



# 2016 Tree Canopy Cover for the National Land Cover Database: Production Data, Methods, Uses, and a Tour Through American Landscapes

Stacie Bender<sup>1</sup> (staciebender@fs.fed.us), Wendy Goetz<sup>2</sup>, Mark Finco<sup>2</sup>, Bonnie Ruefenacht<sup>2</sup>, Vicky Johnson<sup>2</sup>, Josh Reynolds<sup>2</sup>, Jan Johnson<sup>2</sup>, Greg Liknes<sup>3</sup>, Zhiqiang Yang<sup>4</sup>, and Kevin Megown<sup>1</sup>



<sup>1</sup>US Forest Service/Geospatial Technology and Applications Center (GTAC), Salt Lake City, UT, <sup>2</sup>RedCastle Resources, Inc., Salt Lake City, UT,

<sup>3</sup>US Forest Service Forest Inventory and Analysis Northern Research Station, Saint Paul, MN, <sup>4</sup>College of Forestry, Oregon State University, Corvallis, OR



## Abstract

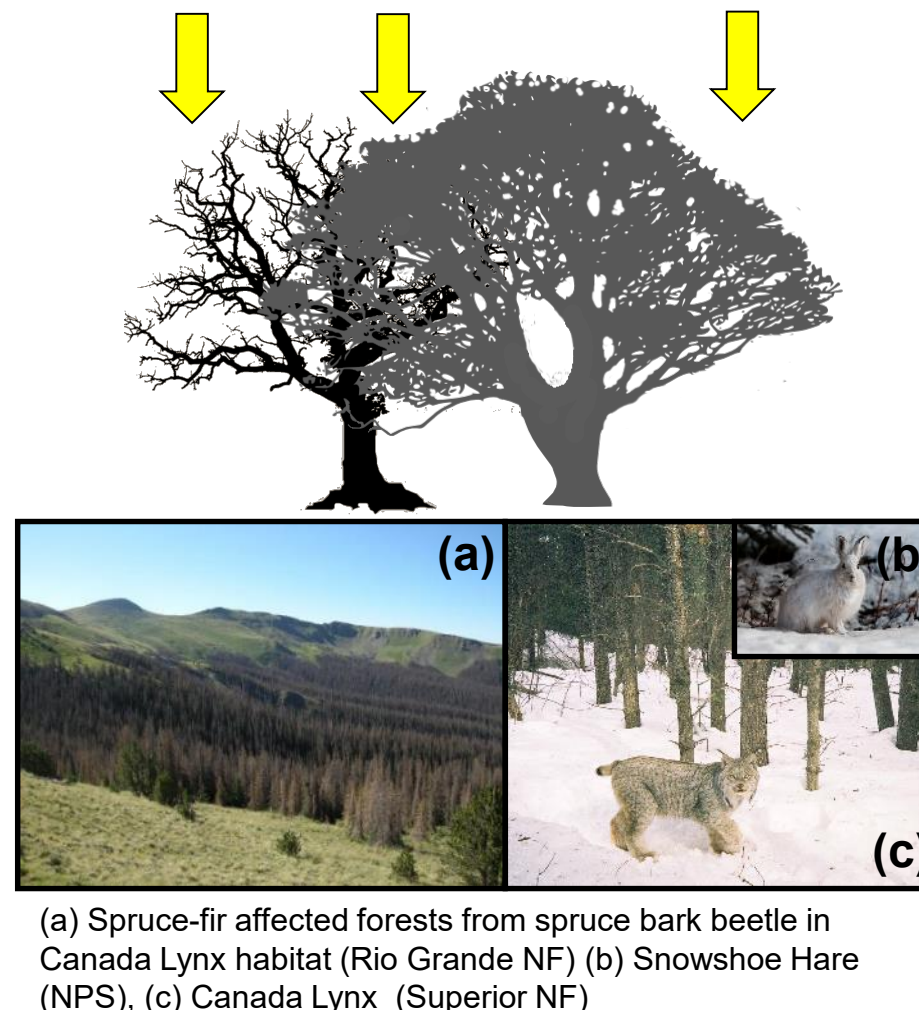
As a member of the Multi-Resolution Land Characteristics Consortium (MRLC), the U.S. Forest Service (USFS) is responsible for producing and maintaining the tree canopy cover (TCC) component of the National Land Cover Database (NLCD). Currently, NLCD components are updated every 5 years, and production of the 2016 NLCD-TCC is well underway at the USFS Geospatial Technology and Applications Center (GTAC). NLCD-TCC data for 2016 are being produced at 30 meter resolution for the conterminous United States (CONUS), coastal Alaska, Hawaii, Puerto Rico, and the U.S. Virgin Islands. Here, we describe the input datasets, data processing, tools, and modeling methods utilized in the production of 2016 NLCD-TCC dataset for MRLC. Development of the NLCD-TCC layers utilizes over 63,000 photo-interpreted training plots and multiple nationwide raster predictor layers. Customized python scripts interface with ERDAS Imagine, ArcGIS, and R to automate the data processing and modeling tasks. We also provide specific examples of the diversity of patterns that are present in the NLCD-TCC dataset across multiple types of tree-covered American landscapes. Heterogeneous and varied landscapes in the United States present interesting and unique challenges with respect to data acquisition, modeling, and mapping. Such landscapes include large forests, plantation forests, woody wetlands, arid forests, urban areas, agricultural lands, orchards, and more. In addition, the NLCD-TCC data for 2011 and 2016 provide an opportunity to examine changes on the landscape, ranging from partial removal of trees through silvicultural thinning to stand-clearing wildfires.

