Thematic classification of a Landsat (OLI & ETM) image of Savannah, Georgia

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Objectives

Classification of a remotely sensed subset images of a Landsat ETM and OLI+ scene of Georgia (path 17, row 38, and path 16, row 38), acquired on 10/23/99 and 03/03/2025, involving the evaluation of spectral signatures for thematic classes for supervised classification, performing a supervised classification, assessing the classification accuracy, and a change detection evaluation.

Methods

The workflow consists of displaying both images (savetm99.img and savannah.tiff) in a false-color composite for both Landsat ETM and Landsat OLI+ sensors and creating training samples for both images to prepare them for classification. The Landsat ETM (Enhanced Thematic Mapper) sensor has bands 1 to 7. For false-color composites, the usual combination for displaying land cover is Band 4 (Red) for vegetation, water bodies, and built-up areas, Band 3 (Green), which shows vegetation and healthy crops, and Band 2 (Blue), which identifies water bodies, areas with less vegetation. The Landsat OLI+ (Operational Land Imager) sensor has similar bands but with slight differences. A common combination of false-color composites is Band 5 (NIR - Near-Infrared), which is used to highlight healthy vegetation, Band 4 (Red), which focuses on built-up areas and vegetation types, and Band 3 (Green) to highlight urban areas and wetland features.

Results

Figure 1 and 2 reveal spectral profiles for the bands for both 1999 and 2025 images. Reflectance values for urban areas in 2025 are higher across all bands compared to 1999. The increase suggests that more impervious materials like concrete and rooftops contribute to higher reflectance, especially in Bands 5 and 6. In 1999, urban profiles were flatter and more varied.

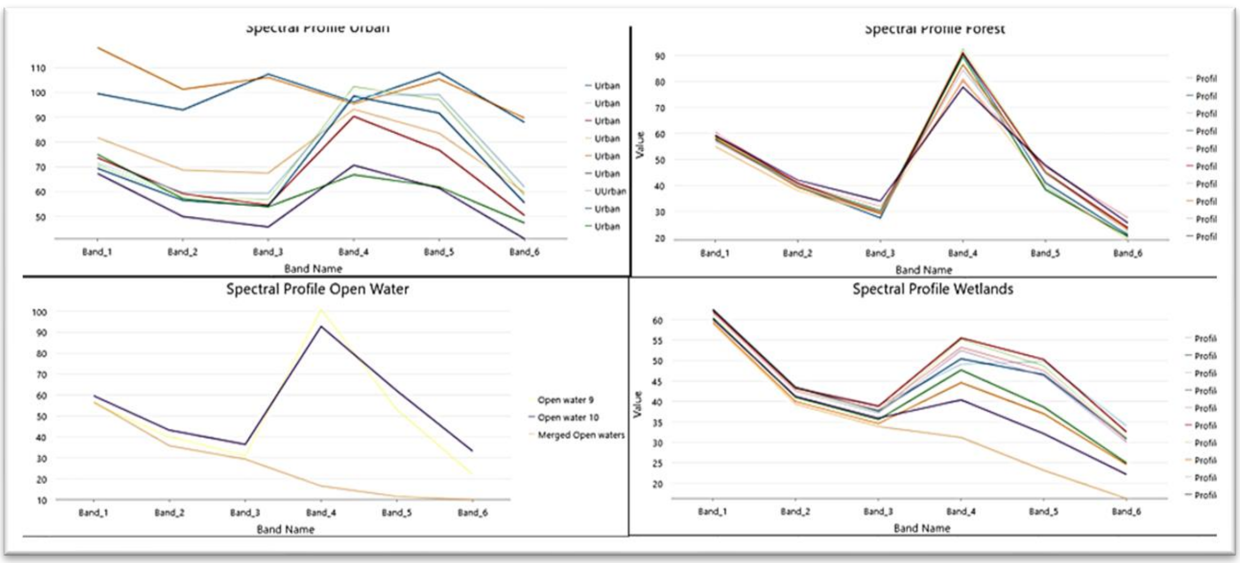

Figure 1. Shows the spectral profiles for the bands of the 1999 Savannah, Georgia imagery.

