California Department of Conservation

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Abstract #383259

STORM INDUCED MASS WASTING ON DISTURBED SLOPES ACROSS A THIRTY-FOUR YEAR TIMELINE

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Over decades, the Eldorado National Forest landscapes have experienced multiple disturbances including numerous events of wildfires, flooding, atmospheric river drenching, and rapid snowmelt which have promoted landslide activity over a palimpsest of forest management activities and post-fire recovery.

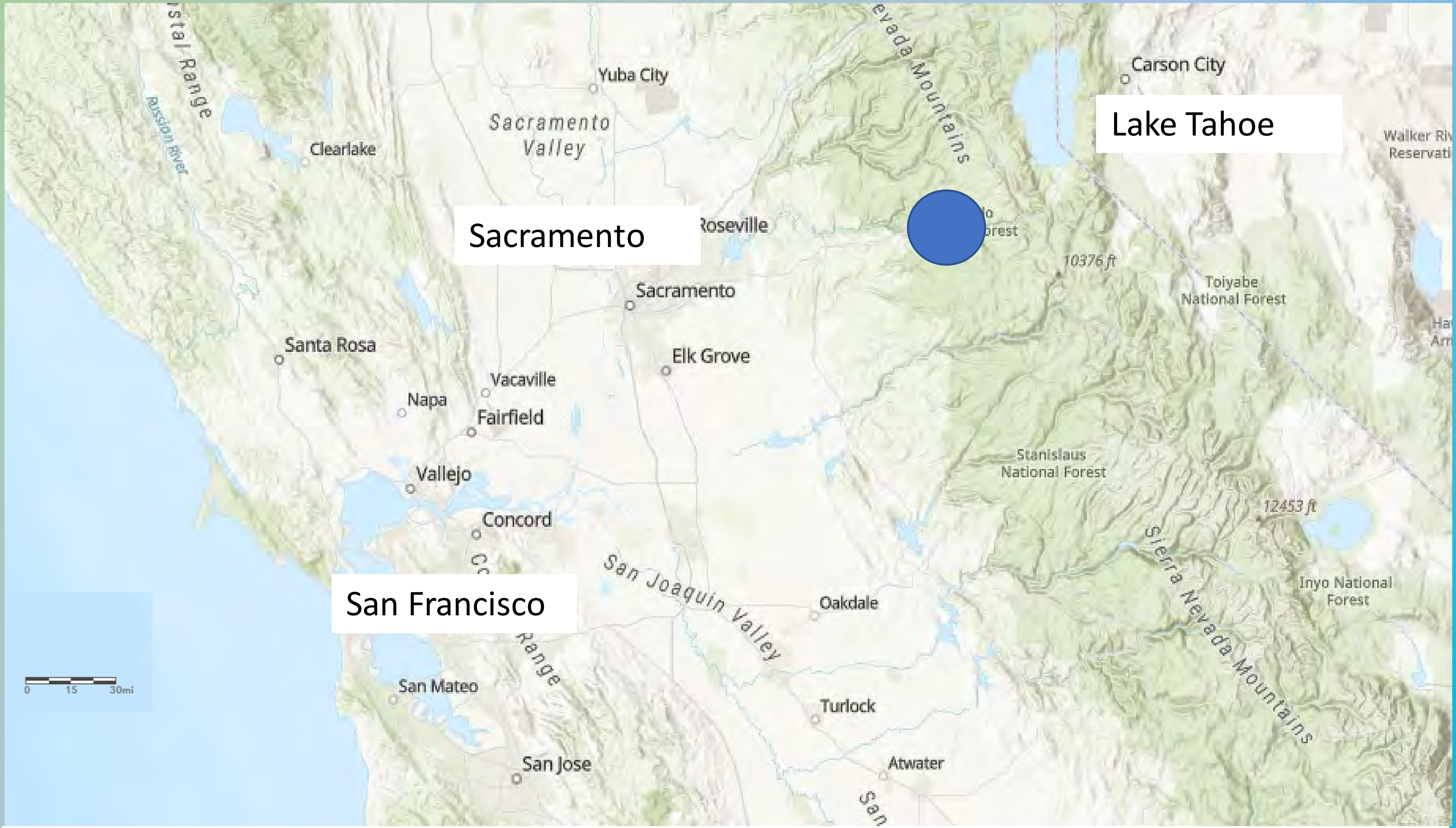
Partners

- California Board of Forestry
- Eldorado National Forest
- The Sierra Nevada Conservancy
- CalFire
- US Geological Survey

Goals

Map storm-induced geomorphic activity using a time series of Lidar

Compare that activity to postfire vegetation conditions


Lake Tahoe
Sacramento
San Francisco
Carson City
Yuba City
Sacramento Valley
Clearlake
Russian River
Roseville
Sacramento
Elk Grove
Santa Rosa
Vacaville
Napa
Fairfield
Vallejo
Concord
San Joaquin Valley
Oakdale
Turlock
Atwater
San Mateo
San Jose
10376 ft
Toiyabe National Forest
Stanislaus National Forest
12453 ft
Sierra Nevada Mountains
Inyo National Forest
0 15 30mi

Study Area

Upper SF American River

Key Events

Year	Event
1992	Cleveland Fire
2004	Freds Fire
2013	Kyburz Fire
2014	Lidar, & Canopy Density
2017	**Storms & Landslides**
2019	Lidar & Dod

Antecedent Events

Reference Year

Data Campaigns

Key Events

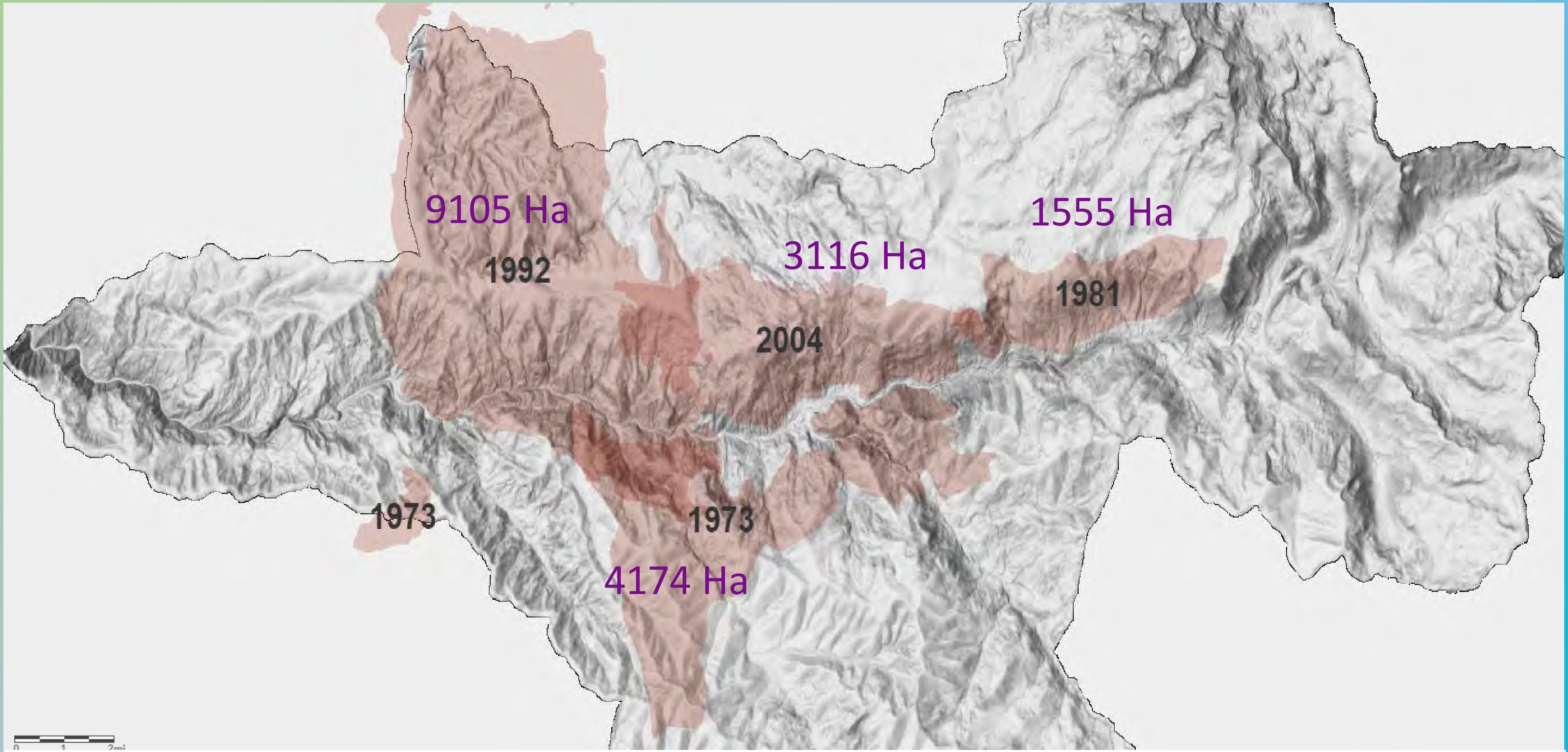
Year	Event
1992	Cleveland Fire
2004	Freds Fire
2013	Kyburz Fire
2014	Lidar, & Canopy Density
2017	**Storms & Landslides**
2019	Lidar & Dod

Antecedent Events (1992–2013)

Reference Year (2017)