## Why map tree canopy cover?

*Tree canopy cover* is defined as the percent of the ground covered by a vertical projection of tree canopy.

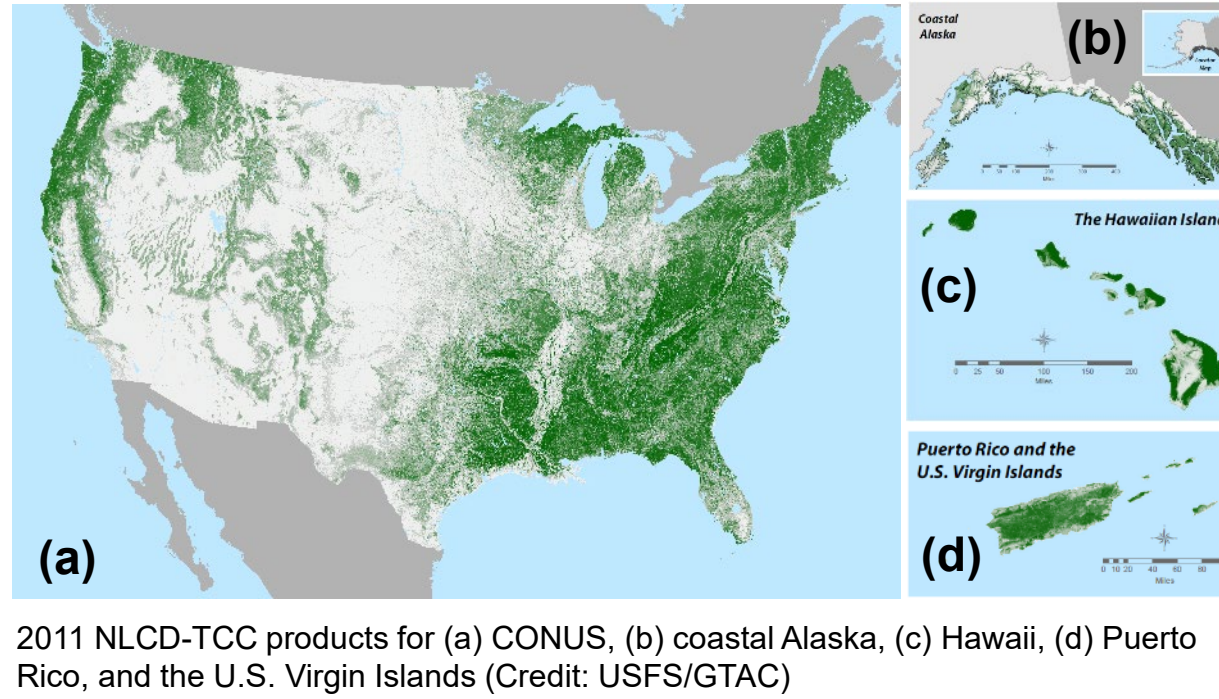
Tree canopy cover data are used for multiple purposes:

