and other site factors (Mulholland 1979; Messina et al. 1986; Giese et al. 2000). Productivity of upland hardwood stands in the southern coastal plain is generally estimated at 3-4 dry Mg/ha/yr (Kline and Coleman 2010).

Annual average productivity for pulpwood quality biomass from plantation pine forestry in the Enviva Ahoskie woodshed is estimated at 9 dry Mg/ha/yr over a 25 year rotation (Kline and Coleman 2010). Based on these values, the minimum area (HAO_1) of plantation pine forestry needed for long-term softwood sourcing of the Enviva Ahoskie facility is estimated as 8,400 hectares.

GAP land cover summary

The 75-mile road network sourcing area (Enviva Map 1) for Enviva provides a total land cover base of approximately 2.78 million hectares. The largest land cover type within this woodshed area is cultivated crop land, which occupies over 666,000 hectares, or approximately 23.7% of the woodshed. With another 5.6% of the woodshed area held in pasture/hay, a little over 29% of the woodshed can be generally characterized as non-forested agricultural land. Another 6.8% of the woodshed is identified as developed areas that can be expected to provide minimal primary forestry biomass to the facility. Most of this developed area is accounted for by sections of the greater Norfolk, VA area that are located in the far northeastern section of the 75-mile woodshed. Another 3.2% of the woodshed is composed of open water, coastal marshlands, and beach land covers. Together these non-forest land covers encompass over 39% of the woodshed area.

Forest resources in the Enviva woodshed are extensive and diverse. Plantation pine forestry occupies approximately 14.9% of the woodshed, and is identified as the most frequent single forest type. Another 9.5% of the woodshed is identified as recently disturbed or ruderal successional ecosystem types, most of which may be contained within or available for managed forestry uses. Natural upland forest types occupy 20.5% of the woodshed, with large areas of coastal plain hardwoods, coastal plain pine forests, and piedmont hardwoods. The upland forest ecosystem with the largest areal coverage in the woodshed is the Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest, which is characterized by a diverse canopy of hardwoods such as the white oak (*Quercus alba*), southern red oak (*Quercus falcata*), water oak (*Quercus nigra*), post oak (*Quercus stellata*), sweetgum (*Liquidiambar styraciflua*), mockernut hickory (*Carya alba*), and pignut hickory (*Carya glabra*). Natural wetland forest types occupy another 15.7%, most of which contain mixed canopy associations of bald cypress (*Taxodium distichum*), pond cypress (*Taxodium ascendens*), river birch (*Betula nigra*), blackgum (*Nyssa biflora*), sweetgum (*Liquidiambar styraciflua*), water elm (*Planera aquatica*), and water oak (*Quercus nigra*). Together these forestry and forest ecosystems occupy over 1.68 million hectares, which is just below 61% of the total woodshed area.

Public lands databases that include federal landholdings and state conservation lands for North Carolina and Virginia indicate that 6.6% of the woodshed is under some form of conservation protection. Major public landholdings with significant conservation importance include: the Great Dismal Swamp National Wildlife Refuge and adjacent Virginia state conservation lands within the Dismal Swamp eco-region, the Pocosin Lakes National Wildlife Refuge, and the Roanoke River National Wildlife Refuge. Enviva Table 1 provides a complete list of GAP ecosystems and associated areas in the 75-mile sourcing area for the Enviva Ahoskie facility, along with areas and percentages identified as either being under public ownership or other forms of conservation protection. Enviva Map 2 provides a visualization of GAP land cover generalized to the macro ecosystem level, as well as outlines of the National Wildlife Refuges located in the woodshed.

NatureServe analysis of G1-G3 ecological associations

Enviva Table 2 lists thirty-six specific ecological associations with G1 (critically imperiled), G2 (imperiled), or G3 (vulnerable) status that NatureServe identified as having at least one element occurrence within the Enviva Ahoskie woodshed. Twenty-nine of these ecological associations are forest types that could potentially serve as a supply for woody biomass extraction or conversion. Avoidance of these and other G1-G3 ecological associations from biomass sourcing within the woodshed can be recommended as a minimum criterion for protecting and conserving biodiversity through sustainable forest management.

Woodshed competition

The competition overlay and network analysis for the Enviva Ahoskie pellet plant identified a total of fifteen other facilities that may be expected to compete for woody biomass within at least some portion of the 75-mile woodshed area (Enviva Map 3). This includes eight active pulp and paper mills, as well as seven bioenergy or bio-pellet facilities active as of April 2013. A more recently opened Enviva-owned biomass facility located at Northampton, NC and a planned Enviva-owned facility in Southampton, VA were not included in this competition analysis, but as located will have woodshed sourcing areas that overlap with the current sourcing area for the Enviva Ahoskie facility.

The four paper mills located within the Enviva Ahoskie facility's 75-mile sourcing area include International Paper's Franklin, VA plant; Georgia Pacific's Jarratt, VA plant; International Paper's Roanoke Rapids, NC plant; and Weyerhaeuser's Plymouth, NC plant. The high demands of the competing pulpwood facilities, which may outbid the biomass facility for high quality pulpwood in many areas of overlapping demand, is likely to have great influence on the areas in which the Enviva Ahoskie facility will obtain primary woody biomass resources. As shown in Enviva Map 4, areas of lowest competition for Enviva Ahoskie are generally located to the east and north of the facility near the Great Dismal Swamp National Wildlife Refuge.

Plantation pine forestry distribution and suitability

A visualization of the Maxent suitability model for plantation pine forestry in the Enviva woodshed is given in Enviva Map 5. Elevation provided the strongest contribution to the Maxent model (55.2%), although the response curve indicates that dominant elevation effects occur at a narrow range near sea level. Categorical soil classifications also provided a strong model contribution (39.9%), and clear break lines in pine plantation suitability throughout the woodshed generally follow changes in soil classification. Relatively minor contributions to the final Maxent model were provided by the distance to road (3.3%) and slope (1.6%) variables.

Hardwood biomass sourcing models and associated ecosystem risks

Results for the Enviva Ahoskie hardwood biomass sourcing model that includes both upland and wetland forests (HDW) are shown in Enviva Map 6, while the hardwood model that is restricted to only upland hardwood sourcing (HNW) is shown in Enviva Map 7. The harvest area objectives and associated suitability classes associated with the color-coding are provided in Enviva Table 3.

While a stepped concentric pattern of suitability that follows network travel distances (i.e., closer areas are generally more suitable than those further away) is generally evident in both hardwood sourcing screens, a corridor of high predicted suitability that stretches into relatively distant areas to the east and northeast of the facility is also apparent. The high predicted suitability in these more distant areas is driven by the relatively low competitive demand pressure associated with other regional wood consuming facilities (Enviva Map 4). Notably, the biomass sourcing model determined that insufficient hardwood land area was available within the woodshed to meet HAO_8 and HAO_10 for the HNW screen. This result suggests that residuals and other secondary biomass resources from upland hardwood forests provide an insufficient material base for sourcing hardwood biomass at the facility's current demand, even under a very strong assumption that this facility provides the only source of demand for such material within the woodshed.

Enviva Tables 4a-4c summarize the GAP forest ecosystem classes predicted to provide the resource base for sourcing the hardwood component of the Enviva Ahoskie facility over an assumed 50-year facility life cycle under the HDW screen at different harvest intensities. Forested wetland ecosystems compose over 61% of the ecosystems at high risk of harvest (Table 4a), with the remainder provided by upland hardwood forests.

Enviva Tables 5a-5c summarize the harvest risk areas for GAP forest ecosystem classes under the HNW screen. Although coastal plain hardwood forests comprise the entirety of hardwood sourcing area for the "High risk" scenario, several piedmont hardwood forests show significant area within the moderate and low risk scenarios. Because the sourcing model could not locate sufficient area to fulfill the HAO_10 (i.e., low risk or residuals-only) scenario, the result in Table 4-c represents a very large percentage of upland hardwood forests not in protected conservation status within the Enviva woodshed.

Softwood biomass sourcing model

Results for the Enviva Ahoskie softwood biomass sourcing model under the FNP screen are shown in Enviva Map 8. The harvest area objectives and associated suitability classes associated with the color-coding are provided in Enviva Table 3. An apparent feature of the map visualization is that the small softwood demand effectively constrains most of the total predicted source area to areas within approximately 25 miles of the facility. All public conservation lands were masked out from consideration in this analysis.

Enviva Tables 6a-6c provide a summary of the GAP forest ecosystem classes that are predicted to provide the highest suitability resource for sourcing the softwood component of the Enviva Ahoskie facility under the FNP sourcing screen. It is notable that over 90% of the areas selected as high suitability for sourcing the facility is identified as either plantation pine or disturbed forest, even when all upland forests are assumed as available. This result suggests that the current softwood sourcing demand from the Enviva Ahoskie facility may not directly imply major pressure for increased conversion of natural upland forest stands into plantation pine. While it is possible that large-scale harvest of upland or bottomland hardwoods for bioenergy or other wood demands could prompt post-harvest conversion into faster growing plantation pine in the Enviva Ahoskie woodshed, detection and attribution of such potential post-harvest landowner behavior and changeable sourcing requirements for the facility is beyond the scope of this current study.

Indicator species analysis

Enviva Tables 7a-7b provide a summary comparison of the GAP distribution overlay for each indicator species under the HDW and HNW screens and using the high (HAO_2) and moderate risk (HAO_6) sourcing scenarios for the Enviva Ahoskie facility. This comparison is not made for the low risk (HAO_10) scenarios due to the failure of the sourcing model to find sufficient land area for achieving the HAO_10 scenario using the HNW screen. Due to the relatively low land footprint for softwood demand, and likelihood that such demand can be met through the large existing plantation forestry base, formal indicator species comparisons are not made for alternative softwood sourcing screens for the Enviva Ahoskie facility.

From a general interpretive perspective, the HDW screen clearly implies a substantially larger potential habitat impact on the wetland dependent prothonotary and Swainson's warbler, while HNW screen implies a substantially larger potential habitat impact on upland species including the brown-headed nuthatch, northern bobwhite, and long-tailed weasel. These results are not surprising due to the fact that forested wetlands are assumed as available and provide a high proportion of the land base for the HDW screen, while forested wetlands are assumed as completely unavailable under HNW. By extension, habitat impacts for wetland-dependent species will almost axiomatically be higher under HDW, and upland-dependent species will be higher under HNW.

Current hardwood sourcing practices for Enviva Ahoskie are generally believed to follow the HDW screen, which includes heavy clear cut sourcing from wetland forests. Under this sourcing regime, the prothonotary warbler shows the greatest relative habitat risk among the indicator species considered in our analysis. Approximately 14.5% of the habitat area for this species in the Enviva Ahoskie woodshed is shown as at high risk of harvest impact, while 37.2% is shown as having moderate risk. Field research of bird responses to forestry treatments in bottomland and upland hardwoods indicates that the prothonotary warbler is highly sensitive to logging disturbance, with large and persistent declines observed in occupancy by this species even after implementation of careful silvicultural practices designed to enhance overall bird diversity (Augenfeld et al. 2009; Cooper et al. 2009; Twedt and Somershoe 2010). Moreover, habitat studies suggest that prothonotary warblers generally require highly contiguous riparian forest corridors with widths greater than 100 meters (Keller et al. 1993; Hodges and Krementz 1996). By extension, temporal fragmentation of wetland and riparian forests through sourcing of hardwood biomass is likely to have significant negative impacts on prothonotary warbler utilization of the Enviva Ahoskie woodshed. As indicated by the much lower habitat area overlap with the HNW screen, sourcing practices that restrict against bottomland harvest can be expected to have high protective value for prothonotary warbler habitat. Logging practices that maintain at least 100 meter corridors directly along streams and are timed to maintain structural connectivity would be necessary to somewhat lessen the habitat degradation effects for the prothontary warbler and other species dependent on contiguous patches of relatively undisturbed wetland forests (Keller et al. 1993) if continued wetland sourcing is assumed.

The Swainson's warbler is the species that shows the highest relative increase in habitat area at high risk under the HDW screen (i.e., over seven times as much area as compared to HNW). Preservation of large unfragmented patches of bottomland forest with moderate clearing disturbance to facilitate understory heterogeneity has long been regarded as the most effective strategy for maintaining Swainson's warbler habitat (Hunter et al. 1994). However, habitat studies indicate that viable populations of Swainson's warbler can be maintained in production forestry landscapes that include continuous hardwood clear cuts as large as 20 hectares (Peters 1999; Graves 2002), although selective cuts of 1 hectare or less likely have greater habitat enhancement effect (Graves 2002). Due to unknowns about potential response to novel sourcing practices for hardwood pellet production, careful monitoring of local Swainson's warbler responses to bottomland hardwood logging for the Enviva Ahoskie facility is likely warranted.

As noted previously, both the brown-headed nuthatch and northern bobwhite show relatively small amounts of GAP habitat distribution overlay under the HDW sourcing screen, with much larger overlay with the HNW scenario. In theory, selective hardwood harvests on upland mixed forest sites could potentially benefit brown-headed nuthatches by promoting early succession pine tree regeneration (Wilson and Watts 1999). However, clear cut logging of both softwoods and hardwoods on natural upland stands, which may be a more likely scenario for economical procurement of biomass from upland sites, would be expected to reduce available habitat for this species, particularly if snag density is significantly reduced (Lloyd and Slater 2007). Although direct responses of northern bobwhite to selective removal or clear cut of hardwoods in upland forests of the coastal plain are not particularly well-known, post-harvest management for open-canopy and diverse herbaceous understory layers may be generally expected to provide some habitat benefit for northern bobwhites, particularly if adjacent to pasture or crop fields (Brennan 1991; White et al. 2005).

Habitat overlay analyses for the long-tailed weasel show somewhat higher impact under the HNW screen. This result is a direct function of this species generally using wetland forest edges and contiguous upland forest corridors, but generally avoiding deep interiors of wetland forests that provide significant sourcing area under the HDW screen. Negative impacts on the long-tailed weasel populations, however, may be large under either screen to the extent that harvest activity creates continuous clearings that increase the temporal fragmentation of the extant forest landscape (Gehring and Swihart 2004). Although little is known about direct impacts of logging and secondary forest regeneration to the long-tailed weasel, knowledge of behavioral avoidance of areas with low canopy covers suggests that rotational harvest strategies which maintain canopy connectivity between core forest patches may be critical for long-term conservation of this species (Gehring and Swihart 2003).

Overlay results for the northern cricket frog showed generally little difference between the HDW and HNW scenarios. Local effects from logging impacts on this species are likely to be most directly associated with water quality impacts in the post-harvest period, particularly in terms of sediment loading, increased temperatures (Smith et al. 2003), or potential runoff of herbicides (Reeder et al. 2005) that may be used to manage the successional stand composition of regenerating trees. Maintenance of non-disturbance buffers around herbaceous wetlands known to contain northern cricket frogs is likely to provide substantial conservation benefit for this species within a working forestry landscape.

Comparative overlay results between the HDW and HNW screens are mixed for the timber rattlesnake, with somewhat larger impact shown for the HNW screen in the high risk scenarios, while the HDW screen shows larger relative impact in the moderate risk scenarios. Divergence in these results is a function of the GAP distribution for the timber rattlesnake distribution being generally restricted to the forested coastal plain portions of the Enviva Ahoskie woodshed. Sensitivity to increased fragmentation from logging activities and direct mortality in interactions with loggers (Reinert et al. 2011) can be considered a major concern for the timber rattlesnake in both upland and bottomland hardwood habitats that may be sourced for bioenergy.

Discussion

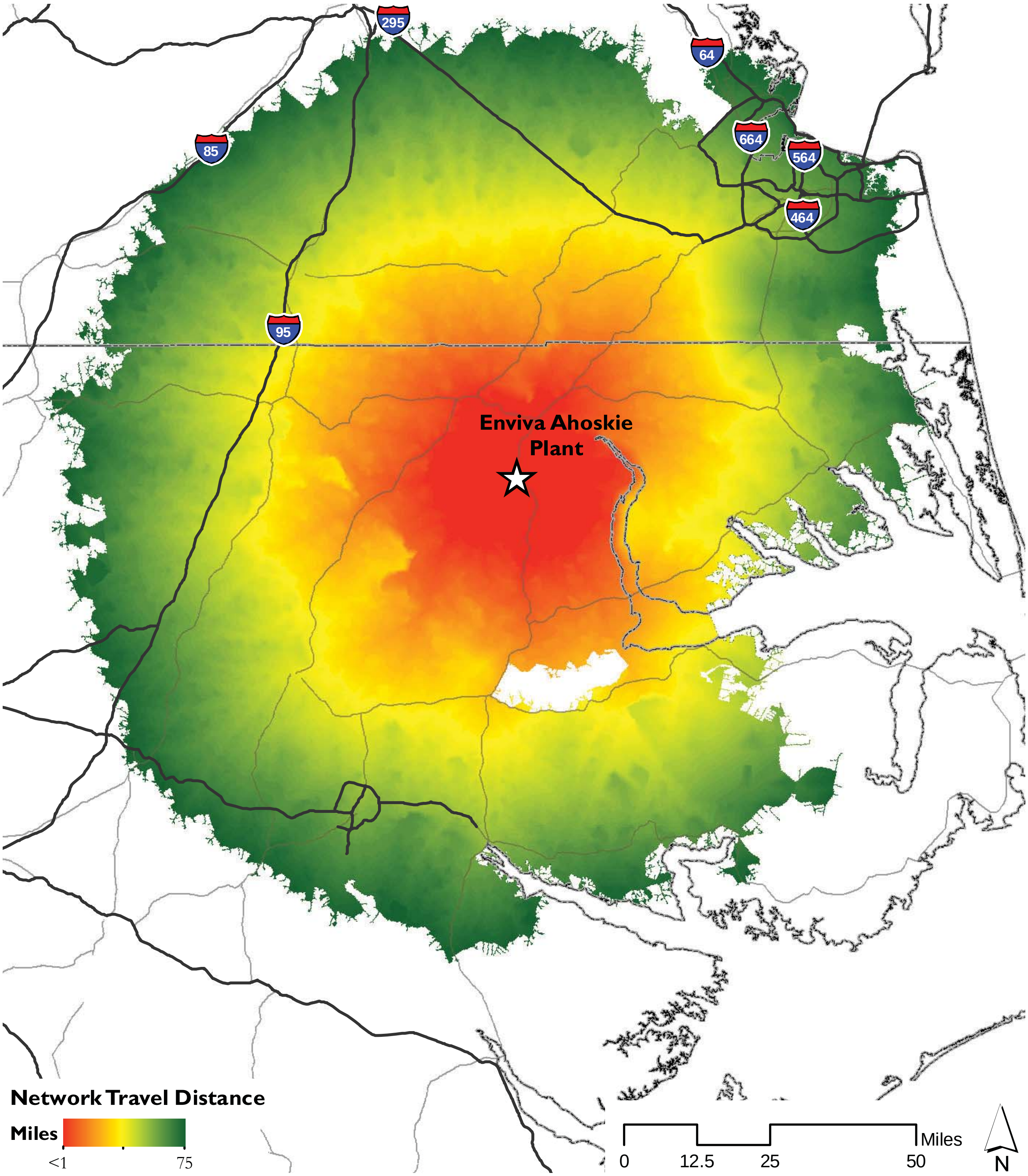
The Enviva Ahoskie facility is unique among the facilities considered in this project, as sourcing models indicate an apparent need to rely heavily upon natural stands of bottomland wetland forests for hardwood demand. The U.S. Environmental Protection Agency (2012b) estimates that 60 percent of the original bottomland forest areas that once existed in the SE U.S. Coastal Plain has been drained or converted to other uses, and that numerous species dependent on these forests are therefore rare, declining, or of conservation concern.

Bottomland forest harvests pose clear habitat degradation concerns for bird species such as the prothonotary warbler that require contiguous riparian corridors (Cooper et al. 2009), and may also pose high risks to local amphibian populations in cases where sufficient post-harvest residuals are not retained on site for microhabitat regeneration (deMaynadier and Hunter 1995; Welsh and Droege 2001). Increased stream sedimentation, alteration of hydrologic regimes, changes in water chemistry, and different thermal profiles that can affect local fish, water birds, and aquatic invertebrates are other post-harvest concerns when sourcing wood from riparian bottomland forests (Ensign and Mallin 2001; Hutchens et al. 2004). Although best management practices (BMPs) are available for bottomland wetland sourcing in the SE U.S. (Stokes and Schilling 1997), climatic variability and hydrologic alterations may provide inherent water quality and regeneration concerns for these ecosystems under even the most careful extractive logging scenarios (Lowrance and Vellidis 1995; King et al. 2009). Long-term bank erosional and riparian habitat loss concerns, as influenced by upstream damming, have been specifically noted for bottomland forests along the Roanoke River basin (Hupp et al. 2009) that show high risk of being sourced by the Enviva Ahoskie facility.

If sustainability criteria for biomass harvesting that prohibit bottomland and wetland sourcing are applied to the Enviva Pellets Ahoskie woodshed, our analyses suggest that natural stands of upland hardwood forests may by unlikely to provide a sustainable source of long-term biomass supply of the facility. This assessment is based on the low productivity values (~3-4 Mg/yr) of upland hardwood forests in the Coastal Plain and Piedmont provinces (Kline and Coleman 2010) and limited area (~388,000 ha) of extant upland hardwood forests within the Enviva Ahoskie woodshed. This implies an appropriation equaling 25% of upland hardwood biomass productivity across the entire 75-mile woodshed for the Enviva Ahoskie facility alone. Although some thinning of upland hardwood forests may provide habitat enhancement, there are substantial biodiversity and overall forest sustainability concerns for upland hardwood forests in the SE Coastal Plain and Piedmont that are exposed to such intensive extractive forestry pressures (Noss et al. 1995).

For these reasons, it is likely that afforestation of pastures and marginal cropland with fast-growing woody feedstocks would be required to meet long-term hardwood demands of Enviva Pellets Ahoskie (and other similar facilities) under biomass sustainability scenarios where wetland sourcing is limited or prohibited. Hybrid poplar (*Populus* sp.) in particular has been a major focus of research for long-term bioenergy sourcing that avoids primary utilization of extant natural forest stands (e.g., Cook and Beyea 2000), as very high productivity values exceeding 15 dry Mg/yr have been reported in the upper coastal plain and other areas of the SE U.S. (Kline and Coleman 2010). Work by Fletcher et al. (2011) further suggests that bird diversity and density are generally higher in hybrid poplar-based plantation forests as compared to agricultural land covers. This could imply that aggressive upland hardwood afforestation for biomass production may potentially produce habitat benefits for forest-dependent species in certain landscape contexts. However, additional research is necessary to more fully understand the local environmental suitability and wildlife habitat responses that may be associated with such alternative biomass feedstock sourcing scenarios in the SE Coastal Plain and Piedmont regions.

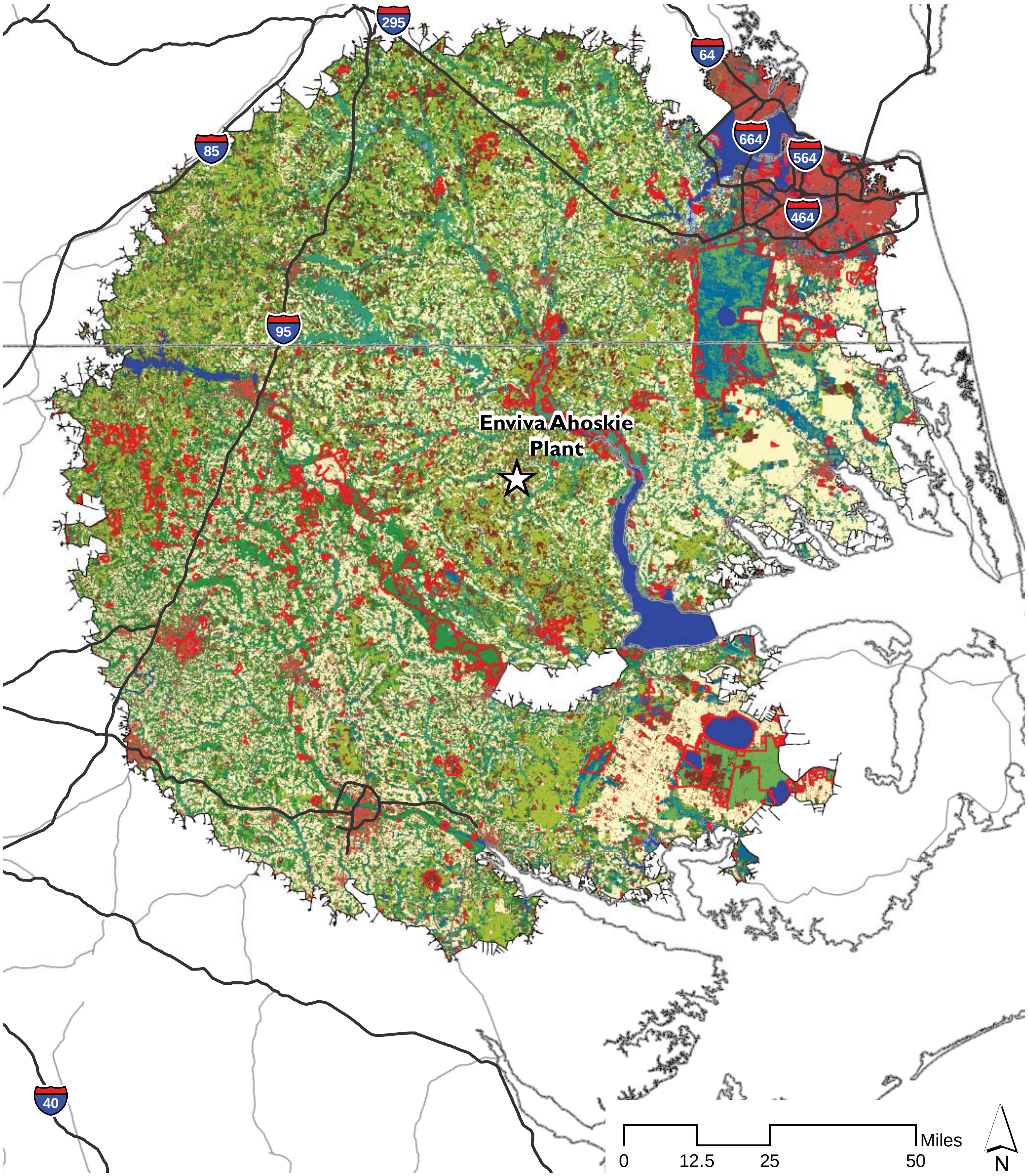
Figure 35. Enviva Map 1: 75-mile Network Travel Distance and Woodshed Delineation



Enviva Table 1. GAP Detailed Ecosystem Summary for 75-Mile Woodshed Area			
Land Cover Type (Detailed)	**Area**	**Protected**	**% Protected**
Cultivated Cropland	660,240	10,603	1.6%
Evergreen Plantation or Managed Pine	413,504	9,394	2.3%
Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	181,095	4,839	2.7%
Pasture/Hay	155,286	3,403	2.2%
Atlantic Coastal Plain Small Blackwater River Floodplain Forest	138,964	15,331	11.0%
Southern Atlantic Coastal Plain Mesic Hardwood Forest	121,584	1,586	1.3%
Atlantic Coastal Plain Upland Longleaf Pine Woodland	111,028	3,057	2.8%
Atlantic Coastal Plain Blackwater Stream Floodplain Forest - Forest Modifier	104,676	1,881	1.8%
Developed, Open Space	95,855	4,021	4.2%
Disturbed/Successional - Shrub Regeneration	88,909	3,927	4.4%
Atlantic Coastal Plain Peatland Pocosin	82,419	33,959	41.2%
Harvested Forest-Shrub Regeneration	67,712	3,875	5.7%
Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest - Taxodium/Nyssa Modifier	66,313	32,125	48.4%
Developed, Low Intensity	61,739	1,489	2.4%
Disturbed/Successional - Grass/Forb Regeneration	58,088	8,031	13.8%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	57,118	1,847	3.2%
Open Water (Brackish/Salt)	52,011	1,331	2.6%
West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	49,849	14,115	28.3%
Harvested Forest - Grass/Forb Regeneration	48,865	1,359	2.8%
Open Water (Fresh)	36,275	12,356	34.1%
Developed, Medium Intensity	22,343	1,193	5.3%
Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest - Oak	19,882	6,535	32.9%
Northern Atlantic Coastal Plain Basin Swamp and Wet Hardwood Forest	15,514	809	5.2%
Central Atlantic Coastal Plain Wet Longleaf Pine Savanna and Flatwoods	13,139	1,115	8.5%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	12,822	237	1.8%
Developed, High Intensity	10,054	1,300	12.9%
Southern Piedmont Small Floodplain and Riparian Forest	9,405	586	6.2%
Southern Piedmont Mesic Forest	8,422	228	2.7%
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	6,630	144	2.2%
Atlantic Coastal Plain Northern Tidal Salt Marsh	6,260	810	12.9%
Quarries, Mines, Gravel Pits and Oil Wells	1,539	29	1.9%
Undifferentiated Barren Land	1,456	124	8.5%
Atlantic Coastal Plain Northern Fresh and Oligohaline Tidal Marsh	1,420	90	6.3%
Unconsolidated Shore	933	695	74.5%
Atlantic Coastal Plain Embayed Region Tidal Salt and Brackish Marsh	682	33	4.8%
Southern Piedmont Large Floodplain Forest - Forest Modifier	504	0	0.0%
Atlantic Coastal Plain Embayed Region Tidal Freshwater Marsh	332	13	3.9%
Atlantic Coastal Plain Southern Tidal Wooded Swamp	297	7	2.4%
Atlantic Coastal Plain Northern Maritime Forest	286	62	21.7%
Atlantic Coastal Plain Central Salt and Brackish Tidal Marsh	209	11	5.3%

Enviva Ahoskie Table 1. GAP Detailed Ecosystem Summary for 75-Mile Woodshed Area

Figure 36. Enviva Map 2: GAP Land Cover and Conservation Lands



Enviva Map 2: Land Cover Characteristics Legend

Conservation Areas

GAP Ecosystem Class (NVC Macro)

- Longleaf Pine & Sand Pine Woodland
- Southeastern North American Ruderal Forest & Plantation
- Eastern North American Ruderal Forest & Plantation
- Southern-Central Oak-Hardwood & Pine Forest
- Central Mesophytic Hardwood Forest
- Northern & Eastern Pine - Oak Forest, Woodland & Barrens
- Southern Floodplain Hardwood Forest
- Southern Coastal Plain Basin Swamp
- Wet Longleaf Pine & Southern Flatwoods
- Eastern North American Coastal Grassland & Shrubland
- Atlantic & Gulf Coastal Plain Bog & Fen
- Atlantic & Gulf Coastal Plain Freshwater Tidal Marsh
- Eastern North American Atlantic Salt Marsh
- Barren
- Herbaceous Agricultural Vegetation
- Recently Disturbed or Modified
- Open Water
- Quarries, Mines, Gravel Pits and Oil Wells
- Developed & Urban

Figure 37. Enviva Map 3: Travel Network Analysis & Locations of Competing Bioenergy and Pulp Mill Facilities

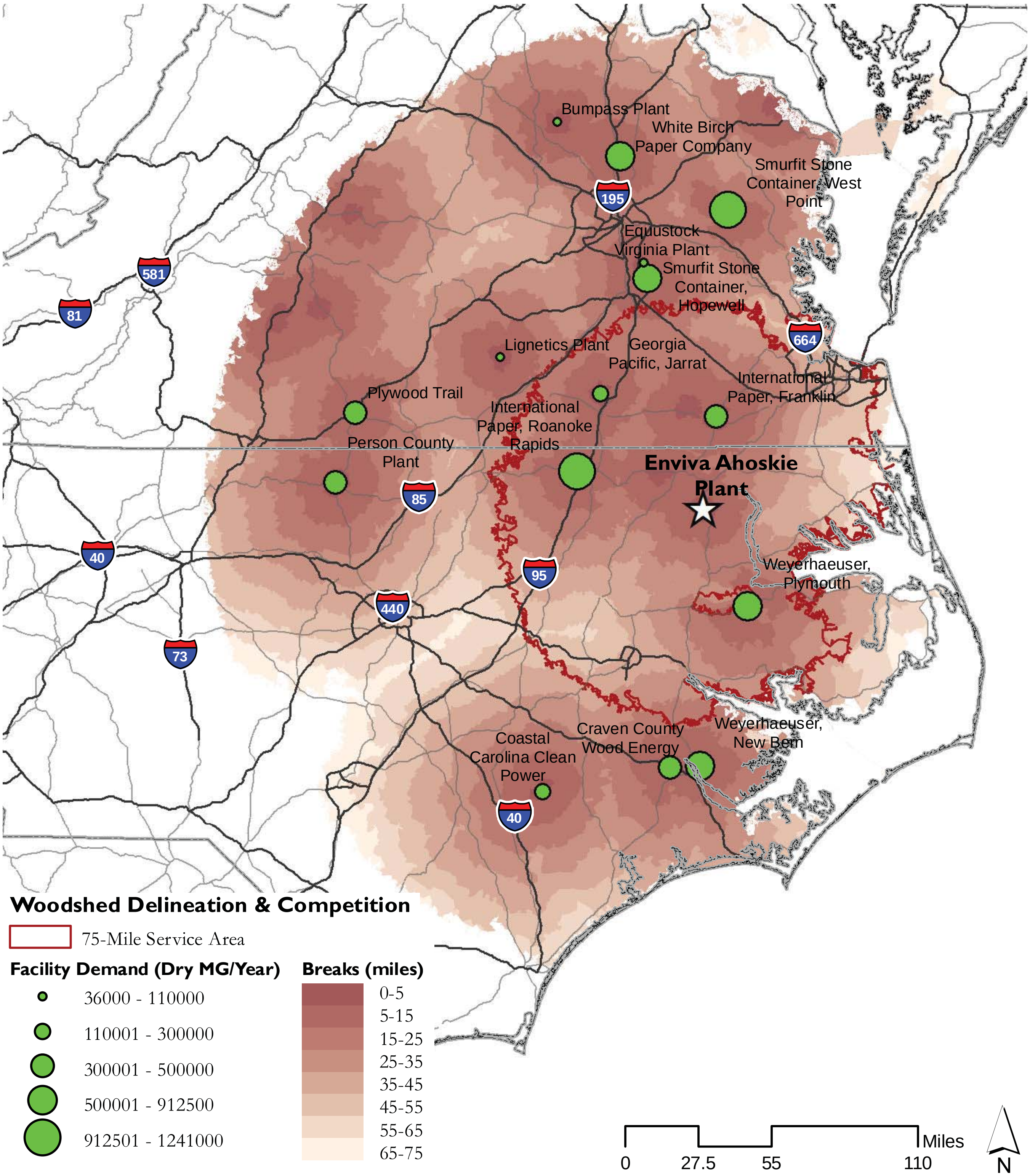


Figure 38. Enviva Map 4 : Competition Demand Strength Analysis, as Annual dry Mg / Network Travel Mile

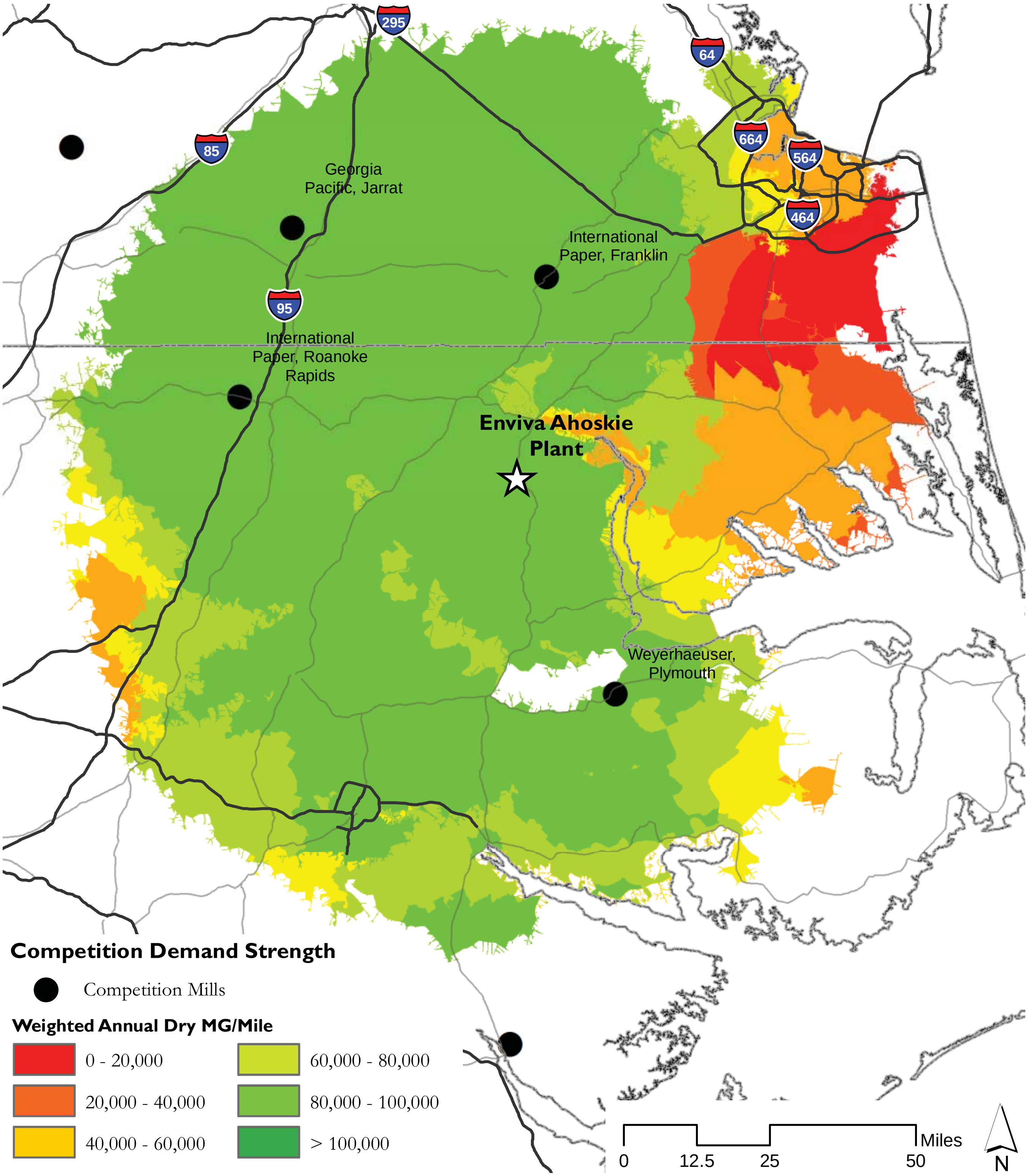


Figure 39. Enviva Map 5: Maximum Entropy Suitability Model for Pine Plantation

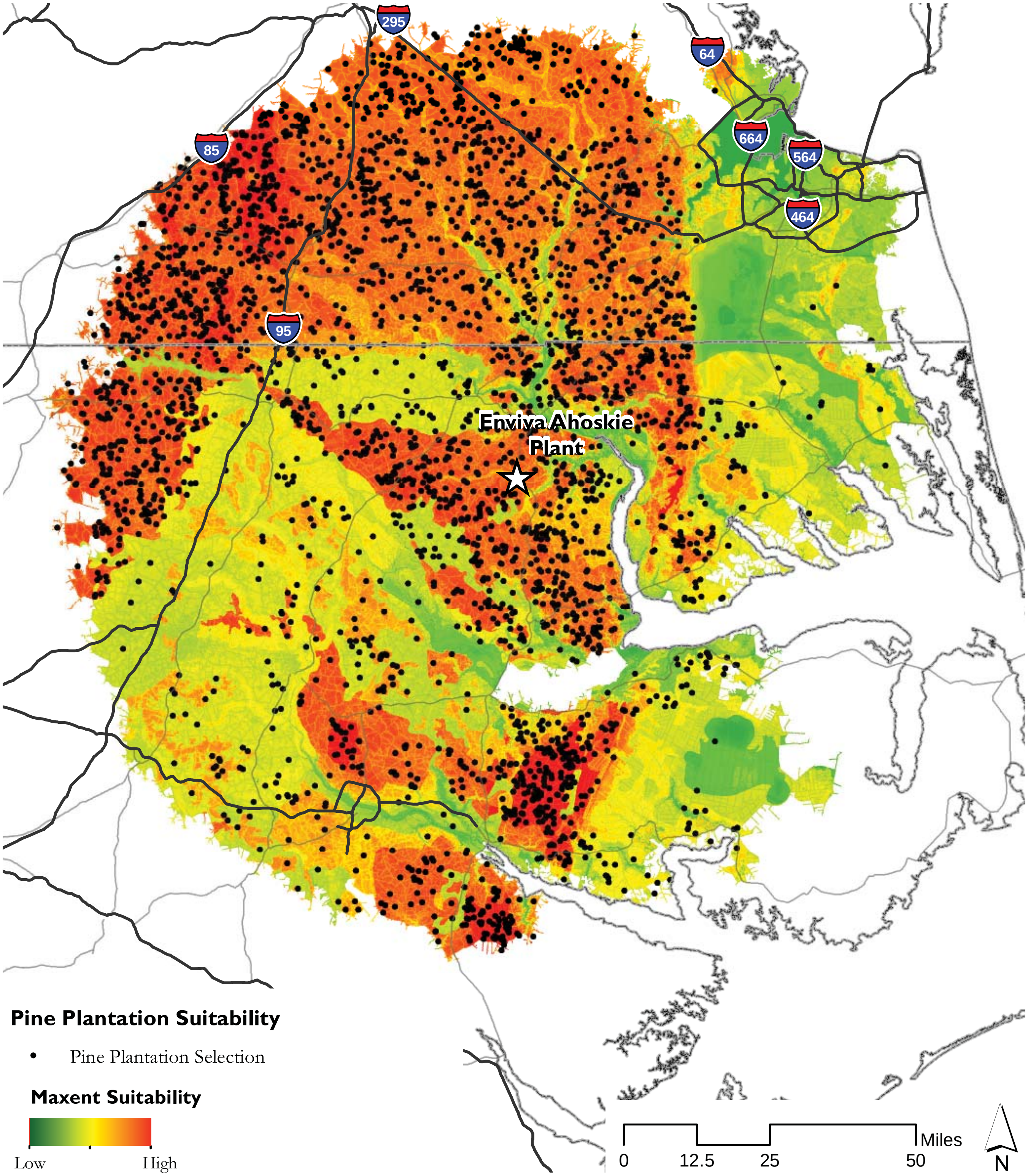


Figure 40. Enviva Map 6: Composite Model of Hardwood (HDW) Sourcing Model Screen

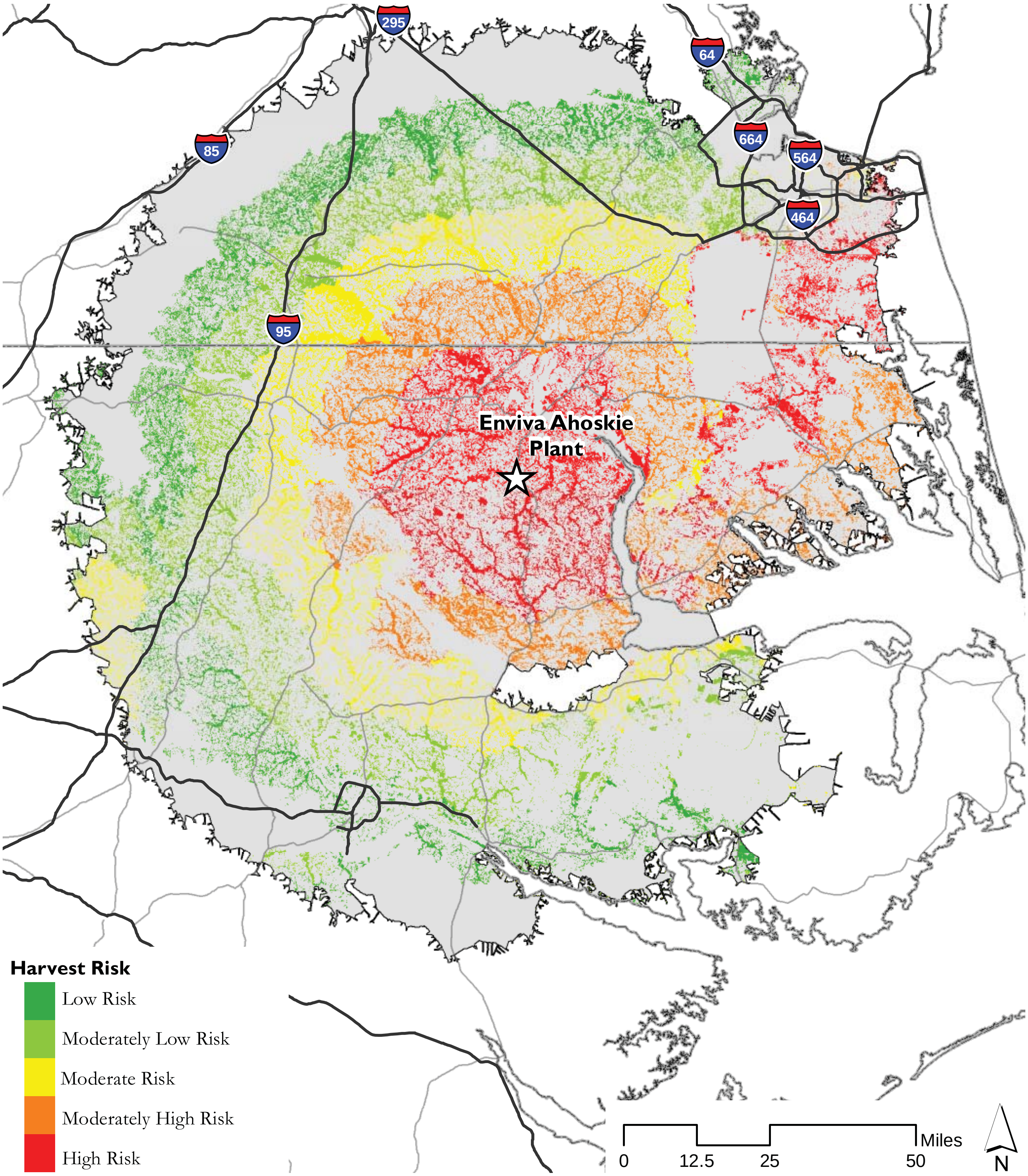
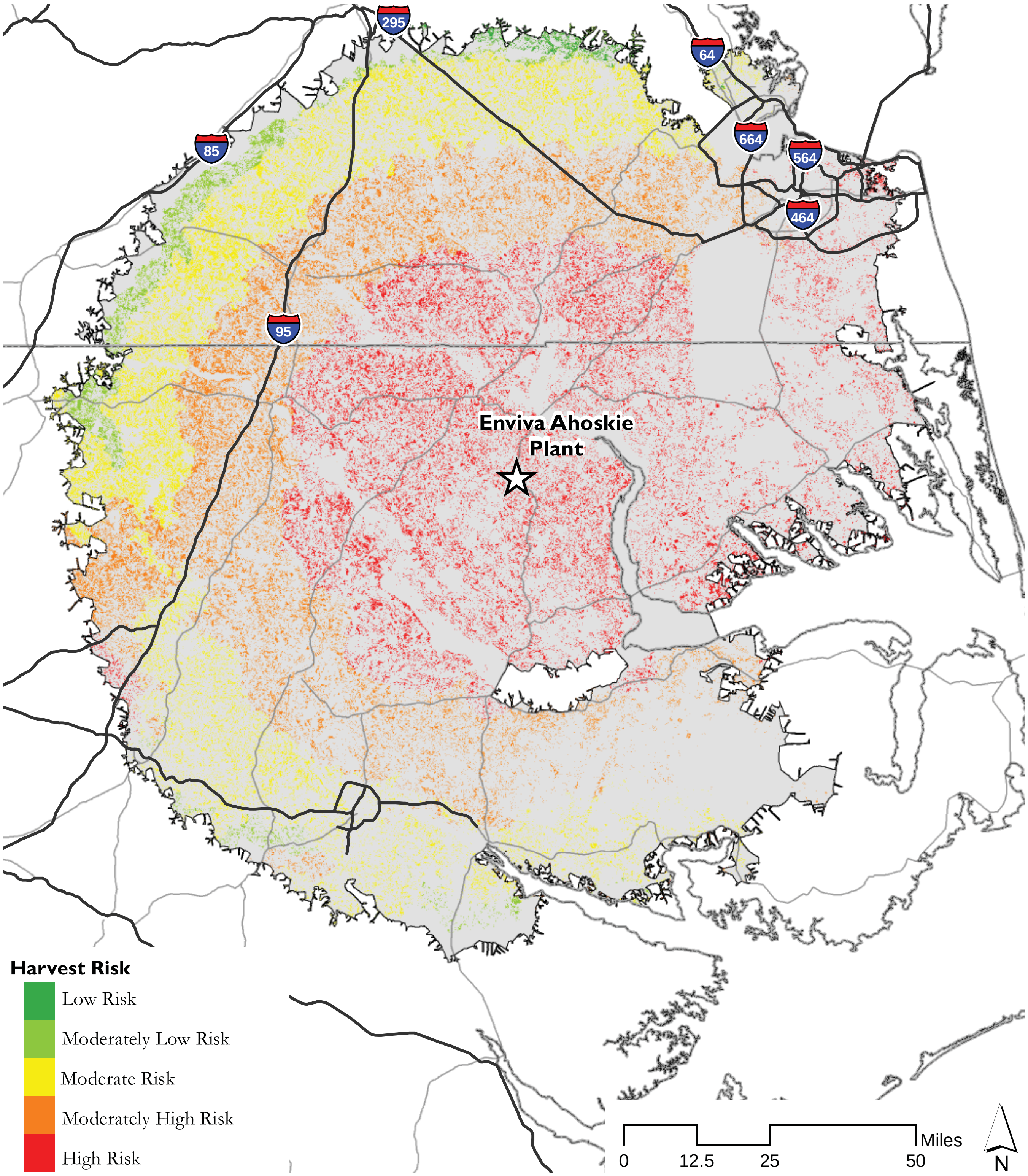


Figure 41. Enviva Map 7: Composite Model of Hardwood no Wetlands (HNW) Sourcing Model Screen



Enviva Table 2. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, excluding conservation areas			
Formal association name	**Common association name**	**Status**	**Woodshed occurrences**
Pinus palustris / Quercus laevis - Quercus incana / Gaylussacia dumosa - Gaylussacia (baccata, frondosa) Woodland	Longleaf Pine / Scrub Oak Sandhill (Northern Type)	G1	14
Pinus serotina / Arundinaria gigantea ssp. tecta Woodland		G1	2
Liquidambar styraciflua / Persea palustris Forest	Sweetgum Coastal Plain Lakeshore Forest	G1	1
Quercus muehlenbergii / Cercis canadensis / Dichanthelium boscii - Bromus pubescens - Erigeron pulchellus var. pulchellus - Aquilegia canadensis Forest	North Atlantic Coastal Plain Dry Calcareous Forest	G1	1
Rhynchospora alba Saturated Herbaceous Vegetation		G1?	1
Taxodium distichum / Cephalanthus occidentalis / Juncus repens Woodland	Lake Drummond Pond Shore	G1?	1
Liquidambar styraciflua - Acer rubrum - Nyssa biflora / Carex joorii Forest	Central Coastal Plain Basin Swamp	G1G2	14
Eleocharis fallax - Eleocharis rostellata - Schoenoplectus americanus - Sagittaria lancifolia Herbaceous Vegetation	Atlantic Coast Tidal Oligohaline Spikerush Marsh	G1G2	1
Quercus michauxii - Quercus pagoda / Clethra alnifolia - Leucothoe axillaris Forest		G2	8
Chamaecyparis thyoides / Persea palustris / Lyonia lucida - Ilex coriacea Forest	Peatland Atlantic White-cedar Forest	G2	5
Talinum teretifolium - Minuartia glabra - Diodia teres - Croton willdenowii Herbaceous Vegetation	Virginia Piedmont Granitic Flatrock Glade	G2	3
Pinus palustris - (Pinus serotina) / Ilex glabra - Gaylussacia frondosa - (Kalmia carolina) Woodland	Wet Longleaf Pine Flatwoods (Northern Type)	G2	2

Enviva Ahoskie Table 2. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, excluding conservation areas

Enviva Table 2. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, excluding conservation areas (cont…)

Formal association name	Common association name	Status	Woodshed occurrences
Nyssa biflora - Acer rubrum var. trilobum - Liriodendron tulipifera / Magnolia virginiana - Asimina triloba / Clethra alnifolia Forest		G2	2
Nyssa biflora - Liquidambar styraciflua - Acer rubrum var. trilobum / Clethra alnifolia Forest	Nonriverine Swamp Forest (Sweetgum Type)	G2?	3
Pinus serotina / Ilex glabra / Woodwardia virginica Woodland		G2?	2
Woodwardia virginica / Sphagnum cuspidatum Herbaceous Vegetation	Chainfern Small Depression Pond	G2?	1
Pinus taeda - Chamaecyparis thyoides - Acer rubrum - Nyssa biflora / Lyonia lucida - Clethra alnifolia Forest		G2G3	13
Taxodium distichum - Nyssa biflora / Berchemia scandens - Toxicodendron radicans / Woodwardia areolata Forest	Bald-cypress - Swamp Blackgum Nonriverine Swamp Forest	G2G3	4
Fagus grandifolia - Quercus alba / Kalmia latifolia - (Symplocos tinctoria, Rhododendron catawbiense) / Galax urceolata Forest	Piedmont Beech / Heath Bluff	G2G3	2
Juncus roemerianus - Pontederia cordata Herbaceous Vegetation		G2G3	1
Quercus laurifolia - Nyssa biflora / Clethra alnifolia - Leucothoe axillaris Forest		G2G3	1
Spartina cynosuroides - Panicum virgatum - Phyla lanceolata Herbaceous Vegetation		G2G3	1
Pinus serotina / Cyrilla racemiflora - Lyonia lucida - Ilex glabra Woodland		G3	3
Pinus taeda / Morella cerifera / Osmunda regalis var. spectabilis Forest	Coastal Loblolly Pine Wetland Forest	G3	3
Pinus serotina - Gordonia lasianthus / Lyonia lucida Woodland		G3	1
Pinus serotina / Lyonia lucida - Ilex glabra - (Cyrilla racemiflora) Shrubland	Evergreen High Pocosin	G3	1

Enviva Table 2. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, excluding conservation areas (cont…)

Formal association name	Common association name	Status	Woodshed occurrences
Taxodium ascendens / (Nyssa biflora) / Leucothoe racemosa - Lyonia lucida - Morella cerifera Depression Forest	Pond-cypress Depression Forest	G3	1
Acer rubrum - Nyssa sylvatica - Magnolia virginiana / Viburnum nudum var. nudum / Osmunda cinnamomea - Woodwardia areolata Forest	Southern Red Maple - Blackgum Swamp Forest	G3?	1
Taxodium distichum - Nyssa aquatica - Nyssa biflora / Fraxinus caroliniana / Itea virginica Forest	Atlantic Coastal Plain Bald-cypress - Water Tupelo Blackwater Small Stream Swamp Forest	G3G4	12
Taxodium distichum - Nyssa biflora / Fraxinus caroliniana / Lyonia lucida Forest	Atlantic Coastal Plain Bald-cypress - Blackgum Swamp	G3G4	7
Quercus laurifolia - Quercus michauxii - Liquidambar styraciflua / Carpinus caroliniana Forest	Diamondleaf Oak Atlantic Brownwater River Floodplain Terrace and Ridge Forest	G3G4	6
Taxodium distichum - Fraxinus pennsylvanica - Quercus laurifolia / Acer rubrum / Saururus cernuus Forest	Coastal Plain Bald-cypress - Mixed Hardwood Forest	G3G4	4
Nyssa biflora - (Taxodium distichum, Nyssa aquatica) / Morella cerifera - Rosa palustris Tidal Forest	Tidal Hardwood Swamp Forest	G3G4	2
Fraxinus pennsylvanica - Quercus laurifolia - Quercus lyrata - Carya aquatica Forest	Green Ash - Diamondleaf Oak - Overcup Oak Brownwater Levee Forest	G3G4	2
Fagus grandifolia - Quercus rubra / Acer barbatum - Aesculus sylvatica / Actaea racemosa - Adiantum pedatum Forest	Piedmont Basic Mesic Mixed Hardwood Forest	G3G4	1
Celtis laevigata - Fraxinus pennsylvanica - Acer negundo - (Juglans nigra) / Asimina triloba / Carex grayi Forest	Atlantic Coastal Plain Sugarberry - Green Ash Levee Forest	G3G5	6

Enviva Table 3.
Harvest area objectives (HAO) and associated risk classes for spatial modeling

