Characterizing the Impact of Land Ownership on Post-Wildfire Forest Recovery in the Sierra Nevada Mountains, California

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Trends in California Wildfires

The dry mixed conifer forests of California's Sierra Nevada, are presently burning at a rate and severity far outside of their historic range of variability

-High severity fire effects within individual fires only accounted for <10% of annual burned area prior to European settlement whereas they presently account for than 25-40% (Brown et al. 2008, Mallek et al. 2013)

-The U.S. Forest Service manages 57% of California Forestlands while private timber companies manage 14%. (California Forests, 2018).

Credit: Associated Press

Why Monitoring Forest Regeneration?

It is important to track and compare post-wildfire regeneration patterns as they can impact ecosystem services such as:

1. **Water Purification** (Miller et al. 2003)
2. **Carbon Sequestration** (Johnson et al. 2005, Liang et al 2017)
3. **Habitat Quality** (Jones et al. 2016)
4. **Human Welfare\Fire Risk** (Kramer et al. 2018)

Does Land Ownership Impact Post-Fire Regeneration?

The post-fire management paradigms implemented by these two landownerships have been shown to be grouped into 2 generalized categories: Relatively “Active” and “Passive”.

1. **Private Timberlands (Active):** Typically managed for maximum sustained timber yield.
   - Expansive salvage logging
   - Seedling planting
   - Chemical vegetation control
   - Forest thinning

2. **National Forests (USFS, Passive):** Typically managed with an emphasis on minimizing human impact on landscape.
   - Reduced salvage logging
   - Increased reliance on natural regeneration
   - Lack of stand maintenance/follow-up treatments

Does Land Ownership Impact Post-Fire Regeneration?

Both paradigms have be criticized

1. **Criticisms of Active Management Paradigm:**
   - Reduced tree and understory plant species diversity
   - Exacerbated soil compaction
   - Degraded habitat quality
   - Delayed understory regeneration

2. **Criticisms of Passive Management Paradigm:**
   - Increased abundance of coarse and fine woody debris
   - Increased likelihood of subsequent high severity wildfires
   - Retention of hydrophobic soil layer
   - Extirpation of non-severe fire adapted species

Research Gap: Both management paradigms have been studied, however their impacts on forest regeneration have rarely been directly compared.

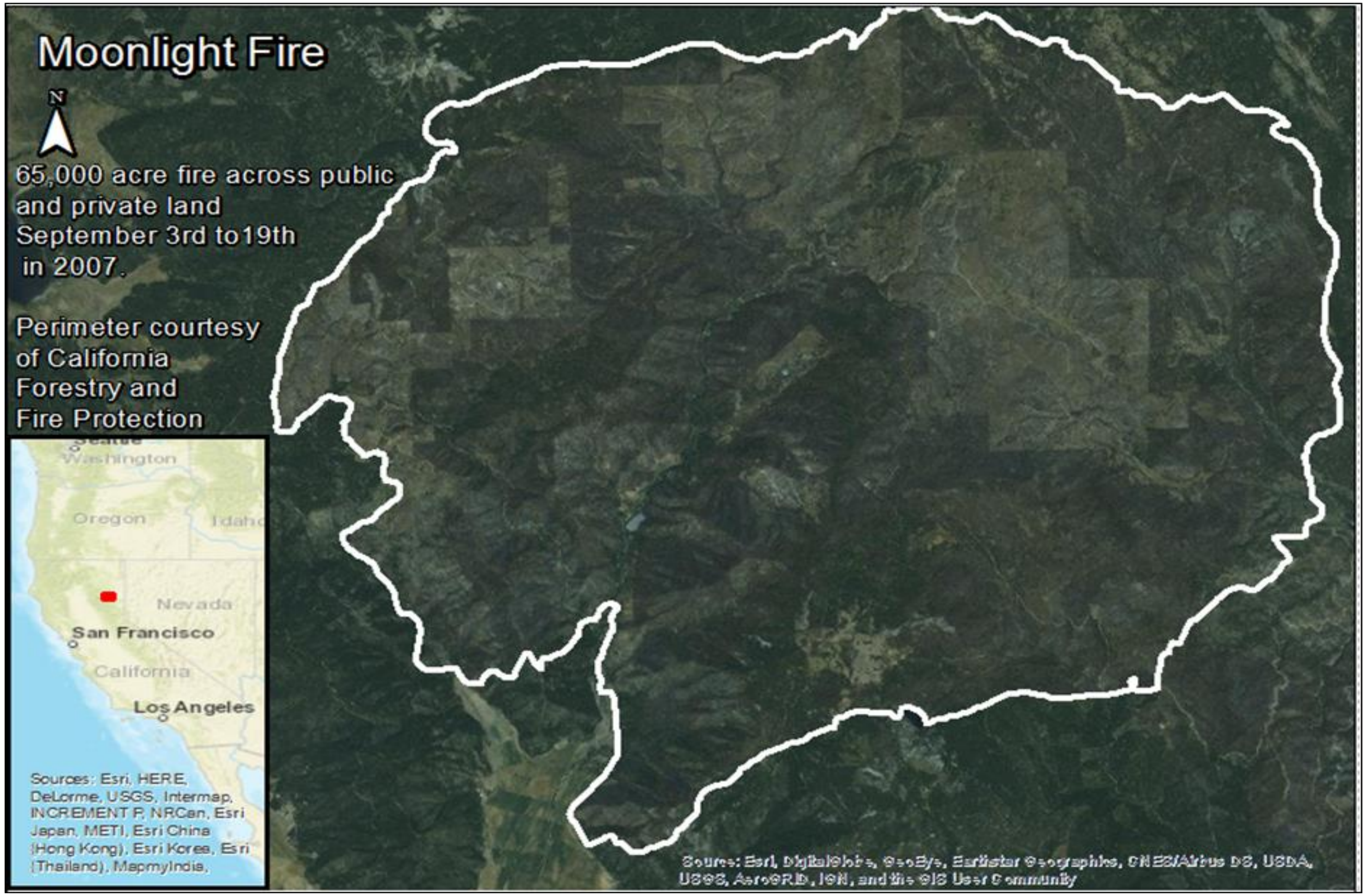
Analysis Outline

Goal: Directly compare trends in post-fire forest regeneration resulting from both active and passive post-fire management paradigms.