- Assessment of the status, changes, and trends in tree landscapes, including forested lands and treed lands not traditionally considered as forest
- Assessment and monitoring of biomass and carbon stocks
- Fire behavior modeling
- Analysis of understory plants
- Wildlife and habitat studies
- Evaluation of land management plans



## NLCD-TCC Products Built by the Forest Service

The NLCD-TCC products are seamless, national 30-m tree canopy cover datasets appropriate for applications with medium to large spatial scales. They are available for the CONUS, coastal Alaska, Hawaii, Puerto Rico, and the U.S. Virgin Islands and updated on a five-year cycle (current version = 2011). The next version (2016) is in production at GTAC and will be released publicly in late 2018.

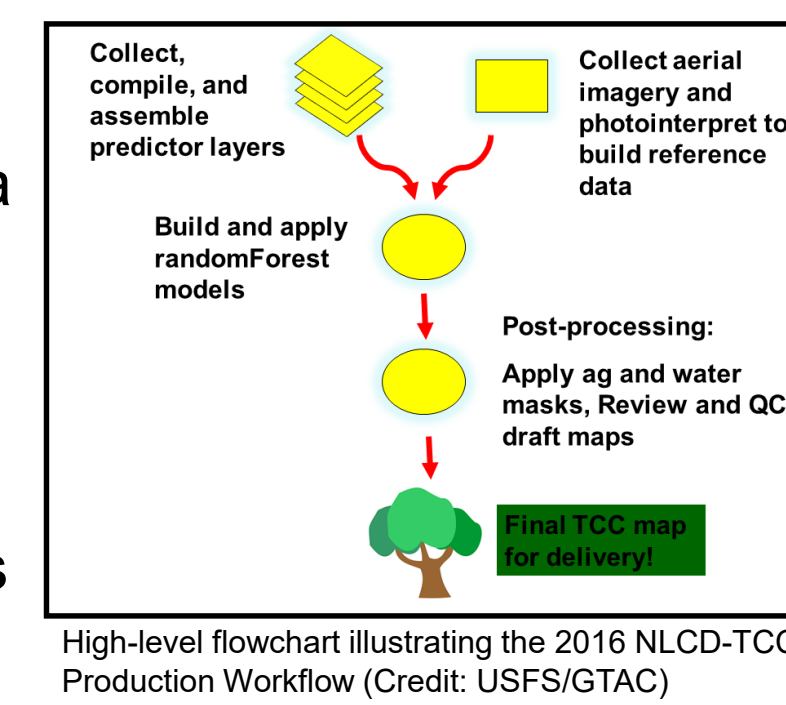


Overview of NLCD-TCC Products			
NLCD-TCC Product	Product Description	Application Type	Product Access
Analytical	Layer 1: percent tree canopy cover • each pixel value = proportion of 30-m cell covered by tree canopy (0-100%) • No masking of obvious non-tree areas  Layer 2: standard error layer • each pixel value = model standard error in the 30-m cell (0-45%) • higher value = greater uncertainty in model estimate of tree canopy value	More analytically vigorous, including apps that require uncertainty information	<b>2011:</b> <a href="http://www.mrlc.gov">www.mrlc.gov</a> <b>2016:</b> from USFS, as a (R&D) dataset ( <i>in produc.; available in late 2018</i> )
Cartographic	Layer 1: percent tree canopy cover • each pixel value = proportion of 30-m cell covered by tree canopy (0-100%) • filtered and masked to eliminate obvious non-tree areas, creating a more cartographically useful product	Standard applications needing best representation of tree canopy	<b>2011:</b> <a href="http://www.mrlc.gov">www.mrlc.gov</a> <b>2016:</b> <a href="http://www.mrlc.gov">www.mrlc.gov</a> ( <i>in produc.; available in late 2018</i> )
Change (2011 to 2016)	Layer 1: estimated change in tree canopy cover between 2011 and 2016	Various	<b>2016:</b> <a href="http://www.mrlc.gov">www.mrlc.gov</a> ( <i>in produc.; available in late 2018</i> )