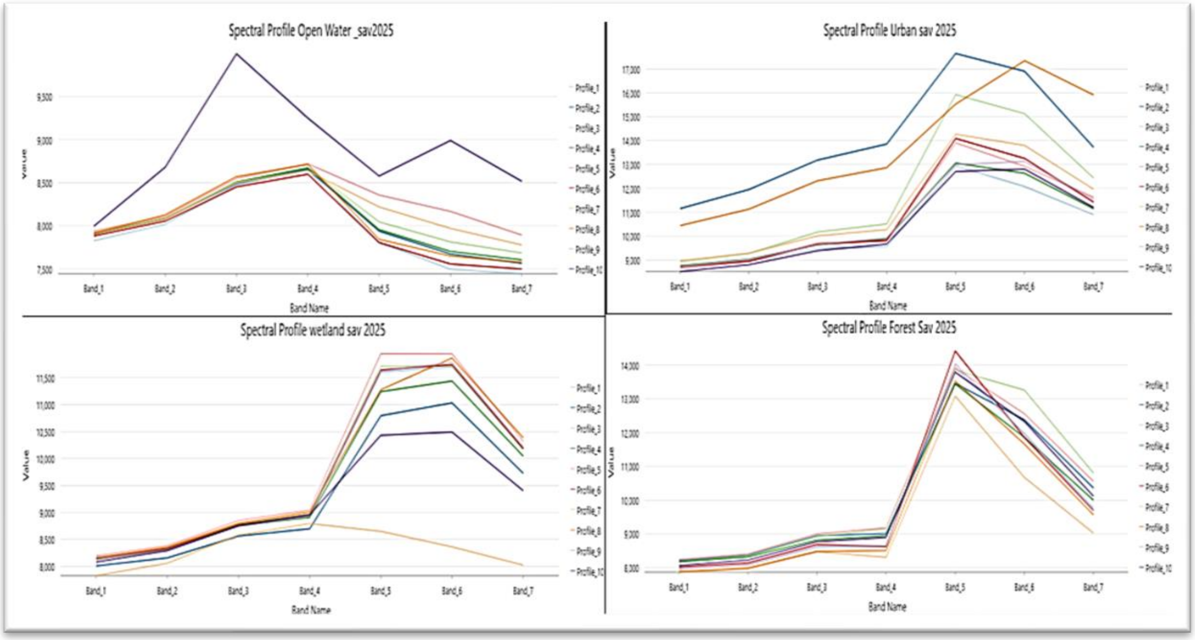

Figure 2. The spectral profiles of the bands of the 2025 Savannah, Georgia imagery.

The forest profiles in both years share a similar peak in Band 4 (NIR), which shows healthy vegetation. However, in 2025, the reflectance in Band 4 is higher, and there is a lot of difference in values across profiles, potentially indicating denser or healthier vegetation. The sharper drop-off in Band 6 and Band 7 in 2025 also suggests signs of vegetation.

The 1999 water profiles show a NIR dip (Band 4), which is expected for water due to absorption. In 2025, the overall reflectance is much higher across all bands, which could be because of shallower water, increased turbidity, or mixed-up pixels from shoreline features.

The wetland profiles for 2025 show a higher reflectance across all bands compared to 1999, especially with large peaks in Bands 5 and 6. The large peaks could indicate a transition from wetlands to emergent forest. The 1999 wetlands were darker and flatter, being water or mixed pixels.

The 1999 land cover classification of Savannah, Georgia, reveals a region characterized by urban development, some forested, areas, a bit of water and a lot of wetlands as seen in Figure 3. The wetlands appear prominent, especially along the river and in lower lying areas. Open water is shown in the eastern section of the study area. This classification provides a benchmark, allowing for comparison with more recent land cover patterns to assess how urban expansion, wetland loss, or forest fragmentation may have evolved over the past two decades.