General Methodology:

- Selection of a suitable study area (fire) whose ownership/management paradigms are relevant and well documented.
- Track revegetation across management paradigm by implementing an annual spectral unmixing time series analysis.
- Implement a 2-step time series analysis (immediate pre-fire - 2007, 11 years post fire - 2018) of forest structure to provide context on current successional pathways.
- Evaluate for differences in trends forest regeneration across management paradigm

Study Area

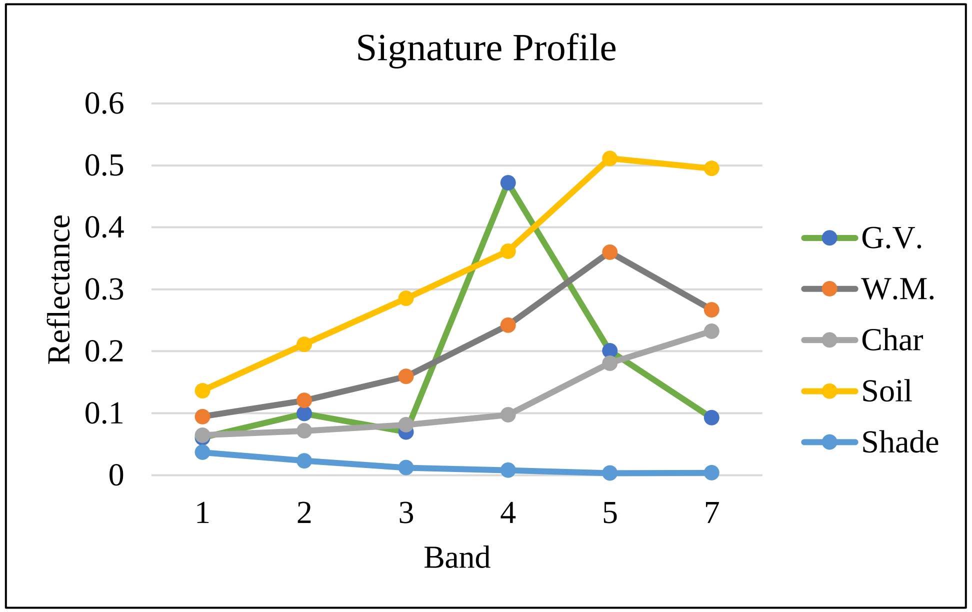


2007 Moonlight Fire

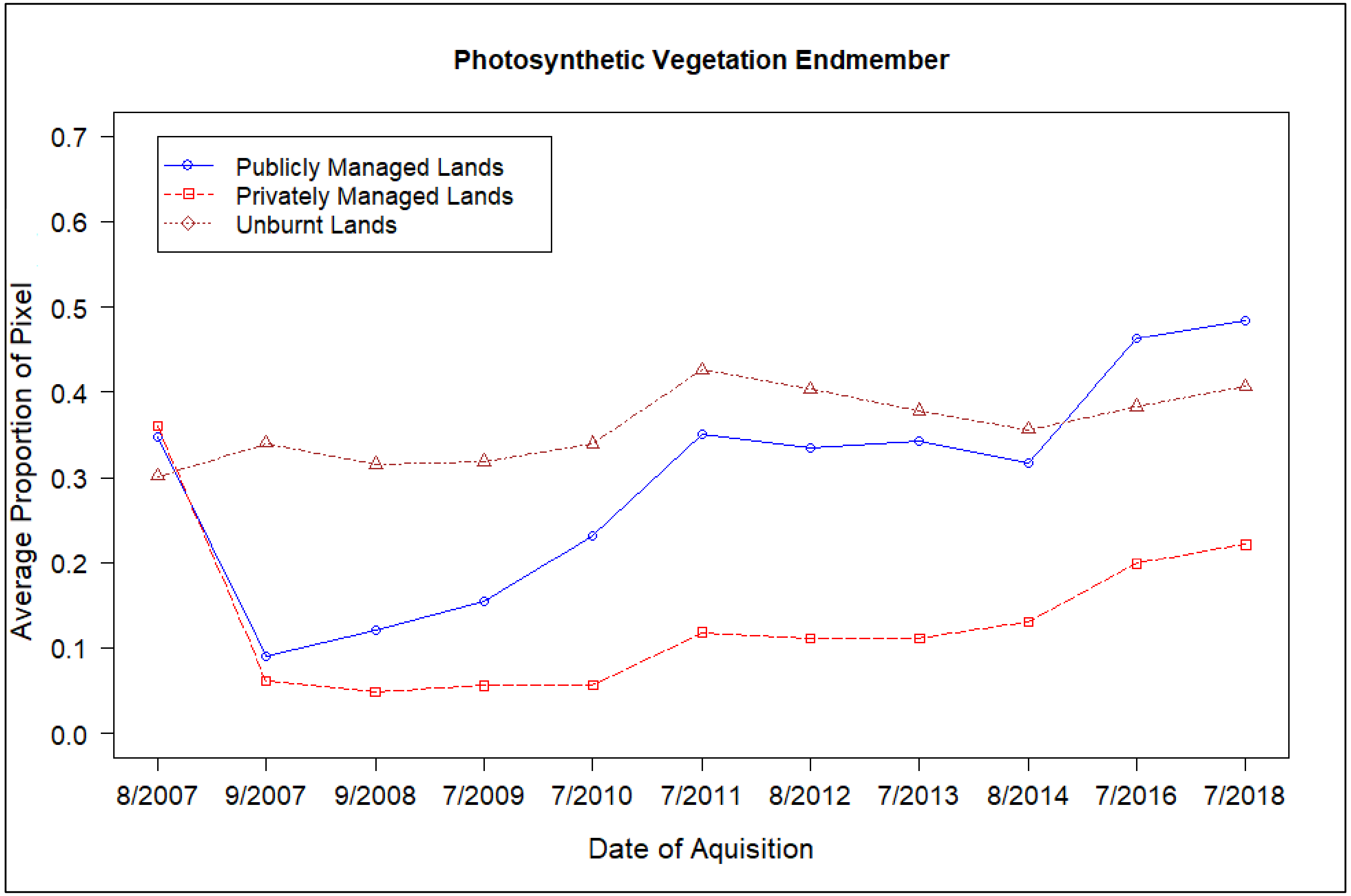
Spectral Unmixing Analysis: Methods

- 5 biophysical endmembers were unmixed to represent landscape conditions.
- Endmember values were averaged across land ownership class by time point allowing for trends in abundance to be compared.

