Climate Change and Implications for Forest Restoration:
Creating a Resilient Landscape

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## Top 20 Largest California Wildfires

<table>
<thead>
<tr>
<th>FIRE NAME (CAUSE)</th>
<th>DATE</th>
<th>COUNTY</th>
<th>ACRES</th>
<th>STRUCTURES</th>
<th>DEATHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MENDOCINO COMPLEX (Under Investigation)</td>
<td>July 2018</td>
<td>Colusa County, Lake County, Mendocino County &amp; Glenn County</td>
<td>459,123</td>
<td>280</td>
<td>1</td>
</tr>
<tr>
<td>THOMAS (Powerlines)</td>
<td>December 2017</td>
<td>Ventura &amp; Santa Barbara</td>
<td>281,893</td>
<td>1,063</td>
<td>2</td>
</tr>
<tr>
<td>CEDAR (Human Related)</td>
<td>October 2003</td>
<td>San Diego</td>
<td>273,246</td>
<td>2,820</td>
<td>15</td>
</tr>
<tr>
<td>RUSH (Lightning)</td>
<td>August 2012</td>
<td>Lassen</td>
<td>271,911 CA / 43,666 NV</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>RIM (Human Related)</td>
<td>August 2013</td>
<td>Tuolumne</td>
<td>257,314</td>
<td>112</td>
<td>0</td>
</tr>
<tr>
<td>ZACA (Human Related)</td>
<td>July 2007</td>
<td>Santa Barbara</td>
<td>240,207</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>CARR (Human Related)</td>
<td>July 2018</td>
<td>Shasta County, Trinity County</td>
<td>229,651</td>
<td>1,614</td>
<td>8</td>
</tr>
<tr>
<td>MATILIA (Undetermined)</td>
<td>September 1932</td>
<td>Ventura</td>
<td>220,000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WITCH (Powerlines)</td>
<td>October 2007</td>
<td>San Diego</td>
<td>197,990</td>
<td>1,650</td>
<td>2</td>
</tr>
<tr>
<td>KLAMATH THEATER COMPLEX (Lightning)</td>
<td>June 2008</td>
<td>Siukiyour</td>
<td>192,038</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>MARBLE CONE (Lightning)</td>
<td>July 1977</td>
<td>Monterey</td>
<td>177,866</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LAGUNA (POWERLINES)</td>
<td>September 1970</td>
<td>San Diego</td>
<td>175,425</td>
<td>382</td>
<td>5</td>
</tr>
<tr>
<td>BASIN COMPLEX (Lightning)</td>
<td>June 2008</td>
<td>Monterey</td>
<td>162,818</td>
<td>58</td>
<td>0</td>
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<tr>
<td>DAY FIRE (Human Related)</td>
<td>September 2006</td>
<td>Ventura</td>
<td>162,702</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>STATION (Human Related)</td>
<td>August 2009</td>
<td>Los Angeles</td>
<td>160,557</td>
<td>209</td>
<td>2</td>
</tr>
<tr>
<td>CAMP FIRE (Powerlines)</td>
<td>November 2018</td>
<td>Butte</td>
<td>153,336</td>
<td>18,804</td>
<td>85</td>
</tr>
<tr>
<td>ROUGH (Lightning)</td>
<td>July 2015</td>
<td>Fresno</td>
<td>151,623</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>McNALLY (Human Related)</td>
<td>July 2002</td>
<td>Tulare</td>
<td>150,696</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>STANISLAUS COMPLEX (Lightning)</td>
<td>August 1987</td>
<td>Tuolumne</td>
<td>145,980</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td>BIG BAR COMPLEX (Lightning)</td>
<td>August 1999</td>
<td>Trinity</td>
<td>140,948</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*There is no doubt that there were fires with significant acreage burned in years prior to 1932, but those records are less reliable, and this list is meant to give an overview of the large fires in more recent times.

**This list does not include fire jurisdiction. These are the Top 20 regardless of whether they were state, federal, or local responsibility.

### Climate Change: The Future is Here

- 16 of the 20 largest CA wildfires occurred in the last 20 years
- Typically high severity is >30% of fire footprint (vs. 3-8% historically)
- Size of high-severity patches is well beyond conifer seed dispersal
- Annual acres needing reforestation has quadrupled over last 20 years

King Fire: >55% high severity
Climate Change: The Future is Here

Overly dense forests are not only a fire problem, they also create water stress: there are too many ‘straws in the ground’

- 2012-2016: Most severe drought in last 1000 years
- In California’s Sierra Nevada >150,000,000 dead trees
- Mortality correlated with climatic water deficit and stand basal area (Young et al. 2017)
- Beetle mortality is particularly accelerating the loss of large, old-growth (>400 yrs) trees
Given these conditions, how do we create resilient forest landscapes in the Sierra Nevada?

Outline:

1. What is landscape resilience and how do we create it?
2. Constraints: spotted owls, limitations on mechanical treatment and on fire use
3. Changing treatment pace and scale
4. Pyrosilviculture proposal
1. What is landscape resilience and how do we create it?