HAO	Hardwood (Ha)	Demand Intensity (Mg/ha/yr)	Softwood (Ha)	Demand Intensity (Mg/ha/yr)	Harvest or Conversion Risk Class
1	57,000	5.30	8,400	9.00	High
2	114,000	2.65	16,800	4.50	
3	171,000	1.77	25,200	3.00	Moderately High
4	228,000	1.33	33,600	2.25	
5	285,000	1.06	42,000	1.80	Moderate
6	342,000	0.88	50,400	1.50	
7	399,000	0.76	58,800	1.29	Moderately Low
8	456,000	0.66	67,200	1.13	
9	513,000	0.59	75,600	1.00	Low
10	570,000	0.53	84,000	0.90	

Enviva Ahoskie Table 3. Harvest Area Objectives and associated risk classes for spatial modeling

Enviva Ahoskie Table 4a. GAP ecosystem overlay for hardwood biomass sourcing including wetland forests (HDW screen) and high biomass removal intensity (HAO_2)

GAP Ecosystem	Hectares	Acres	Sourcing %
Atlantic Coastal Plain Blackwater Stream Floodplain Forest - Forest Modifier	18,016	44,500	15.9%
Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	15,006	37,065	13.2%
Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest - Taxodium/Nyssa Modifier	14,752	36,437	13.0%
Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest - Oak Dominated Modifier	941	2,324	0.8%
Atlantic Coastal Plain Northern Maritime Forest	15	37	0.0%
Atlantic Coastal Plain Small Blackwater River Floodplain Forest	30,638	75,676	27.0%
Atlantic Coastal Plain Southern Tidal Wooded Swamp	0	0	0.0%
Northern Atlantic Coastal Plain Basin Swamp and Wet Hardwood Forest	5,142	12,701	4.5%
Southern Atlantic Coastal Plain Mesic Hardwood Forest	28,874	71,319	25.5%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	0	0	0.0%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	0	0	0.0%
Southern Piedmont Large Floodplain Forest - Forest Modifier	0	0	0.0%
Southern Piedmont Mesic Forest	0	0	0.0%
Southern Piedmont Small Floodplain and Riparian Forest	0	0	0.0%

Enviva Ahoskie Table 4a. GAP ecosystem overlay for hardwood biomass sourcing including HDW screen and HAO_2

Enviva Ahoskie Table 4b. GAP ecosystem overlay for hardwood biomass sourcing including wetland forests (HDW screen) and moderate biomass removal intensity (HAO_6)

GAP Ecosystem	Hectares	Acres	Sourcing %
Atlantic Coastal Plain Blackwater Stream Floodplain Forest - Forest Modifier	62,938	155,457	18.9%
Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	76,119	188,014	22.9%
Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest - Taxodium/Nyssa Modifier	21,846	53,960	6.6%
Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest - Oak Dominated Modifier	3,557	8,786	1.1%
Atlantic Coastal Plain Northern Maritime Forest	90	222	0.0%
Atlantic Coastal Plain Small Blackwater River Floodplain Forest	82,342	203,385	24.8%
Atlantic Coastal Plain Southern Tidal Wooded Swamp	39	96	0.0%
Northern Atlantic Coastal Plain Basin Swamp and Wet Hardwood Forest	11,590	28,627	3.5%
Southern Atlantic Coastal Plain Mesic Hardwood Forest	72,083	178,045	21.7%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	1,304	3,221	0.4%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	285	704	0.1%
Southern Piedmont Large Floodplain Forest - Forest Modifier	0	0	0.0%
Southern Piedmont Mesic Forest	228	563	0.1%
Southern Piedmont Small Floodplain and Riparian Forest	245	605	0.1%

Enviva Ahoskie Table 4b. GAP ecosystem overlay for hardwood biomass sourcing including HDW screen and HAO_6

Enviva Ahoskie Table 4c. GAP ecosystem overlay for hardwood biomass sourcing including wetland forests (HDW screen) and low biomass removal intensity (HAO_10)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Atlantic Coastal Plain Blackwater Stream Floodplain Forest - Forest Modifier	91,430	225,832	16.3%
Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	150,956	372,861	27.0%
Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest - Taxodium/Nyssa Modifier	30,437	75,179	5.4%
Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest - Oak Dominated Modifier	10,946	27,037	2.0%
Atlantic Coastal Plain Northern Maritime Forest	224	553	0.0%
Atlantic Coastal Plain Small Blackwater River Floodplain Forest	111,126	274,481	19.8%
Atlantic Coastal Plain Southern Tidal Wooded Swamp	202	499	0.0%
Northern Atlantic Coastal Plain Basin Swamp and Wet Hardwood Forest	14,652	36,190	2.6%
Southern Atlantic Coastal Plain Mesic Hardwood Forest	103,808	256,406	18.5%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	29,476	72,806	5.3%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	6,982	17,246	1.2%
Southern Piedmont Large Floodplain Forest - Forest Modifier	376	929	0.1%
Southern Piedmont Mesic Forest	4,542	11,219	0.8%
Southern Piedmont Small Floodplain and Riparian Forest	4,947	12,219	0.9%

Enviva Ahoskie Table 4c. GAP ecosystem overlay for hardwood biomass sourcing including HDW screen and HAO_10

Enviva Ahoskie Table 5a. GAP ecosystem overlay for hardwood biomass sourcing excluding wetland forests (HNW screen) and high biomass removal intensity (HAO_2)

GAP Ecosystem	Hectares	Acres	Sourcing %
Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	52,542	129,779	46.1%
Atlantic Coastal Plain Northern Maritime Forest	90	222	0.1%
Southern Atlantic Coastal Plain Mesic Hardwood Forest	61,368	151,579	53.8%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	-	-	0.0%
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	-	-	0.0%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	-	-	0.0%
Southern Piedmont Mesic Forest	-	-	0.0%

Enviva Ahoskie Table 5a. GAP ecosystem overlay for hardwood biomass sourcing excluding HDW screen and HAO_2

Enviva Ahoskie Table 5b. GAP ecosystem overlay for hardwood biomass sourcing excluding wetland forests (HNW screen) and moderate biomass removal intensity (HAO_6)

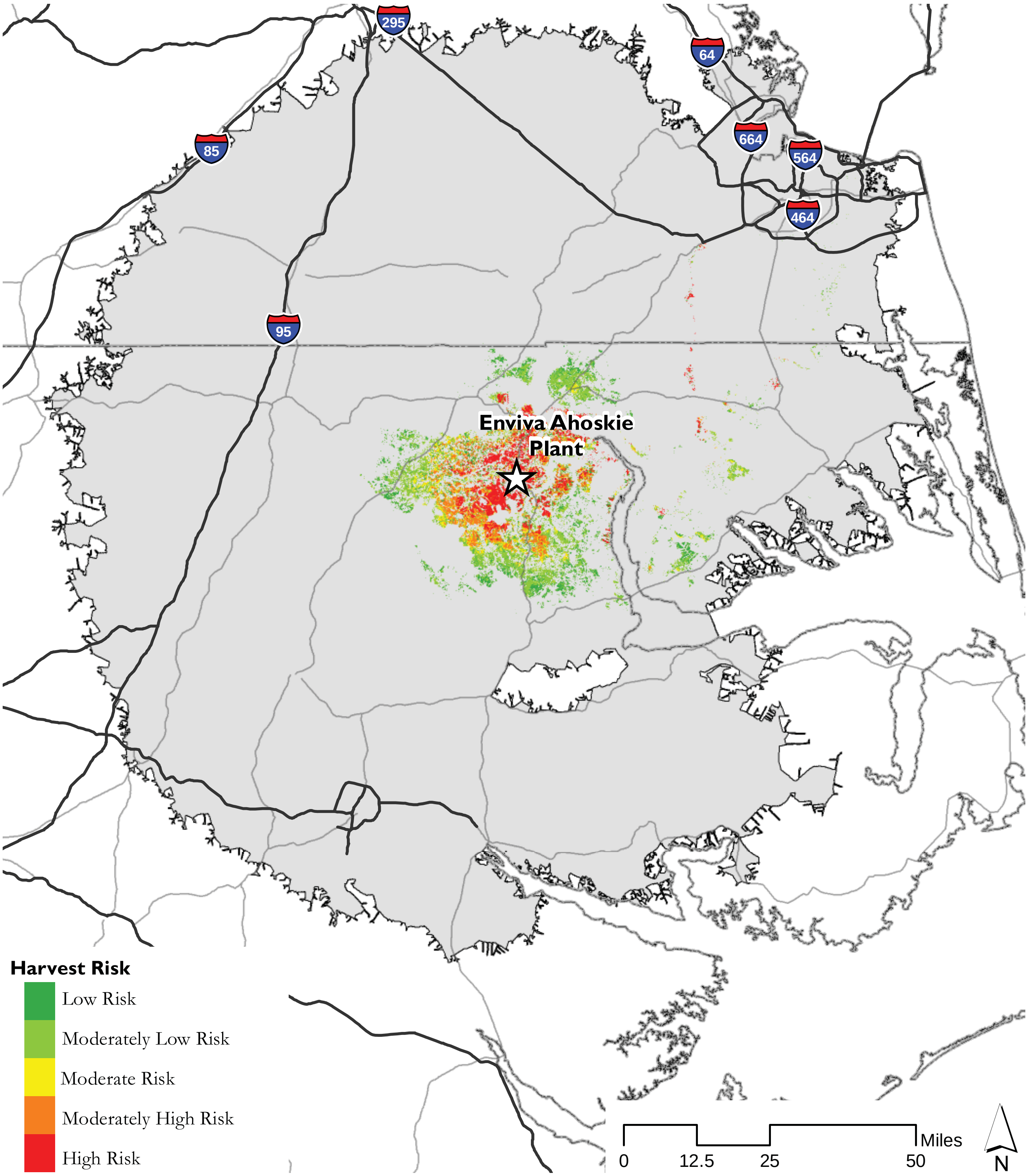
GAP Ecosystem	Hectares	Acres	Sourcing %
Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	167,577	413,915	50.7%
Atlantic Coastal Plain Northern Maritime Forest	224	553	0.1%
Southern Atlantic Coastal Plain Mesic Hardwood Forest	103,008	254,430	31.1%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	39,943	98,659	12.1%
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	4,731	11,686	1.4%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	9,225	22,786	2.8%
Southern Piedmont Mesic Forest	6,020	14,869	1.8%

Enviva Ahoskie Table 5b. GAP ecosystem overlay for hardwood biomass sourcing excluding HDW screen and HAO_6

Enviva Ahoskie Table 5c. GAP ecosystem overlay for hardwood biomass sourcing excluding wetland forests (HNW screen) and low biomass removal intensity (HAO_10)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	173,109	427,579	48.9%
Atlantic Coastal Plain Northern Maritime Forest	237	585	0.1%
Southern Atlantic Coastal Plain Mesic Hardwood Forest	106,542	263,159	30.1%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	49,412	122,048	14.0%
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	5,733	14,161	1.6%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	11,372	28,089	3.2%
Southern Piedmont Mesic Forest	7,408	18,298	2.1%

Enviva Ahoskie Table 5c. GAP ecosystem overlay for hardwood biomass sourcing excluding HDW screen and HAO_10

Figure 42. Enviva Map 8: Composite Model of Upland Forest, No Pasture Softwood (FNP) Sourcing Model Screen



Enviva Ahoskie Table 6a. GAP ecosystem overlay for softwood biomass sourcing without forest protection (FNP screen) and high biomass removal intensity (HAO_2)

GAP Ecosystem	Hectares	Acres	Sourcing %
Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	117	289	0.7%
Southern Atlantic Coastal Plain Mesic Hardwood Forest	1,482	3,661	8.8%
West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	29	72	0.2%
Disturbed/Successional - Grass/Forb Regeneration	399	986	3.1%
Disturbed/Successional - Shrub Regeneration	4,912	12,133	37.9%
Evergreen Plantation or Managed Pine	9,575	23,650	73.9%
Harvested Forest - Grass/Forb Regeneration	37	91	0.3%
Harvested Forest-Shrub Regeneration	205	506	1.6%

Enviva Ahoskie Table 6a. GAP ecosystem overlay for softwood biomass sourcing without FNP screen and HAO_2

Enviva Ahoskie Table 6b. GAP ecosystem overlay for softwood biomass sourcing without forest protection (FNP screen) and moderate biomass removal intensity (HAO_6)

GAP Ecosystem	Hectares	Acres	Sourcing %
Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	1,577	3,895	3.1%
Southern Atlantic Coastal Plain Mesic Hardwood Forest	8,167	20,172	16.2%
West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	36	89	0.1%
Disturbed/Successional - Grass/Forb Regeneration	1,120	2,766	2.2%
Disturbed/Successional - Shrub Regeneration	12,465	30,789	24.8%
Evergreen Plantation or Managed Pine	26,369	65,131	52.4%
Harvested Forest - Grass/Forb Regeneration	56	138	0.1%
Harvested Forest-Shrub Regeneration	489	1,208	1.0%

Enviva Ahoskie Table 6b. GAP ecosystem overlay for softwood biomass sourcing without FNP screen and HAO_6

Enviva Ahoskie Table 6c. GAP ecosystem overlay for softwood biomass sourcing without forest protection (FNP screen) and low biomass removal intensity (HAO_10)

GAP Ecosystem	Hectares	Acres	Sourcing %
Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	2,532	6,254	2.9%
Southern Atlantic Coastal Plain Mesic Hardwood Forest	13,151	32,483	15.3%
West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	86	212	0.1%
Disturbed/Successional - Grass/Forb Regeneration	2,506	6,190	2.9%
Disturbed/Successional - Shrub Regeneration	19,333	47,753	22.5%
Evergreen Plantation or Managed Pine	47,105	116,349	54.8%
Harvested Forest - Grass/Forb Regeneration	116	287	0.1%
Harvested Forest-Shrub Regeneration	1,124	2,776	1.3%

Enviva Ahoskie Table 6c. GAP ecosystem overlay for softwood biomass sourcing without FNP screen and HAO_10

Enviva Ahoskie Table 7a. GAP species distribution overlay comparison for sourcing from hardwood forests that include wetlands (HDW screen) versus sourcing only from upland hardwood forests (HNW screen) with high biomass removal intensity (HAO_2)					
Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with HDW screen (% of woodshed habitat)	Hectares of habitat overlay with HNW screen (% of woodshed habitat)	Hectares of Increased habitat overlay with HDW	% Increase in habitat overlay with HDW
Brown-headed Nuthatch	271,892	1,463 (0.5%)	4,682 (1.7%)	-3,219	-68.8%
Northern Bobwhite	1,312,813	21,806 (1.6%)	33,749 (2.6%)	-12,663	-37.5%
Swainson's Warbler	110,129	7,223 (6.6%)	882 (0.8%)	6,341	718.9%
Prothonotary Warbler	272,148	39,576 (14.5%)	7,116 (2.6%)	32,460	456.2%
Long-tailed Weasel	1,426,954	68,632 (4.8%)	83,810 (5.9%)	-15,178	-18.1%
Northern Cricket Frog	40,108	1,087 (2.7%)	1,064 (2.7%)	23	2.2%
Timber Rattlesnake	390,334	33,223 (8.5%)	34,607 (8.9%)	-1,384	-4.0%

Enviva Ahoskie Table 7a. GAP species distribution overlay comparison for sourcing from hardwood forests that include HDW screen versus sourcing only from HNW screen with HAO_2

Enviva Ahoskie Table 7b. GAP species distribution overlay comparison for sourcing from hardwood forests that include wetlands (HDW screen) versus sourcing only from upland hardwood forests (HNW screen) with moderate biomass removal intensity (HAO_6)					
Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with HDW screen (% of woodshed habitat)	Hectares of habitat overlay with HNW screen (% of woodshed habitat)	Hectares of Increased habitat overlay with HDW	% Increase in habitat overlay with HDW
Brown-headed Nuthatch	271,892	11,139 (4.1%)	33,152 (12.2%)	-22,013	-66.4%
Northern Bobwhite	1,312,813	69,511 (5.3%)	101,213 (7.7%)	-31,702	-31.3%
Swainson's Warbler	110,129	11,301 (10.3%)	4,723 (4.3%)	6,578	139.3%
Prothonotary Warbler	272,148	101,333 (37.2%)	13,925 (5.1%)	87,408	627.7%
Long-tailed Weasel	1,426,954	207,633 (14.6%)	244,034 (17.1%)	-36,401	-14.9%
Northern Cricket Frog	40,108	3,533 (8.8%)	3,453 (8.6%)	80	2.3%
Timber Rattlesnake	390,334	76,383 (19.6%)	64,362 (16.5%)	12,021	18.7%

Enviva Ahoskie Table 7b. GAP species distribution overlay comparison for sourcing from hardwood forests that include HDW screen versus sourcing only from HNW screen with HAO_6

VII. CASE STUDY OF PIEDMONT GREEN POWER

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Facility description

Piedmont Green Power is a 60.5 MW electric generating unit located near Barnesville, Georgia. This facility entered into service in early 2013, and is sourced by pine stemwood, logging residues, and woody debris from land clearing. An approximate wood demand of 384,000 dry Mg/year of biomass is required meet the facility's power output. Assuming a baseline condition of moderately managed plantation pine replanted on cutover forestry lands in the Georgia Piedmont province (Yin and Sedjo 2001), we estimated annual average productivity for woody biomass at 8 dry Mg/ha. Based on these sourcing demands and productivity values, a minimum sourcing area (HAO_1) of 48,000 hectares was applied for this facility.

GAP land cover summary

The 75-mile road network sourcing area (Piedmont Green Power Map 1) provides a

Figure 43. Piedmont Plantation Pine, Photo Credit: Robinson Schelhas

total land cover base of approximately 3.22 million hectares. Plantation pine forestry is the single largest land cover type within the woodshed, accounting for over 546,000 hectares or approximately 16.9% of the total woodshed area. About 345,000 additional hectares, or 10.8% of the woodshed, is classified as deciduous plantation, recently harvested or in a ruderal disturbed/successional state. Taken together, the existing plantation pine and disturbed forestry lands account for a little over 27.7% of the Piedmont Green Power woodshed.

Although the Piedmont Green Power facility is located in the Piedmont province, the southern reaches of the woodshed includes significant areas of the Coastal Plain and the transitional Fall Line (i.e., border region between the Piedmont and Coastal Plain) provinces. Due to this geologic diversity, the woodshed of this facility contains the largest number of distinct upland and wetland native forest types (a total of 29 detailed forest types according to the GAP land cover classifications listed in Piedmont Green Power Table 1) among the facilities considered in this study.

The most common native forest type in the Piedmont Green Power woodshed is the Southern Piedmont Dry Oak (Pine) Forest. This forest class is characterized by a diverse association of hardwoods such as white oak (*Quercus alba*), southern red oak (*Quercus falcata*), post oak (*Quercus stellata*), black oak (*Quercus vellutina*), sourwood (*Oxydendrum arboreum*), tulip poplar (*Liriodendron tulipifera*), pignut hickory (*Carya glabra*), dogwood (*Cornus florida*), redbud (*Cercis candensis*), and southern sugar maple (*Acer floridanum*) mixed with shortleaf (*Pinus echninata)* and loblolly (Pinus taeda) pines (see, e.g., White and Lloyd 1998). Including both the Hardwood, Loblolly Pine, and Mixed Modifier classes of this forest type, total areal coverage in the Piedmont Green Power woodshed is over 663,000 hectares

Figure 44. Southern Piedmont Dry Oak, Photo Credit: Robinson Schelhas

according to the GAP land cover dataset. The Southern Piedmont Mesic Forest, a hardwood-dominated community which occurs on wetter sloped sites, accounts for over 106,000 additional hectares. Major tree species within the Piedmont Mesic Forest associations generally include swamp chestnut oak (*Quercus michauxii*), bitternut hickory (*Carya cordiformis*), American beech (*Fagus grandifolia*), tulip poplar, white oak, red oak, black walnut (*Juglans nigra*), southern sugar maple, and slippery elm (*Ulmus ubra*). Altogether, upland hardwood and mixed forests in the Piedmont province account for over 769,000 hectares, or 23.9% of the Piedmont Green Power woodshed.

The Fall Line and Coastal Plain portions of the woodshed, by contrast, contain a wide diversity of upland pine forests, including several types of longleaf pine (*Pinus palustris*) associated woodlands. These native pine forests altogether account for over 319,000 hectares, or 9.9% of the woodshed. An additional 81,000 additional hectares, or 2.5% of the woodshed, is characterized as various upland coastal plain hardwood ecosystems. Total area of native upland forested ecosystems across the woodshed, regardless of geologic province, amounts to over 1.17 million hectares (~36.3%). Over 173,000 additional hectares (5.4%) of the woodshed is classified as a type of native forested swamp, including isolated wetland and floodplain ecosystems across the Piedmont and Coastal Plain.

Pasture/Hay is the largest agricultural land cover, and occupies about 11.4% of the woodshed area. More intensively managed Cultivated Croplands account for an additional 3.9% of the woodshed, thus placing approximately 15.3% of the woodshed in some form of agricultural usage. Another 13.7% of the woodshed is classified as developed, with most of this development concentrated in sections of the northern woodshed that are contained within the outskirts of the greater Atlanta metropolitan area. Most of the remaining area is accounted for by open water (~1.4%).

Public lands databases that include federal landholdings and Georgia state conservation indicate that 5.5% of the woodshed is under some form of conservation protection. Notable federal landholdings and conservation areas include Piedmont National Wildlife Refuge, Oconee National Forest, Bond Swamp National Wildlife Refuge, and Fort Benning. The state of Georgia also owns and maintains a number of state parks and wildlife management areas in the woodshed.

Piedmont Green Power Table 1 provides a complete summary of ecosystem area coverage in the 75-mile sourcing area for the Piedmont Green Power facility, along with associated areas and percentages identified as either being under public ownership or other forms of conservation protection. Piedmont Green Power Map 2 provides a visualization of GAP land cover generalized to the macro ecosystem level, as well as outlines of major conservation lands located in the woodshed.

Woodshed competition

The competition overlay and network analysis for the Piedmont Green Power facility identified a total of eight other facilities that may be expected to compete for woody biomass within at least some portion of the 75-mile woodshed area (Piedmont Green Power Map 3). This includes six pulp and paper mills, one bio-pellet facility, and one bio-power facility active as of April 2013. However, several of the large paper mills (i.e., International Paper, Augusta; August

Newsprint; and Inland Paperboard & Packaging) and the Lumber City pellet facility show only marginal woodshed overlap, and thus may be expected to exert relatively little influence on the sourcing practices of Piedmont Green Power. As represented in Piedmont Green Power Map 4, the most intense demand competition from the pulp and paper industry is associated with the Graphic Packaging, Weyerhaueser (Oglethorpe), and MeadWestvaco (Cottonton, AL) facilities. Notably, these large biomass competitors are all located to the south of the Piedmont Green Power facility, and thus exert most competitive pressure on forestry lands throughout the Coastal Plain and Fall Line portions of the woodshed. By contrast, competitive pressure is relatively light throughout the northern portions of the woodshed. The geography of this competitive pressure suggests that primary sourcing areas for the Piedmont Green Power facility will indeed be located in the Piedmont province.

Plantation pine forestry distribution and suitability

A visualization of the Maxent suitability model for plantation pine forestry distribution in the Piedmont Green Power woodshed is shown in Piedmont Green Power Map 5. Soil type provided the strongest contribution to the Maxent model (36.5%). Road distance (28.8%) and slope (27.6%) also provided major contributions to the model, with elevation providing the remaining contribution (7.1%).

Biomass sourcing models and associated ecosystem risks

The full series of biomass sourcing screen results for the Georgia Biomass facility are presented in Piedmont Green Power Maps 6-10. The HAO for each model run and associated suitability classes associated with the color-coding are provided in Piedmont Green Power Table 2. A clear feature of these visualizations is that competitive demand pressure from the southern and southeastern woodshed effectively pushes the sourcing model northward. Model runs for the most restrictive screen of plantation only (PO) found sufficient area in this land cover to source the HAO_10 (low risk) scenario (Piedmont Green Power Map 6), suggesting that this facility could theoretically be sourced through a residuals-only policy on extant plantation forestry. Results from the less restrictive PNP model (Piedmont Green Power Map 7) further suggest that there currently is a large resource base of plantation and disturbed forestry lands available to supply the Piedmont Green Power facility without primary sourcing and/or conversion of natural forests for bioenergy supply purposes.

The worst case screen from a forest biodiversity conservation standpoint for the Piedmont Green Power facility is “Forest No Pasture” (FNP). This screen assumes that sourcing and conversion of upland forests may occur with no restriction and that no existing pastures will serve as a potential donor land cover. A spatial visualization of the predicted risks to upland forest ecosystems under FNP is provided by Piedmont Green Power Map 11. Total land cover areas that fall within the HAO_2 (High Risk), HAO_6 (Moderate Risk), and HAO_10 (Low Risk) scenarios for this screen are summarized in Piedmont Green Power Tables 3a-3c.

Under all risk scenarios, sourcing models under the FNP screen consistently predicted approximately 50% of the land area being sourced from natural forest stands, with the other 50% being sourced from plantation and disturbed forestry land covers. Notably, overlay analyses for all risk scenarios not showed no sourcing from natural stands of coastal plain forest types, a result that clearly was influenced by the assumption of high competition pressure from paper mills in the southern woodshed. Instead, the FNP sourcing screen indicated that dry and mesic Piedmont forests could be most highly affected by biomass procurement for the Piedmont Green Power facility under an assumption of no protection for natural forest stands. Although much of the existing plantation pine forestry in the piedmont province was initially established on abandoned agricultural land, conversion of secondary hardwood stands into plantation pine has occurred with some frequency in the piedmont over the past several decades (Allen et al. 1996). For this reason, the high contribution of sourcing area provided by natural forest stands under an assumption of no protection is worthy of concern.

NatureServe analysis of G1-G3 ecological associations

NatureServe analyses found no known occurrences of G1 (critically imperiled), G2 (imperiled), or G3 (vulnerable) ecological associations within the Piedmont Green Power woodshed. This result is believed to be an artifact of very limited ecological association mapping in Georgia, and does not indicate that G1-G3 associations are not present in this woodshed. Because of the paucity of available data, detailed identification and protection of G1-G3 ecological associations can be recommended as a near-term need for ensuring that biodiversity conservation can be implemented as part of sustainable biomass energy procurement practices in this woodshed.

Indicator species analysis

Piedmont Green Power Tables 4a-4c provide a summary comparison of indicator species habitat areas that overlay the high harvest risk (HAO_2) results for both the FNP and PNP sourcing screens. Although there clearly are important differences between natural forest stands in the piedmont and coastal plain, behavioral and population responses of several indicator species to plantation pine conversion and/or hardwood logging pressure in the Piedmont Green Power facility may be generally similar to those discussed previously for the Georgia Biomass and Enviva Ahoskie facilities. With the notable exception of the northern bobwhite, affected areas of the GAP habitat distribution for all indicator species are larger under the FNP screen for all considered indicator species in the high risk/primary sourcing scenarios (Piedmont Green Power Table 4a). However, increased habitat risk under the PNP screen is shown for the long-tailed weasel, northern cricket frog, and northern bobwhite under the low risk/residuals sourcing scenario (Piedmont Green Power Table 4c). This latter result for the long-tailed weasel and northern cricket frog is generally a function of the PNP screen sourcing into more southern areas of the woodshed that have higher upland connectivity to coastal plain wetlands.

The Swainson's warbler is the species that shows the highest relative woodshed risk and percentage increase in habitat risk under the FNP screen for the Piedmont Green Power facility. These results reflect the generally low occupancy of the Swainson's warbler in plantation pine forestry, and the bird's preference for riparian and upland hardwood forests. While utilization of plantation pine forestry by Swainson's warblers is known in the SE U.S., (Bassett-Touchell and Stouffer 2006), conversion and fragmentation of upland hardwood stands to plantation pine forestry can be expected to have negative impacts on the occupancy rates and local abundance of this species (Hunter et al. 1994) in the Piedmont Green Power woodshed.

The brown-headed nuthatch shows relatively low habitat overlay risk under both the FNP and PNP screens for the Piedmont Green Power woodshed (i.e., lower percentage of predicted impact than all species except the gopher frog). However, relative habitat overlay risk is substantially higher for the FNP screen under all scenarios, which generally reflects the species showing preferential utilization of mixed hardwood and pine sites that have open understories, and less utilization of dense plantation pine, in the piedmont. This preference can likely be attributed to higher pine snag density in these mixed forests as compared to plantation pine (McComb et al. 1986; Land et al. 1989). However, commercial thinning practices that reduce pine canopy, suppress understory hardwoods, and increase herbaceous/shrubby groundcover may potentially result in rapid increases of brown-headed nuthatch utilization at the site scale (Wilson and Watts 1999). On existing pine plantations, bioenergy sourcing practices that promote mid-rotation thinnings, while also retaining some snag matter, may have the potential to provide some benefit to local brown-headed nuthatch populations in the Piedmont Green Power woodshed.

The northern bobwhite shows a consistent pattern of higher overlay risk with the PNP screen for the Piedmont Green Power scenario runs. This result is consistent with work suggesting that northern bobwhite quail populations can be relatively resilient to natural stand conversion into plantation pine (Felix et al. 1986; Dixon et al. 1996), and more generally reflects the northern bobwhite's high utilization of early successional and disturbed areas (Blank 2013; Janke and Gates 2013) that form a large portion of the PNP land cover base in this woodshed. Similar to the previous discussion of northern bobwhite for the Georgia Biomass facility, population responses to bioenergy procurement from the forestry landscape will likely be dependent on edge dynamics between plantation pines, early successional natural forest stands, pasture/grasslands, and agricultural lands at a broader landscape scale (Seckinger et al. 2008). Because newer stand-establishment methods may be less conducive for northern bobwhites as compared to historic plantation pine forestry practices (Jones et al. 2010), there may be legitimate concern about negative responses of northern bobwhites to the afforestation of disturbed fields or other early successional ecosystems in the piedmont province. However, thinning regimes for biomass procurement combined with prescribed burning on plantation pine and other forestry lands may generally be expected to have habitat enhancement effects for the northern bobwhite (Burger 2001).

The Eastern spotted skunk consistently shows the second highest overall area in at-risk habitat for the FNP screen among the eight indicator species. Large declines of this species across its range, including in SE Georgia, are well-documented over the past several decades, although specific factors behind this decline have long been regarded as unclear (Gompper and Hackett 2005). Eastern spotted skunks have home ranges that require relatively large patches (~80 ha) of young pine and hardwood forest s with high structural complexity in both the canopy and understory layers (Lesmeister et al. 2013), all of which are typical of natural piedmont forest stands. For this reason, introduction of heavy understory control in intensive plantation pine forestry may be hypothesized as a potential source of additional degradation for Eastern spotted skunk habitat for the Piedmont Green Power woodshed, particularly in scenarios where natural forest stands are converted. For all these reasons, sourcing practices that prohibit conversion of natural forest stands are likely critical for maintenance of suitable Eastern spotted skunk habitat in the Piedmont Green Power woodshed. Increased afforestation of young stand age pine forests for bioenergy production along edges with pastures may have the potential to enhance habitat for the Eastern spotted skunk, particularly if coupled with increased connectivity to riparian corridors and large patches of contiguous upland hardwood.

The long-tailed weasel is the indicator species that shows the highest overall area of overlay impact under all scenarios, a result that reflects both its large home ranges and wide diversity of forest habitat utilization (Simms 1979). However, habitat overlay risk is only marginally higher (1.2 – 1.3%) for FNP as compared to PNP for the high and moderate risk scenarios, while habitat overlay risk is approximately 5% less for FNP under the low risk scenario. Although the long-tailed weasel has high behavioral sensitivity to fragmentation of the forest landscape through agricultural clearing (Gehring and Swihart 2004), specific impacts from conversion of natural forest stands into plantation pine conversion is not well-known for the SE U.S. Managed forests with high canopy cover are, however, likely to provide long-tailed weasels with connectivity between higher quality natural forest stand habitats (Simms 1979; Gehring and Swihart 2003). For example, the higher overlay risk for the PNP screen in the low risk scenario likely is associated with decreased pasture density and higher plantation forest density in the southern woodshed of Piedmont Green Power. This landscape configuration provides greater forest connectivity for long-tailed weasel habitat as compared to the woodshed's piedmont forests, which are more fragmented by pasture. Rotational management regimes that maintain or create dynamic connectivity corridors between higher stand age plantation pines and natural forest stands in the piedmont may therefore minimize, or perhaps even enhance, long-tailed weasel habitat in the Piedmont Green Power woodshed.

Although showing a GAP habitat distribution of over 68,000 hectares in the Piedmont Green Power woodshed, minimal habitat overlay was found for the FNP or PNP screens at any scenario intensity. This result is a function of the gopher frog distribution being limited to the southern coastal plain sections of the woodshed where our models generally predict little to no conversion risk for natural forest stands due to the sourcing demands of Piedmont Green Power.

Similar to the results for the long-tailed weasel, the northern cricket frog shows somewhat higher habitat distribution overlay for FNP under the high and moderate risk scenarios, but shows a somewhat higher distribution overlay for PNP under the low risk scenario. This result is generally explained by the GAP data set predicting heavier northern cricket frog utilization of harvested forest or disturbed/successional lands in the southern woodshed. Northern cricket frogs are generally known to prefer wetland edges that are free from tall vegetation (Beasley et al. 2005), suggesting that heavy edge afforestation around permanent wetlands could indeed have negative impacts on northern cricket frogs in the Piedmont Green Power woodshed. As noted in discussion of the Georgia Biomass facility, because declines in northern cricket frogs may be linked to contamination from herbicides such as atrazine (Reeder et al. 2005), common use of such herbicides for understory vegetation control in plantation pines (Bullock 2012) could be regarded as a major concern if wetland edges are converted into intensive forestry for bioenergy supply. Maintenance of herbaceous buffer areas around wetlands containing northern cricket frogs, and particularly minimizing or avoiding use of herbicide control of forestry near these buffers, may be recommended as an approach for increased conservation and protection of this species within this and other woodsheds. The highly localized habitat area predicted for this species, which amounts to approximately 3% of the total Piedmont Green Power woodshed area and includes many wetland areas unsuitable for plantation pine forestry, provides apparent opportunity for such an approach.

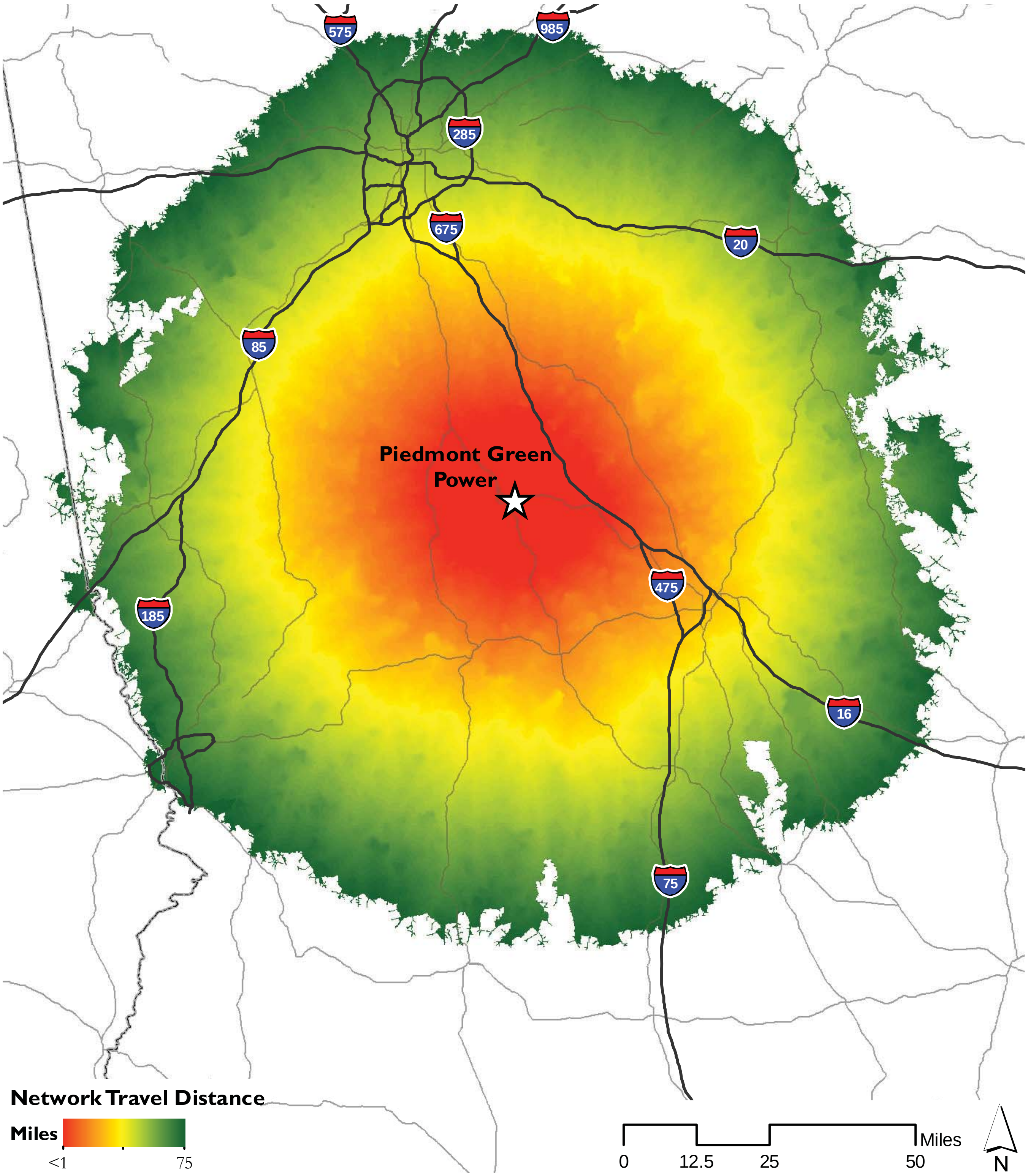
Results for the timber rattlesnake show that the FNP screen pose a very large relative (88.3 – 95.4%) increase in habitat overlay risk as compared to the PNP screen. Timber rattlesnakes are found in both natural and plantation pine stands, they show a very high preference for upland and mesic hardwood forests in the Piedmont Green Power woodshed. Similar to other woodsheds, conversion of such hardwood forests into plantation pine may be generally expected to reduce habitat values for the timber rattlesnake (Garst 2007), while also resulting in significant direct mortality when the poisonous snake is encountered by loggers and other site workers (Reinert et al. 2011). Sourcing practices that restrict against conversion of natural forests, and particularly hardwood forests, into plantation pine are likely to provide very high protective value for the timber rattlesnake. Because there is some evidence that timber rattlesnakes may readily utilize plantation pine and other edges contiguous to hardwood forests independently of the structural diversity in these edges (Anderson and Rosenberg 2011), management inside plantation forests may have little effect on the overall landscape quality of habitat for this species, provided that core forest habitat areas are maintained intact.

Discussion

The biomass sourcing models for Piedmont Green Power suggest that there is the potential for substantial effects on remaining native Piedmont forest types due to plantation conversion. Existing pressures on native Piedmont forests in Georgia over the past several decades, and prior to emergence of the bioenergy industry, include conversion to plantation forestry, agriculture and developed land covers (Hoover and Parker 1991; Allen et al. 1996). With the advent of an energy market for cleared forest material, a worst case scenario for wildlife habitat may be envisioned as additional incentive for more rapid clearing of native forests followed by full conversion into plantation pine or more intensive non-forestry land cover types (Zhang and Polyakov 2010). High urban development pressures in the metro-Atlanta region, which forms portions of the northern woodshed for the Piedmont Green Power facility, are especially notable. Increases in the rate of such land cover conversion can be expected to have further negative implications for wildlife species that are dependent on native upland Piedmont forests (Noss et al. 1995).

The Piedmont Green Power's relatively modest biomass demands, combined with the large baseline of existing plantation forestry in the woodshed, may provide opportunities for development of sourcing policies that may minimize – or even serve as a force for ameliorating – biodiversity impacts to native forests and wildlife. For example, results from the PNP scenarios suggest that sufficient biomass is readily available from the existing plantation and disturbed forest ecosystems to source the facility at a very low demand level of 0.8 Mg/ha/yr (HAO_10). Moreover, the sourcing model suggest that biomass demand at the HAO_10 level can be achieved through a sourcing area that remains generally constrained to the Piedmont province. In theory, the HAO_10 demand could be sourced solely through use of residual material. However, low competitive demand pressure suggests that the facility can in practice source large amounts and thinnings and pulpwood grade material from plantation forestry throughout much of its northern woodshed. The emergence of a market for thinnings from plantation forestry in this region of the Piedmont province could potentially benefit wildlife species, such as the northern bobwhite and wild turkey (*Meleagris gallopavo*), that are adapted to more open understory conditions (Miller et al. 2009; Verschuyl et al. 2011). Implementation of site-level thinning practices that provide co-management control of major invasive understory plant species could also further benefit the wildlife habitat and native plant biodiversity values of the plantation forestry landscape (Huebner 2006; Young et al. 2011). Increased market opportunities for woody biomass in this woodshed may arguably provide marginal reductions in leapfrog patterns of urban sprawl in the southern Atlanta metropolitan area, although such effects will require additional research to understand more fully.

Figure 45. Piedmont Green Power Map 1: 75-mile Network Travel Distance and Woodshed Delineation



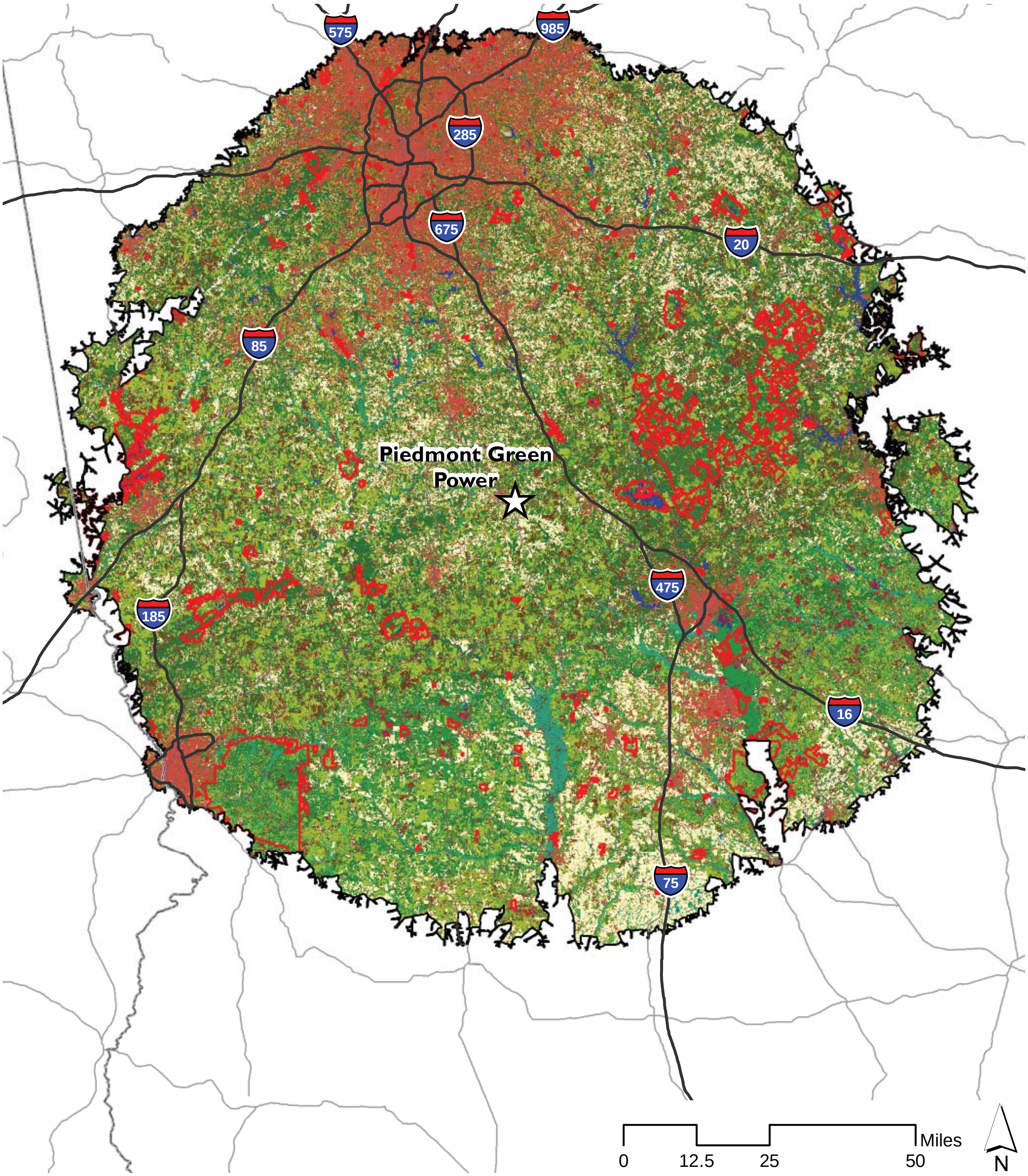
Piedmont Green Power Table 1. GAP Detailed Ecosystem Summary for 75-Mile Woodshed Area

GAP Ecosystem	Area	Protected	% Protected
Evergreen Plantation or Managed Pine	546,049	33,248	6.1%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	462,949	32,120	6.9%
Pasture/Hay	367,408	2,988	0.8%
Developed, Open Space	237,142	6,287	2.7%
Disturbed/Successional - Grass/Forb Regeneration	191,159	5,442	2.8%
Developed, Low Intensity	139,788	850	0.6%
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	131,246	13,573	10.3%
Cultivated Cropland	125,968	1,460	1.2%
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Open	106,440	12,582	11.8%
Southern Piedmont Mesic Forest	106,192	6,678	6.3%
Southern Piedmont Small Floodplain and Riparian Forest	92,999	5,783	6.2%
Disturbed/Successional - Shrub Regeneration	80,466	2,120	2.6%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	69,001	8,358	12.1%
Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	62,557	4,935	7.9%
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Offsite	52,888	5,397	10.2%
Atlantic Coastal Plain Fall-Line Sandhills Longleaf Pine Woodland - Loblolly	46,856	5,610	12.0%
Open Water (Fresh)	44,263	6,271	14.2%
Developed, Medium Intensity	41,516	131	0.3%
Harvested Forest-Shrub Regeneration	39,314	1,183	3.0%
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Offsite	39,244	2,656	6.8%
Atlantic Coastal Plain Upland Longleaf Pine Woodland	33,756	2,262	6.7%
Atlantic Coastal Plain Blackwater Stream Floodplain Forest - Forest Modifier	30,239	695	2.3%
Developed, High Intensity	24,018	20	0.1%
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Open	23,672	3,751	15.8%
East Gulf Coastal Plain Small Stream and River Floodplain Forest	18,155	3,115	17.2%
Deciduous Plantations	17,663	351	2.0%
Harvested Forest - Grass/Forb Regeneration	16,526	868	5.3%
Southern Atlantic Coastal Plain Mesic Hardwood Forest	15,014	1,067	7.1%
West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	12,036	3,175	26.4%
East Gulf Coastal Plain Large River Floodplain Forest - Forest Modifier	11,508	392	3.4%
Atlantic Coastal Plain Small Blackwater River Floodplain Forest	8,742	727	8.3%
Quarries, Mines, Gravel Pits and Oil Wells	3,982	9	0.2%
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Loblolly	3,781	150	4.0%
Southern Coastal Plain Nonriverine Cypress Dome	3,658	95	2.6%
Southern Coastal Plain Dry Upland Hardwood Forest	2,623	614	23.4%
Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest -	1,988	114	5.7%

Piedmont Green Power Table 1. GAP Detailed Ecosystem Summary for 75-Mile Woodshed Area

Piedmont Green Power Table 1. GAP Detailed Ecosystem Summary for 75-Mile Woodshed Area			
GAP Ecosystem	**Area**	**Protected**	**% Protected**
Southern Piedmont Large Floodplain Forest - Forest Modifier	1,866	329	17.6%
Southern Coastal Plain Hydric Hammock	1,859	235	12.6%
Southern Coastal Plain Blackwater River Floodplain Forest	1,598	0	0.0%
Southern Piedmont Granite Flatrock	1,256	166	13.2%
Southern Coastal Plain Nonriverine Basin Swamp	993	6	0.6%
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Scrub/Shrub	934	83	8.9%
Undifferentiated Barren Land	869	495	57.0%
Southern Ridge and Valley / Cumberland Dry Calcareous Forest	730	91	12.5%
Southern Coastal Plain Oak Dome and Hammock	489	0	0.0%
Unconsolidated Shore	267	30	11.2%
Atlantic Coastal Plain Xeric River Dune	234	110	47.0%

Figure 46. Piedmont Green Power Map 2: GAP Land Cover and Conservation Lands



Piedmont Green Power Map 2: Land Cover Characteristics Legend

Conservation Areas

GAP Ecosystem Class (NVC Macro)

Longleaf Pine & Sand Pine Woodland
Southeastern North American Ruderal Forest & Plantation
Eastern North American Ruderal Forest & Plantation
Southern-Central Oak-Hardwood & Pine Forest
Central Mesophytic Hardwood Forest
Northern & Eastern Pine - Oak Forest, Woodland & Barrens
Southern Floodplain Hardwood Forest
Southern Coastal Plain Basin Swamp
Wet Longleaf Pine & Southern Flatwoods
Eastern North American Coastal Grassland & Shrubland
Atlantic & Gulf Coastal Plain Bog & Fen
Atlantic & Gulf Coastal Plain Freshwater Tidal Marsh
Eastern North American Atlantic Salt Marsh
Barren
Herbaceous Agricultural Vegetation
Recently Disturbed or Modified
Open Water
Quarries, Mines, Gravel Pits and Oil Wells
Developed & Urban

Figure 47. Piedmont Green Power Map 3: Travel Network Analysis & Locations of Competing Bioenergy and Pulp Mill Facilities

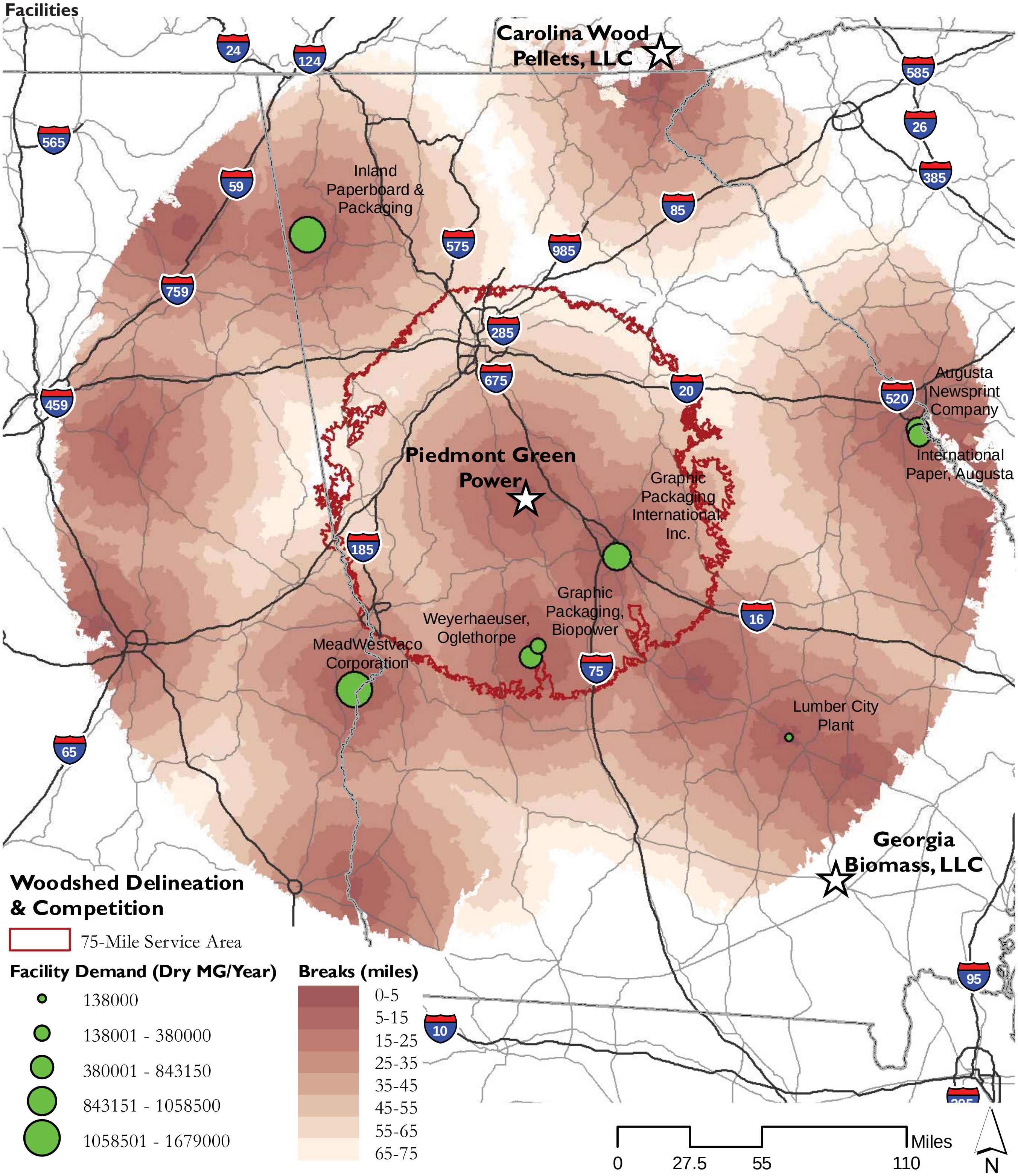


Figure 48. Piedmont Green Power Map 4 : Competition Demand Strength Analysis, as Annual dry Mg / Network Travel Mile

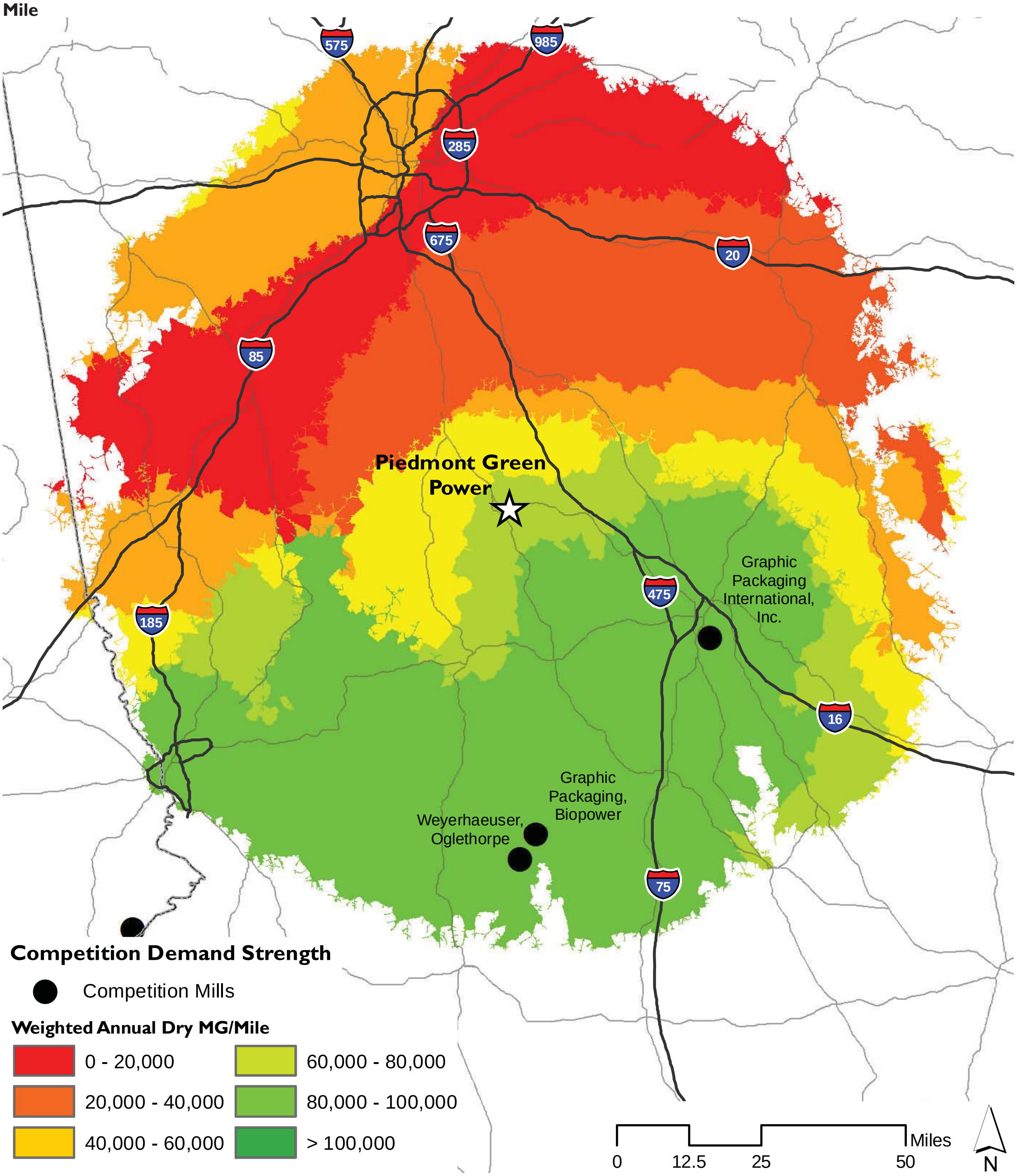


Figure 49. Piedmont Green Power Map 5: Maximum Entropy Suitability Model for Pine Plantation