Endmembers	Source	Year
Green Vegetation	JFS Spectral Library	2007 - 2018
Woody Materials	JFS Spectral Library	2007 - 2018
Soil	Image Derived	2007 - 2018
Shade	Image Derived	2007 - 2018
Burnt Area	JFS Spectral Library	2007, 2008



Trends in Green Vegetation Regeneration



Forest Structure Classification Analysis: Methods

- 2 step time series analysis of forest structure was implemented (2007, 2018).

- 5 landcover types were classified. These were selected based on the classical model of coniferous forest succession as described in Oliver and Larson (1990).
  - "Forb/Rock/Soil"
  - "Shurb Dominant"
  - "Young Forest"
  - "Mature Forest – Closed Canopy"
  - "Mature Forest – Open Canopy"

- The Random Forest algorithm was selected to conduct classification.
  - ~600 ground control points were created (120/landcover class)
  - ~100 ground control points taken with handheld GPS, ~500 digitized using NAIP imagery

Forest Structure Classification Analysis: Methods

"Forb/Soil/Rock"

"Mature Forest – C.C."

TPH: 407.72 (114.69)
Tree Height(m): 14.85 (3.53)
Tree DBH(cm): 31.41 (7.47)

"Shrub Dominant"

TPH: 64.81 (119.49)
Tree Height(m): 0.95 (0.35)
Shrub Height(m): 0.82 (0.25)
% Shrub Cover: 90.0 (9.0)

"Mature Forest – O.C."

TPH: 244.27 (35.72)
Tree Height(m): 21.27 (7.89)
Tree DBH(cm): 39.23 (15.79)

"Young Forest"

TPH: 440 (-)
Tree Height(m): 2.13 (-)
Tree DBH(cm): 2.54 (-)