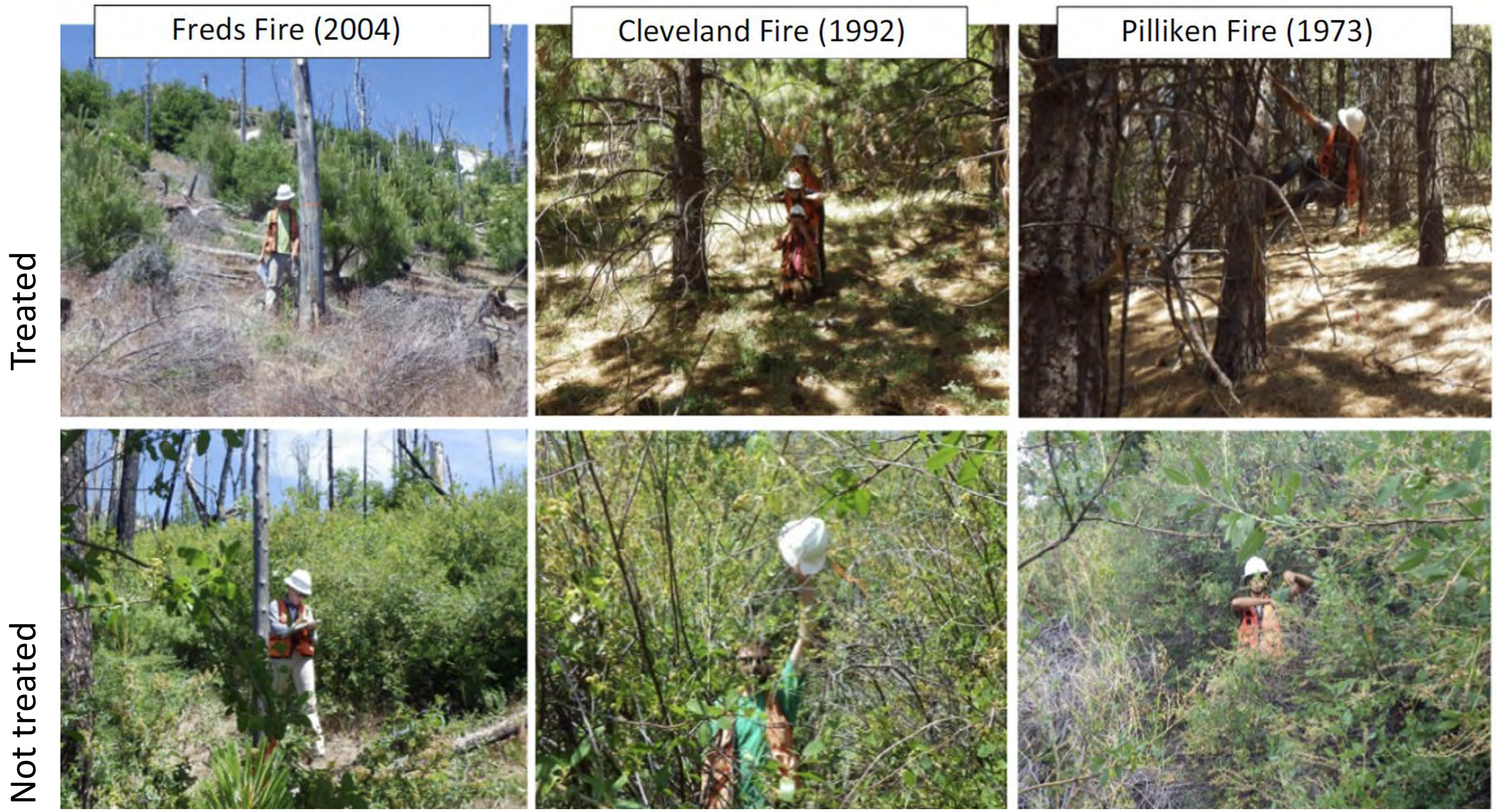
Data Campaigns (2014–2019)

Wildfires



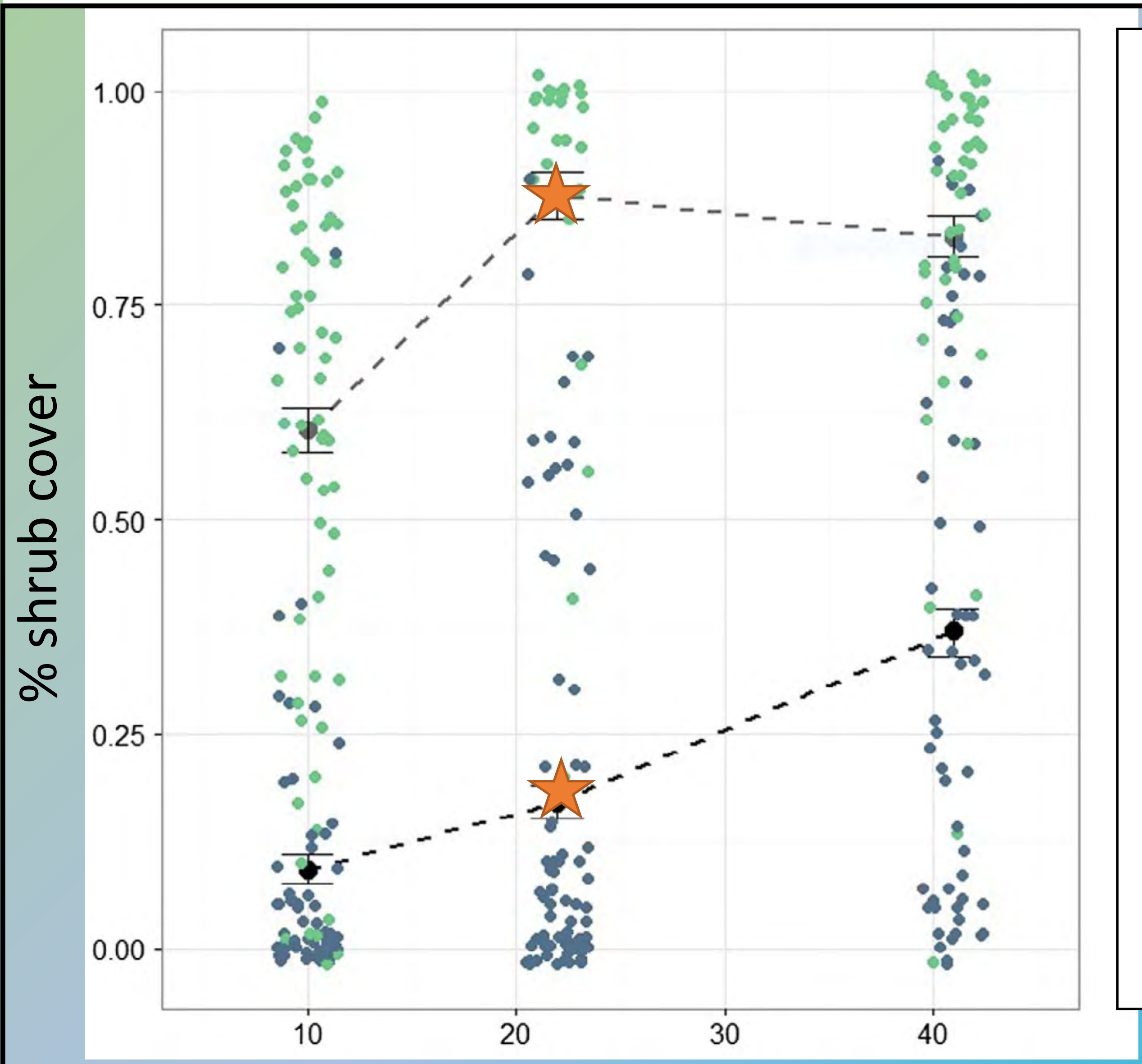
Stand-replacing Fires

Canopy Density (CD)



Field Photos from Bolman et al., 2016

Vegetation Plot Data



Years since fire

Legend

- Threshold
- Plots – not treated
- Plots – treated
- Predicted median – untreated
- Predicted median - treated

Modified from Bolman et al., 2016

The Crystal Range – Headwaters of the SF American River

Snowpack in the SF American River Headwaters

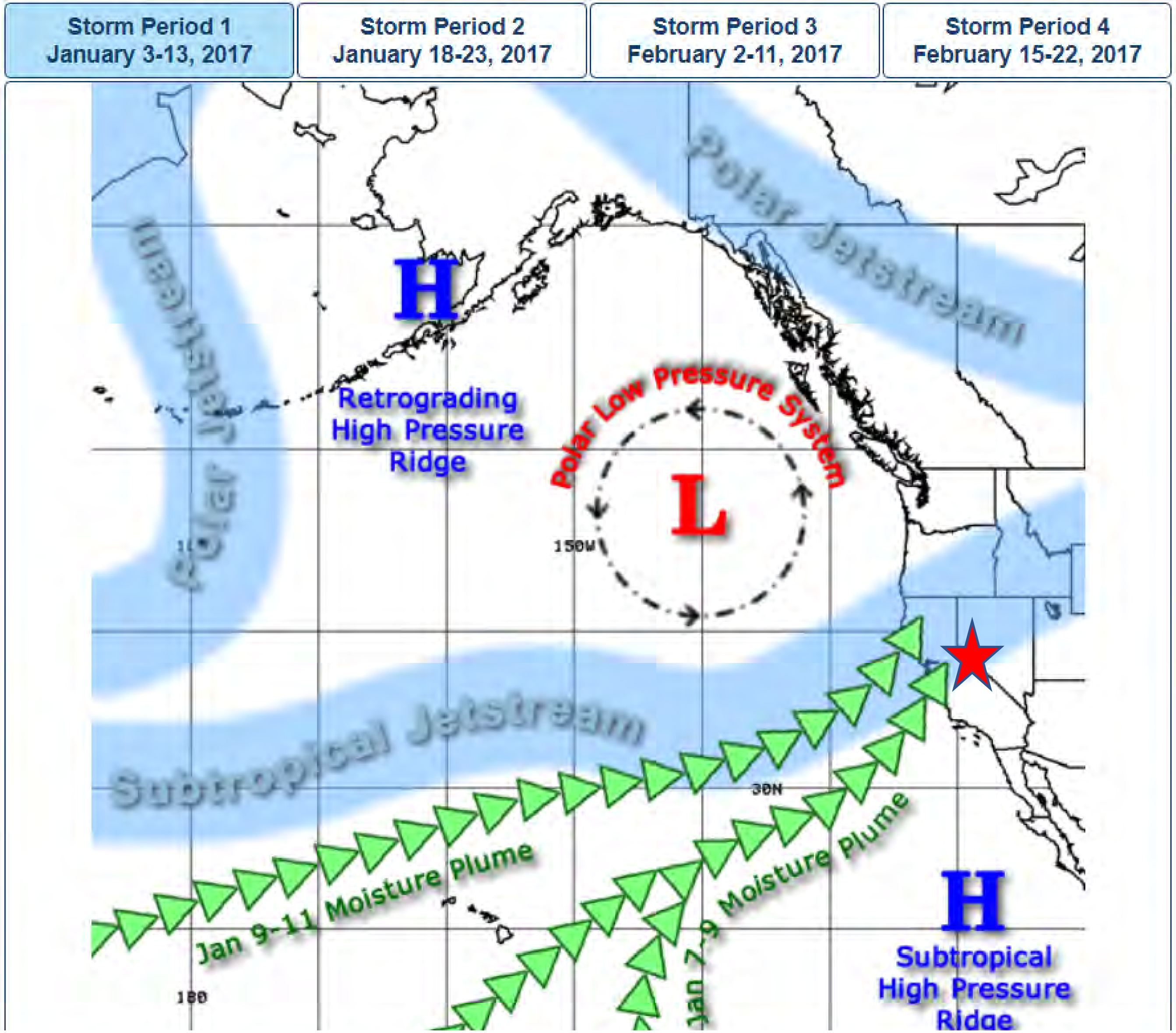
The Washington Post
Democracy Dies in Darkness

