TECHNICAL GUIDE FOR ASSESSING AND PLANNING FOR RESILIENT COASTAL FORESTS

May 2022

Green Infrastructure Center

Technical Guide for Assessing and Planning for Resilient Coastal Forests

Published by the Green Infrastructure Center Inc.
May 2022

Green Infrastructure Center

With support from the South Carolina Forestry Commission, the Georgia Forestry Commission, the Virginia Department of Forestry and the USDA Forest Service, Southern Region.

Acknowledgements

All images, graphics and maps in this report are by the Green Infrastructure Center, unless otherwise credited. Contributing authors to this report include Green Infrastructure Center staff: Matt Lee, Karen Firehock, Stuart Sheppard and Tim Lewis.

To obtain any materials presented in this report please contact us at:
GIC, 320 Valley St., Scottsville VA 24590-4996
Phone: 434-286-3119 and visit our website for resources www.gicinc.org

Special thanks to the state and local stakeholder committee members from Georgia, South Carolina and Virginia who provided expertise and collaboration on this project.

Table of Contents

Introduction

This guide is provided to help users of the data understand how the data were created for the Resilient Coastal Forests (RCF) study led by the Green Infrastructure Center and the state forestry agencies of South Carolina, Georgia and Virginia. It can also inform those who wish to undertake similar efforts. The work was funded by a grant from the USDA Forest Service.

Coastal forests are affected by myriad issues, some of which are uniquely coastal. For example, storm surge that may have high salt concentrations can weaken trees and make them more susceptible to other problems, such as insect infestation. Trees dead from saltwater also become higher fire risks.

The RCF project was a three-year effort to model the benefits of coastal forests, as well as the interacting and reinforcing threats that affect their sustainability, and was also utilized to determine how resilient they are and what actions can be taken today to ensure their survival into the future. Those reports can be found on agency websites and also at: http://www.gicinc.org/res_coastal_forests.htm

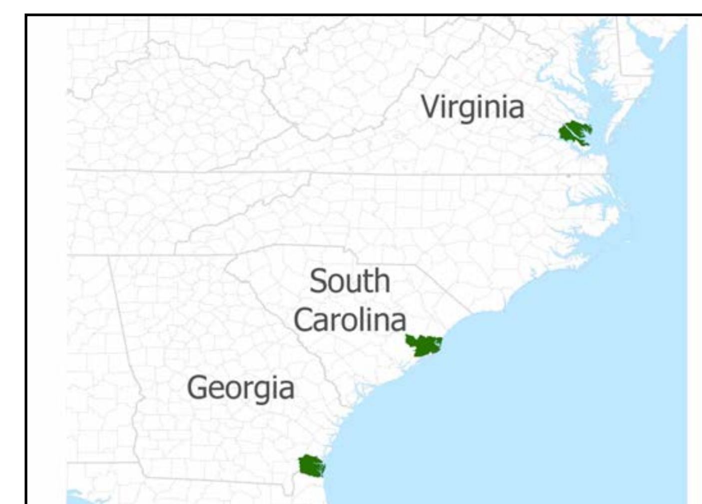
Defining the Study Area

The study area for each of the three states was delineated by the state forestry agency in that state. The general approach was to capture a lower sub-watershed of a major river that emptied into the Atlantic Ocean or Chesapeake Bay. An additional factor considered for the study area selection was that it had to have a mix of land uses, thereby capturing both rural lands and urban centers. The goal was to diversify and expand stakeholder collaboration and highlight the different challenges and potential solutions between landscape-scale conservation and the urban forest.

Lesson Learned

While a watershed-scale analysis of coastal forests may seem the best approach when considering such environmental variables as calculating ecosystem service benefits for stormwater uptake, the result for stakeholder participation is less cohesive. For example, in the Virginia and South Carolina study areas, partial counties were included under a watershed-scale approach, but a significant portion of those counties' land cover was not mapped, which limited its value to the county and lowered their incentive to fully engage. So, for local government engagement, the entire county or municipal boundary should be included.

Another interesting logistical challenge arising from the Virginia study area was the barrier of the York River. Getting local stakeholders to cross from one side of the river to the other was a challenge; although there were bridges, the river seemed to present a psychological barrier to participation with stakeholders unwilling to cross to the other side for regional meetings. This necessitated individual consultations with local governments. In summary, a study area can be any size but regions should be inclusive of jurisdictional boundaries and try to avoid real or perceived barriers.



South Carolina Study Area

Georgia Study Area

Virginia Study Area

Modeling Forest Cores

Introduction

A forest core is an intact area of native forest cover that is large enough – 100 acres or greater – to support an abundance of native species. Forest cores are modeled using land cover and fragmenting features such as roads and large rivers are used to evaluate where breaks serve as barriers to wildlife movement. Smaller areas such as woodlands also have value and can be included, but they have lesser values for sustaining large mammals or interior forest birds.

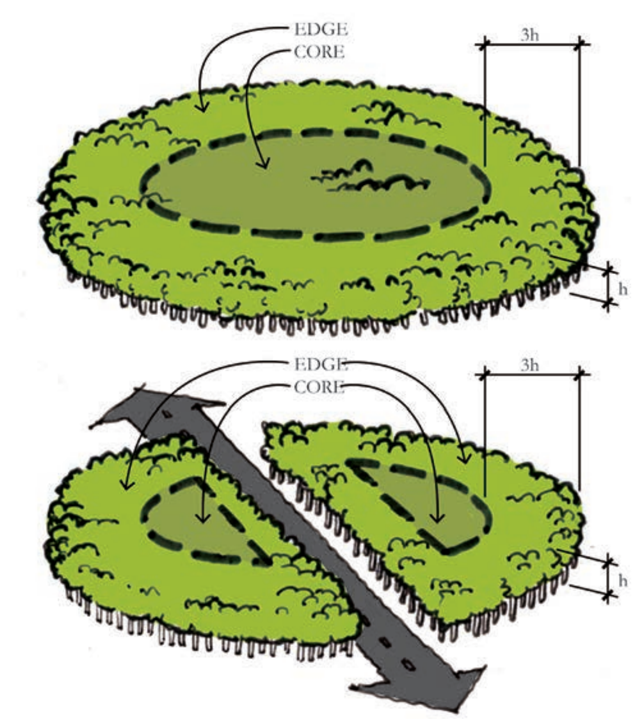
Each core consists of two parts: a central area of undisturbed wildlife habitat, which is surrounded by an edge area that absorbs impacts from outside the core (such as erosion, wind, human intrusion, and invasive species). This edge habitat serves as a buffer; where disturbance may occur but it also protects the inner core habitat from encroachment. Roads and rail lines were then intersected with the land cover to ensure forest cores could not be bisected by one of those features. The forest areas were then buffered in 300 feet from edge; where the remaining area was greater than 100 acres it was deemed to be a core. The 300 feet of edge habitat was then added back to form the final core shape.

Definitions

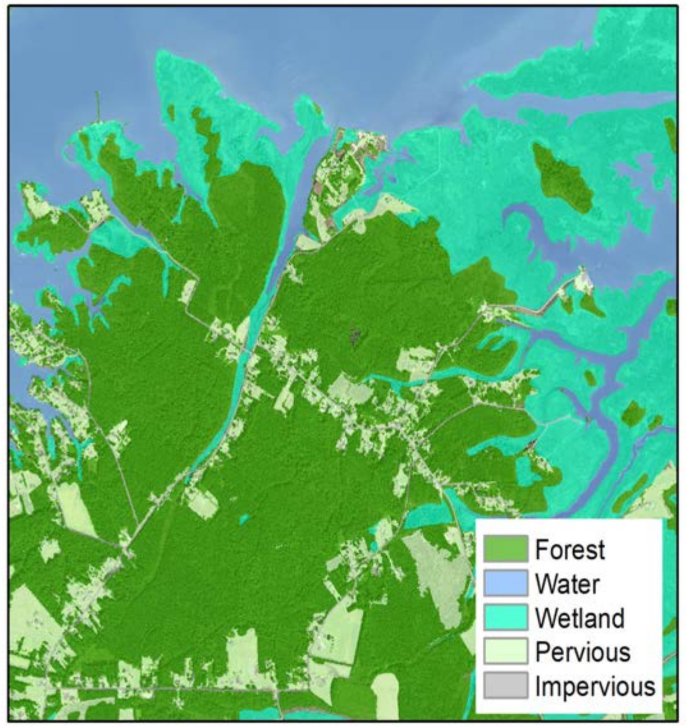
Patch: a relatively homogeneous, nonlinear area of natural cover (such as a forest, dune, marshland, or grassland) that differs from its surroundings.

Core: A core is an area or patch of relatively intact habitat that is sufficiently large to support more than one individual of a species. Consider that the greater the number of interior species present and the greater the diversity of habitats, the more important it is to conserve the core intact.

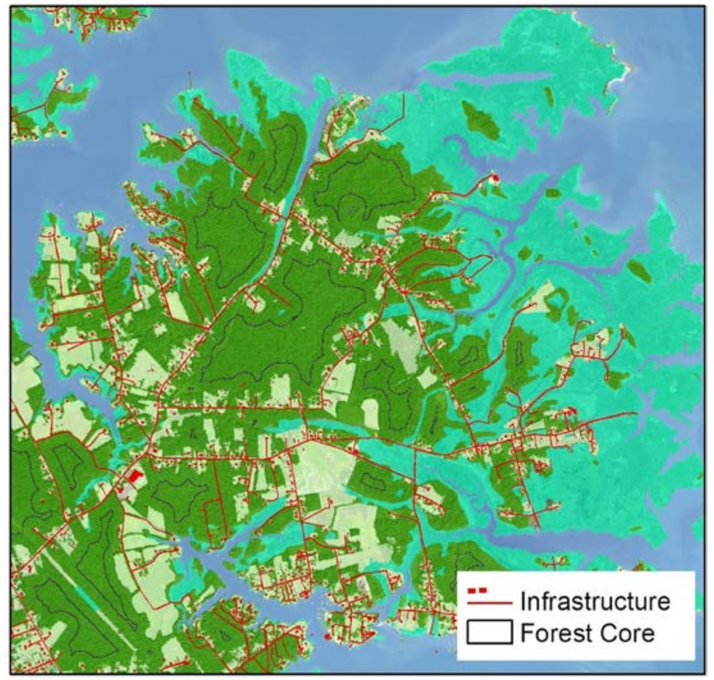
Edge: The transitional boundary of a core, where the vegetation assemblage and structure differs markedly from the interior, such as forest edges. The structural diversity of the edge (with different heights and types of vegetation) affects its species diversity, as well as the prevalence or abundance of native or invasive species.



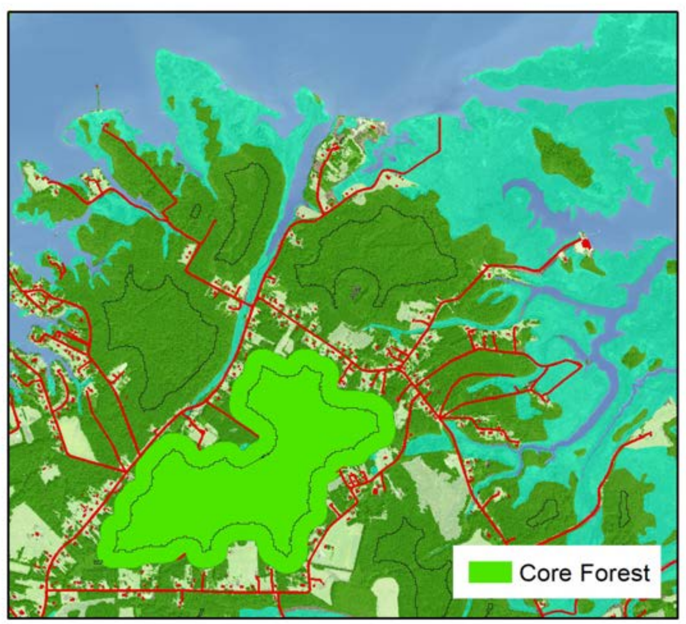
Edge area = Average tree height (h) X 3
Core = Total area - Edge area
Ideally, Core ≥ 100 acres



Land Cover



Forests are buffered in 300 ft from forest edge and significant Infrastructure.



Where buffer results in a core area greater than 100 acres the forest is identified as a Core Forest. Otherwise the core area less than 100 acres is classified as a Forest Core Fragment.

Summary

Coastal forest composition was dramatically different in Virginia compared to South Carolina and Georgia. Virginia's coastal forests were predominantly mixed deciduous-evergreen forests (41%) while South Carolina and Georgia were nearly even split between evergreen (pine) forest and wooded wetlands (32-35% and 27% respectively). Existing forest composition factors into some of the strategies around restoration with the SC and GA participating in the Longleaf Alliance Partnership to restore and manage longleaf pine forests on the landscape.

Despite the variety of land uses, ownership status and proximity to major metropolitan areas, the relative amount of coastal forest within each study area was fairly consistent. However, the amount of land within each study under some type of protection (public ownership, easement, etc.) varied. Virginia and Georgia had 18% of the study area's land under protection, while SC had 42%, with the majority of this land under federal ownership in Francis Marion National Forest. In Virginia and South Carolina, land protection was concentrated in the southern half of the study area with the northern areas much less protected. This uneven distribution of protected lands can lead to less resiliency as corridors become more fragmented and refugia are spaced further apart for wildlife to repopulate.

Total coastal forest acres in VA –
237,501 acres (58% of the study area).

Total coastal forest acres in SC –
361,987 acres (69% of the study area).

Total coastal forest acres in GA –
227,469 acres (54% of the study area).

Ranking Forest Cores

In addition to forest geometry and extent, coastal forest cores were ranked based on two overarching factors: environmental attributes and cultural or human values. Assigning attributes and values to each forest core allows for the identification and prioritization of specific high-quality and high-value forest habitat during strategy development. The Green Infrastructure Center recognizes some forests will be impacted or lost and that resources for management or conservation are limited. Ranking forests for the values they provide allows land-use planners, agency officials and site managers to prioritize specific forests that best meet management goals and objectives, while providing the highest value for native species.

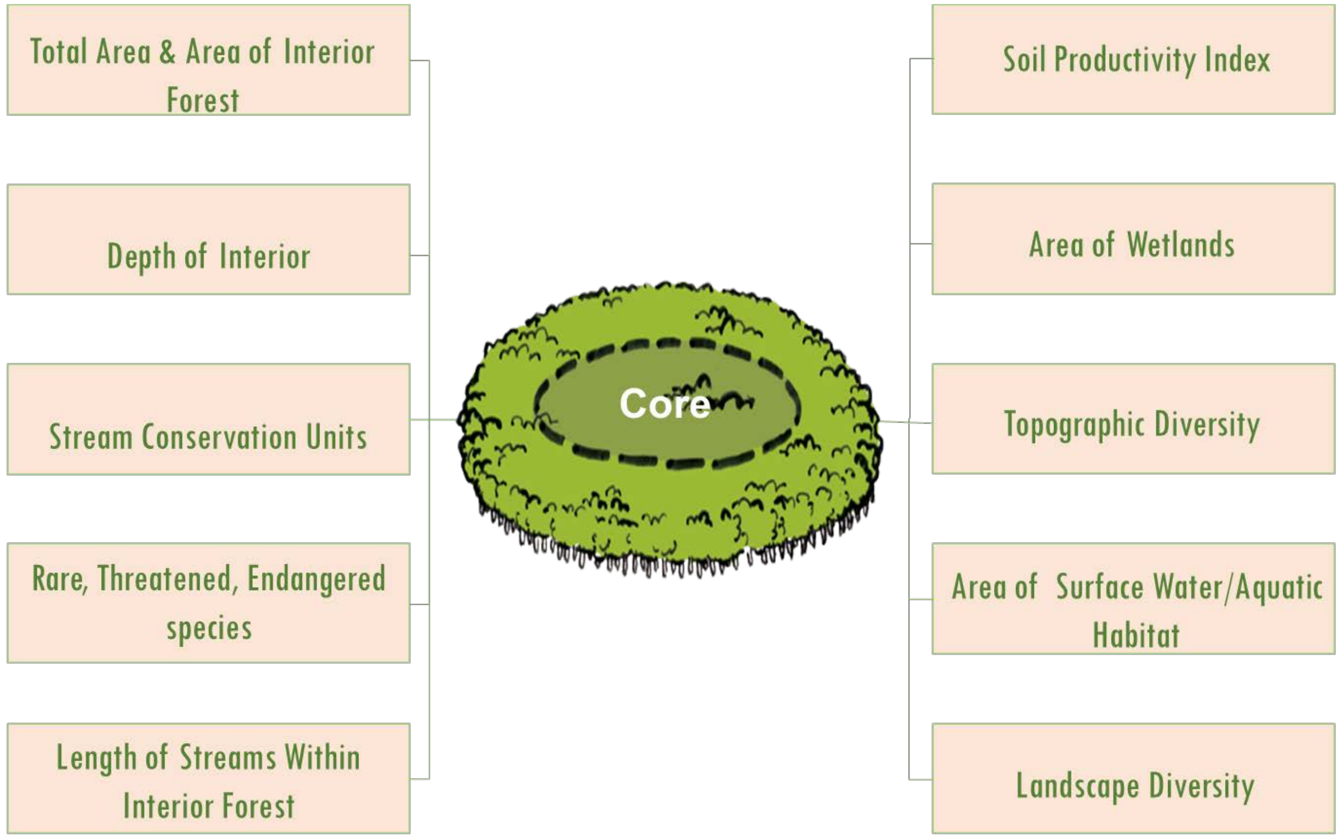
Environmental and ecological rankings

The first level of rankings used landscape-based environmental and ecological attributes. Examples of environmental attributes data used to rank forest cores included the number of wetlands found within a core; the presence of rare, threatened or endangered species; species richness; soil diversity; the length of stream miles; and topography. These factors all influence the diversity of plants, insects, animals and other biota within a forest core. The formula and weights applied to each of the attributes for the ecological ranking include the following:

*([Area_Rank]*0.4) + ([Thick_Rank]*0.1) + ([Topo_Rank]*0.05) + ([Wetland_Rank]*0.05) + ([Soil_Rank]*0.03) + ([Compact_Rank]*0.02) + ([Stream_Rank]*0.1)+ ([SRichness_Rank]*0.1)+ ([RTEAbun_Rank]*0.1) + ([RTEDiv_Rank]*0.1)*

Core Ranks used quintiles
Area_Rank = Area of core
Thickness_Rank = Using Euclidian distance from the edge of each woodland inward - the highest number represents the thickness. This is then divided into Quintiles.
Topo_Rank = Ranked by standard deviation of elevation values for forest
Wetland_Rank = Ranked by amount of wooded wetland in core
Soil_Rank = Ranked by number of soil types in forest
Compact_Rank = (([Shape_Area] /([Shape_Length] * [Shape_Length])*3.14159)) *10
Stream_Rank = Rank by length of streams
SRichness_Rank = Number of different species that occur in forest
RTEAbun_Rank = Number of Element Occurrences of RTE species*
RTEDiv_Rank = Variety of Element Occurrences of RTE species

*(*RTE = rare, threatened or endangered species)*



Forests provide a variety of values to the coastal plain whether it is providing habitat for wildlife or protecting a cultural site such as a cemetery.

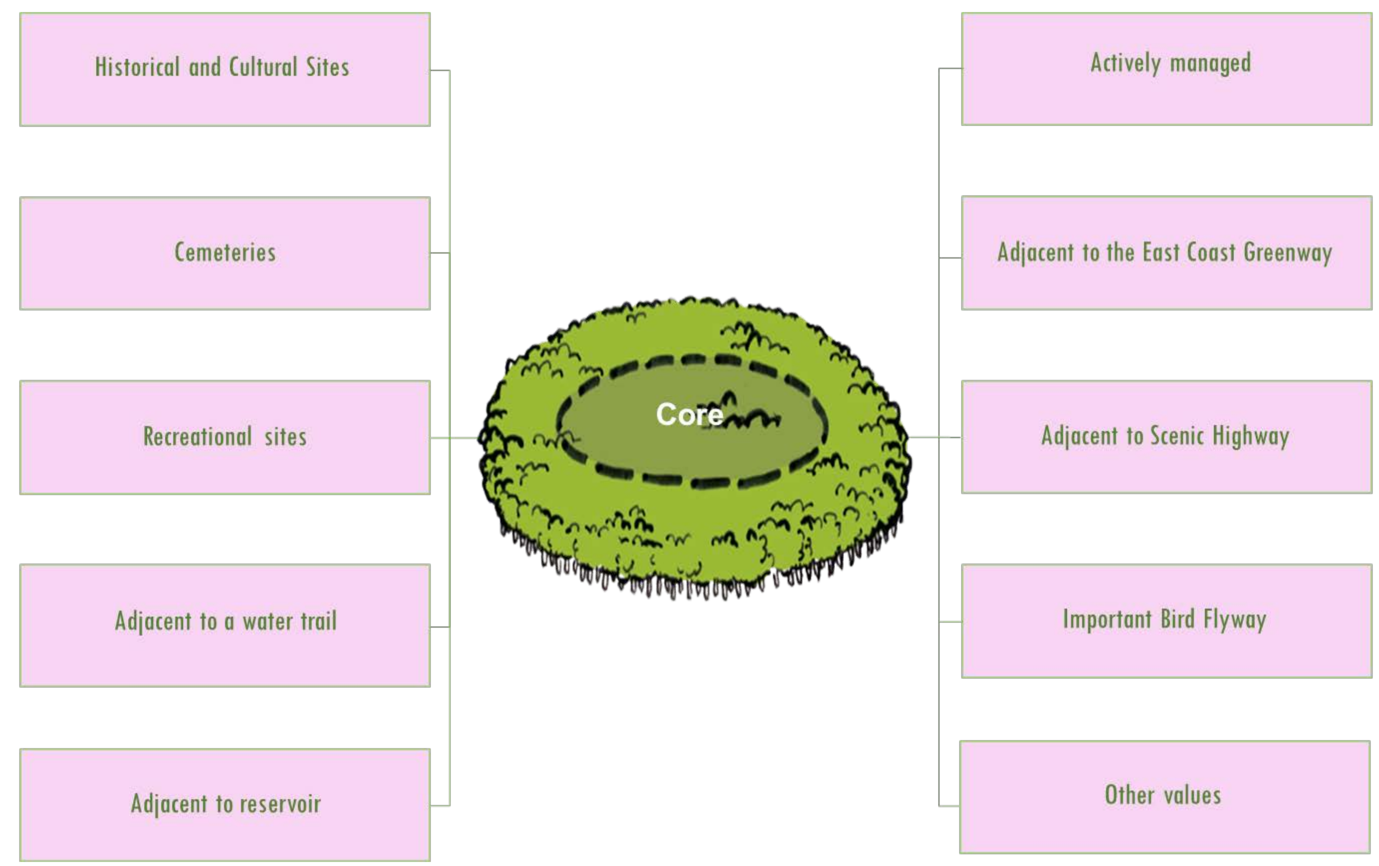
Human-interest (cultural) rankings

The second level of rankings include those cultural or human values people assign to the natural landscape, specifically coastal forests. Examples of human values incorporated into the ranking systems include forests supporting reservoirs or drinking water protection zones; recreational sites and parks; cemeteries; greenways; trails or bikeways; scenic view spots; and cultural or historical structures, properties and related features. The features to be included in the human value ranks were datasets identified by the local stakeholder committee. Forests support these uses whether physically, such as cleansing the water, or socially, such as forming the setting or backdrop to an historic or sacred site.

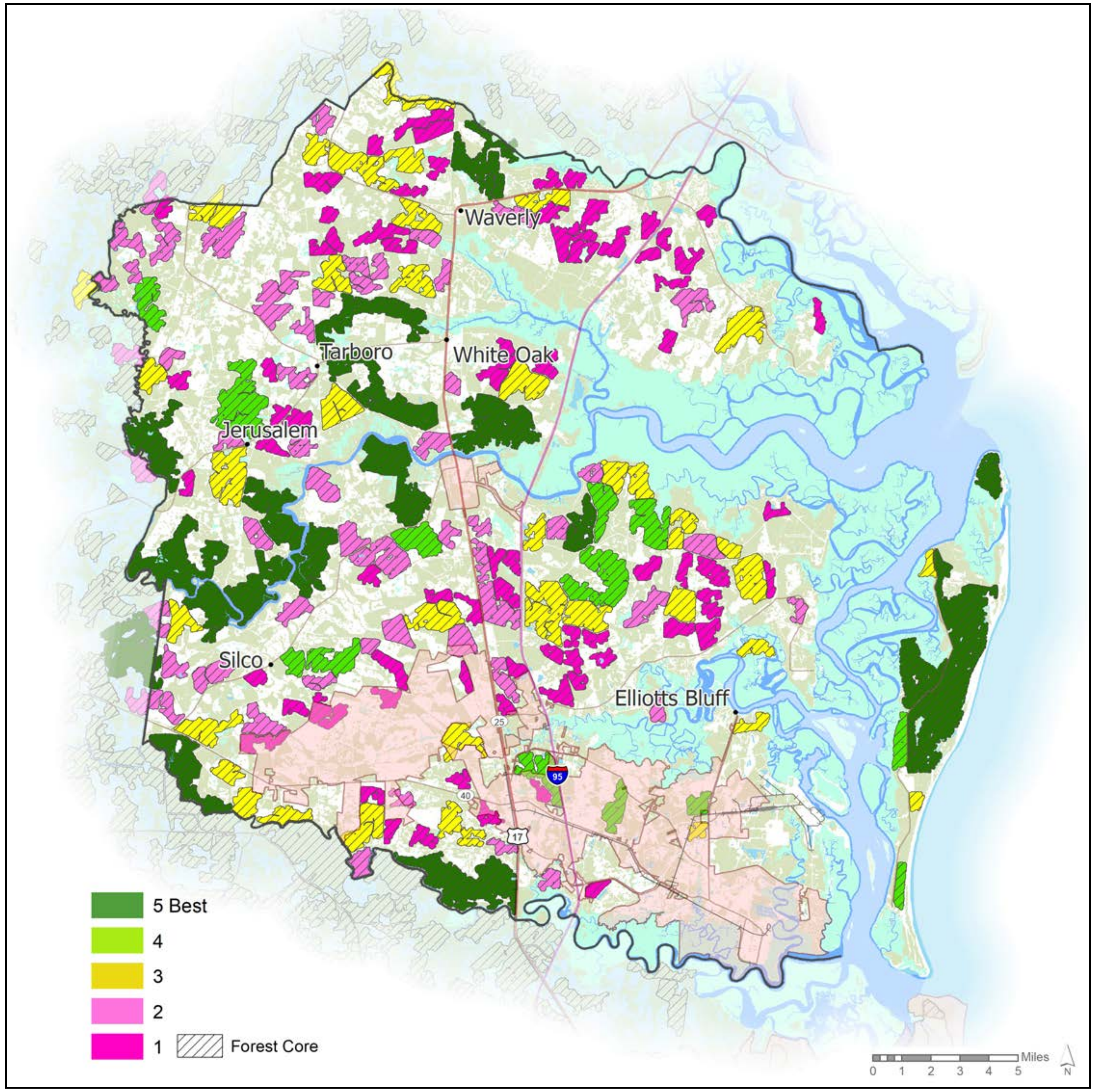
Cores were given a "Human-Interest Modifier" if they met the following criteria:

- Touched a reservoir
- Within 1000 ft of a cemetery
- Within 1000 ft of a historical site
- Within 1000 ft of a recreation site
- Had a water trail (in river or reservoir boating trail)
- Has cultural significance (identified by stakeholders)
- Has specific management objective

The cultural or human values of coastal forests were not weighted because of the subjective nature of different value systems. For example, it is impossible to comparatively rank a historical site to a reservoir without introducing bias. Therefore, the human values were simply added to the forest core score.
Add Human Interest (Add to Score)
[HasResvoir]+ [Wthin1000ftCem] + [Wthin1000ftHist] + [Wthin1000ftRec] + [User_PosWaterTrail] + [User_HasCulSig] + [HasMgmt]



Georgia Forest Core Ranks with Human- Interest Modifiers



A map of forest cores ranked by their ecological and cultural (human) assets across the Georgia study area.