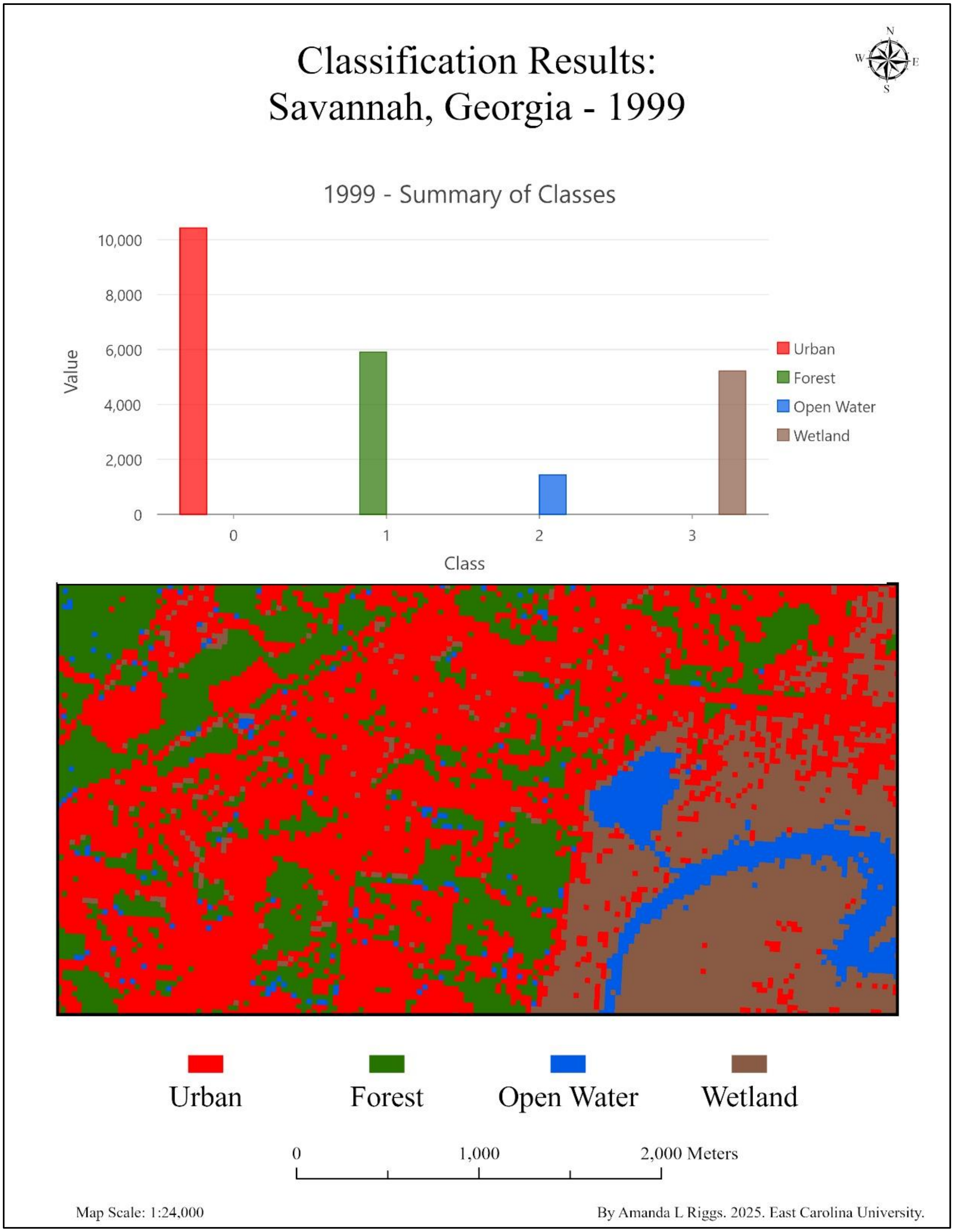

Figure 3. Summary of class counts for Savannah, Georgia – 1999 based on supervised classification.

The 2025 supervised classification results for Savannah, Georgia, shown in Figure 4, reflect a landscape increasingly influenced by urban expansion and land use change. Wetlands now represent the most abundant land cover class, particularly concentrated in the southeastern portion of the study area.