After 63 feet of snow, Northern California mountains break record for wettest water year

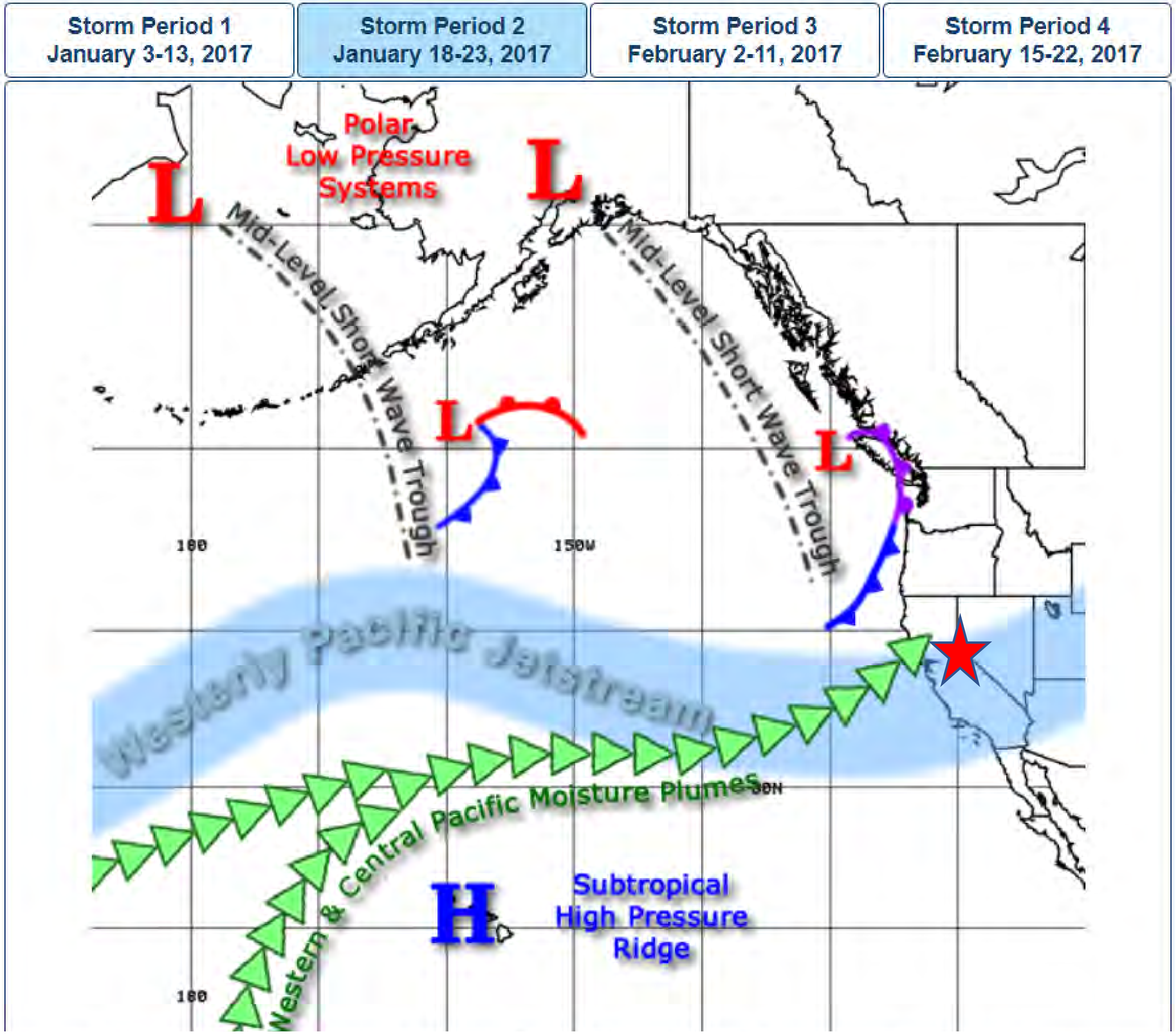
By Jason Samenow

April 13, 2017 at 3:46 p.m. EDT

Annual Measurement of Snowpack in 2017

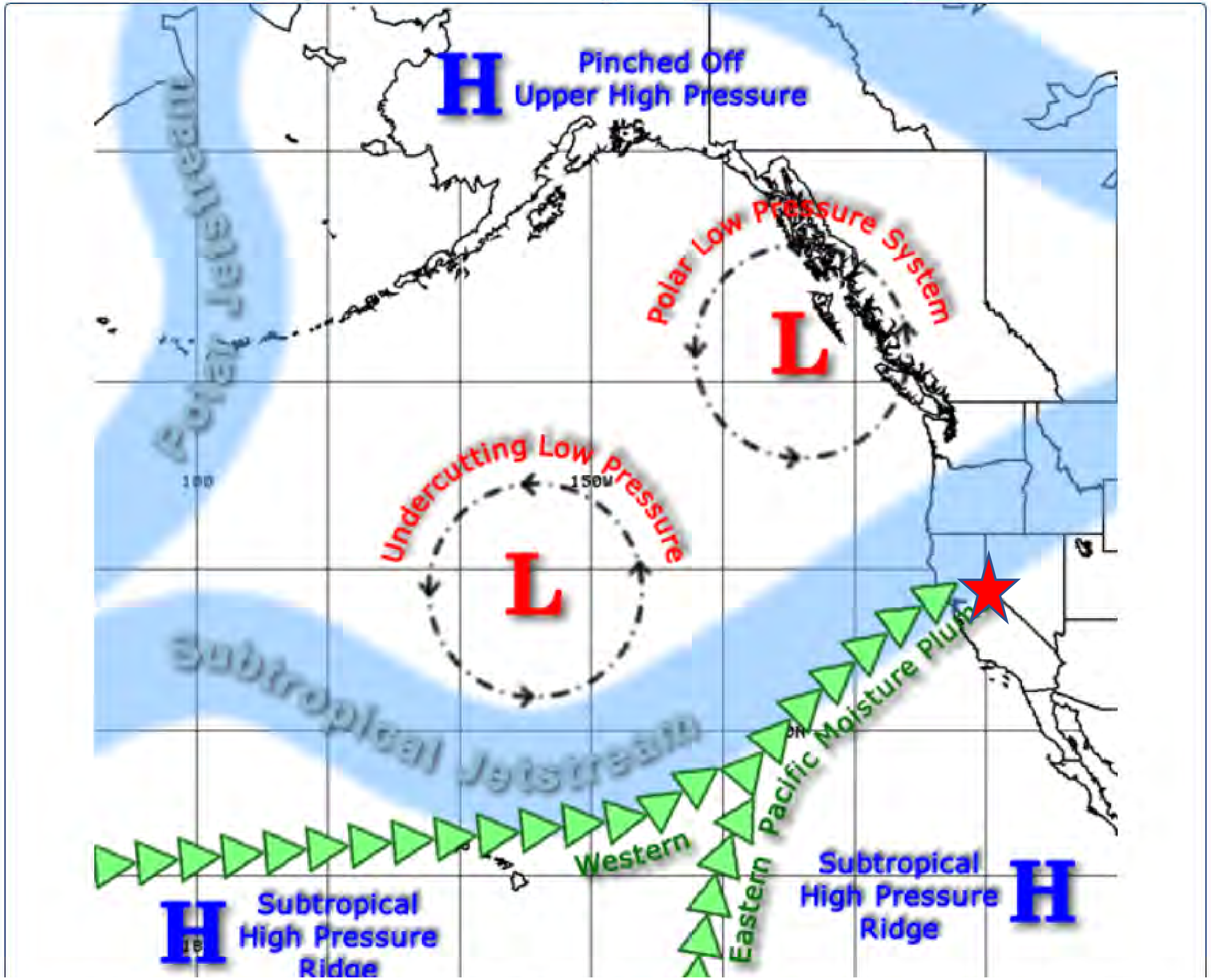

Storm Period 1
January 3-13, 2017
Storm Period 2
January 18-23, 2017
Storm Period 3
February 2-11, 2017
Storm Period 4
February 15-22, 2017
Polar Jetstream
Polar Jetstream
H
Retrograding
High Pressure
Ridge
Polar Low Pressure System
L
150W
Subtropical Jetstream
30N
Jan 9-11 Moisture Plume
Jan 7-9 Moisture Plume
180
H
Subtropical
High Pressure
Ridge

Storm 1


Storm Period 1
January 3-13, 2017
Storm Period 2
January 18-23, 2017
Storm Period 3
February 2-11, 2017
Storm Period 4
February 15-22, 2017
Polar
Low Pressure
Systems
L
L
Mid-Level Short Wave Trough
L
Mid-Level Short Wave Trough
L
180
150W
Westerly Pacific Jetstream
Western & Central Pacific Moisture Plumes
30N
H
Subtropical
High Pressure
Ridge
180