Modeling Corridors

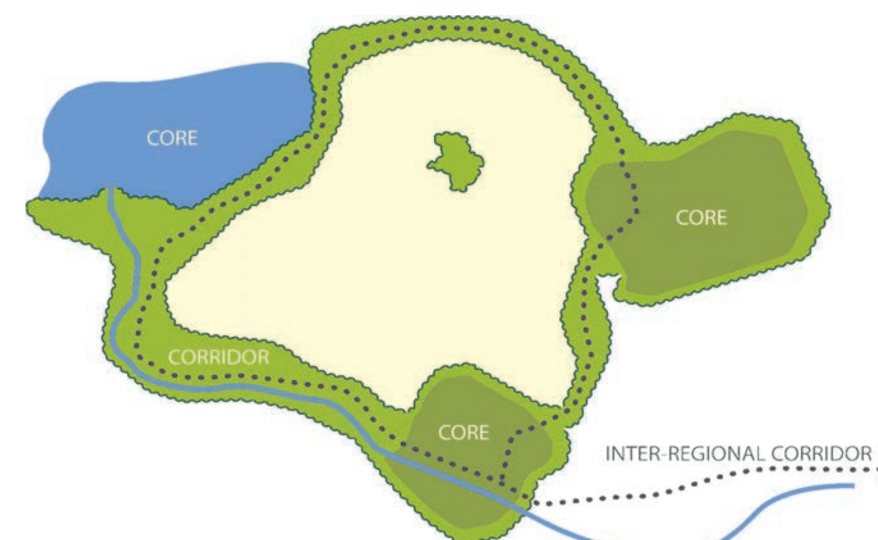
Corridors are used by species to move between cores, so they need to be wide enough to allow wildlife to progress across the landscape within conditions similar to their interior habitat. For this reason, it is recommended that these connections be at least 300 yards wide: a central 100-yard width of interior habitat, with a 100-meter edge on either side to protect safe passage and buffer against human intrusion and invasive species. Streams are natural corridors and the width of the vegetative corridor on either side should reflect the stream order (i.e. larger streams need wider forested buffers).

In addition to wildlife movement, corridors allow populations of plants and animals to respond to changes in land cover, surrounding land use and microclimate changes over the long term. For example, if a species in a core area is compromised because habitat conditions become unsuitable, it is more likely to survive if it can occupy corridors outside its core that provide some connection to surrounding areas. Thus, the larger a network of interconnected corridors and cores happens to be, the more likely it is that overall species' diversity and functioning ecosystems can be maintained amidst a changing landscape.

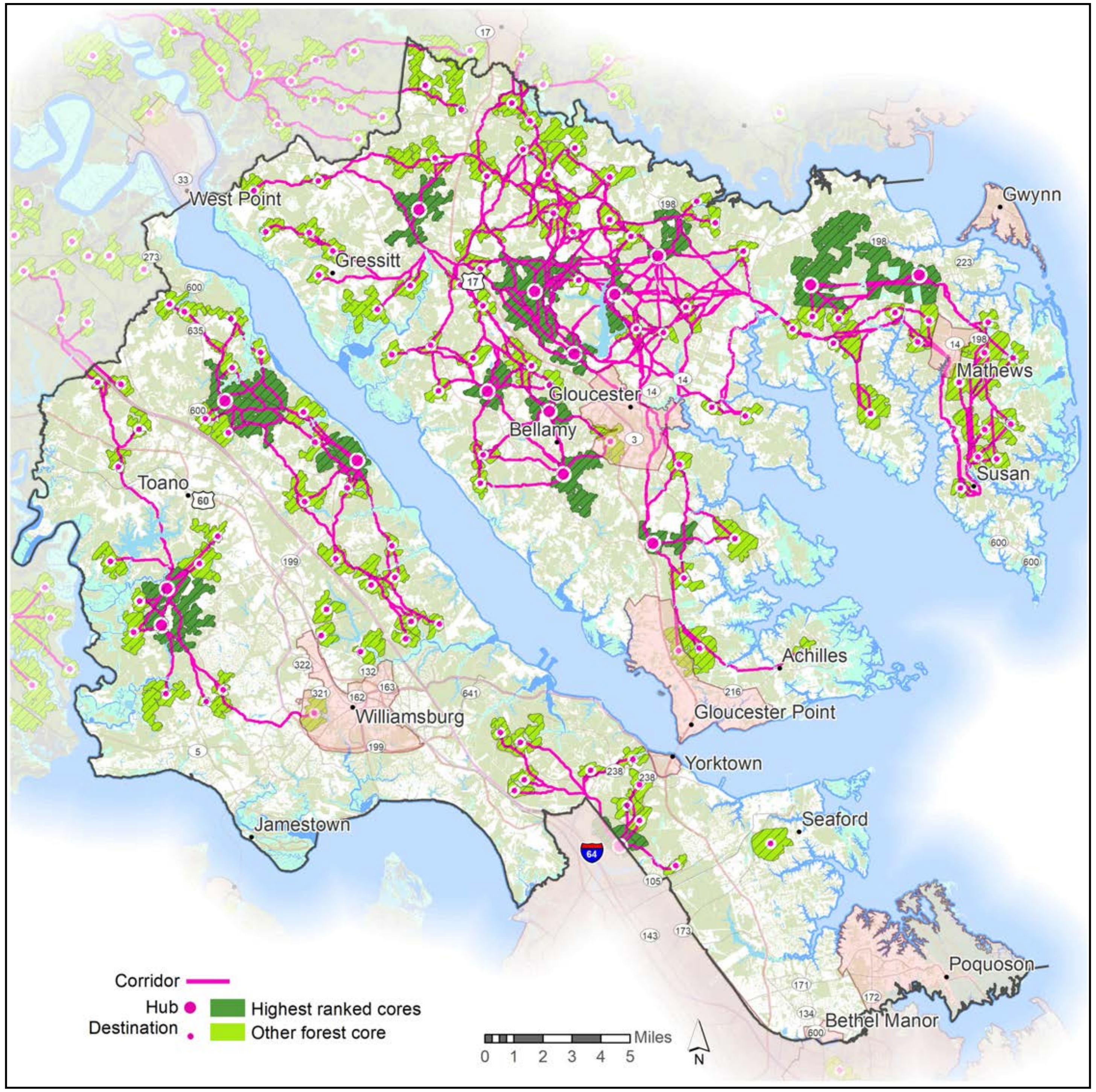
Methodology

The corridor script runs least cost path analyses between the highest ranked forest cores and all other cores. The least cost paths model potential habitat corridors that allow for the movement of plants and animals. This script is not meant to model any particular species, but rather provide results generally suitable for multiple species. However, the results are most applicable to larger, terrestrial mammals. The corridor "hubs" for this analysis used the forest cores ranked in the top 20% (rank 1). The model attempted to connect all other cores using the following rules:

1. Surface path is created prioritizing natural features.
2. A path cannot cross major road. A path can cross a local (small) road but only once.
3. Flatter slopes are prioritized.
4. Priority given to streams.
5. Path can cross roads larger than the local road only if stream goes underneath it and allows some terrestrial passage alongside the stream (based on the National Hydrography Dataset).



Virginia's Study Area Forest Corridors



A map of forest corridors and linkages across the Virginia study area.

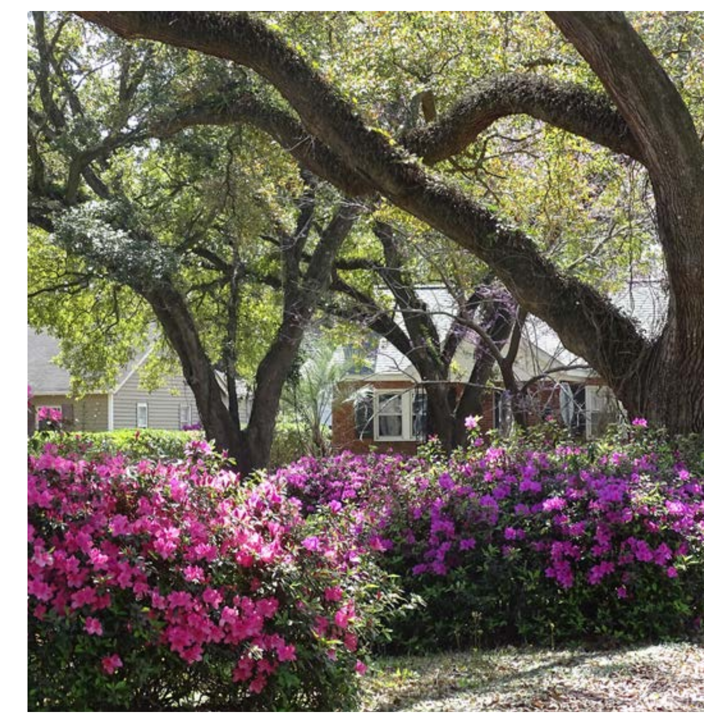
Modeling Urban Tree Canopy

Coastal forests also included urban woodland and tree canopies in the cities and towns within the region. Urban forests have unique challenges compared to large, forested landscapes. The urban environment can be an inhospitable place for many tree species, with spaces designed and built with little regard for adequate tree growth and health. Other urban infrastructure can create conflicts with trees, such as powerlines, water and sewer pipes, and land uses that don't support trees. In addition, many species are ill-suited for survival in urban environments, with the added heat stress, salt, soil compaction and mechanical injuries.

Urban forests are also at a much higher risk for development and many urban natural areas are degraded by non-native plants and animals that take over and colonize areas more aggressively, wiping out native species. Urban forests also require specialized emergency response plans to identify trees and limbs at risk of falling prior to storms in order to pre-establish cleanup procedures and to have plans in place ahead of time to rapidly reforest damaged areas after the storm.

To account for the land cover changes that occur at a much smaller scale in a city or town than in a rural forested area, the urban tree canopy of towns and cities in the study area was mapped using high-resolution imagery at one-meter scale. Potential planting areas (PPA) and potential tree canopy (PTC) were mapped to show where additional trees could be planted and to allow municipalities to strategically plan for future plantings.

Urban forests are an integral component to daily life and provide an increased quality of life.



Trees beautify our communities but also clean the air, shade our homes and mitigate stormwater.

Mapping Urban Land Cover

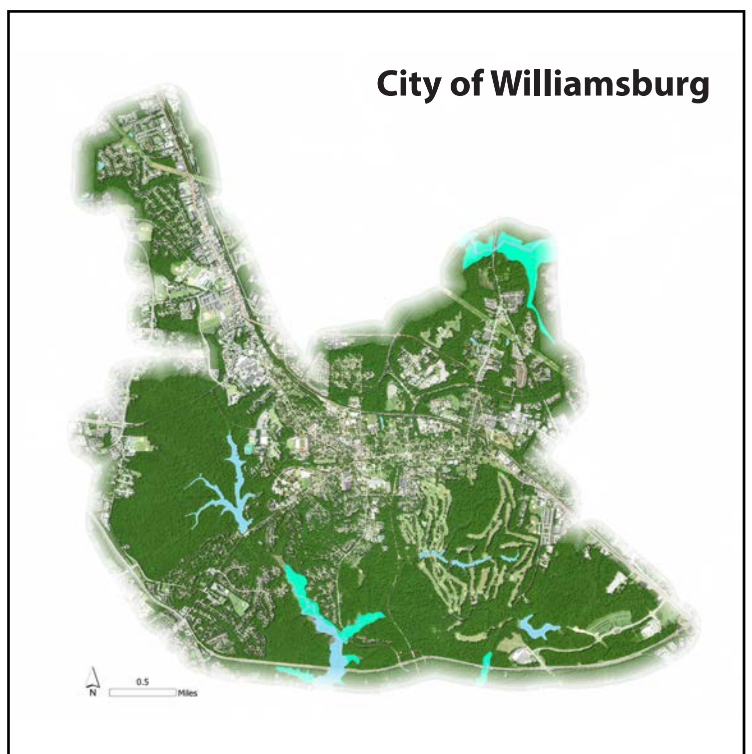
Urban Land cover data were created using NAIP aerial imagery and, where available, LiDAR data. Also, existing buildings, roads, rail lines and other known pervious surfaces were used to avoid miss-classification of such already-identified features. In addition, wetlands and water data from the National Hydrography Database were included. Using LiDAR, the tree canopy can be mapped accurately by creating an NDVI and intersecting with feature height derived from LiDAR data. If a feature is green and above 10ft tall then it is classified as a tree. If not green and above 10ft then it is a building. Pervious surfaces and other features can be extracted similarly. In areas where LiDAR data were not available or necessary to supplement limited existing vector data; a remote sensing object-based recognition tool called Feature Analysist was used.

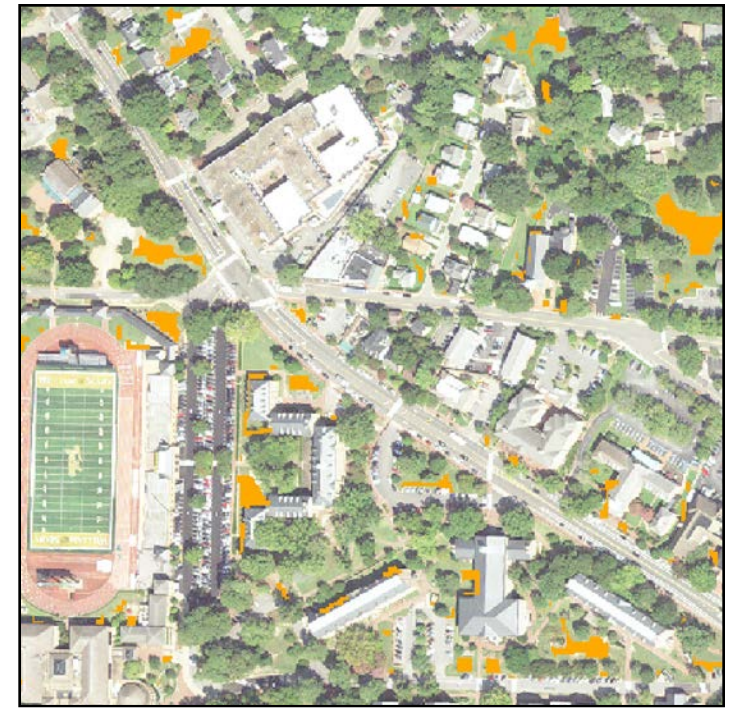
Mapping Potential Tree Canopy

The Potential Planting Area (PPA) is created by selecting the land cover features that have space available for planting trees. Only pervious, turf and bare earth are considered for PPA. Next, these eligible planting areas are limited based on their proximity to features that might either interfere with a tree's natural growth (such as buildings) or places such as power lines, sidewalks or roads which a tree might impact by interfering with pavement or overhead wires. This was done by selecting the identified available landcover types (pervious and bare earth) and then buffering in 10ft which represents the distance a tree should be from any other features. Playing fields, cemeteries and other known land uses that would not be appropriate for tree cover were also avoided. However, there may be some existing land uses (e.g., golf courses, agricultural lands, etc.) that are unlikely to be used for tree planting areas, but that were not excluded from the PPA. In a more involved process, these features would be removed in consultation with local cities and towns.

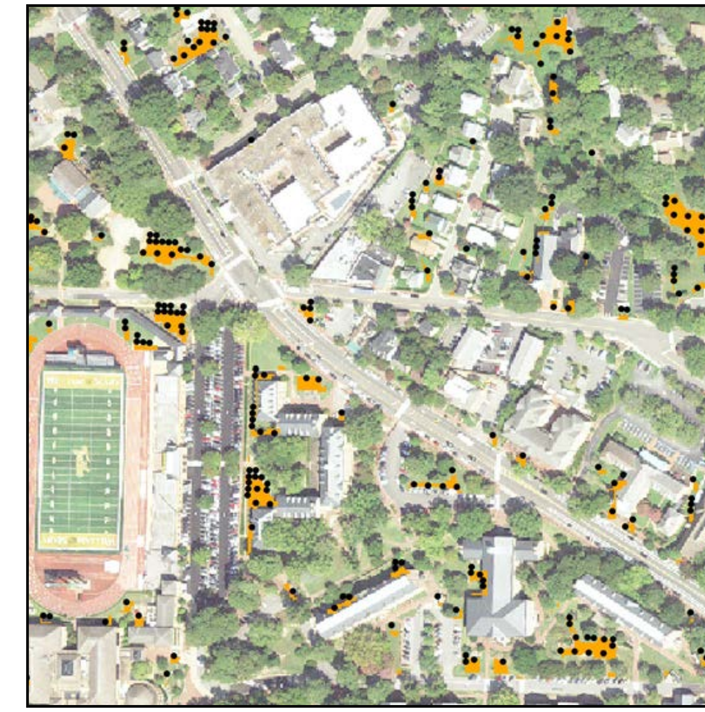
The Potential Planting Spots (PPS) are created from the PPA. The potential planting areas (PPA) are run through a GIS model that selects spots a tree can be planted depending on the size trees that are desired. This modeling used a tree planting scenario based on a 20ft and 40ft mature tree canopy with a 30% overlap. The Potential Canopy Area (PCA) is created from the PPS. Once the PPS are selected, a buffer around each point that represents a tree's mature canopy is created. For this analysis, that buffer radius is either 10ft or 20ft, which results in either a 20ft or 40ft diameter canopy for each tree. These individual tree canopies are then dissolved together to form the potential overall canopy area.

Example Tree Canopy Map

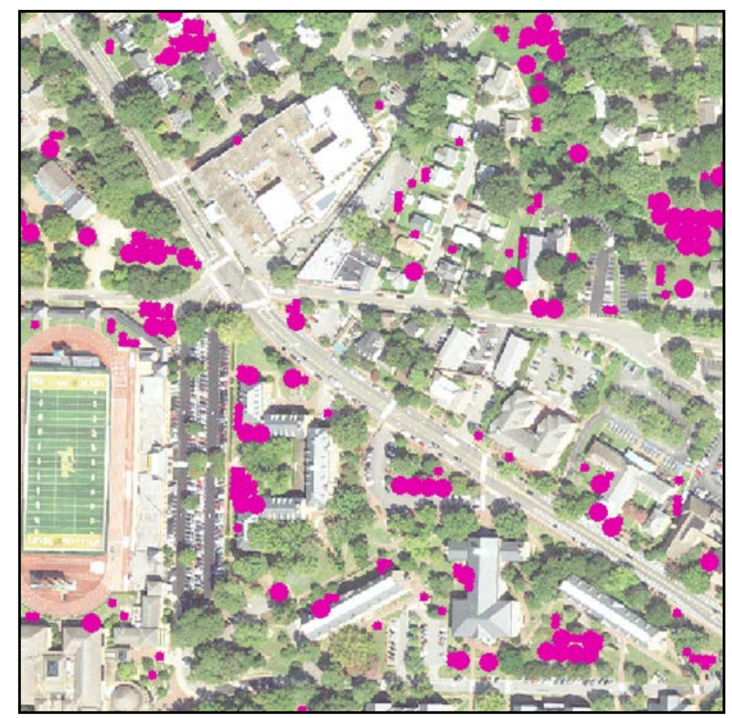




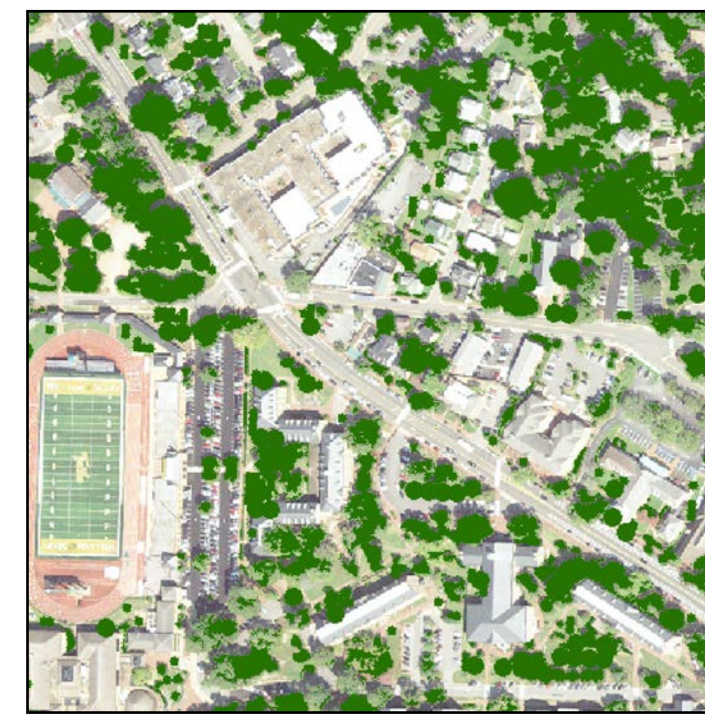
Potential Planting Areas (PPA)



Potential Planting Spots (PPS)



Potential Canopy Area (PCA)



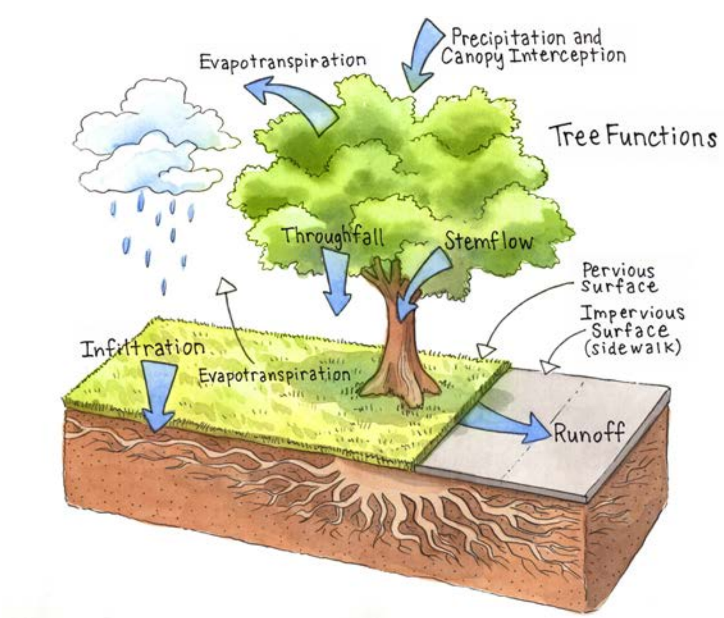
Potential Tree Canopy (PTC)

Modeling Forest Benefits

Water Quality & Quantity

The best land cover for taking up urban stormwater is treed landscapes. GIC evaluated stormwater runoff and uptake for each city's tree canopy using its Trees and Stormwater Calculator (TSC) Tool. This tool estimates the capture of precipitation by tree canopies and the resulting reductions in runoff yield. It considers the interaction of land cover and soil hydrologic conditions. It can also be used to run 'what-if' scenarios, specifically losses of tree canopy from development or storms, and increases in tree canopy from tree planting programs.

Trees intercept, take up, and slow the rate of stormwater runoff. Canopy interception varies from 100% at the beginning of a rainfall event to about 3% at maximum rain intensity. Trees take up more water early on during storm events and less as storm events proceed and the ground becomes saturated (Xiao et al. 2000).* Many forestry scientists, as well as civil engineers, have recognized that trees have important stormwater benefits (Kuehler 2017, 2016).** (See diagram of tree water flow below).



Trees capture stormwater through their crowns and trunks and pull water out of the soil back into the atmosphere as water vapor through evapotranspiration.

**Xiao, Qingfu, E. Gregory McPherson, Susan L. Ustin, Mark E. Grismer, and James R. Simpson. "Winter rainfall interception by two mature open-grown trees in Davis, California." Hydrological processes 14, no. 4 (2000): 763-784.*

***Kuehler, Eric, Jon Hathaway, and Andrew Tirpak. "Quantifying the benefits of urban forest systems as a component of the green infrastructure stormwater treatment network." Ecohydrology 10, no. 3 (2017).*

Air Quality & Climate

Air quality pollution removal values were calculated by applying the multipliers used by the i-Tree models. I-Tree is a peer-reviewed software suite from the USDA Forest Service that provides urban and rural forestry analysis and benefit assessment tools. The i-Tree researchers developed standard pollution removal values per acre for various air pollutants. The following i-Tree model values for urban areas were used to multiply acres of canopy to derive the pollution removal values calculated.