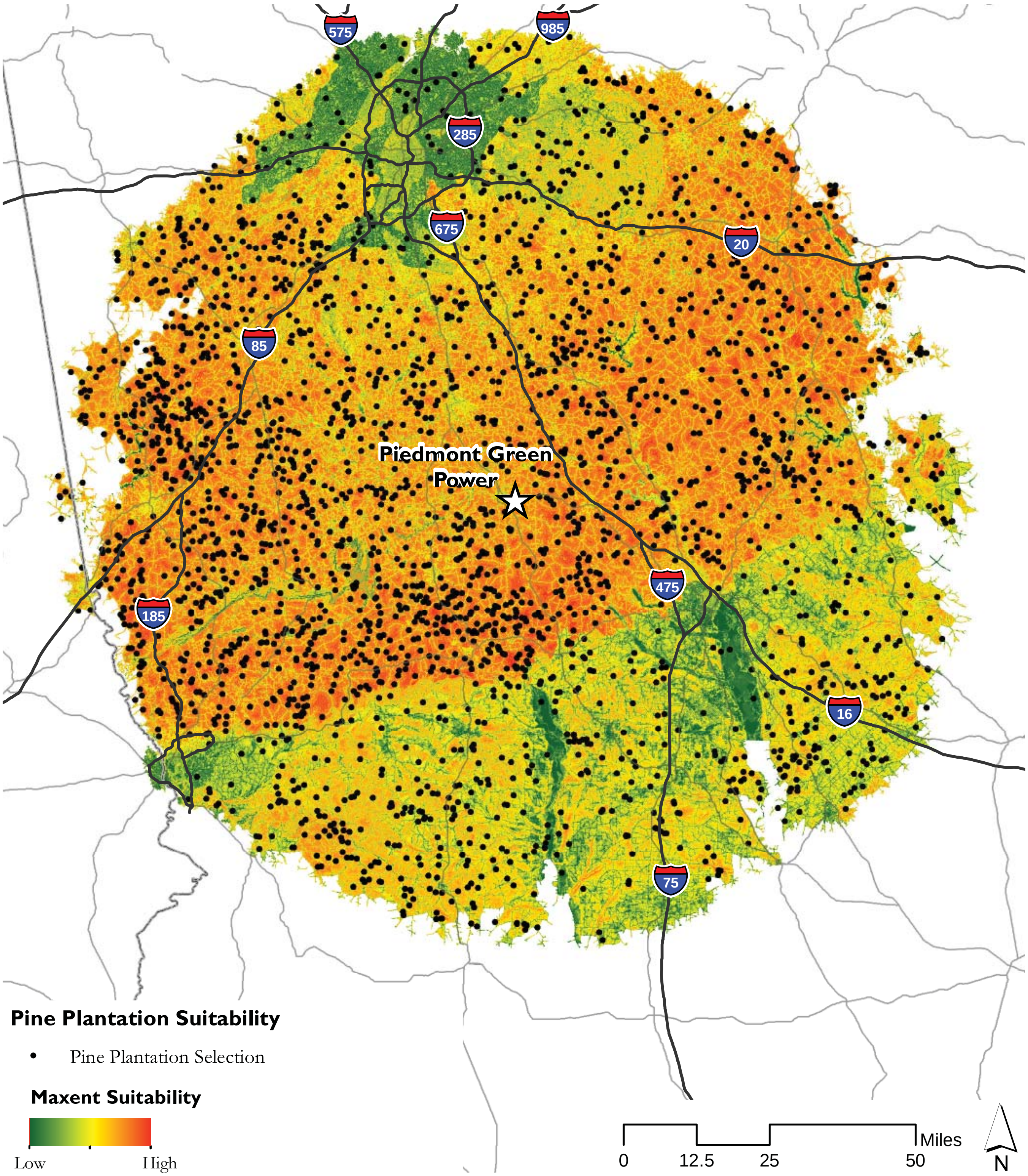


Figure 50. Piedmont Green Power Map 6: Composite Model of Pine Plantation Only (PO) Sourcing Model Screen

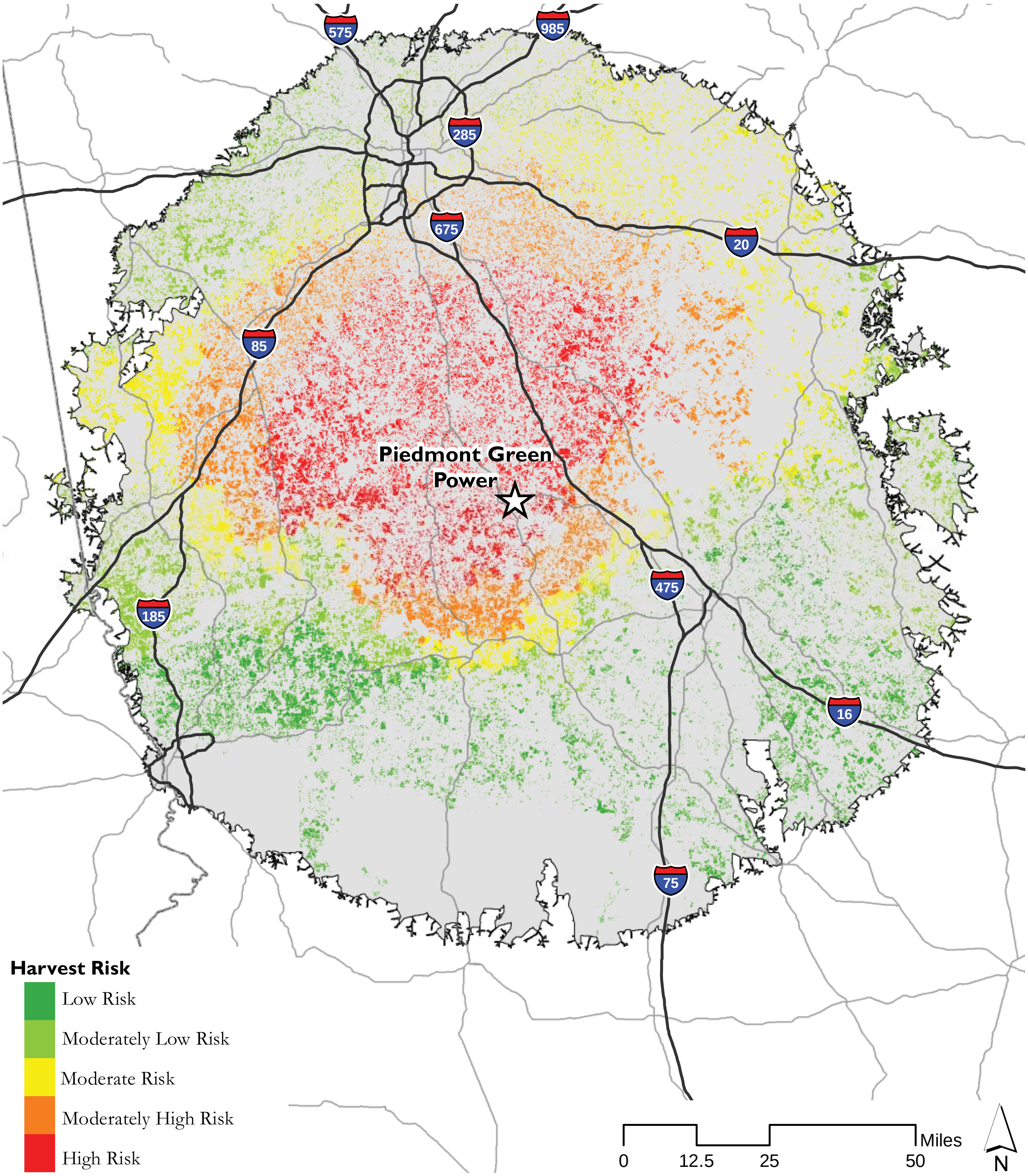


Figure 51. Piedmont Green Power Map 7: Composite Model of Pine & Disturbed, No Pasture (PNP) Sourcing Model Screen

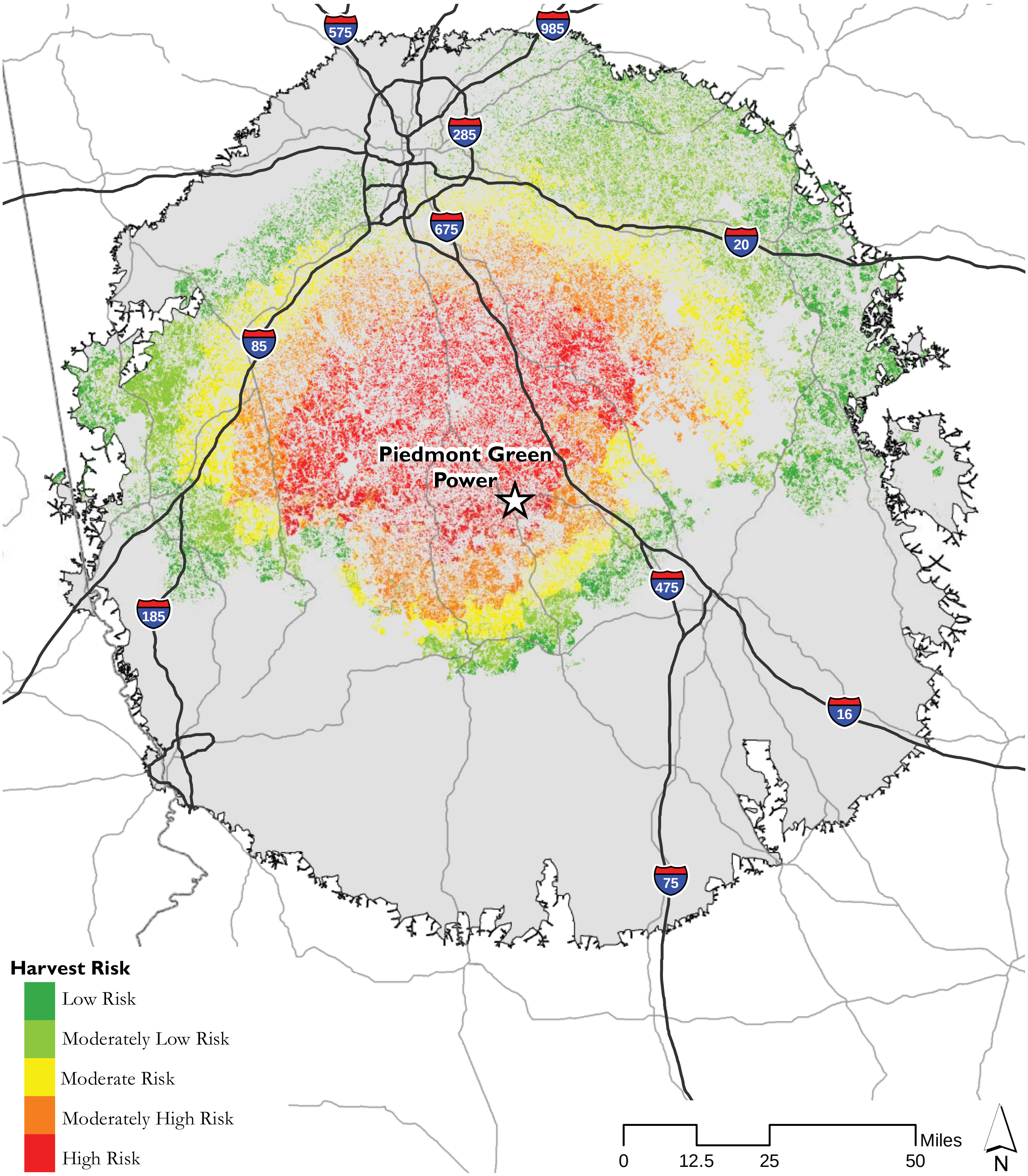


Figure 52. Piedmont Green Power Map 8: Composite Model of Pine, Disturbed & Pasture Risk Composite Sourcing Model Screen

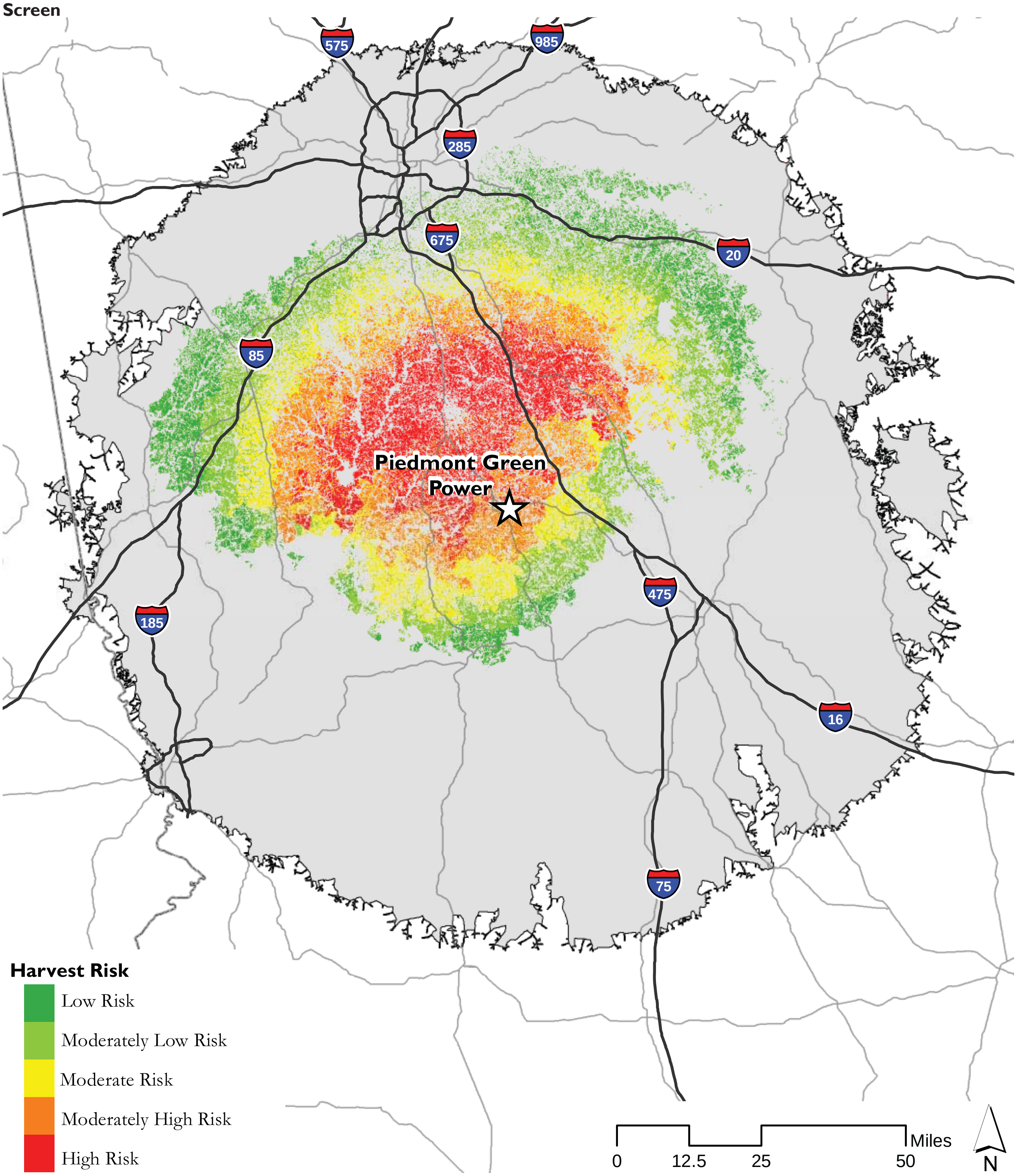


Figure 53. Piedmont Green Power Map 9: Composite Model of Upland Forest, No Pasture Risk Composite Sourcing Model Screen

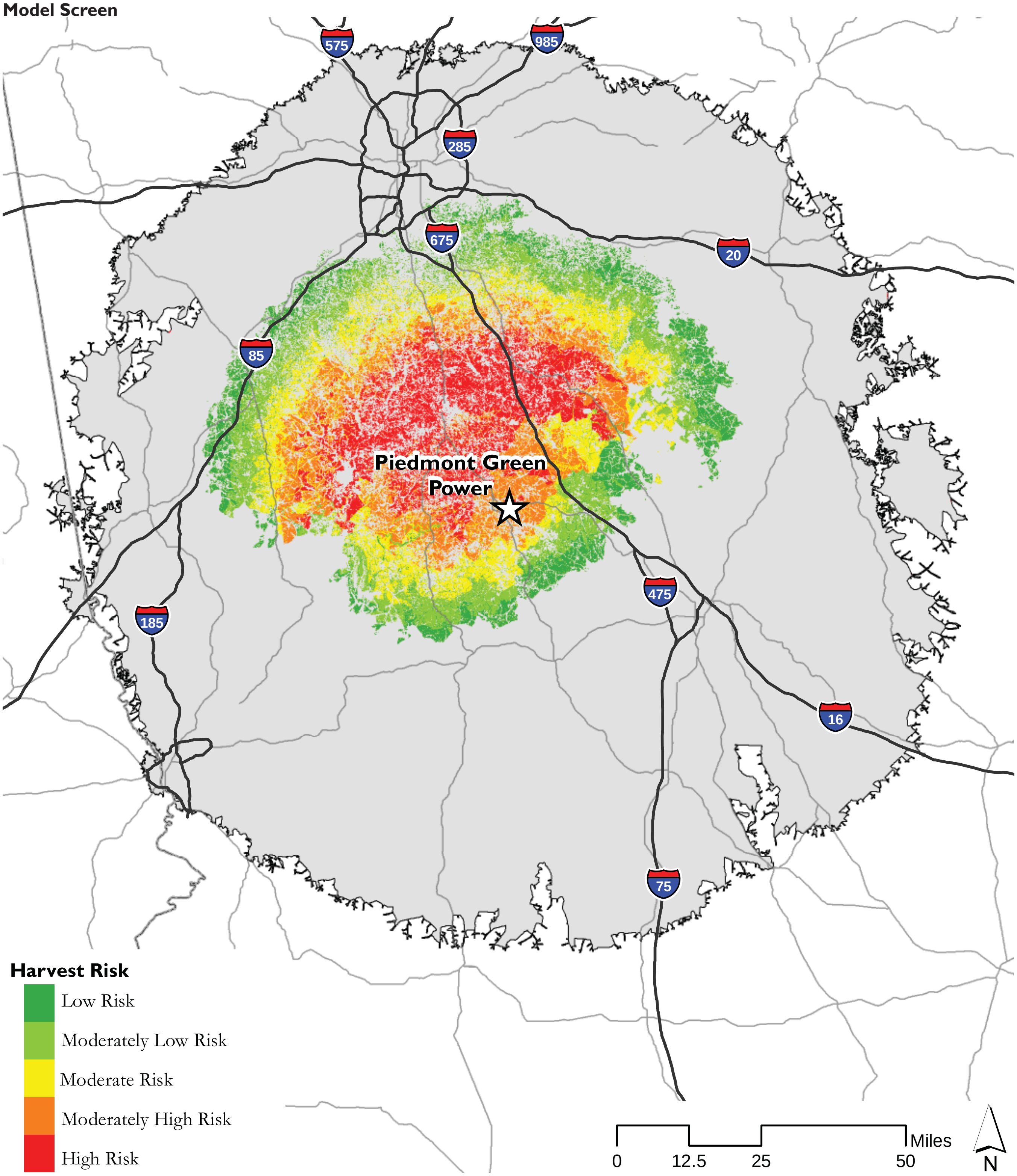


Figure 54. Piedmont Green Power Map 10: Composite Model of Upland Forest & Pasture Risk Composite Sourcing Model Screen

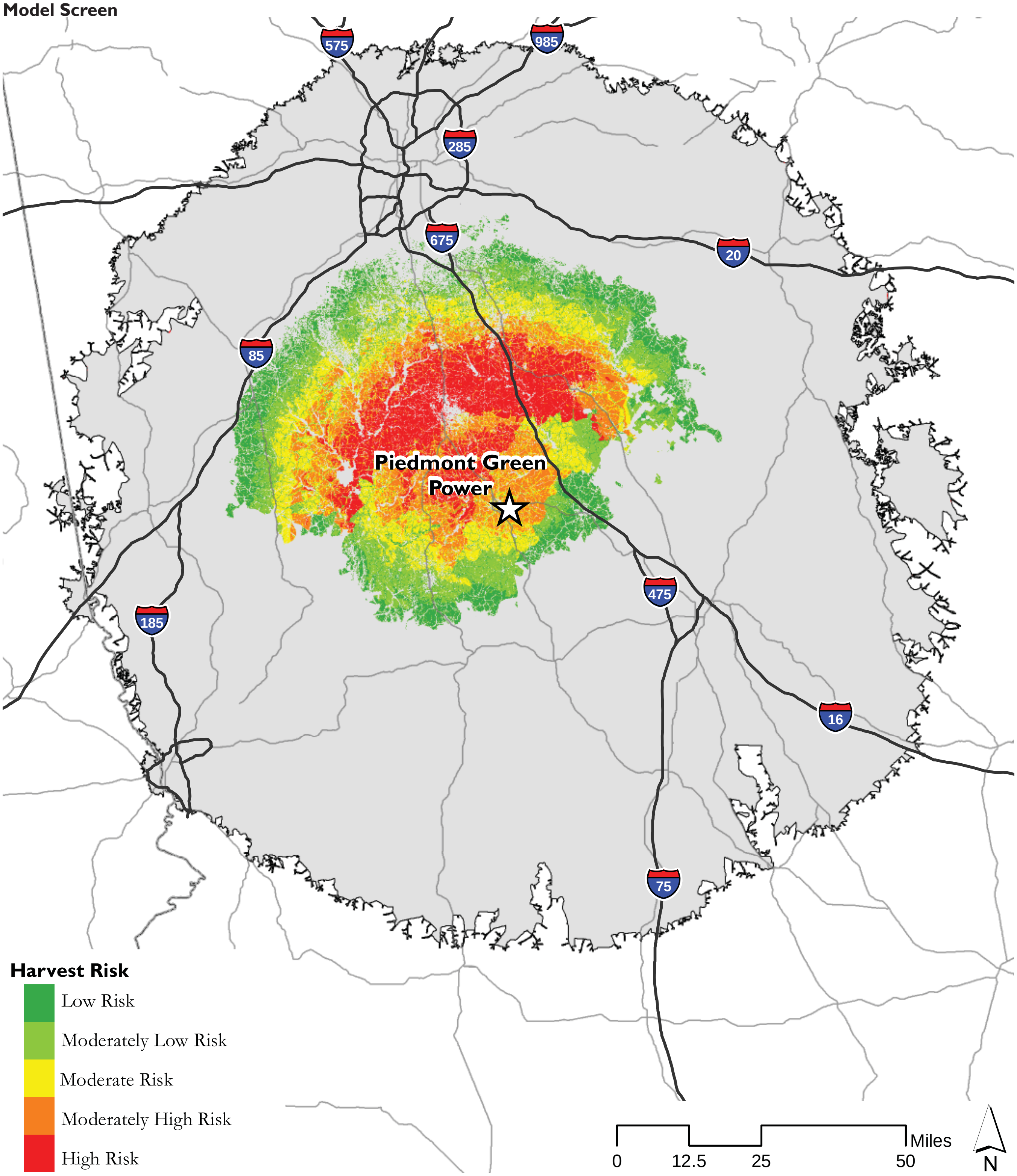
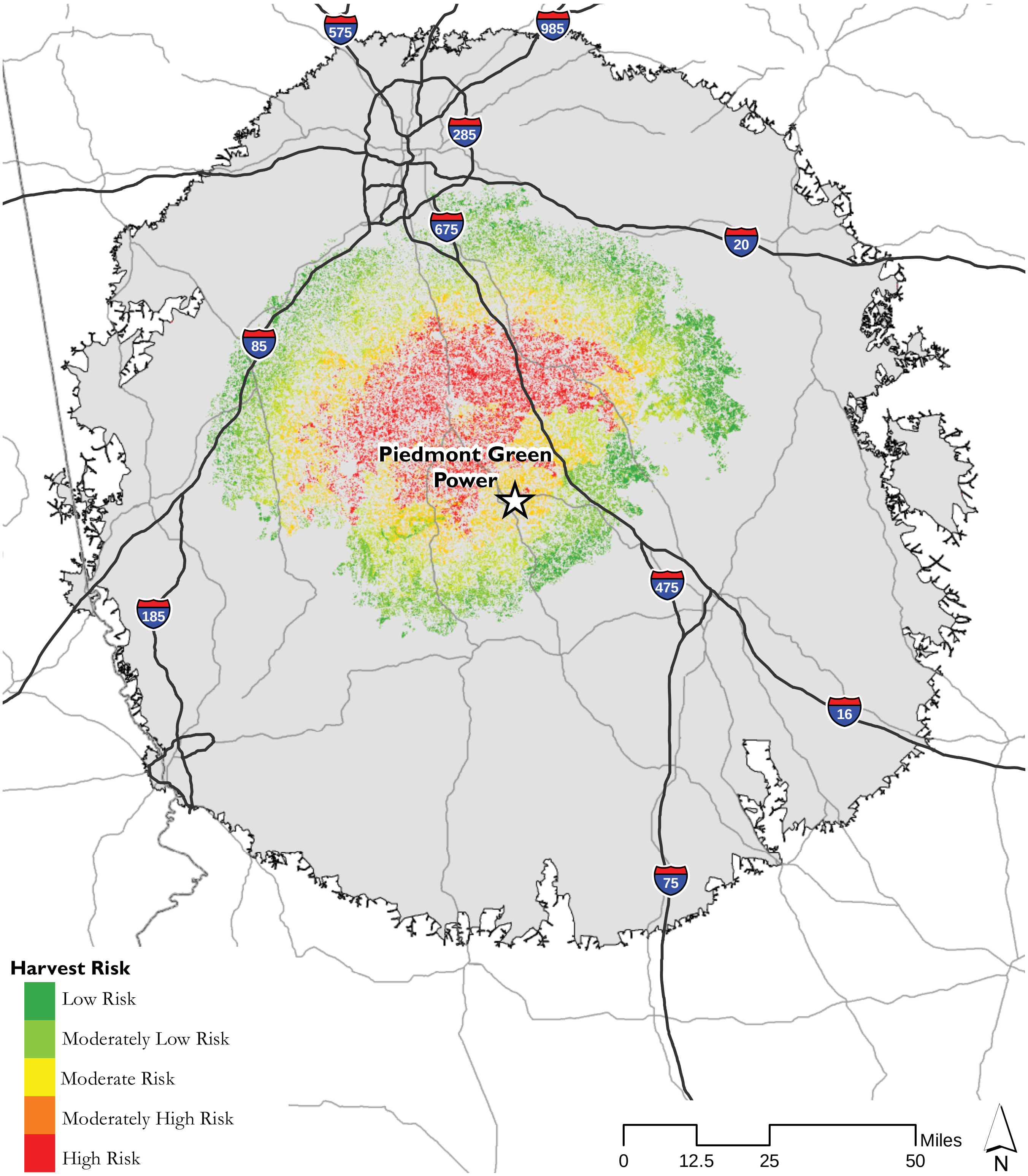


Figure 55. Piedmont Green Power Map 11: Composite Plantation Pine Conversion Risk for Natural Forest Stands



Piedmont Green Power Table 2.
Harvest area objectives (HAO) and associated risk classes for spatial modeling

HAO	Softwood (Ha)	Demand Intensity (Mg/ha/yr)	Harvest/ Conversion Risk Class
1	48,000	8.00	High
2	96,000	4.00	
3	144,000	2.67	Moderately High
4	192,000	2.00	
5	240,000	1.60	Moderate
6	288,000	1.33	
7	336,000	1.14	Moderately Low
8	384,000	1.00	
9	432,000	0.89	Low
10	480,000	0.80	

Piedmont Green Power Table 2. Harvest area objectives and associated risk classes for spatial modeling

Piedmont Green Power 3a. GAP ecosystem overlay for softwood biomass sourcing without forest protection (FNP screen) and high biomass removal intensity (HAO_2)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	30,088	74,317	31.4%
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	6,196	15,304	6.5%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	4,429	10,940	4.6%
Southern Piedmont Mesic Forest	7,787	19,234	8.1%
Disturbed/Successional - Grass/Forb Regeneration	8,880	21,934	9.2%
Disturbed/Successional - Shrub Regeneration	5,101	12,599	5.3%
Evergreen Plantation or Managed Pine	31,860	78,694	32.8%
Harvested Forest-Shrub Regeneration	1,574	3,888	1.6%

Piedmont Green Power Table 3a. GAP ecosystem overlay for softwood biomass sourcing without FNP screen and HAO_2

Piedmont Green Power Table 3b. GAP ecosystem overlay for softwood biomass sourcing without forest protection (FNP screen) and moderate biomass removal intensity (HAO_6)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	18898.00	46678.06	6.6%
Disturbed/Successional - Grass/Forb Regeneration	28846.00	71249.62	10.0%
Disturbed/Successional - Shrub Regeneration	14614.00	36096.58	5.1%
Evergreen Plantation or Managed Pine	96343.00	237967.21	33.5%
Harvested Forest-Shrub Regeneration	4649.00	11483.03	1.6%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	88928.00	219652.16	30.9%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	12708.00	31388.76	4.4%
Southern Piedmont Mesic Forest	22876.00	56503.72	7.9%

Piedmont Green Power Table 3b. GAP ecosystem overlay for softwood biomass sourcing without FNP screen and HAO_6

Piedmont Green Power Table 3c. GAP ecosystem overlay for softwood biomass sourcing without forest protection (FNP screen) and low biomass removal intensity (HAO_10)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	150,315	371,278	31.3%
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	34,064	84,138	7.1%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	21,926	54,157	4.6%
Southern Piedmont Mesic Forest	37,714	93,154	7.9%
Disturbed/Successional - Grass/Forb Regeneration	47,680	117,770	9.9%
Disturbed/Successional - Shrub Regeneration	22,329	55,153	4.7%
Evergreen Plantation or Managed Pine	157,261	388,435	32.8%
Harvested Forest-Shrub Regeneration	8,397	20,741	1.8%

Piedmont Green Power Table 3c. GAP ecosystem overlay for softwood biomass sourcing without FNP screen and HAO_10

Piedmont Green Power Table 4a. GAP species distribution overlay comparison for sourcing with no natural forest stand protection (FNP screen) versus sourcing only from plantation or disturbed forestry lands (PNP screen) with high biomass removal intensity (HAO_2)					
Species	**Total woodshed habitat, as hectares**	**Hectares of habitat overlay with FNP screen (% of woodshed habitat)**	**Hectares of habitat overlay with PNP screen (% of woodshed habitat)**	**Hectares of increased habitat overlay with FNP**	**% Increase in habitat overlay with FNP**
Brown-headed Nuthatch	676,585	10,112 (1.5%)	6,863 (1.0%)	3,249	47.3%
Northern Bobwhite	1,460,391	30,557 (2.1%)	35,804 (2.5%)	-5,247	-14.7%
Swainson's Warbler	342,414	12,679 (3.7%)	6,138 (1.8%)	6,541	106.6%
Eastern Spotted Skunk	1,498,360	45,482 (3.0%)	26,239 (1.8%)	19,243	73.3%
Long-tailed Weasel	1,788,493	59,622 (3.3%)	58,831 (3.3%)	791	1.3%
Northern Cricket Frog	103,197	2,574 (2.5%)	2,534 (2.5%)	40	1.6%
Gopher Frog	68,534	2 (0.0%)	0 (0.0%)	2	N/A
Timber Rattlesnake	1,358,639	44,575 (3.3%)	23,674 (1.7%)	20,901	88.3%

Piedmont Green Power Table 4a. GAP species distribution overlay comparison for sourcing with no FNP screen versus sourcing only from PNP screen with HAO_2

Piedmont Green Power Table 4b. GAP species distribution overlay comparison for sourcing with no natural forest stand protection (FNP screen) versus sourcing only from plantation or disturbed forestry lands (PNP screen) with moderate biomass removal intensity (HAO_6)					
Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with FNP screen (% of woodshed habitat)	Hectares of habitat overlay with PNP screen (% of woodshed habitat)	Hectares of increased habitat overlay with FNP	% Increase in habitat overlay with FNP
Brown-headed Nuthatch	676,585	32,814 (4.9%)	23,297 (3.4%)	9,517	40.9%
Northern Bobwhite	1,460,391	91,669 (6.3%)	106,975 (7.3%)	-15,307	-14.3%
Swainson's Warbler	342,414	41,920 (12.2%)	20,041 (5.9%)	21,879	109.2%
Eastern Spotted Skunk	1,498,360	132,139 (8.8%)	73,780 (4.9%)	58,359	79.1%
Long-tailed Weasel	1,788,493	171,870 (9.6%)	169,890 (9.5%)	1,980	1.2%
Northern Cricket Frog	103,197	7,545 (7.3%)	7,025 (6.8%)	520	7.4%
Gopher Frog	68,534	13 (0.0%)	0 (0.0%)	13	N/A
Timber Rattlesnake	1,358,639	129,792 (9.6%)	66,423 (4.9%)	63,369	95.4%

Piedmont Green Power Table 4b. GAP species distribution overlay comparison for sourcing with no FNP screen versus sourcing only from PNP screen with HAO_6

Piedmont Green Power Table 4c. GAP species distribution overlay comparison for sourcing with no natural forest stand protection (FNP screen) versus sourcing only from plantation or disturbed forestry lands (PNP screen) with low biomass removal intensity (HAO_10)					
Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with FNP screen (% of woodshed habitat)	Hectares of habitat overlay with PNP screen (% of woodshed habitat)	Hectares of increased habitat overlay with FNP	% Increase in habitat overlay with FNP
Brown-headed Nuthatch	676,585	60,398 (8.9%)	41,822 (6.2%)	18,576	44.4%
Northern Bobwhite	1,460,391	151,040 (10.3%)	188,251 (12.9%)	-37,211	-19.8%
Swainson's Warbler	342,414	78,334 (22.9%)	32,329 (9.4%)	46,005	142.3%
Eastern Spotted Skunk	1,498,360	220,279 (14.7%)	124,636 (8.3%)	95,643	76.7%
Long-tailed Weasel	1,788,493	276,471 (15.5%)	290,932 (16.3%)	-14,461	-5.0%
Northern Cricket Frog	103,197	11,873 (11.5%)	12,973 (12.6%)	-1,100	-8.5%
Gopher Frog	68,534	30 (0.0%)	0 (0.0%)	30	N/A
Timber Rattlesnake	1,358,639	216,679 (16.0%)	112,717 (8.3%)	103,962	92.2%

Piedmont Green Power Table 4c. GAP species distribution overlay comparison for sourcing with no FNP screen versus sourcing only from PNP screen with HAO_10

VIII. CASE STUDY OF SOUTH BOSTON ENERGY

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Facility description

The South Boston Energy facility is a 49.95 MW power facility scheduled to come online in 2013. Located in South Boston, VA, proposed feedstocks for this power facility include wood wastes, wood chips and slash. The estimated biomass requirement for this facility is approximately 344,000 dry Mg/yr.

Working from an initial assumption of waste material sourcing, we modeled the facility using a mixture of 50% softwood to 50% hardwood, which generally fits the long-term biomass productivity potential in the woodshed given existing land cover. A return interval of 25 years was applied for softwood sourcing, with piedmont pine plantation productivity estimated at 8 dry

Figure 56. Southern Piedmont Dry Oak, photo Credit: Robinson Schelhas

Mg/ha (Yin and Sedjo 2001). Piedmont hardwood forest productivity was modeled at 4 dry Mg/ha, which represents a high end of productivity over an assumed 50 year facility lifespan (Kline and Coleman 2010). Based on these productivity values and assumed sourcing requirements, a minimum area of 21,500 ha of plantation pine is required for softwood sourcing, while a minimum area of 43,000 ha in hardwood forest would be harvested over the assumed 50-year facility life cycle.

GAP land cover summary

The 75-mile road network sourcing area (South Boston Energy Map 1) provides a total land cover base of approximately 3.1 million hectares. Forest resources in this woodshed are extensive, with all native, plantation, and disturbed forest land covers accounting for over 2.1 million hectares, or 67.6% of the total woodshed area.

The most common land cover in the South Boston Energy woodshed is the Southern Piedmont Dry Oak (Pine) Forest. This forest class is characterized by a diverse association of hardwoods such as white oak (*Quercus alba*), southern red oak (*Quercus falcata*), post oak (*Quercus stellata*), black oak (*Quercus vellutina*), sourwood (*Oxydendrum arboreum*), tulip poplar (*Liriodendron tulipifera*), pignut hickory (*Carya glabra*), dogwood (*Cornus florida*), redbud (*Cercis candensis*), and southern sugar maple (*Acer floridanum*) mixed with shortleaf (*Pinus echninata)* pines (see, e.g., White and Lloyd 1998). Including the Hardwood, Loblolly Pine, and Mixed Modifier classes of this forest type, total areal coverage in the South Boston Energy woodshed is over 1.2 million hectares, or approximately 40.8% of the woodshed area. The Southern Piedmont Mesic Forest, a hardwood-dominated community which occurs on wetter sloped sites, accounts for over 116,000 additional hectares. Major tree species within the Piedmont Mesic Forest associations generally include swamp chestnut oak (*Quercus michauxii*), bitternut hickory (*Carya cordiformis*), American beech (*Fagus grandifolia*), tulip poplar, white oak, red oak, black walnut (*Juglans nigra*), southern sugar maple, and slippery elm (*Ulmus ubra*). Altogether, upland hardwood and mixed forests in the Piedmont province account for over 1.38 million hectares, or 44.5% of the South Boston Energy woodshed. Over 85,000 hectares of the woodshed are classified as riparian forested wetlands, and an additional 4,551 hectares are Appalachian upland hardwood forest types. Taking into account these forested wetland and mountain forests, total native forest cover amounts to over 47.4% of the South Boston Energy woodshed.

Plantation pine forestry is the third largest land cover type within the woodshed, accounting for over 371,000 hectares or approximately 12% of the total woodshed area. Much of this plantation pine is held in loblolly pine (*Pinus taeda*), which, while native to the SE U.S. region, likely was not a major component of native forests in this woodshed area (Felix et al. 1983). Over 257,000 additional hectares, or 8.3% of the woodshed, is classified as recently harvested or in a ruderal disturbed/successional state. Taken together, the existing plantation pine and disturbed forestry lands account for approximately 20.3% of the South Boston Energy woodshed.

Pasture/Hay is the largest agricultural land cover, and occupies approximately 19.1% of the woodshed area. More intensively managed Cultivated Croplands account for an additional 2.8% of the woodshed, bringing total agricultural land covers to over 656,000 hectares, or 21.9% of the woodshed area. Over 275,000 hectares (8.9%) of the woodshed are classified as developed, much of which is concentrated in areas of the southern woodshed that are contained within the outskirts of the greater Raleigh-Durham metropolitan area. Most of the remaining area is accounted for by open water (~1.8%).

Public lands databases that include federal landholdings and state conservation lands in Virginia and North Carolina indicate that 5.4% of the woodshed is under some form of conservation protection. However, significant portions of this public lands area are contained in two large U.S. Army Corps of Engineers reservoir projects: the John H. Kerr Reservoir and the B. Everett Jordan Dam and Lake. The largest public landholdings with major forest ecosystem coverage include the Fort Pickett Military Reservation (Virginia), Appomattox-Buckingham State Forest (Virginia), Camp Butner National Guard Training Center (North Carolina), and the William B. Umstead State Park.

South Boston Energy Table 1 provides a complete summary of ecosystem area coverage in the 75-mile sourcing area for the South Boston Energy facility, along with associated areas and percentages identified as either being under public ownership or other forms of conservation protection. South Boston Energy Map 2 provides a visualization of GAP land cover generalized to the macro ecosystem level, as well as outlines of major conservation lands located in the woodshed.

NatureServe analysis of G1-G3 ecological associations

South Boston Energy Table 2 lists sixteen ecological associations with G1 (critically imperiled), G2 (imperiled), or G3 (vulnerable) status that NatureServe analyses show as having at least one element occurrence within the South Boston Energy woodshed. Ten of these ecological associations are forest types that could potentially serve as a supply for woody biomass extraction or conversion. Avoidance of these and other G1-G3 ecological associations from biomass sourcing within the woodshed can be recommended as a minimum criterion for protecting and conserving biodiversity through sustainable forest management.

Woodshed competition

The competition overlay and network analysis for the South Boston Energy facility identified a total of seventeen other facilities that may be expected to compete for woody biomass within at least some portion of the 75-mile woodshed area (South Boston Energy Map 3). This includes nine pulp and paper mills, four bio-pellet facilities, and four bio-power facilities active as of April 2013. Competitive demand pressure is generally highest in the northern half of the woodshed, and is largely associated with sourcing overlap with the Pittsylvania and Altavista biomass energy power facilities (both of which are located inside the 75-mile sourcing area) and several large paper mill facilities (all of which are located outside of the 75-mile sourcing area. Competitive pressure is relatively light throughout areas near the South Boston Energy facility, and throughout much of the southern and southwestern woodshed areas.

Plantation pine forestry distribution and suitability

A visualization of the Maxent suitability model for plantation pine forestry distribution in the South Boston Energy woodshed is shown in South Boston Energy Map 5. Elevation provided the dominant contribution to the Maxent model (61%), with soils (19.8%), distance to road (10.6%) and slope (8.7%) providing progressively smaller contributions for predicting pine plantation forestry distribution in the South Boston Energy woodshed.

Biomass sourcing models and associated ecosystem risks

The harvest area objectives and associated suitability classes for all South Boston Energy sourcing models are provided in South Boston Energy Table 3.

Hardwood sourcing scenario results with no wetland restriction (HDW) are visualized in South Boston Energy Map 6, with land cover overlays for high, moderate, and low risk scenarios summarized in South Boston Energy Tables 4a-4c. Sourcing is predicted from three upland and two wetland hardwood forests, although with over 94% predicted from uplands for all risk scenarios. Given the very high sensitivity of piedmont streams to erosion and sedimentation from logging disturbance and the small relative contribution that wetland forests may contribute to biomass sourcing in this woodshed, riparian buffer restrictions may likely be employed with great water quality benefit and minimal impact on wood supply.

The HNW results, which restrict against wetland sourcing, for the South Boston Energy facility are visualized in South Boston Energy Map 7, with ecosystem overlays summarized in South Boston Energy Tables 5a-5c. These results indicate sourcing from three detailed ecosystem types, including the Southern Piedmont Dry Oak (Pine) Forest (Hardwood and Mixed Modifiers) and Southern Piedmont Mesic Forest types. Relative sourcing percentages are similar for all ecosystems. Because the South Boston Energy facility is projected to begin operations with a large residual harvest sourcing, it is notable that the "Low Risk" (HAO_10) scenario suggests eventual sourcing over approximately 1/3 of each upland forest ecosystem across the facility woodshed. Because this scenario approximates the harvest area impact from a residuals-only sourcing scenario from hardwood forests over the 50-year lifetime of the facility, long-term continuation of a large-scale residuals sourcing policy from the South Boston Energy facility likely would imply wildlife and forestry management impacts over a very extensive area of native upland piedmont forests in this woodshed.

South Boston Energy Maps 8-12 show the visualizations of all softwood sourcing screens. From the standpoint of softwood sourcing, the worst case screen from a forest biodiversity conservation standpoint for the South Boston Energy facility is FNP (South Boston Energy Map 11). This screen assumes that sourcing and conversion of upland forests to plantation forestry may occur with no restriction and that no existing pastures will serve as a potential donor land cover. Total land cover areas that fall within the HAO_2 (High Risk), HAO_6 (Moderate Risk), and HAO_10 (Low Risk) scenarios for this screen are summarized in South Boston Energy Tables 6a-6c.

The results for FNP screen suggests that the native forests with most significant relative risk for plantation conversion is the Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier. Some areas of other Southern Piedmont Dry Oak forest types and Southern Piedmont Mesic Forests also show conversion risk, but overall percentages at risk for these ecosystems are relatively small. Based on our modeling results, over 84% of the predicted land use base for direct softwood sourcing for the South Boston Energy facility would be provided by plantation forestry and other disturbed/

ruderal or barren land cover types under the FNP screen. A spatial visualization of the predicted risks to upland forest ecosystems under FNP is provided by South Boston Energy Map 13.

Indicator species analysis

South Boston Energy Tables 8a-8c provide a summary comparison of indicator species habitat areas that overlay the harvest risk scenario results for the HDW and HNW hardwood sourcing screens. Although the amount of riparian wetlands that are sourced under the HDW screen is relatively low (South Boston Energy Tables 4a-4c), significant increases in at-risk habitat are identified for the Swainson's warbler (8.1 – 48.4%), the northern cricket frog (13.7 – 37.7%), and the timber rattlesnake (13.5 – 37.7%) under the HDW scenario. For these and other species that heavily utilize riparian corridors, heavy wood-sourcing along highly erodible piedmont streams is likely to have high negative short-term and long-term habitat effects. Due to the very small amount of biomass sourcing that may be obtained from these areas relative the overall woodshed supply, maintenance of riparian corridors can be clearly recommended as a sustainable sourcing criteria for this woodshed.

Although there clearly are important differences between natural forest stands in the piedmont and coastal plain, behavioral and population responses of several indicator species to plantation pine conversion and/or hardwood logging pressure in the South Boston Energy facility may be generally similar to those discussed previously for the Georgia Biomass and Enviva Ahoskie facilities. With the notable exception of the northern bobwhite, affected areas of the GAP habitat distribution for all indicator species are larger under the FNP screen for all considered indicator species in the high risk/primary sourcing scenarios (South Boston Energy Table 8a). However, increased habitat risk under the PNP screen is shown for the long-tailed weasel, northern cricket frog, and northern bobwhite under the low risk/residuals sourcing scenario (South Boston Energy Table 8c). This latter result for the long-tailed weasel and northern cricket frog is generally a function of the PNP screen sourcing into more southern areas of the woodshed that have higher upland connectivity to coastal plain wetlands.

Among the chosen indicator species, the Swainson's warbler shows the highest relative woodshed risk and percentage increase in habitat risk under the FNP screen for the South Boston Energy facility. These results reflect the generally low occupancy of the Swainson's warbler in plantation pine forestry, and the bird's preference for riparian and upland hardwood forests. While utilization of plantation pine forestry by Swainson's warblers is known in the SE U.S., (Bassett-Touchell and Stouffer 2006), conversion and fragmentation of upland hardwood stands to plantation pine forestry can be expected to have negative impacts on the occupancy rates and local abundance of this species (Hunter et al. 1994) in the South Boston Energy woodshed.

The brown-headed nuthatch shows relatively low habitat overlay risk under both the FNP and PNP screens for the South Boston Energy woodshed (i.e., lower percentage of predicted impact than all species except the gopher frog). However, relative habitat overlay risk is substantially higher for the FNP screen under all scenarios, which generally reflects the species showing preferential utilization of mixed hardwood and pine sites that have open understories, and less utilization of dense plantation pine, in the piedmont. This preference can likely be attributed to higher pine snag density in these mixed forests as compared to plantation pine (McComb et al. 1986; Land et al. 1989). However, commercial thinning practices that reduce pine canopy, suppress understory hardwoods, and increase herbaceous/shrubby groundcover may potentially result in rapid increases of brown-headed nuthatch utilization at the site scale (Wilson and Watts 1999). On existing pine plantations, bioenergy sourcing practices that promote mid-rotation thinnings, while also retaining some snag matter, may have the potential to provide some benefit to local brown-headed nuthatch populations in the South Boston Energy woodshed.

The northern bobwhite shows a consistent pattern of higher overlay risk with the PNP screen for the South Boston Energy scenario runs. This result is consistent with work suggesting that northern bobwhite quail populations can be relatively resilient to natural stand conversion into plantation pine (Felix et al. 1986; Dixon et al. 1996), and more generally reflects the northern bobwhite's high utilization of early successional and disturbed areas (Blank 2013; Janke and Gates 2013) that form a large portion of the PNP land cover base in this woodshed. Similar to the previous discussion of northern bobwhite for the Georgia Biomass facility, population responses to bioenergy procurement from the forestry landscape will likely be dependent on edge dynamics between plantation pines, early successional natural forest stands, pasture/grasslands, and agricultural lands at a broader landscape scale (Seckinger et al. 2008). Because newer stand-establishment methods may be less conducive for northern bobwhites as compared to historic plantation pine forestry practices (Jones et al. 2010), there may be legitimate concern about negative responses of northern bobwhites to the afforestation of disturbed fields or other early successional ecosystems in the piedmont province.

The Eastern spotted skunk consistently shows the second highest overall area in at-risk habitat for the FNP screen among the eight indicator species. Large declines of this species across its range, including in SE Georgia, are well-documented over the past several decades, although specific factors behind this decline have long been regarded as unclear (Gompper and Hackett 2005). Eastern spotted skunks have home ranges that require relatively large patches (~80 ha) of young pine and hardwood forest s with high structural complexity in both the canopy and understory layers (Lesmeister et al. 2013), all of which are typical of natural piedmont forest stands. For this reason, introduction of heavy understory control in intensive plantation pine forestry may be hypothesized as a potential source of additional degradation for Eastern spotted skunk habitat for the South Boston Energy woodshed, particularly in scenarios where natural forest stands are converted. For all these reasons, sourcing practices that prohibit conversion of natural forest stands are likely critical for maintenance of suitable Eastern spotted skunk habitat in the South Boston Energy woodshed. Increased afforestation of young stand age pine forests for bioenergy production along edges with pastures may have the potential to enhance habitat for the Eastern spotted skunk, particularly if coupled with increased connectivity to riparian corridors and large patches of contiguous upland hardwood.

The long-tailed weasel is the indicator species that shows the highest overall area of overlay impact under all scenarios, a result that reflects both its large home ranges and wide diversity of forest habitat utilization (Simms 1979). However, habitat overlay risk is only marginally higher (1.2 – 1.3%) for FNP as compared to PNP for the high and moderate risk scenarios, while habitat overlay risk is approximately 5% less for FNP under the low risk scenario. Although the long-tailed weasel has high behavioral sensitivity to fragmentation of the forest landscape through agricultural clearing (Gehring and Swihart 2004), specific impacts from conversion of natural forest stands into plantation pine conversion is not well-known for the SE U.S. Managed forests with high canopy cover are, however, likely to provide long-tailed weasels with connectivity between higher quality natural forest stand habitats (Simms 1979; Gehring and Swihart 2003). For example, the higher overlay risk for the PNP screen in the low risk scenario likely is associated with decreased pasture density and higher plantation forest density in the southern woodshed of South Boston Energy. This landscape configuration provides greater forest connectivity for long-tailed weasel habitat as compared to the woodshed's piedmont forests, which are more fragmented by pasture. Rotational management regimes that maintain or create dynamic connectivity corridors between higher stand age plantation pines and natural forest stands in the piedmont may therefore minimize, or perhaps even enhance, long-tailed weasel habitat in the South Boston Energy woodshed.

Similar to the results for the long-tailed weasel, the northern cricket frog shows somewhat higher habitat distribution overlay for FNP under the high and moderate risk scenarios, but shows a somewhat higher distribution overlay for PNP under the low risk scenario. This result is generally explained by the GAP data set predicting heavier northern cricket frog utilization of harvested forest or disturbed/successional lands in the southern woodshed. Northern cricket frogs are generally known to prefer wetland edges that are free from tall vegetation (Beasley et al. 2005), suggesting that heavy edge afforestation around permanent wetlands could indeed have negative impacts on northern cricket frogs in the South Boston Energy woodshed. As noted in discussion of the Georgia Biomass facility, because declines in northern cricket frogs may be linked to contamination from herbicides such as atrazine (Reeder et al. 2005), common use of such herbicides for understory vegetation control in plantation pines (Bullock 2012) could be regarded as a major concern if wetland edges are converted into intensive forestry for bioenergy supply. Maintenance of herbaceous buffer areas around wetlands containing northern cricket frogs, and particularly minimizing or avoiding use of herbicide control of forestry near these buffers, may be recommended as an approach for increased conservation and protection of this species within this and other woodsheds. The highly localized habitat area predicted for this species, which amounts to approximately 3% of the total South Boston Energy woodshed area and includes many wetland areas unsuitable for plantation pine forestry, provides apparent opportunity for such an approach

Results for the timber rattlesnake show that the FNP screen pose a very large relative (88.3 – 95.4%) increase in habitat overlay risk as compared to the PNP screen. Timber rattlesnakes are found in both natural and plantation pine stands, they show a very high preference for upland and mesic hardwood forests in the South Boston Energy woodshed. Similar to other woodsheds, conversion of such hardwood forests into plantation pine may be generally expected to reduce habitat values for the timber rattlesnake (Garst 2007), while also resulting in significant direct mortality when the poisonous snake is encountered by loggers and other site workers (Reinert et al. 2011). Sourcing practices that restrict against conversion of natural forests, and particularly hardwood forests, into plantation pine are likely to provide very high protective value for the timber rattlesnake. Because there is some evidence that timber rattlesnakes may readily utilize plantation pine and other edges contiguous to hardwood forests independently of the structural diversity in these edges (Anderson and Rosenberg 2011), management inside plantation forests may have little effect on the overall landscape quality of habitat for this species, provided that core forest habitat areas are maintained intact.

Discussion

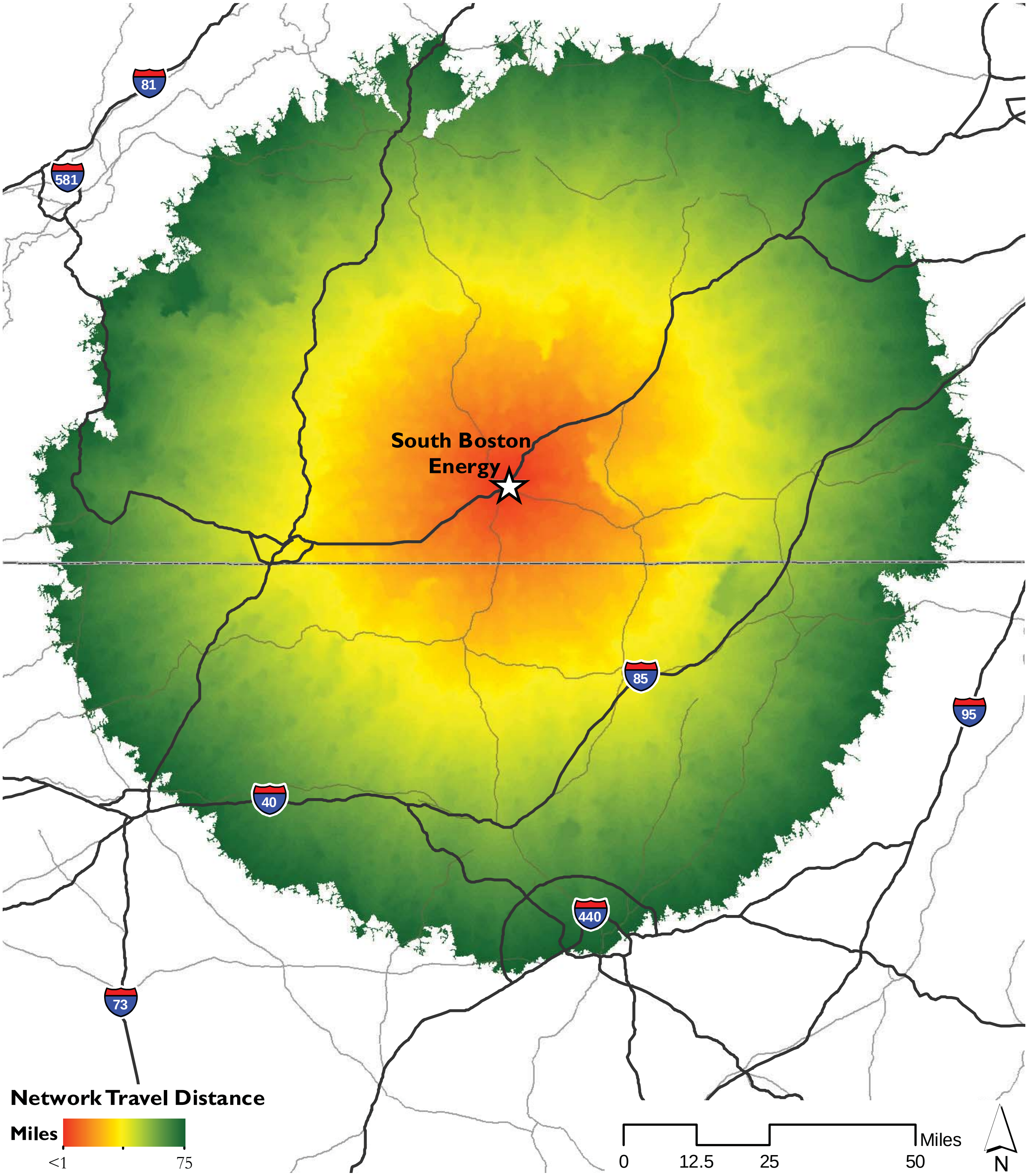
The biomass sourcing models for South Boston Energy suggest that there is the potential for substantial effects on native Piedmont forest types, including from both plantation conversion (softwood sourcing) and habitat change associated with increased biomass extraction (hardwood sourcing). Existing pressures on native Piedmont forests in Virginia over the past several decades, and prior to emergence of the bioenergy industry, include conversion to loblolly pine-based plantation forestry, agriculture and developed land covers (Felix et al. 1983; Orwig and Adams 1994; Allen et al. 1996). With the advent of a market for cleared forest material, a worst case scenario for biodiversity may be envisioned as additional incentive for more rapid clearing of native forests followed by full conversion into plantation pine or more intensive non-forestry land cover types including agriculture and exurban development (Zhang and Polyakov 2010). Increases in this land cover conversion pattern can be expected to have further negative implications for native wildlife species that are dependent on native upland Piedmont forests (Childers et al. 1986; Noss et al. 1995).

