

# Changes in forest structure in Ponderosa pine-dominated ecosystems following restoration treatments

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## INTRODUCTION

### Background:

- Increased large, high-severity wildfires in the West have had devastating effects on water resources such as post-fire erosion and sedimentation.
- This has prompted Colorado-based restoration collaborative Peaks to People Water Fund (P2P) to implement restoration treatments in priority watersheds.
- P2P focuses on increasing forest resiliency to future wildfires by meeting the following objectives:
  - Reduce canopy cover**
  - Increase large openings (gaps)**
  - Increase forest heterogeneity**

- The purpose of this study was to measure the success of forest restoration treatments using remote sensing methods.

### Research Question:

- Do P2P restoration treatments reach management objectives aimed at increasing forest resiliency?

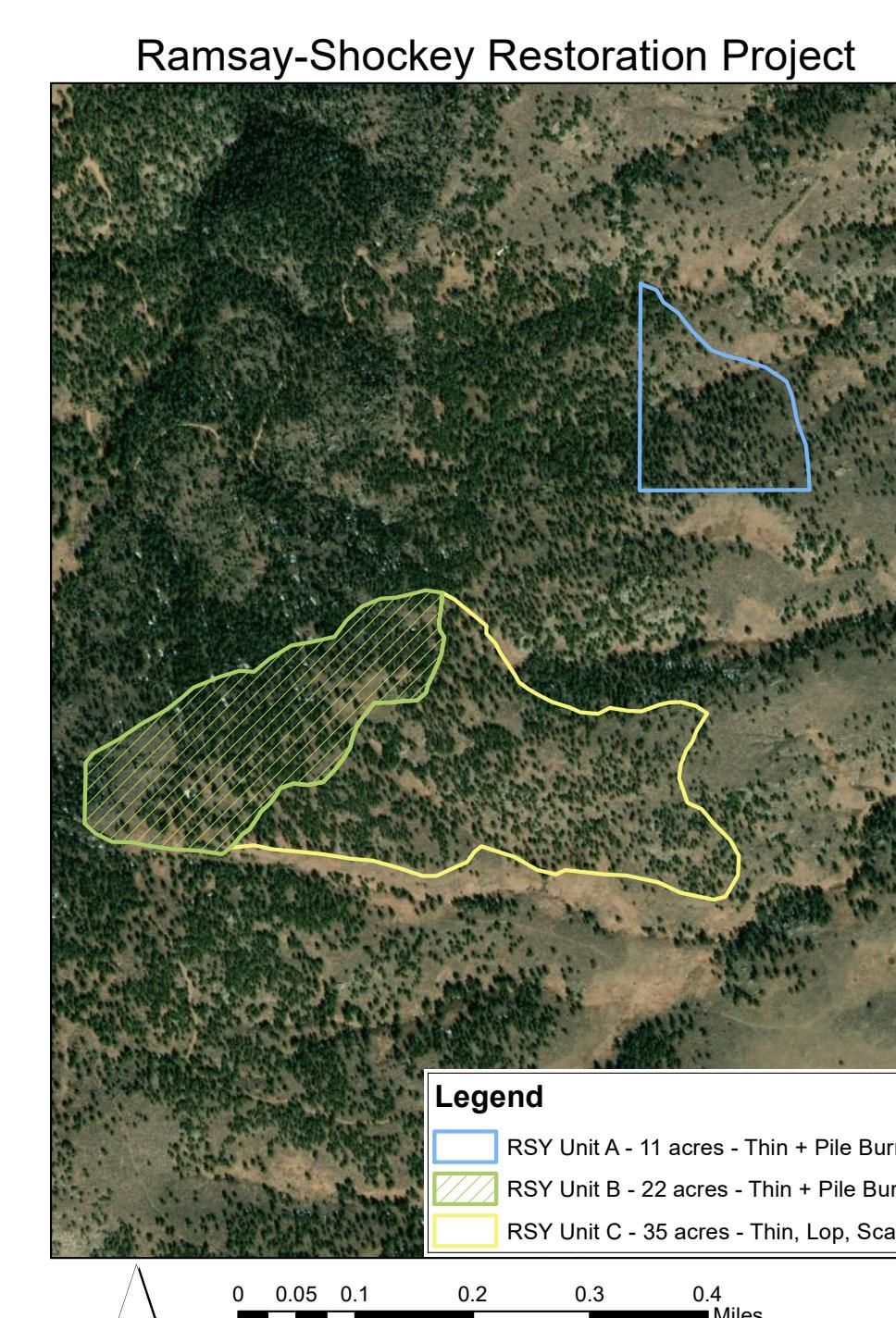
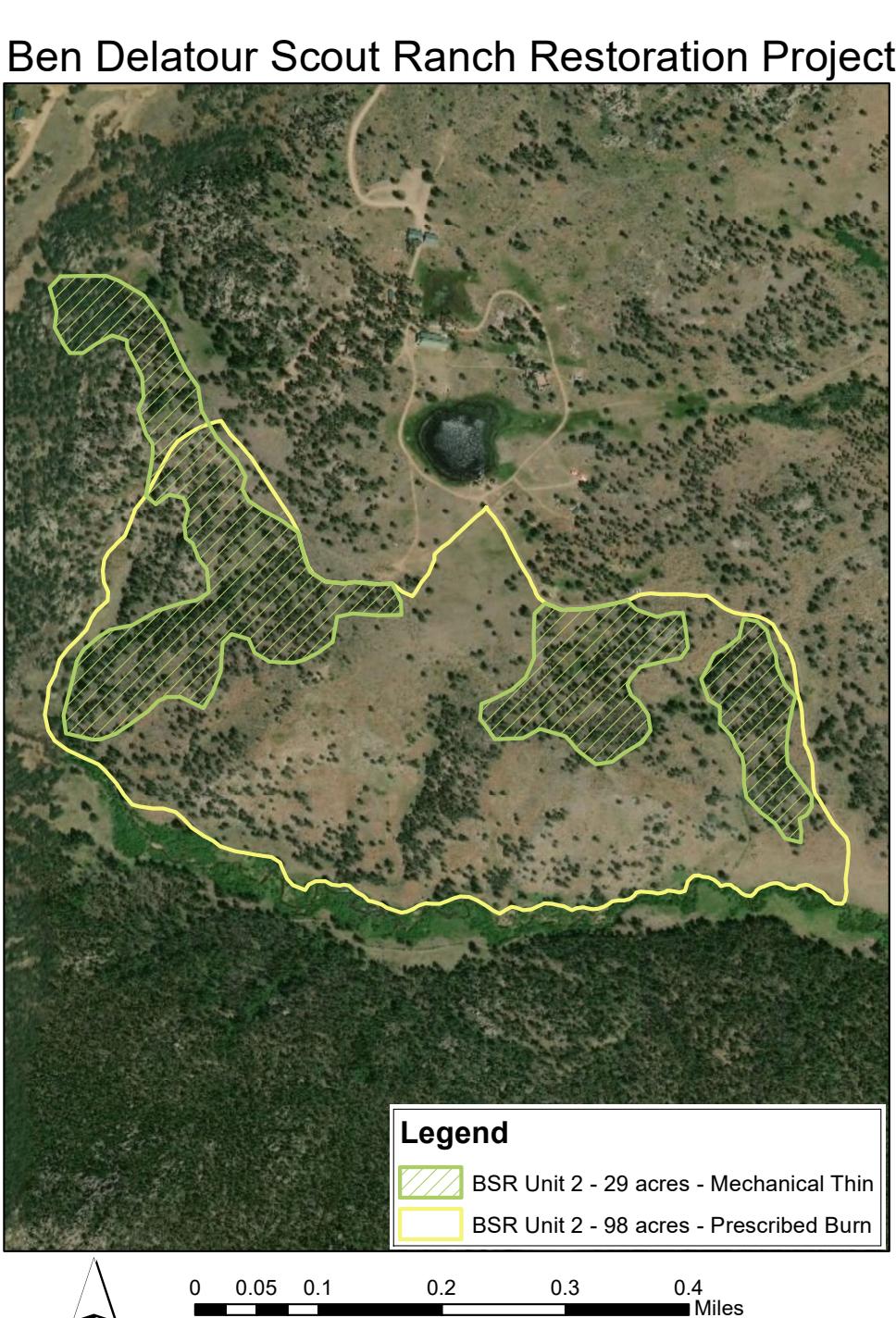
## STUDY DESIGN