Economic

Forest economic data were supplied by each state forestry agency's forest economist from recent reports quantifying the value of the forest products' industry at the county or statewide level, depending on what level the state aggregated the data.

Species

For benefits' analysis, species attributes such as "richness" came from BiodiversityMapping.org, https://biodiversitymapping.org/, while rare, threatened and endangered (RTE) species came from state datasets (see listed sources below). Species richness for all major vertebrate classes and tree species was included. All rare, threatened and endangered species (RTE), both federal and state listed species that fell within the study area were included in reporting on benefits provided for species. The following are source data used by state.

Virginia
"Predicted Suitable Habitats" acquired from the Virginia Geographic Information Network.

South Carolina
"Element Occurrences" from South Carolina Department of Natural Resources.

Georgia
Camden County "Element Occurrences" (summarized to Quarter Quads) from Georgia Department of Natural Resources.

Gopher tortoises are a state-listed species in the study.

Historical and Cultural Values

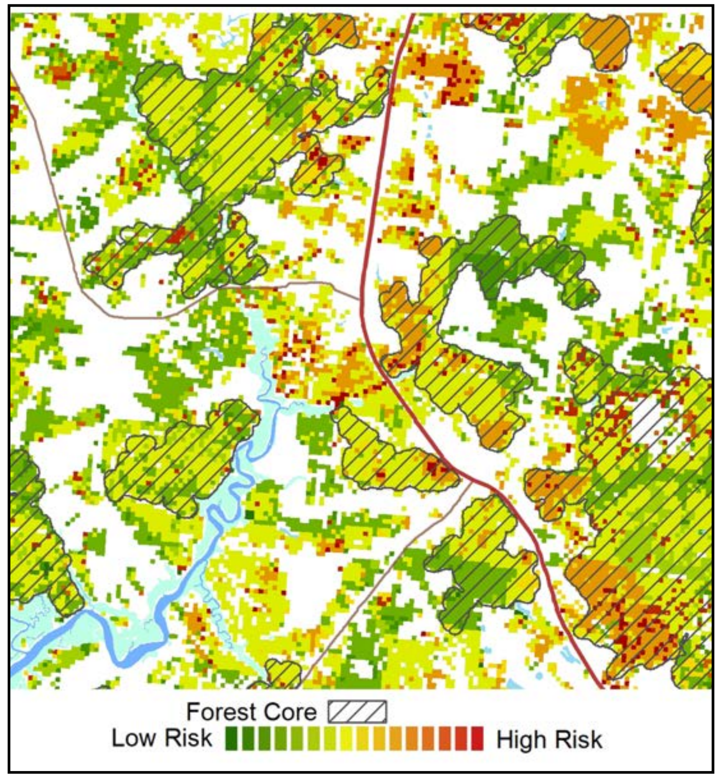
All historical and cultural sites listed from Natural Resources Conservation Service (NRCS) were reported for the benefits report. More cultural and historical sites and resources were identified by the local stakeholders during the forest cores ranking process described in an earlier section of this guide.

Historic structures such as the Dungeness ruins add cultural value to the forest landscape.

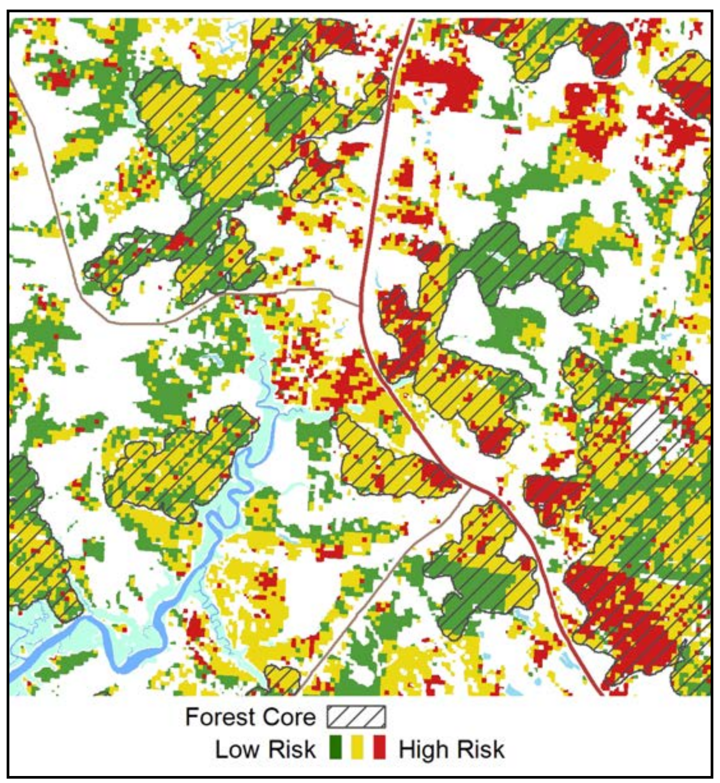
Modeling Forest Threats

Summarizing Threats to Forest Cores

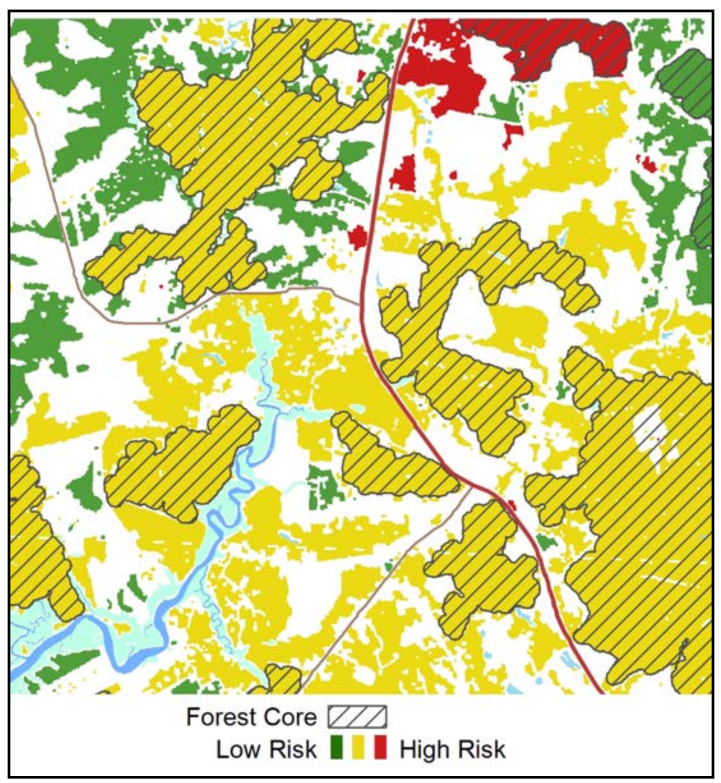
For each risk the threat was calculated for every pixel on the landscape. This meant that a forest could have a variety of risks within its borders. To establish a singular risk across an entire and contiguous patch of forest or woodland, the majority of type of risk (High, Moderate or Low) was calculated and assigned for that patch (see the graphic below for further illustration). Forest cores and woodlands were modeled separately from each other due to the different ways they are calculated and identified on the landscape. Therefore, to derive the final rank, the Forest Core Risk values were used over the Woodland Risk if (due to statistical calculations) there were differences between Forest Core values and woodlands.



Raw surface data (forested land cover only).



Surface data split into three risk ranks..



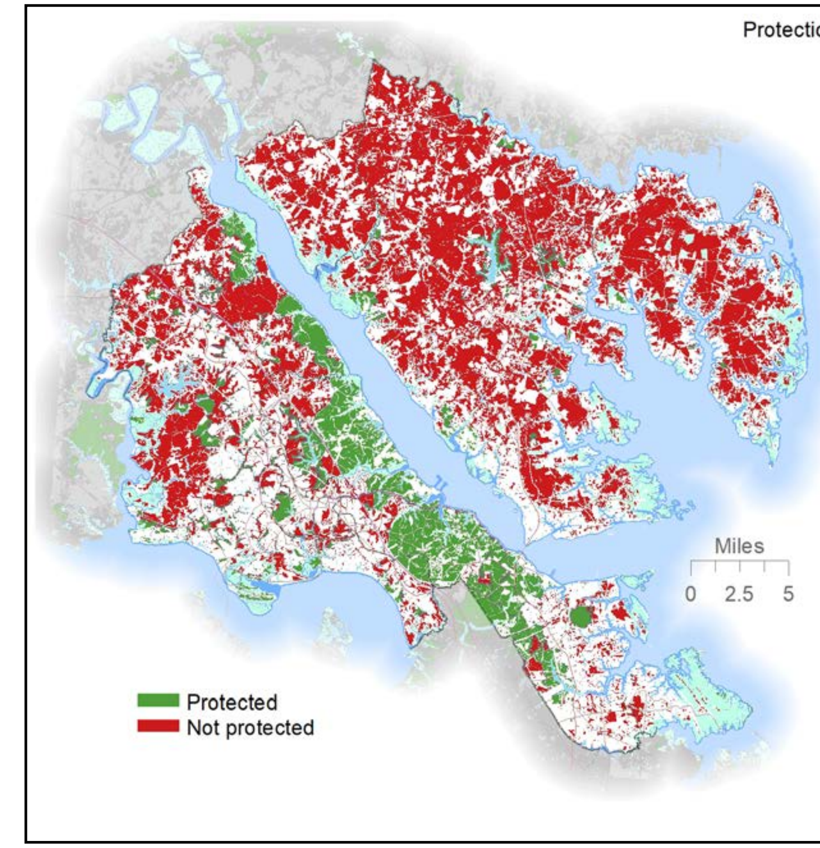
Surface risk data summarized across forest core or woodland.

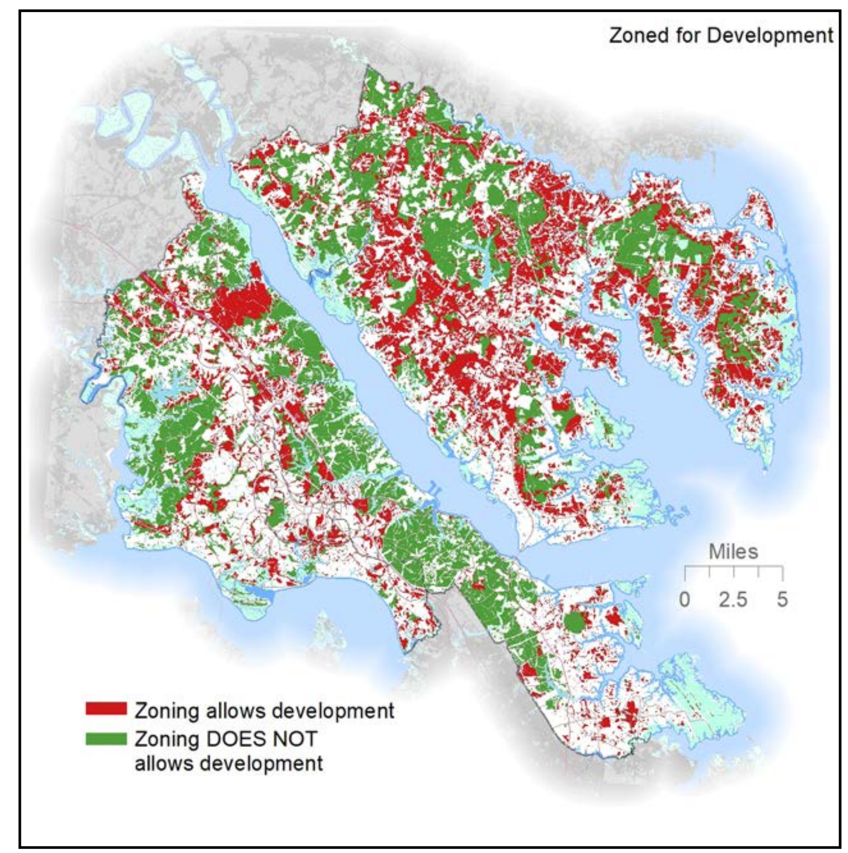
Development Inputs

Protected lands data

Data downloaded from local sources and Virginia Department of Conservation and Recreation: Department of Conservation and Recreation's Virginia Conservation Lands Database https://www.dcr.virginia.gov/natural-heritage/clinfo

These areas were excluded from the development layer because of their protected land status.





Zoning

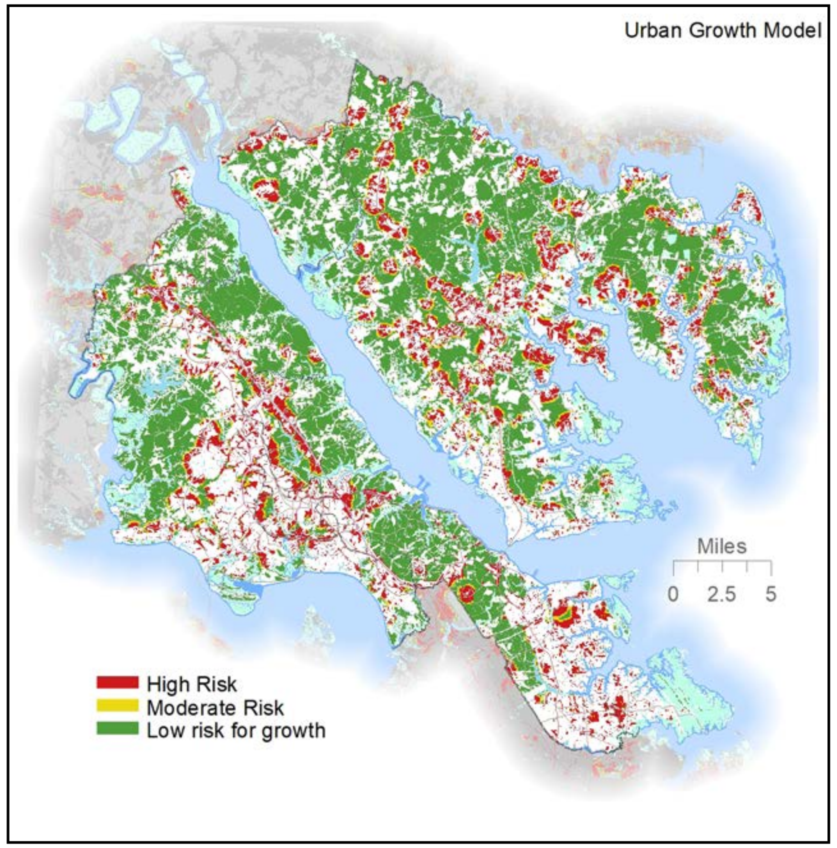
Data acquired from each county. Zoning classes were recoded for whether they were likely to be developed with higher intensity uses (e.g. commercial, industrial, high density residential received a "1") versus low intensity (rural, agricultural, conservation received a "0").

Many tracts of forest are for sale and zoned for development.

Development Inputs

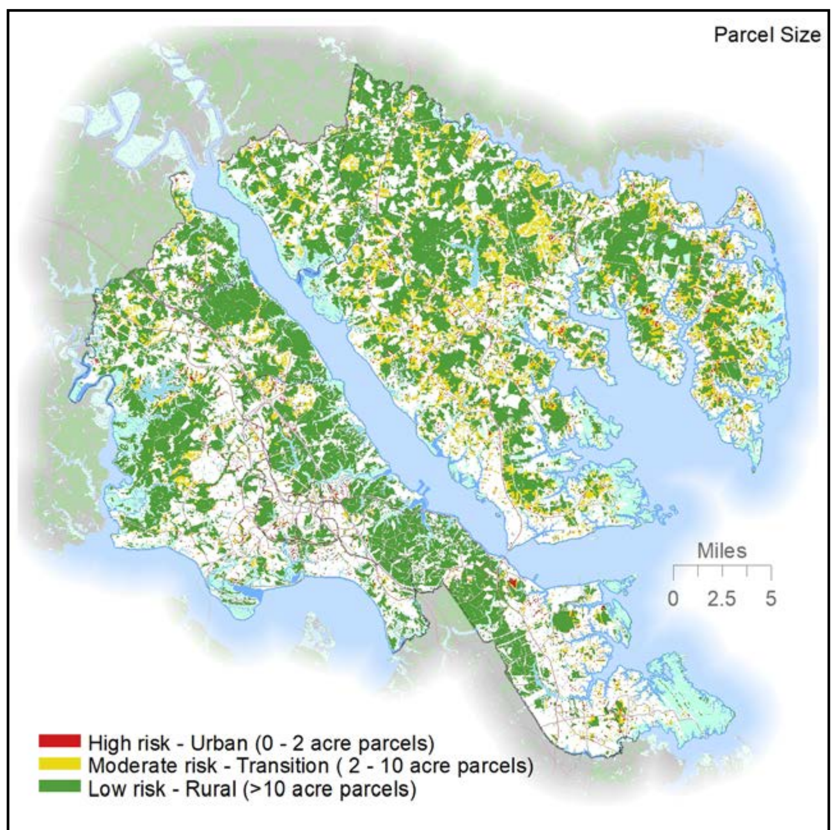
SLEUTH (Urban Growth Model) – to year 2060

This dataset represents the extent of urbanization (for the year 2060) predicted by the model SLEUTH, developed by Dr. Keith C. Clarke, at the University of California, Santa Barbara, Department of Geography and modified by David I. Donato of the United States Geological Survey (USGS) Eastern Geographic Science Center (EGSC). Further model modification and implementation was performed at the Biodiversity and Spatial Information Center at North Carolina State University. Downloaded from: https://databasin.org/datasets/e5860ced8b4844e88431cdbefe425e1a/



Urban context/Parcel size

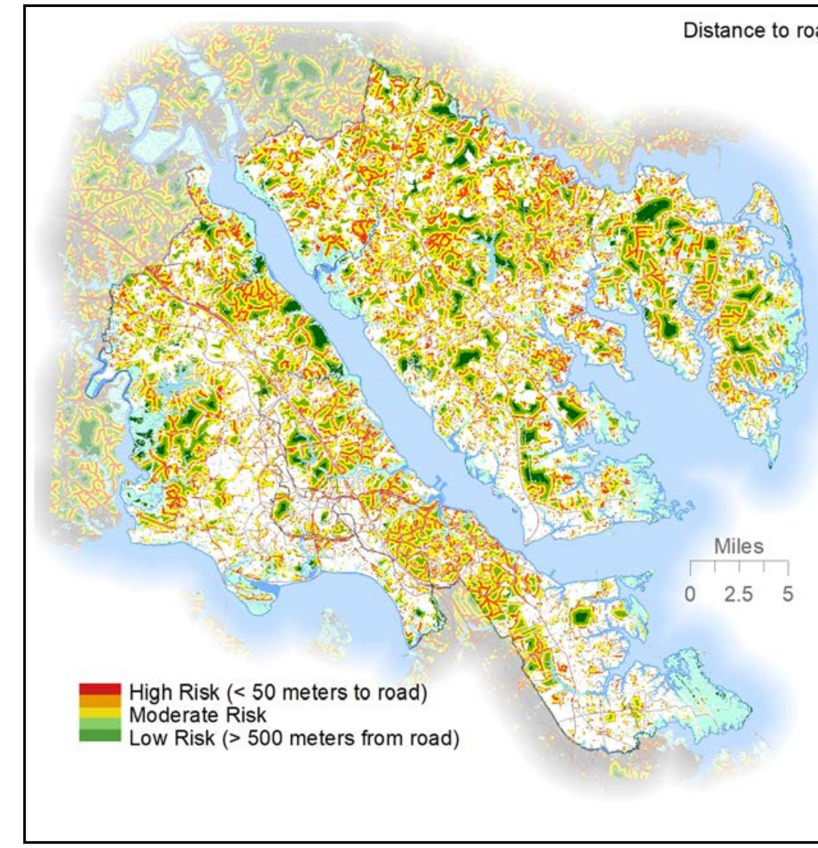
Based on 2020 parcels downloaded from the Virginia Geographic Information Network. This layer represents parcels that would be more likely to develop based on their smaller parcel size. Smaller parcels are more likely be developed due to lower costs for purchase, clearing and development.



Development Inputs

Distance from major roads

Areas further from major roads are less likely to be developed. Roads play a major role in allowing people to commute farther and faster to population centers to access necessities such as jobs, grocery stores, hospitals, etc.



Steps:

The first layer is the Development Severity Risk layer created by combining the above datasets. The layer represents the risk each pixel would have from development.

1. Only areas zoned for development are considered. Protected lands were removed from the risk map.
2. The Urban Growth Model, Parcel Size and Distance from major roads were ranked as follows:

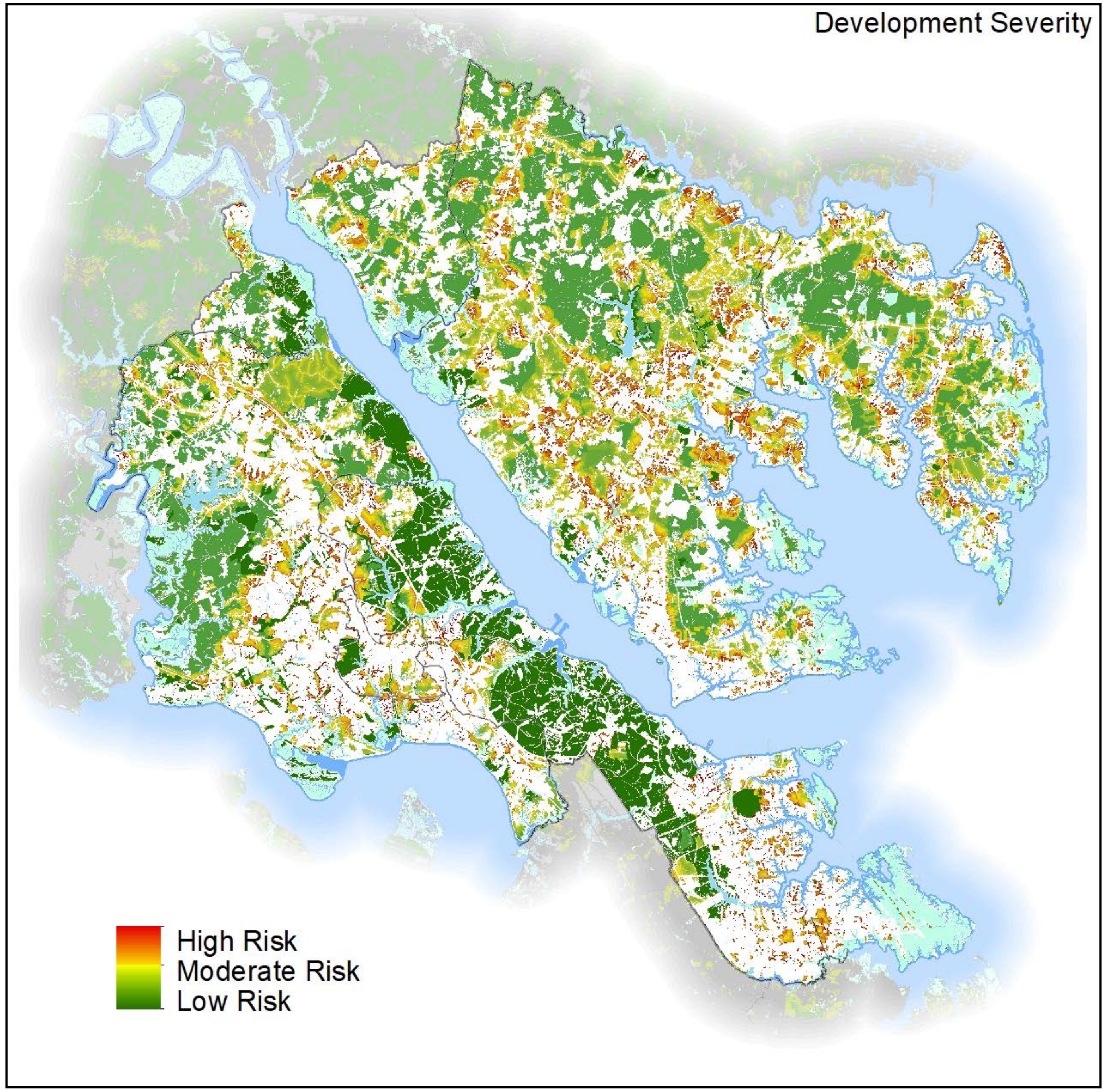
Urban Growth Model: SLEUTH's values for year 2060 were used and broken up into the following ranks:
- 100% (5 High Risk)
- 10 – 90% (3 Moderate Risk)
- < 10% (1 Low Risk)

Parcel Size (Context)
- Urban small parcels less than 2 acres (5 = High Risk)
- Transition urban to rural parcels 2 to 10 acres (3 = Moderate Risk)
- Rural large parcels > 10 acres (1 = Low Risk)

Distance to roads
- 0 – 50 meters from road (5 Highest risk)
- 50 – 100 (4)
- 100 – 250 (3)
- 250 – 500 (2)
- 500 - > (1)

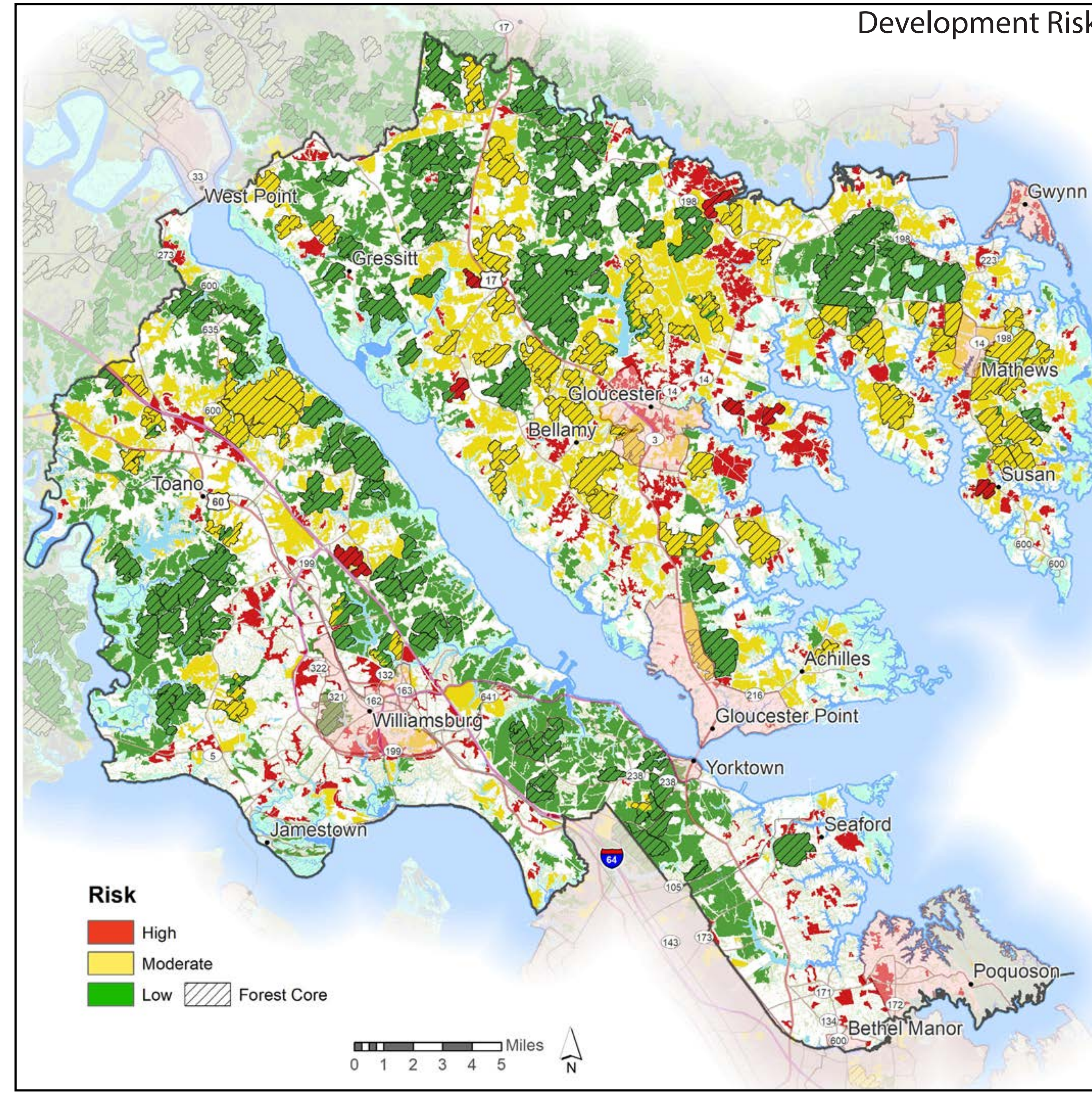
3. The above layers were added together to create the development severity layer.
4. The severity layer was then summed using the forest cores and woodlands. The result was then clustered based on three natural breaks to High, Moderate and Low risk for the habitat cores and woodlands individually.
5. For the final rank, the Forest Core Risk values were used over the Woodland Risk if (due to statistical calculations) there were differences between Forest Core values and woodlands.