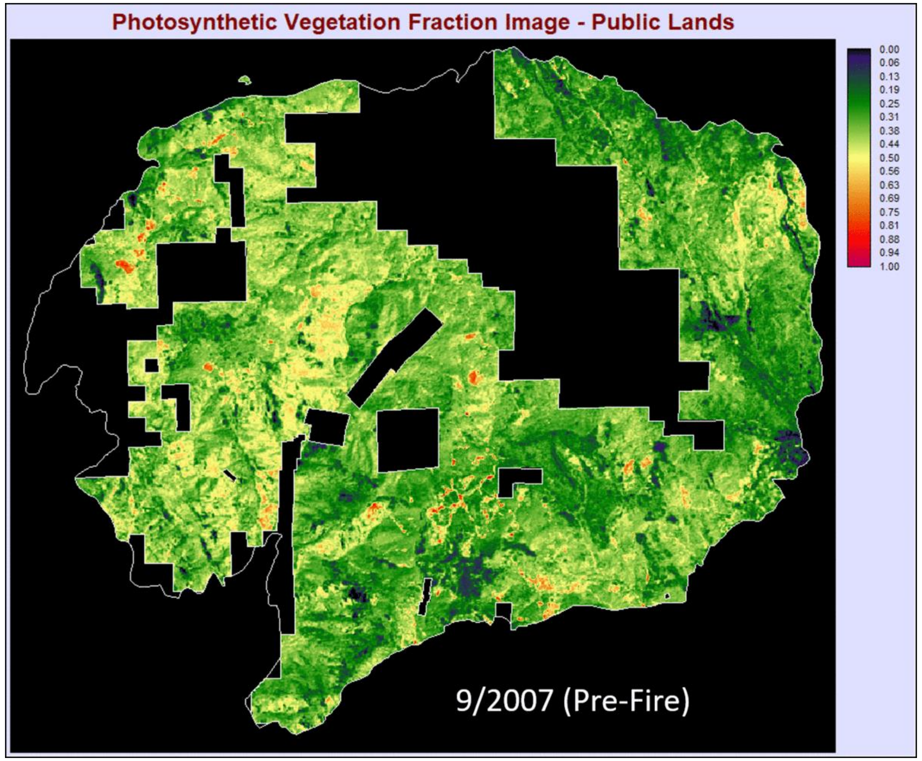
Property Boundary

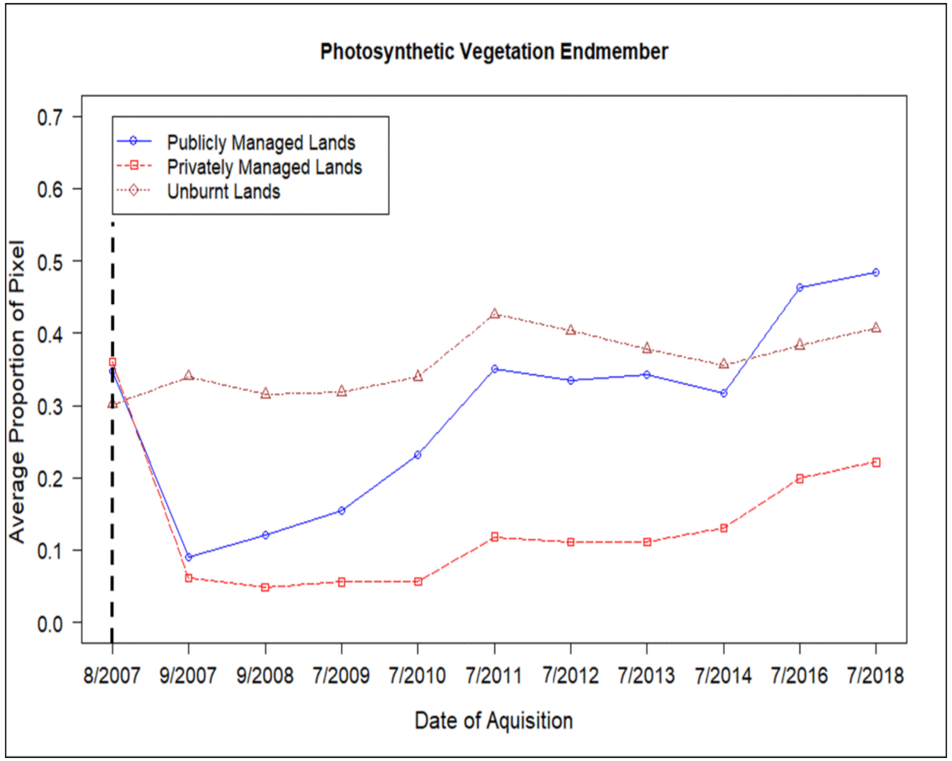
Forest Structure Classification Analysis: Data

Dataset	Coverage	Resolution	Year
TM/ETM+ Optical Bands	Full	30 m	2007, 2018
Unmixed Endmembers	Full	30 m	2007, 2018
NDVI	Full	30 m	2007, 2018
SAVI	Full	30 m	2007, 2018
(NDVI-SAVI)	Full	30 m	2007, 2018
Elevation	Full	30 m	2007, 2018
Slope	Full	30 m	2007, 2018
LiDAR-Derived % Canopy Cover	Federal Only	30 m	2018
Sentinel-1 Surface Texture Products	Full	30 m	2018

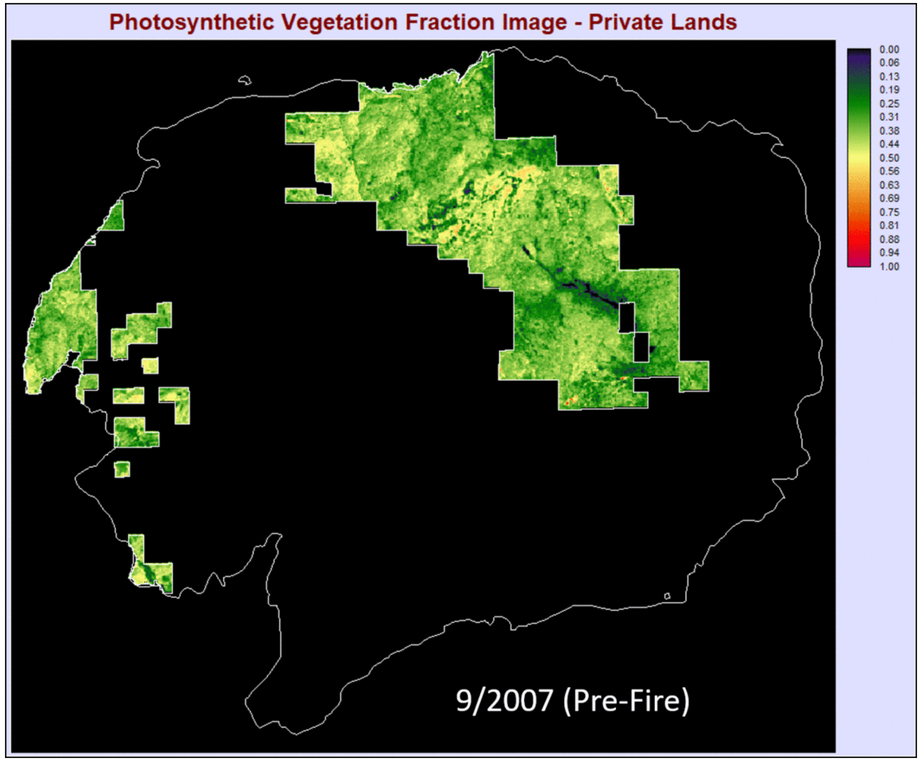
- Datasets were selected using the framework outlined by Franklin (1995).

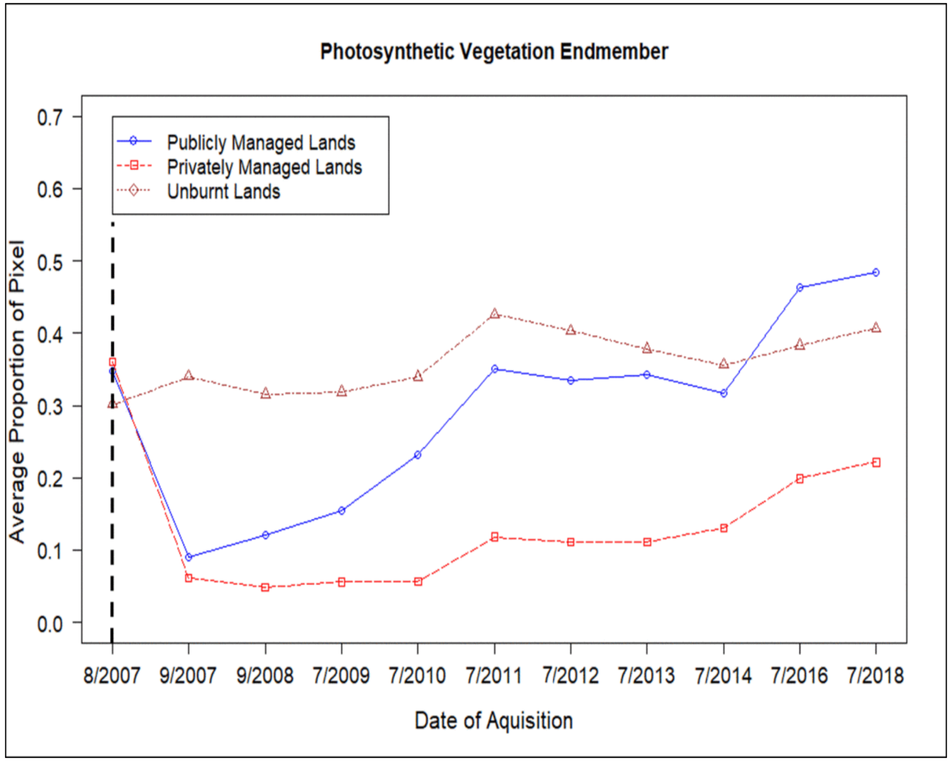
Trends in Green Vegetation Regeneration: Public Lands