Two areas within priority watersheds were selected as demonstration sites:

### 1. Ben Delatour Scout Ranch (BSR) – Cache La Poudre River

### 2. Ramsay-Shockey (RSY) – Big Thompson River

- Sites are within lower montane, Ponderosa pine-dominated forests with high wildfire risk.
- Treatments included mechanical thinning and prescribed burn. This study evaluates post-treatment conditions following mechanical thinning only.



## METHODS

- We examined pre- and post-treatment satellite imagery for BSR and RSY collected by Worldview-2 and Quickbird-2 satellites with ~3m spatial resolution and 4- or 8-band spectral resolution.
- Approximately 110 training areas were stratified across treatment unit boundaries in each image.
- Supervised random forest classification was utilized to classify imagery to assess canopy cover changes:
  - Training areas were classified as either opening (yellow), canopy (green), or shadow (grey).
  - Shadows were re-classified into opening or canopy using Normalized Difference Vegetation Index (NDVI) thresholds.

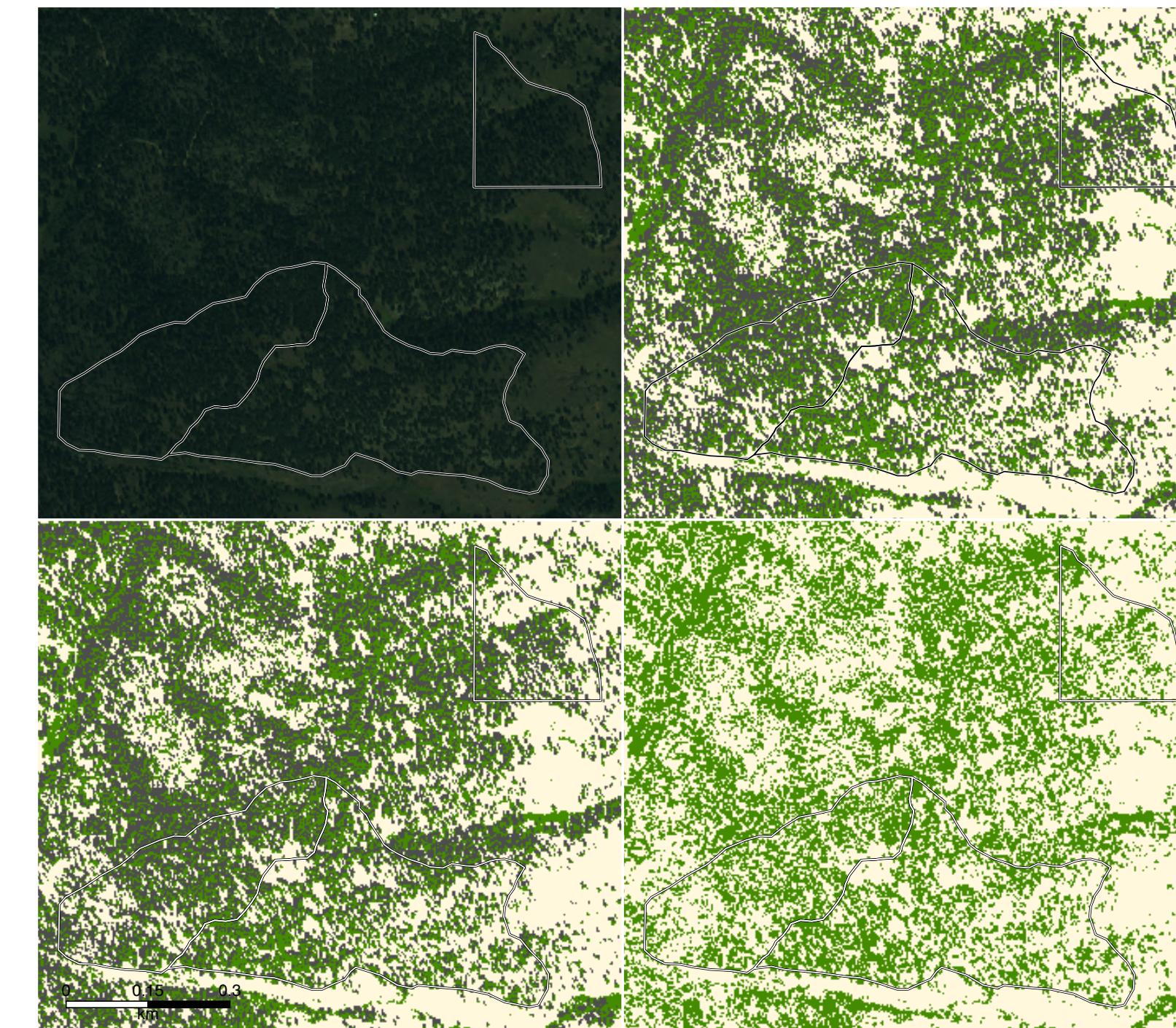


Figure 1a: Image classification of RSY pre-treatment.