Results



A map of the surface data of development risk before summarizing across forest cores and woodlands.

Results



A map of development risk summarized across forest cores and woodlands in the Virginia study area,

Development Inputs

Summary of trends

Highest risk of development:

Virginia
21,757 acres (9%)

South Carolina
27,314 acres (8%)

Georgia
38,862 acres (20%)

High risk of development was fairly consistent across each of the study areas with Georgia having an overall greater potential forest loss at 20%. Camden County, the study area for Georgia, is experiencing significant growth due to stable regional employers such as the naval base, recreational tourism from Cumberland Island National Seashore and cheaper land and easy interstate commuting to accommodate sprawling urban growth from the Jacksonville, Florida metropolitan area.

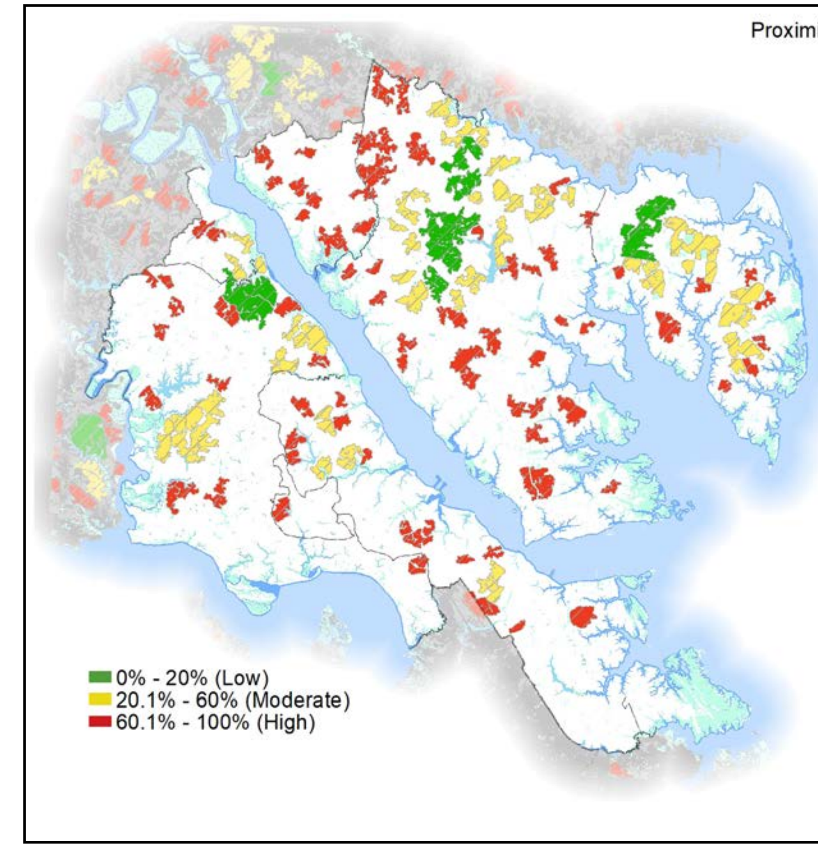
In contrast, Virginia's study area in the southern half is already well developed and growth patterns reduced by the York River bisecting and reducing access to regional employment and population centers such as Hampton Roads, making it less desirable for suburban sprawl due to longer commutes. For South Carolina, the southern region of the study area is predominantly the Francis Marion National Forest, limiting the extent of urban development and blocking easy access to the Charleston metropolitan region. However, these areas will still be experiencing growth and continued forest loss which will limit connectivity and overall available habitat, particularly forested uplands which are some of the least protected landscapes in coastal regions. This challenge is evident in Georgia, where forest uplands are the best sites for longleaf pine restoration, but also the most desirable for residential growth due to the predominance of lowlands and the propensity for the region to flood.

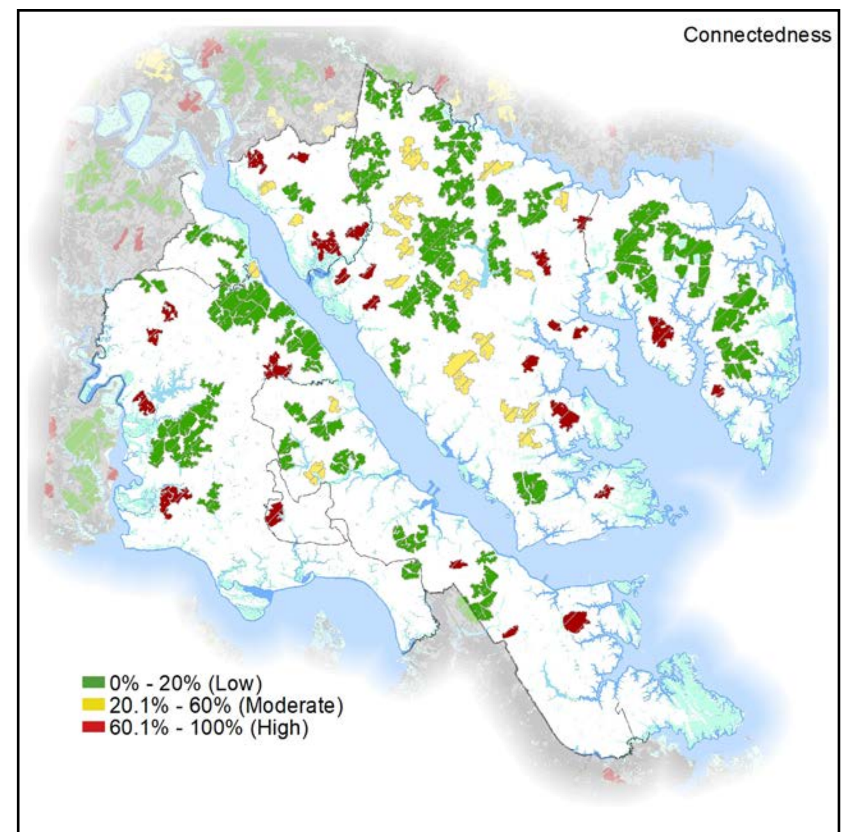
Development is a leading cause of forest loss and fragmentation in the Southern U.S.

Fragmentation Inputs

Proximity (number of nearest neighbors)

This input conveyed the amount of opportunity for a species to find adjacent or nearby habitat to quickly colonize or find refuge when needed. The more nearby forest cores, the greater the selectivity and ability to find to suitable habitat should a core be lost. This input value is based on the number of forest cores within 500 meters of each other.





Remoteness (distance to nearest neighbor)

This input was based on how far a species would need to travel to find a similar forest habitat. Forest cores that are too far apart make it much less likely a species will locate that forest habitat and safely make the journey across the landscape. Cores further from any neighbor are more at risk.

Fragmentation Inputs

Steps:
1. Proximity is created by buffering forest cores 500 meters to get a count of neighbors within a network of cores not further than 500 meters away. This is then clustered into 3 natural breaks.
2. Remoteness is calculated from distance to closest neighbor and then assigned ranks based on the following distance breaks:
- 0 – 200 meters away (1 - Low)
- 200 – 500 meters away (3 - Moderate)
- 500 + meters away (5 - High)

3. The two are then added together and grouped by three natural breaks for the final fragmentation rank.

Summary of trends

Miles of roads:
Virginia
2,640 miles

South Carolina
1,130 miles

Georgia
1,208 miles

Virginia had the greatest amount of road miles in the study area, more than twice that of South Carolina and Georgia. This was not unexpected since Virginia was the most developed and populous of the three coastal study regions. The amount of road miles contributed significantly to the fragmentation of Virginia's coastal forest habitats with 128 forest core habitats making up only 68,417 acres of the more than 237,501 acres of coastal forest in the region. Therefore, the majority of coastal forest habitat is composed of less than 100 acre-sized patches of forest, providing less connectivity and ultimately less resiliency for forests.

In contrast, South Carolina and Georgia had a similar number of road miles within their respective study areas; however, South Carolina had nearly four times as many forest cores greater than 1000+ acres in size than Georgia. This illustrates that built infrastructure such as roads, can be routed in a manner that limits fragmentation of coastal forest habitat. In South Carolina's case, nearly half of the study area was under protection and management by Francis Marion National Forest, which limits the extent of major road corridors bisecting coastal forest habitat. In addition, Georgia's study area had significant fragmentation of forest habitat from large rivers and estuaries which can limit species from accessing adjacent forest habitat.

Virginia Forest Cores

Size Class	Count	Total Acres
100 – 500 acres	83	24982
501 – 1000 acres	33	22771
1000+ acres	12	20664
Total	128	68417

South Carolina Forest Cores

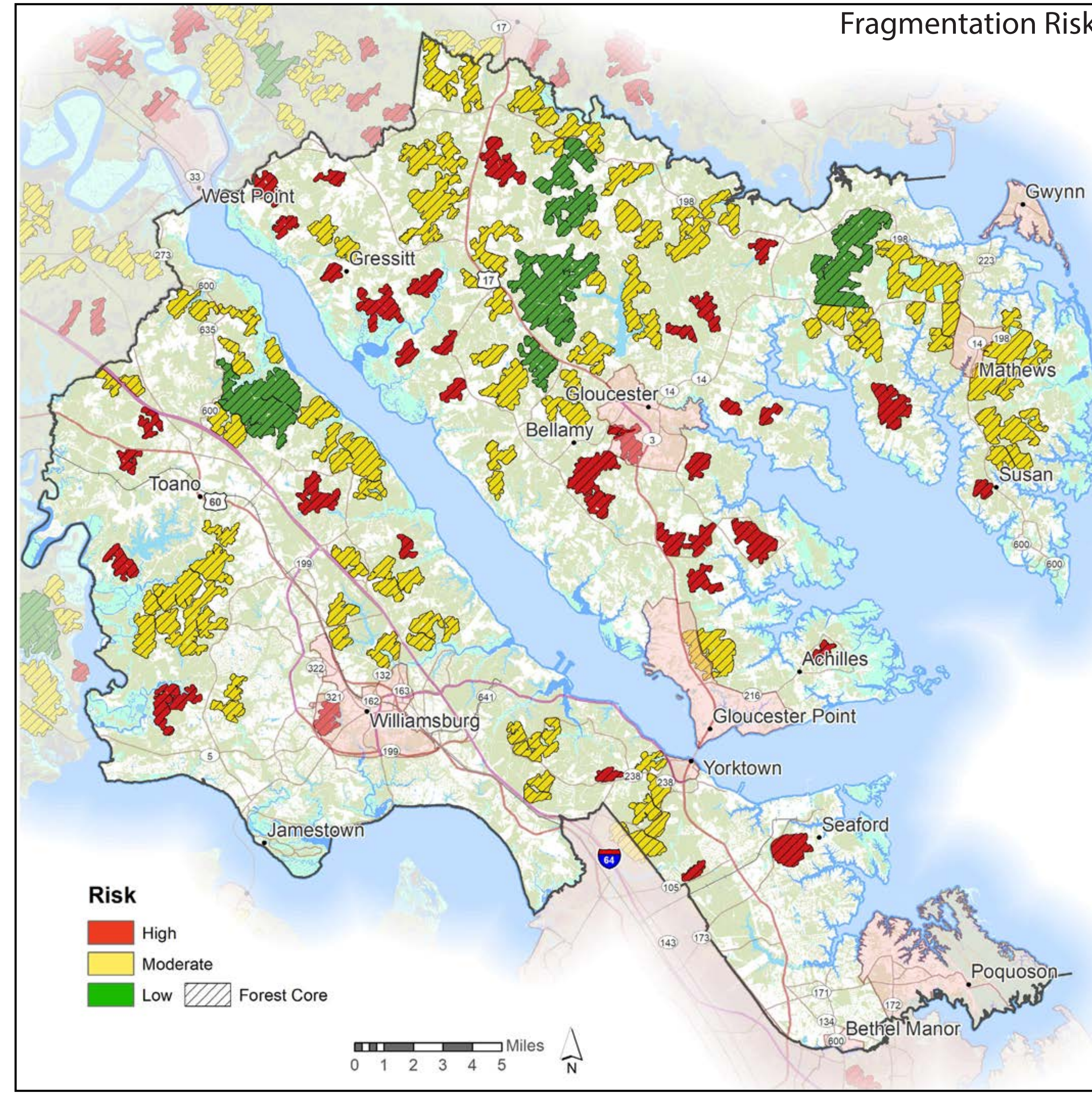
Size Class	Count	Total Acres
100 – 500 acres	123	33,941
501 – 1000 acres	70	41,078
1000+ acres	81	177,779
Total	274	252,798

Georgia Forest Cores

Size Class	Count	Total Acres
100 – 500 acres	141	40,037
501 – 1000 acres	41	27,215
1000+ acres	23	39,880
Total	205	108,132

Fragmentation Inputs

Results

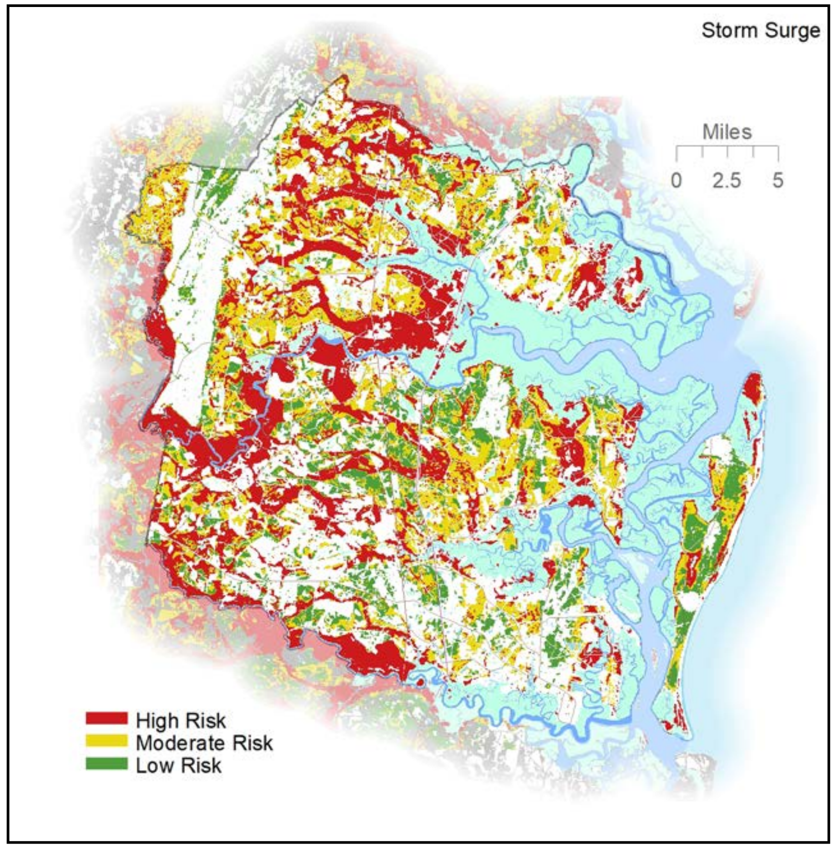


A map of forest cores that are at a higher risk of fragmentation in the Vrginia study area.

Invasives & Pest Inputs

Storm surge

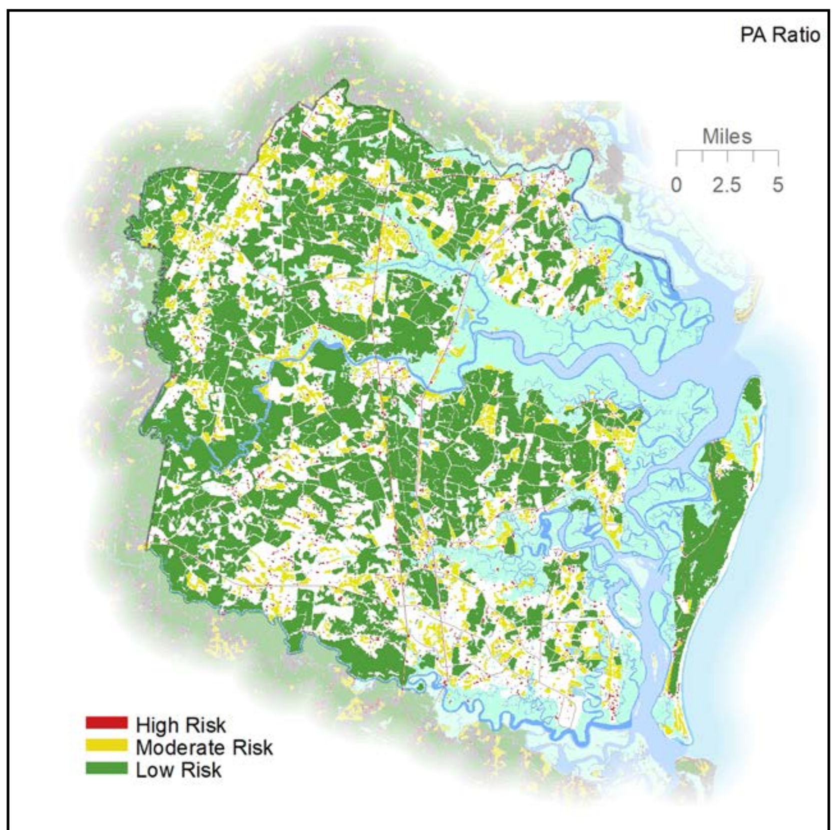
Storm surge categories of 1 – 5 were used to show area of greater risk where storm surge was most frequent based on the National Oceanic and Atmospheric Administration's (NOAA) models. Storm surge was used as a predictor of saltwater inundation and salt spray which can cause stress and decline of forest quality, making a forest more susceptible to a pest outbreak or colonization by invasive species. Salt in forest soils also can limit availability of nitrogen, an essential plant nutrient.



Edge to area ratio

Used to prioritize compactness over longer thinner cores. The greater the amount of edge habitat, the greater the chance for establishment of non-native and invasive species. Edge habitat is more likely to be disturbed and have harsher microclimates (exposure to wind, sunlight and heat) which can stress trees and allow invasive species establishment.

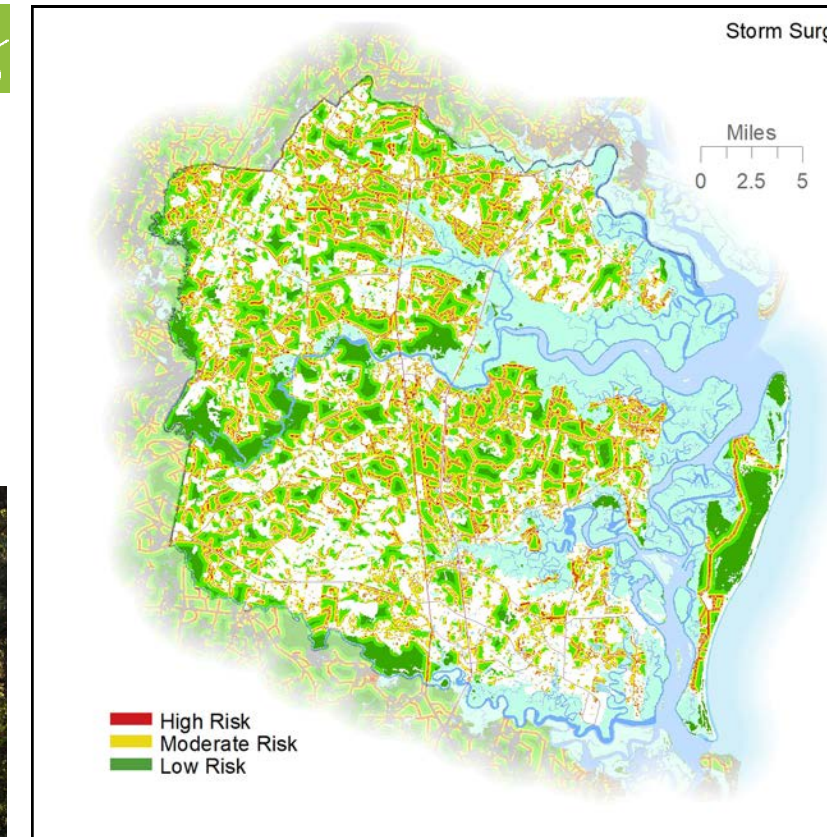
([Length_Meters])/ [Shape_Acres]

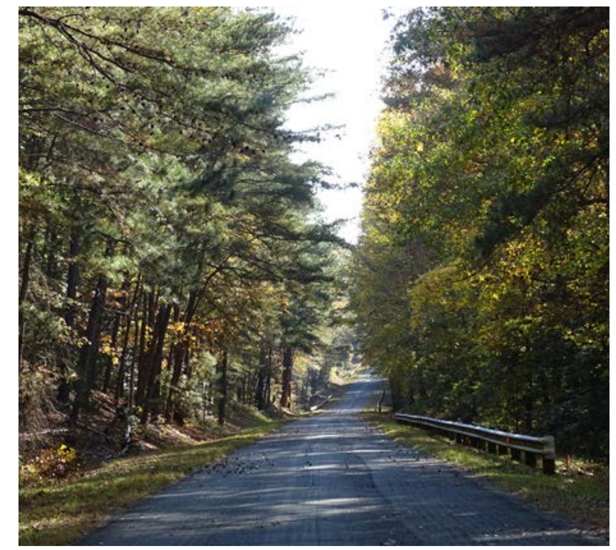


Invasives & Pest Inputs

Distance to roads

Roads are a major vector for dispersing non-native species and pests across the landscape. The closer a forest is to a road, the more likely it will be impacted by pests and invasive species.

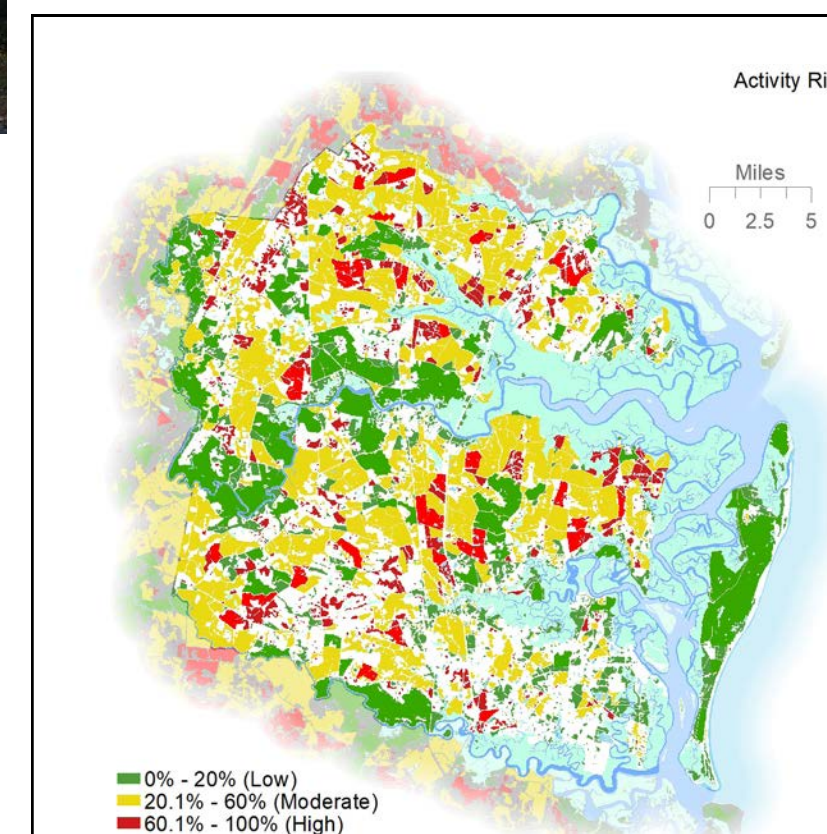




Roads provide pathways for invasive species and pests to spread and establish.