However, the South Boston Energy's relatively modest biomass demands, combined with the large baseline of existing plantation forestry in the woodshed, may provide opportunities for development of sourcing policies that can minimize – or even serve as a force for ameliorating – biodiversity impacts to native forests and wildlife. Similar to the Georgia Biomass and Piedmont Green Power facilities, the emergence of a market for thinnings from plantation pine forestry in this region of the Piedmont province could potentially benefit wildlife species that are adapted to more open understory conditions (Miller et al. 2009; Verschuyl et al. 2011). Implementation of site-level thinning practices that provide co-management control of major invasive understory plant species could also further benefit the wildlife habitat and native plant biodiversity values of the plantation forestry landscape (Huebner 2006; Young et al. 2011). Increased market opportunities for woody biomass in this woodshed may arguably provide marginal reductions in leapfrog patterns of urban sprawl in the Raleigh-Durham metropolitan area, although such effects will require additional research to understand more fully.

Sourcing of residuals and/or primary woody biomass material from native Piedmont forests poses a different set of biodiversity concerns than plantation-based sourcing. While the dominant biodiversity risk to Piedmont forests has historically been associated clear cutting and post-conversion into other land covers (Noss et al. 1995), over-harvest of residuals on sites that are intended for regeneration into native Piedmont forest types does pose habitat concern for wildlife and ecosystem health. These concerns long-term reduction of snag, cavity, and downed woody matter (DWM) that provides habitat complexity an refuge for amphibians, snakes, lizards, birds, and mammals, as well as potential reduction of propagule seed source and soil nutrient base that together promote native forest succession (Forest Guild 2012). Similar to other situations where residual material from native forests may be used as a large-scale bioenergy feedstock, sustainable residual utilization from native Piedmont forests requires site-level consideration of such effects and implementation of practices that ensure sufficient residuals to sustain wildlife and succession are maintained on the forest land base (Forest Guild 2012).

Although the potential biodiversity risks from native forest biomass sourcing in the South Boston Energy woodshed are significant, there may also be opportunities for usage of native forest materials in ways that pose minimal risk, or potentially even provide long-term benefits, to wildlife habitat and biodiversity. For example, low-level fires were historically an important component of Dry and Mesic Hardwood/Mixed Forests in the Piedmont province, but have largely been excluded from this forest landscape since the early twentieth century (see, e.g., Abrams 1992; Cowell 1998; Abrams 2003). Canopy and understory thinning for low cost bioenergy utilization could potentially be implemented to mimic and/or in conjunction with the reintroduction of low-level fire disturbance management (Kline and Coleman 2010). As noted above for plantation forestry, co-implementation of invasive plant control or removal through thinning and fire management protocols may also be regarded as a promising opportunity for restoration of native vegetation and associated wildlife habitat improvement in Piedmont forests (Huebner 2006; Young et al. 2011). Ultimate success of such habitat enhancement projects will development/implementation of best practices and verification through careful monitoring regimes (Forest Guild 2012).

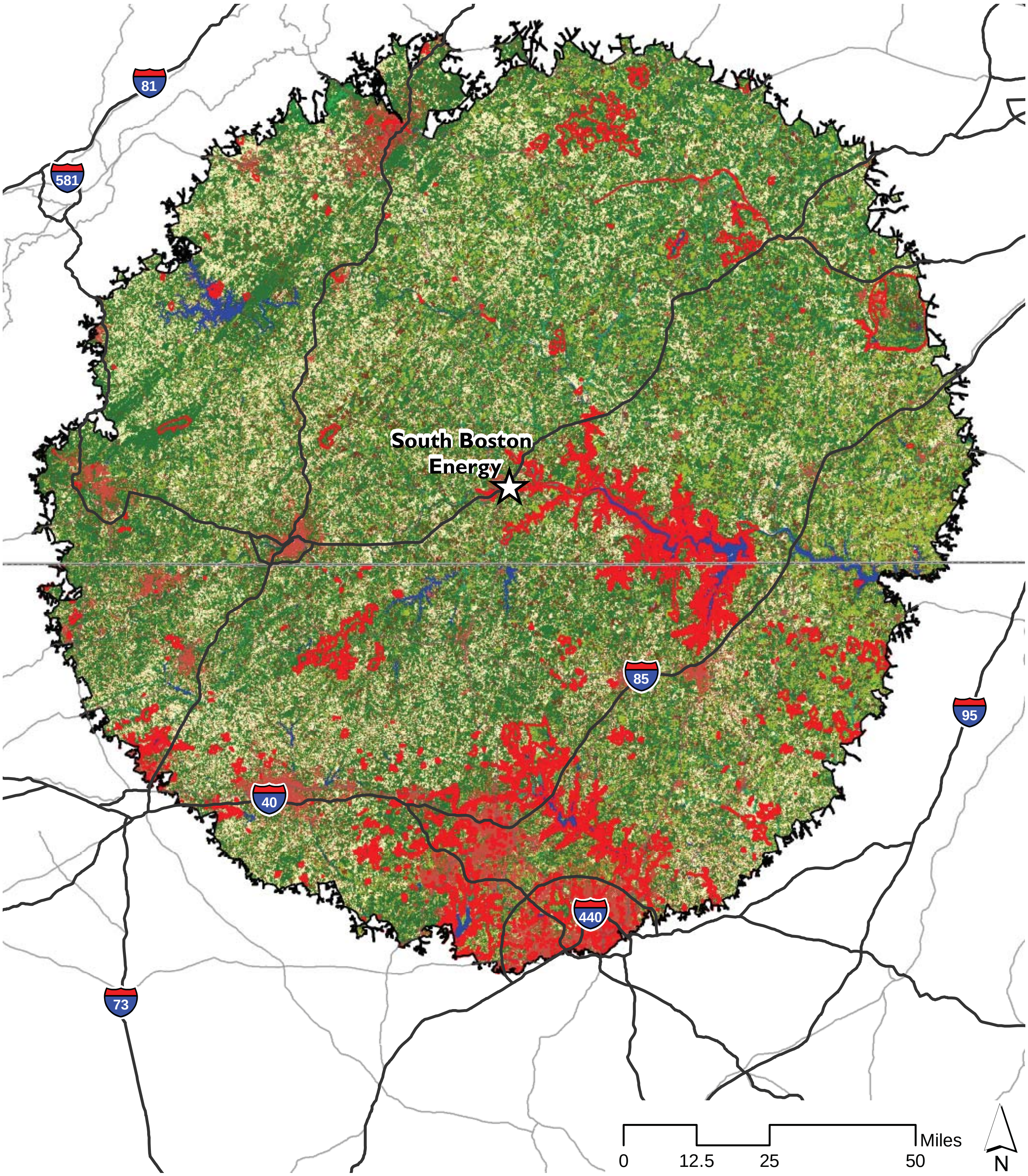
Figure 57. South Boston Energy Map 1: 75-mile Network Travel Distance and Woodshed Delineation



South Boston Energy Table 1. GAP Detailed Ecosystem Summary for 75-Mile Woodshed Area			
Land Cover Type (Detailed)	**Area**	**Protected**	**% Protected**
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	991,089	53,122	5.4%
Pasture/Hay	592,940	9,373	1.6%
Evergreen Plantation or Managed Pine	371,599	26,087	7.0%
Developed, Open Space	182,367	5,533	3.0%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	173,295	10,328	6.0%
Disturbed/Successional - Grass/Forb Regeneration	137,018	6,084	4.4%
Southern Piedmont Mesic Forest	116,921	5,088	4.4%
Disturbed/Successional - Shrub Regeneration	113,901	3,810	3.3%
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	101,500	5,769	5.7%
Southern Piedmont Small Floodplain and Riparian Forest	80,036	11,494	14.4%
Developed, Low Intensity	67,692	1,012	1.5%
Cultivated Cropland	63,742	1,774	2.8%
Open Water (Fresh)	57,324	24,456	42.7%
Developed, Medium Intensity	18,666	289	1.5%
Undifferentiated Barren Land	13,324	481	3.6%
Developed, High Intensity	6,807	64	0.9%
Harvested Forest-Shrub Regeneration	6,200	28	0.5%
Southern Piedmont Large Floodplain Forest - Forest Modifier	5,260	2,776	52.8%
Southern and Central Appalachian Cove Forest	2,844	0	0.0%
Southern and Central Appalachian Oak Forest	1,707	0	0.0%
Harvested Forest - Grass/Forb Regeneration	299	0	0.0%

South Boston Energy Table 1. GAP Detailed Ecosystem Summary for 75-Mile Woodshed Area

Figure 58. South Boston Energy Map 2: GAP Land Cover and Conservation Lands



South Boston Energy Map 2: Land Cover Characteristics Legend

Conservation Areas

GAP Ecosystem Class (NVC Macro)

- Southeastern North American Ruderal Forest & Plantation
- Central Oak-Hardwood & Pine Forest
- Eastern North American Ruderal Forest & Plantation
- Southern-Central Oak-Hardwood & Pine Forest
- Central Mesophytic Hardwood Forest
- Northern & Central Swamp Forest
- Southern Floodplain Hardwood Forest
- Eastern North American Cliff & Rock Vegetation
- Eastern Temperate Summit & Flatrock
- Barren
- Herbaceous Agricultural Vegetation
- Recently Disturbed or Modified
- Open Water
- Quarries, Mines, Gravel Pits and Oil Wells
- Developed & Urban

Figure 59. South Boston Energy Map 3: Travel Network Analysis & Locations of Competing Bioenergy and Pulp Mill Facilities

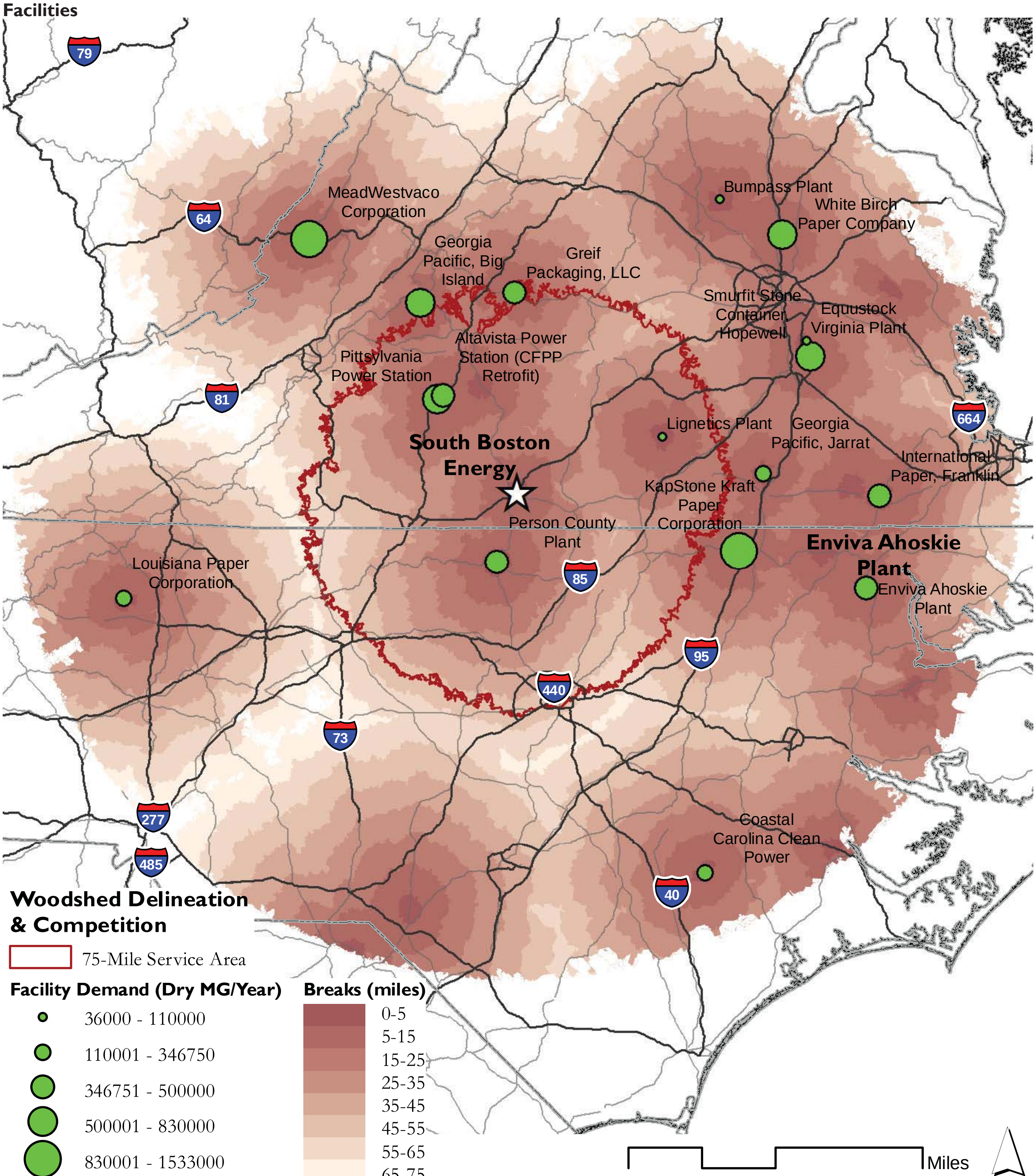


Figure 60. South Boston Energy Map 4: Competition Demand Strength Analysis, as Annual dry Mg / Network Travel Mile

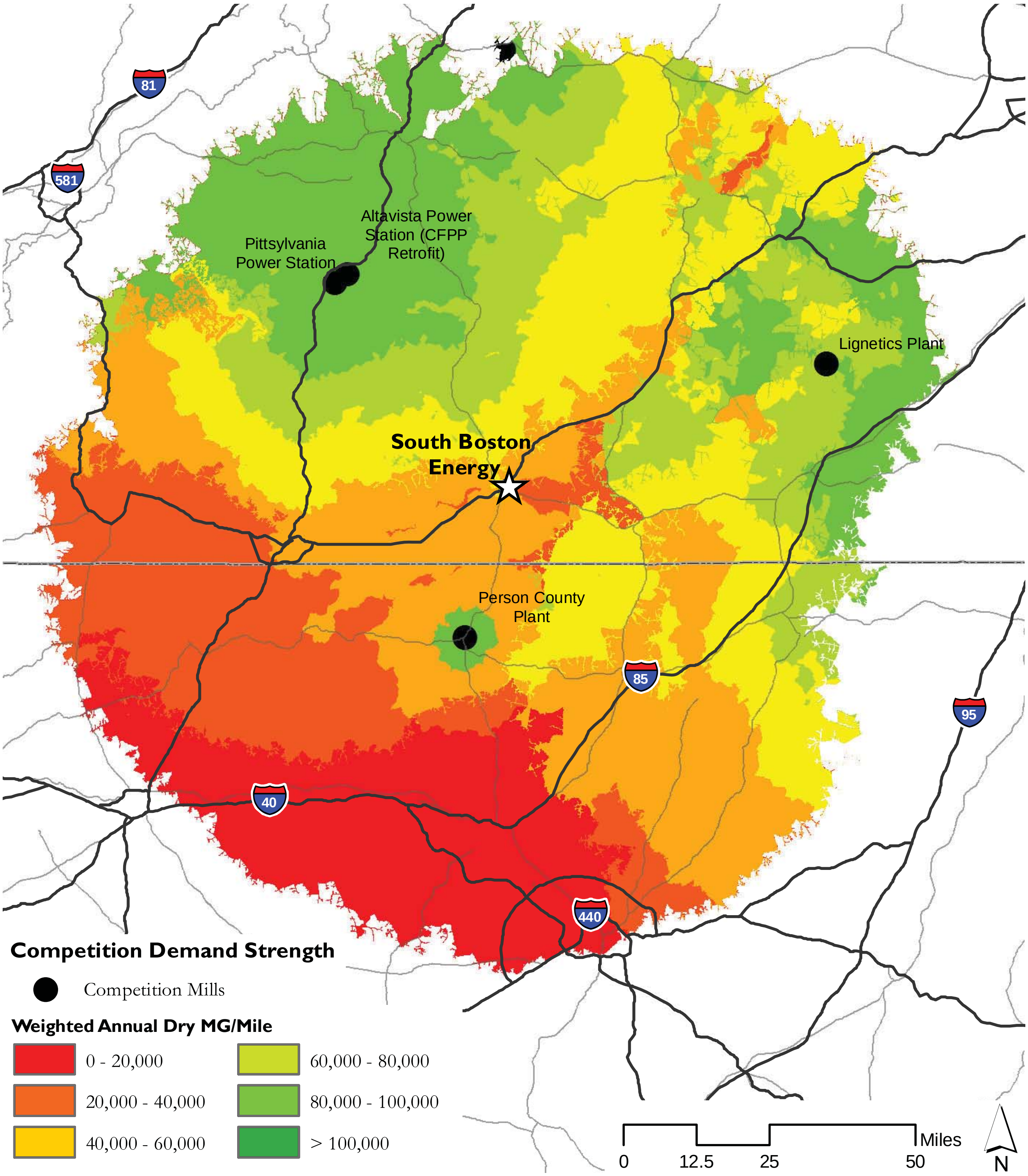


Figure 61. South Boston Energy Map 5: Maximum Entropy Suitability Model for Pine Plantation

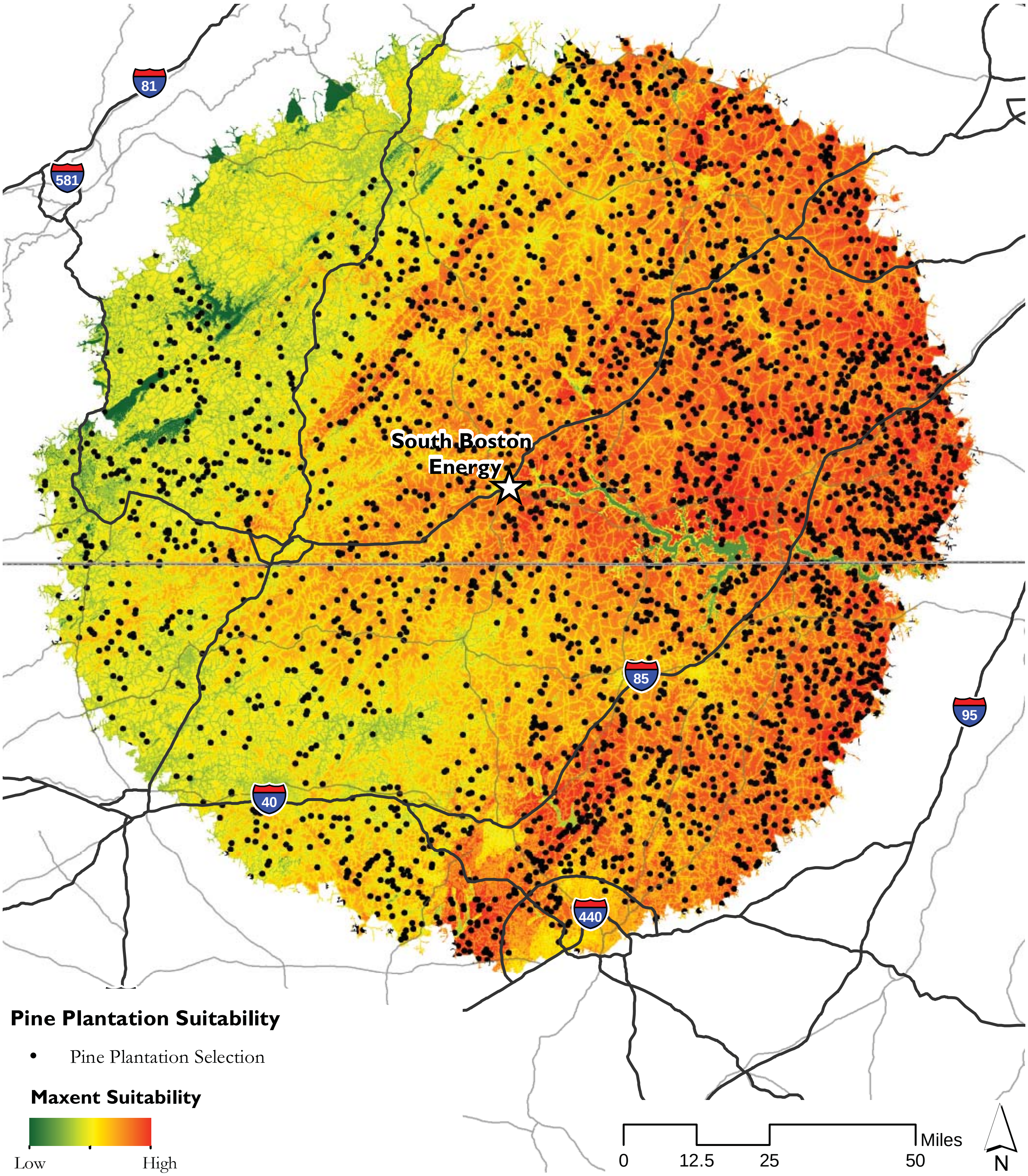
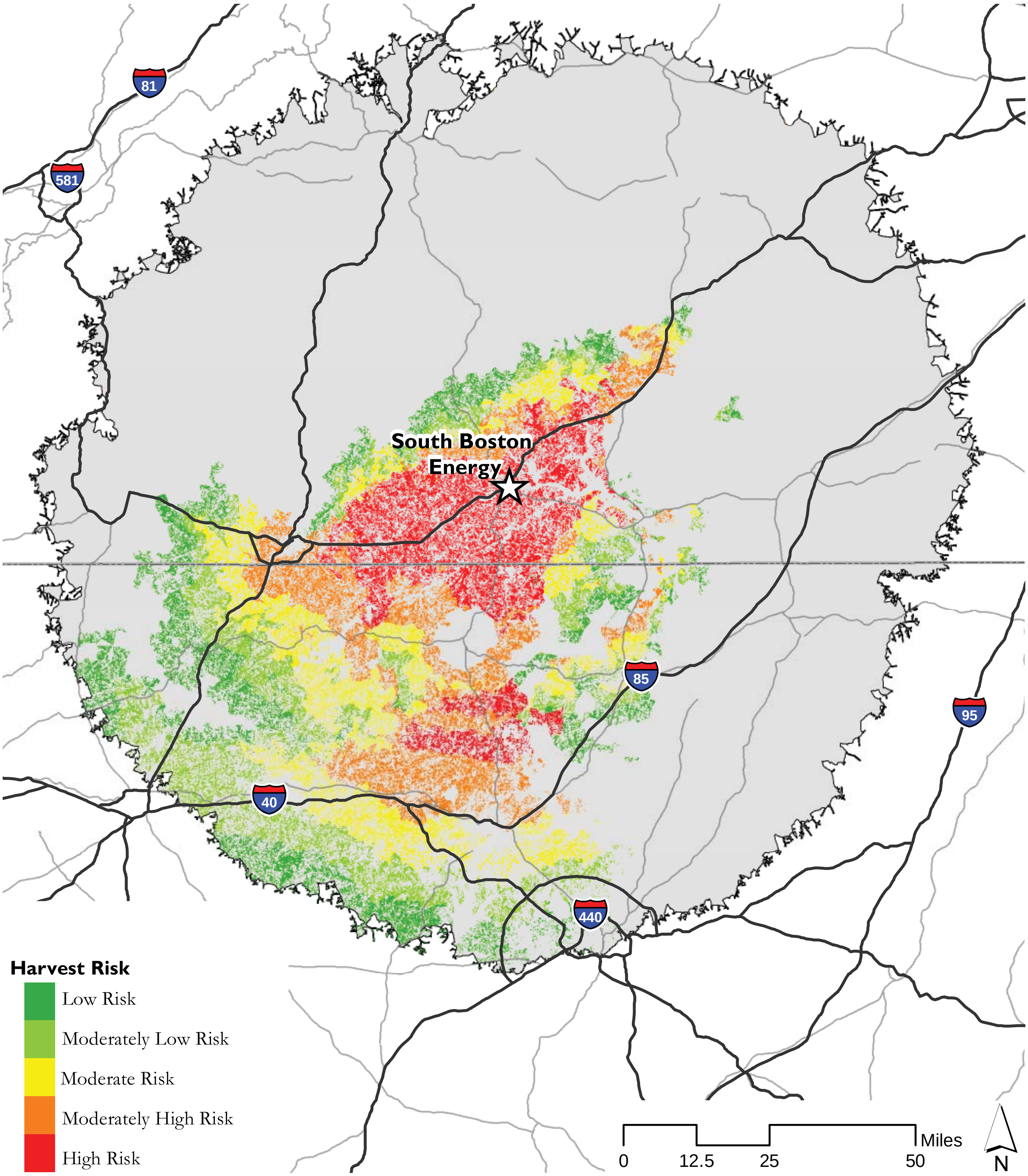


Figure 62. South Boston Energy Map 6: Composite Model of Hardwood (HDW) Sourcing Model Screen



South Boston Energy Table 2. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, excluding conservation areas			
Formal association name	**Common association name**	**Status**	**Woodshed occurrences**
Cephalanthus occidentalis - (Leucothoe racemosa) / Carex joorii Shrubland	Typic Piedmont Upland Pool	G1	1
Pinus rigida / Schizachyrium scoparium - Packera plattensis Wooded Herbaceous Vegetation	Ultramafic Outcrop Barrens	G1	1
Quercus alba / Physocarpus opulifolius / Packera plattensis - Hexastylis arifolia var. ruthii Forest	Southern Blue Ridge Ultramafic Outcrop Barrens (Deciduous Forest Type)	G1	1
Talinum teretifolium - Minuartia glabra - Diodia teres - Croton willdenowii Herbaceous Vegetation	Virginia Piedmont Granitic Flatrock Glade	G2	12
Fraxinus americana - Carya glabra / Muhlenbergia sobolifera - Helianthus divaricatus - Solidago ulmifolia Woodland	Central Appalachian Basic Woodland	G2	3
Quercus stellata - Carya carolinae-septentrionalis / Acer leucoderme / Piptochaetium avenaceum - Danthonia spicata Woodland	Piedmont Basic Hardpan Forest (Rocky Type)	G2	1
Carya (glabra, alba) - Fraxinus americana - (Juniperus virginiana var. virginiana) Woodland	Montane Basic Hardwood - (Red-cedar) Woodland	G2	1
Fagus grandifolia - Acer barbatum - Quercus muehlenbergii / Sanguinaria canadensis Forest	Basic Mesic Ravine Forest	G2?	1
Fagus grandifolia - Quercus alba / Kalmia latifolia - (Symplocos tinctoria, Rhododendron catawbiense) / Galax urceolata Forest	Piedmont Beech / Heath Bluff	G2G3	14
Quercus phellos / Carex (albolutescens, intumescens, joorii) / Climacium americanum Forest	Piedmont Upland Depression Willow Oak Swamp Forest	G2G3	11
Quercus stellata - Carya (carolinae-septentrionalis, glabra) - (Quercus marilandica) / Ulmus alata / (Schizachyrium scoparium, Piptochaetium avenaceum) Woodland	Piedmont Montmorillonite Woodland	G2G3	7

South Boston Energy Table 2. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, excluding conservation areas

South Boston Energy Table 2. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, excluding conservation areas (cont…)

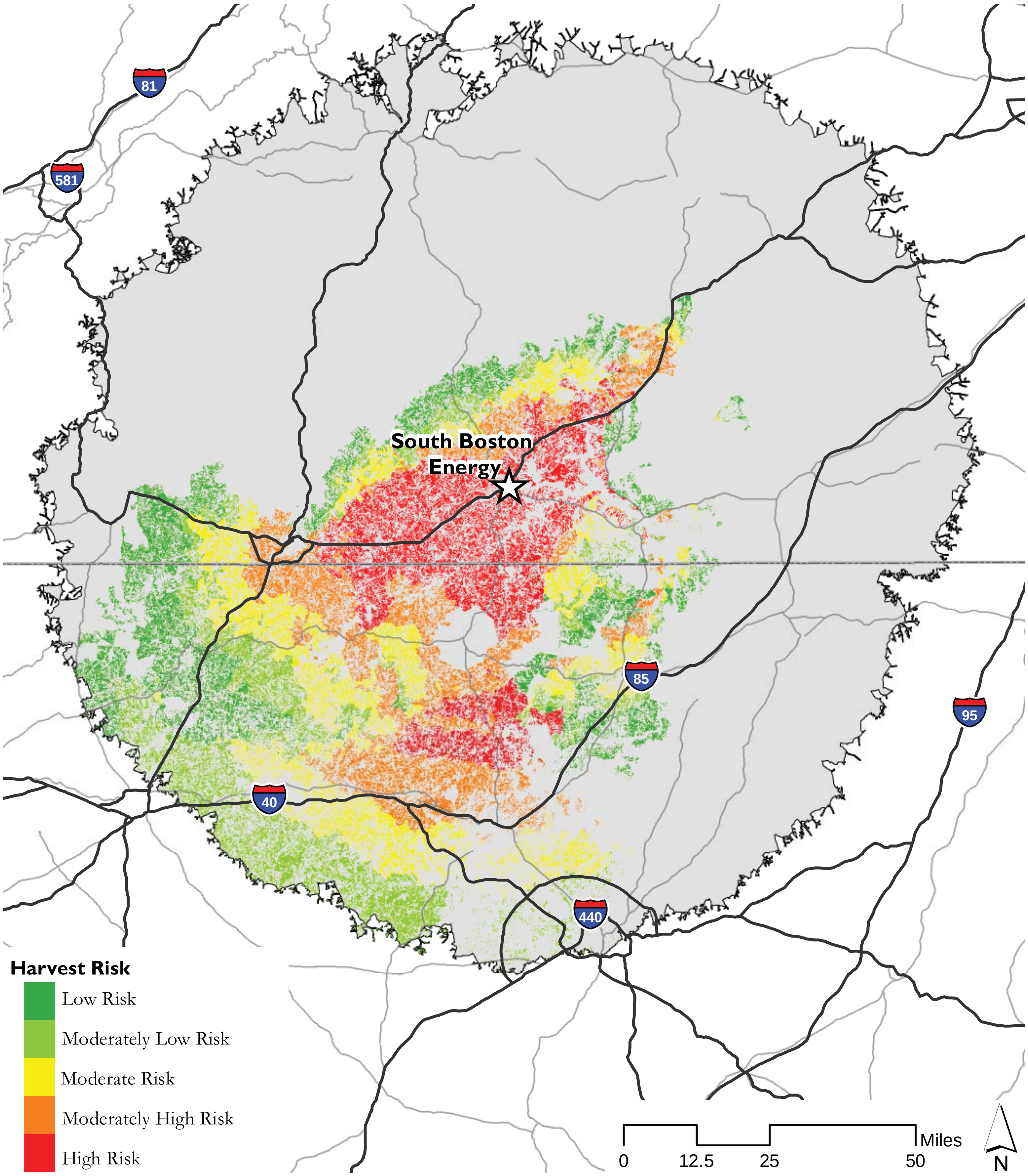
Formal association name	Common association name	Status	Woodshed occurrences
Peltandra virginica - Saururus cernuus - Boehmeria cylindrica / Climacium americanum Herbaceous Vegetation	Floodplain Pool	G2G3	3
Eragrostis hypnoides - Ludwigia palustris - Lindernia dubia - Cyperus squarrosus Herbaceous Vegetation	Appalachian-Atlantic River Bar Drawdown Shore	G3	1
Acer rubrum - Nyssa sylvatica - Magnolia virginiana / Viburnum nudum var. nudum / Osmunda cinnamomea - Woodwardia areolata Forest	Southern Red Maple - Blackgum Swamp Forest	G3?	1
Quercus alba - Quercus rubra - Carya (ovata, carolinae-septentrionalis) / Cercis canadensis Forest	Piedmont Dry-Mesic Basic Oak - Hickory Forest	G3G4	1
Fagus grandifolia - Quercus rubra / Acer barbatum - Aesculus sylvatica / Actaea racemosa - Adiantum pedatum Forest	Piedmont Basic Mesic Mixed Hardwood Forest	G3G4	1

South Boston Energy Table 3.
Harvest area objectives (HAO) and associated risk classes for spatial modeling

HAO	Softwood (Ha)	Demand Intensity (Mg/ha/yr)	Hardwood (Ha)	Demand Intensity (Mg/ha/yr)	Harvest or Conversion Risk Class
1	21,500	8.00	43,000	4.00	High
2	43,000	4.00	86,000	2.00	
3	64,500	2.67	129,000	1.33	Moderately High
4	86,000	2.00	172,000	1.00	
5	107,500	1.60	215,000	0.80	Moderate
6	129,000	1.33	258,000	0.67	
7	150,500	1.14	301,000	0.57	Moderately Low
8	172,000	1.00	344,000	0.50	
9	193,500	0.89	387,000	0.44	Low
10	215,000	0.80	430,000	0.40	

South Boston Energy Table 3. Harvest area objectives and associated risk classes for spatial modeling

Figure 63. South Boston Energy Map 7: Composite Model of Hardwood no Wetlands (HNW) Sourcing Model Screen



South Boston Energy Table 4a. GAP ecosystem overlay for hardwood biomass sourcing including wetland forests (HDW screen) and high biomass removal intensity (HAO_2)

GAP Ecosystem	Hectares	Acres	Sourcing %
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	61,161	151,068	71.1%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	12,248	30,253	14.2%
Southern Piedmont Large Floodplain Forest - Forest Modifier	498	1,230	0.6%
Southern Piedmont Mesic Forest	7,648	18,891	8.9%
Southern Piedmont Small Floodplain and Riparian Forest	4,445	10,979	5.2%

South Boston Energy Table 4a. GAP ecosystem overlay for hardwood biomass sourcing including HDW screen and HAO_2

South Boston Energy Table 4b. GAP ecosystem overlay for hardwood biomass sourcing including wetland forests (HDW screen) and moderate biomass removal intensity (HAO_6)

GAP Ecosystem	Hectares	Acres	Sourcing %
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	188,805	466,348	73.2%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	33,118	81,801	12.8%
Southern Piedmont Large Floodplain Forest - Forest Modifier	710	1,754	0.3%
Southern Piedmont Mesic Forest	22,820	56,365	8.8%
Southern Piedmont Small Floodplain and Riparian Forest	12,547	30,991	4.9%

South Boston Energy Table 4b. GAP ecosystem overlay for hardwood biomass sourcing including HDW screen and HAO_6

South Boston Energy Table 4c. GAP ecosystem overlay for hardwood biomass sourcing including wetland forests (HDW screen) and low biomass removal intensity (HAO_10)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	318,226	786,018	74.0%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	53,259	131,550	12.4%
Southern Piedmont Large Floodplain Forest - Forest Modifier	948	2,342	0.2%
Southern Piedmont Mesic Forest	36,923	91,200	8.6%
Southern Piedmont Small Floodplain and Riparian Forest	20,640	50,981	4.8%

South Boston Energy Table 4c. GAP ecosystem overlay for hardwood biomass sourcing including HDW screen and HAO_10

Figure 64. South Boston Energy Map 8: Composite Model of Pine Plantation Only (PO) Sourcing Model Screen

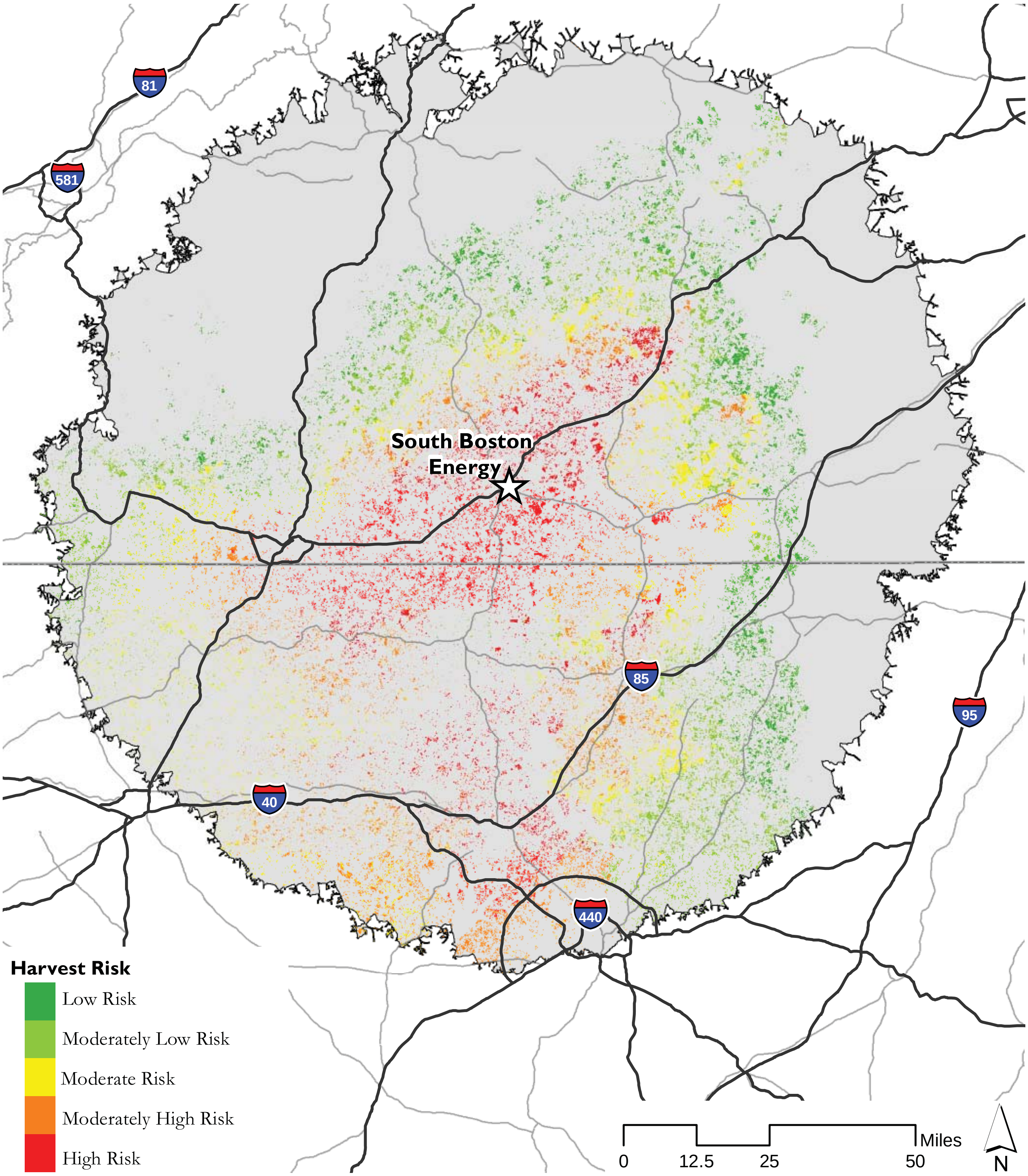


Figure 65. South Boston Energy Map 9: Composite Model of Pine & Disturbed, No Pasture (PNP) Sourcing Model Screen

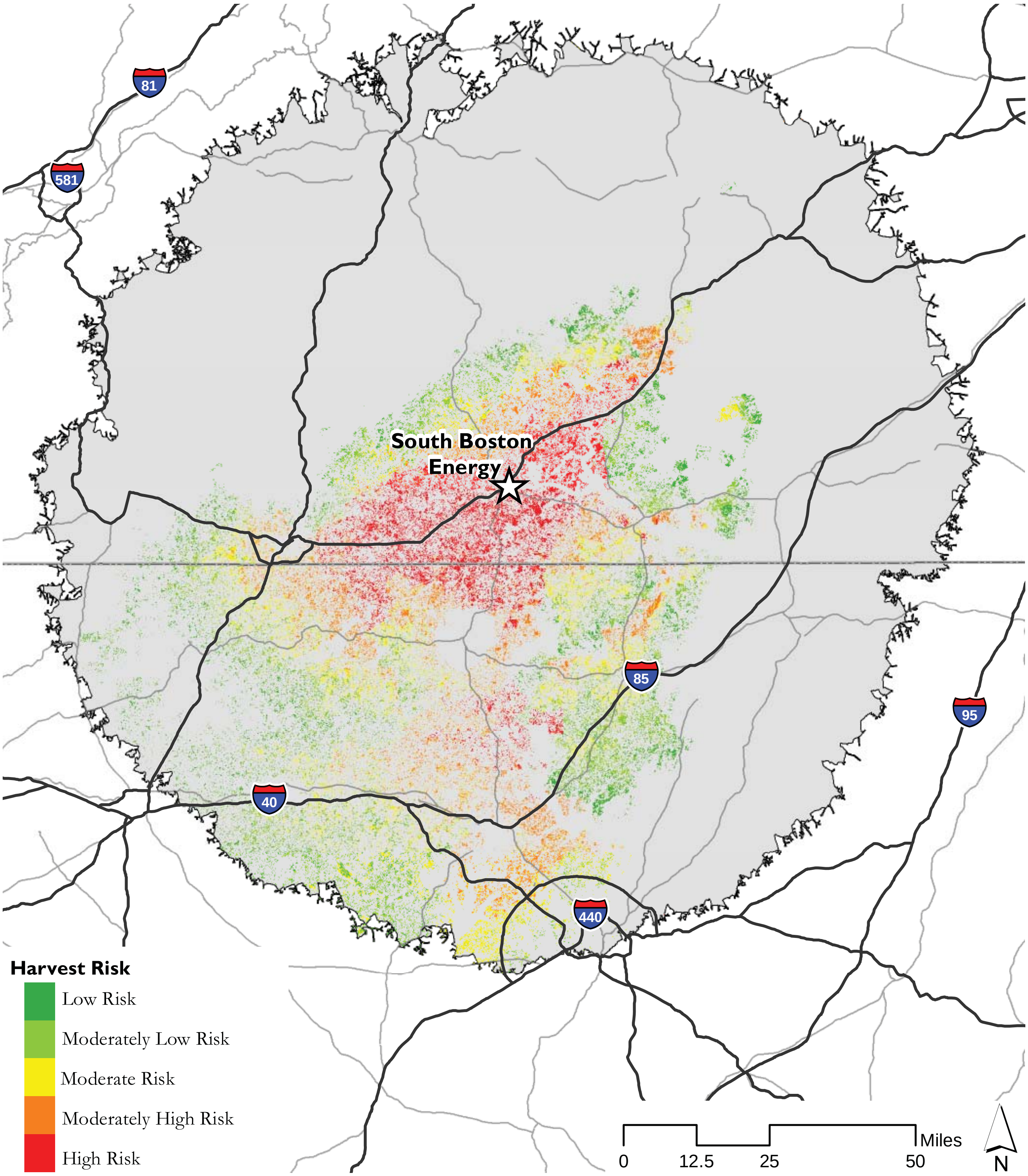


Figure 66. South Boston Energy Map 10: Composite Model of Pine, Disturbed & Pasture Risk Composite Sourcing Model Screen

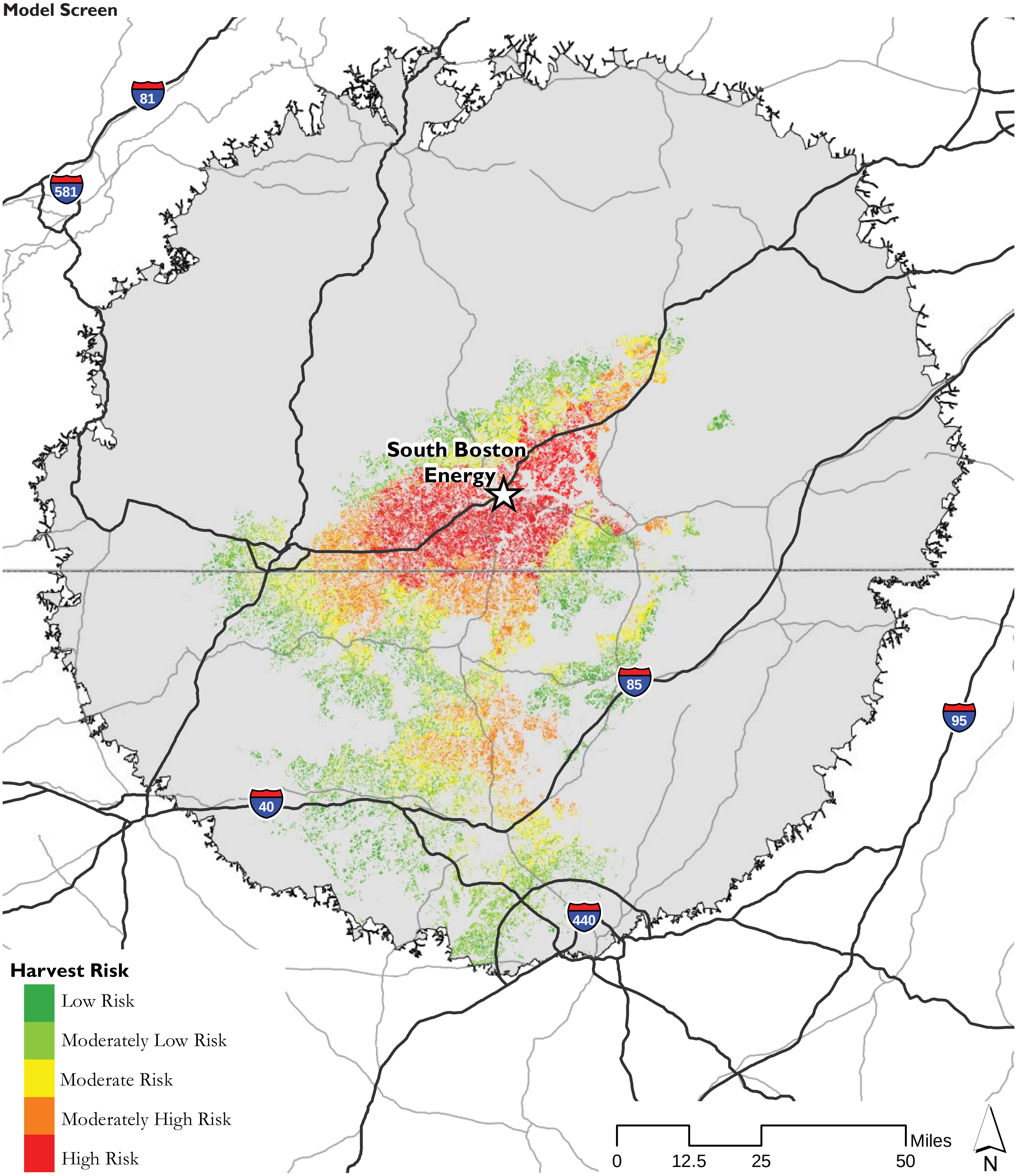


Figure 67. South Boston Energy Map 11: Composite Model of Upland Forest, No Pasture Risk Composite Sourcing Model Screen

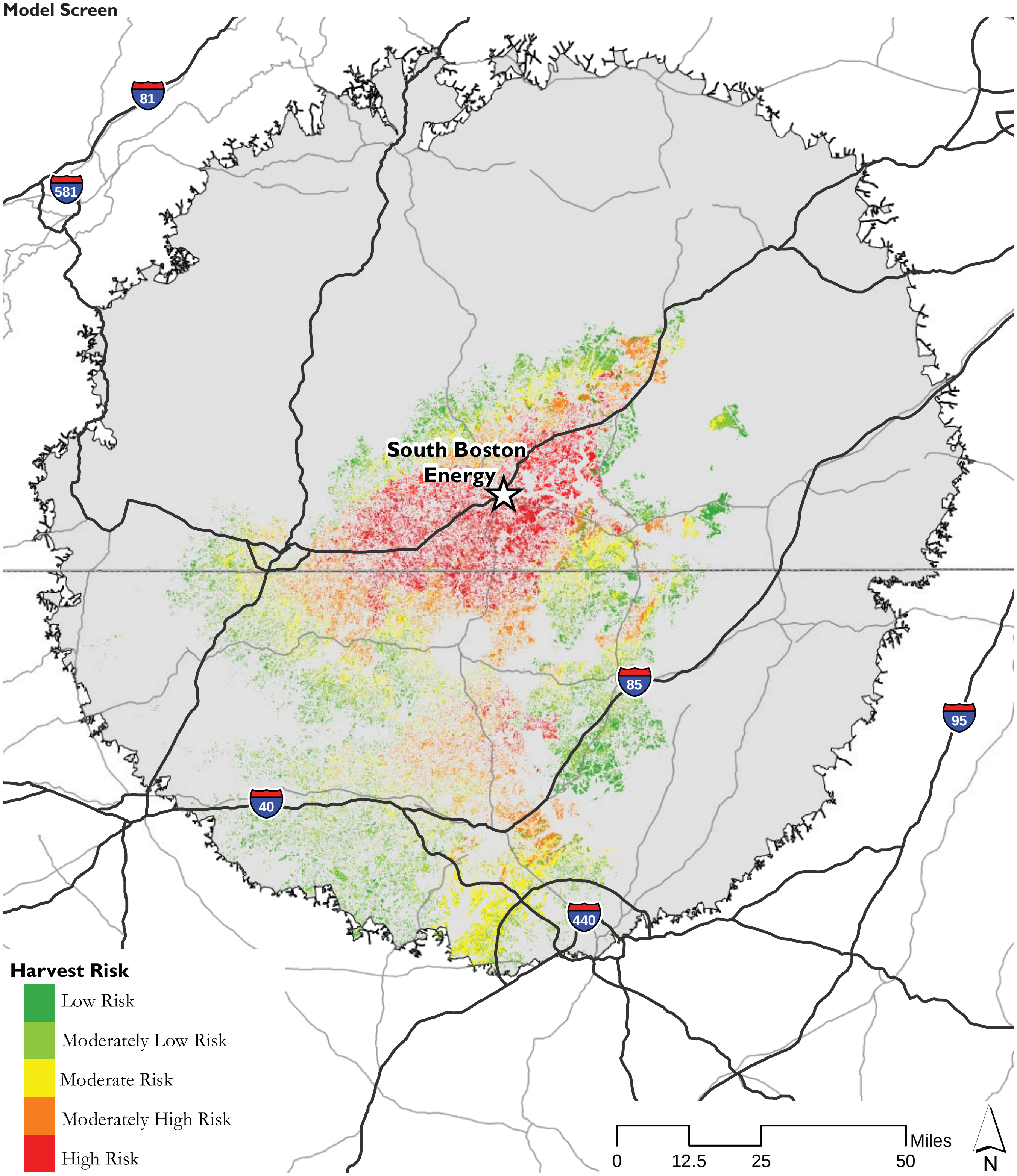


Figure 68. South Boston Energy Map 12: Composite Model of Upland Forest & Pasture Risk Composite Sourcing Model Screen

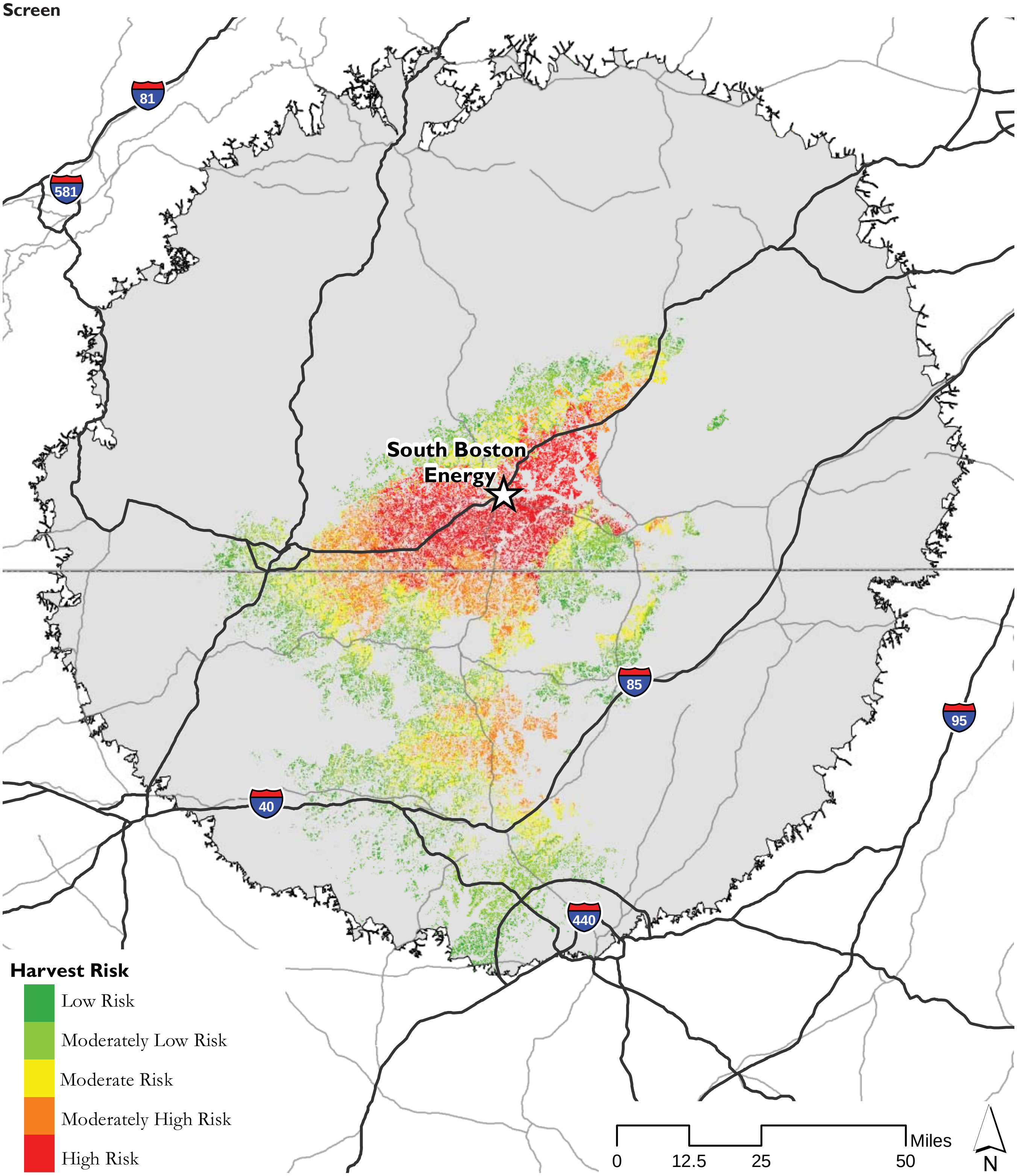
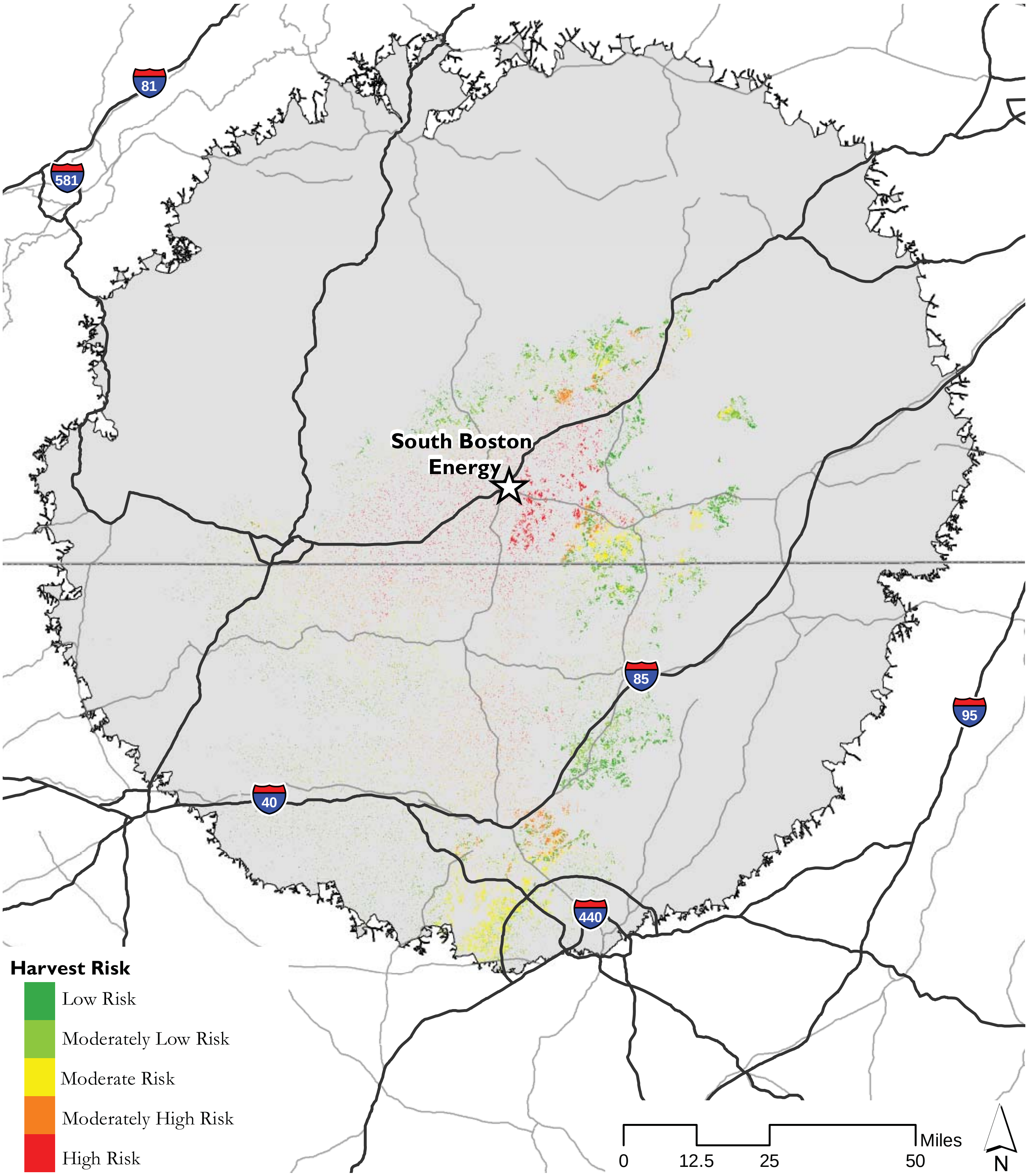