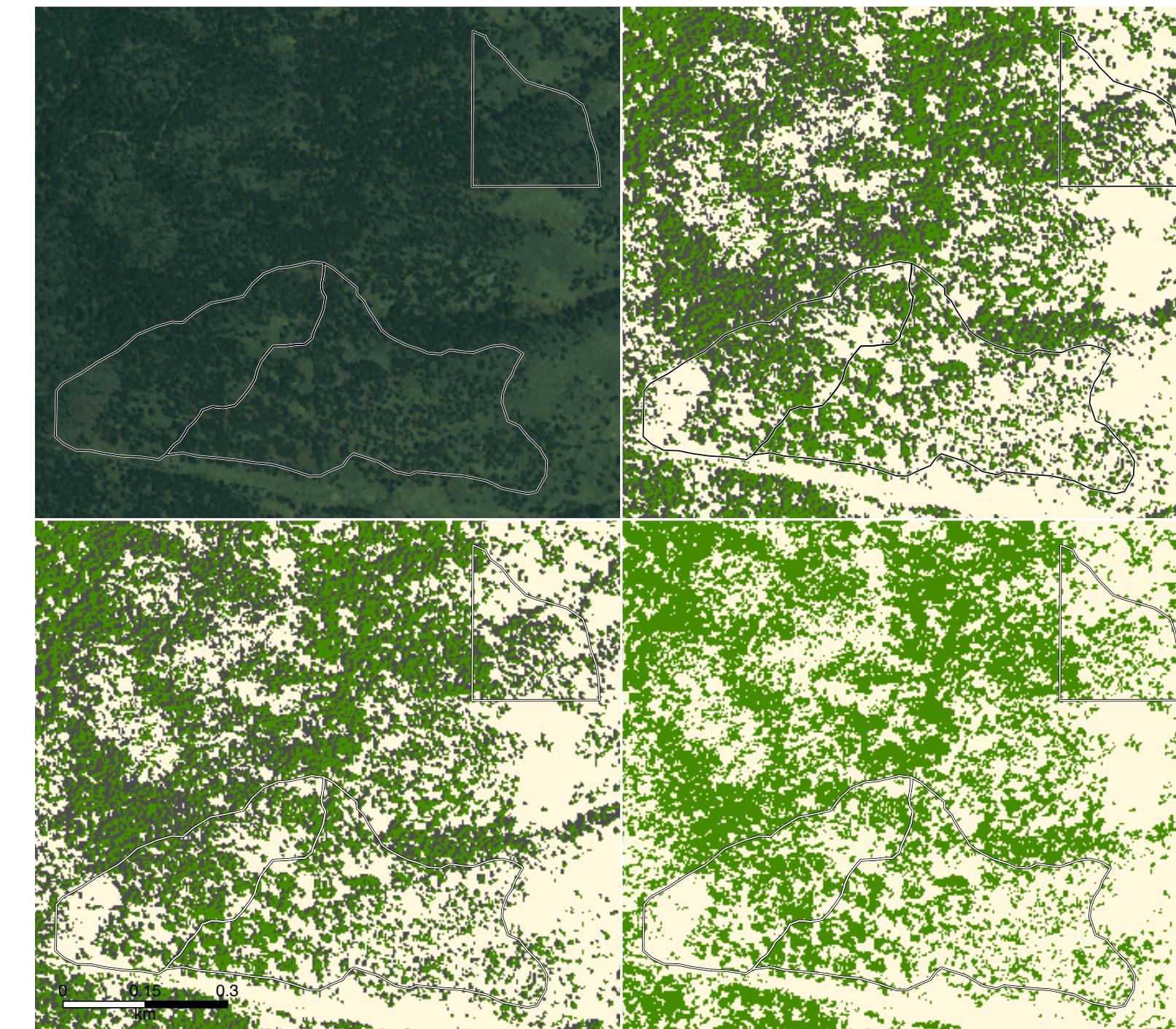


Figure 1b: Image classification of RSY post-treatment.

Figures 1a, b: Maps of RSY pre- and post-treatment show progression of classification process. Raw, unclassified satellite imagery (upper left panels) is classified into land cover categories informed by training areas (upper right). Land cover is then classified into opening, canopy, or shadow (lower left), then reclassified into opening or canopy using NDVI threshold.

- Using the classified imagery, we delineated large openings (defined here as “all contiguous regions with <5% canopy cover over a 0.1-acre area”<sup>1</sup>) which were used to calculate the following:
  - Gap cover:** Percent cover of large openings as they are defined above.
  - Gap decay coefficient:** the rate of decay for the interior area of an opening.
  - Gap size variability:** variability of the size of openings, measured by the coefficient of variation.
- Classification accuracy was tested for each site using a confusion matrix.

	Classification Method	Overall Accuracy	Training Plots	Mean Size (m <sup>2</sup> )
BSR Pre-Treatment	Random Forest	97.19	120	54.48
Sample	Predicted 1	Predicted 2	Predicted 3	
Sample 1	82	0	0	
Sample 2	0	31	1	
Sample 3	0	0	64	

Table 1: Confusion Matrix for BSR Pre-Treatment. Overall classification accuracy is 97.2%

## RESULTS

Canopy Cover (%)			
BSR		RSY	
Pre	Post	Pre	Post
44%	41%	41%	35%

Table 2: Canopy Cover at BSR and RSY Pre- and Post-Treatment.

Gap Cover (%)			
BSR		RSY	
Pre	Post	Pre	Post
41%	46%	25%	40%

Table 3: Gap Cover at BSR and RSY Pre- and Post-Treatment.

Gap Decay Coefficient			
BSR		RSY	
Pre	Post	Pre	Post
0.025	0.024	0.051	0.043

Table 4: Gap Decay Coefficient at BSR and RSY Pre- and Post-Treatment.