Disturbance/Activity (Hansen data)

The greater and more frequent are land disturbance through major land cover changes, the greater the opportunity for non-native and invasive species to be introduced and established. A forest with greater than 20% activity is more at risk.



FEMA FIRM 100-year floodplain

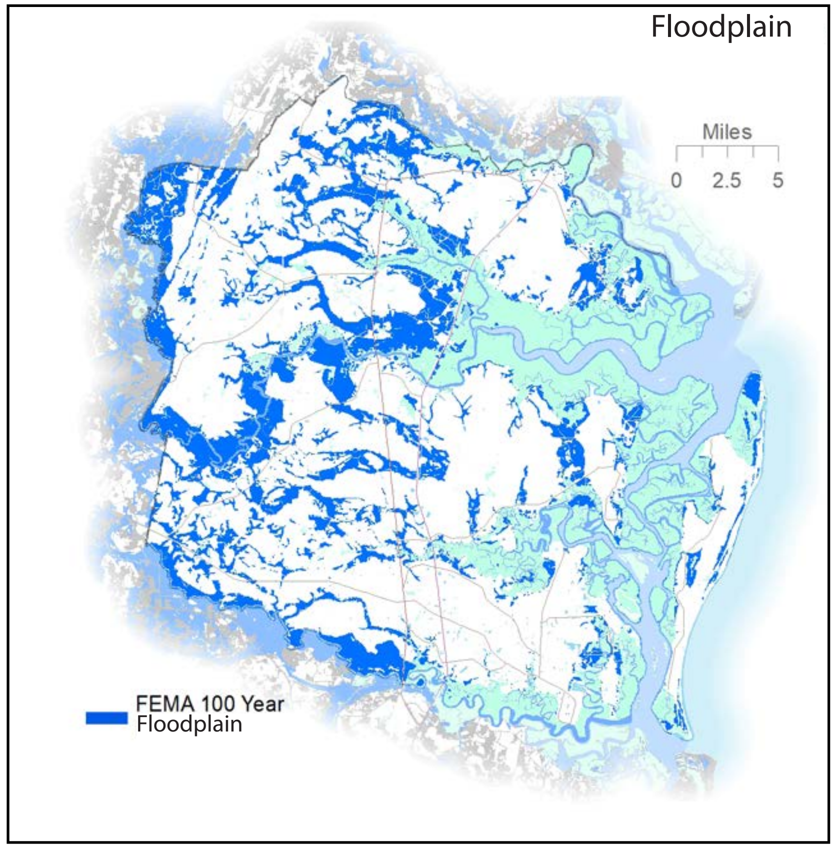
Areas that are flooded can bring in invasive species from upstream. In addition, prolonged flooding can stress the forest making them more susceptible to pest outbreaks.

Steps:

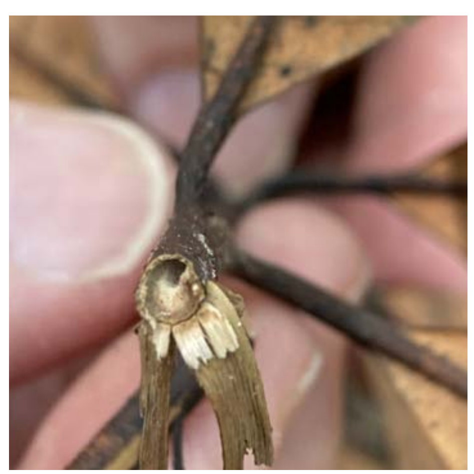
1. The Pest and Invasives Severity Risk surface was first created by ranking the individual threat indicators by natural breaks for the following factors:

- Storm Surge
  Storm surge categories of 1 – 5 were used to show area of greater risk where storm surge is most frequent (category 1).
- Perimeter-to-Area Ratio
  [Length_Feet]/ [Shape_Acres]
  Break into five natural breaks
- Distance to roads
  Distance to road' was grouped into 5 ranks:
  - 0 – 30 meters from road highest risk (5)
  - 30 – 100 (4)
  - 100 – 200 (3)
  - 200 – 500 (2)
  - 500 < (1)
- Activity Greater than 20 percent
  Presence/absence where at least 20% of polygon (core or woodland) is affected by forest clearing
- FEMA_FIRM_100yr
  FEMA's Flood Inventory Risk Map Presence/absence in 100-year floodplain.

2. The above layers were added together to get the severity layer.

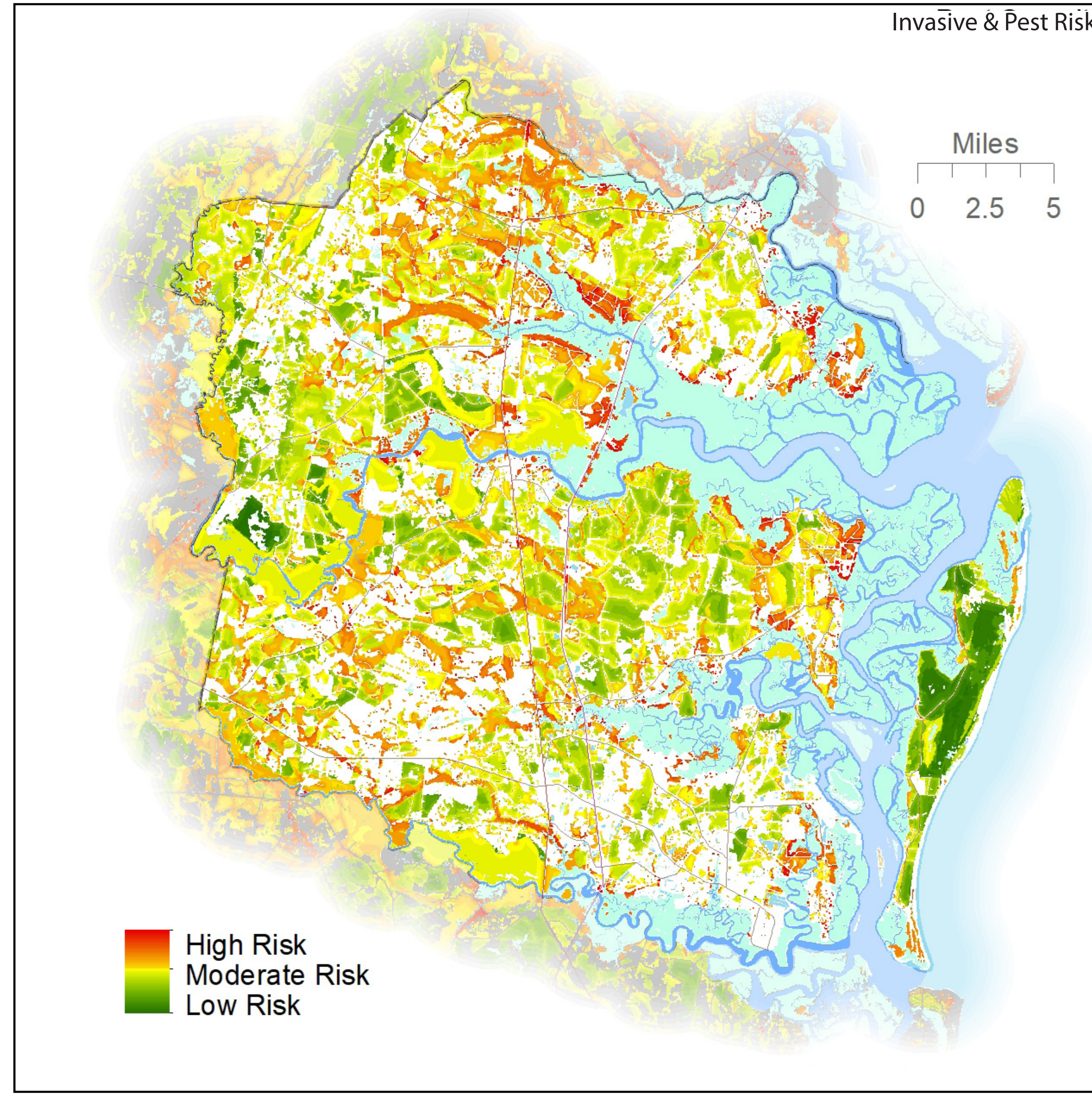


3. The severity layer was then summed using the forest cores and woodlands. The result was then clustered based on three natural breaks; High, Moderate and Low risk for the habitat cores and woodlands individually.
4. To derive the final rank, the Forest Core Risk values were used over the Woodland Risk if (due to statistical calculations) there were differences between Forest Core values and woodlands.



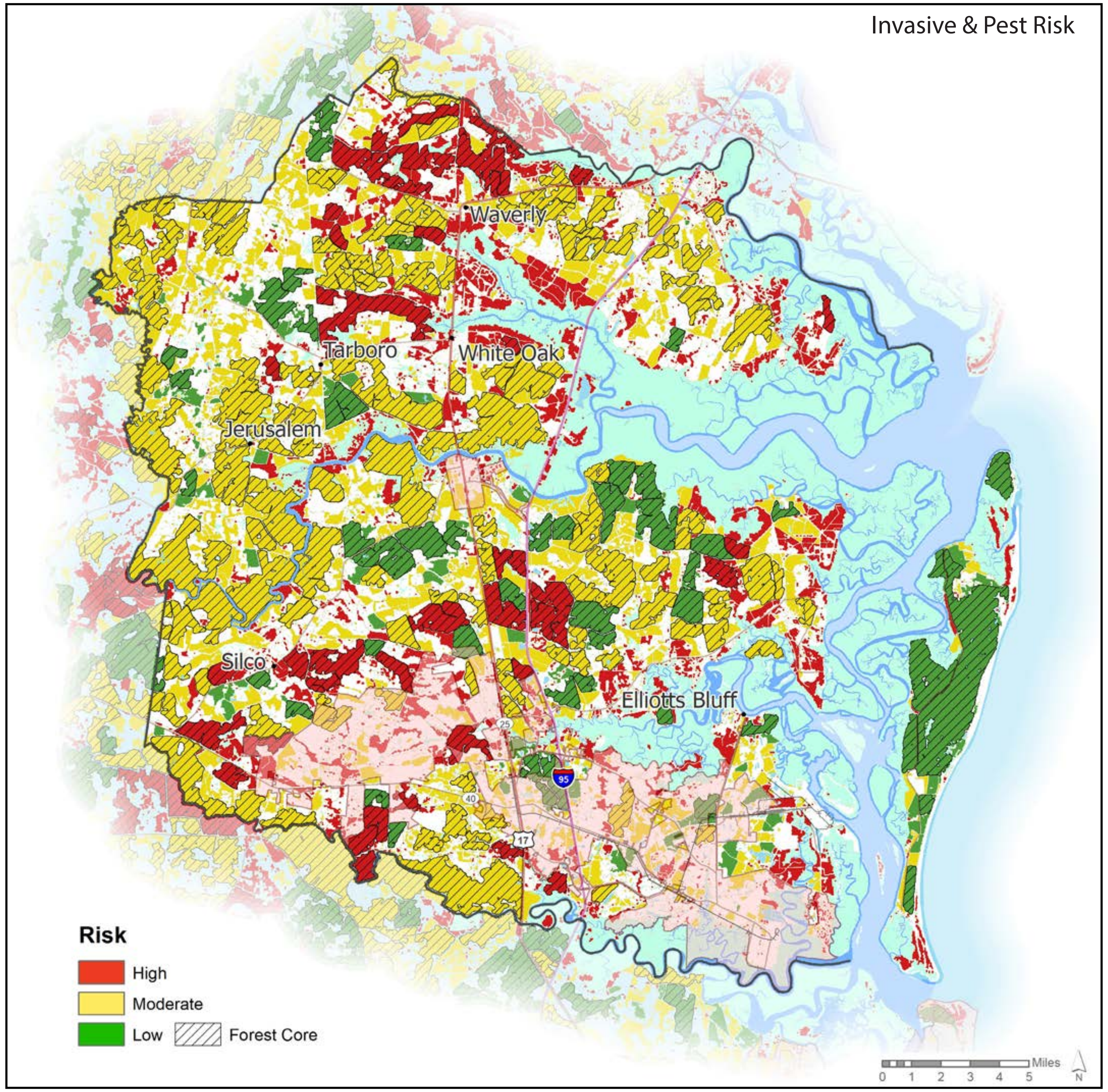
Pests such as the ambrosia beetle are killing native trees and altering the species compistion of coastal forests.

Results



A map of the surface data of invasive species, pests and disease risk before summarizing across forest cores and woodlands.

Results



A map of risk of invasive species, pests and disease summarized across forest cores and woodlands in the Georgia study area.

Summary of trends

Areas of greatest risk of invasive species, pests & disease

Virginia
8,361 acres (3.5%)

South Carolina
125,580 acres (39%)

Georgia
51,083 acres (27%)

The risk of potential invasive species, pests and disease was based on indicators of stress to the forest such as flooding, salt spray, disturbance, proximity to roads and development and edge effects. South Carolina and Georgia both had greater potential impacts from storm surge and flooding due to their low topographic positions and relative locations on the Atlantic Seaboard which makes them more vulnerable to tropical storms. In addition, both South Carolina and Georgia had greater areas of disturbance from higher levels of forestry activity which relates to the greater amount of rural land within their study boundaries. Georgia's study area had a widespread population of nonnative and invasive species. A large contributing factor was the Interstate 95 corridor which bisected the region. Invasive species from Florida are migrating north along this corridor. Also, species previously limited to Southern Florida's more tropical climate, are moving northward as climate change is increasing the habitability range of many of these species.

While South Carolina and Georgia had the most forest cover at risk from invasive species and pests, it is important to note this model does not factor in current management practices and level of investment in controlling or eradicating invasive species or pest populations by local, state and federal stakeholders. This model was by far the most challenging or which to model risk because invasive species and pests can be introduced and established through a variety of means. In addition, no comprehensive spatial data sets existed that were also readily accessible to map all locations of invasive species and pest observations within the study area. Further refinement of this model would be beneficial to get a clearer picture of invasive species spread and establishment in a region, but for the purposes of this study, this model was sufficient to capture the effects of invasive species and pests on forests in coastal regions.

Invasive species can colonize and smother forests leading to their ultimate decline and loss.

Sea Level Rise Inputs

NOAA 2017 sea level rise data – nearest gauge to the study area used to predict rise to the year 2060.

The intermediate-high curve was chosen for each state based on the likelihood of occurring in the future and from feedback from local and state stakeholders that this is the most commonly used curve for long-range planning in coastal regions. For Virginia, the curve showed 3 feet rise by 2060, while 2 feet was used for both South Carolina and Georgia. NOAA's sea level rise curves can be found at the following link: https://coast.noaa.gov/slrdata/

Steps

1. Zonal stats as raster data using Woodlands/Cores
2. Reclassify if > 20% of the forest is inundated in the year 2060 then risk is high. Otherwise, risk was classified as low.

Summary of trends

Areas of greatest risk of sea level rise

Virginia
2,000 acres (0.8%)

South Carolina
42,766 acres (13%)

Georgia
47,018 acres (25%)

Virginia – While Virginia had the highest projected sea level rise (3-ft in the year 2060) of the three study areas, it had the least impact to coastal forests (2,000 acres or 0.8% of coastal forests) due to the general topography (the escarpment formed by an ancient meteor) and proximity of forests to the sea.

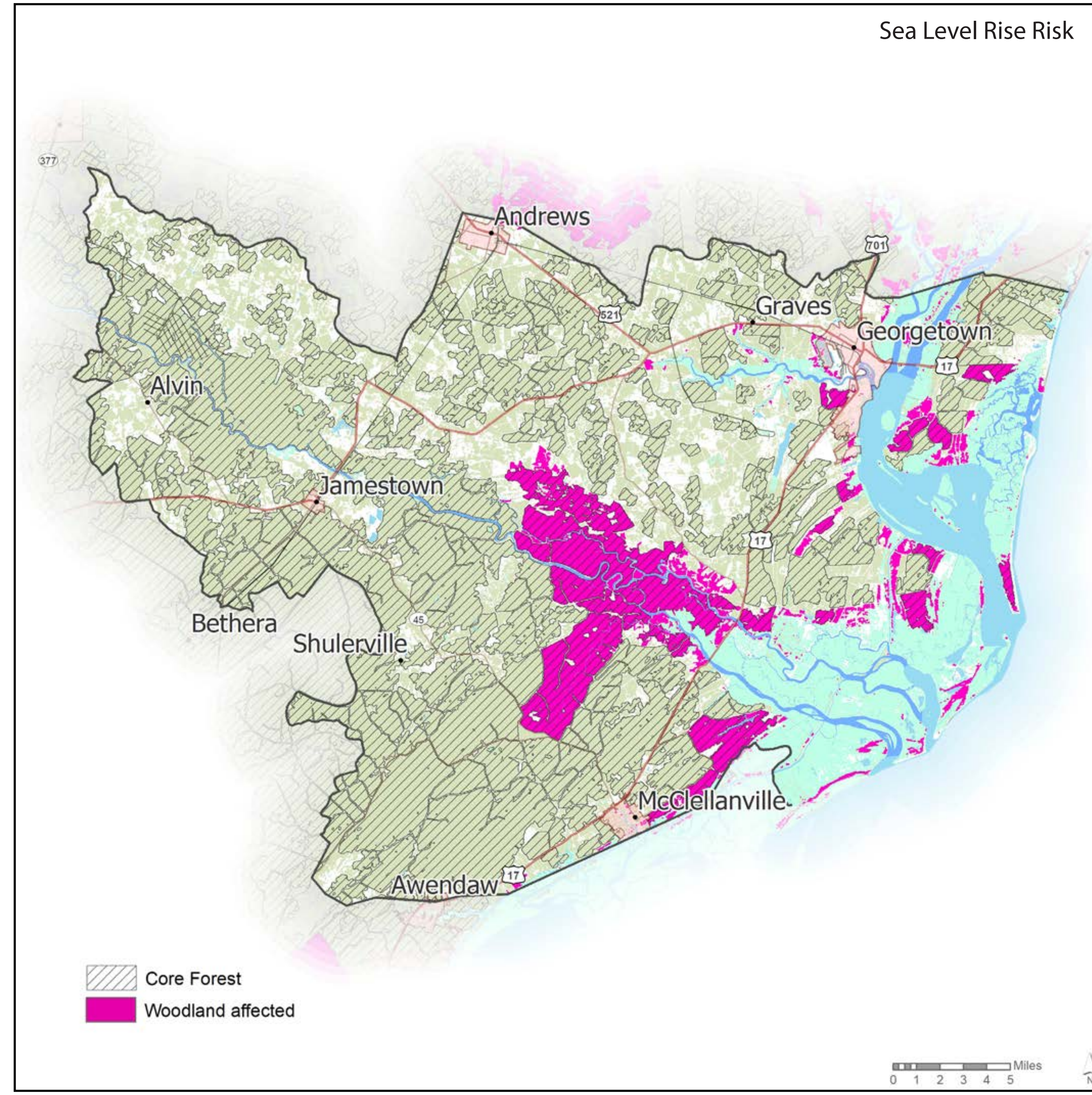
South Carolina – South Carolina is similar in scale of losses in terms of acreage to Georgia (42,766 acres) but the area has an overall smaller percentage of the coastal study area affected at 13%.

Georgia – Georgia had the most potential losses (47,018 acres or 25%) from a 2-ft sea level rise due to wide river corridors and generally flat terrain. In addition, saltwater marshes were also significantly impacted and adaptation efforts for both marsh migration and coastal forest migration need to be considered across the landscape as sea levels continue to rise.

High tides are already reaching further inland as sea levels continue to rise.

Sea Level Rise Inputs

Results



A map of the risk of 2-feet of sea level rise to the year 2060 across the South Carolina study area.

Solar Development Inputs

Argonne Lab's Solar Site Suitability Analysis

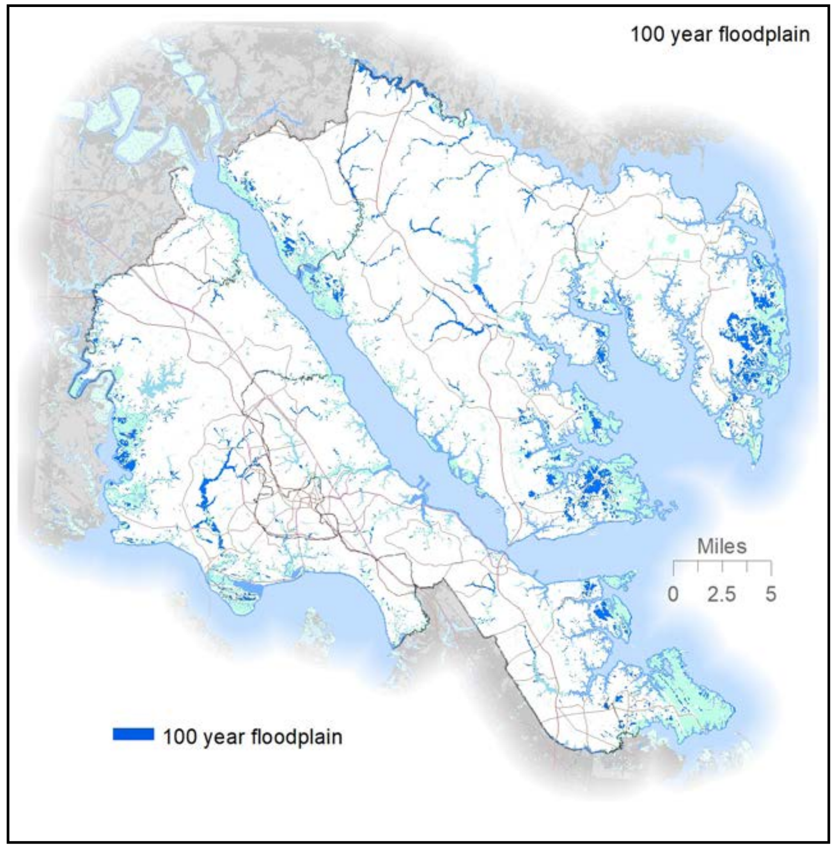
The main purpose of the EISPC Energy Zones (EZ) Study was to develop a comprehensive mapping tool that would enable EISPC members and other stakeholders to identify areas within the U.S. portion of the Eastern Interconnection that are suitable for the development of clean (low- or no-carbon) electricity generation Download tool: https://ezmt.anl.gov/

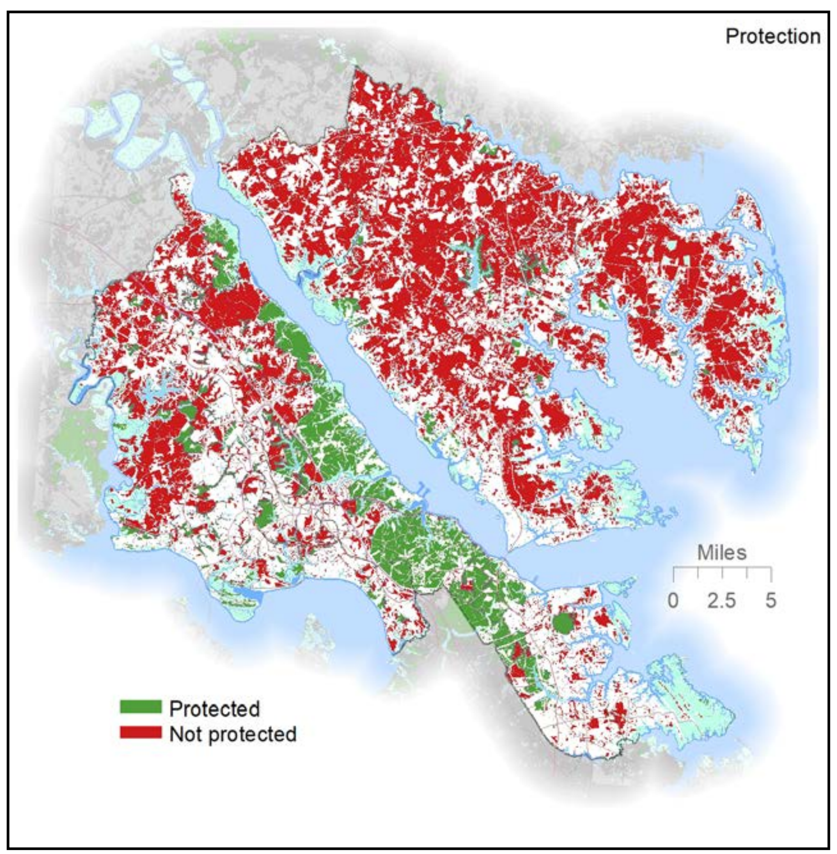
Areas to exclude as unsuitable from the model as determined by the local stakeholder committees are as follows:

- FEMA floodplain data (with wetlands)
- Wetlands
- Protection

Steps

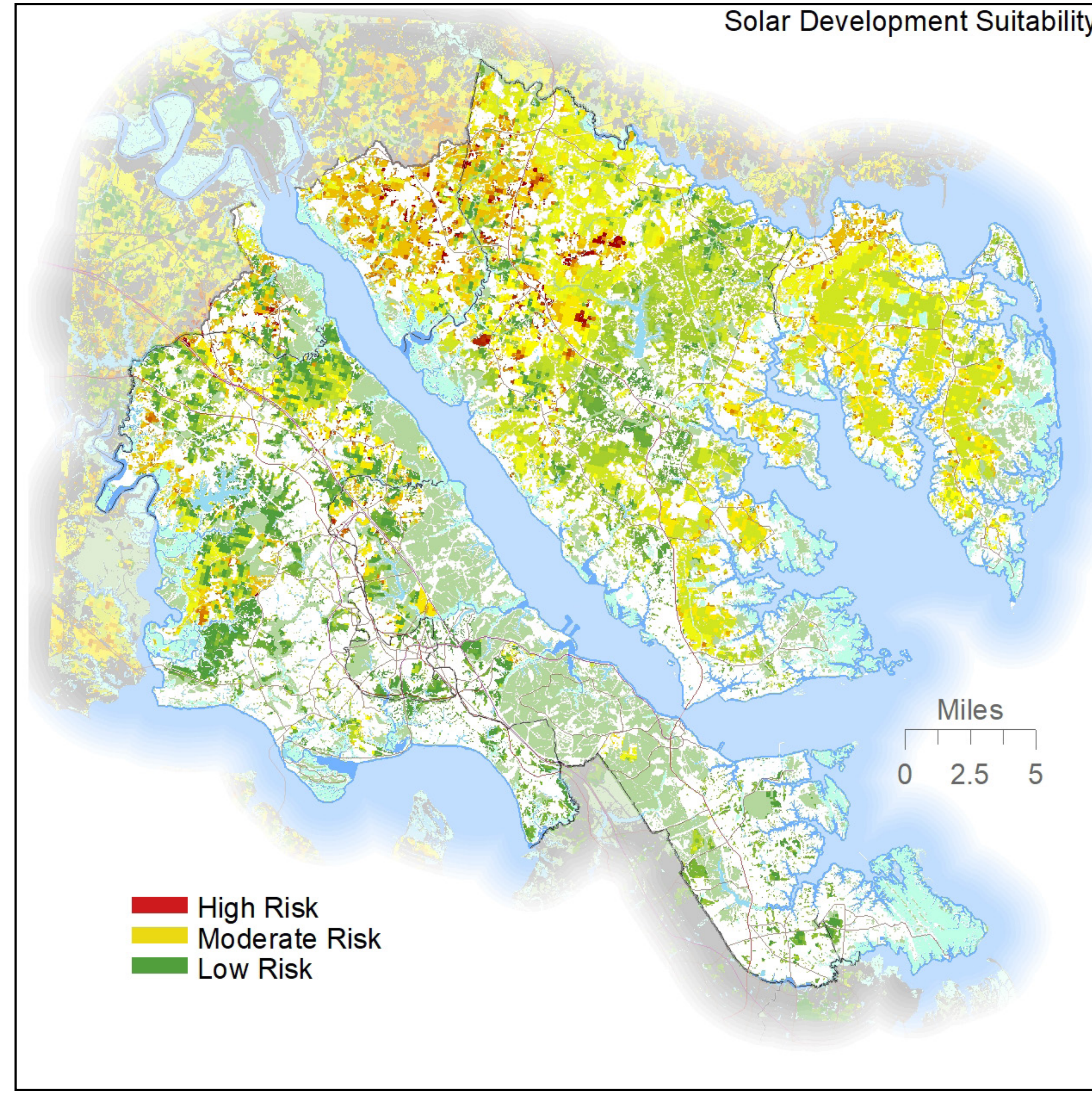
1. Floodplains, Wetlands and Protected areas were excluded from the analysis because finer scale data than used for the source data were available.
2. The Argonne Labs Suitability surface was then clustered by natural breaks as follows
   - 45 – 65 (3 High risk)
   - 30 – 45 (2 Moderate Risk)
   - 0 – 30 (1 Low Risk)
3. The severity layer was then summed using the forest cores and woodlands. The result was then clustered based on three natural breaks to High, Moderate and Low risk for the habitat cores and woodlands individually.
4. For final Rank, the Forest Core Risk values were used over the Woodland Risk if (due to statistical calculations) there were differences between Forest Core values and woodlands.