Forest cover has declined significantly in 2025 compared to 1999. This pattern aligns with observed urban encroachment as development expands outward from city centers into formerly vegetated areas. Urban land, although appearing reduced in total area relative to wetlands, remains widely distributed throughout the landscape. Pockets of open water are still evident, particularly along the river and reservoir areas in the east and are more clearly delineated in this classification. Unlike in 1999, agriculture does not appear to be a separate class, either due to changes in land use or because it was removed from the classification schema.

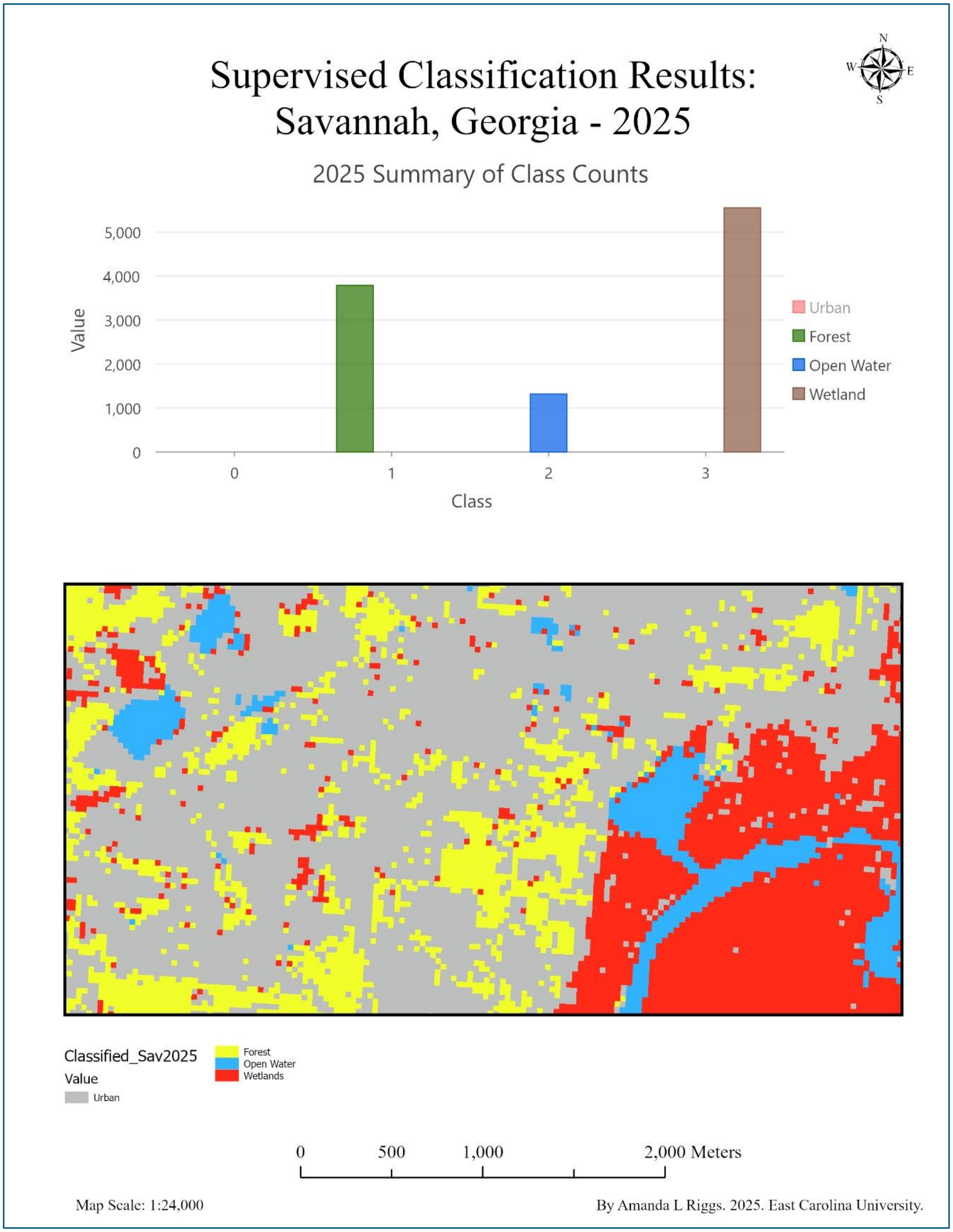

Figure 4. Summary of class counts for Savannah, Georgia – 2025 based on supervised classification

The change detection analysis for Savannah, Georgia, between 1999 and 2025 reveal patterns of urban expansion and the corresponding loss of natural land cover types, mostly forests and wetlands revealed in Figure 5.