Trends in Green Vegetation Regeneration: Private Lands





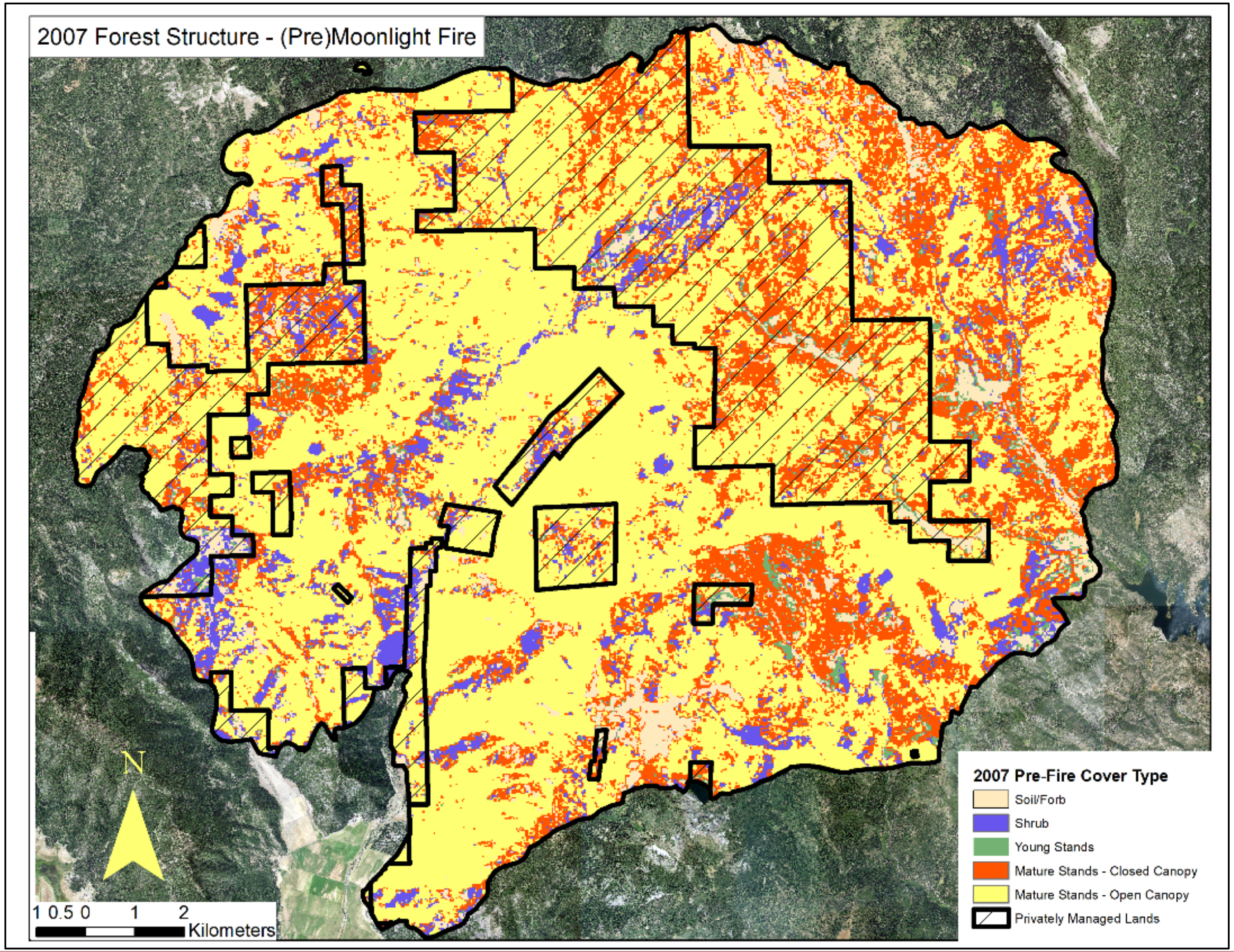
Forest Structure Classification Analysis: Model Results

- Model Out of Bag Error Rates (OBO) were 10.01% (2007) and 9.76% (2018) respectively