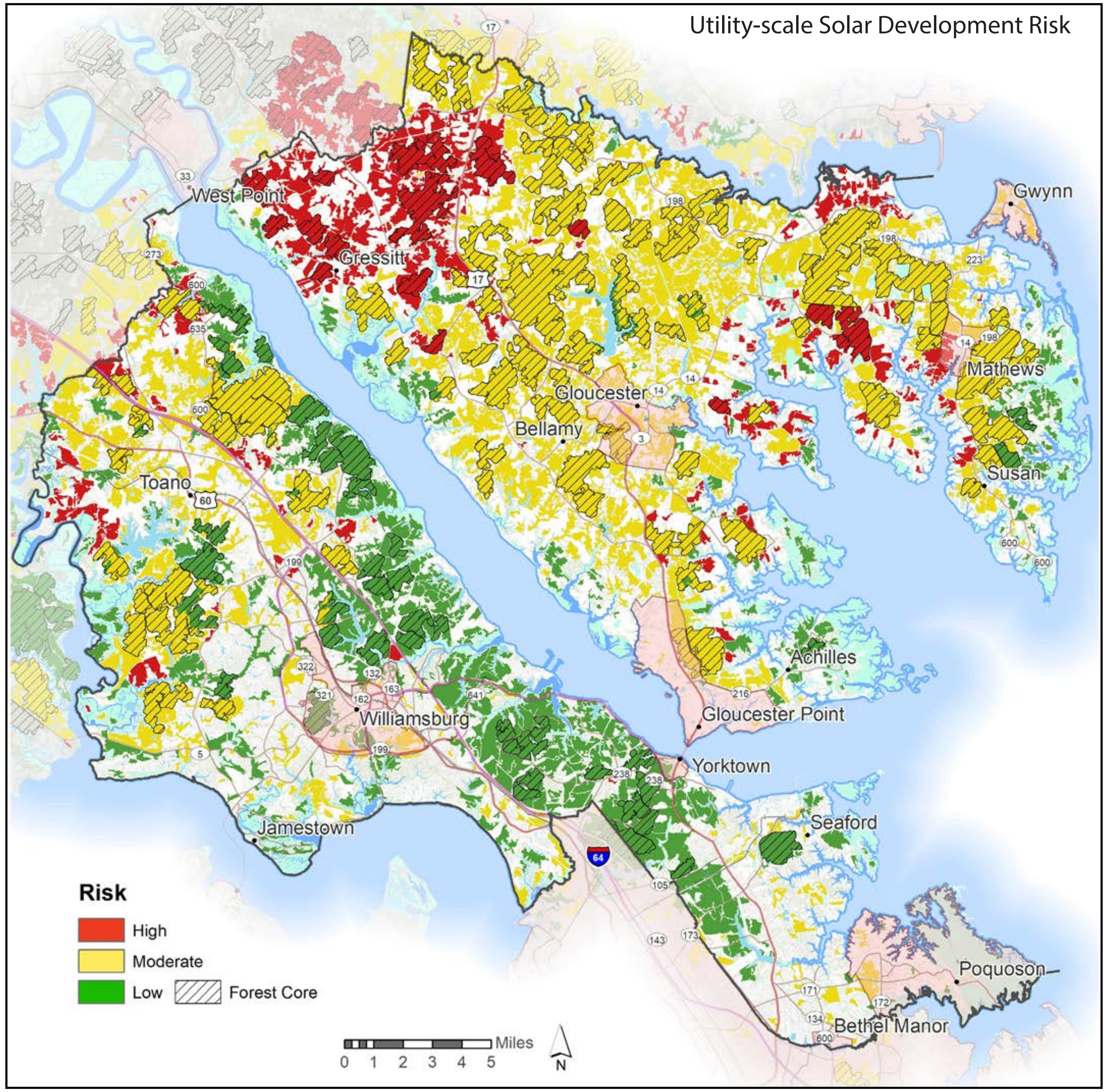
Solar Development Inputs

Results



A map of the surface data of solar suitability before summarizing across forest cores and woodlands.

Results



A map of utility-scale solar development risk in the Virginia study area,

Summary of trends

Areas at greatest risk of utility-scale solar developments

Virginia
25,627 acres (11%)

South Carolina
116,661 acres (36%)

Georgia
77,938 acres (41%)

Utility-scale solar development was an unidentified risk that became a pressing threat in the study areas over the course of the project.

While South Carolina and Georgia had the most forest cover at risk from utility-scale solar development, Virginia's study region was experiencing a sudden and rapid development of solar applications. Virginia's Gloucester County was inundated with permit applications for new solar utility developments during the course of this study and the data produced by this project informed the county's analysis and decision to regulate solar development in their zoning code in order to better protect rural lands. Since publishing the resiliency plans, the localities in the South Carolina study region have communicated that there are several very large (1000+ acres) solar developments in early application stages.

This new threat was not imagined at the beginning of the study, but the impacts of the rapid conversion of a state's energy generation portfolio towards more solar is having an impact on forest habitat. While clean energy is critical to the U.S.'s long-term efforts to cut greenhouse gas emissions, a more thoughtful and land-use conscious approach was consistently expressed by local and state stakeholders across all three states. Since a main reason for solar power is to avoid carbon releases, large intact forests – which sequester and regularly absorb carbon in trees and forest soils – should not be converted to turf covered by solar arrays.

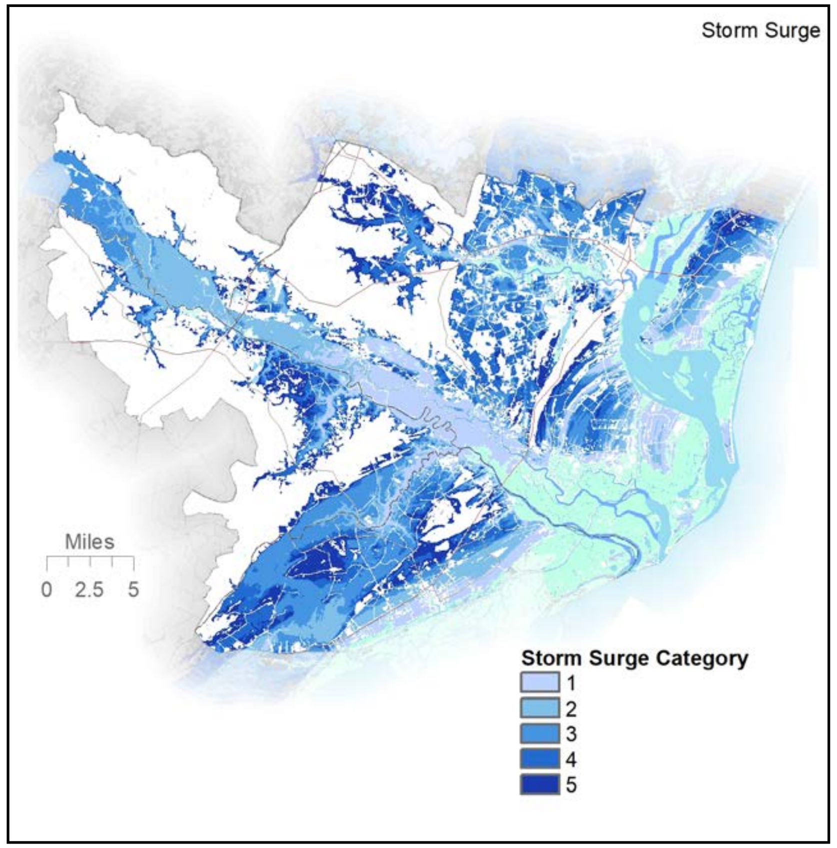
Storm Inputs

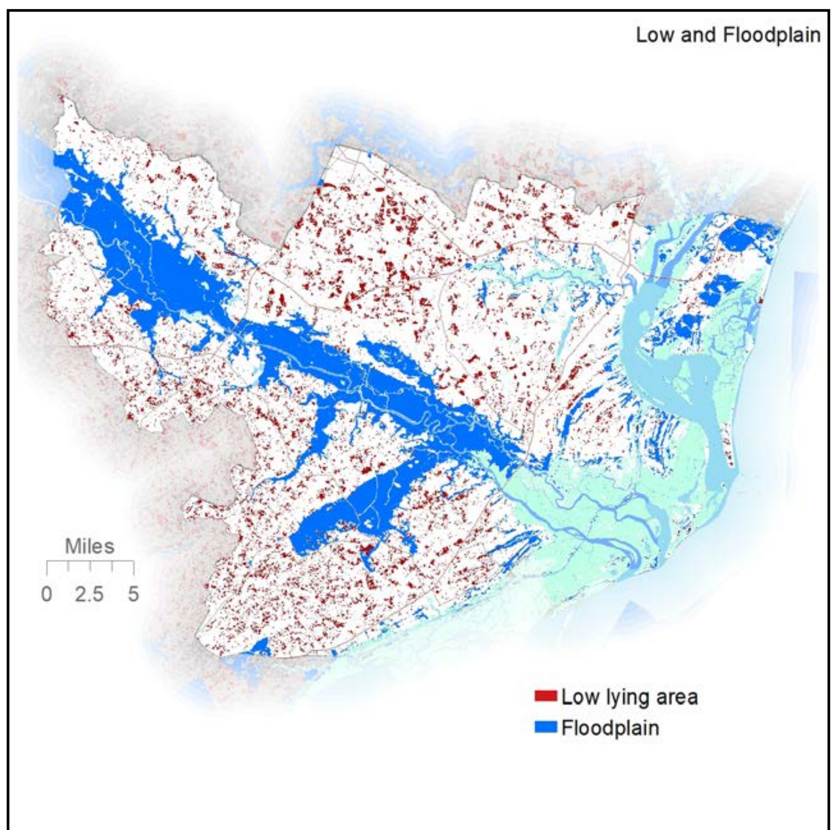
NOAA storm surge data

This national depiction of storm surge flooding vulnerability helps people living in hurricane-prone coastal areas along the U.S. East and Gulf Coasts, Puerto Rico, U.S. Virgin Islands (USVI), Hawaii, and Hispaniola to evaluate their risk to storm surge hazard. https://www.nhc.noaa.gov/nationalsurge/:

Low-lying topographic positions

Low lying areas were selected from the ecologically-relevant geophysical (ERGo) landforms dataset, a comprehensive classification of landforms based on hillslope position and dominant physical processes that covers most of North America. Four hillslope positions form a natural sequence of topographic units along the catena: ridges/peaks (summits), upper slopes (shoulders), lower slopes (foot slopes), and valley bottoms (toe slopes). The position within each of these hillslopes as a function of solar orientation is to reflect how ecological processes (especially soil moisture and evapotranspiration) are influenced by insolation. Also included are very flat (i.e. areas <2°) or very steep (i.e. "cliffs" >50°). These data are at 30-meter resolution, grouped by Landscape Conservation Cooperative boundaries. For a more detailed description, please refer to: Theobald DM, Harrison-Atlas D, Monahan WB, Albano CM. 2015. Ecologically-relevant maps of landforms and physiographic diversity for climate adaptation planning. PLOS ONE. Published: December 7, 2015 http://dx.doi.org/10.1371/journal.pone.0143619Data





Storm Inputs

Availability: Datasets are available at: https://www.sciencebase.gov/catalog/

Value, Class name

- 1 Peak/ridge warm
- 2 Peak/ridge
- 3 Peak/ridge cool
- 4 Mountain/divide
- 5 Cliff
- 6 Upper slope warm
- 7 Upper slope neutral
- 8 Upper slope cool
- 9 Upper slope flat
- 10 Lower slope warm
- 11 Lower slope neutral
- 12 Lower slope cool
- 13 Lower slope flat
- 14 Valley

FEMA floodplain data

Steps

1. The storm surge data were classified based on frequency that high level storms would most likely hit.
   - Storm Category 1 = High Risk (because most frequent)
   - Category 2 and 3 = Mid
   - Category 4 and 5 = Low
2. Next, if an area within a storm range (e.g. has a storm category) is either low lying or in the floodplain, then the risk was bumped up one category. If the area was already at the highest risk then nothing was added.

Summary of trends

Areas at greatest risk of storms

Virginia
42,609 acres (18%)

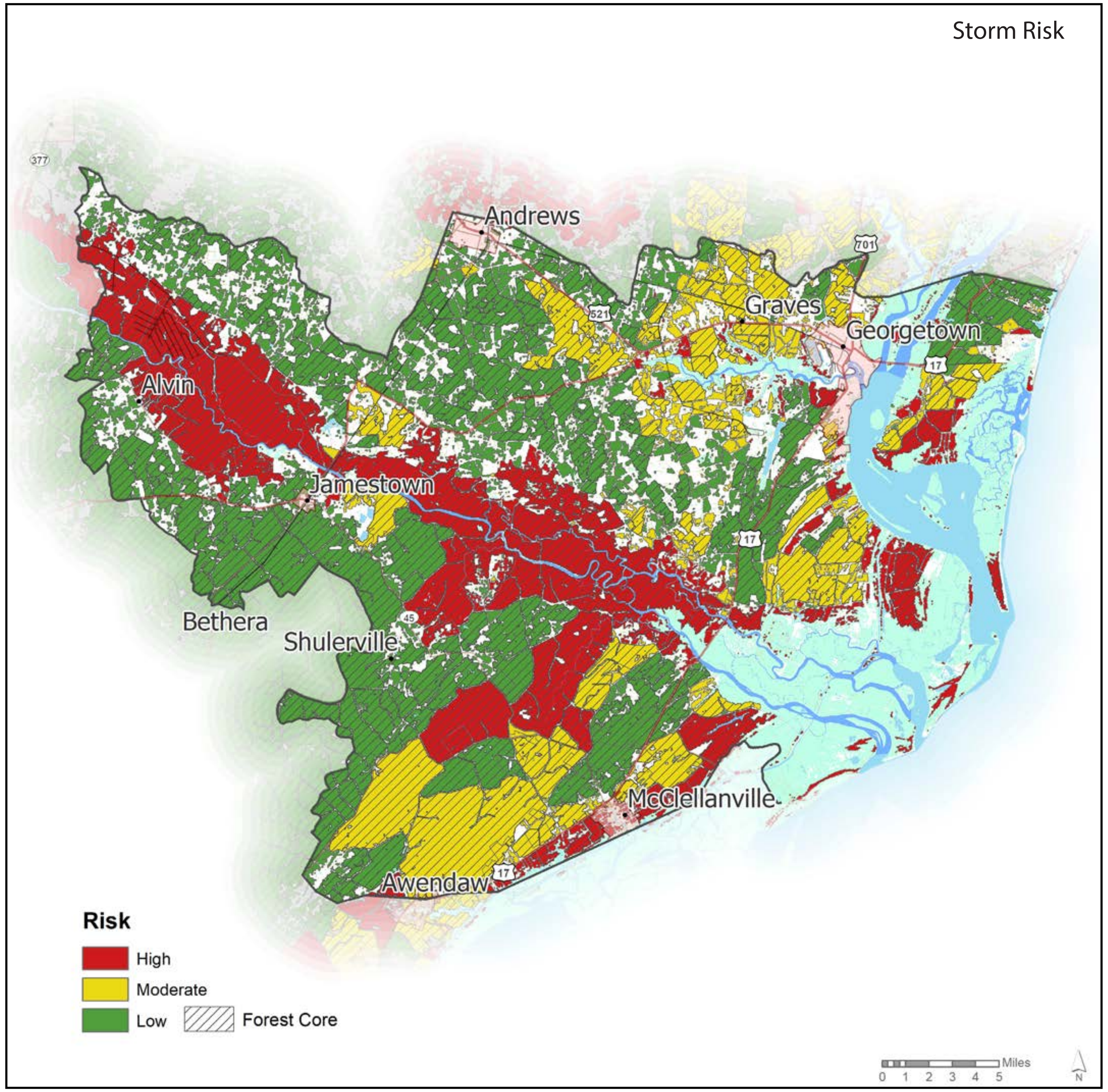
South Carolina
101,100 acres (31%)

Georgia
90,353 acres (47%)

The general topography of Virginia's study area has greater variability and the escarpment protects the shoreline along the Chesapeake Bay. In contrast, the greater amount of low-lying land in Georgia and South Carolina and wide-flat river corridors, storm surge and inland flooding are a much higher risk in those regions. Nearly half of the coastal forests in the two study areas are wooded wetlands, so much of the forest is resilient to periods of flooding; however, these freshwater forested wetlands are susceptible to saltwater and salt spray from storm surge and can cause long-term disruptions to the ecology and soils. In addition, the natural buffers that protected coastal forests such as saltwater marsh are being lost due to sea level rise or declining due to nonpoint source pollution, making forests more vulnerable to future storm impacts. A holistic approach that includes all coastal resources will be needed and this body of research and planning can support and be integrated with other state and regional initiatives such as Coastal Master Planning or the South Atlantic Saltwater Marsh Initiative (SASMI).

Storm Inputs

Results



A map of storm risk in the South Carolina study area,

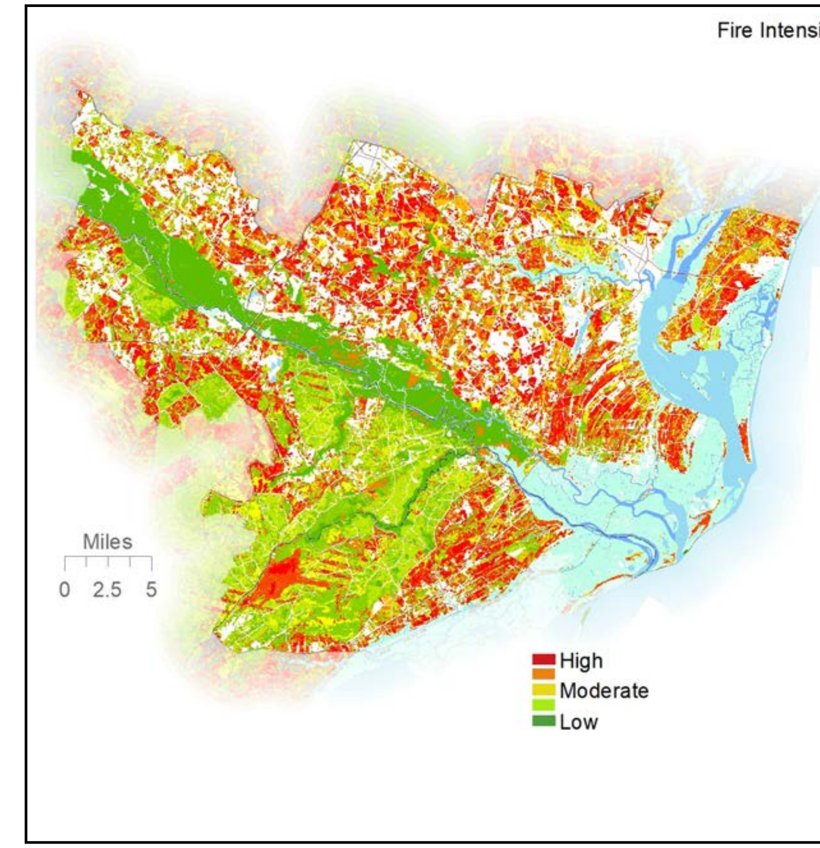
Wildfire Inputs

Fire Severity

Fire severity created by modifying Southern Group of State Forester's Wildfire Risk Assessment Portal's (South WRAP) intensity with general forest age (e.g. older than 20 years or not older than 20 years).

Fire Intensity

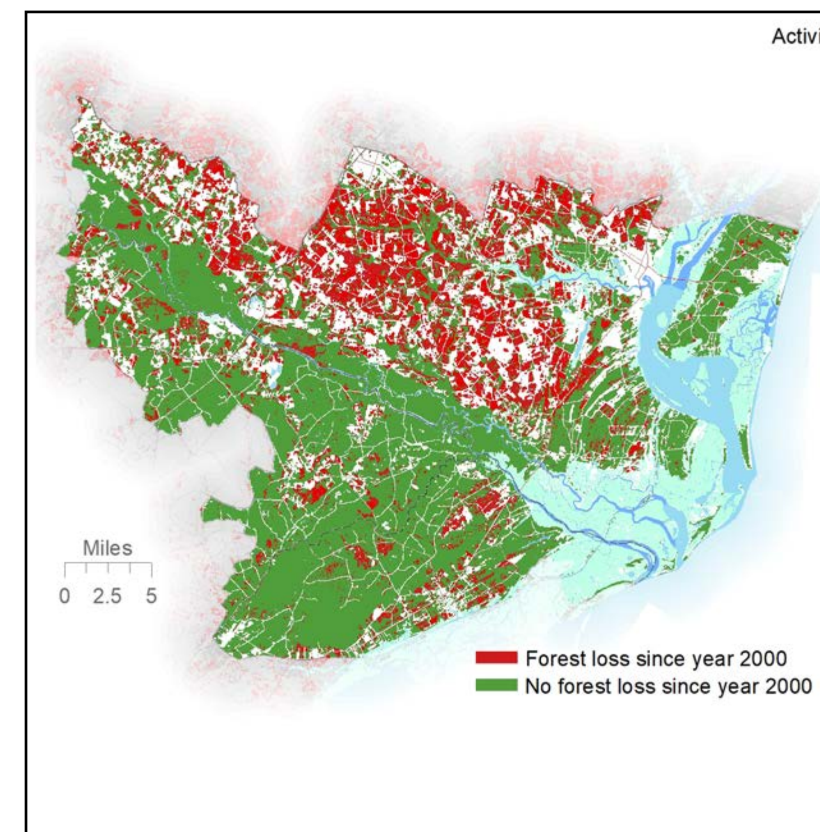
- Characteristic Fire Intensity Scale (FIS) specifically identifies areas where significant fuel hazards and associated dangerous fire behavior potential exist based on weighted average of four percentile weather categories. Similar to the Richter scale for earthquakes, FIS provides a standard scale to measure potential wildfire intensity. FIS consist of 5 classes where the order of magnitude between classes is ten-fold. The minimum class, Class 1, represents very low wildfire intensities and the maximum class, Class 5, represents very high wildfire intensities.
- Fire Intensity (Severity) Scale: Southern Group of State Foresters data on fire severity. The portal link: https://www.fdacs.gov/Forest-Wildfire/Wildland-Fire/Resources/Fire-Tools-and-Downloads



Activity

Hansen deforestation event modifier

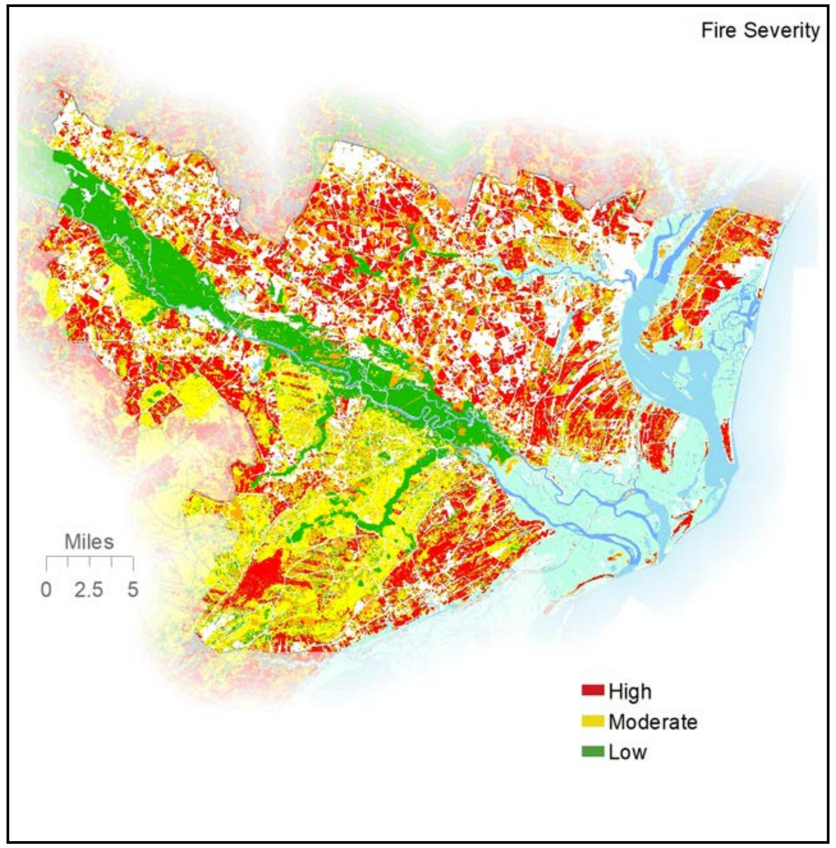
- Modifier: Where deforestation events have occurred in last 20 years, the fire intensity is lowered.