Figure 69. South Boston Energy Map 13: Composite Plantation Pine Conversion Risk for Natural Forest Stands



South Boston Energy Table 5a. GAP ecosystem overlay for hardwood biomass sourcing excluding wetland forests (HNW screen) and high biomass removal intensity (HAO_2)

GAP Ecosystem	Hectares	Acres	Sourcing %
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	65,255	161,180	75.9%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	12,703	31,376	14.8%
Southern Piedmont Mesic Forest	8,042	19,864	9.4%

South Boston Energy Table 5a. GAP ecosystem overlay for hardwood biomass sourcing excluding HNW screen and HAO_2

South Boston Energy Table 5b. GAP ecosystem overlay for hardwood biomass sourcing excluding wetland forests (HNW screen) and moderate biomass removal intensity (HAO_6)

GAP Ecosystem	Hectares	Acres	Sourcing %
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	199,242	492,128	77.2%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	34,809	85,978	13.5%
Southern Piedmont Mesic Forest	23,949	59,154	9.3%

South Boston Energy Table 5b. GAP ecosystem overlay for hardwood biomass sourcing excluding HNW screen and HAO_6

South Boston Energy Table 5c. GAP ecosystem overlay for hardwood biomass sourcing excluding wetland forests (HNW screen) and low biomass removal intensity (HAO_10)

GAP Ecosystem	Hectares	Acres	Sourcing %
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	336,361	830,812	78.2%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	55,153	136,228	12.8%
Southern Piedmont Mesic Forest	38,486	95,060	9.0%

South Boston Energy Table 5c. GAP ecosystem overlay for hardwood biomass sourcing excluding HNW screen and HAO_10

South Boston Energy Table 6a. GAP ecosystem overlay for softwood biomass sourcing without forest protection (FNP screen) and high biomass removal intensity (HAO_2)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	1,910	4,718	4.4%
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	4,013	9,912	9.3%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	470	1,161	1.1%
Southern Piedmont Mesic Forest	321	793	0.7%
Disturbed/Successional - Grass/Forb Regeneration	9,697	23,952	22.6%
Disturbed/Successional - Shrub Regeneration	7,031	17,367	16.4%
Evergreen Plantation or Managed Pine	18,647	46,058	43.4%
Undifferentiated Barren Land	838	2,070	2.0%

South Boston Energy Table 6a. GAP ecosystem overlay for softwood biomass sourcing without FNP screen and HAO_2

South Boston Energy Table 6b. GAP ecosystem overlay for softwood biomass sourcing without forest protection (FNP screen) and moderate biomass removal intensity (HAO_6)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	10,655	26,318	8.3%
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	13,705	33,851	10.6%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	2,733	6,751	2.1%
Southern Piedmont Mesic Forest	1,494	3,690	1.2%
Disturbed/Successional - Grass/Forb Regeneration	28,060	69,308	21.7%
Disturbed/Successional - Shrub Regeneration	19,943	49,259	15.4%
Evergreen Plantation or Managed Pine	50,500	124,735	39.1%
Undifferentiated Barren Land	2,004	4,950	1.6%

South Boston Energy Table 6b. GAP ecosystem overlay for softwood biomass sourcing without FNP screen and HAO_6

South Boston Energy Table 6c. GAP ecosystem overlay for softwood biomass sourcing without forest protection (FNP screen) and low biomass removal intensity (HAO_10)

GAP Ecosystem	Hectares	Acres	Sourcing %
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	14,980	37,001	7.0%
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	24,628	60,831	11.5%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	4,213	10,406	2.0%
Southern Piedmont Mesic Forest	2,140	5,286	1.0%
Disturbed/Successional - Grass/Forb Regeneration	47,055	116,226	21.9%
Disturbed/Successional - Shrub Regeneration	33,253	82,135	15.5%
Evergreen Plantation or Managed Pine	85,686	211,644	39.9%
Undifferentiated Barren Land	3,066	7,573	1.4%

South Boston Energy Table 6c. GAP ecosystem overlay for softwood biomass sourcing without FNP screen and HAO_10

South Boston Energy Table 7a. GAP species distribution overlay comparison for sourcing from hardwood forests that include wetlands (HDW screen) versus sourcing only from upland hardwood forests (HNW screen) with high biomass removal intensity (HAO_2)

Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with HDW screen (% of woodshed habitat)	Hectares of habitat overlay with HNW screen (% of woodshed habitat)	Hectares of Increased habitat overlay with HDW	% Increase in habitat overlay with HDW
Brown-headed Nuthatch	385,780	11,059 (2.9%)	11,319 (2.9%)	-260	-2.3%
Northern Bobwhite	1,195,365	22,263 (1.9%)	21,441 (1.8%)	822	3.8%
Swainson's Warbler	75,151	4,382 (5.8%)	2,952 (3.9%)	1,430	48.4%
Eastern Spotted Skunk	171,461	N/A	N/A	N/A	N/A
Long-tailed Weasel	1,770,459	51,600 (2.9%)	51,182 (2.9%)	418	0.8%
Northern Cricket Frog	103,482	1,850 (1.8%)	1,403 (1.4%)	447	31.9%
Timber Rattlesnake	703,339	15,105 (2.1%)	10,967 (1.6%)	4,138	37.7%

South Boston Energy Table 7a. GAP species distribution overlay comparison for sourcing from hardwood forests that include HDW screen versus sourcing only from HNW screen with HAO_2

South Boston Energy Table 7b. GAP species distribution overlay comparison for sourcing from hardwood forests that include wetlands (HDW screen) versus sourcing only from upland hardwood forests (HNW screen) with moderate biomass removal intensity (HAO_6)

Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with HDW screen (% of woodshed habitat)	Hectares of habitat overlay with HNW screen (% of woodshed habitat)	Hectares of Increased habitat overlay with HDW	% Increase in habitat overlay with HDW
Brown-headed Nuthatch	385,780	34,031 (8.8%)	35,142 (9.1%)	-1,111	-3.2%
Northern Bobwhite	1,195,365	67,565 (5.7%)	66,795 (5.6%)	770	1.2%
Swainson's Warbler	75,151	14,808 (19.7%)	11,732 (15.6%)	3,076	26.2%
Eastern Spotted Skunk	171,461	N/A	N/A	N/A	N/A
Long-tailed Weasel	1,770,459	156,598 (8.8%)	156,740 (8.9%)	-142	-0.1%
Northern Cricket Frog	103,482	5,697 (5.5%)	4,811 (4.6%)	886	18.4%
Timber Rattlesnake	703,339	37,984 (5.4%)	30,848 (4.4%)	7,136	23.1%

South Boston Energy Table 7b. GAP species distribution overlay comparison for sourcing from hardwood forests that include HDW screen versus sourcing only from HNW screen with HAO_6

South Boston Energy Table 7c. GAP species distribution overlay comparison for sourcing from hardwood forests that include wetlands (HDW screen) versus sourcing only from upland hardwood forests (HNW screen) with low biomass removal intensity (HAO_10)

Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with HDW screen (% of woodshed habitat)	Hectares of habitat overlay with HNW screen (% of woodshed habitat)	Hectares of Increased habitat overlay with HDW	% Increase in habitat overlay with HDW
Brown-headed Nuthatch	385,780	56,253 (14.5%)	57,126 (14.8%)	-873	-1.5%
Northern Bobwhite	1,195,365	110,353 (9.2%)	112,983 (9.5%)	-2,630	-2.3%
Swainson's Warbler	75,151	20,956 (27.9%)	19,383 (25.8%)	1,573	8.1%
Eastern Spotted Skunk	171,461	N/A	N/A	N/A	N/A
Long-tailed Weasel	1,770,459	259,047 (14.6%)	263,134 (14.9%)	-4,087	-1.6%
Northern Cricket Frog	103,482	9,162 (8.9%)	8,061 (7.8%)	1,101	13.7%
Timber Rattlesnake	703,339	58,351 (8.3%)	51,413 (7.3%)	6,938	13.5%

South Boston Energy Table 7c. GAP species distribution overlay comparison for sourcing from hardwood forests that include HDW screen versus sourcing only from HNW screen with HAO_10

South Boston Energy Table 8a. GAP species distribution overlay comparison for sourcing with no natural forest stand protection (FNP screen) versus sourcing only from plantation or disturbed forestry lands (PNP screen) with high biomass removal intensity (HAO_2)					
Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with FNP screen (% of woodshed habitat)	Hectares of habitat overlay with PNP screen (% of woodshed habitat)	Hectares of increased habitat overlay with FNP	% Increase in habitat overlay with FNP
Brown-headed Nuthatch	385,780	4,987 (1.3%)	4,313 (1.1%)	674	15.6%
Northern Bobwhite	1,195,365	15,357 (1.3%)	16,111 (1.3%)	-754	-4.7%
Swainson's Warbler	75,151	1,262 (0.3%)	291 (0.4%)	971	333.8%
Eastern Spotted Skunk	171,461	N/A	N/A	N/A	N/A
Long-tailed Weasel	1,770,459	25,825 (1.5%)	26,441 (1.5%)	-616	-2.3%
Northern Cricket Frog	103,482	1,186 (1.1%)	1,223 (1.2%)	-37	-3.0%
Timber Rattlesnake	703,339	1,432 (0.2%)	1,180 (0.2%)	252	21.3%

South Boston Energy Table 8a. GAP species distribution overlay comparison for sourcing with no FNP screen versus sourcing only from PNP screen with HAO_2

South Boston Energy Table 8b. GAP species distribution overlay comparison for sourcing with no natural forest stand protection (FNP screen) versus sourcing only from plantation or disturbed forestry lands (PNP screen) with moderate biomass removal intensity (HAO_6)					
Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with FNP screen (% of woodshed habitat)	Hectares of habitat overlay with PNP screen (% of woodshed habitat)	Hectares of increased habitat overlay with FNP	% Increase in habitat overlay with FNP
Brown-headed Nuthatch	385,780	16,958 (4.4%)	14,225 (3.7%)	2,733	19.2%
Northern Bobwhite	1,195,365	45,970 (3.8%)	49,008 (4.1%)	-3,038	-6.2%
Swainson's Warbler	75,151	4,039 (5.4%)	2,034 (2.7%)	2,005	98.6%
Eastern Spotted Skunk	171,461	N/A	N/A	N/A	N/A
Long-tailed Weasel	1,770,459	79,772 (4.5%)	81,327 (4.6%)	-1,555	-1.9%
Northern Cricket Frog	103,482	4,003 (3.9%)	4,239 (4.1%)	-236	-5.6%
Timber Rattlesnake	703,339	6,319 (0.9%)	5,914 (0.8%)	405	6.8%

South Boston Energy Table 8b. GAP species distribution overlay comparison for sourcing with no FNP screen versus sourcing only from PNP screen with HAO_6

South Boston Energy Table 8c. GAP species distribution overlay comparison for sourcing with no natural forest stand protection (FNP screen) versus sourcing only from plantation or disturbed forestry lands (PNP screen) with low biomass removal intensity (HAO_10)

Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with FNP screen (% of woodshed habitat)	Hectares of habitat overlay with PNP screen (% of woodshed habitat)	Hectares of increased habitat overlay with FNP	% Increase in habitat overlay with FNP
Brown-headed Nuthatch	385,780	30,302 (7.9%)	23,981 (6.2%)	6,321	26.4%
Northern Bobwhite	1,195,365	80,365 (6.7%)	83,033 (6.9%)	-2,668	-3.2%
Swainson's Warbler	75,151	7,834 (10.4%)	3,756 (5.0%)	4,078	108.6%
Eastern Spotted Skunk	171,461	5 (0%)	5 (0%)	0	0.0%
Long-tailed Weasel	1,770,459	138,122 (7.8%)	135,793 (7.7%)	2,329	1.7%
Northern Cricket Frog	103,482	7,359 (7.1%)	7,410 (7.2%)	-51	-0.7%
Timber Rattlesnake	703,339	16,903 (2.4%)	13,501 (1.9%)	3,402	25.2%

South Boston Energy Table 8c. GAP species distribution overlay comparison for sourcing with no FNP screen versus sourcing only from PNP screen with HAO_10

IX. CASE STUDY OF CAROLINA WOOD PELLETS

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Facility description

Carolina Wood Pellets, located in Otto, North Carolina, is a facility that manufactures hardwood pellets for domestic home stoves. The facility has been producing pellets since 2009 at an estimated output of 68,000 Mg/yr, which requires an estimated biomass demand of 74,000 dry Mg/yr. The current feedstock is residual wood from manufacturing, logging and construction sources.

We modeled the facility based on an assumed residual sourcing of 24 dry Mg/ha for Appalachian hardwood sites at the time

Figure 70. Southern and Central Appalachian Oak, Photo Credit: Robinson Schelhas

of harvest (Vanderberg et al. 2012) over an assumed 50 year facility lifespan. Using this baseline, the total residual harvest area impact over 50 year facility lifespan (HAO_10) was calculated as 154,000 hectares. Although the model sourcing objectives were derived through the residual sourcing assumption, more intense HAO levels representative of increased bioenergy utilization of primary woody biomass material (i.e., large-scale use of primary biomass in HAO_2) were modeled for consistency with other considered facilities.

GAP land cover summary

The 75-mile road network sourcing area (Carolina Wood Pellets Map 1) provides a total land cover base that is just over 2 million hectares. This relatively constrained woodshed area stems from the presence of steep mountain ridges that limit road network passages, particularly in the northern woodshed. Although the sourcing area is mostly contained within the Appalachian Mountain provinces, the southern woodshed stretches down gradient into the piedmont province. Forest resources including all native, plantation, and disturbed forest land covers accounting for over 1.5 million hectares, or over 76.4% of the total woodshed area.

The most common land cover in the Carolina Wood Pellets woodshed is Southern and Central Appalachian Oak Forests. Canopy tree species in this forest include the scarlet oak (*Quercus coccinea*), northern red oak (*Quercus rubra*), eastern black oak (*Quercus velutina*), red maple (*Acer rubrum*), black tupelo(*Nyssa silvatica*), sourwood (*Oxydendrum abororeum*), white oak (*Quercus alba*), and chestnut oak (*Quercus prinus*). Including the Xeric modifier of this forest type, total areal coverage is over 657,000 hectares, or 32.4%, within the woodshed area. Over 259,000 additional hectares, or 12.7% of the woodshed, are classified as other types of Appalachian hardwood forests. Almost 72,000 hectares are classified as pine-dominated Appalachian forests. Altogether, Appalachian Mountain forest types account for over 989,000 hectares, or 48.8%, of the woodshed area.

Approximately 355,000 hectares, or 17.5%, of the woodshed is contained in native upland Piedmont forest types similar to those described for the Piedmont Green Power and South Boston Energy facilities. Over 65,000 additional hectares, or 3.2% of the woodshed, is classified as Evergreen Plantation or Managed Pine, with most of this plantation forestry area located in the Piedmont province. Harvested, ruderal, and disturbed forestry lands account for over 128,000 hectares, or 6.3% of the woodshed. Another 35,000 hectares (1.7%) is classified as riparian or wetland.

Pasture/Hay is the largest agricultural land cover, and occupies approximately 11.7% of the woodshed area. More intensively managed Cultivated Croplands are present, but account for less than 1% of the land cover base. Over 181,000 hectares (8.9%) of the woodshed are classified as developed. Much of this development is concentrated in the far northeast sections of the woodshed adjacent to the Asheville, NC metropolitan area, and in the far southwest woodshed including and near the city of Gainesville, GA. Most of the remaining area is open water (~1.7%).

Public lands databases that include federal landholdings and state conservation lands in Georgia, North Carolina, South Carolina, and Tennessee indicate that 24.8% of the woodshed is under some form of public ownership. The public lands are heavily concentrated in the Appalachian Mountains section of the woodshed, and include large areas of the Nantahala National Forest, Chattahoochee National Forest, and Pisgah National Forests.

Carolina Wood Pellets Table 1 provides a complete summary of ecosystem area coverage in the 75-mile sourcing area for the Carolina Wood Pellets facility, along with associated areas and percentages identified as either being under public ownership or other forms of conservation protection. Carolina Wood Pellets Map 2 provides a visualization of GAP land cover generalized to the macro ecosystem level, as well as outlines of major conservation lands located in the woodshed.

NatureServe analysis of G1-G3 ecological associations

Carolina Wood Pellets Table 2a lists fifty-seven specific ecological associations with G1 (critically imperiled), G2 (imperiled), or G3 (vulnerable) status that NatureServe analyses show as having at least one element occurrence within the Carolina Wood Pellets woodshed, including non-Wilderness National Forest areas. Twenty-six of these ecological associations are hardwood forest types that could potentially serve as a supply for woody biomass extraction.

Carolina Wood Pellets Table 2b lists fifty specific ecological associations with G1 (critically imperiled), G2 (imperiled), or G3 (vulnerable) status that NatureServe analyses show as having at least one element occurrence within the Carolina Wood Pellets woodshed, excluding all National Forests and other mapped conservation areas. Twenty-three of these ecological associations are hardwood forest types that could potentially serve as a supply for woody biomass extraction.

The lesser amounts of G1-G3 ecological associations found through overlays that excluded National Forest lands is likely due to a combination of an area effect (i.e., removal of National Forest area directly results in less occurrences), increased survey effort on public lands, and concentration of high conservation value areas within large patches of public land. Independently of land holding status, avoidance of G1-G3 ecological associations from biomass sourcing within the woodshed can be recommended as a minimum criterion for protecting and conserving biodiversity through sustainable forest management.

Woodshed competition

The competition overlay and network analysis for the Carolina Wood Pellets facility identified a total of five other facilities that may be expected to compete for woody biomass within at least some portion of the 75-mile woodshed area (Carolina Wood Pellets Map 3). This includes four pulp and paper mills and one biomass power producer. The most significant competitive demand pressure occurs in the northeast woodshed, and is almost entirely associated with the Evergreen Packaging paper mill located in Canton, NC. Generally low competitive demand is found throughout much of southern and western woodshed.

Biomass sourcing models and associated ecosystem risks

The harvest area objectives and associated suitability classes for all Caroline Wood Pellets sourcing models are provided in Carolina Wood Pellets Table 3.

The sourcing screens for Carolina Wood Pellets varied according to two factors: 1) allowing or disallowing riparian hardwood sourcing (HDW = allow riparian, HNW = disallow riparian); and 2) allowing or disallowing hardwood sourcing from non-Wilderness National Forest areas. Carolina Wood Pellet Maps 5-6 respectively show the HNW and HDW sourcing screens with National Forest areas allowed for harvest. Carolina Wood Pellet Maps 7-8 respectively show the HNW and HDW sourcing screens with non-Wilderness National Forest areas assumed as unavailable for harvest.

Carolina Wood Pellet Tables 4a-4c show habitat overlays for all HDW scenarios with sourcing allowed from non-Wilderness National Forest areas, while Carolina Wood Pellet Tables 5a-5c show the similar results for the HNW screen. Carolina Wood Pellets Tables 6a-6c show the habitat overlays for HDW scenarios with sourcing disallowed from all National Forest lands, while Carolina Wood Pellet Tables 7a-7c show the HNW scenarios with National Forest harvesting disallowed.

For all scenarios, the highest areas of sourcing are provided by Southern and Central Appalachian Oak Forests, which are the dominant forest type in the mountain province of this woodshed. A consistent result from all HDW scenario runs is that forested wetland and riparian areas represented approximately 2% or less of the land cover base. Removal of National Forest areas has the effect of "pushing" the sourcing model to further reaches of the woodshed (Carolina Wood Pellet Maps 7-8), even to the extent of indicating some potential for sourcing from piedmont forests at moderate and low demand intensities (i.e., HAO_6 and HAO_10).

Indicator species analysis

Carolina Wood Pellets Tables 8a-8c provide a summary comparison of indicator species habitat areas that overlay the harvest risk scenario results for the HDW and HNW sourcing screens with National Forest harvesting assumed as allowed. Carolina Wood Pellets Tables 9a-9c show the same HDW and HNW comparison with National Forest harvesting disallowed. Notably, the only species that shows any consistent or potentially substantive difference between the HDW and HNW screens is the northern cricket frog, which in all cases shows a higher habitat overlay with the HDW screen. This result is explained by the high dependence of northern cricket frogs on riparian and wetland habitat in this woodshed, and may serve as a proxy for potential impact on other riparian-dependent amphibians including the three-lined salamander and slimy salamander group. The lack of clear results for other indicator species considered here is generally a function of two factors: 1) the very small amount of riparian area being sourced in the HDW scenario; and 2) high utilization of upland hardwood habitats by each species. However, due to the very small amount of biomass sourcing that may be obtained from riparian areas relative the overall woodshed supply, exclusion of riparian wetlands and associated stream buffer corridors for woody biomass extraction emerges as a clear sustainable sourcing criterion for this woodshed.

A further comparison of indicator species habitat under the HNW screen with and without potential sourcing from non-Wilderness National Forest lands is presented in Carolina Wood Pellets Tables 10a-10c. For these analyses, three species show consistently higher potential habitat impact under scenarios where National Forest harvest is allowed: Swainson's warbler, Eastern spotted skunk, and timber rattlesnake. This result is generally explained by these species having habitat distributions that are more heavily concentrated in the mountainous regions of the Carolina Wood

Pellets woodshed. By contrast, four species show consistently higher potential habitat impact where National Forest harvest is disallowed: brown-headed nuthatch, northern bobwhite, long-tailed weasel, and northern cricket frog. Similarly, these latter results generally reflect species distributions that are more heavily concentrated in the piedmont and foothills regions.

Biomass sourcing for the Carolina Wood Pellets facility is currently based on residual sourcing of hardwoods with no assumption of land cover change. Based on this sourcing practice, habitat effects on all considered indicator species are likely to be subtle and will require further research to resolve in more detail.

Because the brown-headed nuthatch shows preference for mixed hardwood and pine sites with open understory in the piedmont (McComb et al. 1986; Land et al. 1989), it may be speculated that this species could potentially benefit from some thinning of understory and canopy hardwoods in mixed stands of pine in the piedmont and mountain regions of the Carolina Wood Pellets woodshed. To reiterate points made with other facilities, retention of pine snag matter in harvested areas is likely the most key habitat feature for this species (Wilson and Watts 1999).

The results for the northern bobwhite generally reflect the higher utilization of forest edges onto agricultural lands, most of which are located outside of National Forest land holdings. The northern bobwhite's high utilization of early successional and disturbed areas (Blank 2013; Janke and Gates 2013) may suggest that understory biomass removal on low slope areas in this woodshed may have the potential to promote habitat for this species. Similar to discussions in previous facilities, population responses of northern bobwhite to bioenergy procurement from the forestry landscape will likely be dependent on edge dynamics between early successional natural forest stands, pasture/grasslands, and agricultural lands at a broader landscape scale (Seckinger et al. 2008).

The Swainson's warbler is the species that shows the highest relative habitat area that overlays all risk scenarios. However, the Swainson's warbler can be attracted to moderate clearing disturbance within other unfragmented hardwood forest patches (Hunter et al. 1994), suggesting that careful biomass forestry removals at the level required by Carolina Wood Pellets could be implemented tin ways that are sensitive to the habitat needs of this species. However, there are unknowns about potential response of this species to novel sourcing practices for hardwood pellet production. For this reason, careful monitoring of local Swainson's warbler responses to biomass removals for the Carolina Wood Pellets facility may be warranted.

The Eastern spotted skunk consistently shows the highest overall area in at-risk habitat for all screens and harvest intensity scenarios. As noted in previous facility descriptions, Eastern spotted skunks have home ranges that require relatively large patches (~80 ha) of young hardwood forest s with high structural complexity in both the canopy and understory layers (Lesmeister et al. 2013). While specific factors behind the decline of this have long been regarded as unclear (Gompper and Hackett 2005), observations of the Eastern spotted skunk in the Ozark Plateau indicate that hollow, rotted logs are frequently used as den sites (McCullough and Fritzell 1984). Based on these observations, it may be speculated that heavy harvest of residual hardwood biomass could potentially have adverse effects on Eastern spotted skunk habitat in the Carolina Wood Pellets woodshed, particularly if it results in significant reductions of large downed, woody debris.

The long-tailed weasel shows a generally low amount of overlay with scenarios that allow for harvest of non-Wilderness National Forest areas, and much higher overlay in scenarios where no National Forest lands are used for biomass harvest. This result is a function of the long-tailed weasel having a much denser distribution in the piedmont sections of this woodshed. Although the long-tailed weasel is sensitive to fragmentation of the forest landscape through agricultural clearing (Gehring and Swihart 2004), it is not known to use snags or log cavities as a critical habitat resource (Loeb 1996). Impacts of biomass harvest on this species that do not result in land cover conversion can be regarded as unknown at this time.

Results for the timber rattlesnake consistently show higher overlay in scenarios where National Forest lands are assumed as available for biomass harvest. Because timber rattlesnakes frequently utilize fallen logs as an ambush habitat for capturing prey (Reinert et al. 1984), high levels of biomass removal from natural forest stands could potentially degrade the snake's habitat over time. As noted in discussions for other facilities, significant direct mortality when the poisonous snake is encountered by loggers and other site workers could also be a conservation concern (Reinert et al. 2011) for this species due to biomass sourcing in the Carolina Wood Pellets woodshed.

Discussion

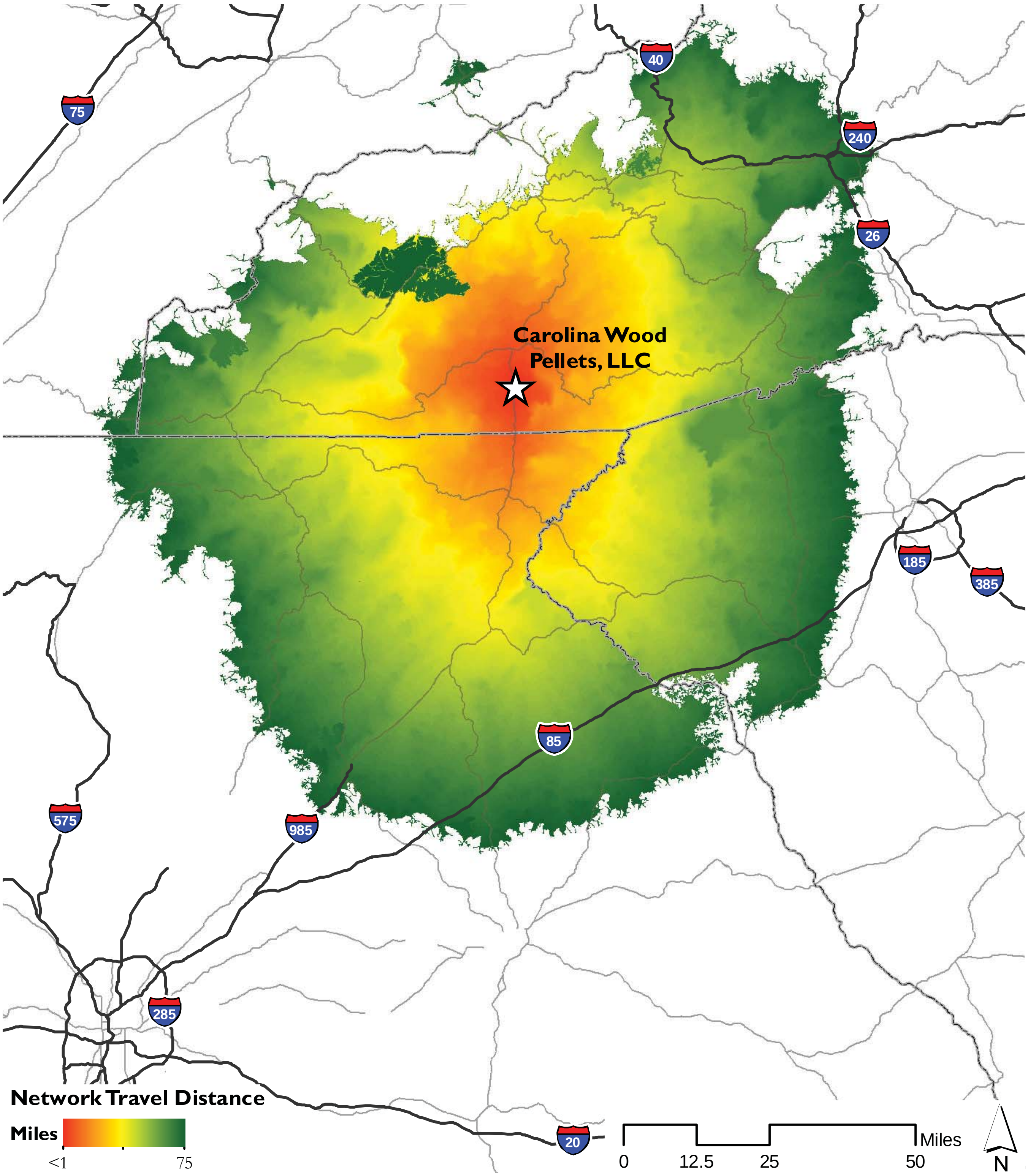
The Carolina Wood Pellets facility has by far the lowest biomass demand for any facility considered in this study. Due to this low relative biomass demand, a residuals-only sourcing strategy may be expected to have more long-term feasibility than for larger biomass energy facilities. However, large-scale residuals sourcing for this facility, particularly given the inherent network travel constraints and uncertainty about availability of material from National Forest lands, may still entail some important concerns for forest health and biodiversity.

For both the protection of the uniquely diverse amphibian populations in this woodshed (Petranka and Smith 2005; Crawford and Semlitsch 2007) and in support of other water quality benefits in mountain stream systems (Jones et al. 1999), an uplands-only sourcing policy that maintains upland buffer strips around stream riparian zones may be recommended as a sustainability criterion with high biodiversity protection values for the Carolina Wood Pellets woodshed. The very low percentage of riparian and wetland hardwood forests in this woodshed make this suggestion readily feasible from a biomass procurement standpoint.

A recent review by Vanderberg et al. (2012) provides a detailed evaluation of potential concerns and management guidelines for biomass utilization in the Appalachians. Vanderberg et al. (2012) note that downed woody matter (DWM) is positively correlated with site-level biodiversity in most Appalachian forest types, and that residuals-based woody bioenergy sourcing may be expected to reduce DWM accumulation from forestry lands. Particular importance of DWM is noted for sensitive and endangered flying mammals such as Indiana bats, northern long-eared bats, and northern flying squirrels. Research by Verschuyl et al. (2011) further suggests that salamander diversity and abundance is likely to be affected adversely by large-scale removal of biomass from Appalachian forests, although research by Brooks (1999) suggests little effects on salamander populations from hardwood forest thinning of up to 50-60% stand density.

The model results suggesting that exclusion of National Forest lands from the Carolina Wood Pellets woodshed procurement area would lead to sourcing from Piedmont hardwood forests is somewhat surprising. Further research into the long-term procurement practices of the facility would be necessary to confirm this model result. Notably, sensitivity to increased costs of up gradient transport of biomass from the Piedmont into the Mountain facilities was not considered in the transport factor for our biomass procurement model. Direct consideration of such costs were outside the scope of this analysis, but generally would be expected to exert long-term sourcing pressure away from the Piedmont and toward Appalachian hardwood forests.

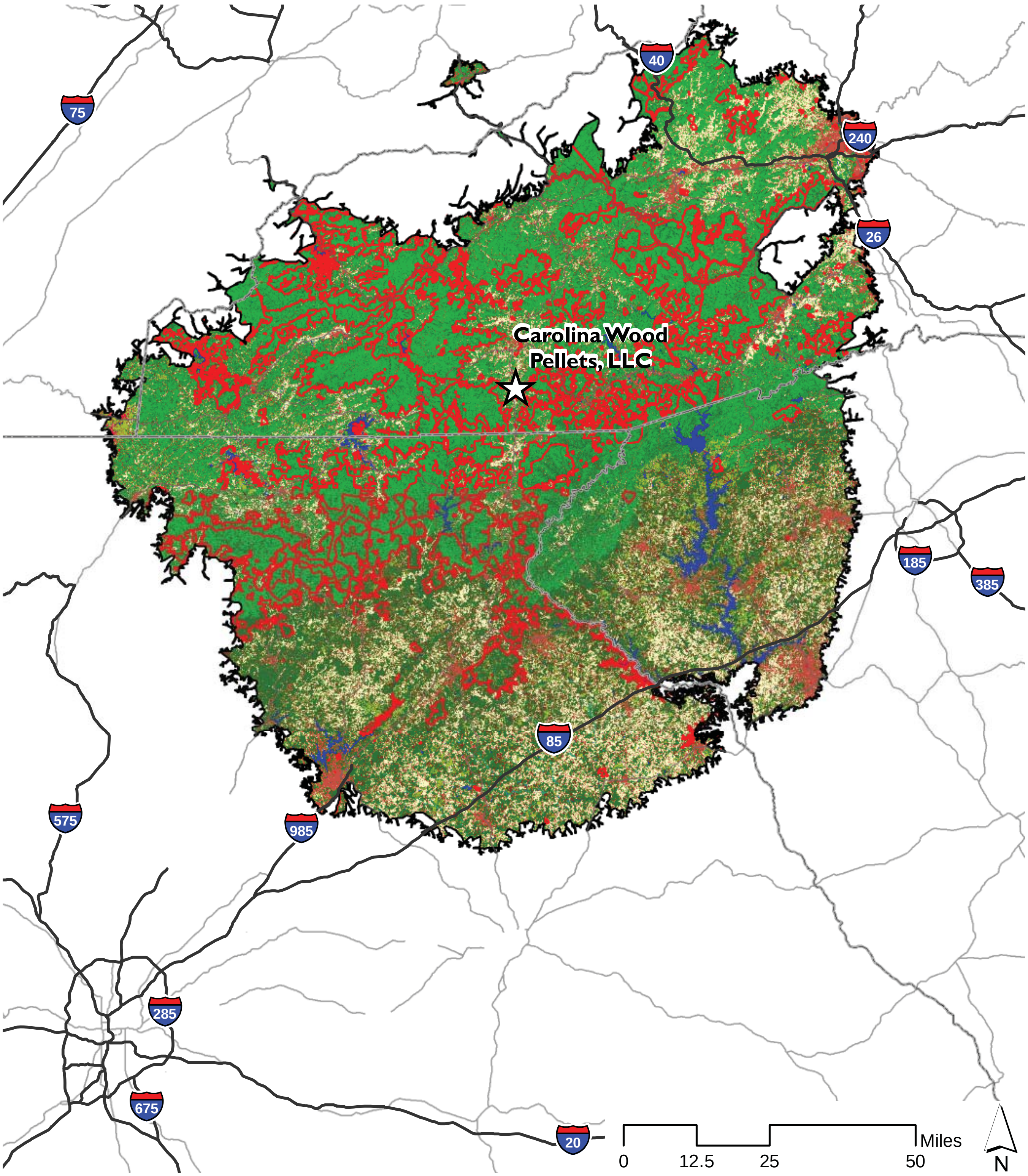
Figure 71. Carolina Wood Pellets Map 1: 75-mile Network Travel Distance and Woodshed Delineation



Carolina Wood Pellets Table 1. GAP Detailed Ecosystem Summary for 75-Mile Woodshed Area			
Land Cover Type (Detailed)	**Area**	**Protected**	**% Protected**
Southern and Central Appalachian Oak Forest	376,841	164,551	43.7%
Southern and Central Appalachian Oak Forest - Xeric	281,009	118,022	42.0%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	244,817	17,797	7.3%
Pasture/Hay	238,260	3,406	1.4%
Southern and Central Appalachian Cove Forest	135,655	57,178	42.1%
Developed, Open Space	130,775	11,642	8.9%
Disturbed/Successional - Grass/Forb Regeneration	76,849	2,010	2.6%
Evergreen Plantation or Managed Pine	65,476	5,156	7.9%
Southern Appalachian Low Mountain Pine Forest	62,754	18,949	30.2%
Central and Southern Appalachian Montane Oak Forest	53,983	31,713	58.7%
Southern Piedmont Mesic Forest	49,096	3,453	7.0%
Appalachian Hemlock-Hardwood Forest	42,455	18,443	43.4%
Disturbed/Successional - Shrub Regeneration	37,901	3,421	9.0%
Developed, Low Intensity	37,538	588	1.6%
Open Water (Fresh)	36,298	2,487	6.9%
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	30,580	3,045	10.0%
Central and Southern Appalachian Northern Hardwood Forest	27,353	21,805	79.7%
South-Central Interior Small Stream and Riparian	19,820	6,848	34.6%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	16,421	1,897	11.6%
Southern Piedmont Small Floodplain and Riparian Forest	14,236	631	4.4%
Harvested Forest-Shrub Regeneration	10,665	290	2.7%
Central and Southern Appalachian Spruce-Fir Forest	2,366	2,066	87.3%
South-Central Interior Large Floodplain - Forest Modifier	939	36	3.8%
Quarries, Mines, Gravel Pits and Oil Wells	890	42	4.7%
Southern Appalachian Grass and Shrub Bald - Herbaceous Modifier	522	371	71.1%
Southern Appalachian Grass and Shrub Bald - Shrub Modifier	503	496	98.6%
Southern Appalachian Montane Cliff	345	216	62.6%
Southern Ridge and Valley Dry Calcareous Forest - Pine modifier	278	115	41.4%
Southern Appalachian Rocky Summit	225	189	84.0%

Carolina Wood Pellets Table 1. GAP Detailed Ecosystem Summary for 75-Mile Woodshed Area

Figure 72. Carolina Wood Pellets Map 2: GAP Land Cover and Conservation Lands



Carolina Wood Pellet Map 2: Land Cover Characteristics Legend

Conservation Areas

GAP Ecosystem Class (NVC Macro)

- Southeastern North American Ruderal Forest & Plantation
- Central Oak-Hardwood & Pine Forest
- Eastern North American Ruderal Forest & Plantation
- Northern Mesic Hardwood & Conifer Forest
- Southern-Central Oak-Hardwood & Pine Forest
- Central Mesophytic Hardwood Forest
- Northern & Eastern Pine - Oak Forest, Woodland & Barrens
- Northern & Central Floodplain Forest & Scrub
- Southern Floodplain Hardwood Forest
- Appalachian & Lauentian Rocky Scrub and Meadow
- Atlantic & Gulf Coastal Plain Bog & Fen
- Eastern North American Freshwater Aquatic Vegetation
- Eastern North American Cliff & Rock Vegetation
- Eastern Temperate Summit & Flatrock
- Herbaceous Agricultural Vegetation
- Recently Disturbed or Modified
- Open Water
- Quarries, Mines, Gravel Pits and Oil Wells
- Developed & Urban

Figure 73. Carolina Wood Pellets Map 3: Travel Network Analysis & Locations of Competing Bioenergy and Pulp Mill Facilities

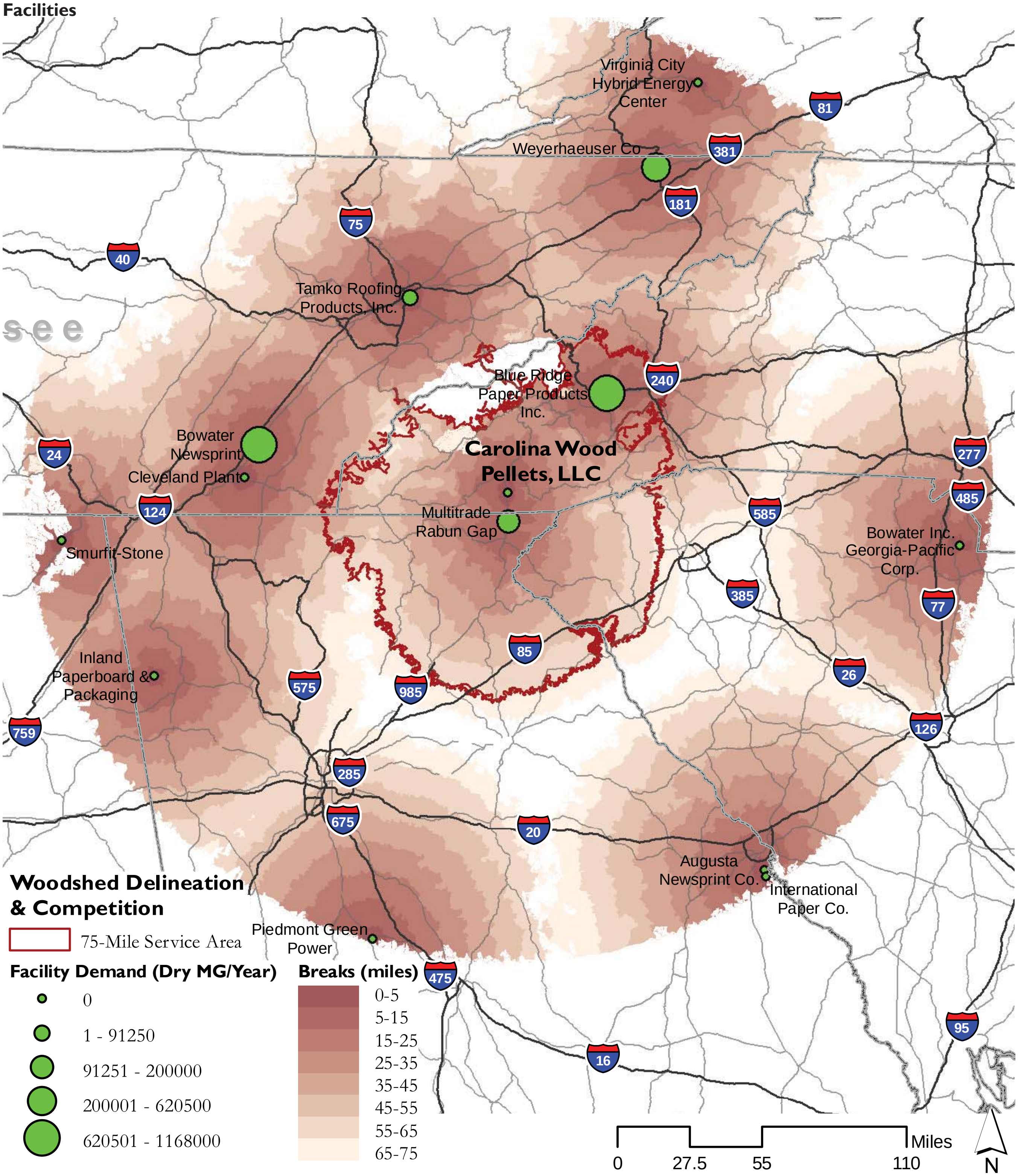


Figure 74. Carolina Wood Pellets Map 4: Competition Demand Strength Analysis, as Annual dry Mg / Network Travel Mile

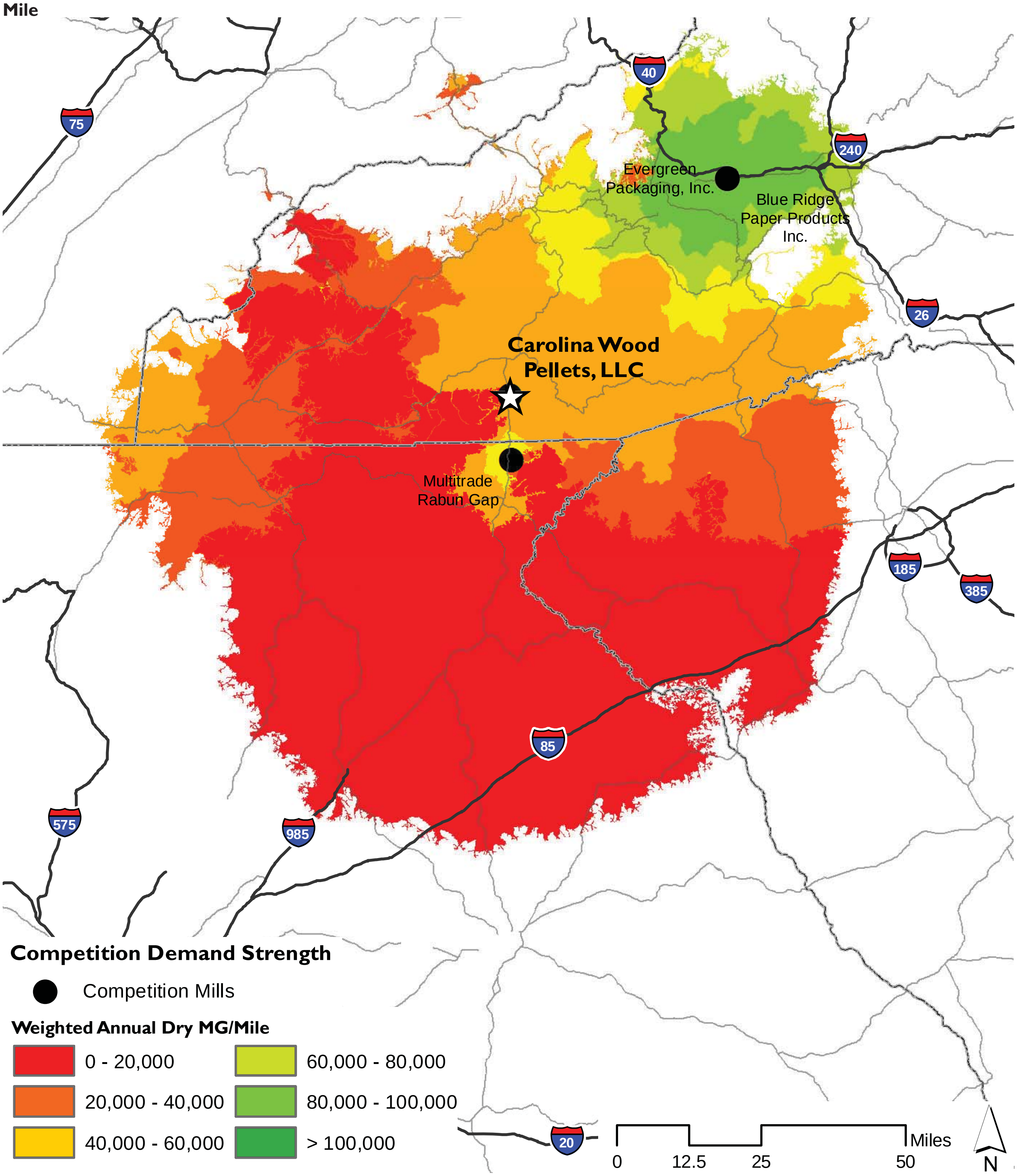


Figure 75. Carolina Wood Pellets Map 5: Composite Model of Hardwood no Wetlands (HNW) Sourcing Model Screen

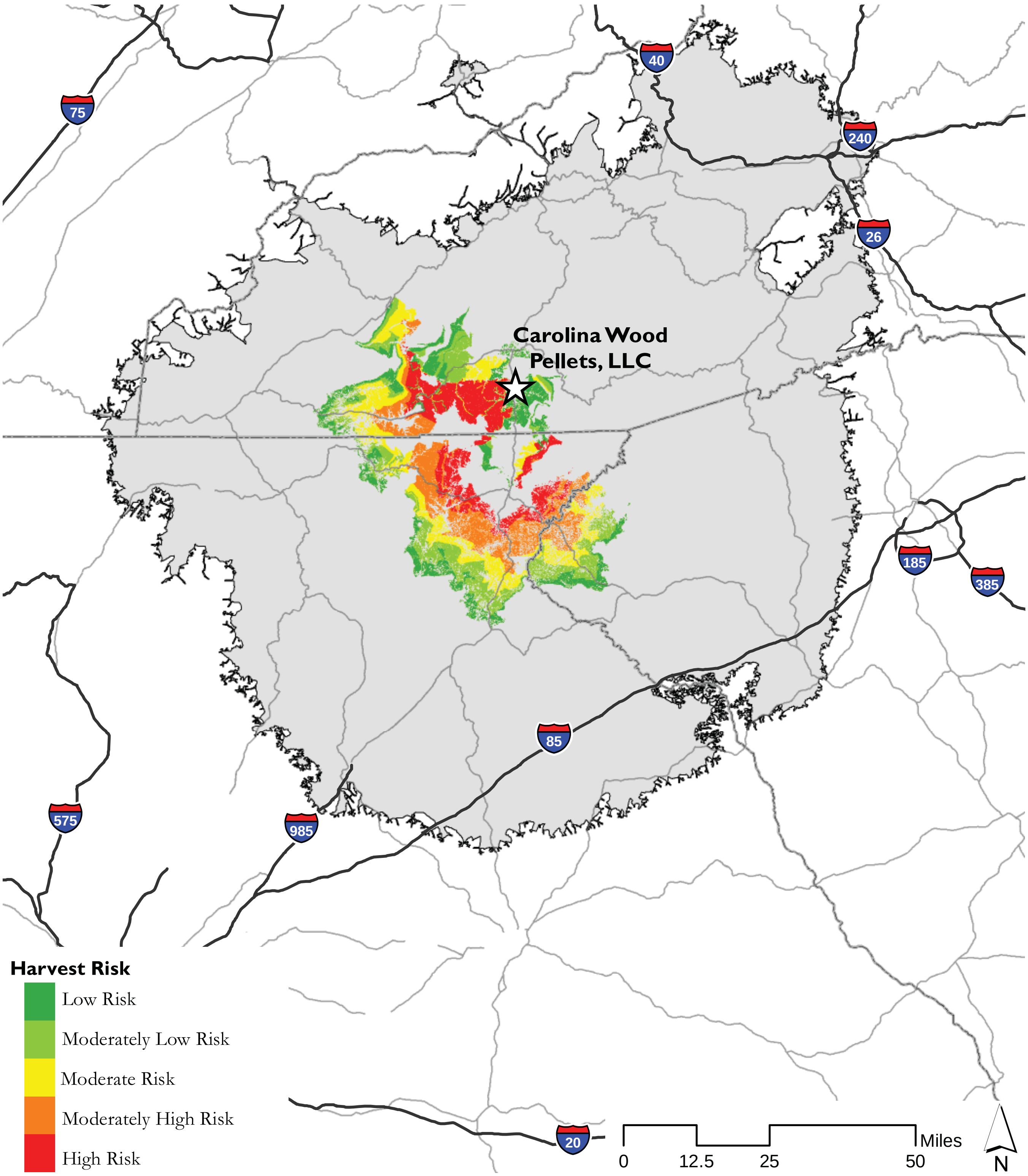


Figure 76. Carolina Wood Pellets Map 6: Composite Model of Hardwood (HDW) Sourcing Model Screen

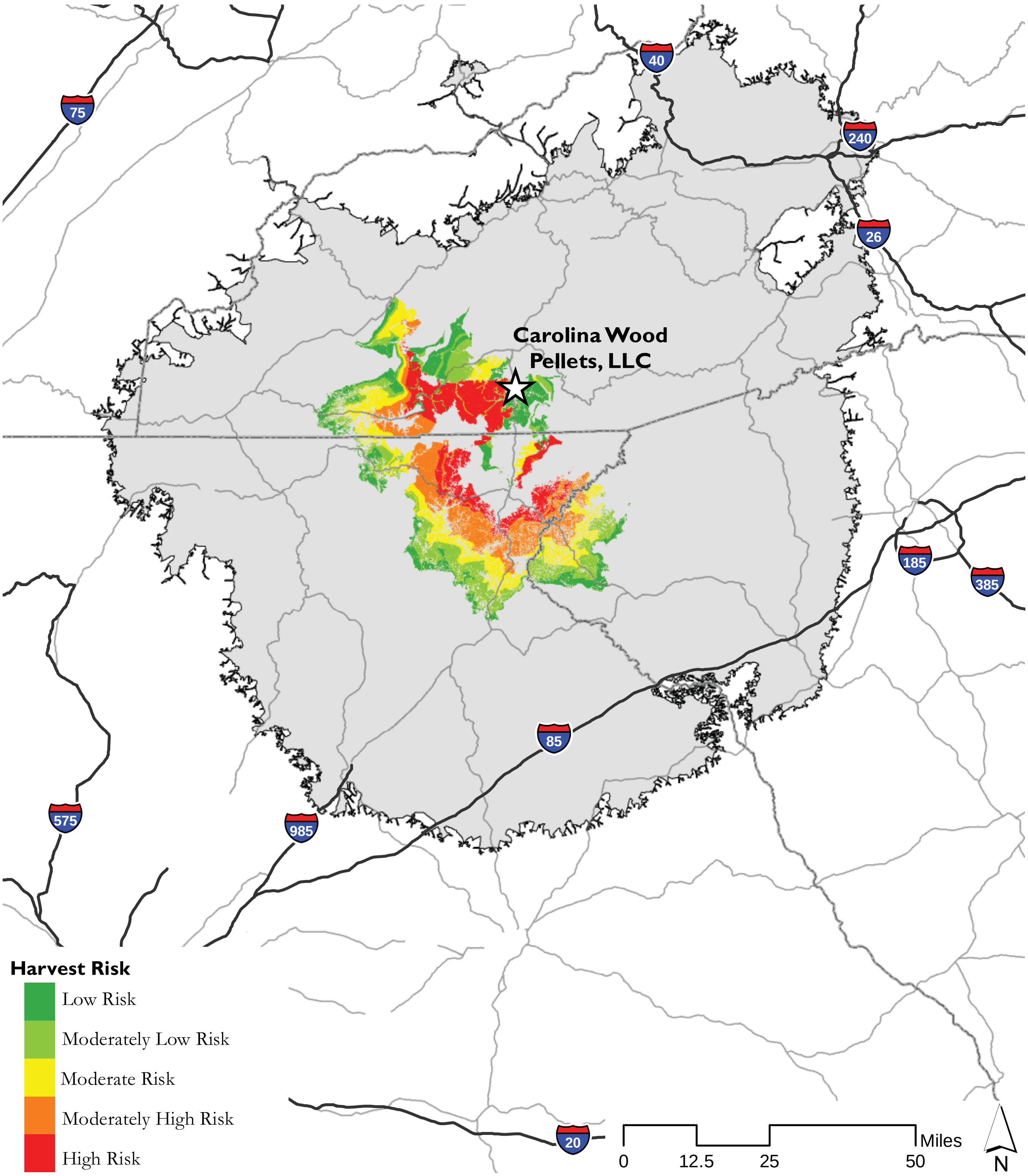


Figure 77. Carolina Wood Pellets Map 7: Composite Model of Hardwood no Wetlands (HNW) Sourcing Model Screen