As seen in the widespread presence of yellow pixels representing forest-to-urban transitions and smaller but noticeable purple and teal areas marking wetland-to-urban and Open water-to-urban changes, the region has experienced a significant increase in developed land.

Simultaneously, there has been a marked reduction in Forest and Wetlands areas, indicated by green and tan transitions (e.g., Forest to Wetlands, urban to Wetlands), which appear in patches across the map.

In contrast, open water bodies have remained stable in size and extent. Although isolated instances of change exist (such as Open Water to Urban or Open Water to Wetland), the overall scale of these transitions is minimal.

Figure 5 highlights the dynamic nature of Savannah's landscape over the past two decades, with a trend toward urbanization at the expense of natural ecosystems, particularly forests and wetlands.

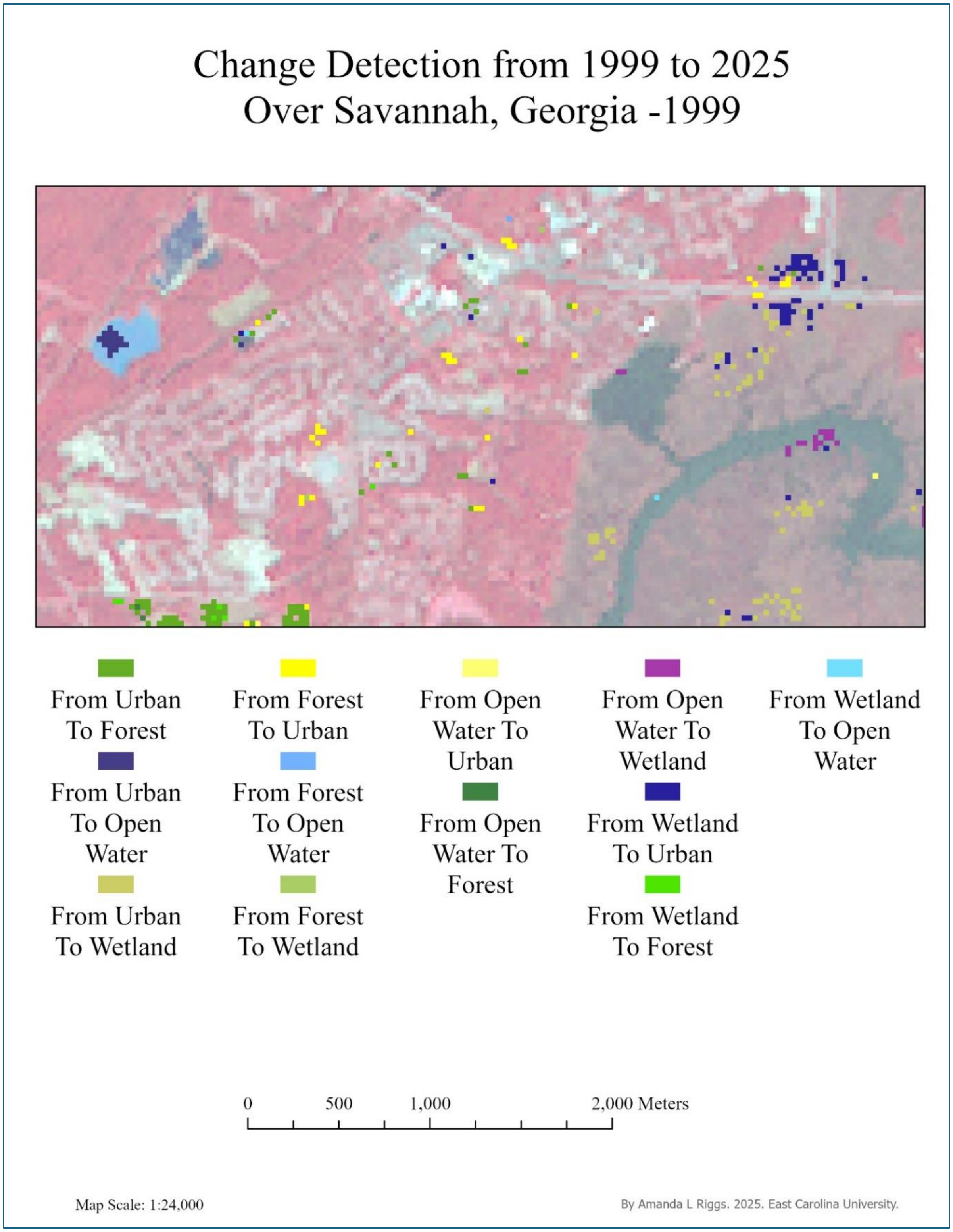

Figure 5. Change detection analysis revealing land cover conversions from one class to another based on supervised training samples.

Validation

The table below presents classification accuracy results for Savannah in 1999 and 2025 across four land cover classes: Forest, Open Water, Urban, and Wetland. For each class and year, it reports the *Producer's Accuracy* which is how often the model correctly identified a reference class and the *User's Accuracy*, meaning how often the model's predicted class was actually correct. These accuracy values are essential for evaluating the confidence in classification outcomes and highlight how well the model performed across both periods.

While User's Accuracy is perfect (100%) for several classes in 2025, this is misleading because it could mean that whenever the model predicted a class it will always be correct. In contrast, the Producer's Accuracy reveals how often each actual land cover was captured and shows more variation. For example, Urban and Wetlands were more positively detected in 2025 than in 1999, while Forest and Open Water showed constant performance across both years.