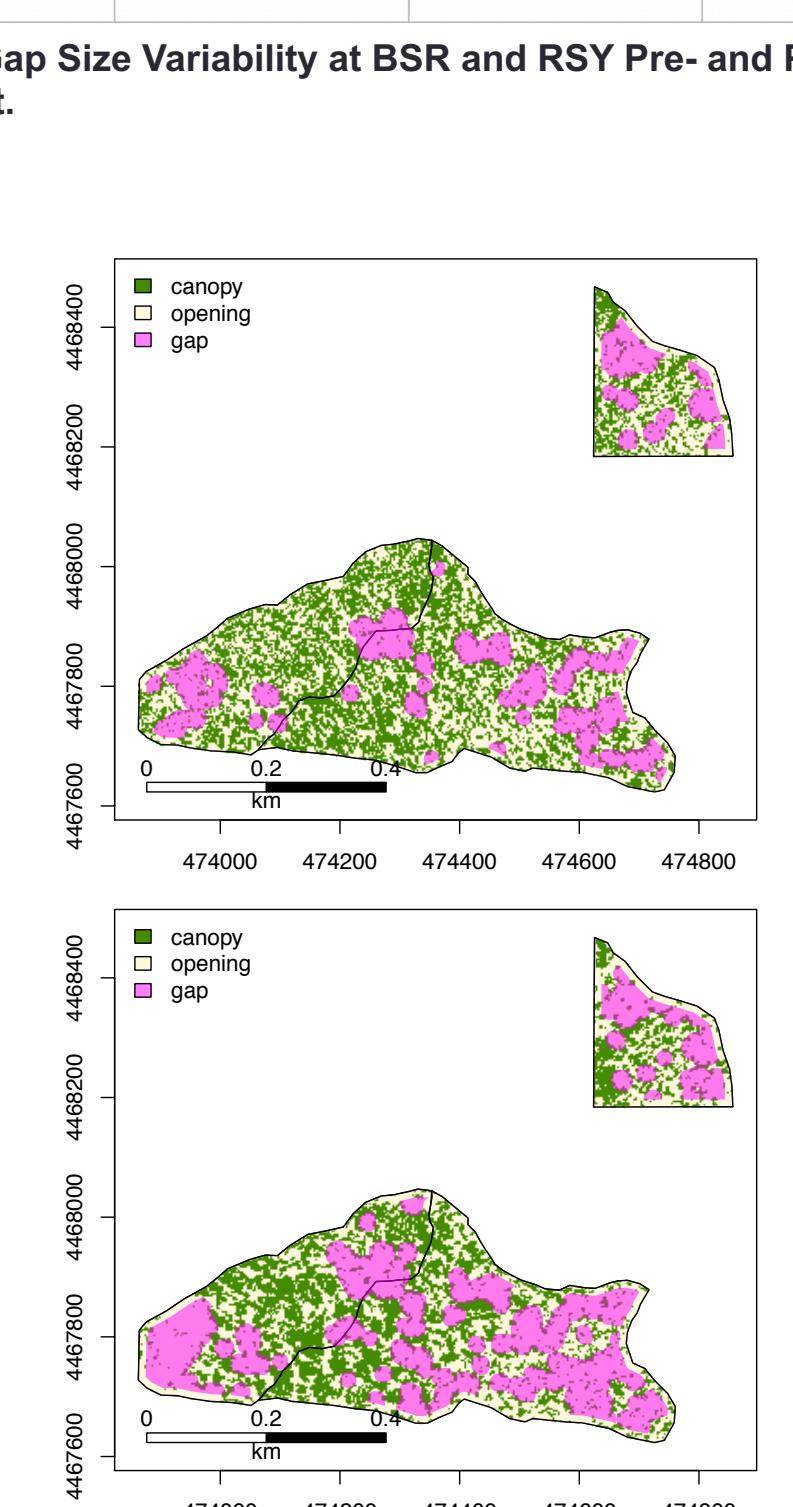


Figure 2: Final classification of treatment units at BSR and RSY. Maps show cover of openings (yellow), canopy (green), and large openings (gaps) (magenta) at BSR pre-treatment (upper left), BSR post-treatment (lower left), RSY pre-treatment (upper right), and RSY post-treatment (lower right).

## DISCUSSION

- Overall, P2P restoration treatments met management objectives:
  - Canopy cover decreased** at both sites (Table 2).
  - Large openings increased** at both sites (Table 3).
  - Decreased gap decay coefficients at both sites and increased gap size variability at RSY contribute to **increased forest heterogeneity** (Tables 4, 5).
- Meeting these objectives should result in improved forest resiliency to and decreased frequency of high-severity wildfires.
- Remote sensing was integral in assessing fine-scale spatial patterns at a landscape-scale before and after restoration treatments.
- P2P's collaborative approach to restoration and use of demonstration sites allowed for interagency cooperation that makes future restoration treatments aimed at resilience possible.