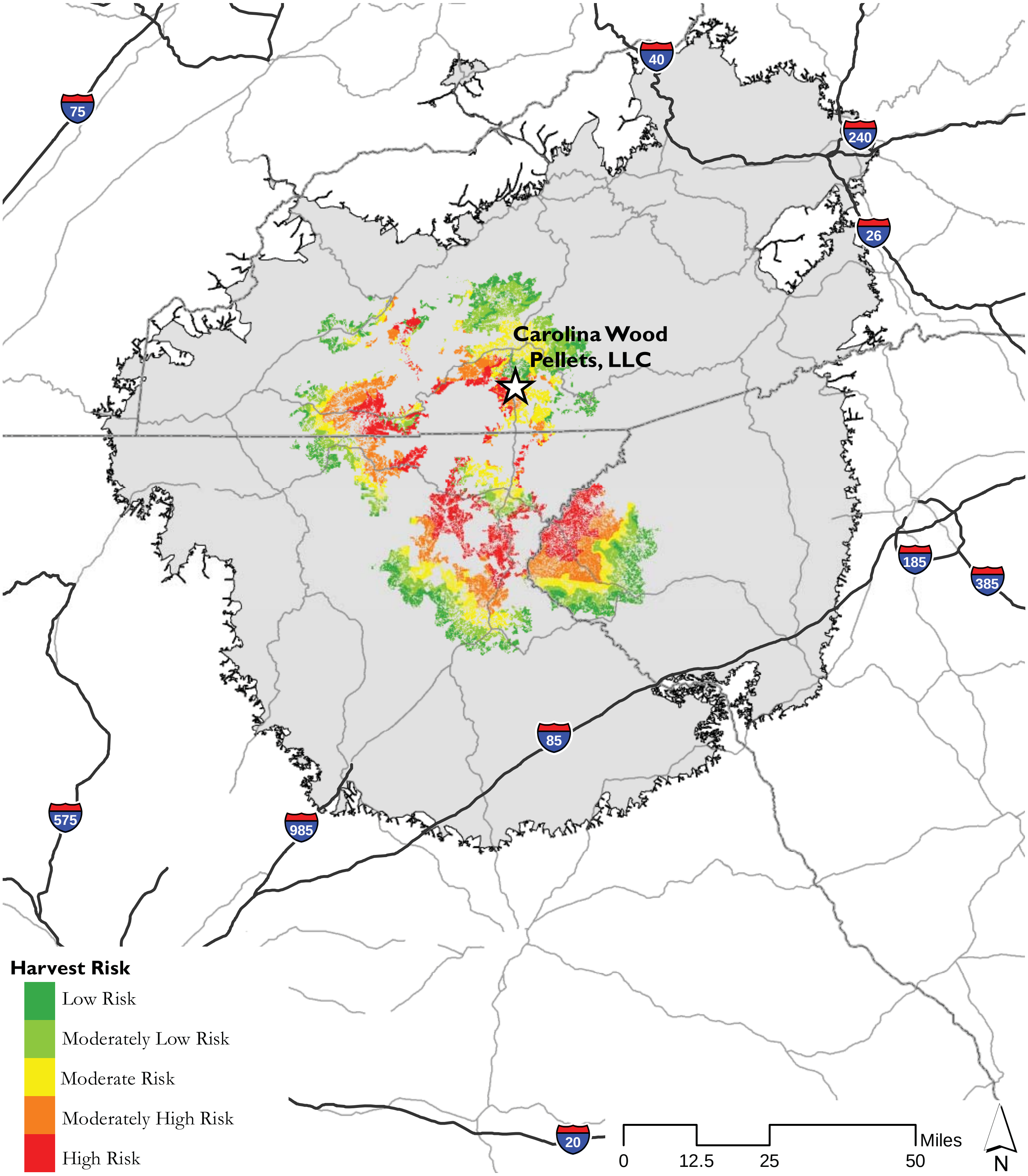
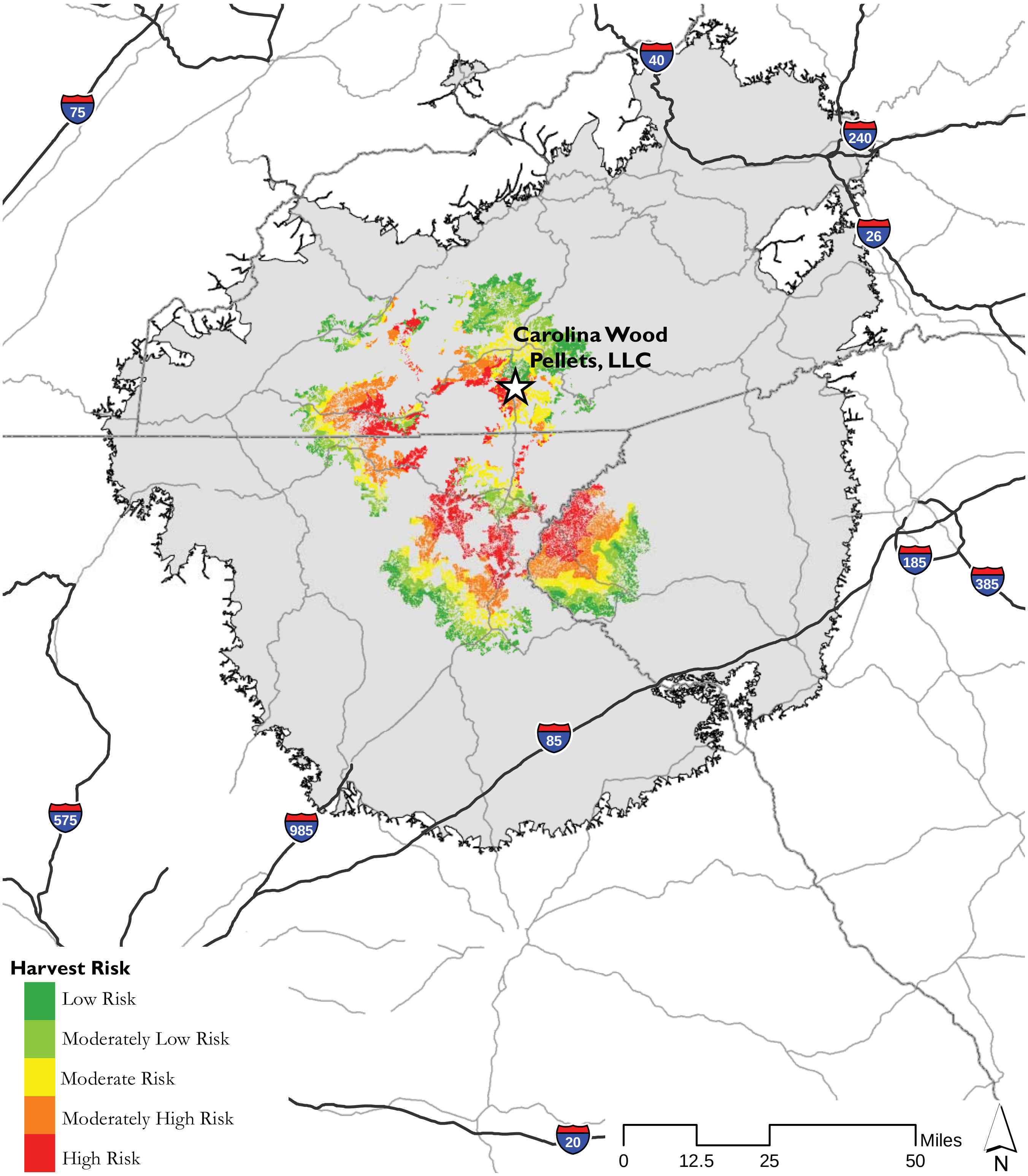


Figure 78. Carolina Wood Pellets Map 8: Composite Model of Hardwood (HDW) Sourcing Model Screen



Carolina Wood Pellets Table 2a. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, including non-Wilderness National Forests and excluding all other conservation areas			
Formal association name	**Common association name**	**Status**	**Woodshed occurrences**
Alnus serrulata - Viburnum nudum var. nudum - Chamaedaphne calyculata / Woodwardia areolata - Sarracenia rubra ssp. jonesii Shrubland	Southern Appalachian Bog (French Broad Valley Type)	G1	4
Picea rubens - (Abies fraseri) / (Rhododendron catawbiense, Rhododendron maximum) Forest	Red Spruce - Fraser Fir Forest (Evergreen Shrub Type)	G1	4
Rhododendron catawbiense - Pieris floribunda Shrubland	Heath Bald (Southern Mixed Type)	G1	2
Fagus grandifolia / Carex pensylvanica - Ageratina altissima var. roanensis Forest	Southern Appalachian Beech Gap	G1	2
Pinus rigida - Quercus alba / Sporobolus heterolepis - Andropogon gerardii Woodland	Southern Blue Ridge Ultramafic Outcrop Barrens (Pitch Pine Woodland Type)	G1	1
Alnus serrulata - Rhododendron arborescens / Sarracenia oreophila - Rhynchospora rariflora Shrubland	Southern Appalachian Low Mountain Seepage Bog	G1	1
Carex atlantica - Solidago patula var. patula - Lilium grayi / Sphagnum bartlettianum Herbaceous Vegetation	Southern Appalachian Herb Bog (Typic Type)	G1	1
Saxifraga michauxii - Carex misera - Oclemena acuminata - Solidago glomerata Herbaceous Vegetation	Southern Appalachian High-Elevation Rocky Summit (High Peak Type)	G1	1
Abies fraseri / Viburnum lantanoides / Dryopteris campyloptera - Oxalis montana / Hylocomium splendens Forest	Fraser Fir Forest (Deciduous Shrub Type)	G1	1
Fagus grandifolia / Ageratina altissima var. roanensis Forest	Southern Appalachian Beech Gap (North Slope Tall Herb Type)	G1	1
Pinus virginiana - Pinus rigida - Quercus stellata / Ceanothus americanus - Kalmia latifolia / Thalictrum revolutum Woodland	Low-Elevation Blue Ridge Serpentine Woodland	G1	1

Carolina Wood Pellets Table 2a. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, including non-Wilderness National Forests and excluding all other conservation areas

Carolina Wood Pellets Table 2a. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, including non-Wilderness National Forests and excluding all other conservation areas (cont…)

Formal association name	Common association name	Status	Woodshed occurrences
Picea rubens - (Betula alleghaniensis, Aesculus flava) / Rhododendron (maximum, catawbiense) Forest	Red Spruce - Northern Hardwood Forest (Shrub Type)	G1?	3
Alnus serrulata - Rhododendron viscosum - Rhododendron maximum / Juncus gymnocarpus - Chelone cuthbertii Shrubland	Southern Appalachian Bog (Low-Elevation Type)	G1G2	11
Alnus serrulata - Kalmia carolina - Rhododendron catawbiense - Spiraea alba / Carex folliculata - Lilium grayi Shrubland	Southern Appalachian Shrub Bog (Typic Type)	G1G2	2
(Quercus prinus) / Vaccinium pallidum / Schizachyrium scoparium - Danthonia spicata / Cladonia spp. Herbaceous Vegetation	Low-Elevation Acidic Glade (Grass Type)	G1G2	2
Tsuga caroliniana - (Tsuga canadensis) / Rhododendron maximum Forest	Carolina Hemlock Forest (Mesic Type)	G1G2	1
Tsuga canadensis - Acer rubrum - (Liriodendron tulipifera, Nyssa sylvatica) / Rhododendron maximum / Sphagnum spp. Forest	Swamp Forest-Bog Complex (Typic Type)	G2	16
Vittaria appalachiana - Heuchera parviflora var. parviflora - Houstonia serpyllifolia / Plagiochila spp. Herbaceous Vegetation	Southern Blue Ridge Spray Cliff	G2	13
Selaginella rupestris - Schizachyrium scoparium - Hylotelephium telephioides - Allium cernuum Herbaceous Vegetation	Low-Elevation Basic Glade (Montane Type)	G2	12
Saxifraga michauxii - Carex misera - Danthonia spicata - Krigia montana Herbaceous Vegetation	Southern Appalachian High-Elevation Rocky Summit (Typic Type)	G2	10
Carya (glabra, alba) - Fraxinus americana - (Juniperus virginiana var. virginiana) Woodland	Montane Basic Hardwood - (Red-cedar) Woodland	G2	7
Selaginella rupestris - Schizachyrium scoparium - Hypericum gentianoides - Bulbostylis capillaris Herbaceous Vegetation	Appalachian Low-Elevation Granitic Dome	G2	5

Carolina Wood Pellets Table 2a. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, including non-Wilderness National Forests and excluding all other conservation areas (cont…)

Formal association name	Common association name	Status	Woodshed occurrences
Carex gynandra - Platanthera clavellata - Drosera rotundifolia - Carex ruthii - Carex atlantica / Sphagnum spp. Herbaceous Vegetation	Southern Blue Ridge High-Elevation Seep (Sedge Type)	G2	5
Quercus alba / Kalmia latifolia Forest	Southern Blue Ridge High-Elevation White Oak Forest	G2	5
Pinus rigida - (Pinus pungens) / Rhododendron catawbiense - Kalmia latifolia / Galax urceolata Woodland	Blue Ridge Table Mountain Pine - Pitch Pine Woodland (High-Elevation Type)	G2	4
Quercus rubra / Carex pensylvanica - Ageratina altissima var. roanensis Forest	High-Elevation Red Oak Forest (Tall Herb Type)	G2	4
Quercus rubra / Rhododendron catawbiense - Rhododendron arborescens Woodland	Southern Blue Ridge Heath Bald Oak Woodland	G2	3
Picea rubens - (Abies fraseri) / Vaccinium erythrocarpum / Oxalis montana - Dryopteris campyloptera / Hylocomium splendens Forest	Red Spruce - Fraser Fir Forest (Deciduous Shrub Type)	G2	3
Rhododendron carolinianum Shrubland	Southern Appalachian Carolina Rhododendron Heath Bald	G2	1
Tsuga caroliniana - Pinus (rigida, pungens, virginiana) Forest	Carolina Hemlock Forest (Pine Type)	G2	1
Platanus occidentalis - Liriodendron tulipifera - Betula (alleghaniensis, lenta) / Alnus serrulata - Leucothoe fontanesiana Forest	Appalachian Montane Alluvial Forest	G2?	5
Picea rubens - (Tsuga canadensis) / Rhododendron maximum Saturated Forest	Swamp Forest - Bog Complex (Spruce Type)	G2?	2
Alnus serrulata - Lindera benzoin / Scutellaria lateriflora - Thelypteris noveboracensis Shrubland	Montane Low-Elevation Seep	G2?	1

Carolina Wood Pellets Table 2a. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, including non-Wilderness National Forests and excluding all other conservation areas (cont…)

Formal association name	Common association name	Status	Woodshed occurrences
Selaginella tortipila - Krigia montana - Houstonia longifolia Herbaceous Vegetation	Southern Appalachian Spike-moss Granitic Dome	G2G3	25
Betula alleghaniensis / Ribes glandulosum / Polypodium appalachianum Forest	Southern Appalachian Boulderfield Forest (Currant and Rockcap Fern Type)	G2G3	5
Betula alleghaniensis - Tilia americana var. heterophylla / Acer spicatum / Ribes cynosbati / Dryopteris marginalis Forest	Southern Appalachian Hardwood Rich Boulderfield Forest	G2G3	4
Quercus alba - Quercus coccinea - Quercus falcata / Kalmia latifolia - Vaccinium pallidum Forest	Appalachian Montane Oak-Hickory Forest (Low-Elevation Xeric Type)	G2G3	4
Peltandra virginica - Saururus cernuus - Boehmeria cylindrica / Climacium americanum Herbaceous Vegetation	Floodplain Pool	G2G3	3
Pinus strobus / Kalmia latifolia - (Vaccinium stamineum, Gaylussacia ursina) Forest	Southern Appalachian White Pine Forest	G2G3	2
Tilia americana var. heterophylla - Fraxinus americana - (Ulmus rubra) / Sanguinaria canadensis - (Aquilegia canadensis, Asplenium rhizophyllum) Forest	Southern Appalachian Cove Forest (Rich Foothills Type)	G2G3	2
Kalmia latifolia - Rhododendron catawbiense - (Gaylussacia baccata, Pieris floribunda, Vaccinium corymbosum) Shrubland	Southern Appalachian Mountain Laurel Bald	G2G3	1
Vitis aestivalis Vine-Shrubland	Montane Grape Opening	G2G3	1
Carex biltmoreana - Pycnanthemum spp. - Krigia montana Herbaceous Vegetation	Southern Appalachian Biltmore Sedge Granitic Dome	G2G3	1

Carolina Wood Pellets Table 2a. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, including non-Wilderness National Forests and excluding all other conservation areas (cont…)

Formal association name	Common association name	Status	Woodshed occurrences
Tsuga caroliniana / Kalmia latifolia - Rhododendron catawbiense Forest	Carolina Hemlock Forest (Typic Type)	G2	1
Quercus alba - Quercus rubra - Quercus prinus / Collinsonia canadensis - Podophyllum peltatum - Amphicarpaea bracteata Forest	Appalachian Montane Oak-Hickory Forest (Rich Type)	G3	13
Pinus pungens - Pinus rigida - (Quercus prinus) / Kalmia latifolia - Vaccinium pallidum Woodland	Blue Ridge Table Mountain Pine - Pitch Pine Woodland (Typic Type)	G3	11
Aesculus flava - Betula alleghaniensis - Acer saccharum / Acer spicatum / Caulophyllum thalictroides - Actaea podocarpa Forest	Southern Appalachian Northern Hardwood Forest (Rich Type)	G3	8
Impatiens (capensis, pallida) - Monarda didyma - Rudbeckia laciniata var. humilis Herbaceous Vegetation	Rich Montane Seep (High-Elevation Type)	G3	5
Sparganium americanum - (Sparganium erectum ssp. stoloniferum) - Epilobium leptophyllum Herbaceous Vegetation	Piedmont/Mountain Semipermanent Impoundment (Montane Boggy Type)	G3?	2
Saxifraga michauxii Herbaceous Vegetation	Low-Elevation Rocky Summit (Acidic Type)	G3?	2
Tsuga canadensis / Rhododendron maximum - (Clethra acuminata, Leucothoe fontanesiana) Forest	Southern Appalachian Eastern Hemlock Forest (Typic Type)	G3G4	14
Asplenium montanum - Heuchera villosa Felsic Cliff Sparse Vegetation	Appalachian Felsic Cliff	G3G4	11
Aesculus flava - Acer saccharum - (Fraxinus americana, Tilia americana var. heterophylla) / Hydrophyllum canadense - Solidago flexicaulis Forest	Southern Appalachian Rich Cove Forest (Montane Calcareous Type)	G3G4	11
Betula alleghaniensis - Fagus grandifolia - Aesculus flava / Viburnum lantanoides / Eurybia chlorolepis - Dryopteris intermedia Forest	Southern Appalachian Northern Hardwood Forest (Typic Type)	G3G4	9

Carolina Wood Pellets Table 2a. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, including non-Wilderness National Forests and excluding all other conservation areas (cont…)

Formal association name	Common association name	Status	Woodshed occurrences
Carex torta Herbaceous Vegetation	Rocky Bar and Shore (Twisted Sedge Type)	G3G4	1
Pinus echinata - Quercus (prinus, falcata) / Oxydendrum arboreum / Vaccinium pallidum Forest	Southern Blue Ridge Escarpment Shortleaf Pine - Oak Forest	G3G4	1
Pinus strobus - Quercus alba - (Carya alba) / Gaylussacia ursina Forest	Appalachian White Pine - Mesic Oak Forest	G3G4	1

Carolina Wood Pellets Table 2b. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, excluding all National Forests and other conservation areas			
Formal association name	**Common association name**	**Status**	**Woodshed occurrences**
Alnus serrulata - Viburnum nudum var. nudum - Chamaedaphne calyculata / Woodwardia areolata - Sarracenia rubra ssp. jonesii Shrubland	Southern Appalachian Bog (French Broad Valley Type)	G1	3
Picea rubens - (Abies fraseri) / (Rhododendron catawbiense, Rhododendron maximum) Forest	Red Spruce - Fraser Fir Forest (Evergreen Shrub Type)	G1	3
Rhododendron catawbiense - Pieris floribunda Shrubland	Heath Bald (Southern Mixed Type)	G1	2
Alnus serrulata - Rhododendron arborescens / Sarracenia oreophila - Rhynchospora rariflora Shrubland	Southern Appalachian Low Mountain Seepage Bog	G1	1
Carex atlantica - Solidago patula var. patula - Lilium grayi / Sphagnum bartlettianum Herbaceous Vegetation	Southern Appalachian Herb Bog (Typic Type)	G1	1
Saxifraga michauxii - Carex misera - Oclemena acuminata - Solidago glomerata Herbaceous Vegetation	Southern Appalachian High-Elevation Rocky Summit (High Peak Type)	G1	1
Fagus grandifolia / Carex pensylvanica - Ageratina altissima var. roanensis Forest	Southern Appalachian Beech Gap	G1	1
Fagus grandifolia / Ageratina altissima var. roanensis Forest	Southern Appalachian Beech Gap (North Slope Tall Herb Type)	G1	1
Pinus virginiana - Pinus rigida - Quercus stellata / Ceanothus americanus - Kalmia latifolia / Thalictrum revolutum Woodland	Low-Elevation Blue Ridge Serpentine Woodland	G1	1
Picea rubens - (Betula alleghaniensis, Aesculus flava) / Rhododendron (maximum, catawbiense) Forest	Red Spruce - Northern Hardwood Forest (Shrub Type)	G1?	3
Alnus serrulata - Rhododendron viscosum - Rhododendron maximum / Juncus gymnocarpus - Chelone cuthbertii Shrubland	Southern Appalachian Bog (Low-Elevation Type)	G1G2	3

Carolina Wood Pellets Table 2b. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, excluding all National Forests and excluding other conservation areas

Carolina Wood Pellets Table 2b. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, excluding all National Forests and other conservation areas (cont…)

Formal association name	Common association name	Status	Woodshed occurrences
Alnus serrulata - Kalmia carolina - Rhododendron catawbiense - Spiraea alba / Carex folliculata - Lilium grayi Shrubland	Southern Appalachian Shrub Bog (Typic Type)	G1G2	1
Tsuga caroliniana - (Tsuga canadensis) / Rhododendron maximum Forest	Carolina Hemlock Forest (Mesic Type)	G1G2	1
Selaginella rupestris - Schizachyrium scoparium - Hylotelephium telephioides - Allium cernuum Herbaceous Vegetation	Low-Elevation Basic Glade (Montane Type)	G2	12
Tsuga canadensis - Acer rubrum - (Liriodendron tulipifera, Nyssa sylvatica) / Rhododendron maximum / Sphagnum spp. Forest	Swamp Forest-Bog Complex (Typic Type)	G2	10
Vittaria appalachiana - Heuchera parviflora var. parviflora - Houstonia serpyllifolia / Plagiochila spp. Herbaceous Vegetation	Southern Blue Ridge Spray Cliff	G2	9
Carya (glabra, alba) - Fraxinus americana - (Juniperus virginiana var. virginiana) Woodland	Montane Basic Hardwood - (Red-cedar) Woodland	G2	6
Saxifraga michauxii - Carex misera - Danthonia spicata - Krigia montana Herbaceous Vegetation	Southern Appalachian High-Elevation Rocky Summit (Typic Type)	G2	6
Selaginella rupestris - Schizachyrium scoparium - Hypericum gentianoides - Bulbostylis capillaris Herbaceous Vegetation	Appalachian Low-Elevation Granitic Dome	G2	5
Pinus rigida - (Pinus pungens) / Rhododendron catawbiense - Kalmia latifolia / Galax urceolata Woodland	Blue Ridge Table Mountain Pine - Pitch Pine Woodland (High-Elevation Type)	G2	3
Quercus rubra / Carex pensylvanica - Ageratina altissima var. roanensis Forest	High-Elevation Red Oak Forest (Tall Herb Type)	G2	3
Quercus alba / Kalmia latifolia Forest	Southern Blue Ridge High-Elevation White Oak Forest	G2	3

Carolina Wood Pellets Table 2b. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, excluding all National Forests and other conservation areas (cont…)

Formal association name	Common association name	Status	Woodshed occurrences
Rhododendron carolinianum Shrubland	Southern Appalachian Carolina Rhododendron Heath Bald	G2	1
Quercus rubra / Rhododendron catawbiense - Rhododendron arborescens Woodland	Southern Blue Ridge Heath Bald Oak Woodland	G2	1
Tsuga caroliniana - Pinus (rigida, pungens, virginiana) Forest	Carolina Hemlock Forest (Pine Type)	G2	1
Picea rubens - (Abies fraseri) / Vaccinium erythrocarpum / Oxalis montana - Dryopteris campyloptera / Hylocomium splendens Forest	Red Spruce - Fraser Fir Forest (Deciduous Shrub Type)	G2	1
Platanus occidentalis - Liriodendron tulipifera - Betula (alleghaniensis, lenta) / Alnus serrulata - Leucothoe fontanesiana Forest	Appalachian Montane Alluvial Forest	G2?	5
Alnus serrulata - Lindera benzoin / Scutellaria lateriflora - Thelypteris noveboracensis Shrubland	Montane Low-Elevation Seep	G2?	1
Selaginella tortipila - Krigia montana - Houstonia longifolia Herbaceous Vegetation	Southern Appalachian Spike-moss Granitic Dome	G2G3	19
Betula alleghaniensis / Ribes glandulosum / Polypodium appalachianum Forest	Southern Appalachian Boulderfield Forest (Currant and Rockcap Fern Type)	G2G3	4
Betula alleghaniensis - Tilia americana var. heterophylla / Acer spicatum / Ribes cynosbati / Dryopteris marginalis Forest	Southern Appalachian Hardwood Rich Boulderfield Forest	G2G3	2
Pinus strobus / Kalmia latifolia - (Vaccinium stamineum, Gaylussacia ursina) Forest	Southern Appalachian White Pine Forest	G2G3	2
Peltandra virginica - Saururus cernuus - Boehmeria cylindrica / Climacium americanum Herbaceous Vegetation	Floodplain Pool	G2G3	2

Carolina Wood Pellets Table 2b. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, excluding all National Forests and other conservation areas (cont…)

Formal association name	Common association name	Status	Woodshed occurrences
Kalmia latifolia - Rhododendron catawbiense - (Gaylussacia baccata, Pieris floribunda, Vaccinium corymbosum) Shrubland	Southern Appalachian Mountain Laurel Bald	G2G3	1
Vitis aestivalis Vine-Shrubland	Montane Grape Opening	G2G3	1
Quercus alba - Quercus coccinea - Quercus falcata / Kalmia latifolia - Vaccinium pallidum Forest	Appalachian Montane Oak-Hickory Forest (Low-Elevation Xeric Type)	G2G3	1
Tilia americana var. heterophylla - Fraxinus americana - (Ulmus rubra) / Sanguinaria canadensis - (Aquilegia canadensis, Asplenium rhizophyllum) Forest	Southern Appalachian Cove Forest (Rich Foothills Type)	G2G3	1
Tsuga caroliniana / Kalmia latifolia - Rhododendron catawbiense Forest	Carolina Hemlock Forest (Typic Type)	G2	1
Quercus alba - Quercus rubra - Quercus prinus / Collinsonia canadensis - Podophyllum peltatum - Amphicarpaea bracteata Forest	Appalachian Montane Oak-Hickory Forest (Rich Type)	G3	11
Pinus pungens - Pinus rigida - (Quercus prinus) / Kalmia latifolia - Vaccinium pallidum Woodland	Blue Ridge Table Mountain Pine - Pitch Pine Woodland (Typic Type)	G3	5
Impatiens (capensis, pallida) - Monarda didyma - Rudbeckia laciniata var. humilis Herbaceous Vegetation	Rich Montane Seep (High-Elevation Type)	G3	3
Aesculus flava - Betula alleghaniensis - Acer saccharum / Acer spicatum / Caulophyllum thalictroides - Actaea podocarpa Forest	Southern Appalachian Northern Hardwood Forest (Rich Type)	G3	3
Sparganium americanum - (Sparganium erectum ssp. stoloniferum) - Epilobium leptophyllum Herbaceous Vegetation	Piedmont/Mountain Semipermanent Impoundment (Montane Boggy Type)	G3?	1

Carolina Wood Pellets Table 2b. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, excluding all National Forests and other conservation areas (cont…)

Formal association name	Common association name	Status	Woodshed occurrences
Saxifraga michauxii Herbaceous Vegetation	Low-Elevation Rocky Summit (Acidic Type)	G3?	1
Asplenium montanum - Heuchera villosa Felsic Cliff Sparse Vegetation	Appalachian Felsic Cliff	G3G4	9
Aesculus flava - Acer saccharum - (Fraxinus americana, Tilia americana var. heterophylla) / Hydrophyllum canadense - Solidago flexicaulis Forest	Southern Appalachian Rich Cove Forest (Montane Calcareous Type)	G3G4	9
Tsuga canadensis / Rhododendron maximum - (Clethra acuminata, Leucothoe fontanesiana) Forest	Southern Appalachian Eastern Hemlock Forest (Typic Type)	G3G4	8
Betula alleghaniensis - Fagus grandifolia - Aesculus flava / Viburnum lantanoides / Eurybia chlorolepis - Dryopteris intermedia Forest	Southern Appalachian Northern Hardwood Forest (Typic Type)	G3G4	7
Pinus echinata - Quercus (prinus, falcata) / Oxydendrum arboreum / Vaccinium pallidum Forest	Southern Blue Ridge Escarpment Shortleaf Pine - Oak Forest	G3G4	1
Pinus strobus - Quercus alba - (Carya alba) / Gaylussacia ursina Forest	Appalachian White Pine - Mesic Oak Forest	G3G4	1

Carolina Wood Pellets Table 3.
Harvest area objectives (HAO) and associated risk classes for spatial modeling

HAO	Hardwood (Ha)	Demand Intensity (Mg/ha/yr)	Harvest or Conversion Risk Class
1	15,400	4.80	High
2	30,800	2.40	
3	46,200	1.60	Moderately High
4	61,600	1.20	
5	77,000	0.96	Moderate
6	92,400	0.80	
7	107,800	0.69	Moderately Low
8	123,200	0.60	
9	138,600	0.53	Low
10	154,000	0.48	

Carolina Wood Pellets Table 3. Harvest area objectives and associated risk classes for spatial modeling

Carolina Wood Pellets Table 4a. GAP ecosystem overlay for hardwood biomass sourcing that includes wetland forests and non-Wilderness National Forest (HDW_NFA screen) with high biomass removal intensity (HAO_2)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing area %**
Appalachian Hemlock-Hardwood Forest	900	2,223	3.0%
Central and Southern Appalachian Montane Oak Forest	2,507	6,192	8.3%
Central and Southern Appalachian Northern Hardwood Forest	750	1,853	2.5%
South-Central Interior Small Stream and Riparian	423	1,045	1.4%
Southern and Central Appalachian Cove Forest	5,114	12,632	16.9%
Southern and Central Appalachian Oak Forest	12,400	30,628	41.1%
Southern and Central Appalachian Oak Forest - Xeric	8,107	20,024	26.8%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	-	-	0.0%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	-	-	0.0%
Southern Piedmont Mesic Forest	-	-	0.0%
Southern Piedmont Small Floodplain and Riparian Forest	-	-	0.0%

Carolina Wood Pellets Table 4a. GAP ecosystem overlay for hardwood biomass sourcing that includes HDW_NFA screen with HAO_2

Carolina Wood Pellets Table 4b. GAP ecosystem overlay for hardwood biomass sourcing that includes wetland forests and non-Wilderness National Forest (HDW_NFA screen) with moderate biomass removal intensity (HAO_6)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing area %**
Appalachian Hemlock-Hardwood Forest	4,264	10,532	4.8%
Central and Southern Appalachian Montane Oak Forest	4,114	10,162	4.6%
Central and Southern Appalachian Northern Hardwood Forest	854	2,109	1.0%
South-Central Interior Small Stream and Riparian	1,782	4,402	2.0%
Southern and Central Appalachian Cove Forest	14,893	36,786	16.8%
Southern and Central Appalachian Oak Forest	34,565	85,376	39.0%
Southern and Central Appalachian Oak Forest - Xeric	25,409	62,760	28.7%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	1,927	4,760	2.2%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	399	986	0.5%
Southern Piedmont Mesic Forest	330	815	0.4%
Southern Piedmont Small Floodplain and Riparian Forest	39	96	0.0%

Carolina Wood Pellets Table 4b. GAP ecosystem overlay for hardwood biomass sourcing that includes HDW_NFA screen with HAO_6

Carolina Wood Pellets Table 4c. GAP ecosystem overlay for hardwood biomass sourcing that includes wetland forests and non-Wilderness National Forest (HDW_NFA screen) with low biomass removal intensity (HAO_10)

GAP Ecosystem	Hectares	Acres	Sourcing area %
Appalachian Hemlock-Hardwood Forest	5,837	14,417	4.0%
Central and Southern Appalachian Montane Oak Forest	6,794	16,781	4.7%
Central and Southern Appalachian Northern Hardwood Forest	1,324	3,270	0.9%
South-Central Interior Small Stream and Riparian	2,737	6,760	1.9%
Southern and Central Appalachian Cove Forest	22,034	54,424	15.2%
Southern and Central Appalachian Oak Forest	54,493	134,598	37.5%
Southern and Central Appalachian Oak Forest - Xeric	39,647	97,928	27.3%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	9,117	22,519	6.3%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	1,334	3,295	0.9%
Southern Piedmont Mesic Forest	1,684	4,159	1.2%
Southern Piedmont Small Floodplain and Riparian Forest	231	571	0.2%

Carolina Wood Pellets Table 4c. GAP ecosystem overlay for hardwood biomass sourcing that includes HDW_NFA screen with HAO_10

Carolina Wood Pellets Table 5a. GAP ecosystem overlay for hardwood biomass sourcing that excludes wetland forests and includes non-Wilderness National Forest (HNW_NFA screen) with high biomass removal intensity (HAO_2)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Appalachian Hemlock-Hardwood Forest	920	2,272	3.0%
Central and Southern Appalachian Montane Oak Forest	2,507	6,192	8.3%
Central and Southern Appalachian Northern Hardwood Forest	750	1,853	2.5%
Southern and Central Appalachian Cove Forest	5,168	12,765	17.1%
Southern and Central Appalachian Oak Forest	12,560	31,023	41.6%
Southern and Central Appalachian Oak Forest	-	-	0.0%
Southern and Central Appalachian Oak Forest - Xeric	8,279	20,449	27.4%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	-	-	0.0%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	-	-	0.0%

Carolina Wood Pellets Table 5a. GAP ecosystem overlay for hardwood biomass sourcing that excludes wetland forests and includes HDW_NFA screen with HAO_2

Carolina Wood Pellets Table 5b. GAP ecosystem overlay for hardwood biomass sourcing that excludes wetland forests and includes non-Wilderness National Forest (HNW_NFA screen) with moderate biomass removal intensity (HAO_6)

GAP Ecosystem	Hectares	Acres	Sourcing %
Appalachian Hemlock-Hardwood Forest	4,317	10,663	4.9%
Central and Southern Appalachian Montane Oak Forest	4,230	10,448	4.8%
Central and Southern Appalachian Northern Hardwood Forest	854	2,109	1.0%
Southern and Central Appalachian Cove Forest	15,170	37,470	17.1%
Southern and Central Appalachian Oak Forest	35,331	87,268	39.9%
Southern and Central Appalachian Oak Forest	330	815	0.4%
Southern and Central Appalachian Oak Forest - Xeric	25,995	64,208	29.4%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	1,927	4,760	2.2%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	399	986	0.5%

Carolina Wood Pellets Table 5b. GAP ecosystem overlay for hardwood biomass sourcing that excludes wetland forests and includes HDW_NFA screen with HAO_6

Carolina Wood Pellets Table 5c. GAP ecosystem overlay for hardwood biomass sourcing that excludes wetland forests and includes non-Wilderness National Forest (HNW_NFA screen) with low biomass removal intensity (HAO_10)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Appalachian Hemlock-Hardwood Forest	5,863	14,482	4.1%
Central and Southern Appalachian Montane Oak Forest	6,818	16,840	4.7%
Central and Southern Appalachian Northern Hardwood Forest	1,408	3,478	1.0%
Southern and Central Appalachian Cove Forest	22,123	54,644	15.3%
Southern and Central Appalachian Oak Forest	54,802	135,361	37.9%
Southern and Central Appalachian Oak Forest	1,880	4,644	1.3%
Southern and Central Appalachian Oak Forest - Xeric	39,873	98,486	27.6%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	10,383	25,646	7.2%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	1,509	3,727	1.0%

Carolina Wood Pellets Table 5c. GAP ecosystem overlay for hardwood biomass sourcing that excludes wetland forests and includes HDW_NFA screen with HAO_10

Carolina Wood Pellets Table 6a. GAP ecosystem overlay for hardwood biomass sourcing that includes wetland forests and excludes all National Forest (HDW_NNF screen) with high biomass removal intensity (HAO_2)

GAP Ecosystem	Hectares	Acres	Sourcing area %
Appalachian Hemlock-Hardwood Forest	1,790	4,421	6.3%
Central and Southern Appalachian Montane Oak Forest	348	860	1.2%
South-Central Interior Small Stream and Riparian	779	1,924	2.7%
Southern and Central Appalachian Cove Forest	4,892	12,083	17.3%
Southern and Central Appalachian Oak Forest	10,957	27,064	38.6%
Southern and Central Appalachian Oak Forest - Xeric	8,525	21,057	30.1%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	761	1,880	2.7%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	147	363	0.5%
Southern Piedmont Mesic Forest	136	336	0.5%
Southern Piedmont Small Floodplain and Riparian Forest	19	47	0.1%

Carolina Wood Pellets Table 6a. GAP ecosystem overlay for hardwood biomass sourcing that includes wetland forests and excludes HDW_NFA screen with HAO_2

Carolina Wood Pellets Table 6b. GAP ecosystem overlay for hardwood biomass sourcing that includes wetland forests and excludes all National Forest (HDW_NNF screen) with moderate biomass removal intensity (HAO_6)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Appalachian Hemlock-Hardwood Forest	3,596	8,882	4.4%
Central and Southern Appalachian Montane Oak Forest	1,332	3,290	1.6%
South-Central Interior Small Stream and Riparian	1,843	4,552	2.2%
Southern and Central Appalachian Cove Forest	11,818	29,190	14.3%
Southern and Central Appalachian Oak Forest	28,232	69,733	34.3%
Southern and Central Appalachian Oak Forest - Xeric	21,449	52,979	26.0%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	10,706	26,444	13.0%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	1,205	2,976	1.5%
Southern Piedmont Mesic Forest	1,923	4,750	2.3%
Southern Piedmont Small Floodplain and Riparian Forest	322	795	0.4%

Carolina Wood Pellets Table 6b. GAP ecosystem overlay for hardwood biomass sourcing that includes wetland forests and excludes HDW_NFA screen with HAO_6

Carolina Wood Pellets Table 6c. GAP ecosystem overlay for hardwood biomass sourcing that includes wetland forests and excludes all National Forest (HDW_NNF screen) with low biomass removal intensity (HAO_10)

GAP Ecosystem	Hectares	Acres	Sourcing %
Appalachian Hemlock-Hardwood Forest	4,821	11,908	3.6%
Central and Southern Appalachian Montane Oak Forest	2,420	5,977	1.8%
South-Central Interior Small Stream and Riparian	2,606	6,437	1.9%
Southern and Central Appalachian Cove Forest	17,393	42,961	13.0%
Southern and Central Appalachian Oak Forest	42,438	104,822	31.7%
Southern and Central Appalachian Oak Forest - Xeric	32,726	80,833	24.4%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	24,106	59,542	18.0%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	2,315	5,718	1.7%
Southern Piedmont Mesic Forest	4,448	10,987	3.3%
Southern Piedmont Small Floodplain and Riparian Forest	802	1,981	0.6%

Carolina Wood Pellets Table 6c. GAP ecosystem overlay for hardwood biomass sourcing that includes wetland forests and excludes HDW_NFA screen with HAO_10

Carolina Wood Pellets Table 7a. GAP ecosystem overlay for hardwood biomass sourcing that excludes wetland forests and all National Forest (HNW_NNF screen) with high biomass removal intensity (HAO_2)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing area %**
Appalachian Hemlock-Hardwood Forest	1,890	4,668	6.7%
Central and Southern Appalachian Montane Oak Forest	348	860	1.2%
Southern and Central Appalachian Cove Forest	5,052	12,478	17.8%
Southern and Central Appalachian Oak Forest	11,244	27,773	39.7%
Southern and Central Appalachian Oak Forest	136	336	0.5%
Southern and Central Appalachian Oak Forest - Xeric	8,739	21,585	30.9%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	761	1,880	2.7%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	147	363	0.5%

Carolina Wood Pellets Table 7a. GAP ecosystem overlay for hardwood biomass sourcing that excludes wetland forests and HDW_NFA screen with HAO_2

Carolina Wood Pellets Table 7b. GAP ecosystem overlay for hardwood biomass sourcing that excludes wetland forests and all National Forest (HNW_NNF screen) with moderate biomass removal intensity (HAO_6)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Appalachian Hemlock-Hardwood Forest	3,656	9,030	4.4%
Central and Southern Appalachian Montane Oak Forest	1,352	3,339	1.6%
Southern and Central Appalachian Cove Forest	12,201	30,136	14.8%
Southern and Central Appalachian Oak Forest	29,057	71,771	35.3%
Southern and Central Appalachian Oak Forest	1,923	4,750	2.3%
Southern and Central Appalachian Oak Forest - Xeric	22,158	54,730	26.9%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	10,706	26,444	13.0%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	1,205	2,976	1.5%

Carolina Wood Pellets Table 7b. GAP ecosystem overlay for hardwood biomass sourcing that excludes wetland forests and HDW_NFA screen with HAO_6

Carolina Wood Pellets Table 7c. GAP ecosystem overlay for hardwood biomass sourcing that excludes wetland forests and all National Forest (HNW_NNF screen) with low biomass removal intensity (HAO_10)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Appalachian Hemlock-Hardwood Forest	4,935	12,189	3.7%
Central and Southern Appalachian Montane Oak Forest	2,549	6,296	1.9%
Southern and Central Appalachian Cove Forest	17,710	43,744	13.3%
Southern and Central Appalachian Oak Forest	43,196	106,694	32.4%
Southern and Central Appalachian Oak Forest	4,635	11,448	3.5%
Southern and Central Appalachian Oak Forest - Xeric	33,338	82,345	25.0%
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	24,775	61,194	18.6%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	2,372	5,859	1.8%

Carolina Wood Pellets Table 7c. GAP ecosystem overlay for hardwood biomass sourcing that excludes wetland forests and HDW_NFA screen with HAO_10

Carolina Wood Pellets Table 8a. GAP species distribution overlay comparison for sourcing from hardwood forests that include wetlands (HDW screen) versus sourcing only from upland hardwood forests (HNW screen) with high biomass removal intensity (HAO_2), National Forest harvest allowed (NFA)

Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with HDW screen (% of woodshed habitat)	Hectares of habitat overlay with HNW screen (% of woodshed habitat)	Hectares of Increased habitat overlay with HDW	% Increase in habitat overlay with HDW
Brown-headed Nuthatch	165,176	983 (0.6%)	997 (0.6%)	-14	-1.4%
Northern Bobwhite	491,191	699 (0.1%)	690 (0.1%)	9	1.3%
Swainson's Warbler	853,883	21,845 (2.6%)	21,861 (2.6%)	-16	0.0%
Eastern Spotted Skunk	1,566,225	29,111 (1.9%)	29,107 (1.9%)	4	0.0%
Long-tailed Weasel	825,452	4,145 (0.5%)	4,133 (0.5%)	12	0.3%
Northern Cricket Frog	69,055	191 (0.3%)	180 (0.3%)	11	6.1%
Timber Rattlesnake	1,507,844	28,176 (1.9%)	28,202 (1.9%)	-26	0.0%

Carolina Wood Pellets Table 8a. GAP species distribution overlay comparison for sourcing from hardwood forests that include HDW screen versus sourcing only from HNW screen with HAO_2, NFA

Carolina Wood Pellets Table 8b. GAP species distribution overlay comparison for sourcing from hardwood forests that include wetlands (HDW screen) versus sourcing only from upland hardwood forests (HNW screen) with moderate biomass removal intensity (HAO_6), National Forest harvest allowed (NFA)					
Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with HDW screen (% of woodshed habitat)	Hectares of habitat overlay with HNW screen (% of woodshed habitat)	Hectares of Increased habitat overlay with HDW	% Increase in habitat overlay with HDW
Brown-headed Nuthatch	165,176	6,502 (3.9%)	6,351 (3.8%)	151	2.4%
Northern Bobwhite	491,191	5,083 (1.0%)	4,933 (1.0%)	150	3.0%
Swainson's Warbler	853,883	68,867 (8.1%)	69,119 (8.1%)	-252	-0.4%
Eastern Spotted Skunk	1,566,225	83,974 (5.4%)	84,121 (5.4%)	-147	-0.2%
Long-tailed Weasel	825,452	18,138 (2.2%)	17,951 (2.1%)	187	1.0%
Northern Cricket Frog	69,055	818 (1.2%)	744 (1.1%)	74	9.9%
Timber Rattlesnake	1,507,844	78,120 (5.2%)	78,587 (5.2%)	-467	-0.6%

Carolina Wood Pellets Table 8b. GAP species distribution overlay comparison for sourcing from hardwood forests that include HDW screen versus sourcing only from HNW screen with HAO_6, NFA

Carolina Wood Pellets Table 8c. GAP species distribution overlay comparison for sourcing from hardwood forests that include wetlands (HDW screen) versus sourcing only from upland hardwood forests (HNW screen) with low biomass removal intensity (HAO_10), National Forest harvest allowed (NFA)

Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with HDW screen (% of woodshed habitat)	Hectares of habitat overlay with HNW screen (% of woodshed habitat)	Hectares of Increased habitat overlay with HDW	% Increase in habitat overlay with HDW
Brown-headed Nuthatch	165,176	10,842 (6.6%)	11,014 (6.7%)	-172	-1.6%
Northern Bobwhite	491,191	10,445 (2.1%)	10,814 (2.2%)	-369	-3.4%
Swainson's Warbler	853,883	113,564 (13.3%)	112,880 (13.2%)	684	0.6%
Eastern Spotted Skunk	1,566,225	138,246 (8.8%)	138,038 (8.8%)	208	0.2%
Long-tailed Weasel	825,452	35,234 (4.3%)	35,722 (4.3%)	-488	-1.4%
Northern Cricket Frog	69,055	1,602 (2.3%)	1,517 (2.2%)	85	5.6%
Timber Rattlesnake	1,507,844	129,827 (8.6%)	130,102 (8.6%)	-275	-0.2%

Carolina Wood Pellets Table 8b. GAP species distribution overlay comparison for sourcing from hardwood forests that include HDW screen versus sourcing only from HNW screen with HAO_10, NFA allowed

Carolina Wood Pellets Table 9a. GAP species distribution overlay comparison for sourcing from hardwood forests that include wetlands (HDW screen) versus sourcing only from upland hardwood forests (HNW screen) with high biomass removal intensity (HAO_2), National Forest harvest not allowed (NNF)					
Species	**Total woodshed habitat, as hectares**	**Hectares of habitat overlay with HDW screen (% of woodshed habitat)**	**Hectares of habitat overlay with HNW screen (% of woodshed habitat)**	**Hectares of Increased habitat overlay with HDW**	**% Increase in habitat overlay with HDW**
Brown-headed Nuthatch	165,176	3,190 (1.9%)	3,232 (2.0%)	-42	-1.3%
Northern Bobwhite	491,191	3,437 (0.7%)	3,329 (0.7%)	108	3.1%
Swainson's Warbler	853,883	21,553 (2.5%)	21,725 (2.5%)	-172	-0.8%
Eastern Spotted Skunk	1,566,225	26,455 (1.7%)	26,503 (1.7%)	-48	-0.2%
Long-tailed Weasel	825,452	10,859 (1.3%)	10,630 (1.3%)	229	2.2%
Northern Cricket Frog	69,055	580 (0.8%)	525 (0.8%)	55	10.5%
Timber Rattlesnake	1,507,844	23,326 (1.5%)	23,428 (1.6%)	-102	-0.4%

Carolina Wood Pellets Table 9a. GAP species distribution overlay comparison for sourcing from hardwood forests that include HDW screen versus sourcing only from HNW screen with HAO_2, NNF

Carolina Wood Pellets Table 9b. GAP species distribution overlay comparison for sourcing from hardwood forests that include wetlands (HDW screen) versus sourcing only from upland hardwood forests (HNW screen) with moderate biomass removal intensity (HAO_6), National Forest harvest not allowed (NNF)

Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with HDW screen (% of woodshed habitat)	Hectares of habitat overlay with HNW screen (% of woodshed habitat)	Hectares of Increased habitat overlay with HDW	% Increase in habitat overlay with HDW
Brown-headed Nuthatch	165,176	8,381 (5.1%)	8,226 (5.0%)	155	1.9%
Northern Bobwhite	491,191	12,467 (2.5%)	12,373 (2.5%)	94	0.8%
Swainson's Warbler	853,883	63,682 (7.5%)	63,923 (7.5%)	-241	-0.4%
Eastern Spotted Skunk	1,566,225	77,978 (5.0%)	78,130 (5.0%)	-152	-0.2%
Long-tailed Weasel	825,452	36,538 (4.4%)	36,550 (4.4%)	-12	0.0%
Northern Cricket Frog	69,055	1,993 (2.9%)	1,832 (2.7%)	161	8.8%
Timber Rattlesnake	1,507,844	71,416 (4.7%)	71,875 (4.8%)	-459	-0.6%

Carolina Wood Pellets Table 9b. GAP species distribution overlay comparison for sourcing from hardwood forests that include HDW screen versus sourcing only from HNW screen with HAO_6, NNF

Carolina Wood Pellets Table 9c. GAP species distribution overlay comparison for sourcing from hardwood forests that include wetlands (HDW screen) versus sourcing only from upland hardwood forests (HNW screen) with low biomass removal intensity (HAO_10), National Forest harvest not allowed (NNF)

Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with HDW screen (% of woodshed habitat)	Hectares of habitat overlay with HNW screen (% of woodshed habitat)	Hectares of Increased habitat overlay with HDW	% Increase in habitat overlay with HDW
Brown-headed Nuthatch	165,176	13,135 (8.0%)	13,197 (8.0%)	-62	0.0%
Northern Bobwhite	491,191	24,037 (4.9%)	24,040 (4.9%)	-3	0.0%
Swainson's Warbler	853,883	100,823 (11.8%)	100,361 (11.8%)	462	0.5%
Eastern Spotted Skunk	1,566,225	127,334 (8.1%)	127,298 (8.1%)	39	0.0%
Long-tailed Weasel	825,452	65,330 (7.9%)	65,593 (7.9%)	-263	-0.4%
Northern Cricket Frog	69,055	3,511 (5.1%)	3,227 (4.7%)	284	8.8%
Timber Rattlesnake	1,507,844	118,779 (7.9%)	119,143 (7.9%)	-364	-0.3%

Carolina Wood Pellets Table 9c. GAP species distribution overlay comparison for sourcing from hardwood forests that include HDW screen versus sourcing only from HNW screen with HAO_10, NNF

Carolina Wood Pellets Table 10a. GAP species distribution overlay comparison for non-Wilderness National Forest harvest allowed (NFA) versus exclude all National Forests (NNF) with high biomass removal intensity (HAO_2), wetlands excluded (HNW screen)

Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with NFA screen (% of woodshed habitat)	Hectares of habitat overlay with NNF screen (% of woodshed habitat)	Hectares of Increased habitat overlay with NFA	% Increase in habitat overlay with NFA
Brown-headed Nuthatch	165,176	997 (0.6%)	3,232 (2.0%)	-2,238	-69.2%
Northern Bobwhite	491,191	690 (0.1%)	3,329 (0.7%)	-2,639	-79.3%
Swainson's Warbler	853,883	21,861 (2.6%)	21,725 (2.5%)	136	0.6%
Eastern Spotted Skunk	1,566,225	29,107 (1.9%)	26,503 (1.7%)	2,601	9.8%
Long-tailed Weasel	825,452	4,133 (0.5%)	10,630 (1.3%)	-6,497	-61.1%
Northern Cricket Frog	69,055	180 (0.3%)	525 (0.8%)	-705	-134.3%
Timber Rattlesnake	1,507,844	28,202 (1.9%)	23,428 (1.6%)	4,774	20.4%

Carolina Wood Pellets Table 10a. GAP species distribution overlay comparison for NFA versus exclude NNF with HAO_2, HNW screen

Carolina Wood Pellets Table 10b. GAP species distribution overlay comparison for non-Wilderness National Forest harvest allowed (NFA) versus exclude all National Forests (NNF) with moderate biomass removal intensity (HAO_6), wetlands excluded (HNW screen)

Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with NFA screen (% of woodshed habitat)	Hectares of habitat overlay with NNF screen (% of woodshed habitat)	Hectares of Increased habitat overlay with NFA	% Increase in habitat overlay with NFA
Brown-headed Nuthatch	165,176	6,351 (3.8%)	8,226 (5.0%)	-1,875	-22.8%
Northern Bobwhite	491,191	4,933 (1.0%)	12,373 (2.5%)	-7,440	-60.1%
Swainson's Warbler	853,883	69,119 (8.1%)	63,923 (7.5%)	5,196	8.1%
Eastern Spotted Skunk	1,566,225	84,121 (5.4%)	78,130 (5.0%)	5,991	7.7%
Long-tailed Weasel	825,452	17,951 (2.1%)	36,550 (4.4%)	-18,599	-50.9%
Northern Cricket Frog	69,055	744 (1.1%)	1,832 (2.7%)	-1,088	-59.4%
Timber Rattlesnake	1,507,844	78,587 (5.2%)	71,875 (4.8%)	6,712	9.3%

Carolina Wood Pellets Table 10b. GAP species distribution overlay comparison for NFA versus exclude NNF with HAO_6, HNW screen

Carolina Wood Pellets Table 10c. GAP species distribution overlay comparison for non-Wilderness National Forest harvest allowed (NFA) versus exclude all National Forests (NNF) with low biomass removal intensity (HAO_10), wetlands excluded (HNW screen)

Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with NFA screen (% of woodshed habitat)	Hectares of habitat overlay with NNF screen (% of woodshed habitat)	Hectares of Increased habitat overlay with NFA	% Increase in habitat overlay with NFA
Brown-headed Nuthatch	165,176	11,014 (6.7%)	13,197 (8.0%)	-2,183	-15.7%
Northern Bobwhite	491,191	10,814 (2.2%)	24,040 (4.9%)	-13,226	-55.0%
Swainson's Warbler	853,883	112,880 (13.2%)	100,361 (11.8%)	12,519	12.5%
Eastern Spotted Skunk	1,566,225	138,038 (8.8%)	127,298 (8.1%)	10,740	8.4%
Long-tailed Weasel	825,452	35,722 (4.3%)	65,593 (7.9%)	-29,871	-45.5%
Northern Cricket Frog	69,055	1,517 (2.2%)	3,227 (4.7%)	-1,710	-53.0%
Timber Rattlesnake	1,507,844	130,102 (8.6%)	119,143 (7.9%)	10,959	9.2%

Carolina Wood Pellets Table 10c. GAP species distribution overlay comparison for NFA versus exclude NNF with HAO_10, HNW screen

X. CASE STUDY OF VIRGINIA CITY HYBRID ENERGY CENTER

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Facility description

Virginia City Hybrid Energy Center, located in St. Paul, Virginia, is a 585 MW electrical generation unit. This facility, operated by Dominion Virginia Power, is designed to co-fire up to 20% biomass in its coal fuelled electric production facility. Based on a 20% biomass utilization assumption, the facility is estimated to demand up to 544,000 dry Mg/year of biomass at full capacity. The identified fuel is wood waste in the form of chips, most of which will likely be sourced from Appalachian hardwood.

We modeled the facility based on an assumed residual sourcing of 24 dry Mg/ha for Appalachian hardwood sites at the time of harvest (Vanderberg et al. 2012) over an assumed 50 year facility lifespan. Using this baseline, the total residual harvest area impact over 50 year facility lifespan (HAO_10) was calculated as 900,000 hectares. Although the model sourcing objective was derived through the residual sourcing assumption, HAOs representing more intensive removal of primary woody biomass material were modeled for consistency with other considered facilities.

GAP land cover summary

The 75-mile road network sourcing area (Virginia Hybrid Energy Center Map 1) provides a total land cover base that is just over 2.1 million hectares. This relatively constrained woodshed area stems from the presence of steep mountain ridges that limit road network passages throughout large sections of the woodshed area. The sourcing area is almost entirely contained within the Appalachian Mountain provinces, although a very small portion of the southern woodshed reaches into the Piedmont prov-

Figure 79. Allegheny-Cumberland Dry Oak Forest and Woodland, Photo Credit:?

ince. Forest resources including all native, plantation, and disturbed forest land covers accounting almost 1.6 million hectares, or over 73.9% of the total woodshed area.