## 2016 NLCD-TCC Production Workflow

The NLCD-TCC products are built in five steps:

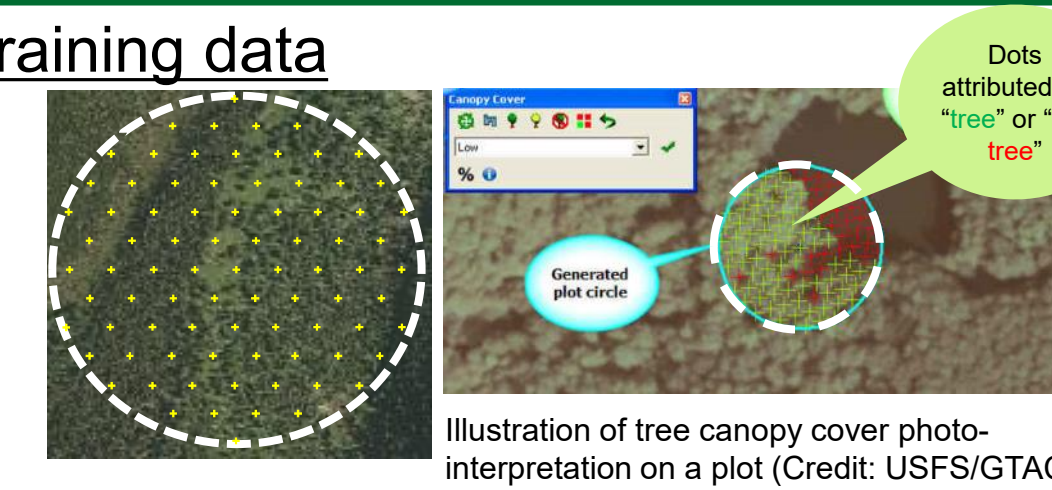
1. Collection of aerial imagery + photointerpretation of reference data
2. Predictor data collection, compilation and assembly
3. Modeling with randomForest
4. Post-processing (model output/draft map review, quality-control, and mask application)
5. Assembly of final maps for delivery to customers and stakeholders (MRLC and beyond!)



## Input Data Collection and Preparation

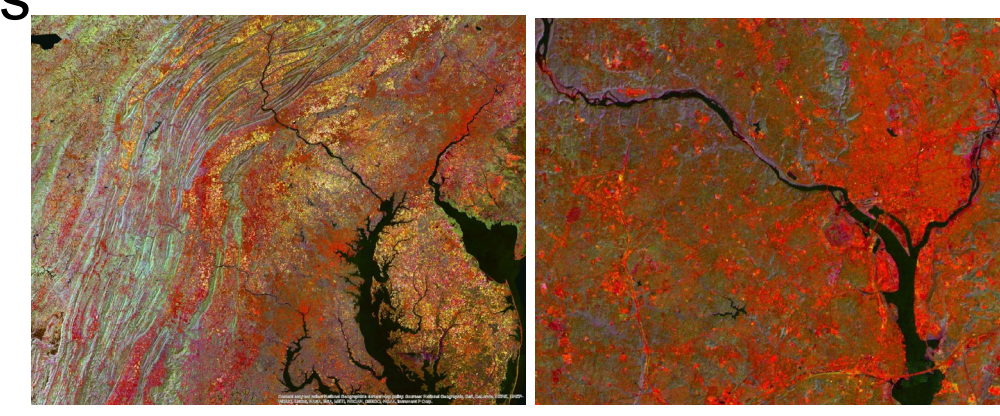
Photo-interpretation (PI) of NAIP imagery to build reference/training data

- >62,000 FIA plot locations PI'd (109 dots per site) for 2011
- Data from most sites used again in 2016, as-is from 2011
- PI data updated to target obviously changed areas, such as burn areas



Raster-based predictor data collection, compilation and assembly

- **Landsat-based data (bands, indices, derivatives):**
  - Median composites of bands
  - Tasseled Cap, NDVI, NDMI
  - Exponentially Weighted Moving Average Change Detection (EWMACD)
  - Harmonic regression data/seasonal info