Forest structure and composition are influenced by largely immutable top down and bottom up factors, that drive disturbance and affect development processes.

Managing for resilience is ‘reverse engineering’ by accentuating differences in forest conditions with topography (bottom-up) to influence disturbance and developmental processes.
So to reverse engineer forest conditions, they should be aligned with key drivers. What were they?

- The drivers of forest variability were productivity (soil moisture availability) and fire regime\(^2\)

- **Overstory** conditions such as *tall trees*, canopy cover, and size and number of large snags is driven by *soil moisture availability*.

- **Understory** conditions such as small (ladder) tree density, shrubs, and logs is determined by *fire frequency and intensity*.

- Historically, forests were heterogenous, which is integral to their resilience\(^1\)

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Schematic of local density, composition, and structure in congruence with how topography influences water availability and fire intensity.

So 2009…and 2020
Is there information on how to do this?

Yes*. Top down climate drivers creates large-scale variability in forest conditions. Using reference sites as guides, we now have quantified target forest conditions for >20 climate classes across the Sierra.

Climate conditions can be readily calculated from publicly available data such as the Flints’ Basin Model.

Map of layers used to classify climate – annual actual evapotranspiration (AET), climatic water deficit (Deficit), and January minimum temperature (Tmin) – across the study area using the Flints’ Basin Model.

Within each climate class, how should forests conditions vary with topography? New paper* provides detailed stand structure metrics.

Hypothesis: In forests that historically had frequent-fire regimes, after treatments ask: “Is competition still driving vegetation composition & structure or disturbance?”

Why:
Ecologists have noted that in grazed and frequent fire communities around the world, a ‘healthy’ system is most resilient when its well below its carrying capacity & largely lacks competition.

Example:
“this region does not now carry over 35% of the timber capacity it is capable of carrying, and that deficiency is wholly due to forest fires” Leiberg (1904)
This idea of keeping frequent-fire forests well below carrying capacity has already been shown to secure stable carbon stocks\(^1\) and recently suggested for drought resilience\(^2\).

Note: If this lack of competition metric is valid, it has important silvicultural impacts:

We manipulate and model forests (i.e., FVS) based on density-dependent [competition] mortality.

Density would be much lower & tree spatial patterns (clumpy/gappy vs. regular spacing) will differ between disturbance and competition driven ecosystems.

Since the CASPO was published in 1992:
✓ Retain at least 40-50% canopy cover
✓ In a more recent paper, Tempel et al. (2014) “>70% canopy cover is associated with higher occupancy and reproduction”

How do you accommodate 70% canopy cover in fire and drought prone forests? How did the owl persist when the forest had an active fire regime and most canopy cover (before 1850) was 25-40%?
### LiDAR Analysis of Spotted Owl Habitat

18 co-authors including prominent spotted owl biologists

- Largest owl habitat analysis (by >10X)
- Dataset >65 Terrabytes, **100% of landscape sampled**
- >2 weeks to run analysis on multi-processor computers

<table>
<thead>
<tr>
<th>Study area</th>
<th>Nest sites</th>
<th>Acres</th>
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<tbody>
<tr>
<td>SEKI*</td>
<td>131</td>
<td>66,518</td>
</tr>
<tr>
<td>Eldorado NF</td>
<td>58</td>
<td>100,223</td>
</tr>
<tr>
<td>Sierra NF</td>
<td>63</td>
<td>101,511</td>
</tr>
<tr>
<td>Tahoe NF</td>
<td>64</td>
<td>770,795</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>316</strong></td>
<td><strong>1,039,047</strong></td>
</tr>
</tbody>
</table>

*SEKI

- Only owl demographic area with increasing population is old growth, much of it with a restored fire regime
- Used for contrast with NF conditions and as possible ‘ideal’ habitat
Contrasting Spotted Owl Habitat

NF: Traditional interpretation of ideal habitat:
- Profile showing large, tall trees
- Top down canopy transect with high (75%) canopy cover

Typical SEKI Habitat
- Canopy transect with 40% cover
- LiDAR also found owl habitat without high cover
- Profile shows tall (>157 ft) trees
Sierra Nevada forests can be managed to provide owl habitat while reducing fuels and increasing tree drought resilience

• Key habitat feature is not total canopy cover, but the cover in tall (>157 ft) trees.

• Owls actually avoid areas with understory (6-50’ strata) cover suggesting that reducing ladder fuels and stem density should not adversely impact owls.
“Work with the hand you’re dealt, but plan for the future”

• BUT… many current owl PACs are not in sustainable locations (i.e., often using steep, remote slopes that were inaccessible to logging where there are remnant older forests) prone to fire and drought.

• Building landscape resilience should consider planning to transition owl habitat to landscape locations best able to support tall trees.

• This means identifying and fostering large tree development in wet, fire refugia areas.