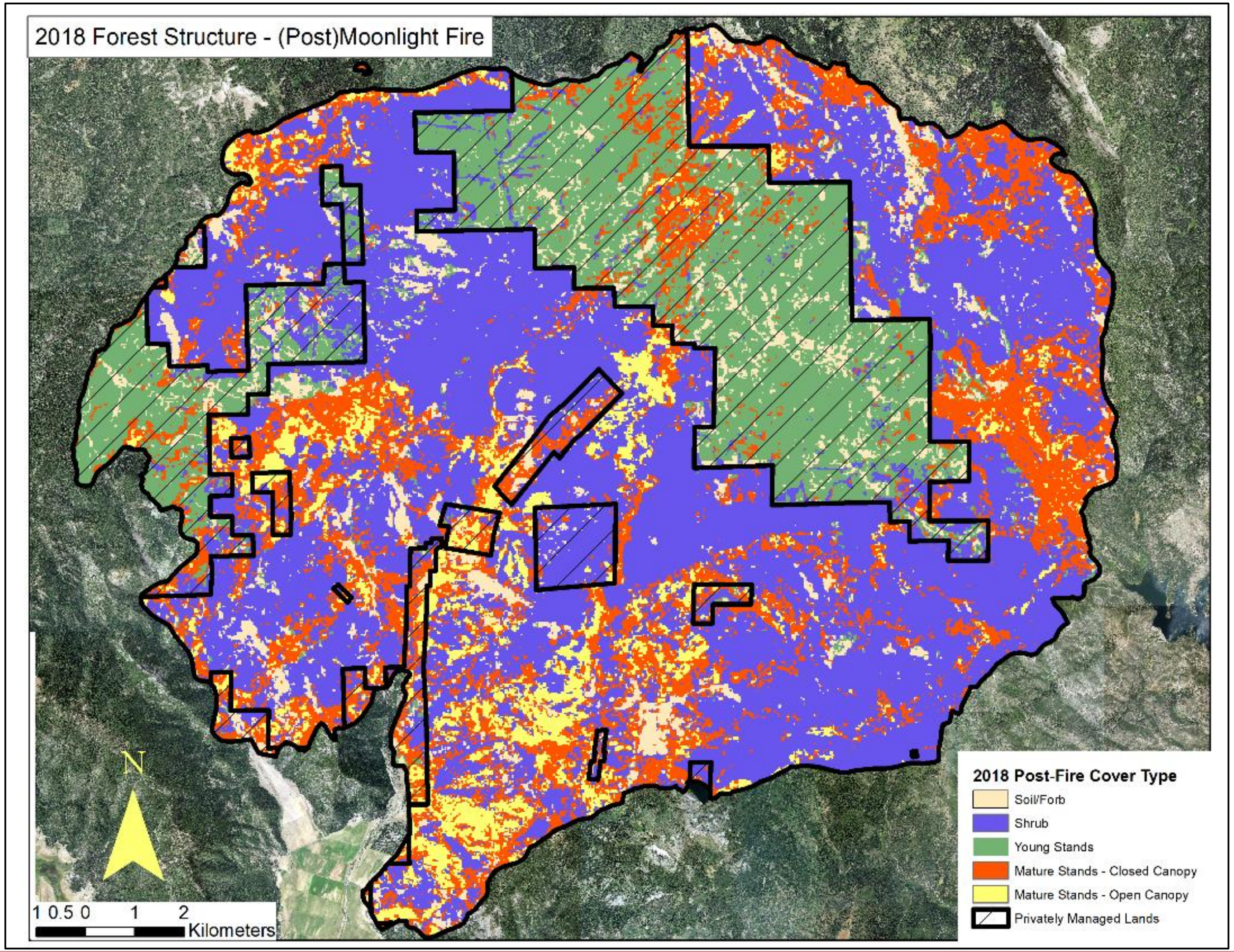
Agreement Matrix (%): Ground Control Point Landcover Class Assignment vs. Random Forest Classification Assignment

GCP Class Assignment	**Random Forest Class Assignment**				
	Forb/Soil/Rock	Shrub Dominate	Young Forest	M.F. Closed Canopy	M.F. Open Canopy
Forb/Soil/Rock	68.3	10	16.7	5	0
Shrub Dominate	0	98.3	0	1.7	0
Young Forest	1.6	0	96.7	1.6	0
M.F. Closed Canopy	1.5	6.2	3.1	89.2	0
M.F. Open Canopy	0	0	0	15	85

Forest Structure Map: 2007(Pre-Fire)