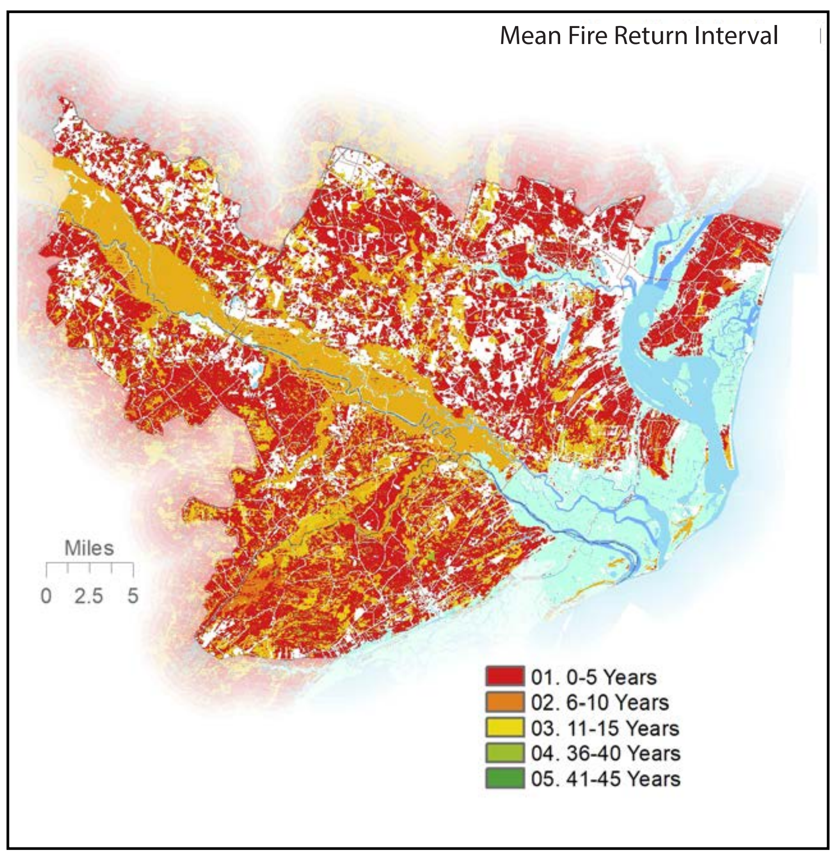
Wildfire Inputs

Likelihood of Ignition (LOI)

LOI was determined by using the LANDFIRE return interval modified by future development prediction. The return interval is the natural frequency of fire return on the landscape based on the land cover and ecology. The future development prediction was used as proxy for ignition since the majority of wildfire ignitions (90% or greater) are human induced through infrastructure (sparks from the electric grid), carelessness (fireworks or escaped brushfires) or maliciousness (arson). The closer a forest was to existing or future urban areas the more likely an ignition source is available.



Fire Return Interval LANDFIRE MFRI. The Mean Fire Return Interval (MFRI) layer quantifies the average period between fires under the presumed historical fire regime. MFRI is intended to describe one component of historical fire regime characteristics in the context of the broader historical time period represented by the LANDFIRE (LF) Biophysical Settings (BpS) layer and BpS Model documentation.



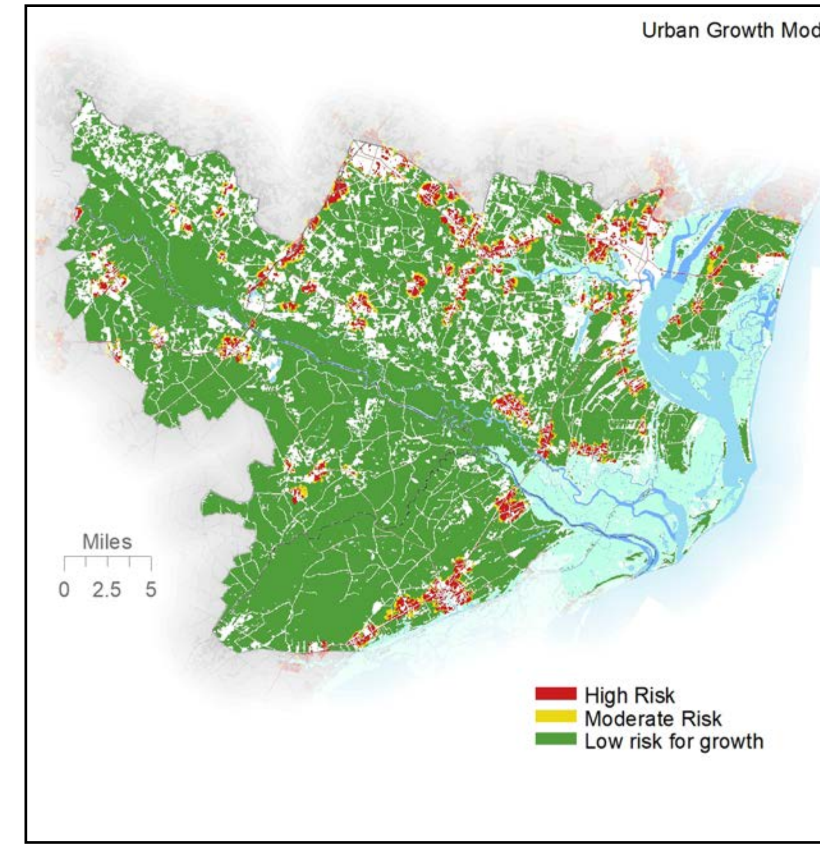
Wildfire Inputs

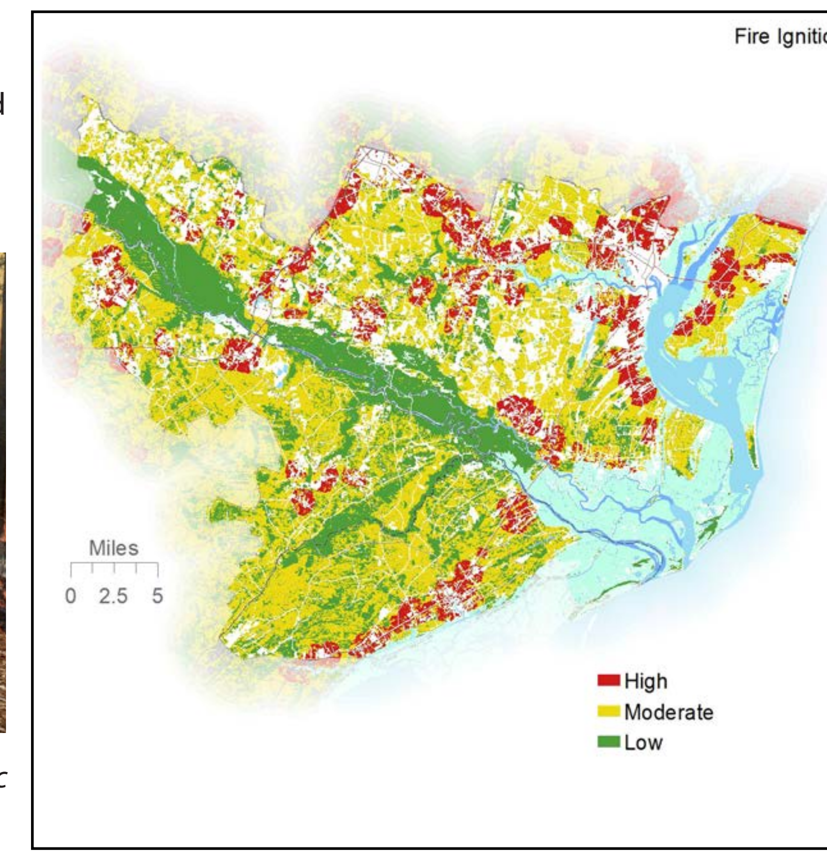
SLEUTH (Urban growth model)
Modified to be higher near growth areas identified in SLEUTH for 2060.

Steps

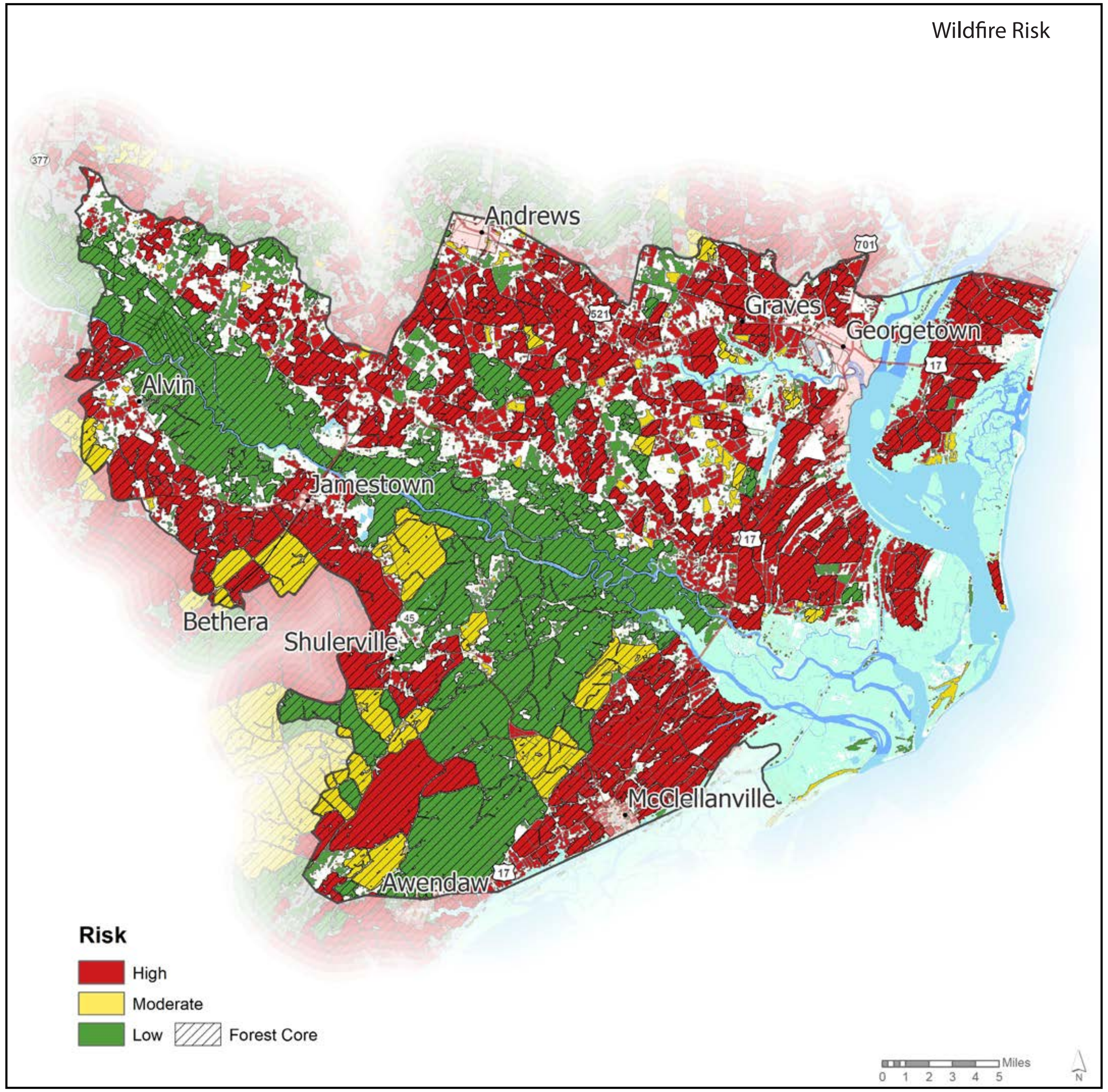
1. To create the fire severity layer, the FIS values are grouped into four categories based on natural breaks. Using the fire intensity scale as the primary value but assuming areas that have been cleared in the last 20 years have less fuel, the values are lowered slightly by subtracting one from the value.
2. Next, the likelihood of ignition was created by grouping the MFRI into four categories based on Natural Breaks. Using the MFRI as the primary value but assuming areas closer to urban growth would most likely have human started fires, they were raised one rank.
3. Fire Severity was multiplied by likelihood of ignition and then grouped into four natural breaks.

Wildfires commonly result from anthropogenic sources.





Results



A map of wildfire risk in the South Carolina study area,

Summary of trends

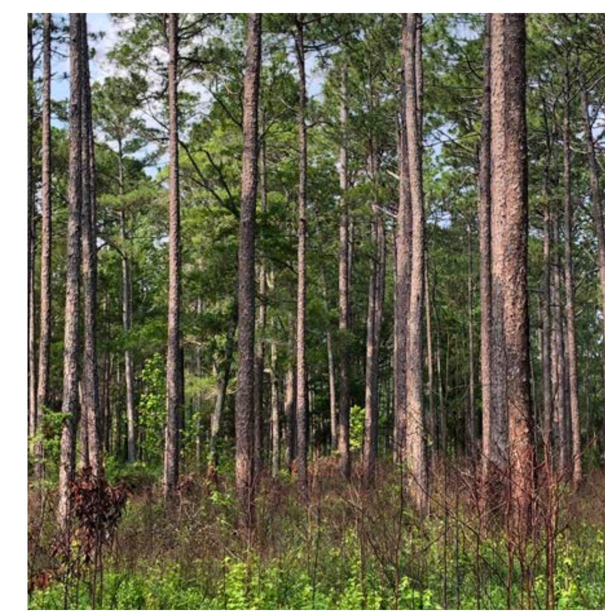
South Carolina and Georgia had the most forest cover at high risk for wildfire. This model did not factor in seasonal changes to fire risk, but rather modeled fire risk based on the season of highest risk for the South which typically runs from February to May. This model also did not factor in future climate and potential changes to precipitation patterns. For example, foresters in the Georgia study region were less concerned with wildfire risk increasing over time because they were experiencing longer and wetter seasons which limited their ability to conduct as many prescribed fires as necessary for forest management. The fire model was vetted by the foresters in each of the agencies to see if it aligned with their experiences in the region and also with local stakeholders. What is clear, based on input from the local stakeholders and the data, is that there is a significant amount of land that needs fire for adequate management and risk reduction and that fire as a natural resource tool is becoming harder to deploy in the landscape. The times when it is not wetter are also the periods when prescribed fires would usually be applied to reduce fuel loads.

Areas at greatest risk of wildfires

Virginia
42,609 acres (18%)

South Carolina
101,100 acres (31%)

Georgia
90,353 acres (47%)



Fire is an important naturally recurring disturbance in coastal forests and necessary to maintain certain forest types such as the longleaf pine savannas that used to be predominant in the coastal plain.

Activity Inputs

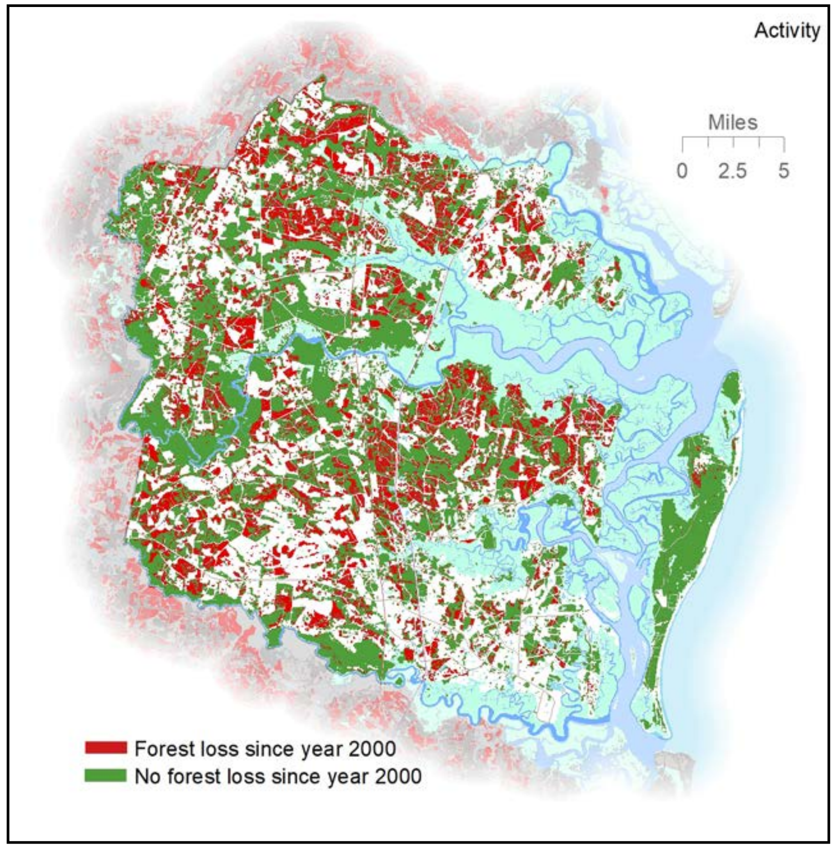
Data are based on Hansen deforestation events. Data are summarized by the percent of forest that has changed in the last 20 years.

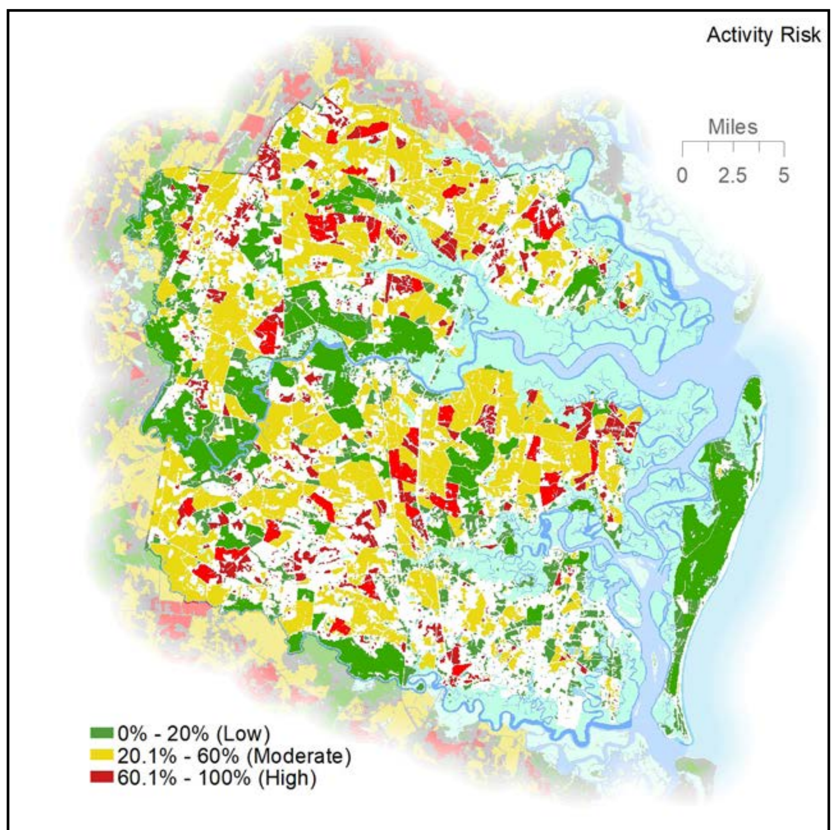
Hansen Deforestation Events: This project is focused on developing global tree cover change data products based on Landsat satellite imagery, which is available for display and download on the Global Forest Watch 2.1 (GFW 2.1) web platform. This is a Landsat-based global, annualized tree cover change product at 30-meter resolution for the years 2000 through 2019.

Steps

1. The percentage of each Forest Core and Woodland that was affected by a forest clearing at some point in the last 20 years was used to rank the cores/ woodland polygons.

This dataset was used to identify additional impacts from recent land cover changes which could be a result of a variety of reasons (development, agriculture, forestry or natural disaster). This layer was used as an input for several of the models for assessing risk, such as invasive species and pests and wildfire.





Sum of All Risks

Coastal forests are under threat from a variety of sources and the impacts from those threats are unequal. For example, sea level rise flooding a coastal forest with saltwater is not equivalent to a wildfire, from which a forest could recover. Development is another example of a permanent impact for forest loss, compared to invasive species which can degrade forest quality over time, but for which human intervention could potentially restore the forest. Due to the wide discrepancy in impacts from each threat, GIC added weights to reflect the severity of the potential threat. In addition, each threat is not occurring in isolation, so multiple threats could impact the same patch of forest. Thus, it is important to capture the sum of all threats to a specific patch of forest to understand its cumulative risk and to inform planning and decision-making.

Steps

Final risk ranks were assigned by adding all the above results and then grouping them into three natural breaks.

Categorized results of above (High, Moderate or Low)

Weighting each by the following schema:

- Sea level rise – 4X
- Development – 4X
- Solar development – 3X
- Storms – 2X
- Invasive species, pests and disease – 2X
- Wildfire – 1X
- Fragmentation – 1X
- Activity – 1x

Multiple threats can combine to increase the risk of forest loss. In this picture, the invasive grass phragmites increases the understory fuel loads which increases the risk of wildfire.

Summary of trends

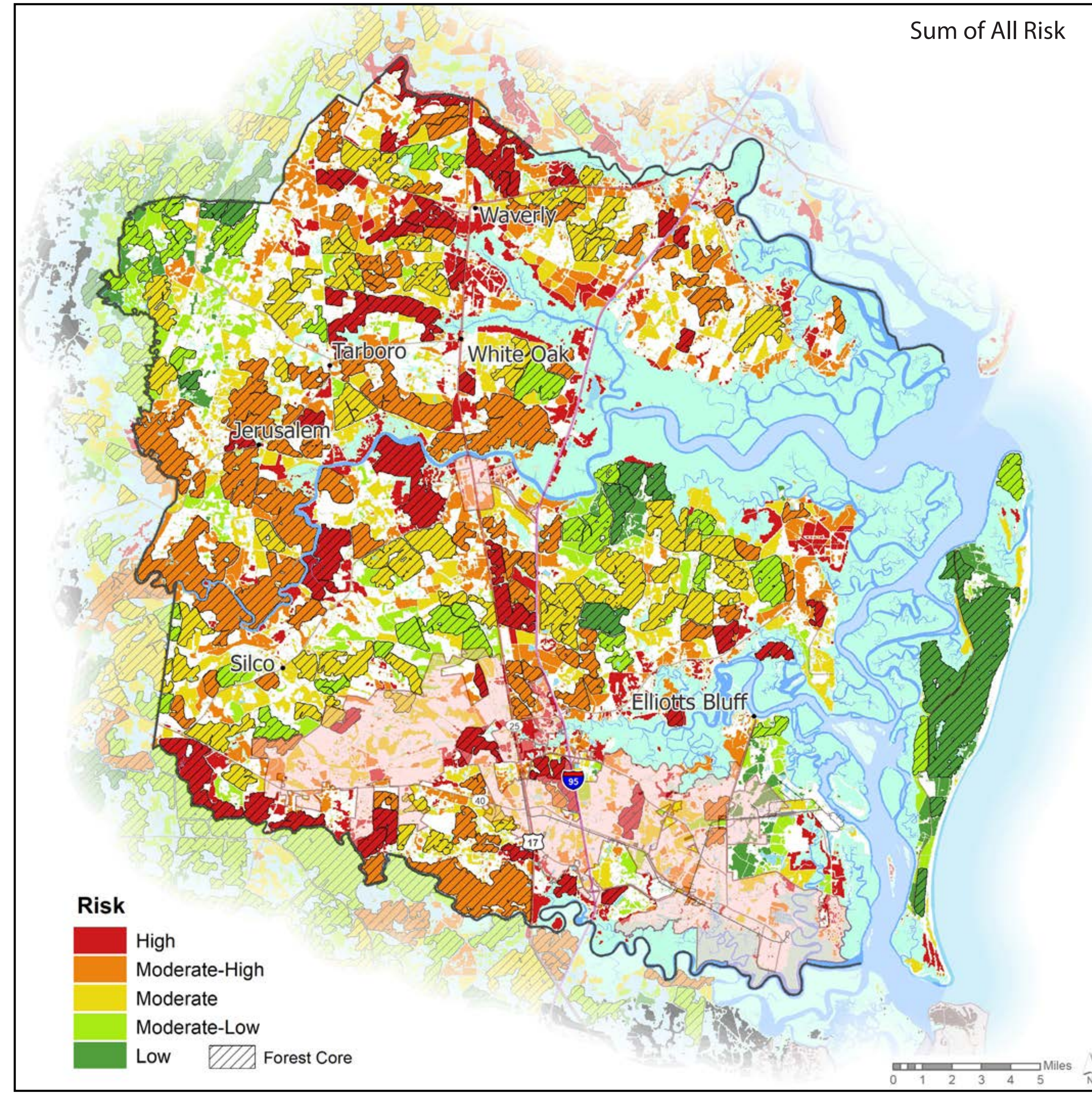
While the percentage of Virginia and South Carolina's coastal forests under high risk of threats is relatively low, it is still a significant percentage of coastal forests. For Georgia, almost a fifth of all coastal forests are at high risk of loss from severe threats, namely sea level rise and development. And for all three study areas, the majority of coastal forests are under moderate to severe threat from multiple sources (three or more), making them vulnerable to repetitive loss or to suffering cumulative impacts that overwhelm the forest's ability to recover. This highlights the need for more and better management and protection of coastal forest resources as these forests provide numerous benefits to rural and urban economies and ecosystems (see GIC's Benefits Reports for each of the three study areas for more information at: http://gicinc.org/res_coastal_forests.htm).