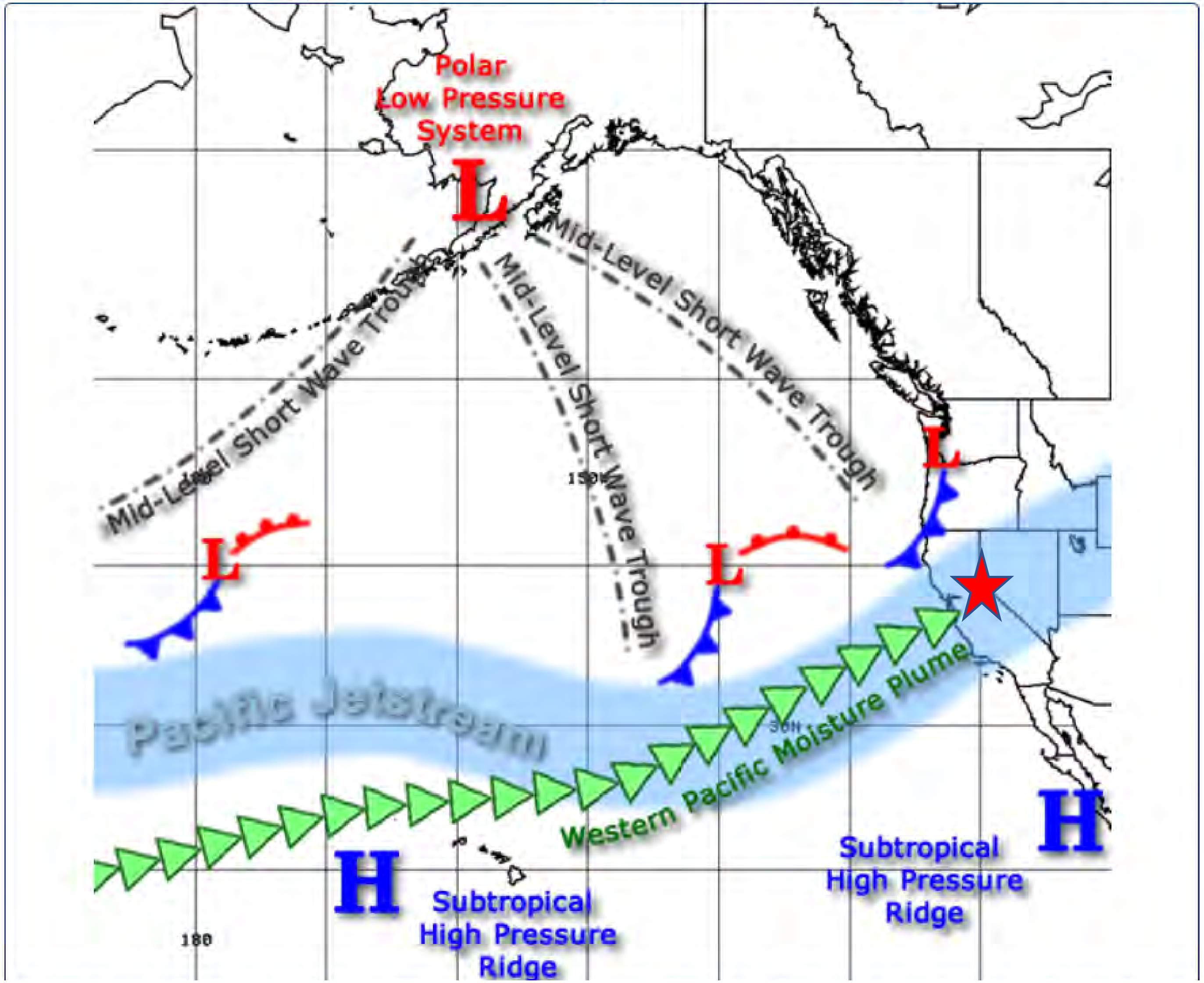
Storm 2

Storm Period 1 January 3-13, 2017	Storm Period 2 January 18-23, 2017	Storm Period 3 February 2-11, 2017	Storm Period 4 February 15-22, 2017

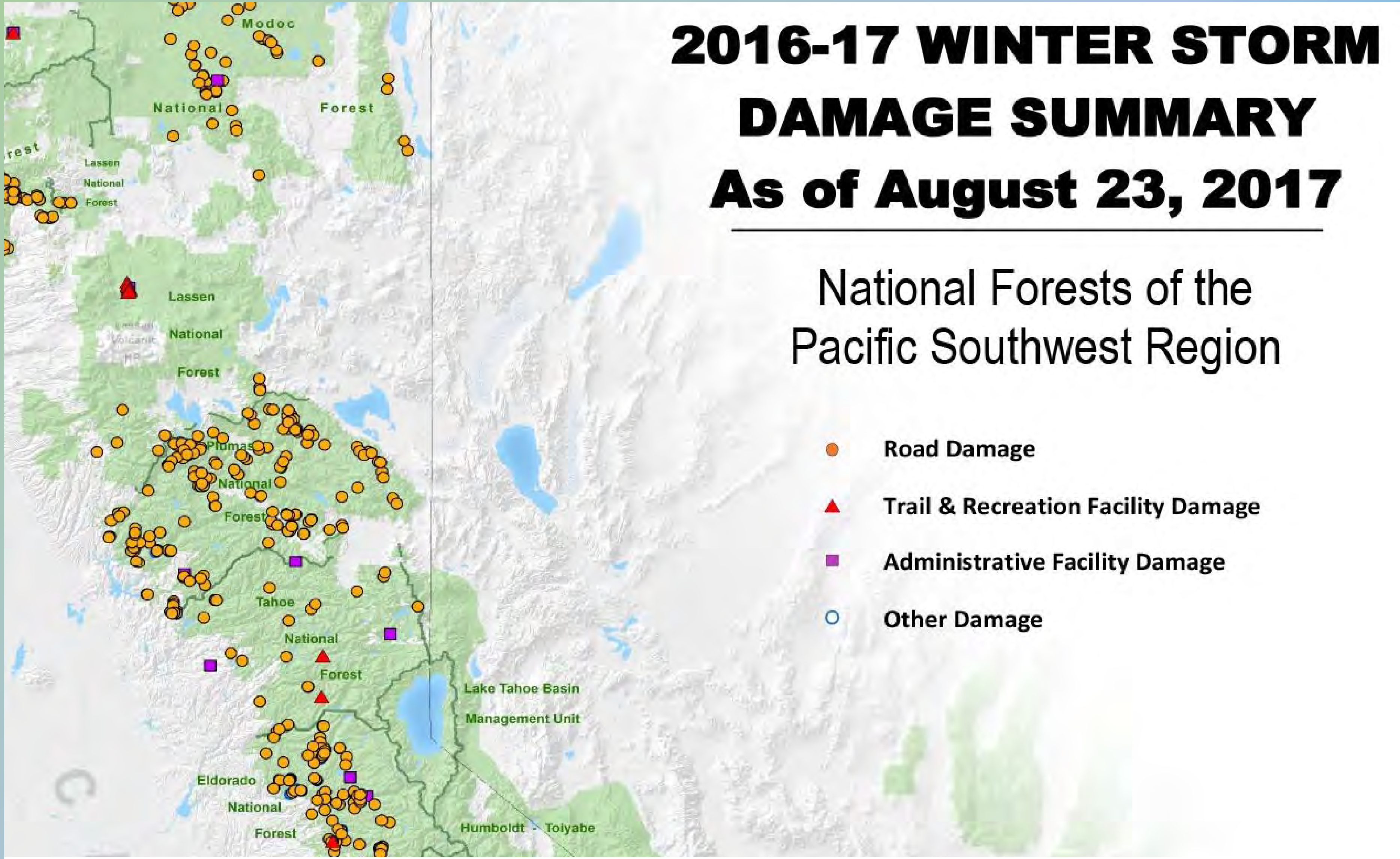


Storm 3

Storm Period 1	Storm Period 2	Storm Period 3	Storm Period 4
January 3-13, 2017	January 18-23, 2017	February 2-11, 2017	February 15-22, 2017



Storm 4



Storm Damage

Methods

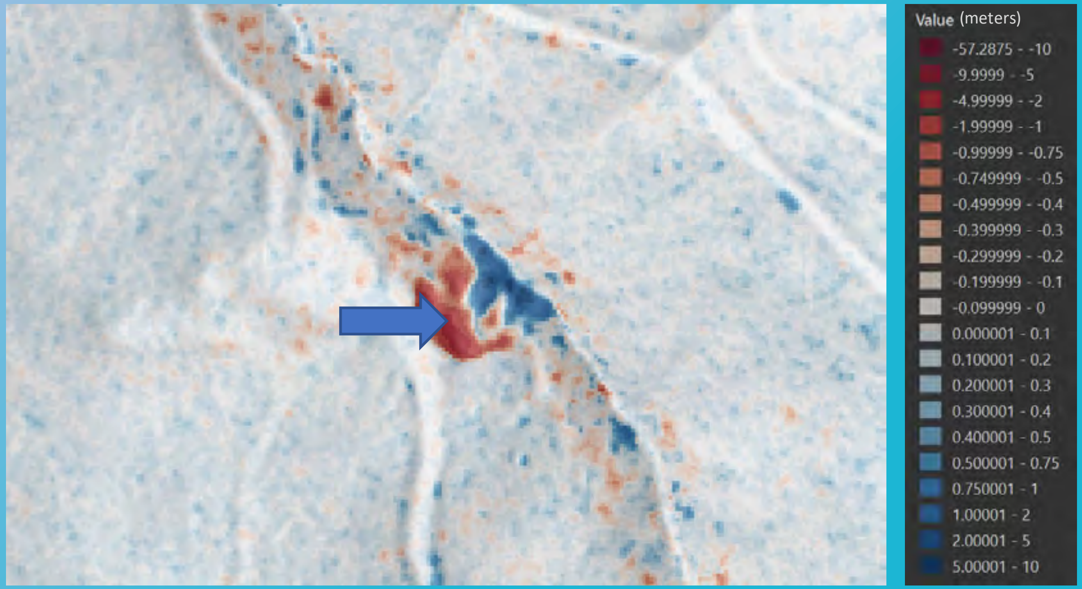
- DEM of Difference
- Potential Geomorphic Features (PGF)
- Canopy density
- PGF density determination
- Fire perimeters and soil burn severity