However, the overall accuracy is low in both years (25.6%), suggesting that the model struggled to classify across the landscape. This indicates either class imbalance, limitations in the training data, or difficulty distinguishing certain land cover types spectrally. I believe that it is because I re-did the classification and removed a class, because the original accuracy results were much higher (above 50%). The original set had several training samples whereas the redo had only ten for each due to time constraints. Future work would include additional training samples and reclassification.

Table 1. Classification Accuracy Metrics for Savannah (1999 vs. 2025).

Class	User's Accuracy (2025)	Producer's Accuracy (2025)	User's Accuracy (1999)	Producer's Accuracy (1999)
Forest	26.3%	100.0%	26.3%	100.0%
Open Water	—	100.0%	—	100.0%
Urban	100.0%	100.0%	—	0.0%
Wetland	—	90.0%	—	10.0%
Overall	25.6%	25.6%	25.6%	25.6%

While the classification model shows some strength in correctly labeling classes it commits to, the low Producer's Accuracy for Wetlands and Urban in 1999 shows these classes were often missed entirely, reducing confidence in land change interpretations for those categories.

Kappa (KHAT) Statistics measure the difference between actual agreement and chance using the following formula:

$$k = \frac{observed\ accuracy - chance\ agreement}{1 - chance\ agreement}$$

Table 2. Kappa statistic results for 1999 and 2025.

Metric	**Savannah 1999**	**Savannah 2025**
Total Samples (N)	39	39
Observed Agreement (Po)	0.2564	0.2564
Chance Agreement (Pe)	0.2564	0.2564
Kappa (κ)	0	0

Kappa for both 1999 and 2025 equal zero percent. A Kappa of 0 means that your classification agreement is no better than random chance. Even though the User's Accuracy is perfect for some classes, the overall match between predicted and reference classes is poor, and the classifier is not generalizing well. This is due to the small number of samples provided. Due to time restrictions, the training samples were recreated using only ten samples for each class. Therefore, future work should be to create more training samples (around 20) for the classifier for better results.