The most common land cover in the Virginia Hybrid Energy Center woodshed is the Allegheny-Cumberland Dry Oak Forest and Woodland – Hardwood Modifier. This single forest type accounts for 34.3% of the woodshed area. Common trees in this association include white oak (*Quercus alba*), scarlet oak (*Quercus coccinea*), southern red oak (*Quercus falcata*), chestnut oak (*Quercus prinus*), Virginia pine (*Pinus virginiana*), red maple (*Acer rubrum*), mockernut hickory (*Carya alba*), pignut hickory (*Carya glabra*), and sourwood (*Oxydendrum arboreum).* Most of the remaining forest area is contained in various Appalachian hardwood associations, which together total over 664,000 hectares or 31.0% of the woodshed. Altogether, upland hardwood forest account for almost 1.4 million hectares, or 65.3% of the woodshed area. Small percentages of the woodshed are classified as Appalachian pine or other evergreen softwoods (~1.6%), forested riparian areas (~0.7%), or Southern Piedmont Dry Oak (<0.1%) Very little woodshed area is classified as plantation pine, totaling only 1,698 hectares – or less than 0.1%. However, over 136,000 hectares, or 6.3% of the woodshed, are classified as ruderal or successional ecosystem types that may serve as an additional intensive forestry base.

The second most common land cover in the Virginia Hybrid Energy Center woodshed is Pasture/Hay, which accounts for over 16.6% of the woodshed area. A little less than 1% of the woodshed is managed as Cultivated Croplands, bringing total agricultural land covers to approximately 17.6% of the woodshed. Over 159,000 hectares (7.4%) of the woodshed are classified as developed, with most of these developed areas concentrated in the southern woodshed in and around the Tennessee cities of Bristol, Kingsport, Johnson City, and Unicoi.

Public lands databases that include federal landholdings and state conservation lands in Virginia, North Carolina, Kentucky, Tennessee, and West virginia indicate that 20.9% of the woodshed is under some form of public ownership. The vast majority of this public land is held in the Jefferson National Forest and Cherokee National Forest.

Virginia Hybrid Energy Center Table 1 provides a complete summary of ecosystem area coverage in the 75-mile sourcing area for the Virginia Hybrid Energy Center facility, along with associated areas and percentages identified as either being under public ownership or other forms of conservation protection. Virginia Hybrid Energy Center Map 2 provides a visualization of GAP land cover generalized to the macro ecosystem level, as well as outlines of major conservation lands located in the woodshed. Virginia Hybrid Energy Map 3 provides a visualization of network travel distances from the facility across the woodshed. Virginia Hybrid Energy

NatureServe analysis of G1-G3 ecological associations

Table 2a lists twenty-one specific ecological associations with G1 (critically imperiled), G2 (imperiled), or G3 (vulnerable) status that NatureServe analyses show as having at least one element occurrence within the Virginia Hybrid Energy woodshed, including non-Wilderness National Forest areas. Fifteen of these ecological associations are forest types that could potentially serve as a supply for woody biomass extraction.

Virginia Hybrid Energy Table 2b lists fourteen specific ecological associations with G1 (critically imperiled), G2 (imperiled), or G3 (vulnerable) status that NatureServe analyses show as having at least one element occurrence within the Virginia Hybrid Energy woodshed, excluding all National Forests and other mapped conservation areas. Eleven of these ecological associations are forest types that could potentially serve as a supply for woody biomass extraction.

The lesser amounts of G1-G3 ecological associations found through overlays that excluded National Forest lands is likely due to a combination of an area effect (i.e., removal of National Forest area directly results in less occurrences), increased survey effort on public lands, and concentration of high conservation value areas within large patches of public land. Independently of land holding status, avoidance of G1-G3 ecological associations from biomass sourcing within the woodshed can be recommended as a minimum criterion for protecting and conserving biodiversity through sustainable forest management.

Woodshed competition

The competition overlay and network analysis for the Virginia Hybrid Energy Center facility identified a total of five other facilities that may be expected to compete for woody biomass within at least some portion of the 75-mile woodshed area (Virginia Hybrid Energy Center Map 4). This includes four pulp and paper mills and one biomass power producer. The most significant competitive demand pressure occurs in the south to southwest woodshed, and is almost entirely associated with the Weyerhaeuser paper mill located in Kingsport, TN. Generally low competitive demand is found throughout much of northern and eastern woodshed.

Biomass sourcing models and associated ecosystem risks

The harvest area objectives and associated suitability classes for all Virginia Hybrid Energy Center sourcing models are provided in Virginia Hybrid Energy Center Table 3.

The sourcing screens for Virginia Hybrid Energy Center varied according to two factors: 1) allowing (FOR screen) or disallowing (FNW screen) riparian sourcing; and 2) allowing or disallowing sourcing from non-Wilderness National Forest areas. Virginia Hybrid Energy Center Maps 5-6 respectively show the FNW and FOR sourcing screens with National Forest areas allowed for harvest. Virginia Hybrid Energy Center Maps 7-8 respectively show the FNW and FOR sourcing screens with non-Wilderness National Forest areas assumed as unavailable for harvest. As shown in Virginia Hybrid Energy Center Tables 4a-4c & Tables 6a-6c, forested wetland and riparian areas account for less than 1% predicted sourcing area for all FOR scenarios.

Virginia Hybrid Energy Center Table 5a-5c shows habitat overlays for the FNW scenarios with sourcing allowed from non-Wilderness National Forest areas, while scenarios summarized in Virginia Hybrid Energy Center Tables 7a-7c remove all National Forest areas from consideration. Under a scenario of residuals-only sourcing (HAO_10), extensive overlays occur with virtually all upland native forest habitats under both National Forest harvest scenarios.

Indicator species analysis

Virginia City Hybrid Energy Center Tables 8a-8c provide a summary of indicator species habitat areas that overlay the harvest risk scenario results for the FNW sourcing screen, with a comparison provided between National Forest harvest either being allowed or disallowed. Comparisons of indicator species habitat overlay between the FNW and FOR screens found no consistent or substantive difference, a result that can be generally explained by the very low percentage of forest habitat in riparian or wetland land cover within this woodshed. For this reason, indicator species analyses of FOR scenarios are not reported. However, maintenance of undisturbed riparian buffers is generally recommended for biodiversity and stream protection in Appalachian forests, as streamside and riparian logging can often results in severe water quality degradation and deleterious changes in the habitat structures required by of rare riparian species in mountain regions (Bryce et al. 1999).

Similar to the discussion for Carolina Wood Pellets, biomass sourcing for the Virginia City Hybrid Energy Center facility is currently based on residual sourcing of hardwoods with no assumption of land cover change. Based on this sourcing practice, habitat effects on all considered indicator species may be subtle and will require further research to resolve in more detail. However, the much higher long-term wood demand for Virginia City Hybrid Energy gives more cause for concern about the strength of potential effects, while also providing more opportunity for field work to account for population changes in these and other species

Similar to the results reported for the Carolina Wood Pellets facility, comparative results for the northern bobwhite show higher overlay outside of National Forest lands. This generally reflects the northern bobwhite's higher utilization of forest edges and agricultural lands, most of which are located outside of National Forest land holdings. The northern bobwhite's high utilization of early successional and disturbed areas (Blank 2013; Janke and Gates 2013) could suggest that understory biomass removal on low slope areas in this woodshed may have the potential to promote habitat for this species. Similar to discussions in all previous facilities, population responses of northern bobwhite to bioenergy procurement from the forestry landscape will likely be dependent on edge dynamics between early successional natural forest stands, pasture/grasslands, and agricultural lands at a broader landscape scale (Seckinger et al. 2008).

The Swainson's warbler is the species that shows the highest relative habitat area that overlays all risk scenarios. This species may be attracted to moderate clearing disturbance within other unfragmented hardwood forest patches (Hunter et al. 1994), which could suggest that careful biomass forestry removals may be implemented in ways that are sensitive to the habitat needs of this species. However, there are unknowns about potential response of this species to novel sourcing practices for hardwood pellet production, particularly at the higher demand levels implied by the Virginia Hybrid Energy facility. For example, with residuals harvesting (Table 7c), approximately 54 – 55% of the Swainson's warbler's habitat in the Virginia City Hybrid Energy City could potentially be impacted over a 50-year facility life cycle. Due to this large effect, careful monitoring of local Swainson's warbler responses to biomass removals for the Virginia City Hybrid Energy Center facility is warranted.

The Eastern spotted skunk consistently shows the highest overall area in at-risk habitat for all screens and harvest intensity scenarios, with very little difference between the National Forest and no National Forest scenarios. As noted in previous facility descriptions, Eastern spotted skunks have home ranges that require relatively large patches (~80 ha) of young hardwood forest s with high structural complexity in both the canopy and understory layers (Lesmeister et al. 2013). While specific factors behind the decline of this species have long been regarded as unclear (Gompper and Hackett 2005), observations of the Eastern spotted skunk in the Ozark Plateau indicate that hollow, rotted logs are frequently used as den sites (McCullough and Fritzell 1984). Based on these observations, it may be speculated that heavy harvest of residual hardwood biomass could potentially have adverse effects on Eastern spotted skunk habitat in the Virginia City Hybrid Energy Center woodshed, particularly if it results in significant reductions of large downed, woody debris.

The long-tailed weasel shows a generally low amount of overlay with scenarios that allow for harvest of non-Wilderness National Forest areas, and somewhat higher overlay in scenarios where no National Forest lands are used for biomass harvest. This result is a function of the long-tailed weasel having a much denser distribution in the piedmont sections of this woodshed. Although the long-tailed weasel is sensitive to fragmentation of the forest landscape through agricultural clearing (Gehring and Swihart 2004), it is not known to use snags or log cavities as a critical habitat resource (Loeb 1996). Impacts of biomass harvest on this species that do not result in land cover conversion can be regarded as unknown at this time.

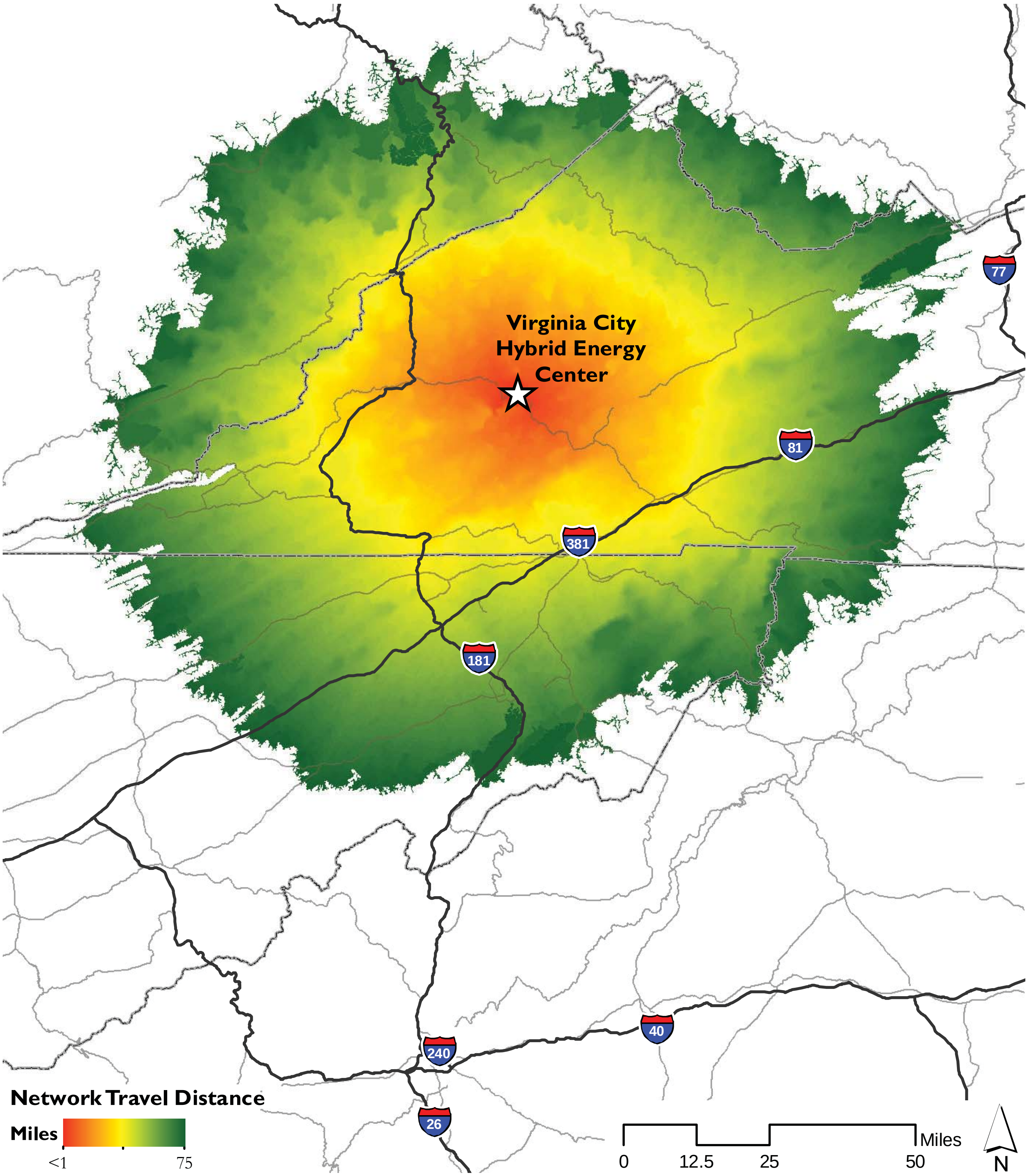
Results for the timber rattlesnake consistently show very marginally higher overlay in scenarios where National Forest lands are assumed as available for biomass harvest. Because timber rattlesnakes frequently utilize fallen logs as an ambush habitat for capturing prey (Reinert et al. 1984), high levels of biomass removal from natural forest stands could potentially degrade the snake's habitat over time. As noted in discussions for other facilities, significant direct mortality when the poisonous snake is encountered by loggers and other site workers could also be a conservation concern (Reinert et al. 2011) for this species due to biomass sourcing in the Virginia City Hybrid Energy Center woodshed.

Discussion

At full design capacity, a long-term residuals-only sourcing policy for the Virginia Hybrid Energy Center implies a potential for extensive woodshed impact. Vanderberg et al. (2012) note that downed woody matter (DWM), which is expected to provide the basis for residuals-based woody bioenergy, is positively correlated with site-level biodiversity in most Appalachian forest types. Particular importance of DWM is noted for sensitive and endangered flying mammals such as Indiana bats, northern long-eared bats, and northern flying squirrels. Research by Verschuyl et al. (2011) suggests that salamander diversity and abundance is likely to be affected adversely be clear cut removal of biomass, although research by Brooks (1999) suggests little effects on salamander populations from hardwood forest thinning of up to 50-60% stand density. While these are significant concerns, additional research will be needed to resolve specific effects of biomass energy removals on micro and macro-habitat effects on vertebrate taxa, as well as forest succession trajectories, in this woodshed.

For both the protection of regionally unique salamander populations (Moseley et al. 2008) and maintenance of water quality in Appalachian stream systems (Bryce et al. 1999), an uplands-only sourcing policy that maintains buffer strips around stream riparian zones may be recommended as a sustainability criterion with high biodiversity protection values for the Virginia Hybrid Energy Center woodshed. The very low percentage of riparian and wetland hardwood forests in this woodshed make this suggestion readily feasible from a biomass procurement standpoint. The flexible fuel sourcing of the Virginia Hybrid Energy Center may provide a fairly unique opportunity for proactive monitoring of landscape habitat effects from biomass harvesting, with regional biodiversity habitat values potentially providing feedback for adjustment of biomass sourcing practices and associated demands by the facility.

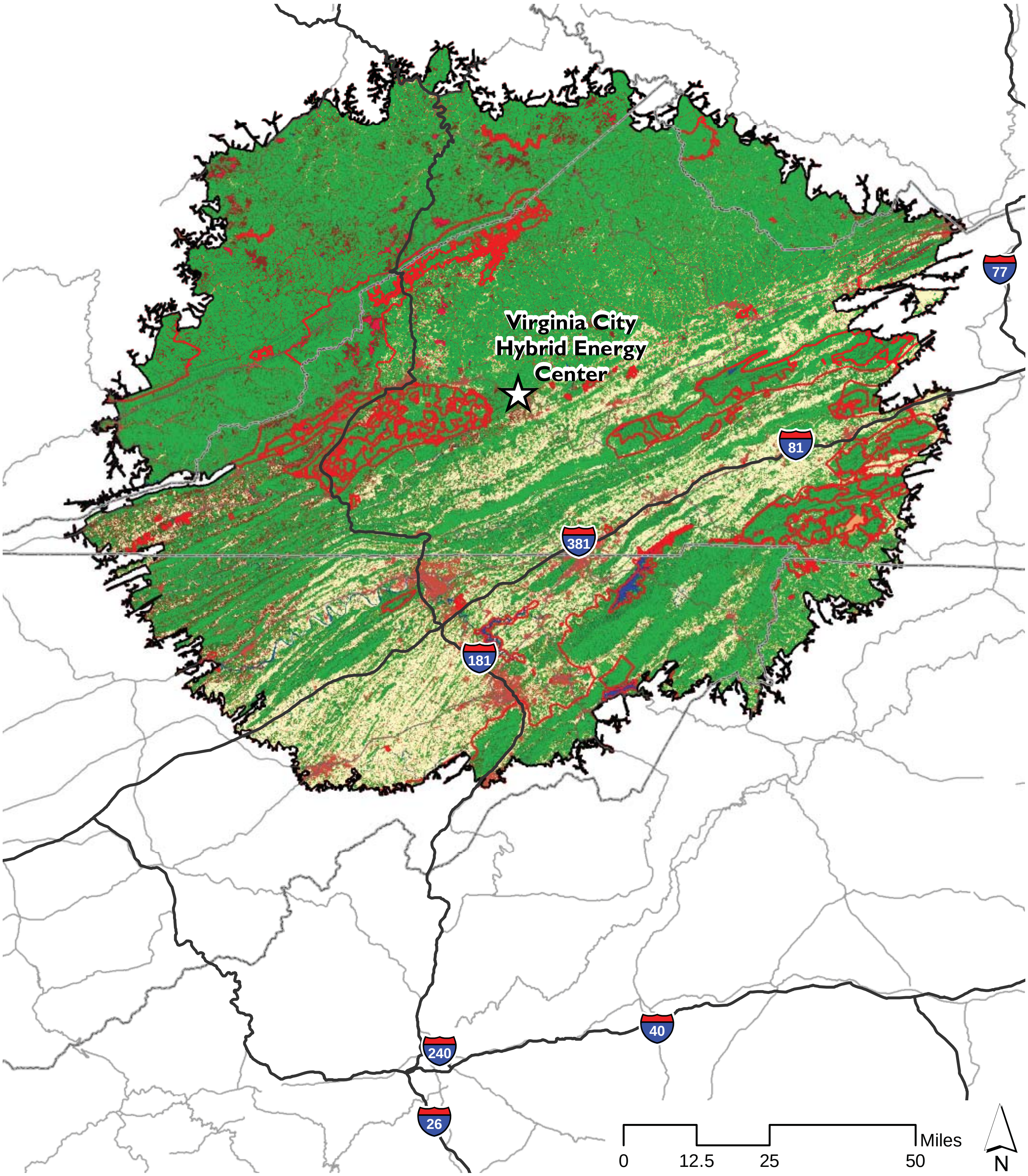
Figure 80. Virginia City Hybrid Energy Center Map 1: 75-mile Network Travel Distance and Woodshed Delineation



Virginia City Hybrid Energy Center Table 1. GAP Detailed Ecosystem Summary for 75-Mile Woodshed Area			
Land Cover Type (Detailed)	**Area**	**Protected**	**% Protected**
Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood	733,992	109,119	14.9%
Pasture/Hay	356,624	36,304	10.2%
Southern Ridge and Valley Dry Calcareous Forest	218,007	24,360	11.2%
Disturbed/Successional - Grass/Forb Regeneration	118,698	14,770	12.4%
Developed, Open Space	98,216	14,840	15.1%
South-Central Interior Mesophytic Forest	97,483	6,907	7.1%
Southern and Central Appalachian Cove Forest	88,182	34,215	38.8%
Northeastern Interior Dry Oak Forest-Hardwood Modifier	77,827	34,601	44.5%
Southern and Central Appalachian Oak Forest	71,863	57,793	80.4%
Southern and Central Appalachian Oak Forest - Xeric	49,859	40,979	82.2%
Developed, Low Intensity	44,620	3,541	7.9%
Appalachian Hemlock-Hardwood Forest	29,315	14,246	48.6%
Central and Southern Appalachian Montane Oak Forest	26,240	19,275	73.5%
Southern Appalachian Low Mountain Pine Forest	21,764	4,146	19.0%
Cultivated Cropland	20,185	1,852	9.2%
Disturbed/Successional - Shrub Regeneration	14,953	4,197	28.1%
Developed, Medium Intensity	13,244	997	7.5%
South-Central Interior Small Stream and Riparian	12,515	3,982	31.8%
Southern Appalachian Montane Pine Forest and Woodland	11,057	5,460	49.4%
Open Water (Fresh)	10,612	6,220	58.6%
Quarries, Mines, Gravel Pits and Oil Wells	7,637	1,985	26.0%
Developed, High Intensity	3,321	156	4.7%
Harvested Forest - Grass/Forb Regeneration	2,700	941	34.9%
Central and Southern Appalachian Northern Hardwood Forest	2,391	2,291	95.8%
Allegheny-Cumberland Dry Oak Forest and Woodland - Pine Modifier	2,131	199	9.3%
Evergreen Plantation or Managed Pine	1,698	713	42.0%
South-Central Interior Large Floodplain - Forest Modifier	1,452	213	14.7%
Northeastern Interior Dry Oak Forest - Virginia/Pitch Pine Modifier	1,100	759	69.0%
Southern Appalachian Grass and Shrub Bald - Herbaceous Modifier	898	896	99.8%
Southern Appalachian Grass and Shrub Bald - Shrub Modifier	648	648	100.0%
Southern Interior Acid Cliff	617	211	34.2%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	572	329	57.5%
Central and Southern Appalachian Spruce-Fir Forest	411	411	100.0%
Southern Ridge and Valley Dry Calcareous Forest - Pine modifier	302	8	2.6%

Virginia City Hybrid Energy Center Table 1. GAP Detailed Ecosystem Summary for 75-Mile Woodshed Area

Figure 81. Virginia City Hybrid Energy Center Map 2: GAP Land Cover and Conservation Lands



Virginia City Hybrid Map 2: Land Cover Characteristics Legend

Conservation Areas

GAP Ecosystem Class (NVC Macro)

- Southeastern North American Ruderal Forest & Plantation
- Central Oak-Hardwood & Pine Forest
- Northern Mesic Hardwood & Conifer Forest
- Southern-Central Oak-Hardwood & Pine Forest
- Central Mesophytic Hardwood Forest
- Northern & Eastern Pine - Oak Forest, Woodland & Barrens
- Northern & Central Floodplain Forest & Scrub
- Appalachian & Lauentian Rocky Scrub and Meadow
- Atlantic & Gulf Coastal Plain Bog & Fen
- Eastern North American Freshwater Aquatic Vegetation
- Eastern North American Cliff & Rock Vegetation
- Eastern Temperate Summit & Flatrock
- Herbaceous Agricultural Vegetation
- Recently Disturbed or Modified
- Open Water
- Quarries, Mines, Gravel Pits and Oil Wells
- Developed & Urban

Figure 82. Virginia City Hybrid Energy Center Map 3: Travel Network Analysis & Locations of Competing Bioenergy and Pulp Mill Facilities

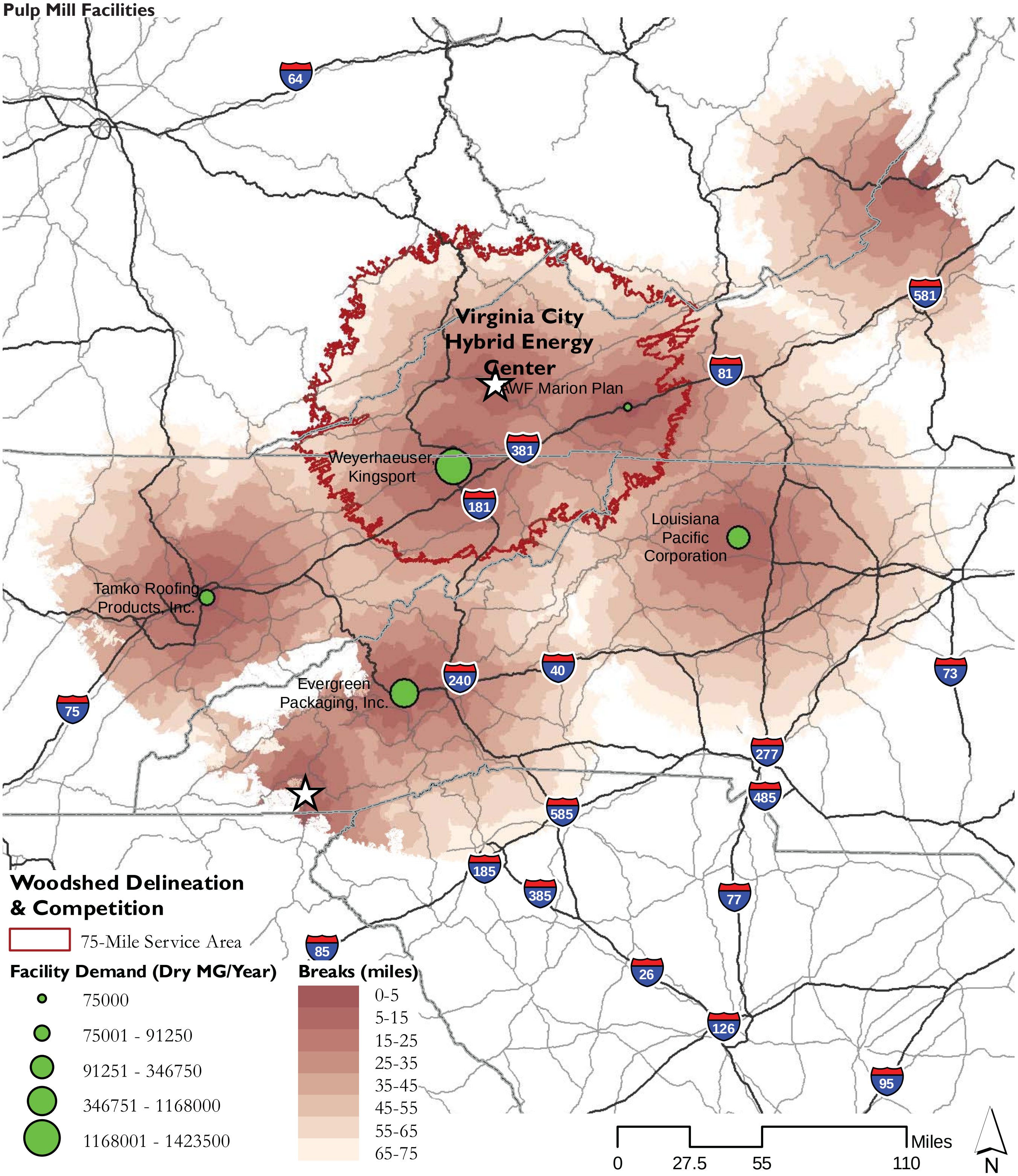


Figure 83. Virginia City Hybrid Energy Center Map 4: Competition Demand Strength Analysis, as Annual dry Mg / Network Travel Mile

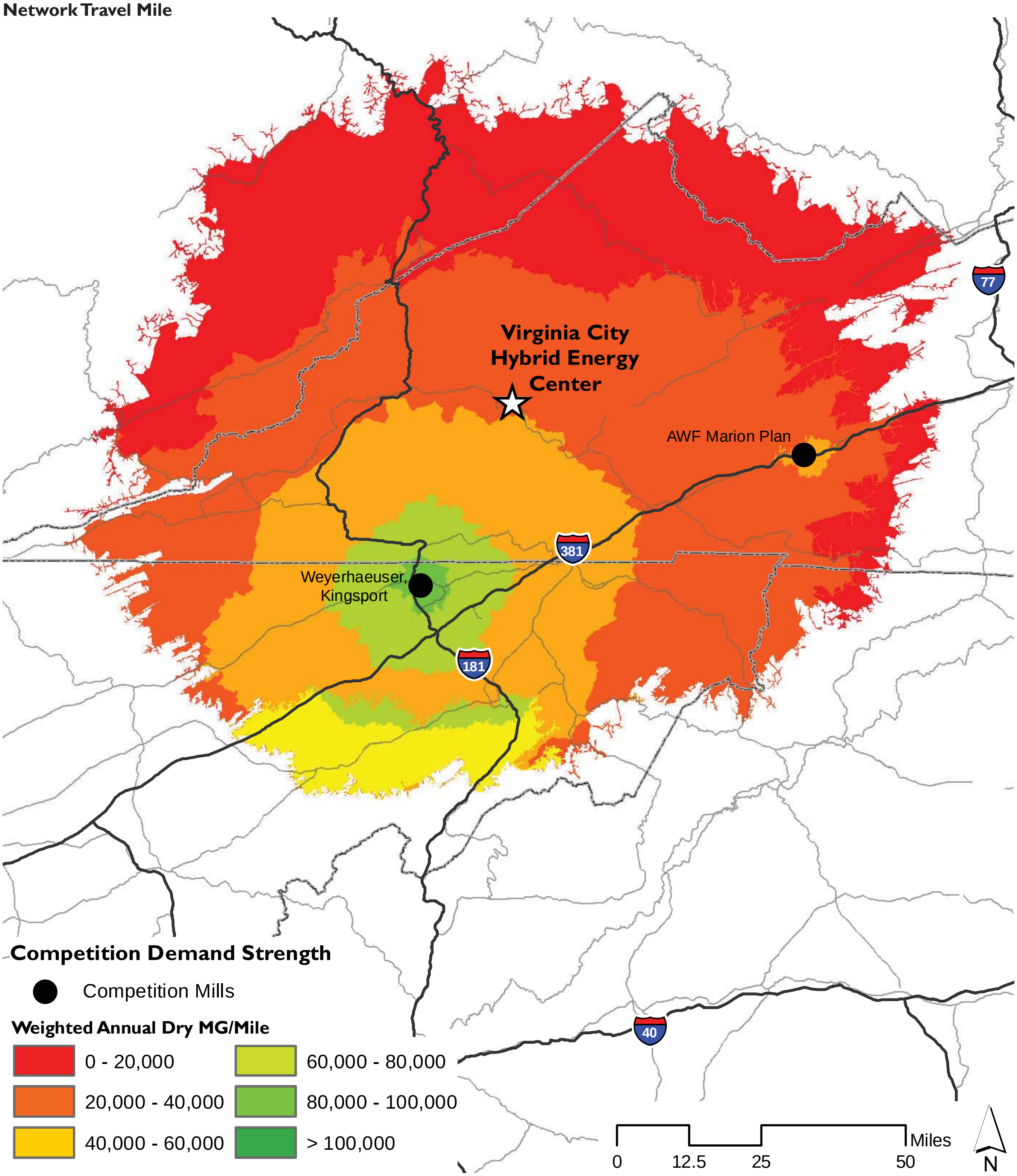


Figure 84. Virginia City Hybrid Energy Center Map 5: Composite Model of Forestry no Wetlands (FNW) Sourcing Model Screen

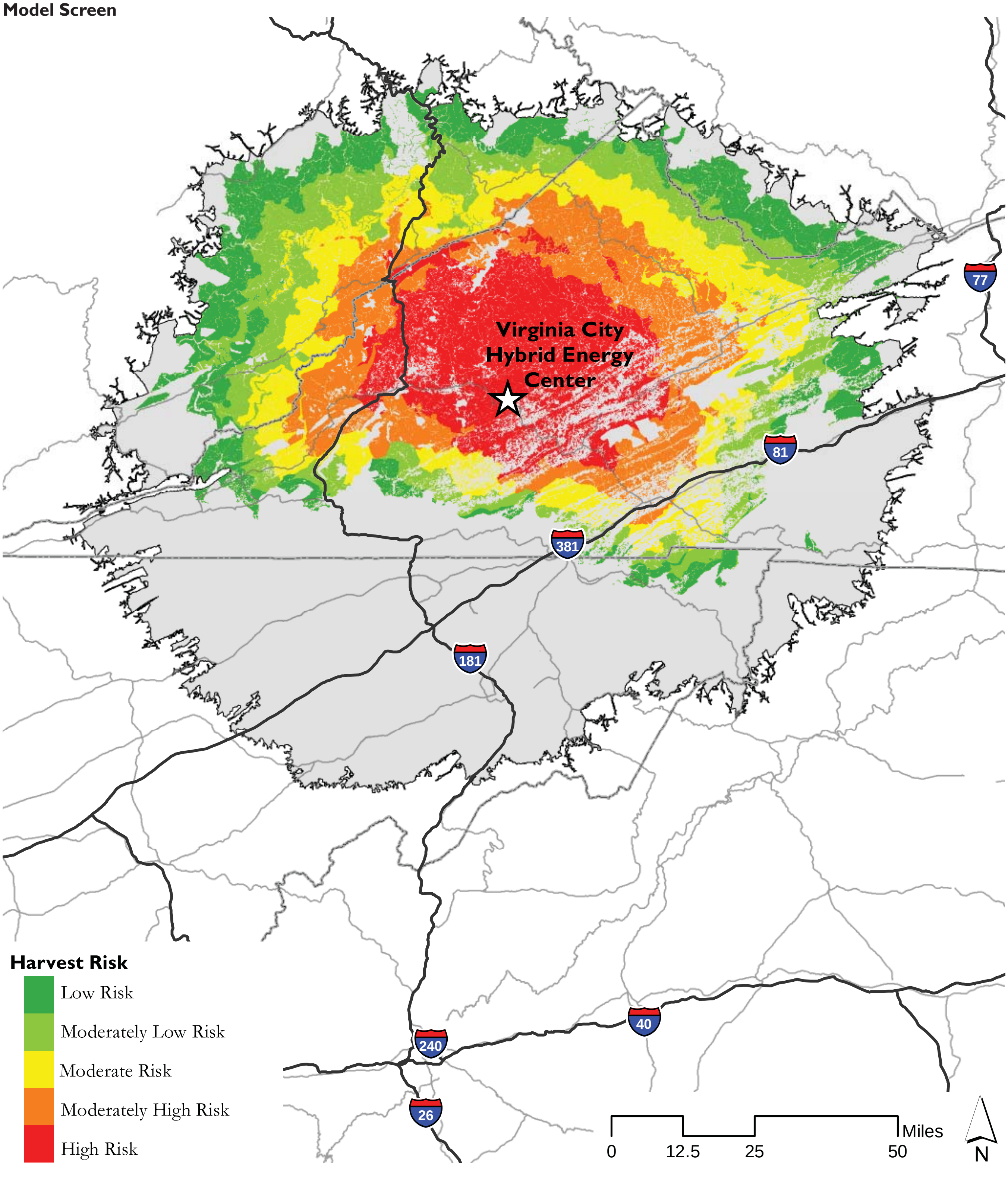


Figure 85. Virginia City Hybrid Energy Center Map 6: Composite Model of Forestry (FOR) Sourcing Model Screen

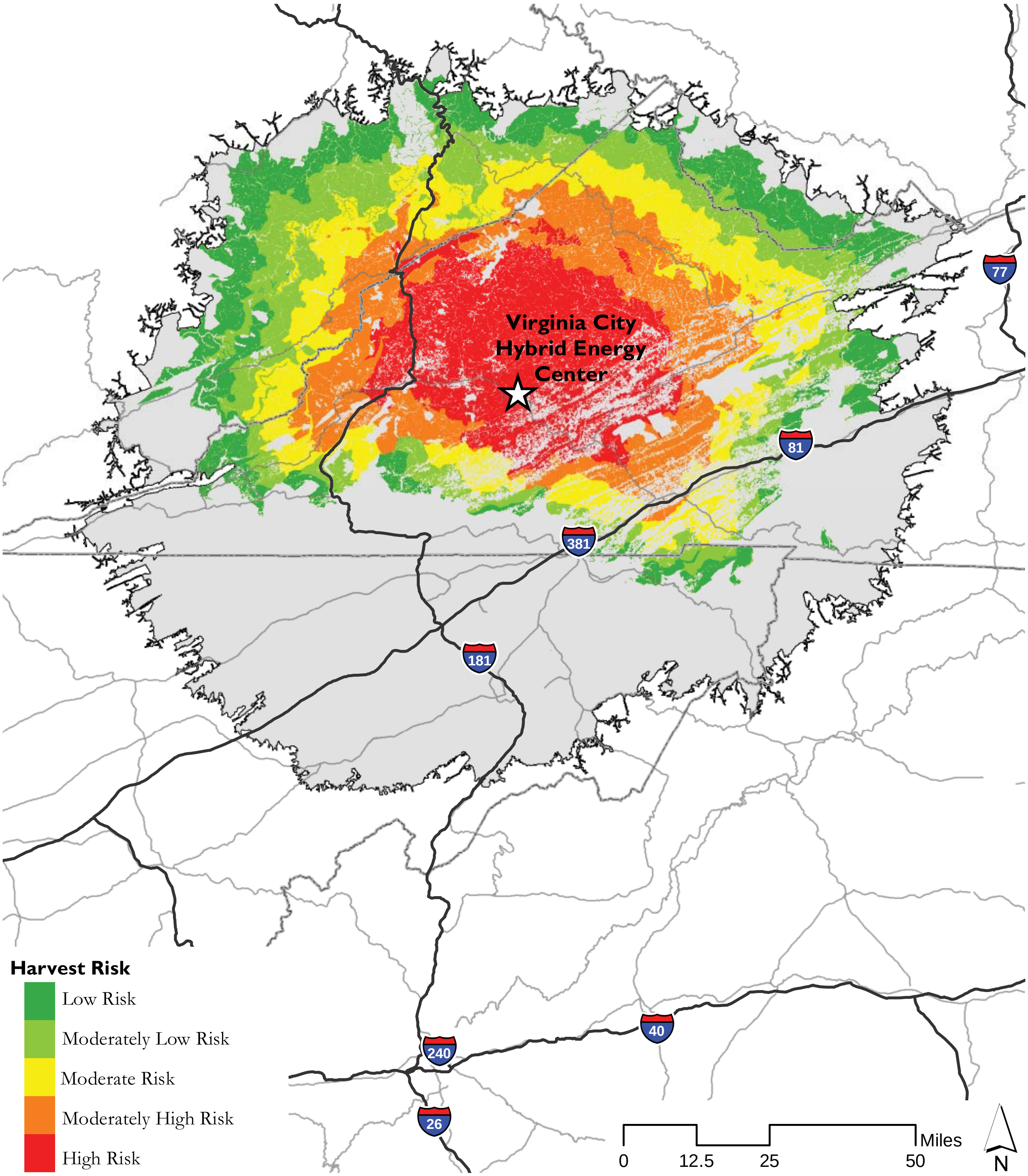


Figure 86. Virginia City Hybrid Energy Center Map 7: Composite Model of Forestry no Wetlands (FNW) Sourcing Model Screen

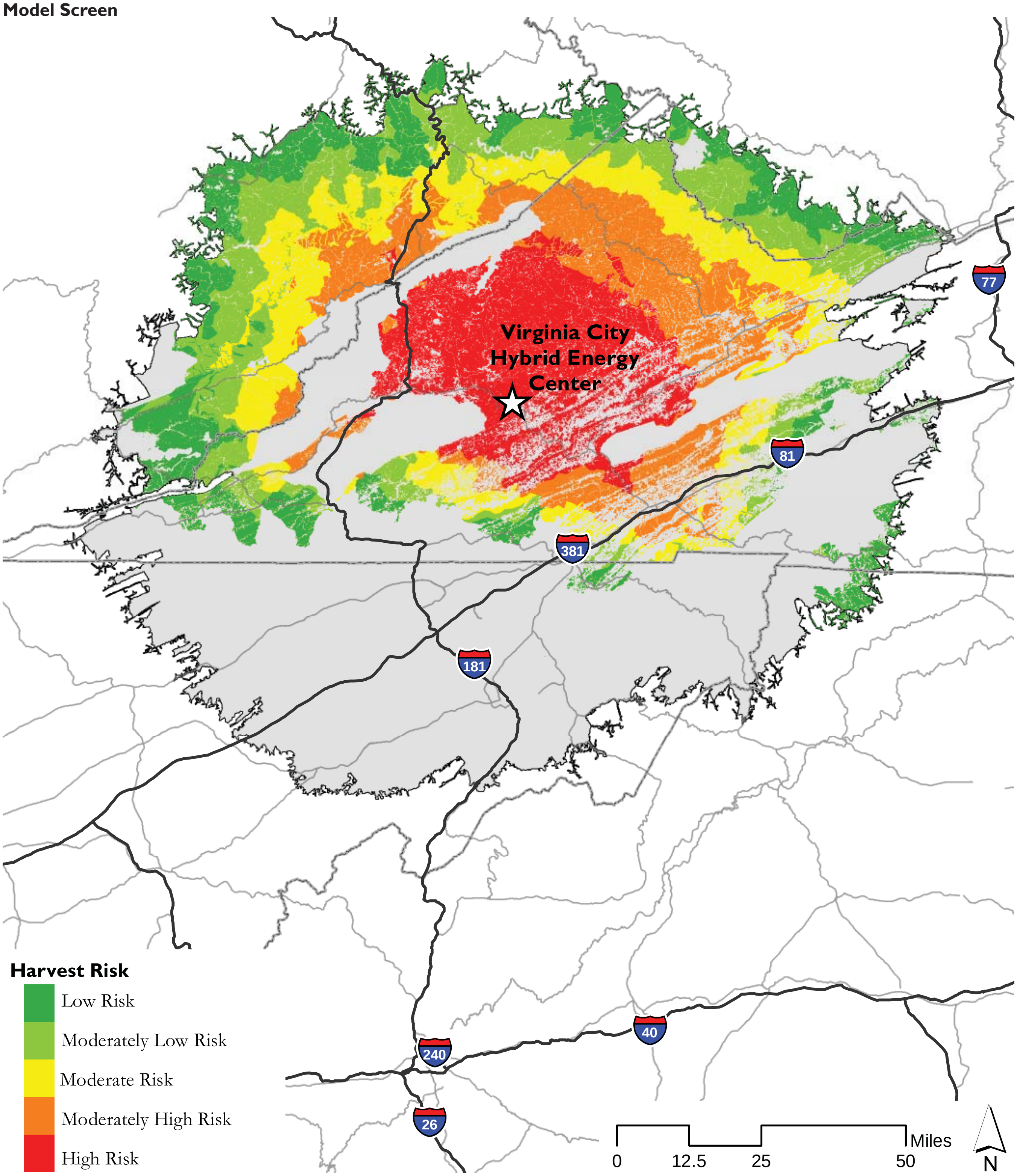
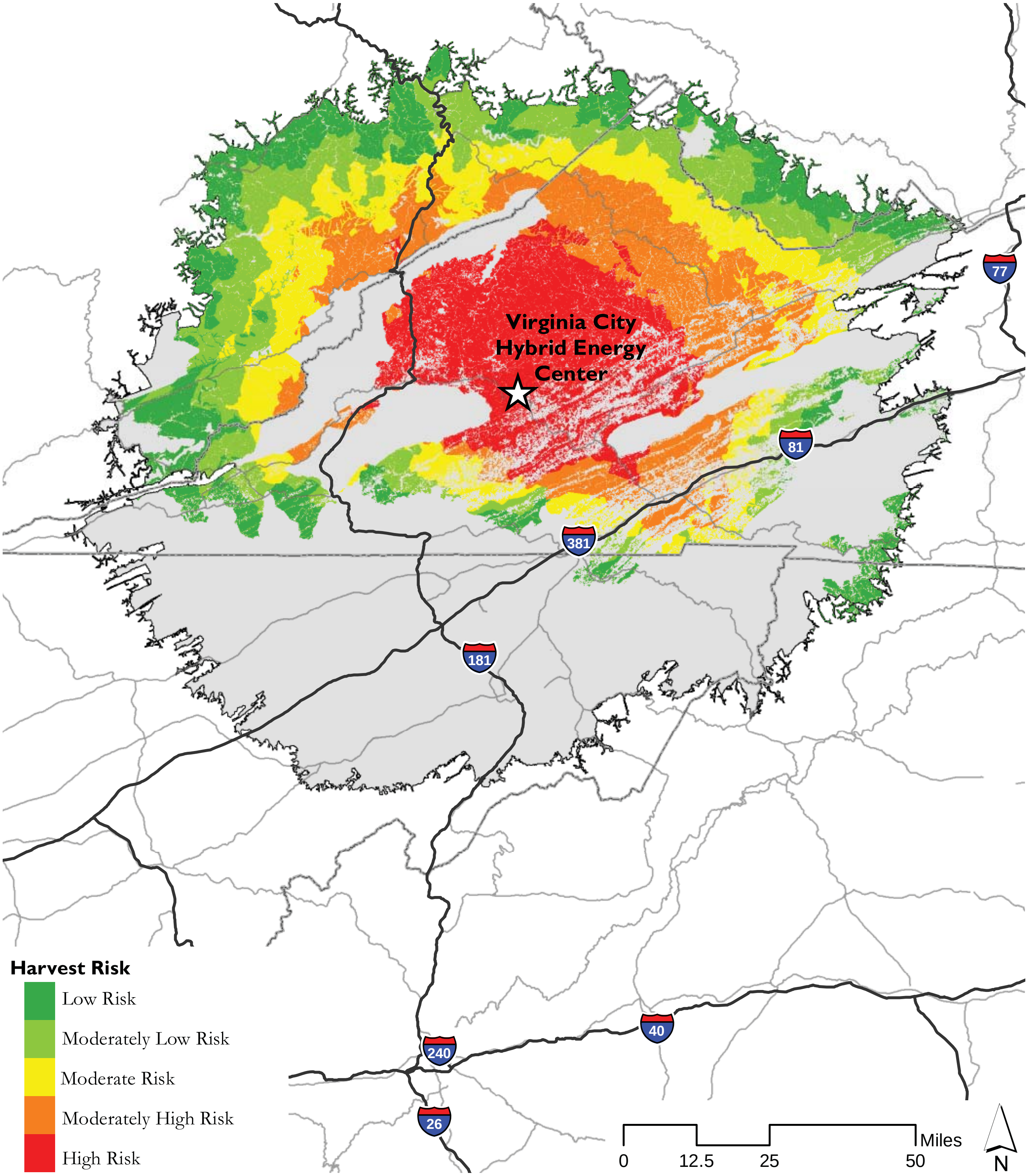


Figure 87. Virginia City Hybrid Energy Center Map 8: Composite Model of Forestry (FOR) Sourcing Model Screen



Virginia City Hybrid Energy Center Table 2a. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, including non-Wilderness National Forests and excluding all other conservation areas			
Formal association name	**Common association name**	**Status**	**Woodshed occurrences**
Rhododendron (maximum, catawbiense) - Ilex collina - Salix sericea / Carex trisperma - Eriophorum virginicum Shrubland	Southern Appalachian Shrub Bog (Long Hope Valley Type)	G1	1
Danthonia compressa - (Sibbaldiopsis tridentata) Herbaceous Vegetation	Grassy Bald (Southern Grass Type)	G1	1
Abies fraseri / Viburnum lantanoides / Dryopteris campyloptera - Oxalis montana / Hylocomium splendens Forest	Fraser Fir Forest (Deciduous Shrub Type)	G1	1
Schoenoplectus robustus - Juncus gerardii - Hordeum jubatum - Atriplex patula Herbaceous Vegetation	Inland Salt Marsh	G1	1
Thuja occidentalis - Pinus strobus - Tsuga canadensis / Carex eburnea Woodland	Southern Appalachian Northern White-cedar Slope Woodland	G1G2	1
Quercus muehlenbergii / Packera plattensis - Parthenium auriculatum - Schizachyrium scoparium Woodland	Ridge and Valley Dolomite Glade	G2	3
Picea rubens - (Abies fraseri) / Vaccinium erythrocarpum / Oxalis montana - Dryopteris campyloptera / Hylocomium splendens Forest	Red Spruce - Fraser Fir Forest (Deciduous Shrub Type)	G2	3
Fraxinus americana - Carya glabra / Muhlenbergia sobolifera - Helianthus divaricatus - Solidago ulmifolia Woodland	Central Appalachian Basic Woodland	G2	1
Rhododendron catawbiense Shrubland	Southern Appalachian Catawba Rosebay Heath Bald	G2	1
Quercus muehlenbergii - Juniperus virginiana / Schizachyrium scoparium - Manfreda virginica Wooded Herbaceous Vegetation	Central Limestone Glade	G2G3	10
Thuja occidentalis / Carex eburnea - Pellaea atropurpurea Woodland	Appalachian Cliff White-cedar Woodland	G2G3	1

Virginia City Hybrid Energy Center Table 2a. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, including non-Wilderness National Forests and excluding all other conservation areas

Virginia City Hybrid Energy Center Table 2a. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, including non-Wilderness National Forests and excluding all other conservation areas (cont…)

Formal association name	Common association name	Status	Woodshed occurrences
Tilia americana var. heterophylla - Fraxinus americana - (Ulmus rubra) / Sanguinaria canadensis - (Aquilegia canadensis, Asplenium rhizophyllum) Forest	Southern Appalachian Cove Forest (Rich Foothills Type)	G2G3	1
Quercus alba - Quercus rubra - Quercus prinus / Collinsonia canadensis - Podophyllum peltatum - Amphicarpaea bracteata Forest	Appalachian Montane Oak-Hickory Forest (Rich Type)	G3	6
Quercus muehlenbergii - Quercus (falcata, shumardii, stellata) / Cercis canadensis / Viburnum rufidulum Forest	Interior Low Plateau Chinquapin Oak - Mixed Oak Forest	G3	5
Aesculus flava - Betula alleghaniensis - Acer saccharum / Acer spicatum / Caulophyllum thalictroides - Actaea podocarpa Forest	Southern Appalachian Northern Hardwood Forest (Rich Type)	G3	1
Asplenium ruta-muraria - Pellaea atropurpurea Sparse Vegetation	Montane Cliff (Calcareous Type)	G3G4	1
Quercus muehlenbergii - Quercus (alba, rubra) - Carya cordiformis / Viburnum prunifolium Forest	Ridge and Valley Limestone Oak - Hickory Forest	G3G4	1
Quercus muehlenbergii - Cercis canadensis / Packera obovata - Lithospermum canescens Woodland	Limestone Chinquapin Oak Woodland	G3G4	1
Betula alleghaniensis - Fagus grandifolia - Aesculus flava / Viburnum lantanoides / Eurybia chlorolepis - Dryopteris intermedia Forest	Southern Appalachian Northern Hardwood Forest (Typic Type)	G3G4	2
Aesculus flava - Acer saccharum - (Fraxinus americana, Tilia americana var. heterophylla) / Hydrophyllum canadense - Solidago flexicaulis Forest	Southern Appalachian Rich Cove Forest (Montane Calcareous Type)	G3G4	4
Betula alleghaniensis - (Tsuga canadensis) / Rhododendron maximum / (Leucothoe fontanesiana) Forest	Blue Ridge Hemlock - Northern Hardwood Forest	G3G4	2

Virginia City Hybrid Energy Center Table 2b. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, excluding all National Forests and other conservation areas

Formal association name	Common association name	Status	Woodshed occurrences
Schoenoplectus robustus - Juncus gerardii - Hordeum jubatum - Atriplex patula Herbaceous Vegetation	Inland Salt Marsh	G1	1
Thuja occidentalis - Pinus strobus - Tsuga canadensis / Carex eburnea Woodland	Southern Appalachian Northern White-cedar Slope Woodland	G1G2	1
Quercus muehlenbergii / Packera plattensis - Parthenium auriculatum - Schizachyrium scoparium Woodland	Ridge and Valley Dolomite Glade	G2	3
Picea rubens - (Abies fraseri) / Vaccinium erythrocarpum / Oxalis montana - Dryopteris campyloptera / Hylocomium splendens Forest	Red Spruce - Fraser Fir Forest (Deciduous Shrub Type)	G2	1
Quercus muehlenbergii - Juniperus virginiana / Schizachyrium scoparium - Manfreda virginica Wooded Herbaceous Vegetation	Central Limestone Glade	G2G3	10
Thuja occidentalis / Carex eburnea - Pellaea atropurpurea Woodland	Appalachian Cliff White-cedar Woodland	G2G3	1
Quercus muehlenbergii - Quercus (falcata, shumardii, stellata) / Cercis canadensis / Viburnum rufidulum Forest	Interior Low Plateau Chinquapin Oak - Mixed Oak Forest	G3	5
Aesculus flava - Betula alleghaniensis - Acer saccharum / Acer spicatum / Caulophyllum thalictroides - Actaea podocarpa Forest	Southern Appalachian Northern Hardwood Forest (Rich Type)	G3	1
Quercus alba - Quercus rubra - Quercus prinus / Collinsonia canadensis - Podophyllum peltatum - Amphicarpaea bracteata Forest	Appalachian Montane Oak-Hickory Forest (Rich Type)	G3	1
Aesculus flava - Acer saccharum - (Fraxinus americana, Tilia americana var. heterophylla) / Hydrophyllum canadense - Solidago flexicaulis Forest	Southern Appalachian Rich Cove Forest (Montane Calcareous Type)	G3G4	3
Asplenium ruta-muraria - Pellaea atropurpurea Sparse Vegetation	Montane Cliff (Calcareous Type)	G3G4	1

Virginia City Hybrid Energy Center Table 2b. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, excluding all National Forests and other conservation areas

Virginia City Hybrid Energy Center Table 2b. NatureServe analysis of element occurrences for G1, G2, and G3 ecological associations in 75-mile woodshed area, excluding all National Forests and other conservation areas (cont…)

Formal association name	Common association name	Status	Woodshed occurrences
Quercus muehlenbergii - Quercus (alba, rubra) - Carya cordiformis / Viburnum prunifolium Forest	Ridge and Valley Limestone Oak - Hickory Forest	G3G4	1
Betula alleghaniensis - (Tsuga canadensis) / Rhododendron maximum / (Leucothoe fontanesiana) Forest	Blue Ridge Hemlock - Northern Hardwood Forest	G3G4	2

Virginia City Hybrid Energy Center Table 3. Harvest area objectives and associated risk classes for spatial modeling

HAO	Hardwood (Ha)	Demand Intensity (Mg/ha/yr)	Harvest or Conversion Risk Class
1	90,000	4.80	High
2	180,000	2.40	
3	270,000	1.60	Moderately High
4	360,000	1.20	
5	450,000	0.96	Moderate
6	540,000	0.80	
7	630,000	0.69	Moderately Low
8	720,000	0.60	
9	810,000	0.53	Low
10	900,000	0.48	

Virginia City Hybrid Energy Center Table 3. Harvest area objectives and associated risk classes for spatial modeling

Virginia City Hybrid Energy Center Table 4a. GAP ecosystem overlay for forestry biomass sourcing that includes wetland forests and non-Wilderness National Forest (FOR_NFA screen) with high biomass removal intensity (HAO_2)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood	115,017	284,092	63.9%
Appalachian Hemlock-Hardwood Forest	3,684	9,099	2.0%
Central and Southern Appalachian Montane Oak Forest	178	440	0.1%
Northeastern Interior Dry Oak Forest - Virginia/Pitch Pine Modifier	61	151	0.0%
Northeastern Interior Dry Oak Forest-Hardwood Modifier	10,076	24,888	5.6%
South-Central Interior Large Floodplain - Forest Modifier	10	25	0.0%
South-Central Interior Mesophytic Forest	2,119	5,234	1.2%
South-Central Interior Small Stream and Riparian	525	1,297	0.3%
Southern and Central Appalachian Cove Forest	17,091	42,215	9.5%
Southern and Central Appalachian Oak Forest	174	430	0.1%
Southern and Central Appalachian Oak Forest - Xeric	125	309	0.1%
Southern Appalachian Low Mountain Pine Forest	490	1,210	0.3%
Southern Appalachian Montane Pine Forest and Woodland	1,924	4,752	1.1%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	31	77	0.0%
Southern Ridge and Valley Dry Calcareous Forest	14,533	35,897	8.1%
Disturbed/Successional - Grass/Forb Regeneration	13,225	32,666	7.3%
Disturbed/Successional - Shrub Regeneration	513	1,267	0.3%
Evergreen Plantation or Managed Pine	85	210	0.0%
Harvested Forest - Grass/Forb Regeneration	92	227	0.1%

Virginia City Hybrid Energy Center Table 4a. GAP ecosystem overlay for forestry biomass sourcing that includes wetland forests and FOR_NFA screen with HAO_2