Lidar Datasets

Time Frame	Dataset	QL	Collection Dates	DEM Post Spacing
Pre-storm	USFS Pacific Southwest Region Lidar *	1	10/2014 – 06/2015	1 m
Post-storm	CA_UpperSouthAmerican_2019_B19	1	10/2019 – 03/2020	1 m

* Provided by USFS Region 5 Remote Sensing Lab

- Source lidar datasets first converted to common coordinate system, geoid, cell size
- DoD (DEM of Difference) created by subtracting 2014 lidar from 2019 lidar



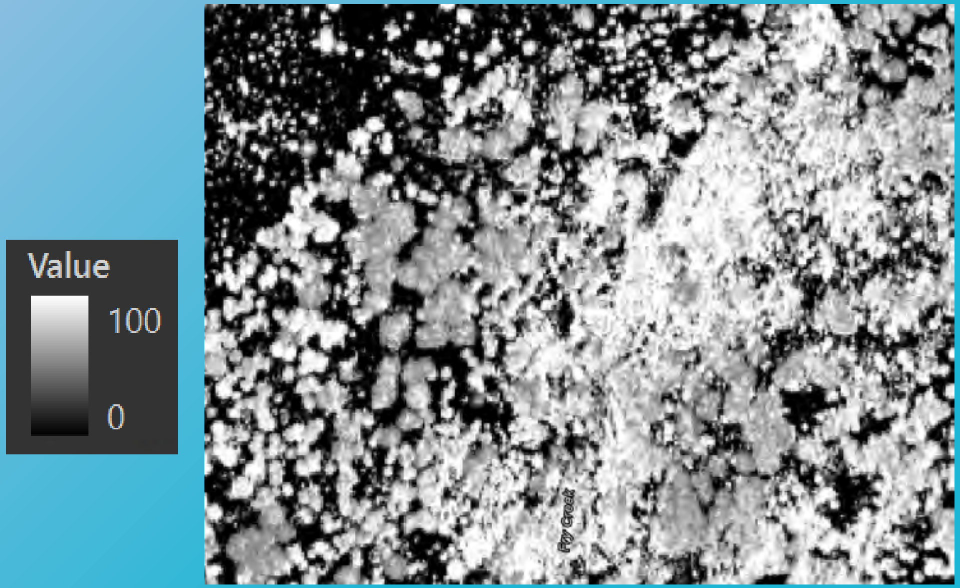
Canopy Density Layer

- Produced by USFS Region 5 Remote Sensing Lab using pre-storm lidar data covering Freds Fire area

- For each 1 m^2 cell, the Canopy Density calculation is the ratio of:

$$\frac{\text{all returns 1 meter or higher above bare earth}}{\text{all returns above bare earth}}$$

In other words, the ratio of canopy (between 0 and 100) that sits 1 or more meters above the bare earth surface.