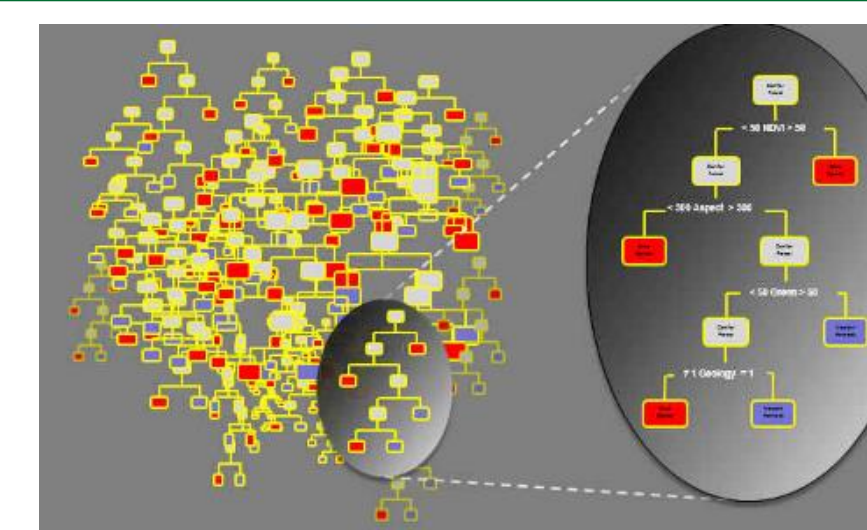


- **Topographic data (elevation, slope, aspect)**



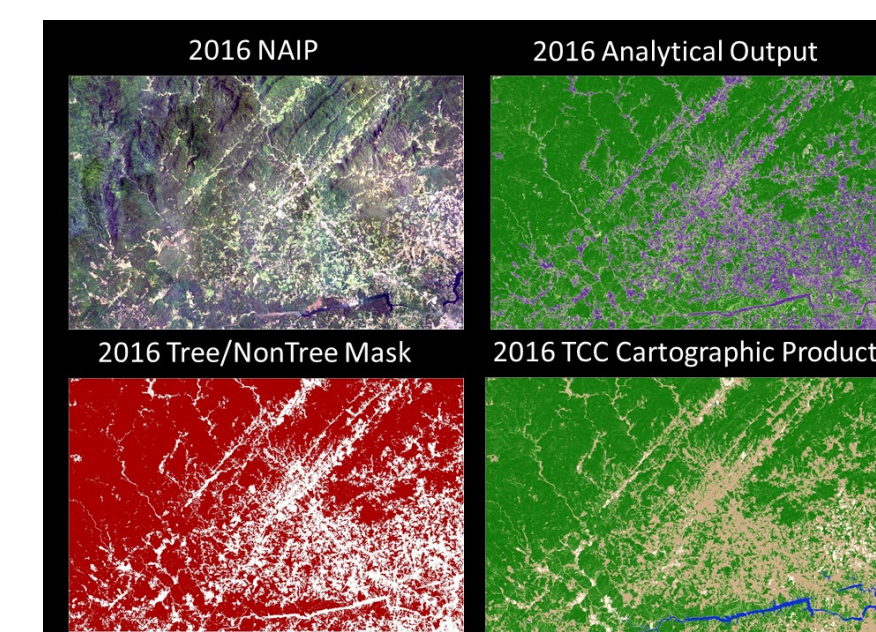
## Modeling with randomForest

- TCC relationships and models generated for MRLC mapping zones
- Model Outputs = TCC estimates + standard error for each pixel
- nTrees = 500 trees (i.e., for every pixel, 500 TCC predictions were made, with model estimate of TCC at a pixel = mean of the predicted TCC values)



## Post-Processing

1. Model outputs reviewed for abnormalities.
2. three types of masks are applied: water, tree/non-tree, agriculture (tree farms and orchards are kept in NLCD-TCC)
3. tree canopy cover threshold applied pixel-by-pixel (e.g., pixel's TCC value = 11% & standard error = 30% → pixel TCC recoded to 0%)



Application of a Tree/NonTree mask in North Carolina (Credit: USFS/GTAC)