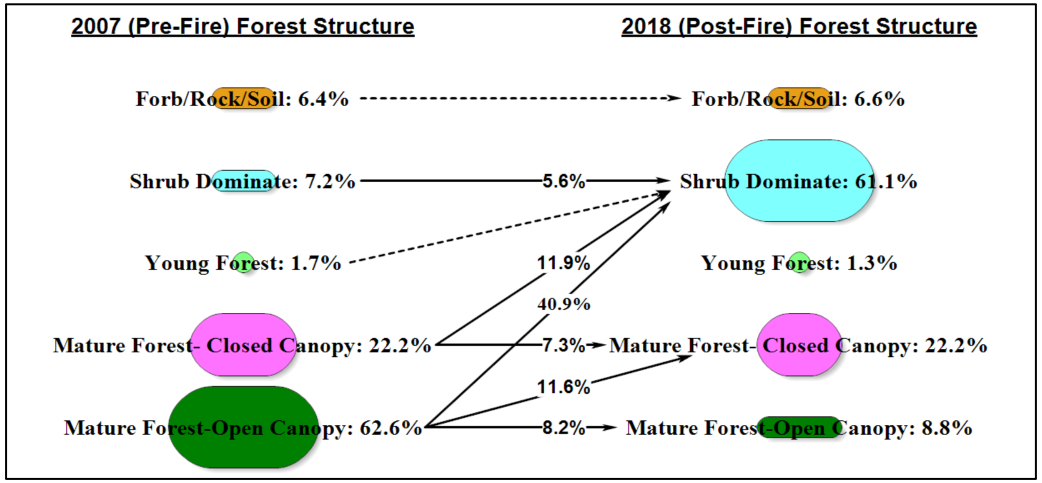


Forest Structure Map: 2018

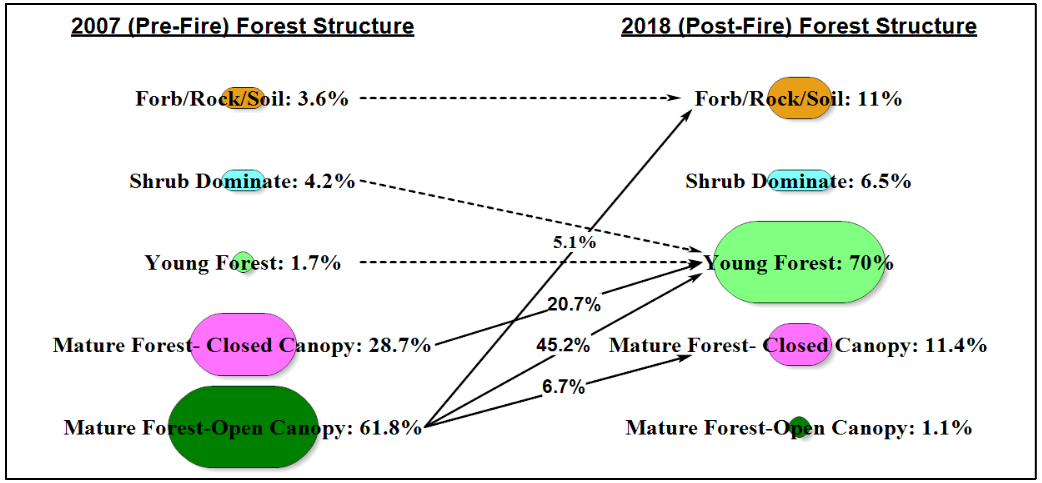


Forest Structure Classification Analysis: Results

Transitions in Publicly Owned Lands



Transitions in Privately Owned Lands



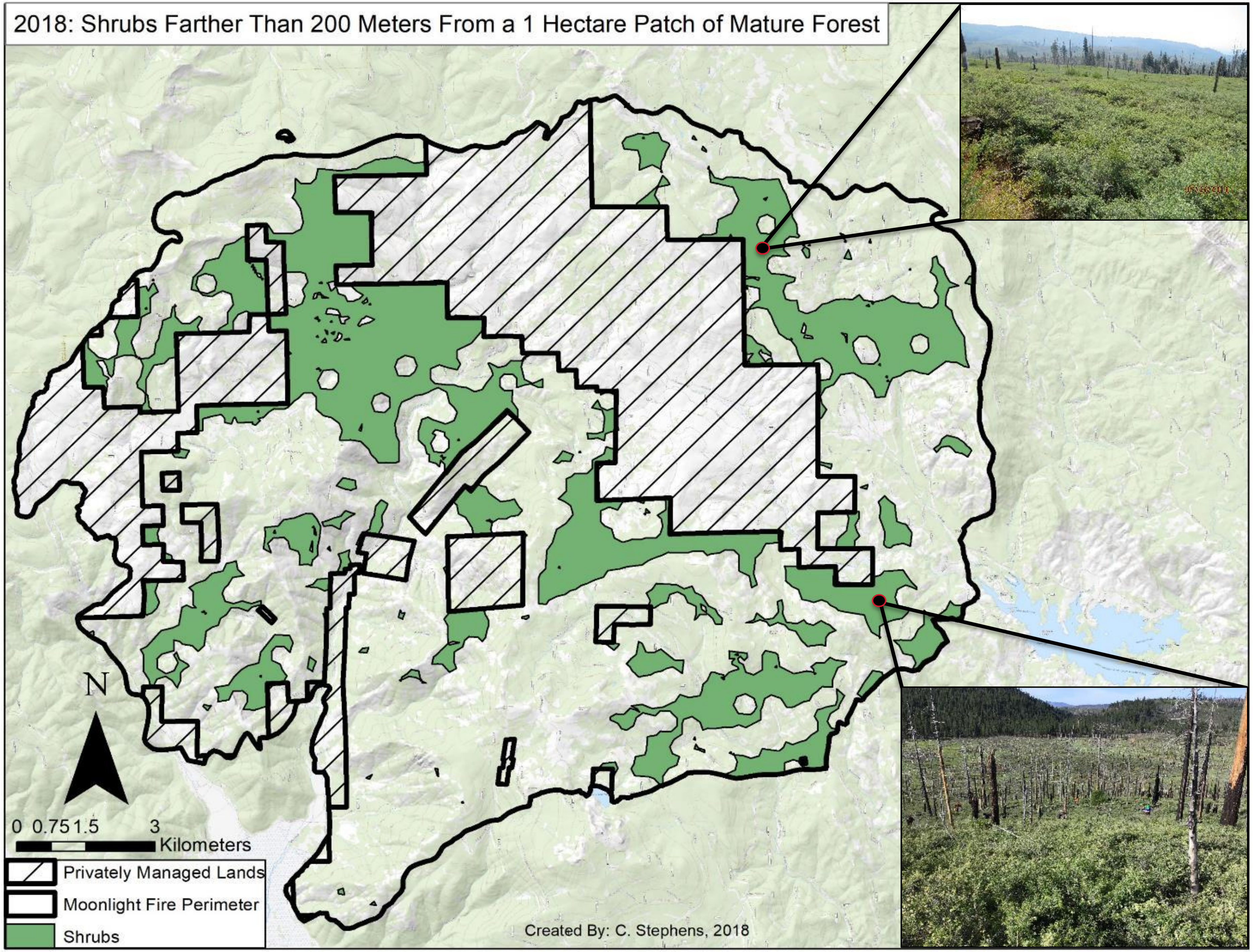
Major Findings:

Privately Owned Lands:

- 78% of privately owned lands transitioned from mature forests to another landcover type over the 11 years post fire.
- 72.8% of mature forests lost on privately owned lands transitioned to the “Young Forest” landcover type.

Publicly Owned Lands:

- 53.8% of publicly owned lands transitioned from mature forests to another landcover type over the 11 years post fire.
- 98.1% of mature forests lost on publicly owned lands transitioned to the “Shrub Dominant” landcover type.
- ~47% of shurblands are located greater than 200 meter from a 1 ha patch of mature forest, reducing their likelihood of being naturally regenerated.


2018: Shrubs Farther Than 200 Meters From a 1 Hectare Patch of Mature Forest
N
0 0.75 1.5 3
Kilometers
Privately Managed Lands
Moonlight Fire Perimeter
Shrubs
Created By: C. Stephens, 2018

Major Findings:

- Management actions taken on privately owned lands appear to have more successfully regenerated conifers than those taken on publicly owned lands.
- Control of competing vegetation seems to have played an important role in this success.
- Public lands revegetated far more quickly than would be ecologically rational for coniferous regeneration.
- While an active post-fire management paradigm may have better facilitated the regeneration of conifers, is it worth the documented ecological consequences? Can the two systems be integrated to capitalize on their respective strengths?