Results

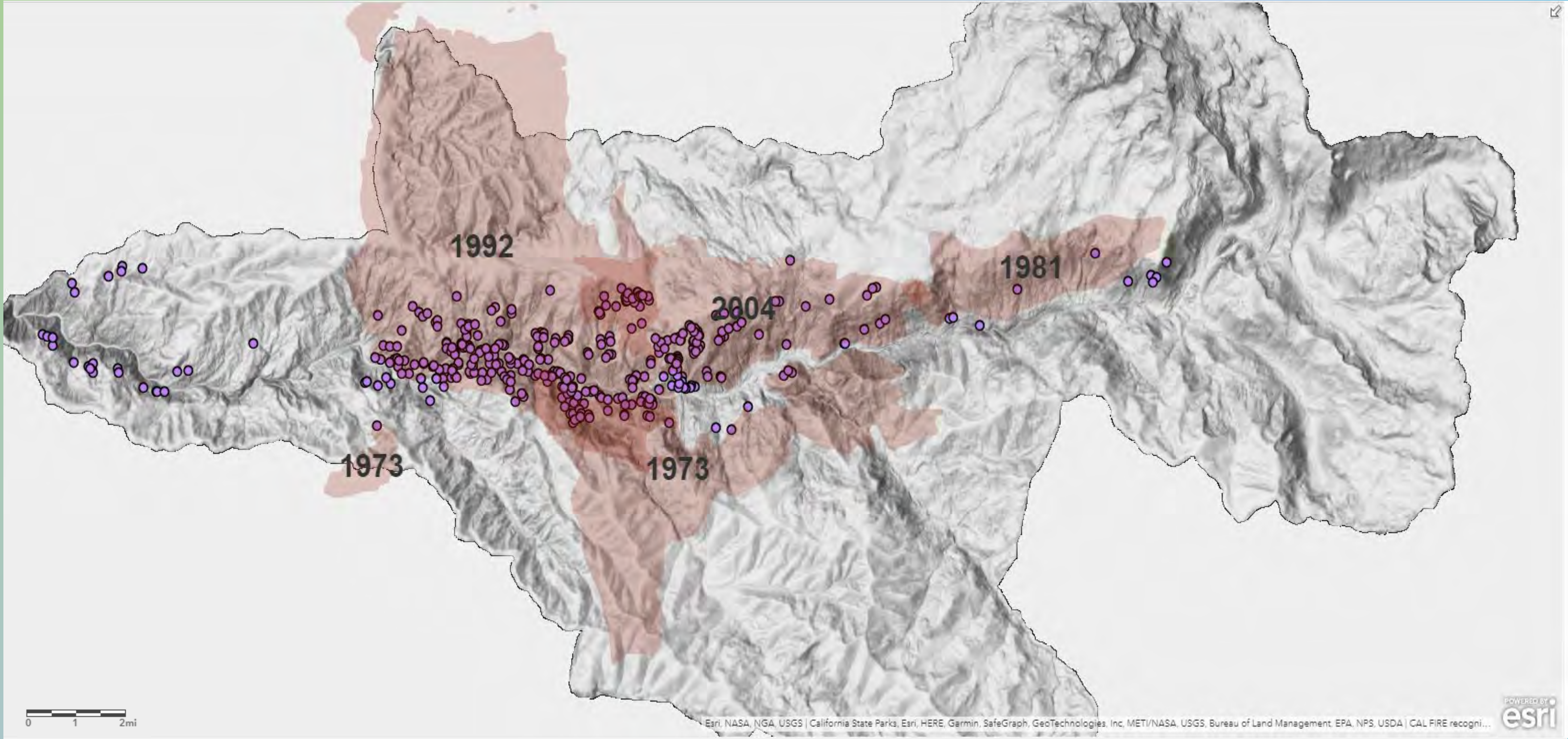
Pearson correlation coefficient = 0.61

PGF distribution

Vegetation Recovery

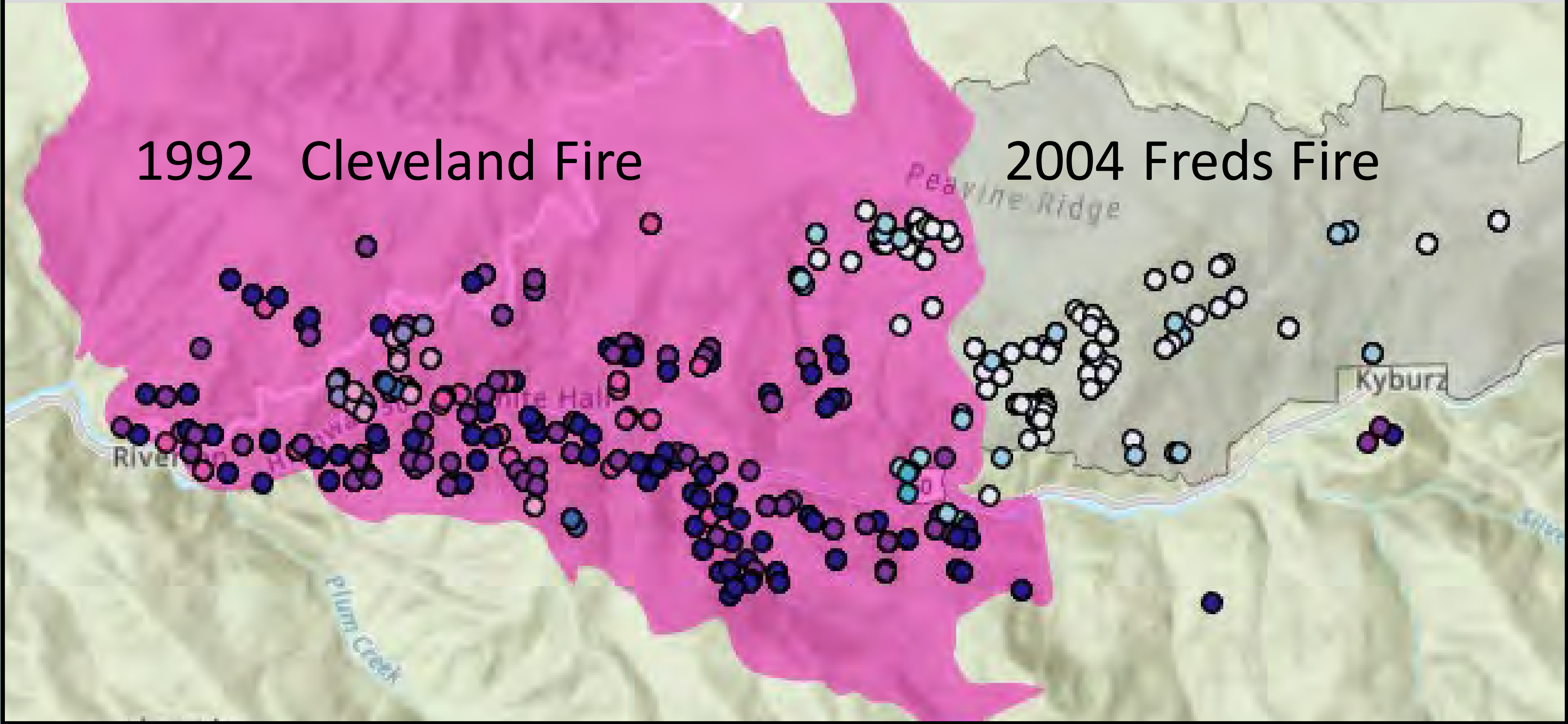
Postfire landslide susceptibility

Possible Thresholds



Potential Geomorphic Features (PGF) and Fire Scarred Areas

Potential Geomorphic Features & Canopy Density

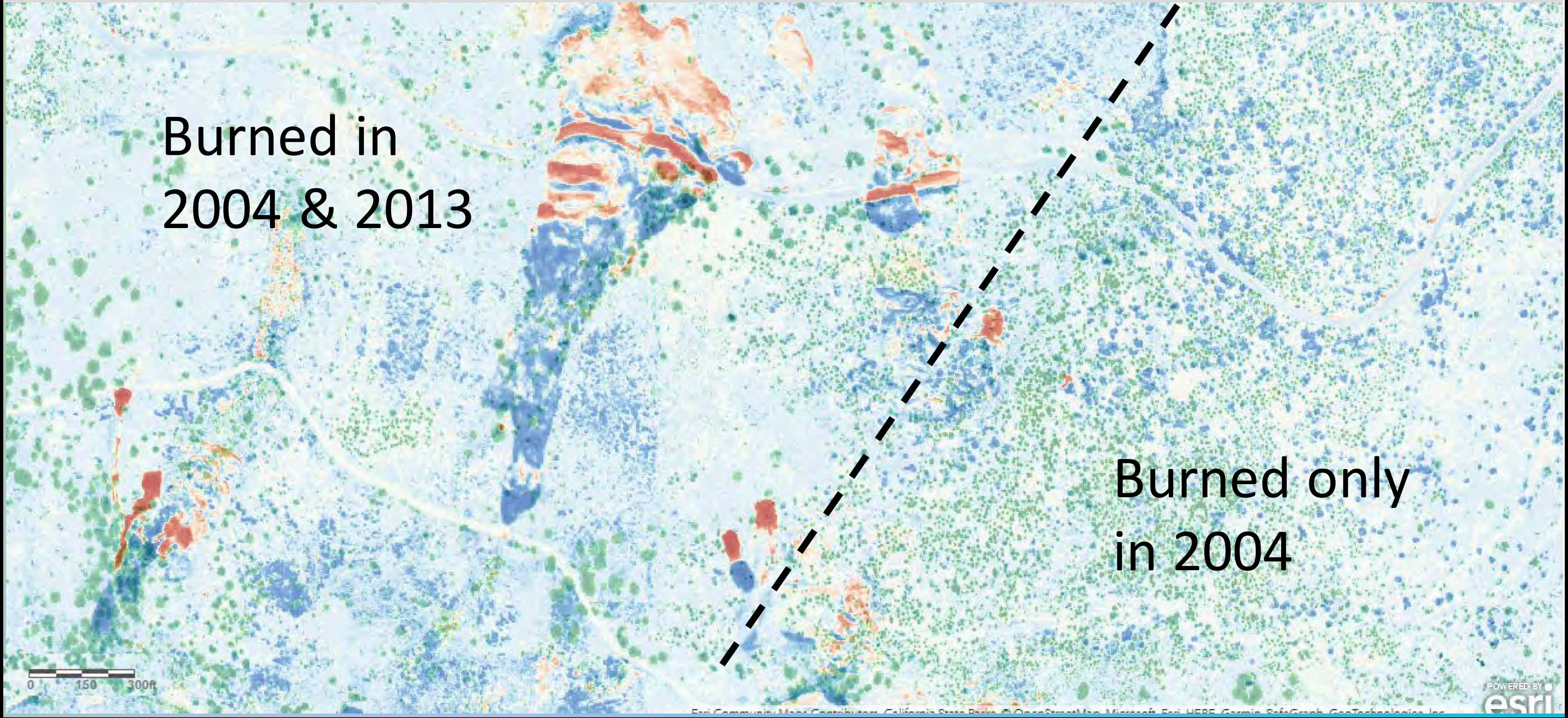


COLOR LEGEND

Old burn
Sparse Dense
Vegetation

Young burn
Sparse Dense
Vegetation

Canopy Density & Elevation Change

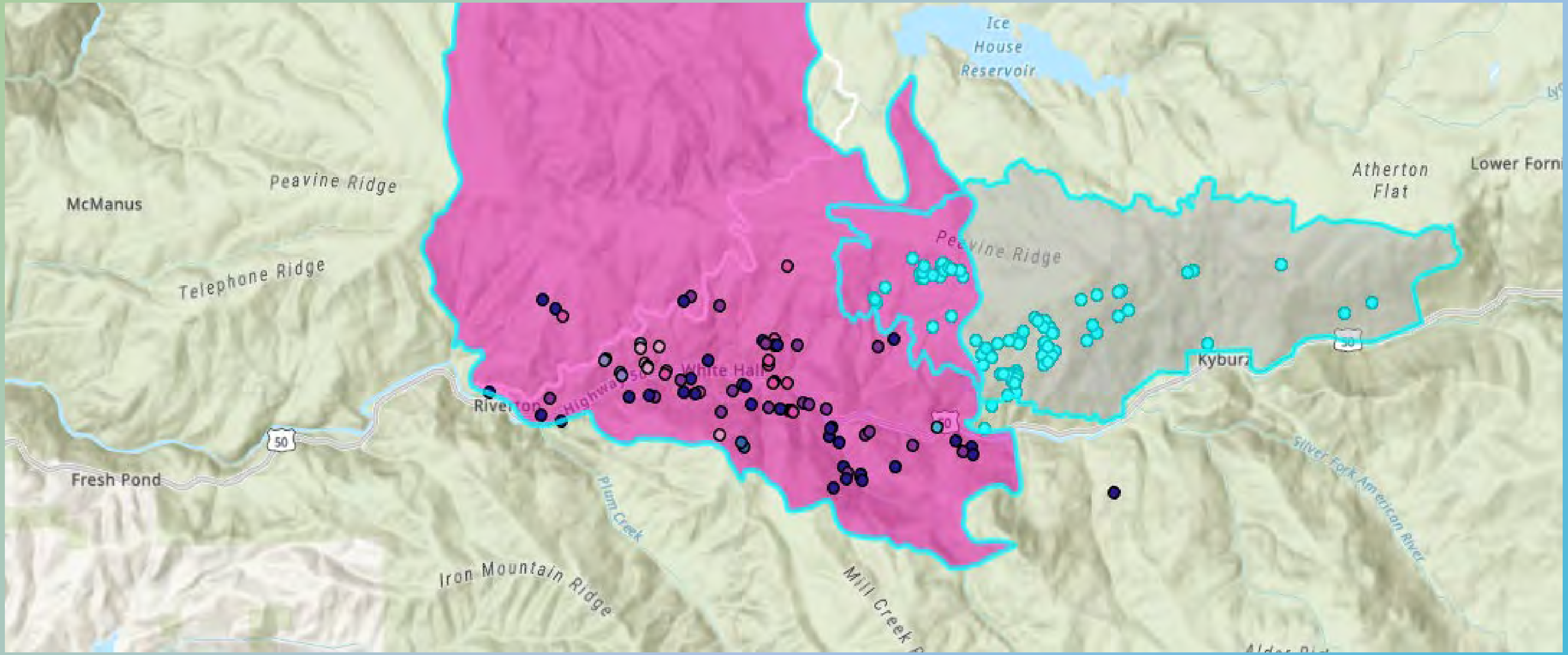


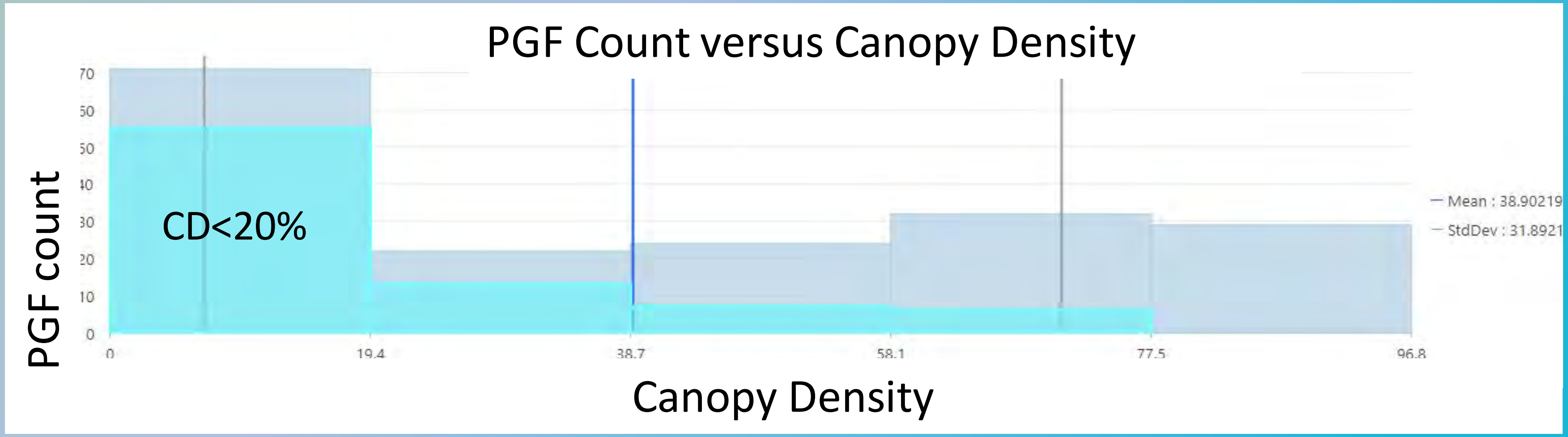
COLOR LEGEND

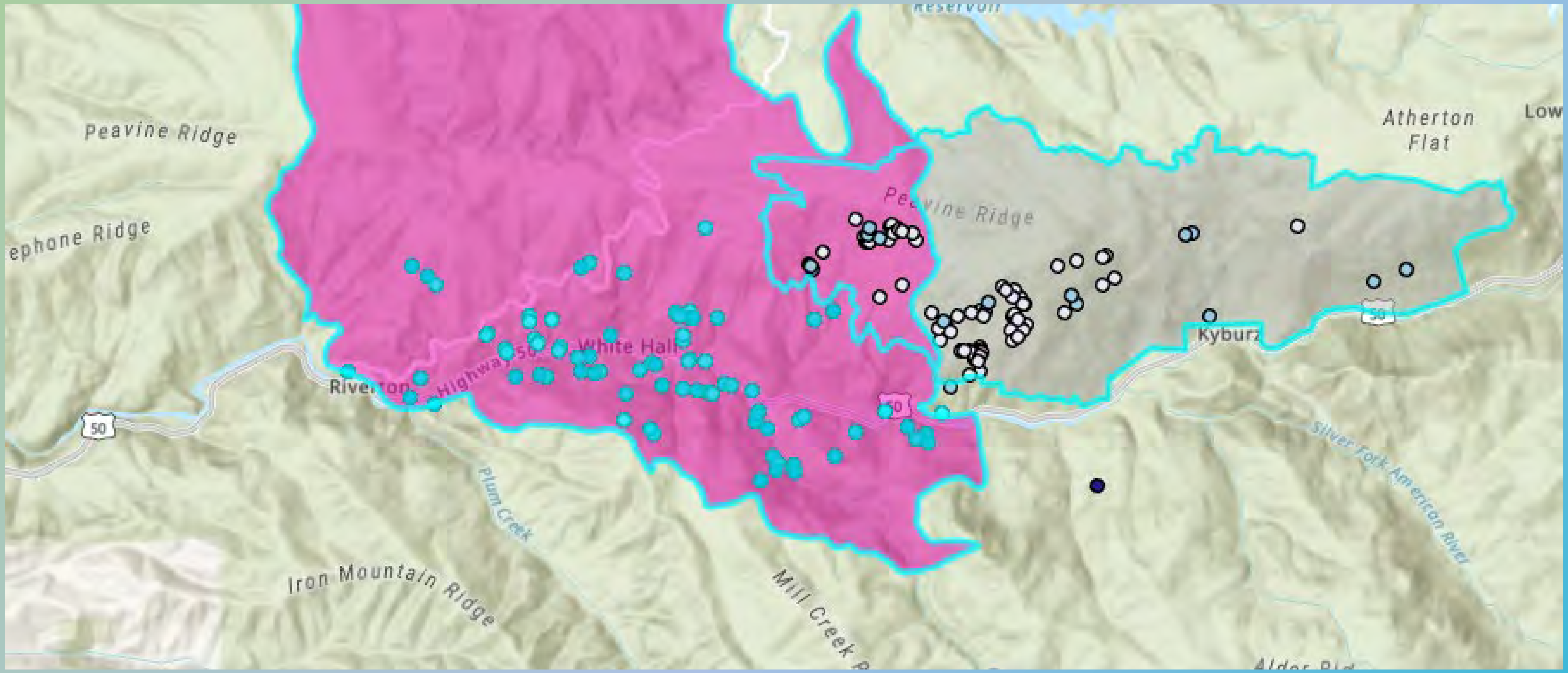
Elevation Change
Negative Positive

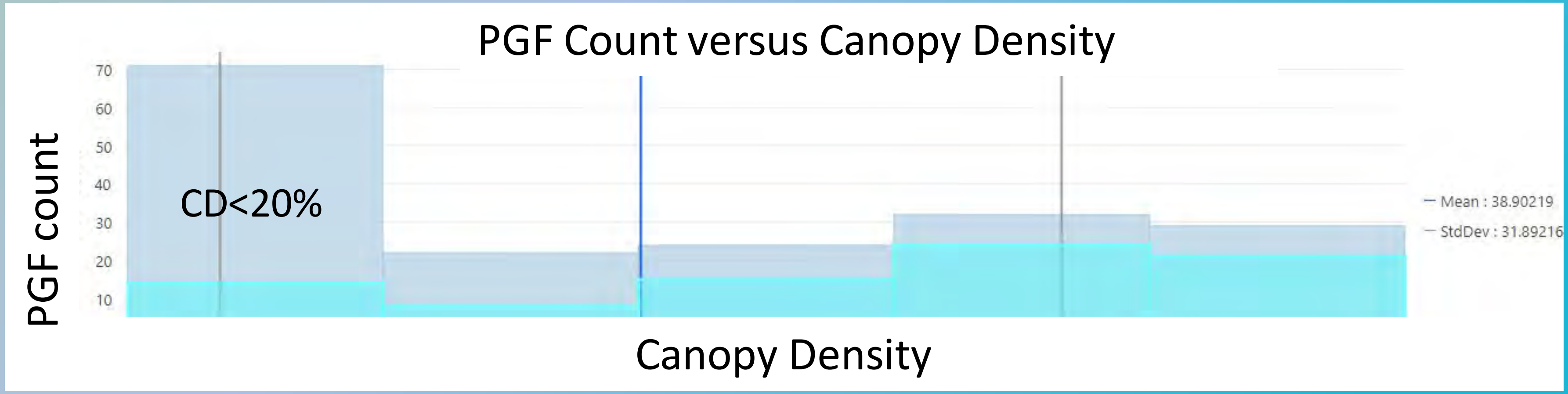