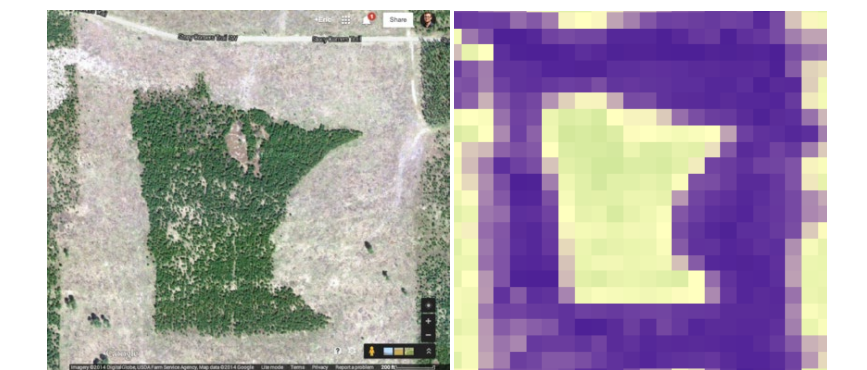
After post-processing is complete, the final NLCD-TCC maps are delivered to MRLC and made available to the public.

## Example Landscapes in Preliminary Version of 2016 NLCD-TCC

At the Forest Service's GTAC, the post-processing step of the NLCD-TCC Production Workflow is well underway. Geospatial and remote sensing analysts are actively reviewing draft maps of 2016 tree canopy cover conditions across the United States. From the post-processing and review activities, several interesting landscapes have been identified.

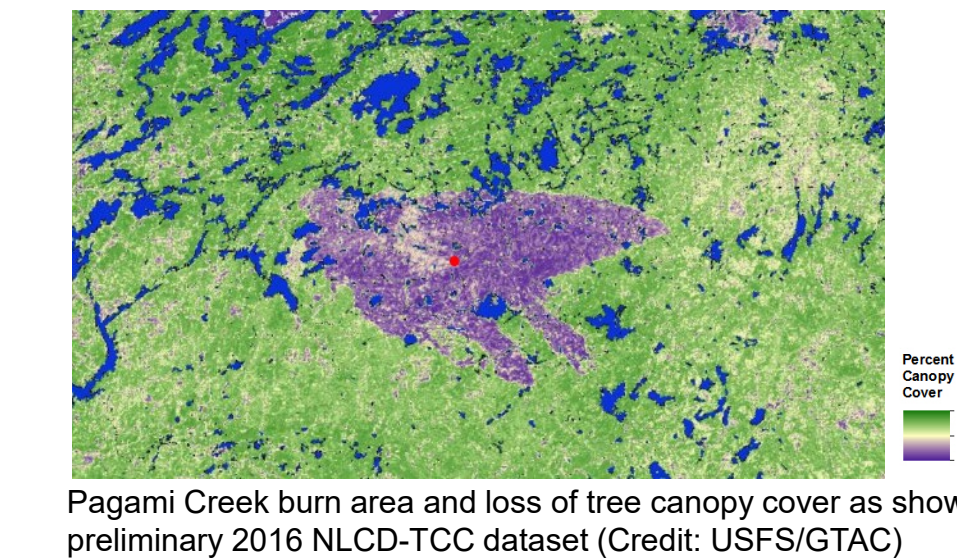
### "Minnesota Forest"

- First shaped in the early 1990s with a compass and analog tools!