Virginia
12,008 acres (5%) are at the highest risk from severe threats
127,939 acres (54%) are at moderate to high risk of three or more threats

South Carolina
9,872 acres (3%) are at the highest risk of from severe threats
178,424 acres (55%) are at moderate to high risk of three or more threats

Georgia
37,312 acres (20%) are at the highest risk of from severe threats
154,062 acres (81%) are at moderate to high risk of three or more threats

Results



A map of the Georgia study area showing the total risk to forest cores and woodlands from the sum of all threats,

Field Investigations

In addition to developing GIS models of threats, GIC staff conducted field visits to the region to photo document current impacts of threats on the forest and to ground truth the model for accuracy. These field visits often included local experts and forestry staff giving guided tours of coastal forests, identifying issues they face, current research in the field and management strategies being used in real-time.

Land Manager Inteviews

GIC staff spoke with forestry staff, scientists, experts and resource managers about the on-the-ground conditions and challenges facing coastal forests. The focus was on large protected and managed forest lands from a variety of stakeholders including, national forests, national parks, military, utilities and research institutions. Many of these guided tours and interviews can be found as case studies in each state's report here http://www.gicinc.org/res_coastal_forests.htm. GIC staff also used these interviews to inform the recommendations and strategies to address threats.

Numerous experts in coastal ecology, forests and the landscape shared their knowledge on the challenges and issues facing coastal forests along with ideas and solutions on how to make them more resilient.

Stakeholder Engagement and Lessons Learned

State Stakeholder Committee

The resilient coastal forests project showed that ensuring healthy coastal forests for the future depends on looking at the multiple and interacting threats our forests are facing. Understanding how one problem (e.g. invasive species such as phragmites or cogon grass) creates are more severe problem for another issue (fire increasing due to more understory fuels and the ladder effect created by tall understory vegetation which allows fires to reach the upper canopy) is important to ensure healthy forests of the future. Another example of an interacting threat is residential development that moves into more wildland areas thereby making it more difficult to conduct forest management activities such as prescribed burns due to residents' complaints or fears. Agencies charged with managing landscapes need to engage with multiple departments more often (e.g. fire division meeting more often with the agency's invasive species and forest health staff) and also with stakeholders on the ground, such as local governments that are making plans for where to develop.

Local Stakeholder Committee

At the local scale, more coordination is happening already. And local groups such as government, land managers of national forests or wildlife areas, local area foresters, extension agents and land trusts already know one another and already work together. However, some of the traditional planning efforts, such as comprehensive plans or transportation plans, also could involve more coordination for conservation. For example, emergency management plans for counties rarely mention trees and yet they are the number one need when it comes to debris removal. Reducing risk with tree risk assessments, pre-contracting for debris cleanup and replanting plans are just one example of how trees should be included in emergency plans.

Another need for collaboration is across boundaries. Forests cross town and county boundaries and yet most planning ends at the jurisdictional boundary. Having a regional map of forest cores, woodlands and corridors can be used to identify boundary issues so that a forest core on one side of the jurisdictional line is not slated for development on the other side. Each state has regional planning entities (Councils of Government or Planning District Commissions) and they can play a role in reinforcing the need to plan across boundaries.

Local and state stakeholder committees provided expertise and feedback on the threat models and developed strategies to help forests mitigate or adapt.

Stakeholder Engagement and Lessons Learned

The Public

Most planners know that there are many "publics" of both interest and of place. Public engagement for this project was severely hampered by two years of the Covid-19 Pandemic that still goes on as of this report's publication (although many governments have now returned to work and vaccines have removed some fears for meetings). Most of the public engagement for this project had to be curtailed for the past two years, but local stakeholders will continue to use this information in their education and outreach.

GIC staff presented this project at conferences such as an agency conference for Georgia's Coast, at planners' workshops and through on-line meetings. In all of the areas studied, growth pressures will continue to foster new people continually moving into the areas; people who are often unfamiliar with the need for prescribed burns, the importance of locally rare species and their needs, how to landscape around the home to become Firewise and prevent catastrophic fires, or the need to continually replant urban areas to recover trees lost to storms or growth. Those communities who have active extension agents should be sure to provide education about how to care for trees, forest management, connectivity and the importance of avoiding forest fragmentation in all of their landowner education sessions.

Despite the severe consequences that large coastal storms have for forests, very few communities have included forests as part of their emergency plans. The public is largely unaware of the importance of tree risk assessment as a way to prepare for storms (rather than after the storm when that sickly tree has already fallen onto the roof or across the road). Some people are still not accepting the notion that climate change is driving sea level rise, and in many cases, more severe storms. For those communities, framing the problem as recurrent inundation may be a way to get attention to those areas that cannot survive due to salt impacts or extended anerobic conditions to roots subjected to standing water.

Public engagment is critical to the long-term success of managing coastal forest resources.

Prioritization of Forest Cores

As mentioned above, a fundamental part of evaluating the benefits, quality of forests and associated risks was to inform planning and decision-making for coastal forest assets. To better facilitate this process, the forest cores were evaluated under multiple scenarios using the data to identify highly valued forest cores at risk of specific threats. This allows planners, decision-makers and the community to be more strategic in protecting the most valuable and most at-risk forests and to apply the appropriate intervention, adaptation or management strategy.

Methodology

A simple query of the data using the ranks and risks was performed to identify specific forest cores on the landscape to aid in strategy development for local stakeholders.

A_Score5_HI is the forest core Score modified by the Human-Interest Value (see earlier in the report under forest core ranking for more information). This identified the highest ranked forest cores both in ecological and human value.

The second part of the query was focused on the various threats where "and B_XXXX" is the risk score.

Example queries used during the project are:
Development Priority
if [A_Score5_HI]>=4 and [B_Dev]>=2 then

Solar Priority
if [A_Score5_HI]>=4 and [B_Solar]>=2 then

Storm Surge
if [A_Score5_HI]>=4 and [B_StormSurge] >=3 then

Fire
if [B_Fire] >=3 and [B_Dev] >=2 then

Ghost Forest Fire
if [B_Fire] >=3 and [B_StormSurge] >=3 then

Hard to Restore
if [B_Fire] >=3 and [B_StormSurge] >=3 and [B_InvPest] >=2 then

Connection Gaps
if [B_Connectedness]<=2 and [B_Dev] >=2 and [B_Solar] >= 2 then

Top Monitoring
if [A_Score5_HI] >=4 and [B_InvPest] >=2 then

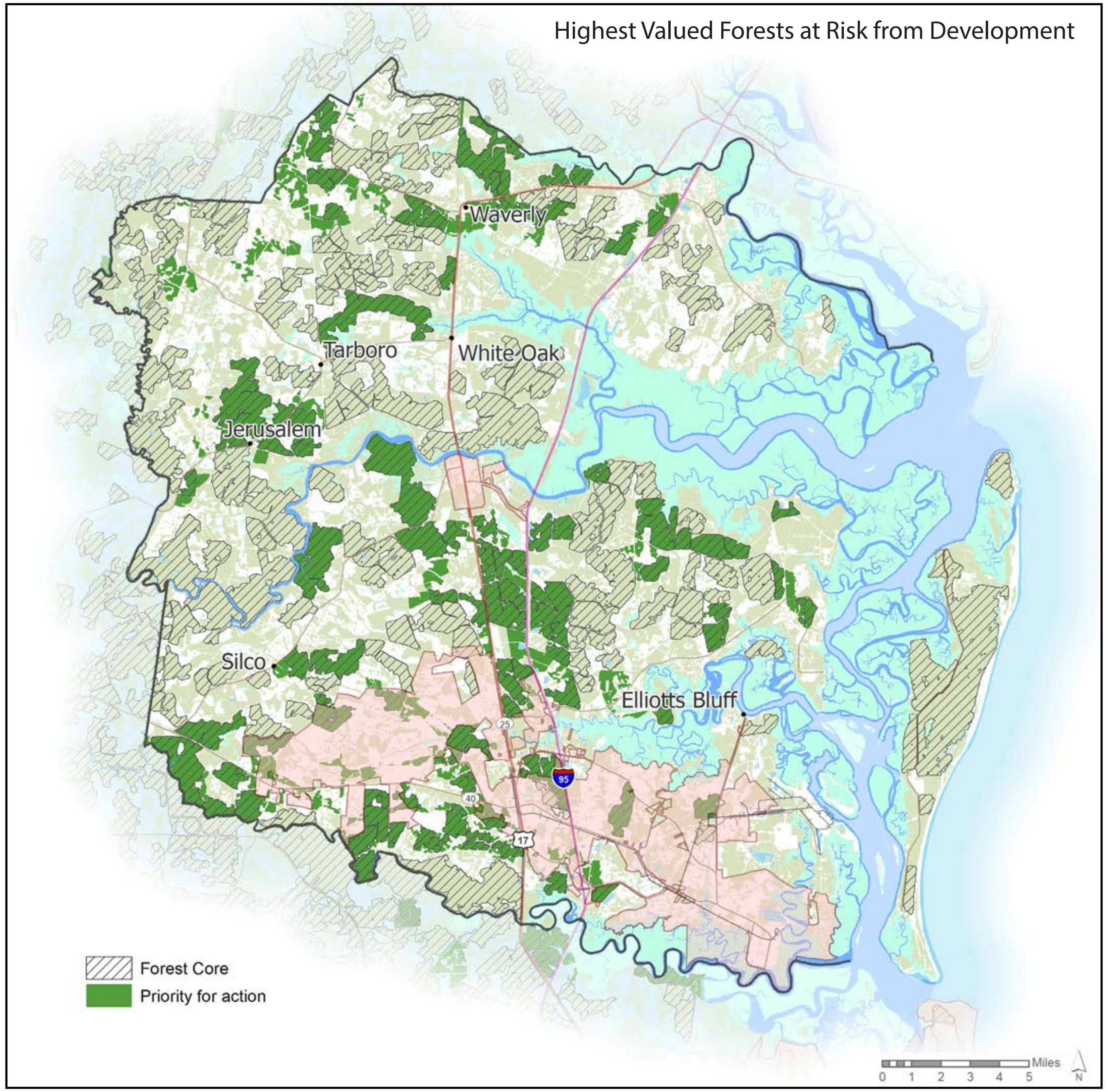
Flood Preventiion
if [B_StormSurge]>=2 SLR = 1 [B_Dev] >=2 then

Impacts of SLR
if [A_SLR] =1 and [B_Connectedness] <=1 then

Total Risk Priorty
if [A_Score5_HI]>=4 and [B_RiskRank] >=3 then

Prioritization of Forest Cores

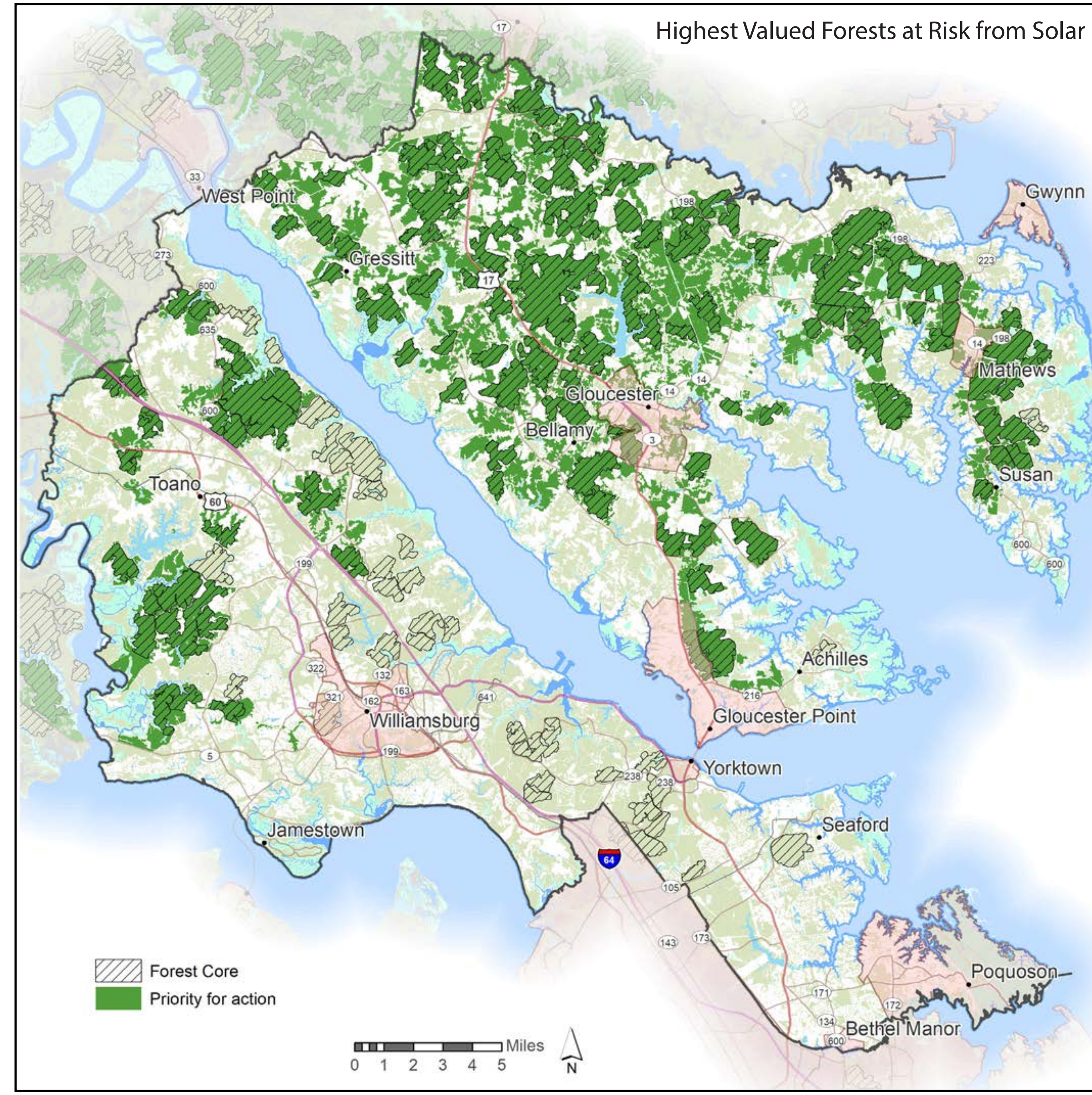
Development Priority
if [A_Score5_HI]>=4 and [B_Dev]>=2 then



The highest ranked coastal forest cores and woodlands that are at the highest risk of development in the Georgia study area.

Prioritization of Forest Cores

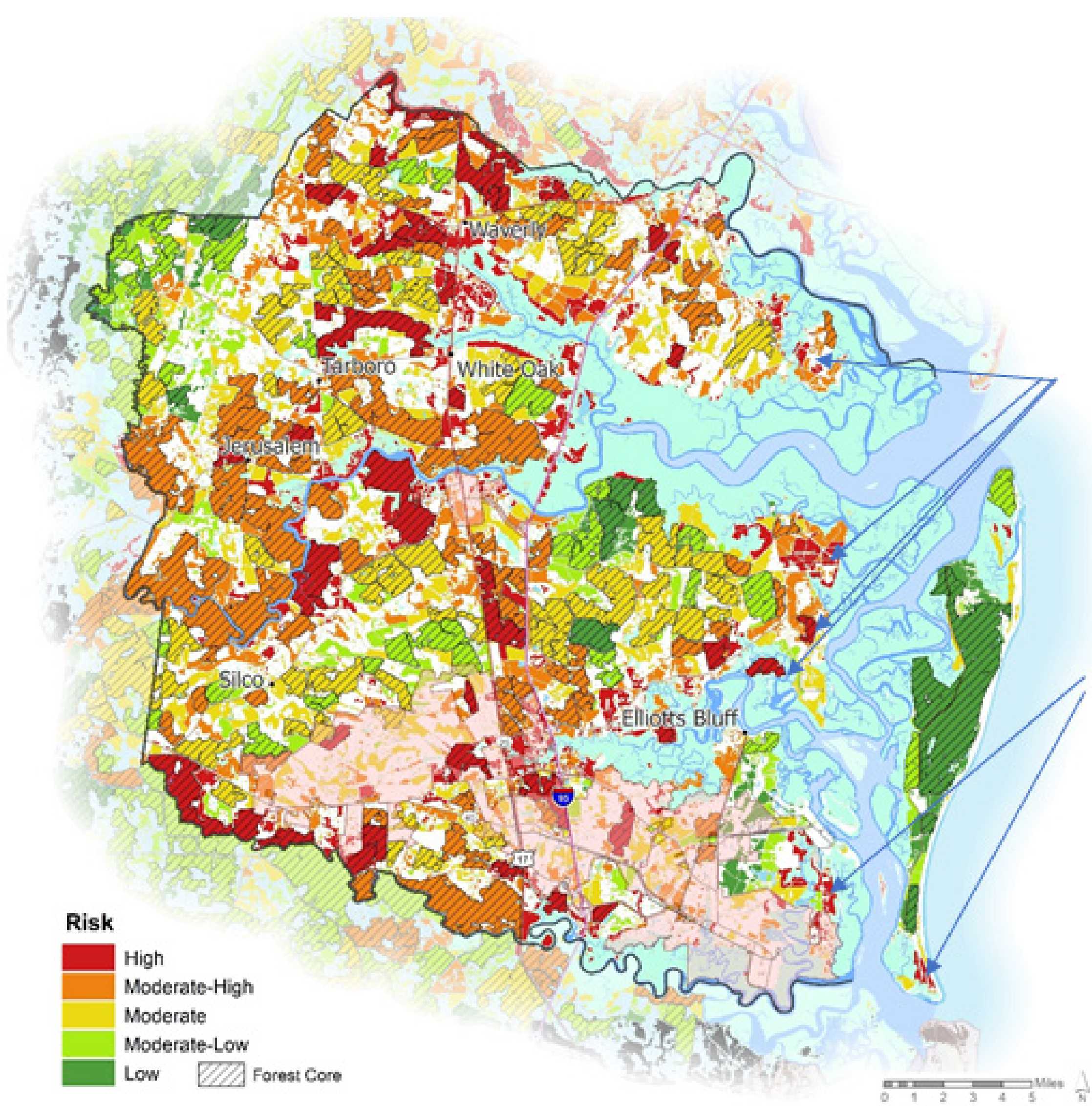
Solar Priority
if [A_Score5_HI]>=4 and [B_Solar]>=2 then



The highest ranked coastal forest cores and woodlands that are at the highest risk of utility-scale solar development in the Virginia study area.

Coastal Forest Planning Scenarios

Once maps are created for both where forests cores and woodlands are located and risk maps applied to show which cores are at risk, there are many actions that can be taken to protect or expand those forests. Overlaying the various risks to obtain a cumulative risk map will show areas that may be at greatest danger for severe or permanent forest losses. Below are some examples for how data on forest importance and risks can be used to inform action plans. For forests that will be lost to sea level rise, this loss is permanent. However, these losses could mean that forests in upland areas are thus more important to protect such as by purchasing these areas if parkland needs replacing when lowland forested parks are lost. See the chart following for examples of actions to take based on outcomes from mapping high value cores and the risks to those maps. Also see the resources section for more GIC guides for how to conserve or restore urban forests.



These cores or woodlands in red on the coast will be lost. This will make upland cores more important to conserve. For ideas see the enclosed chart.

Examples of how communities can use resilient forest data

Planning Type	Purpose	Action to take
Planting and long-term harvest plans	Use existing forests and overlay risks to determine where harvest may be difficult due to inundation.	Avoid planting areas for harvest where they will not be successful. Identify other upland sites where forestry will be viable long term and work with landowners to plan for those areas.
Forest management	Use existing forests and development maps to see where forests will be harder to manage in the future.	Work with local governments to show them potential conflicts. Suggest conservation or rural area zoning, expansion of AgForestal Districts, and limiting lot divisions to 20 acres or greater. For areas without zoning (lands really should be zoned) consider limiting provision of services such as water and sewer to disincentivize growth in those areas that are important for forestry.
Resiliency plans	Add strategies for forest conservation to resiliency plans.	Forests buffer areas from storms and soak up stormwater. While many resiliency plans only deal with flooding they should include forest cores and woodlands conservation in plans since trees soak up floodwaters.
Growth plans	Avoid targeting growth to areas with high value forest cores that should not be developed.	When planning for development zones or areas for expansion, try to avoid choosing areas with high value forest cores. If the area is still needed for growth consider using GIC's Conservation Design guide.
Urban forests	Protect tree cover in cities and towns for health, shade, beauty and thriving neighborhoods.	Protect clusters of trees (small woodlands) as much as possible. Include them as open space, require tree retention on site, adopt codes to limit tree loss (see Planners Forest Toolkit).
Stormwater management	Trees soak up stormwater and forests act as a sponge to recharge aquifers.	Add trees to stormwater management strategies. Protect forests upland of cities and towns. Adopt a buffer ordinance to protect trees along creeks and bays to reduce erosion and buffer from storms.
Storm planning and emergency plans	Trees buffer against storms but also need plans to deal with storm damage.	Review emergency plans and add tree risk reduction, tree removals and cleanup and replanting to emergency plans. See GIC publications for more.

Planning Type	Purpose	Action to take
Park plans	Parks may be lost to climate change and repetitive flooding.	Identify upland forested areas or replant uplands and acquire them to ensure that forested parklands will be available.
Wildlife and RTE species conservation	Forests that are refugia or provide habitat for RTE species should be protected.	High value habitat cores can be protected to support wildlife by partnering with land trusts to establish conversation easements. Work with landowners to establish forest management plans that support species regeneration.
Transportation plans	Use resilient forest maps when developing long range (20 yrs.) and short range (6 yrs.) plans.	Use resilient forest maps to inform where future roads are sited to avoid bisecting high value cores. Use new federal funding to provide wildlife bridges and tunnels for forest connectivity and to avoid accidents. Use resiliency maps to inform where state Departments of Transportation could acquire land to restore or conserve as part of required habitat mitigation for roads constructed elsewhere.
Solar utility sites	Use maps to identify areas where utility-scale solar is inappropriate.	Create overlays for counties for where solar is allowed or not allowed. Discourage large scale cleaning of forested sites for solar facilities by 1) limiting the percentage of rural lands that can be developed for solar, 2) adopt policy guidance that discourages clearing more than x% of forests for utility solar, 3) adopt stormwater management rules for sites, 4) require mitigation for trees removed for solar sites.

Opportunities for Other Coastal Communities

The methods to map forest landcover are described in the earlier sections of this guide. For more advanced mapping instructions, GIC has authored a book *Green Infrastructure, Map and Plan the World With GIS* available through Esri Press. It includes more information on applications for how to utilize habitat core data for planning. The habitat cores mapped for that book will be updated by Esri in summer 2022 and that data can be downloaded for free to map larger habitat cores for any state. For South Carolina, GIC has updated the state habitat cores model and that dataset is available directly from GIC. For other states along the Atlantic Coast, the Esri data for habitat cores should be available.

Smaller woodlands also should be included and mapping those requires use of GIS to convert landcover imagery into maps of forests that are at least ten acres in size. If your community is interested in hiring GIC to do this work for your region, please be in touch. The reports for the three states showing how the data informed the work and can be applied are available here: http://www.gicinc.org/res_coastal_forests.htm

Additional GIC Resources – available for free download

For GIC's Studies of trees for stormwater management see: http://www.gicinc.org/trees_stormwater.htm

GIC Guides:
Planners Forest Toolkit: GIC's guide to all the policies and codes that communities should have in place to ensure a healthy urban forest. Also includes arguments to convince local leaders to take action. Although written for South Carolina it can be applied anywhere in the United States. June 2021. Download Toolkit.
Forest Connectivity Design Guide: Get GIC's design guide for conserving forests and other habitats, even when developing! The guide, Forest Connectivity in the Developing Landscape: A Design Guide for Conservation Developments was written for the Carolinas, but design ideas can be applied anywhere! The guide includes case studies for two GIC-designed sites. Sept. 2019 Contact GIC for print copies or download here.

The Community Forest Storm Mitigation Planning Workbook. This guide can help your community prepare for storm damages, develop strategies to manage debris and recover faster from disasters that impact the urban forest. Based on existing state guides, this national version includes the latest FEMA guidance and is designed as a workbook for community use. 2021. Download here.

Example of Urban Tree Assessment, GIC conducts many city assessments for clients. This is an example for Boynton Beach FL: GIC's Tree Canopy Assessment for Boynton Beach, Florida, together with a strategy plan and recommendations for action. Download here.

Tree Planning and Planting Campaigns: A guide for reforesting cities and towns. GIC's comprehensive guide to how to energize communities to take on planting campaigns and to use sound data to inform decisions affecting urban forests. Available at www.gicinc.org