Canopy Density
Sparse Dense

Granite Springs Road

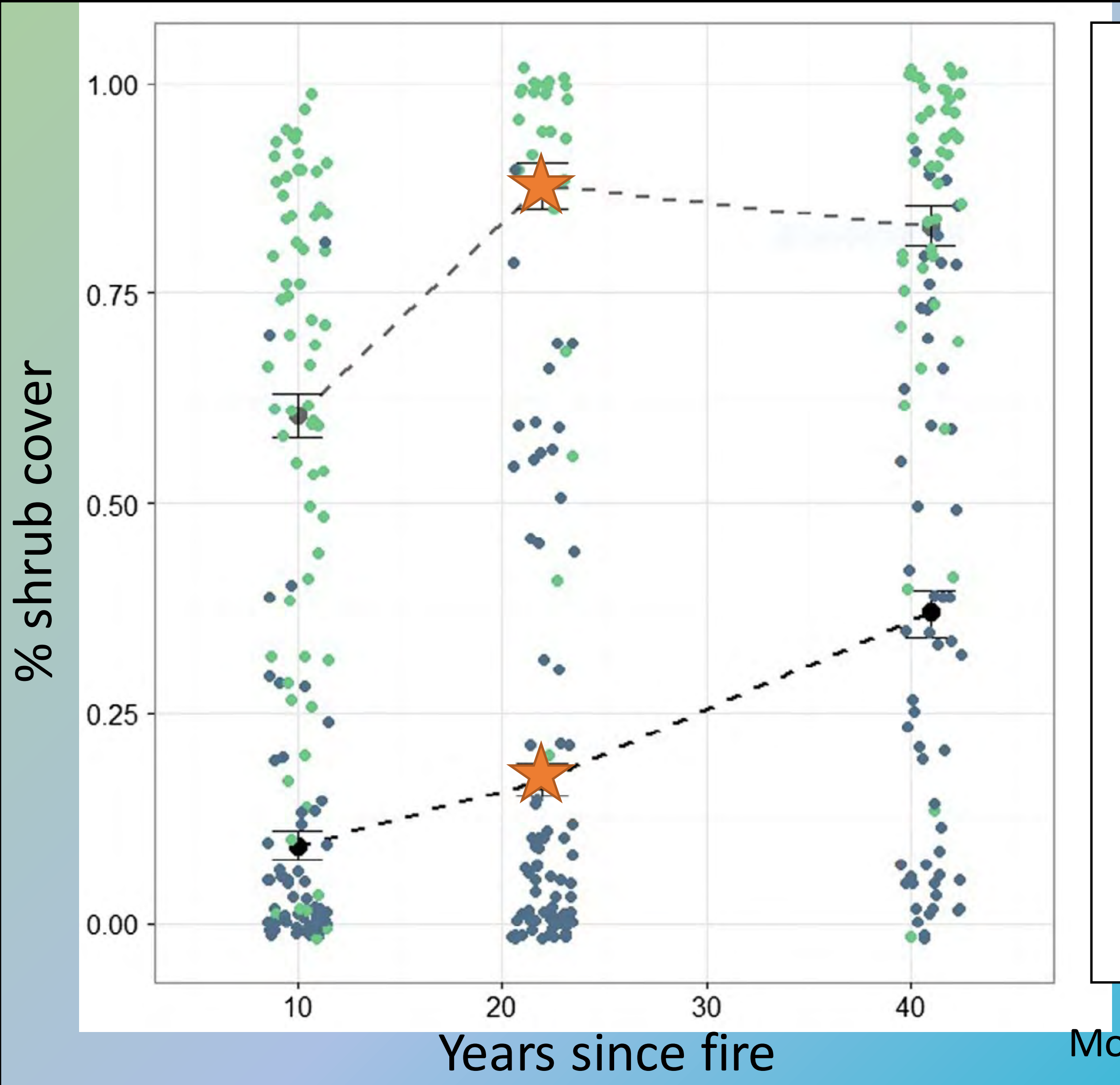

Ice
House
Reservoir
Peavine Ridge
McManus
Telephone Ridge
Peavine Ridge
Atherton
Flat
Lower Forni
Kyburz
White Hall
Riverton
50
Fresh Pond
Plum Creek
Iron Mountain Ridge
Mill Creek
Silver Fork American River


PGF Count versus Canopy Density
PGF count
CD<20%
Mean : 38.90219
StdDev : 31.8921
0
19.4
38.7
58.1
77.5
96.8
Canopy Density


Peavine Ridge
ephone Ridge
Atherton Flat
Low
Peavine Ridge
White Hall
Riverton
Highway 50
Kyburz
50
Plum Creek
Iron Mountain Ridge
Mill Creek
Silver Fork American River


PGF Count versus Canopy Density
PGF count
Canopy Density
CD<20%
70
60
50
40
30
20
10
Mean : 38.90219
StdDev : 31.89216