Virginia City Hybrid Energy Center Table 4b. GAP ecosystem overlay for forestry biomass sourcing that includes wetland forests and non-Wilderness National Forest (FOR_NFA screen) with moderate biomass removal intensity (HAO_6)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood	332,199	820,532	61.5%
Appalachian Hemlock-Hardwood Forest	10,535	26,021	2.0%
Central and Southern Appalachian Montane Oak Forest	1,142	2,821	0.2%
Northeastern Interior Dry Oak Forest - Virginia/Pitch Pine Modifier	276	682	0.1%
Northeastern Interior Dry Oak Forest-Hardwood Modifier	32,726	80,833	6.1%
South-Central Interior Large Floodplain - Forest Modifier	124	306	0.0%
South-Central Interior Mesophytic Forest	16,995	41,978	3.1%
South-Central Interior Small Stream and Riparian	2,320	5,730	0.4%
Southern and Central Appalachian Cove Forest	39,928	98,622	7.4%
Southern and Central Appalachian Oak Forest	813	2,008	0.2%
Southern and Central Appalachian Oak Forest - Xeric	627	1,549	0.1%
Southern Appalachian Low Mountain Pine Forest	2,348	5,800	0.4%
Southern Appalachian Montane Pine Forest and Woodland	5,020	12,399	0.9%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	157	388	0.0%
Southern Ridge and Valley Dry Calcareous Forest	52,930	130,737	9.8%
Disturbed/Successional - Grass/Forb Regeneration	38,671	95,517	7.2%
Disturbed/Successional - Shrub Regeneration	2,430	6,002	0.5%
Evergreen Plantation or Managed Pine	207	511	0.0%
Harvested Forest - Grass/Forb Regeneration	384	948	0.1%

Virginia City Hybrid Energy Center Table 4b. GAP ecosystem overlay for forestry biomass sourcing that includes wetland forests and FOR_NFA screen with HAO_6

Virginia City Hybrid Energy Center Table 4c. GAP ecosystem overlay for forestry biomass sourcing that includes wetland forests and non-Wilderness National Forest (FOR_NFA screen) with low biomass removal intensity (HAO_10)

GAP Ecosystem	Hectares	Acres	Sourcing %
Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood	559,364	1,381,629	62.2%
Appalachian Hemlock-Hardwood Forest	15,807	39,043	1.8%
Central and Southern Appalachian Montane Oak Forest	3,112	7,687	0.3%
Northeastern Interior Dry Oak Forest - Virginia/Pitch Pine Modifier	550	1,359	0.1%
Northeastern Interior Dry Oak Forest-Hardwood Modifier	53,227	131,471	5.9%
South-Central Interior Large Floodplain - Forest Modifier	290	716	0.0%
South-Central Interior Mesophytic Forest	36,148	89,286	4.0%
South-Central Interior Small Stream and Riparian	3,778	9,332	0.4%
Southern and Central Appalachian Cove Forest	55,061	136,001	6.1%
Southern and Central Appalachian Oak Forest	5,770	14,252	0.6%
Southern and Central Appalachian Oak Forest - Xeric	4,139	10,223	0.5%
Southern Appalachian Low Mountain Pine Forest	5,257	12,985	0.6%
Southern Appalachian Montane Pine Forest and Woodland	6,823	16,853	0.8%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	371	916	0.0%
Southern Ridge and Valley Dry Calcareous Forest	77,857	192,307	8.7%
Disturbed/Successional - Grass/Forb Regeneration	65,213	161,076	7.3%
Disturbed/Successional - Shrub Regeneration	4,694	11,594	0.5%
Evergreen Plantation or Managed Pine	360	889	0.0%
Harvested Forest - Grass/Forb Regeneration	756	1,867	0.1%

Virginia City Hybrid Energy Center Table 4b. GAP ecosystem overlay for forestry biomass sourcing that includes wetland forests and FOR_NFA screen with HAO_10

Virginia City Hybrid Energy Center Table 5a. GAP ecosystem overlay for forestry biomass sourcing that excludes wetland forests and includes non-Wilderness National Forest (FNW_NFA screen) with high biomass removal intensity (HAO_2)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood	97,871	241,741	54.4%
Appalachian Hemlock-Hardwood Forest	3,736	9,228	2.1%
Central and Southern Appalachian Montane Oak Forest	243	600	0.1%
Northeastern Interior Dry Oak Forest - Virginia/Pitch Pine Modifier	72	178	0.0%
Northeastern Interior Dry Oak Forest-Hardwood Modifier	14,946	36,917	8.3%
South-Central Interior Mesophytic Forest	5,031	12,427	2.8%
Southern and Central Appalachian Cove Forest	16,567	40,920	9.2%
Southern and Central Appalachian Oak Forest	246	608	0.1%
Southern and Central Appalachian Oak Forest - Xeric	192	474	0.1%
Southern Appalachian Low Mountain Pine Forest	908	2,243	0.5%
Southern Appalachian Montane Pine Forest and Woodland	1,662	4,105	0.9%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	44	109	0.0%
Southern Ridge and Valley Dry Calcareous Forest	24,889	61,476	13.8%
Disturbed/Successional - Grass/Forb Regeneration	12,130	29,961	6.7%
Disturbed/Successional - Shrub Regeneration	1,121	2,769	0.6%
Evergreen Plantation or Managed Pine	63	156	0.0%
Harvested Forest - Grass/Forb Regeneration	234	578	0.1%

Virginia City Hybrid Energy Center Table 5a. GAP ecosystem overlay for forestry biomass sourcing that excludes wetland forests and includes FNW_NFA screen with HAO_2

Virginia City Hybrid Energy Center Table 5b. GAP ecosystem overlay for forestry biomass sourcing that excludes wetland forests and includes non-Wilderness National Forest (FNW_NFA screen) with moderate biomass removal intensity (FOR_2)

GAP Ecosystem	Hectares	Acres	Sourcing%
Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood	264,612	653,592	49.0%
Appalachian Hemlock-Hardwood Forest	10,074	24,883	1.9%
Central and Southern Appalachian Montane Oak Forest	955	2,359	0.2%
Northeastern Interior Dry Oak Forest - Virginia/Pitch Pine Modifier	261	645	0.0%
Northeastern Interior Dry Oak Forest-Hardwood Modifier	36,885	91,106	6.8%
South-Central Interior Mesophytic Forest	32,990	81,485	6.1%
Southern and Central Appalachian Cove Forest	38,946	96,197	7.2%
Southern and Central Appalachian Oak Forest	1,544	3,814	0.3%
Southern and Central Appalachian Oak Forest - Xeric	1,108	2,737	0.2%
Southern Appalachian Low Mountain Pine Forest	4,618	11,406	0.9%
Southern Appalachian Montane Pine Forest and Woodland	4,274	10,557	0.8%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	208	514	0.0%
Southern Ridge and Valley Dry Calcareous Forest	99,384	245,478	18.4%
Disturbed/Successional - Grass/Forb Regeneration	37,981	93,813	7.0%
Disturbed/Successional - Shrub Regeneration	4,820	11,905	0.9%
Evergreen Plantation or Managed Pine	348	860	0.1%
Harvested Forest - Grass/Forb Regeneration	826	2,040	0.2%

Virginia City Hybrid Energy Center Table 5b. GAP ecosystem overlay for forestry biomass sourcing that excludes wetland forests and includes FNW_NFA screen with HAO_6

Virginia City Hybrid Energy Center Table 5c. GAP ecosystem overlay for forestry biomass sourcing that excludes wetland forests and includes non-Wilderness National Forest (FNW_NFA screen) with low biomass removal intensity (HAO_10)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood	452,815	1,118,453	50.3%
Appalachian Hemlock-Hardwood Forest	15,231	37,621	1.7%
Central and Southern Appalachian Montane Oak Forest	10,296	25,431	1.1%
Northeastern Interior Dry Oak Forest - Virginia/Pitch Pine Modifier	333	823	0.0%
Northeastern Interior Dry Oak Forest-Hardwood Modifier	53,916	133,173	4.0%
South-Central Interior Mesophytic Forest	59,009	145,752	6.2%
Southern and Central Appalachian Cove Forest	52,634	130,006	5.9%
Southern and Central Appalachian Oak Forest	2,634	6,506	0.3%
Southern and Central Appalachian Oak Forest - Xeric	9,754	24,092	1.1%
Southern Appalachian Low Mountain Pine Forest	6,506	16,070	0.7%
Southern Appalachian Montane Pine Forest and Woodland	6,827	16,863	0.8%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	409	1,010	0.0%
Southern Ridge and Valley Dry Calcareous Forest	151,630	374,526	12.6%
Disturbed/Successional - Grass/Forb Regeneration	65,637	162,123	7.3%
Disturbed/Successional - Shrub Regeneration	8,260	20,402	0.9%
Evergreen Plantation or Managed Pine	658	1,625	0.1%
Harvested Forest - Grass/Forb Regeneration	1,512	3,735	0.2%

Virginia City Hybrid Energy Center Table 5c. GAP ecosystem overlay for forestry biomass sourcing that excludes wetland forests and includes FNW_NFA screen with HAO_10

Virginia City Hybrid Energy Center Table 6a. GAP ecosystem overlay for forestry biomass sourcing that includes wetland forests and excludes Wilderness National Forest (FOR_NNF screen) with high biomass removal intensity (HAO_2)

GAP Ecosystem	Hectares	Acres	Sourcing %
Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood	109,771	271,134	61.0%
Appalachian Hemlock-Hardwood Forest	3,531	8,722	2.0%
Central and Southern Appalachian Montane Oak Forest	127	314	0.1%
Northeastern Interior Dry Oak Forest - Virginia/Pitch Pine Modifier	82	203	0.0%
Northeastern Interior Dry Oak Forest-Hardwood Modifier	11,364	28,069	6.3%
South-Central Interior Large Floodplain - Forest Modifier	18	44	0.0%
South-Central Interior Mesophytic Forest	2,755	6,805	1.5%
South-Central Interior Small Stream and Riparian	547	1,351	0.3%
Southern and Central Appalachian Cove Forest	16,491	40,733	9.2%
Southern and Central Appalachian Oak Forest	158	390	0.1%
Southern and Central Appalachian Oak Forest - Xeric	120	296	0.1%
Southern Appalachian Low Mountain Pine Forest	640	1,581	0.4%
Southern Appalachian Montane Pine Forest and Woodland	1,837	4,537	1.0%
Southern Ridge and Valley Dry Calcareous Forest	18,403	45,455	10.2%
Disturbed/Successional - Grass/Forb Regeneration	13,269	32,774	7.4%
Disturbed/Successional - Shrub Regeneration	642	1,586	0.4%
Evergreen Plantation or Managed Pine	45	111	0.0%
Harvested Forest - Grass/Forb Regeneration	98	242	0.1%

Virginia City Hybrid Energy Center Table 6a. GAP ecosystem overlay for forestry biomass sourcing that includes wetland forests and excludes FOR_NNF screen with HAO_2

Virginia City Hybrid Energy Center Table 6b. GAP ecosystem overlay for forestry biomass sourcing that includes wetland forests and excludes Wilderness National Forest (FOR_NNF screen) with moderate biomass removal intensity (HAO_6)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing%**
Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood	331,909	819,815	61.5%
Appalachian Hemlock-Hardwood Forest	8,480	20,946	1.6%
Central and Southern Appalachian Montane Oak Forest	563	1,391	0.1%
Northeastern Interior Dry Oak Forest - Virginia/Pitch Pine Modifier	242	598	0.0%
Northeastern Interior Dry Oak Forest-Hardwood Modifier	27,888	68,883	5.2%
South-Central Interior Large Floodplain - Forest Modifier	177	437	0.0%
South-Central Interior Mesophytic Forest	23,324	57,610	4.3%
South-Central Interior Small Stream and Riparian	2,308	5,701	0.4%
Southern and Central Appalachian Cove Forest	33,256	82,142	6.2%
Southern and Central Appalachian Oak Forest	587	1,450	0.1%
Southern and Central Appalachian Oak Forest - Xeric	438	1,082	0.1%
Southern Appalachian Low Mountain Pine Forest	3,069	7,580	0.6%
Southern Appalachian Montane Pine Forest and Woodland	3,676	9,080	0.7%
Southern Ridge and Valley Dry Calcareous Forest	61,778	152,592	11.4%
Disturbed/Successional - Grass/Forb Regeneration	38,571	95,270	7.1%
Disturbed/Successional - Shrub Regeneration	2,806	6,931	0.5%
Evergreen Plantation or Managed Pine	126	311	0.0%
Harvested Forest - Grass/Forb Regeneration	452	1,116	0.1%

Virginia City Hybrid Energy Center Table 6b. GAP ecosystem overlay for forestry biomass sourcing that includes wetland forests and excludes FOR_NNF screen with HAO_6

Virginia City Hybrid Energy Center Table 6c. GAP ecosystem overlay for forestry biomass sourcing that includes wetland forests and excludes Wilderness National Forest (FOR_NNF screen) with low biomass removal intensity (HAO_10)

GAP Ecosystem	Hectares	Acres	Sourcing %
Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood	570,390	1,408,863	63.5%
Appalachian Hemlock-Hardwood Forest	12,499	30,873	1.4%
Central and Southern Appalachian Montane Oak Forest	2,087	5,155	0.2%
Northeastern Interior Dry Oak Forest - Virginia/Pitch Pine Modifier	299	739	0.0%
Northeastern Interior Dry Oak Forest-Hardwood Modifier	35,991	88,898	4.0%
South-Central Interior Large Floodplain - Forest Modifier	332	820	0.0%
South-Central Interior Mesophytic Forest	43,707	107,956	4.9%
South-Central Interior Small Stream and Riparian	3,580	8,843	0.4%
Southern and Central Appalachian Cove Forest	46,598	115,097	5.2%
Southern and Central Appalachian Oak Forest	4,740	11,708	0.5%
Southern and Central Appalachian Oak Forest - Xeric	3,801	9,388	0.4%
Southern Appalachian Low Mountain Pine Forest	5,920	14,622	0.7%
Southern Appalachian Montane Pine Forest and Woodland	5,139	12,693	0.6%
Southern Ridge and Valley Dry Calcareous Forest	85,046	210,064	9.5%
Disturbed/Successional - Grass/Forb Regeneration	71,670	177,025	8.0%
Disturbed/Successional - Shrub Regeneration	4,753	11,740	0.5%
Evergreen Plantation or Managed Pine	353	872	0.0%
Harvested Forest - Grass/Forb Regeneration	686	1,694	0.1%

Virginia City Hybrid Energy Center Table 6c. GAP ecosystem overlay for forestry biomass sourcing that includes wetland forests and excludes FOR_NNF screen with HAO_10

Virginia City Hybrid Energy Center Table 7a. GAP ecosystem overlay for forestry biomass sourcing that excludes wetland forests and non-Wilderness National Forest (FNW_NNF screen) with high biomass removal intensity (HAO_2)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood	92,135	227,573	51.2%
Appalachian Hemlock-Hardwood Forest	3,458	8,541	1.9%
Central and Southern Appalachian Montane Oak Forest	46	114	0.0%
Northeastern Interior Dry Oak Forest - Virginia/Pitch Pine Modifier	82	203	0.0%
Northeastern Interior Dry Oak Forest-Hardwood Modifier	15,706	38,794	8.7%
South-Central Interior Mesophytic Forest	6,229	15,386	3.5%
Southern and Central Appalachian Cove Forest	15,626	38,596	8.7%
Southern and Central Appalachian Oak Forest	98	242	0.1%
Southern and Central Appalachian Oak Forest - Xeric	43	106	0.0%
Southern Appalachian Low Mountain Pine Forest	1,048	2,589	0.6%
Southern Appalachian Montane Pine Forest and Woodland	1,498	3,700	0.8%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	56	138	0.0%
Southern Ridge and Valley Dry Calcareous Forest	29,225	72,186	16.2%
Disturbed/Successional - Grass/Forb Regeneration	13,073	32,290	7.3%
Disturbed/Successional - Shrub Regeneration	1,322	3,265	0.7%
Evergreen Plantation or Managed Pine	51	126	0.0%
Harvested Forest - Grass/Forb Regeneration	252	622	0.1%

Virginia City Hybrid Energy Center Table 7a. GAP ecosystem overlay for forestry biomass sourcing that excludes wetland forests and FNW_NNF screen with HAO_2

Virginia City Hybrid Energy Center Table 7b. GAP ecosystem overlay for forestry biomass sourcing that excludes wetland forests and non-Wilderness National Forest (FNW_NNF screen) moderate high biomass removal intensity (HAO_6)

GAP Ecosystem	Hectares	Acres	Sourcing%
Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood	252,439	623,524	46.8%
Appalachian Hemlock-Hardwood Forest	7,923	19,570	1.5%
Central and Southern Appalachian Montane Oak Forest	395	976	0.1%
Northeastern Interior Dry Oak Forest - Virginia/Pitch Pine Modifier	220	543	0.0%
Northeastern Interior Dry Oak Forest-Hardwood Modifier	34,782	85,912	6.4%
South-Central Interior Mesophytic Forest	41,300	102,011	7.7%
Southern and Central Appalachian Cove Forest	32,236	79,623	6.0%
Southern and Central Appalachian Oak Forest	521	1,287	0.1%
Southern and Central Appalachian Oak Forest - Xeric	420	1,037	0.1%
Southern Appalachian Low Mountain Pine Forest	5,986	14,785	1.1%
Southern Appalachian Montane Pine Forest and Woodland	3,099	7,655	0.6%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	167	412	0.0%
Southern Ridge and Valley Dry Calcareous Forest	115,645	285,643	21.4%
Disturbed/Successional - Grass/Forb Regeneration	37,991	93,838	7.0%
Disturbed/Successional - Shrub Regeneration	5,516	13,625	1.0%
Evergreen Plantation or Managed Pine	263	650	0.0%
Harvested Forest - Grass/Forb Regeneration	893	2,206	0.2%

Virginia City Hybrid Energy Center Table 7b. GAP ecosystem overlay for forestry biomass sourcing that excludes wetland forests and FNW_NNF screen with HAO_6

Virginia City Hybrid Energy Center Table 7c. GAP ecosystem overlay for forestry biomass sourcing that excludes wetland forests and non-Wilderness National Forest (FNW_NNF screen) with low biomass removal intensity (HAO_10)			
GAP Ecosystem	**Hectares**	**Acres**	**Sourcing %**
Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood	468,679	1,157,637	52.1%
Appalachian Hemlock-Hardwood Forest	11,446	28,272	1.3%
Central and Southern Appalachian Montane Oak Forest	1,126	2,781	0.1%
Northeastern Interior Dry Oak Forest - Virginia/Pitch Pine Modifier	337	832	0.0%
Northeastern Interior Dry Oak Forest-Hardwood Modifier	42,486	104,940	4.7%
South-Central Interior Mesophytic Forest	69,601	171,914	7.7%
Southern and Central Appalachian Cove Forest	43,687	107,907	4.9%
Southern and Central Appalachian Oak Forest	1,784	4,406	0.2%
Southern and Central Appalachian Oak Forest - Xeric	1,132	2,796	0.1%
Southern Appalachian Low Mountain Pine Forest	11,989	29,613	1.3%
Southern Appalachian Montane Pine Forest and Woodland	4,501	11,117	0.5%
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	243	600	0.0%
Southern Ridge and Valley Dry Calcareous Forest	160,511	396,462	17.8%
Disturbed/Successional - Grass/Forb Regeneration	71,749	177,220	8.0%
Disturbed/Successional - Shrub Regeneration	8,216	20,294	0.9%
Evergreen Plantation or Managed Pine	418	1,032	0.0%
Harvested Forest - Grass/Forb Regeneration	1,344	3,320	0.1%

Virginia City Hybrid Energy Center Table 7c. GAP ecosystem overlay for forestry biomass sourcing that excludes wetland forests and FNW_NNF screen with HAO_10

Virginia City Hybrid Energy Center Table 8a. GAP species distribution overlay comparison for non-Wilderness National Forest harvest allowed (NFA) versus exclude all National Forests (NNF) with high biomass removal intensity (HAO_2), wetlands excluded (FNW screen)

Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with NFA screen (% of woodshed habitat)	Hectares of habitat overlay with NNF screen (% of woodshed habitat)	Hectares of Increased habitat overlay with NFA	% Increase in habitat overlay with NFA
Northern Bobwhite	527,653	17,003 (3.2%)	18,503 (3.5%)	-1,500	-8.1%
Swainson's Warbler	1,200,765	138,188 (11.5%)	135,120 (11.3%)	3,068	2.3%
Eastern Spotted Skunk	1,837,386	162,087 (8.8%)	162,153 (8.8%)	-66	0.0%
Long-tailed Weasel	872,734	77,045 (8.8%)	81,325 (9.3%)	-4,280	-5.3%
Northern Cricket Frog	31,375	0 (0.0%)	0 (0.0%)	0	0.0%
Timber Rattlesnake	1,800,158	163,200 (9.1%)	162,217 (9.0%)	983	0.6%

Virginia City Hybrid Energy Center Table 8a. GAP species distribution overlay comparison for NFA versus exclude all NNF with HAO_2, FNW screen

Virginia City Hybrid Energy Center Table 8b. GAP species distribution overlay comparison for non-Wilderness National Forest harvest allowed (NFA) versus exclude all National Forests (NNF with moderate biomass removal intensity (HAO_6), wetlands excluded (FNW screen)					
Species	**Total woodshed habitat, as hectares**	**Hectares of habitat overlay with NFA screen (% of woodshed habitat)**	**Hectares of habitat overlay with NNF screen (% of woodshed habitat)**	**Hectares of Increased habitat overlay with NFA**	**% Increase in habitat overlay with NFA**
Northern Bobwhite	527,653	54,009 (10.2%)	58,263 (11.0%)	-4,254	-7.3%
Swainson's Warbler	1,200,765	409,728 (34.1%)	395,125 (32.9%)	14,603	3.7%
Eastern Spotted Skunk	1,837,386	482,510 (17.6%)	482,152 (26.2%)	358	0.1%
Long-tailed Weasel	872,734	227,699 (26.1%)	240,740 (27.6%)	-14,041	-5.8%
Northern Cricket Frog	31,375	719 (2.3%)	1,288 (4.1%)	-569	-44.2%
Timber Rattlesnake	1,800,158	482,709 (26.8%)	481,211 (26.7%)	1,498	0.3%

Virginia City Hybrid Energy Center Table 8b. GAP species distribution overlay comparison for NFA versus exclude all NNF with HAO_6, FNW screen

Virginia City Hybrid Energy Center Table 8c. GAP species distribution overlay comparison for non-Wilderness National Forest harvest allowed (NFA) versus exclude all National Forests (NNF) with low biomass removal intensity (HAO_10), wetlands excluded (FNW screen)

Species	Total woodshed habitat, as hectares	Hectares of habitat overlay with NFA screen (% of woodshed habitat)	Hectares of habitat overlay with NNF screen (% of woodshed habitat)	Hectares of Increased habitat overlay with NFA	% Increase in habitat overlay with NFA
Northern Bobwhite	527,653	89,951 (17.0%)	97,968 (18.6%)	-8,017	-8.2%
Swainson's Warbler	1,200,765	667,017 (55.5%)	649,832 (54.1%)	17,185	2.6%
Eastern Spotted Skunk	1,837,386	802,259 (43.7%)	802,048 (43.7%)	211	0.0%
Long-tailed Weasel	872,734	368,310 (42.2%)	381,727 (43.7%)	-13,417	-3.5%
Northern Cricket Frog	31,375	4,249 (13.5%)	4,013 (12.8%)	236	5.9%
Timber Rattlesnake	1,800,158	799,806 (44.4%)	793,936 (44.1%)	5,870	0.7%

Virginia City Hybrid Energy Center Table 8c. GAP species distribution overlay comparison for NFA versus exclude all NNF with HAO_10, FNW screen

XI. WOODY BIOMASS FOR BIOENERGY: A POLICY OVERVIEW

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Background

Woody biomass from forests has been a traditional source of energy use worldwide. In recent years woody biomass received renewed interest as a near term alternative with the potential under some scenarios for reducing greenhouse gas emissions (GHG), especially CO2, from fossil fuel burning. (Abbasi and Abbasi 2010; U.S. Department of Energy 2011; Gan and Cashore 2013). Accordingly, public and private investment for the deployment of biomass-based energy sources has surged in many areas of the world. In the United States alone, use of biomass for production of liquid fuels, electricity, and thermal heating increased by approximately 63% from 2001-2010 (Boundy et al. 2011).

Given a current energy policy landscape that is heavily promoting bioenergy production (e.g., U.S. Congress 2007; U.S. Department of Energy 2011) and exerting increased regulatory pressure against coal and other carbon-intensive fuel sources (U.S. Environmental Protection Agency 2012a), there is great potential for bioenergy to continue a rapid growth trajectory in the U.S. and other countries (Raunikar et al. 2010; U.S. Energy Information Administration 2012; Berger et al. 2013). Projected European biomass demand over the next 20 years, due to a 20% renewable portfolio goal of European Union nations, ranges from 35–315 million tons, with estimates of imports accounting for 16–60 million tons of this volume (Joudrey 2012).

Recently, Renewable Portfolio Standards (RPS) have served as one of the key drivers for the development of domestic biopower facilities in the U.S. However, of the 38 states that have outlined such standards only two are in the Southeast (see table 1 below) and one of these (Virginia) is voluntary. A RPS is a regulation that requires that a specified portion of the production of energy come from renewable energy sources, such as biomass, wind, solar, and geothermal. Of those states with RPS polices, each has set their own standards specifying that electric utilities deliver a certain amount of electricity from renewable or alternative energy sources. While the success of state efforts in increasing renewable or alternative energy production will depend in part on federal policies such as production tax credits, state RPS policies have been generally effective in encouraging alternative energy generation (www.c2es.org 2013).

At the federal level, the recent policy focus on increased use of bioenergy in the U.S. has been geared largely towards biofuel production, especially corn based ethanol and second generation cellulosic biofuels production (Sissine 2007; International Risk Governance Council, 2008; Renewable Fuels Association 2009). However, the combined biomass demand for bioenergy (heat, electricity and pellet productions alone, excluding liquid biofuels) production in the U.S. has been estimated at between 170 and 336 million green tons by 2050, which would represent an increase of 54 to 113 percent over current levels (Alavalapati et al. 2012). Although consumption forecasts for forest biomass-based energy, which are based on Energy Information Administration projections, have a high level of uncertainty, such a scale-up of bioenergy systems is broadly regarded as requiring management intensification and/or land use change to produce economically adequate scales of biomass supply (Field et al. 2008; Dale et al. 2009; Alavalapati et al. 2012).

In order to sustain the biomass supply chains for bioenergy production in different forms, a credible assurance mechanism of sustainable sourcing of the wood fiber is an important first step in the biomass and bioenergy policy sphere. There are various existing sustainable forest management (SFM) certification programs and guidelines in the U.S. and around the globe. These include certifications by American Tree Farm System (ATFS), Sustainable Forestry Initiative (SFI), Forest Stewardship Council (FSC), and chain-of-custody (CoC) certification. These policy tools are elaborated on in the following sections.

Certification Tools

U.S. foresters have almost 20 years of experience with SFM certifications, which are widely looked to as a potential basis for the emerging development of bioenergy certification programs in the SE U.S. (Gan and Cashore 2013). Forest certification is a system of standards, rules and procedures for assessing conformity with specific forestry requirements (CEPI 2004). Forest management certification is a generally achieved through an accreditation process in which third- party auditors verify claims about forest management relative to a particular standard (Kittler et al. 2012). The following sub-sections briefly outline major certification programs, as well as BMPs and harvest guidelines in the SE U.S.

Forest Stewardship Council

The Forest Stewardship Council (FSC) is a global certification initiative with an international governance structure and membership. Each member country has its own national initiative, e.g., the FSC-US represents the U.S.A. certification issues. The U.S. FSC uses different processes for assessing and documenting percentage mix claims and specifically the incorporation of non-certified wood into the supply chain. Currently about 1% of the U.S. forest area is under this category of certification (Kittler et al. 2012). The FSC forest management standards for the U.S. do not yet discuss biomass harvests as a particular type of removal.

While it has been previously argued that the key environmental considerations associated with biomass energy are already addressed by previous FSC (Kittler et al. 2012), these standards are currently under review. Principle 6 of FSC addresses the environmental impacts of harvesting operations, and indicator 6.3.f requires that “management maintains, enhances, or restores habitat components and associated stand structures, in abundance and distribution that could be expected from naturally occurring processes.” This includes “live trees with decay or declining health, snags, and well-distributed coarse down and dead woody material” (Evans et al. 2010). Principle 10 of FSC focuses on plantations, and requires clear justification for management activities, protection of “natural forests” and species diversity (Kittler 2010). Under the FSC guidelines on opening sizes (Indicator 6.3.g.1), regional limits to forestry extraction are set, large clear-cuts are disallowed and preservation of ecological integrity of the forests is an explicit management goal.

The FSC guidelines put forth clear requirements to maintain high conservation value forests, which include but are not strictly limited to listed G1 (Critically imperiled), G2 (Imperiled) , and G3 (Vulnerable) ecological associations. FSC strictly prohibits deforestation practices, including the conversion of bio-diversity rich natural forests to monoculture plantations and other non-forest uses (Principle 10: Plantation Management). The FSC bans the use of Genetically Modified Organisms, which are allowable under other certification standards. Furthermore, the FSC provides standards for the protection of rights of indigenous people and local communities. Based on the strength of these standards (including biodiversity), it is often argued that the FSC is more protective of the biodiversity as compared to other certification regimes (Stryjewski 2007). While small forest owners have historically been less likely to join FSC due to costs and other considerations, the program does allow for the grouping of parcels as a means of reducing cost burdens to single landowners (Bowyer et al. 2011).

Sustainable Forestry Initiative

SFI was originally established by the American Forest and Paper Association (AF&PA), as a means to help ensure that AF&PA members use responsible forest management practices. The SFI certification system is a U.S. initiative, which is currently an independent certification program endorsed by the Program on the Endorsement of Forest Certification Programs. SFI objectives include reforestation, protection of water quality, enhancement of wildlife habitat, improvement of harvest operation aesthetics, protection of unique sites, considerations for biological diversity, continued improvements in wood utilization, and the responsible use of pesticides and fertilizers.

The SFI objectives and performance measures do not include specific protocols for biomass harvesting. The SFI system has an emphasis on training of actors in the supply chain, which is required for facility procurement officers; certified entities are strongly encouraged to provide training for forest managers and loggers (e.g., BMP training). Scientific research and adaptive management is another emphasis area of SFI. There are various logger training programs and extension programs offered through forestry schools and colleges, which assist in the sustainability of biomass sourcing.

The Fiber Sourcing standard is the means through which certified entities can claim a mass balance percentage mix of the product is certified and thus label it as such. The Fiber Sourcing standard does not apply the specific SFI forest management standards and require compliance with them. Instead it relies on general landowner and logger education and adherence to water quality BMPs.

American Tree Farm System

The ATFS is a certification program, which is designed to help family woodlot owners to develop and implement a forest management plan. The plan includes (AFF 2010):

1. The owners' goals appropriate to the management objectives
2. A tract map noting stands and conditions
3. Important features including:
    a. Special sites
    b. Management recommendations that address:
        i. wood and fiber production
        ii. wildlife habitat
        iii. owner-designated fish, wildlife and plant species to be conserved/enhanced, threatened

iv. endangered species
v. high conservation value forests and other special sites
vi. invasive species and integrated pest management environmental quality
vii. if present and desired by the landowner, recreational opportunities

The ATFS standard also includes periodic monitoring to encourage landowners to monitor for changes that could interfere with their management objectives. After the forest management plan is developed, the property is inspected by an ATFS volunteer forester annually to verify whether the management plan is being implemented. About 6.3% of forest area in the U.S. has been enrolled with this program.

The ATFS does not have its own CoC certification, however it does offer CoC through PEFC. The ATFS is endorsed by PEFC, meaning that wood fiber from ATFS certified forests can be counted as certified content for the SFI label. Third-party certification audits are required under ATFS. These are carried out annually by ANSI-ANAB accredited auditors. The comparison of dominant certification systems in terms of plantations and natural stands, green up interval, harvest size, harvest openings, and biodiversity is outlined in table 2 below.

Roundtable on Sustainable Biomaterials
The Roundtable on Sustainable Biomaterials (RSB) is an international multi-stakeholder initiative that provides the global standard for socially, environmentally and economically sustainable production of biomass and biomaterials. Modeled on the FSC, with robust standards and an independent third party certification system, the RSB achieved consensus on the standard among over 120 members from around the world, and thousands of individual commenters, including farmers, companies, trade unions, non-governmental organizations, academic experts, and inter-governmental agencies, concerned with ensuring the sustainability of biomass production and processing. The standard covers biomass production, processing and blending (where that is relevant), and includes a chain of custody system to enable full supply chains to include mixes of certified and uncertified materials.

The RSB Principles and Criteria encompass biological diversity conservation, air and water quality, and soil protection, as well as social safeguards such as labor conditions, land and water rights and food security. In March 2013 RSB was broadened from a biofuels-only focus, to cover all products derived from biomass (namely "biomaterials") that are used as substitutes for petroleum-based products in the manufacturing of textiles, plastics, food additives and other industrial sectors. In the assessment of forest products used for biomass, the RSB permits only forest residues to be used, and those must come from FSC certified forests. Operators which are already FSC certified can receive RSB certification using a simplified process. Notably, RSB certification includes a 50% greenhouse gas emission reduction requirement compared to the fossil fuel equivalent.

The RSB standards are used by several governments as a basis of their regulatory frameworks, and by the Inter-American Development Bank as a project screening tool. RSB certification is recognized by the EU as providing proof of compliance with the sustainability requirements of the EU's Renewable Energy Directive (biofuels mandate). While there are not comparable provisions in place for demonstrating biomass sustainability, some commentators suggest that this might be a useful next step in improving the sustainability outcomes for biomass used for energy in Europe.

Earlier this year, RSB members adopted the Low Indirect Impact Biofuels (LIIB) approach to address indirect impacts of biofuels and biomaterials. The LIIB approach incentivizes producers who source biomass from residues, by-products, restoration of degraded land and increased yields on existing fields or forests. The RSB is a relatively new certification system not yet widely used in the U.S., but provides another option for certification of sustainability in biomass sourcing.

Forest management and chain-of-custody certification

Currently only 17% of southern forests are certified under existing certification programs. The reason behind this low enrollment may be the cost of certification and land owners' unwillingness to participate. Costs of certification vary in the range of ~$0.70/acre -~$1.30/acre, with discrepancies related to differences in the size of the audit teams and the scope of the audits. Forest certification also includes the cost of required management changes, which can be significant if lands have previously been unmanaged or managed poorly (Cubbage et al. 2002). Since certification is voluntary, large landowners and/or companies already adhering to stated certification standards are usually the first to adopt (Centamore 2008).

The Southern Group of State Foresters recently articulated that annualized per-acre costs for ownerships less than 10,000 acres is $15 for SFI and $3 for FSC (Lowe et al. 2011). Keeping in mind the transaction cost of certification, Mendell and Lang (2012), argue that the FSC strategy can internalize the costs by intending to drive change through financial rewards in the marketplace. They state that the FSC mechanism includes labeling forest products to differentiate these goods as coming from lands complying with a superior set of criteria and principles.

While it remains unclear as to how the various certification systems and their components will ultimately be viewed by European buyers, regulations to ensure sustainability of sourced biomass are currently being developed. Because the new European Timber Regulation calls for chain-of-custody (CoC) tracking to ensure compliance with sustainable forestry sourcing, it seems likely that CoC certification will be encouraged or demanded by European wood pellet buyers in the near future.

Other sustainability standards and programs

Regulatory approaches that include procedural rules, legislatively prescribed practices, reporting, monitoring, compliance, and enforcement are useful tools in influencing SFM for private forest owners (Ellefson et al. 2004). Equally important in this context are non-regulatory schemes such as extension education, information sharing, technical assistance, tax incentives, and other financial incentives (Barrett et al. 2012).

Most states in the southern region of the U.S. rely on a framework of forestry practices and guidelines focused mainly on a variety of issues (e.g. water quality, fire management, pest management, that are bound together by voluntary programs focused on outreach to landowners and loggers. In a nation-wide review of state-level regulations affecting forestry operations, Ellefson et al. (2004) found that the South has the highest portion of states that have no regulation of practices, or that only regulate under certain conditions. As a consequence, SE states rely almost exclusively on voluntary approaches, with the forest industry historically playing a larger role than government in carrying out outreach to land owners or providing financial and/or technical assistance in the development of forest management plans (Ellefson, et al. 2004).

Voluntary programs most often take the form of incentives such as cost share payments, technical assistance, grants and loans, education programs, preferential access to contracts with forest product companies, practice guidelines, and certification programs (Ellefson et al. 2004). Some government funded landowner incentive programs may be of relevance for sourcing strategies, particularly those that focus on sourcing from lands operating under a forest management plan. The majority of these programs focus on providing incentives to landowners to undertake and/ or implement forest management plans. A summary of the state, federal, and privately administered programs available to non-industrial private forest landowners in SE states can be found in Kittler (2010). On average there are 20 programs available to landowners in each state, some of which, the Forest Stewardship Program and Biomass Crop Assistance Program for example, may be of relevance to pellet facilities seeking to establish a sustainable supply chain.

State and federal financial incentives: *Forest Stewardship Program:* The USDA Forest Service administers the Forest Stewardship Program (FSP), which provides financial incentives to compensate landowners who work with a forester to develop forest stewardship plans (FSPs), which cover a broader range of sustainability indicators, including wildlife. These plans also confer eligibility for a broader suite of incentives to implement practices that improve forest productivity and habitat conditions. The vast majority of private forest landowners in the U.S. do not currently have forest management plans, despite the fact that FMPs are widely viewed as one of the most effective means of ensuring responsible management of woodlots. Overall, coverage of FSP in the 13 Southern states is limited. The program covered just over 4.1 million acres, or roughly 3% of all NIPF lands in the South as of 2010.

Biomass Crop Assistance Program (BCAP) is a new program added to the energy title in the 2008 Farm Bill. This program authorizes payments to agricultural producers for the establishment, maintenance, collection, harvest, transport, and storage of eligible biomass energy feedstocks, including woody biomass from non-industrial private forestlands. Participating landowners within a BCAP project area must develop a forest stewardship plan that covers the acres enrolled in BCAP.

Best Management Practices

Forestry operations are responsible for approximately 10% of water quality impairments in the U.S. This is largely due to sedimentation associated with roads and stream crossings and the improper implementation of BMPs (Edwards and Williard 2010). Best Management Practices (BMPs) were developed as a requirement of an exemption granted to silvicultural activities in the non-point source pollution permitting requirements of the Federal Clean Water Act. Each set of BMPs was developed at the state level using science-based information to create guidance on how to protect water resources. Overall, BMPs offer guidance on streamside management zones (SMZs), forest roads, stream crossings, timber harvesting, and site preparation.

In over half of Southern states, BMPs are voluntary with potential enforcement by a state agency, with three States (Florida, North Carolina, and Virginia) linking BMP implementation to other state regulatory programs (Prud'homme and Greis 2002). Very few BMPs include guidance on secondary goals related to wildlife (Aust and Blinn 2004), although the South Carolina Forestry Commission does outline wildlife enhancement as an "additional management option." When implemented effectively, existing BMPs are presumed as sufficient to address most water quality concerns during and immediately after biomass harvests, but are not designed or intended to address potential risks to biodiversity and wildlife habitat maintenance. (Evans et al. 2010).

Harvesting guidelines

A body of research evaluating the removal of biomass during timber harvests highlights the importance of retaining some harvest residues distributed across harvested areas to minimize impacts on soil and water resources (Shepard 2006; Benjamin et al. 2009; Evans et al. 2010; Lal et al. 2011). Building on existing BMP programs, at least eight states in the country have developed voluntary biomass harvesting guidelines that supplement BMPs to include practices that protect soil fertility, wildlife habitat, water quality, and other values during biomass harvests (Benjamin 2009).

Similarly, the Forest Guild (2012), a professional organization promoting responsible forestry as a means of sustaining the integrity of forest ecosystems, has developed regional biomass harvesting and retention guidelines for the forests of the SE U.S. The main focus of these guidelines is the amount of down woody material (DWM) (i.e., coarse woody debris and fine woody debris) that can be sustainably removed without impairing nutrient cycling, water quality, and habitat values (Evans et al. 2010). Based largely on Forest Guild guidelines, the State of South Carolina in December 2012 published biomass harvesting recommendations as a supplement to their forestry BMPs (South Carolina Forestry Commission 2012).

Summary

Government policies and growing demand for alternative energy are expected to result in dramatic increases in bioenergy production in the U. S. over the next two decades. While there is a substantive body of policy literature that assesses potential carbon emission impacts of bioenergy-driven land-use change and energy substitution away from fossil fuels, less attention has been given to the direct habitat and biodiversity implications of large-scale bioenergy feedstock production from SE forests.

There currently is some uncertainty facing the SE wood biomass export market due to sustainability criteria being developed by the European Commission. Finalization of these criteria may remove policy uncertainty, and may potentially result in more SE forest landholders entering into sustainability certification programs for the purpose of maintaining access to European markets. The social acceptability and adoption rates of these sustainability criteria may depend on the process of updating state level BMPs to include stronger biodiversity and habitat protection criteria, particularly in terms of combining public involvement with a science-based process to develop appropriately protective criteria at both stand and landscape scales (Alavalapati and Lal 2009).

Comparison of SFI, ATFS, PEFC and FSC Forest Management Standards				
	SFI	**ATFS**	**PEFC**	**FSC**
Plantation vs. Natural Stands	Standard does not distinguish between plantations and natural stands.	Standard does not distinguish between plantations and natural stands.	Exclusion of certification of plantations established by conversions.	Distinguishes between plantation and natural stands based on cut-off date. Auditors in U.S. now classify planted stands of native species (traditionally thought of as plantations) as "semi-natural" forests.
Green-up Interval: Restrictions on period of time between harvests of adjacent stands	South: 3 years old or 5 feet tall.	Standard does not specify green-up interval.	Guideline states that harvesting levels of both wood and non-wood forest products shall not exceed a rate that can be sustained in the long term.	South: Standard does not have green-up rules; defaults to auditor interpretation and guidance; state BMPs if available; some timberland owners use SFI guidelines.
Harvest Size Requirements	Standard states 120 acre average for the South. Nobinding maximum unless under state forest practices rules; landowners have been known to use 250 acres in some cases.	Standard does not have harvest size restriction.	Standard does not have harvest size restriction.	Plantations - Standard: 40 acre average and 80 acre maximum.
Retention in Harvest Openings	Landowners leave small patches of non-merchantable trees.	Standard does not have a specific retention requirement.	Standard does not have a specific retention requirement.	South: Retention implementation left to auditors; often mirrors that of SFI.
Biodiversity	Program managers shall promote biodiversity at stand and landscape levels.	Requires that forest management activities maintain or enhance habitat for threatened or endangered communities and species.	Requires that forest management planning shall aim to maintain, conserve and enhance biodiversity on ecosystem, species and genetic levels and, where appropriate, diversity at landscape level.	Samples of existing ecosystems within the landscape shall be protected in their natural state.
Source: Adapted from Mendell and Lang (2012) and Stryjewski (2007)				

Table 4. Comparison of SFI, ATFS, PEFC and FSC Forest Management Standards

XII. SUMMARY AND CONCLUSIONS

This study utilized a scenario-based, geospatial risk analysis approach to assess potential ecosystem and wildlife habitat impacts associated with six woody biomass energy facilities that have recently opened or will soon begin operations in the SE U.S. Although these facilities only represent a partial sampling of existing or planned woody biomass energy facilities in the region, they have high diversity in terms of their physiographic location (i.e., two in the coastal plain, two in the piedmont, and two in the mountain), feedstock utilization (i.e., softwood, hardwood, or mixed), and product output (i.e., three wood pellet facilities, and three bio-power facilities). For this reason, the results of the case studies are expected to inform assessments of potential impacts in other similar facilities throughout the region, while also suggesting key sets of questions that require additional research, analysis, and policy development.

The biomass sourcing models for this study included spatially explicit analyses of travel distance, woodshed competition, environmental characteristics, and a series of land cover constraints in conjunction with estimates of facility biomass demand and local forest productivity. The sourcing models were run over a 50-year facility lifetime, and thus reflect cumulative potential for habitat impact over that period under an assumed biomass demand. These scenario assessments thus provide an objective starting point for understanding the forest ecosystem types that may be most likely to face increased conversion or harvest pressure from biomass sourcing under scenarios of no forest protection, while also identifying opportunities for bioenergy sustainability criteria that can be protective of wildlife and biodiversity values.

Softwood sourcing

For facilities that are sourcing large amounts of plantation pine-based softwood materials (i.e., Georgia Biomass, Piedmont Green Power, and South Boston Energy), the primary wildlife and wider ecological concerns are associated with bioenergy demands providing increased pressure/incentive for landowners to convert remnant natural forest stands into plantation pine land cover. Widespread conversion of native forest types into pine plantation forestry for sourcing saw mills and pulp/paper mills is widely noted alongside agricultural clearing and suburban encroachment as a key conservation concern for natural forest stands and dependent species in these woodsheds.

In the Georgia Biomass woodshed, substantial areas of longleaf pine forest were identified as having high conversion risk to plantation pine forest under a long-term biomass energy sourcing scenario that assumed “no protection” of extant natural forest stands. In both the Piedmont Green Power and South Boston Energy woodsheds, large areas of Southern Piedmont Dry Oak forest types were identified as having high risk for plantation pine conversion. While it is known that plantation pine forestry can provide suitable habitat for many native SE wildlife species, a number of specialized animal and plant species are highly adapted and/or dependent on the habitat provided by natural forest stands.

Regional indicator species with GAP distributions that showed high potential for habitat loss and/or degradation from conversion of natural forest stands into plantation pine forestry include the brown-headed nuthatch, Swainson's warbler, timber rattlesnake, and eastern spotted skunk. In the Georgia Biomass woodshed, high habitat risk was also shown for the more locally distributed gopher frog. Based on existing knowledge, it is probable that these, and a variety of other wildlife species dependent on natural forest stands, could experience further population and/or range declines under future land cover change outcomes that are characterized by increased conversion of natural forest stands into plantation forestry for bioenergy sourcing purposes.

However, analyses for all these woodsheds indicated substantial land cover areas in extant plantation pine, ruderal, or disturbed forestry conditions at levels that appear sufficient for meeting long-term softwood bioenergy demands without need for additional conversions of natural forest stands. Sourcing from forest landowners in compliance with FSC standards for controlled wood or forest management, which specifically prohibit use of wood that results in conversion of natural forests or harvested from forests where conservation values are threatened, would arguably provide a mechanism for protecting extant natural forest stands from land cover change. The Piedmont Green Power and South Boston Energy woodsheds also contain relatively large amounts of pasture/hay land covers that could potentially be incentivized as an additional base for biomass-driven afforestation. Pasture afforestation would likely provide direct habitat benefits for many forest species, including the long-tailed weasel, brown-headed nuthatch, and timber rattlesnake. However, it is possible that some species of conservation concern that utilize forest-grassland edges, such as the northern bobwhite and eastern spotted skunk, could show some negative response to large-scale pasture afforestation.

Within the extant pine plantation landscape, the development of biomass markets is widely thought to offer additional market incentive for landowners to conduct more regular thinning treatments. If implemented holistically and in conjunction with prescribed fire, thinning practices may benefit a number of native wildlife species, particularly by providing for more open understory conditions that somewhat simulate reference longleaf pine savannahs and pine flatwood ecosystems. Managed thinnings can also provide important landscape benefits through the reduction of high forest fuel loads that, particularly in times of drought, can catalyze fast-moving and catastrophic crown fires. However, there is some worry that management of pine plantations to optimize biomass harvest could include significantly increased stem density plantings. If not managed properly, high stem density plantings could have the effect of reducing habitat values for species that cue onto open understories and low stem density forests, while also providing the potential for increases in long-term fuel load. Further research is needed to understand the extent to which landowners may adopt new biomass optimizing strategies on pine plantation lands, as well as to determine differences in habitat quality associated with altered plantation forestry management practices.

Hardwood sourcing

For facilities that are sourcing large amounts of hardwood material (Enviva Ahoskie, South Boston Energy, Carolina Wood Pellets, and Virginia City Hybrid Energy), primary wildlife concerns are associated with the effects of direct logging disturbance and, more subtly, increased residual removal impacts. Most SE upland hardwood forests have experienced historic pressures from logging, agricultural or plantation pine conversion, and exurban development. Bottomland hardwood forests have also been widely influenced by historic logging pressures, as well as drainage of isolated wetland systems, large-scale hydroperiod shifts in floodplain wetlands systems due to upstream damming, and in some cases conversion into plantation pine or agriculture after drainage.

The Enviva Ahoskie facility is unique among the considered facilities in the sense that current biomass sourcing practices appear dependent on extraction of hardwood from natural stands of bottomland and floodplain forest. Large-scale clear cut harvest of such forests can affect a number of wetland-dependent wildlife species, which in our analysis was demonstrated by heavy overlap with GAP habitat for the prothonotary warbler and Swainson's warbler. Literature reviews suggest that Swainson's warbler populations can be somewhat adaptable to managed silvicultural regimes in bottomland forests, but interior-dependent species such as prothonotary warbler generally show negative response to most riparian or wetland logging disturbance. Literature further suggests that indirect effects of riparian harvest may include increased sediment loading and temperature fluxes in local streams, both of which can have cascading negative effects on sensitive aquatic organisms. Long-term sustainable sourcing of hardwood biomass for this facility that minimizes overall biodiversity impacts may require large-scale afforestation on extant pasture or marginal crop lands, potentially through fast-growing woody biomass crops such as *Populus* sp.

Sourcing models for South Boston Energy, Carolina Wood Pellets, and Virginia City Hybrid Energy indicate very low percentages of hardwood biomass supplies within riparian or wetland ecosystems. For all of these facilities, implementation of riparian buffers as part of a sustainable sourcing standard is generally justified from a habitat protection standpoint, and appears readily achievable in terms of facility wood demands. However, key unknowns from a wildlife management perspective include the relative percentage of primary to residual biomass that may be sourced by these facilities. Although residual materials are often promoted as an attractive source of biomass for bioenergy sourcing, concentration of large amounts of residual materials for transport over a much more extensive harvest area is economically challenging. This raises doubt about the long-term feasibility of residuals-only strategies for facilities with large biomass demands, which arguably includes all facilities considered for this study with the exception of Carolina Wood Pellets. From a wildlife perspective, literature suggests that increased removal of residuals from forest lands can have negative impacts on forest regeneration. High rates of residual removal may pose significant risks of habitat degradation for species that heavily utilize downed woody matter, including the eastern spotted skunk and timber rattlesnake. Conversely, selective thinning of piedmont and low slope mountain hardwood forests for bioenergy sourcing may have the potential to improve habitat for the northern bobwhite and, more arguably, the northern cricket frog. However, field differences in residual removal and thinning practices for woody biomass as compared to traditional silvicultural treatments are currently not well-quantified from an applied management sense. For this reason, specific effects on wildlife species will require additional research before definitive habitat enhancement recommendations can be provided.

POLICY AND RESEARCH IMPLICATIONS

As an industry that has developed in recent years as a direct consequence of government intervention intended to promote energy alternatives for non-renewable fossils fuels and reduced carbon emissions, the woody biomass energy sector is currently under increasing scrutiny by policy-makers, environmental regulators, and public interest organizations. Accordingly, many ongoing policy discussions reflect increased interest to develop and implement sustainability standards that reflect a wide suite of conservation, biodiversity, and stewardship values.

This study represents one of the first detailed analyses of biodiversity and habitat concerns associated with forestry biomass energy in the SE U.S. region. Because of the regional nature of this study and the idiosyncratic or even unknown responses of wildlife taxa to variable sourcing practices, it is important to note that it not possible to make firm conclusions of impact that would apply to all sites, species, and harvest practices. However, the results of this study do support several generalizations that can inform policy discussions and research priorities for promoting increased sustainability of forestry biomass energy moving forward.

1. The primary conservation concern for softwood biomass sourcing in the SE Coastal Plain and Piedmont provinces is land cover change away from existing natural forest stands into plantation pine forestry. Such conversion is historically known as a primary factor in the loss or degradation of much wildlife habitat in the SE U.S., including for many species of conservation concern. Using existing land cover as a base, woodsheds with relatively large extant areas of plantation pine and ruderal forestry lands generally pose less concern for future biodiversity impacts as compared to those with relatively large areas of natural forest stands.

2. Biomass thinning for energy production may in many cases provide wildlife habitat enhancement within the extant plantation pine forestry landscape in the Coastal Plain and Piedmont, particularly in cases where lack of other markets has resulted in landowner neglect of planted forests. Such thinning practices can provide some structural and functional simulation of longleaf pine ecosystems that were historically a dominant upland habitat throughout the SE.

3. In the Coastal Plain, the most biologically productive hardwood forests are generally located in bottomland areas, including riparian floodplain and isolated basin wetland systems. Large-scale hardwood biomass sourcing within the Coastal Plain sites therefore will generally imply substantial logging pressure on natural wetland forests. While wetland forestry BMPs such as streamside riparian buffers and erosion control measures are available in the SE U.S., unique challenges associated with degradation of wildlife habitat, local and downstream water quality impacts, and uncertainties of natural stand regeneration after intensive harvests of SE bottomland and floodplain forests

are all documented within the ecological literature. However, sourcing of upland hardwood biomass in the Coastal Plain may in some cases have habitat enhancement effects, particularly on sites that have experienced hardwood succession away from pines due to fire exclusion.

4. In the Piedmont and Mountain provinces, relatively low amounts of hardwood forest land are contained within wetland forests. There are substantial concerns regarding erosion, sedimentation, and wildlife habitat impacts associated with riparian and wetland forest harvesting in both the Piedmont and Mountain provinces. Avoidance of such wetland areas for biomass sourcing through riparian buffer strips can be recommended with minimal effects on overall hardwood biomass supply in the Piedmont and Mountain provinces.

5. Moderate biomass sourcing of upland hardwood biomass from the Piedmont and, to a lesser extent, the Mountains may in some cases have habitat enhancement effects, particularly when coupled with understory thinning. However, biomass harvest practices that result in large-scale reductions of cavity trees, snags, and downed woody matter are a habitat concern for a wide variety of wildlife taxa found in Piedmont and Mountain hardwood forests.

6. Specific field research is required to better understand long-term habitat responses associated with different biomass management regimes, and to compare these responses to control regimes that are not sourced for biomass. Such research will be critical for the long-term co-management of SE forestry ecosystems for both wildlife habitat maintenance and sustainable bioenergy production.

7. State-level BMP guidelines for forestry operations are not designed for the enhancement or maintenance of biodiversity at stand or landscape levels, but instead to ensure compliance with federal regulations related to the Clean Water Act. Biomass sustainability policies that aspire to be protective or restorative of landscape biodiversity and native forest vegetation types of high conservation value are likely to require additional certification regimes and compliance procedures beyond those provided by BMP guidelines.

8. The U.S. forestry sector has a number of existing sustainable forest management (SFM) certification programs, including the Forest Stewardship Council (FSC), Sustainable Forestry Initiative (SFI), American Tree Farm System (ATFS), the Program on the Endorsement of Forest Certification (PEFC), and more recently the Roundtable on Sustainable Biomaterials. These programs are voluntary for forest landowners, and only 17% of SE forestry lands are presently certified through one of the major sustainability certification programs. There currently is no SFM certification in the U.S. that specifically applies to bioenergy production.

9. While all of the major SFM certification programs in the U.S. contain biodiversity protection criteria, FSC certifications are generally regarded as the most protective of remaining natural forest stands and associated wildlife habitat in the working forestry landscape. In particular, the FSC Controlled Wood and

Forest Management Standards provide restrictions against conversion of extant natural stand forests into plantation forestry. If adopted for softwood sourcing biomass energy facilities that rely upon plantation pine feedstocks, these FSC standards would be expected to offer a high level of protection against biodiversity degradation associated with natural stand conversions to plantation forestry.

10. Biomass energy sourcing from natural stands of hardwood forests poses a more complex set of potential impacts for wildlife habitat and associated forest sustainability certification regimes. Specific recommendations for reducing habitat impacts from biomass sourcing in natural hardwood stands have recently been developed by the Forest Guild (2012). These recommendations generally focus on retaining sufficient snags, cavity trees, and downed woody matter to maintain opportunities for wildlife habitat regeneration. However, rates of voluntary compliance with these practices are currently unknown, as are specific wildlife responses to recommended and actual biomass harvest practices across different habitat and ecosystem types. Additional research will be required to more fully resolve these questions, and thus provide adaptive guidance for the long-term protection of biodiversity and wildlife resources under sustained forestry biomass sourcing.

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IX. APPENDIX SECTION PLACEHOLDER