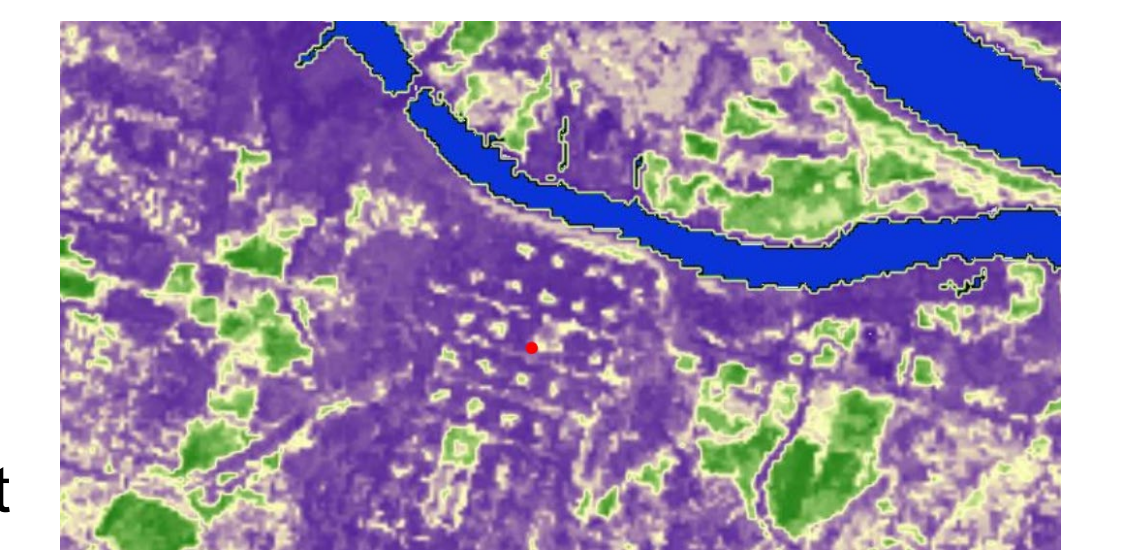
### Pagami Creek Fire, Minnesota

- 3<sup>rd</sup> largest fire in recorded Minnesota history
- began with a lightning strike in August 2011
- Spread to > 92,000 acres during hot, dry, windy weather to areas beyond the Boundary Waters Canoe Area Wilderness



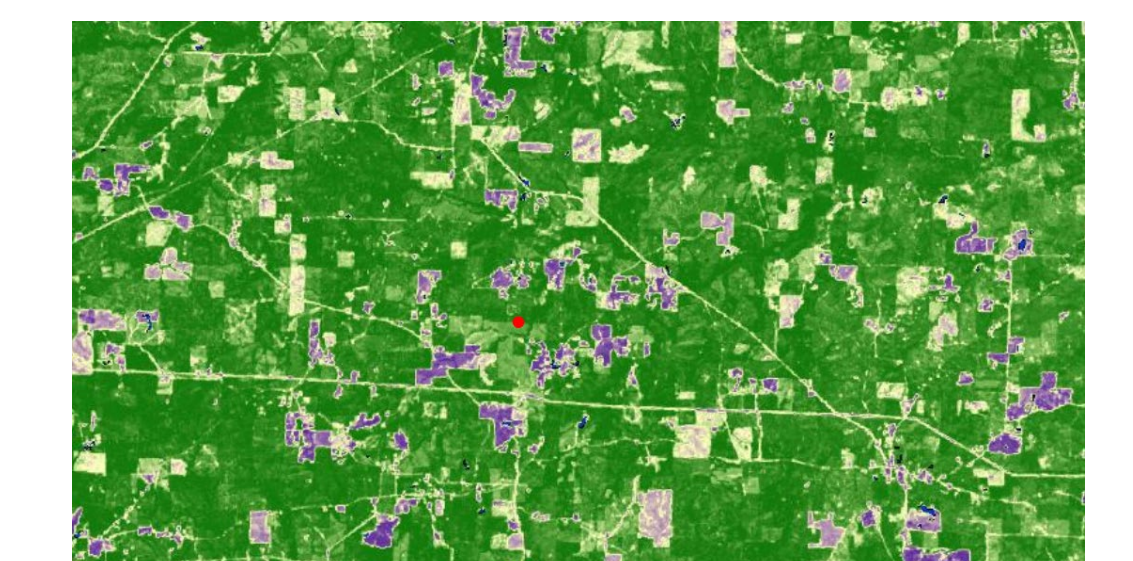
### Historic City Squares in Savannah, GA

- 24 small urban green spaces and parks established in the 1700s and 1800s; 22 still exist today as urban parks and green spaces
- urban tree landscapes found in NLCD-TCC but not found on traditional forest maps.