Vegetation Plot Data

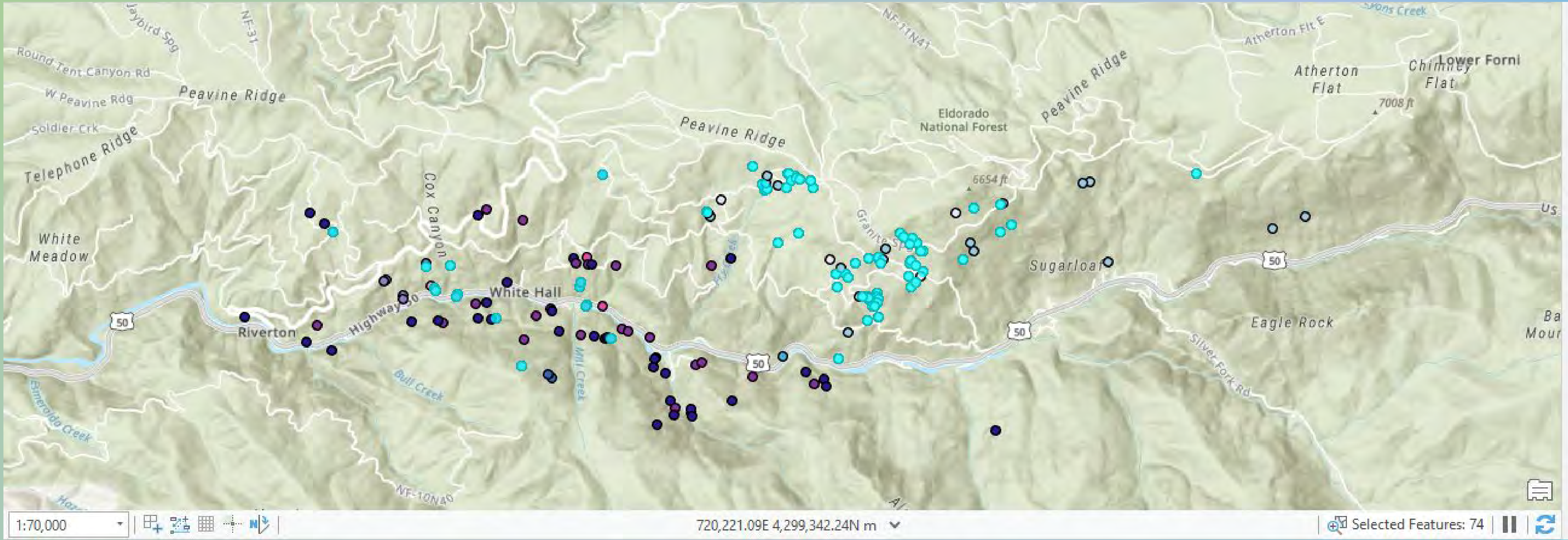


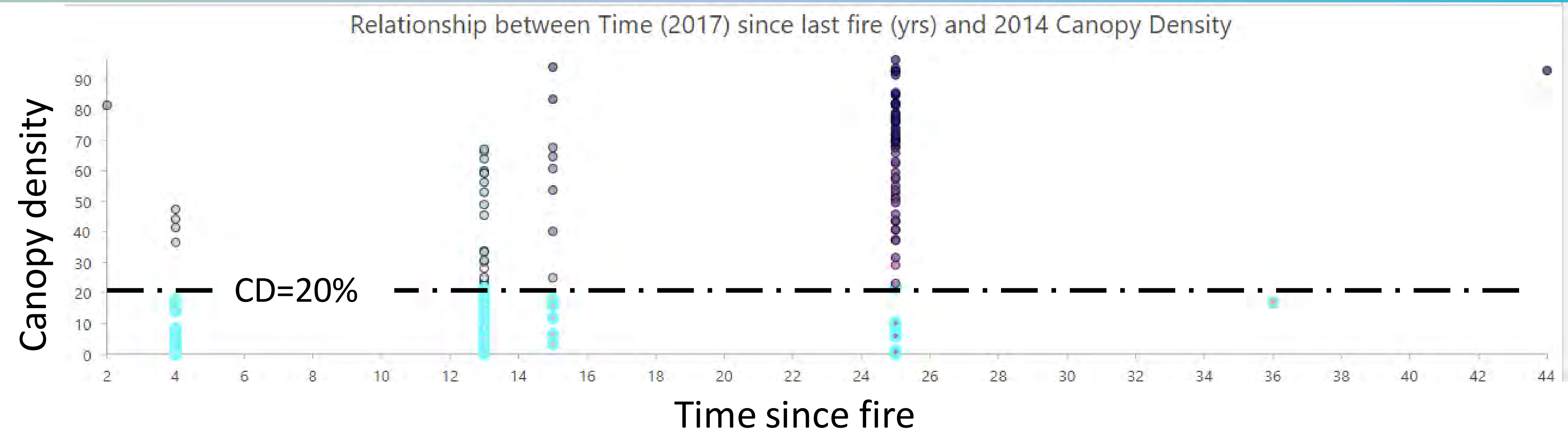
Legend

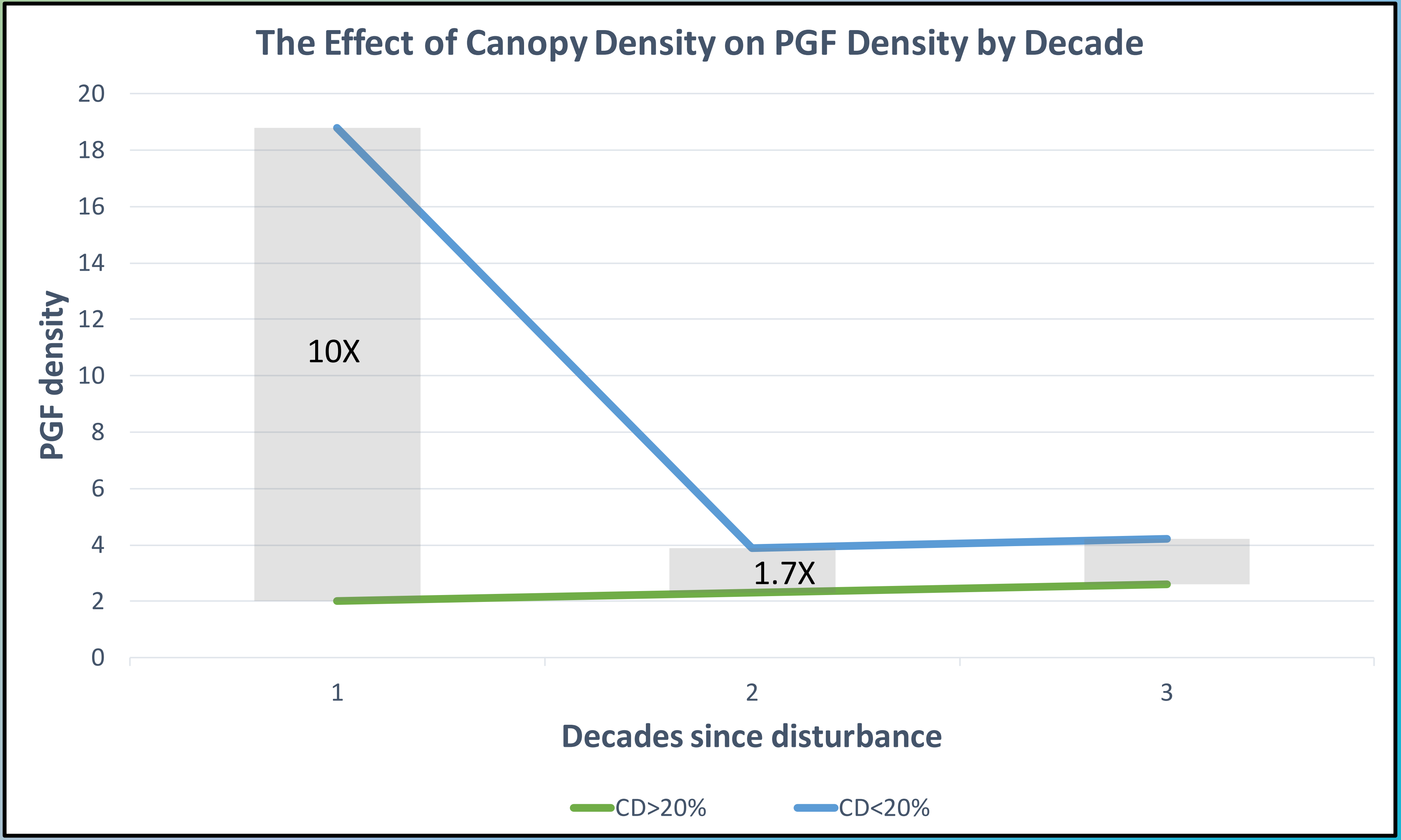
- Threshold
- Plots – not treated
- Plots – treated
- Predicted median – untreated
- Predicted median - treated

Below threshold areas showed:
10X more PGFs in 1st decade,
1.7X in decades 2 and 3.

Modified from Bolman et al., 2016


Round Tent Canyon Rd
W Peavine Rdg
Soldier Crk
Telephone Ridge
Peavine Ridge
White Meadow
Riverton
Highway 50
White Hall
Cox Canyon
Bull Creek
Peavine Ridge
Eldorado National Forest
Peavine Ridge
6654 ft
Sugarloaf
Atherton Flt E
Atherton Flat
Chimney Flat
Lower Forni
7008 ft
Eagle Rock
Silver Fork Rd
50
1:70,000
720,221.09E 4,299,342.24N m
Selected Features: 74


Relationship between Time (2017) since last fire (yrs) and 2014 Canopy Density
Canopy density
0
10
20
30
40
50
60
70
80
90
CD=20%
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
Time since fire



The Effect of Canopy Density on PGF Density by Decade
PGF density
20
18
16
14
12
10
8
6
4
2
0
10X
1.7X
1
2
3
Decades since disturbance
CD>20%
CD<20%

Conclusions

PGF density was highest where canopy density was less than 20% ***which in reforested areas lasted for 20 years****.*

During this prolonged recovery period, the 2017 storms hit while canopy density remained below the ***geomorphic threshold****.*

Conclusions

The Sierra Nevada are prone to natural disasters which combine to increase landslide susceptibility.

Shrub reduction affected slope stability for decades, especially in the 1st decade.

Pairing the DoD with CD provided insight into post-disturbance vegetation recovery and slope stability.

Societal Significance

Extreme storms and wildfires are on the rise.

Due to megafire, enormous investments are underway to modify forest conditions.

Projects should consider landslide susceptibility and this newly recognized geomorphic threshold.