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- Spaital Informatics Group – Ancillary Imagery

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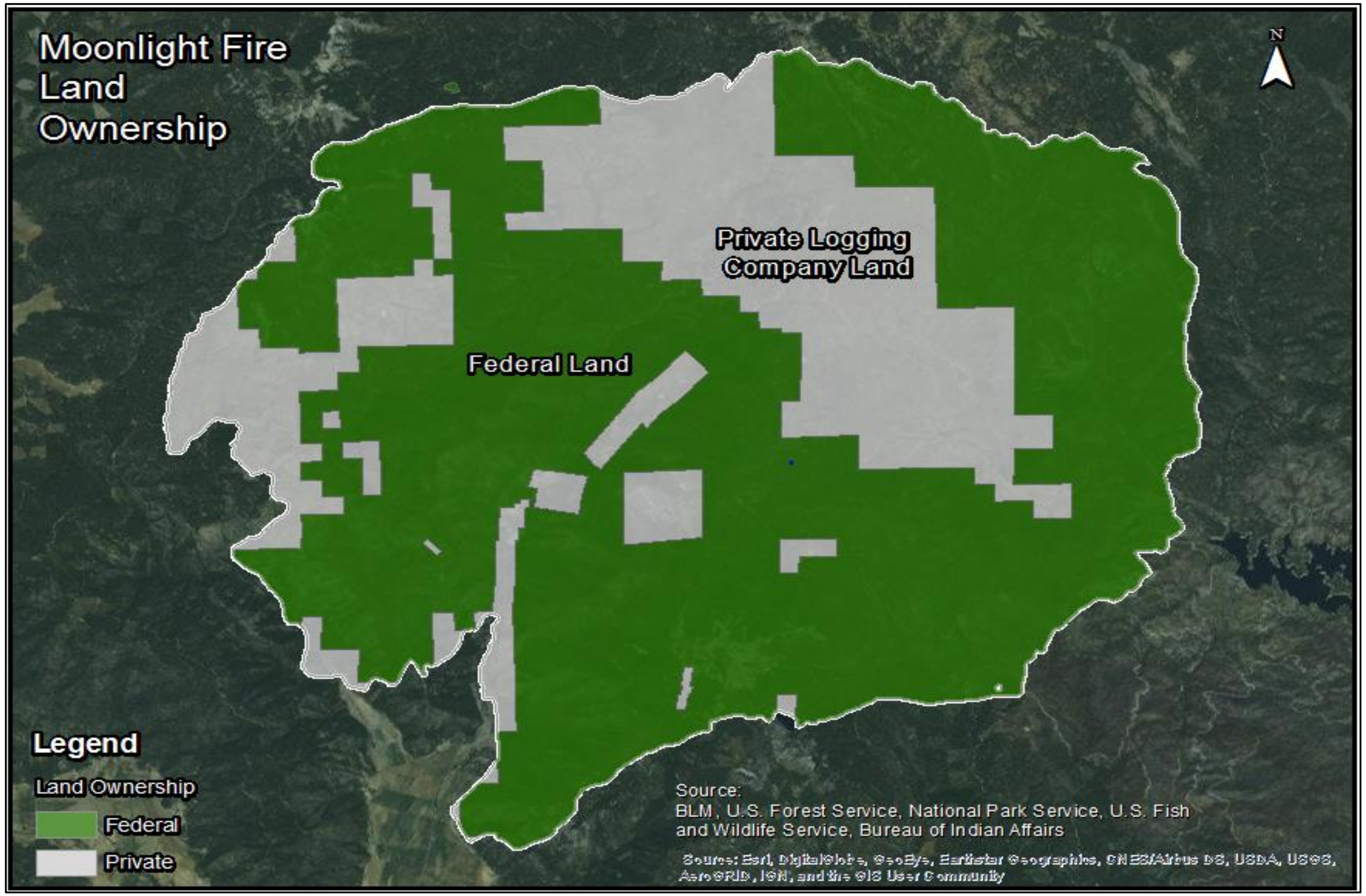
Supporting Information

Study Area



2007 Moonlight Fire

Spectral Unmixing Analysis: Data

Timepoint Represented	Date of Acquisition	Sensor
2007 (Pre-Fire)	2007-AUG-22	Landsat 5 TM
2007 (Post-Fire)	2007-SEP-16	Landsat 5 TM
2008	2008-SEP-09	Landsat 5 TM
2009	2009-JUL-26	Landsat 5 TM
2010	2010-JUL-29	Landsat 5 TM
2011	2011-JUL-25	Landsat 5 TM
2012	2012-JUL-26 2012-AUG-11	Landsat 7 ETM+
2013	2013-JUN-27 2013-JUL-13	Landsat 7 ETM+
2014	2014-AUG-17 2014-SEP-02	Landsat 7 ETM+
2016	2016-JUL-05 2016-JUL-21	Landsat 7 ETM+
2018	2018-JUL-11 2018-JUL-27	Landsat 7 ETM+

Resolution:
30 m (~0.1 HA)

- **Landsat scenes used to represent the 11 years post fire (2007 - 2018)**
- **Years 2015 and 2017 are missing due to cloud-free data availability**

Forest Structure Classification Analysis: Model Results

- Model Out of Bag Error Rates (OBO) were 10.01% (2007) and 9.76% (2018) respectively

Predictor Variable Rank	2007 Model	2018 Model
1	(NDVI-SAVI)	(NDVI-SAVI)
2	TM Band 3 (Red)	ETM+ Band 7 (SWIR)
3	TM Band 2 (Green)	ETM+ Band 3 (Red)
4	TM Band 4 (NIR)	% Canopy 0.15-0.5m
5	TM Band 5 (SWIR)	ETM+ Band 2 (Green)

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