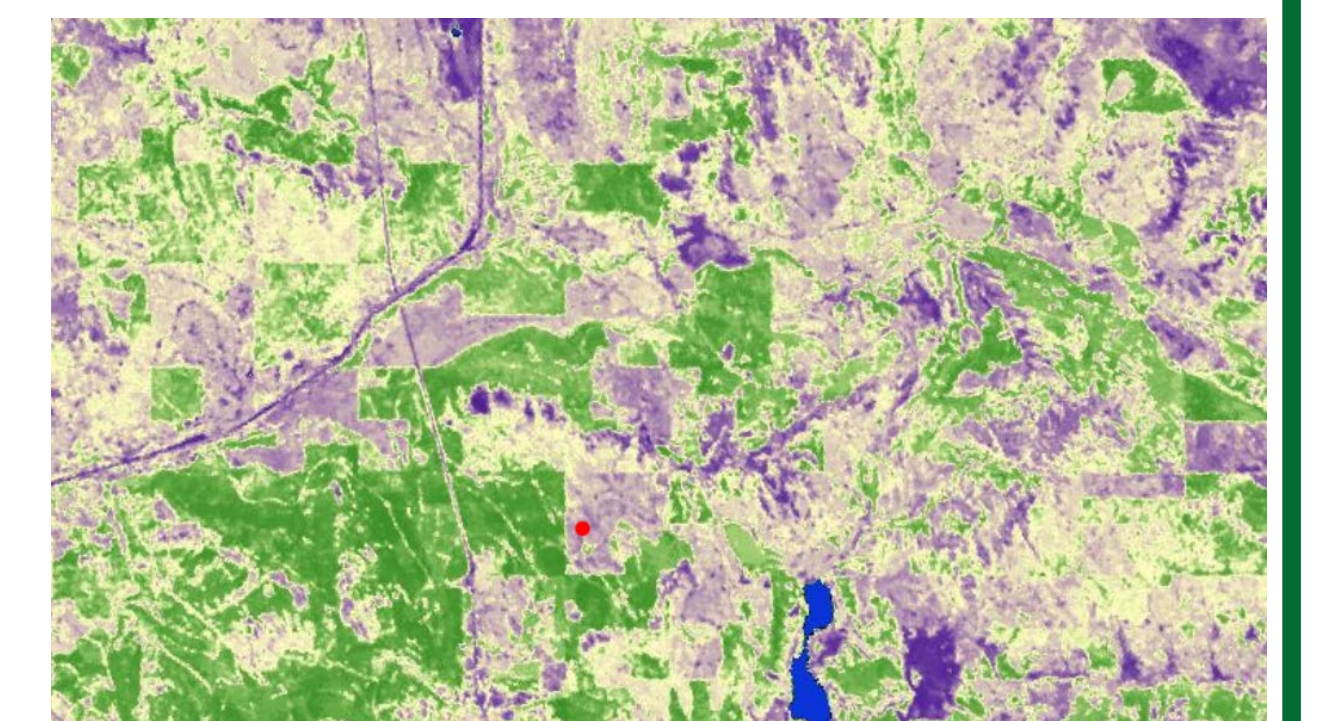
### Private Timber Harvest in Arkansas

- part of the "wood basket" of the United States (logs, furniture, pulp, paper, and more)
- Southern forests = 63 percent of the total timber harvest, by volume, in 2011 (Oswalt et al 2014)
- 2016 value of standing timber = \$12.6B



### Checkerboard Land Ownership in Montana

- lands divided into checkerboards in mid 1800s; federal government granted expanding railroads every other square
- many squares sold to private landowners - land use now varies among timber management, agriculture, and developed
- USFS works with nonprofits and others to purchase privately-owned "squares", reducing fragmentation on the landscape



## Photo Credits

USFS (2016). Fire severity and ecosystem impacts immediately following an extreme fire event in northern Minnesota. [https://www.nrs.fs.fed.us/disturbance/fire/extreme\\_fire\\_effects\\_mn/](https://www.nrs.fs.fed.us/disturbance/fire/extreme_fire_effects_mn/)  
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National Park Service (2017). Snowshoe Hare. <https://www.nps.gov/articles/snowshoe-hare.htm>  
USFS Superior National Forest (2010). Canada Lynx Survey and Monitoring <https://www.fs.usda.gov/detail/superior/landmanagement/resourcemanagement/?cid=stelprdb5209910>