**Background**

Spatially-explicit tree species distribution maps are increasingly valuable to forest managers and researchers, particularly in light of the effects of climate change and invasive pests on forest resources. Advanced remote sensing techniques, such as spectral unmixing and object-based image analysis (OBIA), utilize spectral and ancillary environmental data to provide information on proportional species composition and enable more precise forest cover mapping. This is especially useful in Northeastern landscapes where species composition is highly mixed. Here, we:

1. **Develop a novel method for classifying tree species genera across a heterogeneous landscape that integrates spectral unmixing and OBIA methods using multitemporal Landsat imagery and ancillary environmental data.**
2. **Compare the accuracy of our approach to large-scale forest mapping products, including the National Land Cover Database (NLCD), LANDFIRE Existing Vegetation Type (EVT Group), and the National Forest Type Map (USFS NFTM).**

### Pixel-based Spectral Unmixing Workflow

**Dataset—** Landsat bands 4, 3, 2, 1, 5, 7, 8, 6, 9, 11, 12, 13.

- **Input:** Spectral reflectance data from multiple dates.
- **Output:** Spatially refined estimates of fractional cover across species or species groups.

**Workflow:**

1. **Spectral unmixing** using a multi-temporal approach to estimate fractional vegetation cover for each species.
2. **Observe and analyze** the fractional cover estimates for each species over time.
3. **Analyze patterns** in the fractional cover estimates to identify temporal changes in species composition.
4. **Generate maps** of species composition at different temporal resolutions.

### Percent Basal Area Results and OBIA Workflow

**Stepwise Regression**

**Species**
- Basswood (Fir)
- Red Maple
- Sugar Maple
- Birches
- American Beech
- Red Spruce
- Eastern White Pine
- Aspens
- Ols
- Eastern Hemlock

**Mean**
- 0.34
- 0.47
- 0.28
- 0.32
- 0.06
- 0.52
- 0.51
- 0.25
- 0.49
- 0.32

**RMSE**
- 0.11
- 0.06
- 0.16
- 0.08
- 0.07
- 0.06
- 0.07
- 0.04
- 0.06
- 0.11

**F**
- 10
- 9.2
- 11
- 7.8
- 3.4
- 17.7
- 6.5
- 0.0
- 0.0
- 0.0

**Object-based Classification—a decision tree-type analysis to classify imagery via user-defined thresholding of spectral and ancillary data layers.**

**Image Classification Scheme:**

1. **Classification rules:**
   - **Non-forest:**
     - Dark areas, low NDVI, high Tasseled Cap brightness
   - **Forest Objects:**
     - Medium NDVI, low Tasseled Cap brightness
   - **NFTM Classes:**
     - High NDVI, high Tasseled Cap brightness

2. **Classification metrics:**
   - **Overall Accuracy:** 90%
   - **Kappa Coefficient:** 0.85

3. **Classification products:**
   - **Landsat IMAGery:**
     - blue, green, red, near-infrared, shortwave infrared
   - **Topographic Attributes:**
     - elevation, slope, aspect
   - **Additional Data Layers:**
     - soil type, hydrology, climate

4. **Classification challenges:**
   - **Data quality:**
     - limited cloud cover, low signal-to-noise ratio
   - **Classification accuracy:**
     - high false positive and false negative rates

### Conclusions

1. **Our integrated unmixing-OBIA approach to forest cover mapping provides increased accuracy and specificity over existing large-scale forest mapping products.**
2. **Utilization of publicly-available imagery and ancillary data ensures that this approach could be applied across larger regions at minimal cost.**
3. **Provides a forest classification product that can be used in management decisions (e.g. invasive insect host distributions) and modeling studies (e.g. aboveground carbon storage).**
4. **Basal area mapping and classification errors are influenced by the number and quality of “pure” calibration sites for unmixing algorithms; limited availability of cloud and error free imagery from all seasons; and the spectral similarities among competing species.** These issues highlight the importance of field inventories, image selection, and preprocessing in integrated classification schemes.
5. **Current efforts include mapping species composition from the Adirondacks to southern Maine at 5 year intervals to understand how and where species distributions may be shifting across the landscape over the past three decades.** This information can guide management (e.g. invasive insect host distributions) and modeling efforts (e.g. carbon storage) into the future.