Location and height of tall trees is driven by scale-nested factors that drive water availability*…easy to identify in GIS

Sierra National Forest
Analysis by “Subwatersheds ≈ Firesheds”

<table>
<thead>
<tr>
<th>National Forest</th>
<th>HUs with &gt;25% FS ownership</th>
<th>Level of Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>High (85-100%)</td>
</tr>
<tr>
<td>Modoc</td>
<td>96</td>
<td>51.0%</td>
</tr>
<tr>
<td>Lassen</td>
<td>98</td>
<td>22.4%</td>
</tr>
<tr>
<td>Plumas</td>
<td>87</td>
<td>20.7%</td>
</tr>
<tr>
<td>Tahoe</td>
<td>54</td>
<td>24.1%</td>
</tr>
<tr>
<td>LTBMU</td>
<td>16</td>
<td>37.5%</td>
</tr>
<tr>
<td>Eldorado</td>
<td>50</td>
<td>26.0%</td>
</tr>
<tr>
<td>Stanislaus</td>
<td>53</td>
<td>49.7%</td>
</tr>
<tr>
<td>Sierra</td>
<td>77</td>
<td>66.2%</td>
</tr>
<tr>
<td>Sequoia</td>
<td>70</td>
<td>72.9%</td>
</tr>
<tr>
<td>Inyo</td>
<td>109</td>
<td>91.7%</td>
</tr>
<tr>
<td></td>
<td>710</td>
<td>46.2%</td>
</tr>
</tbody>
</table>

- **20%** of subwatersheds you could thin your way to resilience
- **46%** of subwatersheds need prescribed fire or managed wildfire for effective landscape treatment
2C: Fire Use Constraints

Fire suppression and human settlement have produced roadblocks

1) Small and intermediate size trees can ‘ladder’ surface or ground burns into catastrophic crown fires.

2) Surface fuel accumulations produce hot, long-duration temperatures that can kill large, old trees.

3) Smoke production

4) Liability

5) Revenue (or lack thereof)

Whatever type of fire is restored, it will not replicate the historical fire regime.
3) Changing treatment pace and scale: Need to increase pace and scale, otherwise treatments are blown out by severe wildfire and drought.

Example: Dinkey CFLRP treated 9310 ha over 9 years.

Over that same period, drought killed roughly 400,000 ha of trees and wildfire burned about 10,000,000 ac.
How do we change current pace and scale on National Forests?

<table>
<thead>
<tr>
<th>Historical Rate of Fire</th>
<th>487,486 acres/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rates of Treatment* (1998-2008)</td>
<td>36,854</td>
</tr>
<tr>
<td>• Mechanical treatment</td>
<td>28,598</td>
</tr>
<tr>
<td>• Prescribed fire</td>
<td>8,256</td>
</tr>
</tbody>
</table>

→ Current treatment is 7.6% of historical rate
→ Annual Deficit = 450,000 acres/year (NF lands in Sierra Nevada)
→ At current pace, due to maintenance, 2/3’s of the forest will never be treated
→ Sierra Nevada forests are very productive…maintenance will kill you unless we find an economic, scalable means of making treatments extensive and economical.

Where does the logic of this lead?

Deficit is so large, there’s no point in arguing over thinning vs. burning priorities: silviculture and fire need to come out of their silos and explicitly work together to increase pace and scale: Pyrosilviculture

Scale up and concentrate efforts: Firesheds (≈30-60,000 ac or HUC 12s) need to be >35-50% fuels reduced to moderate fire intensity. Higher % to be drought/beetle resistant.

Use the extensive but blunt effects of fire to link landscape treatments, thin density, and for phenotypic selection (i.e., individuals with thicker bark and earlier branch abscission).

Use precision but limited scale of silviculture to affect fuel abundance and continuity, generate revenue to support fire, and facilitate widespread fire use.

Some Deductions:
Increase mechanical by using it to not only aid suppression, but also to strategically place anchors to facilitate fire use

- There are many Sierra Nevada fire/water sheds untreated because mechanically available acreage is too small to effect fire with thinning alone...however mechanical treatment could establish ‘anchors’ for expanding fire use.

- In eastern Australia, with about 20% of landscape in strategic ‘anchors’, they reached a tipping point for widespread fire use.
3 Early Adopter NFs in southern Sierra used the mechanical constraints and other analyses to delineate 4 zones in the NF with different levels of fire use. The wildfire ‘Restoration’ and ‘Maintenance’ now require justification for putting out a fire in those zones.

- To scale up Rx/managed fire, will need to keep it burning using Yosemite’s push/pull approach: ‘Push’ fire into low fuel areas (ex. granite outcrops) during bad weather/dispersion and ‘pull’ it across landscape during good conditions (ARC will need to allow much longer burn windows).
- Wildfire is by far the largest forest ‘treatment’ (100-500,000 ac/yr). Move focus beyond just salvaging & planting high severity leverage ‘restoration work’ of low/moderate severity areas, by continuing fuels and density reduction.
Questions?

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Lab website: http://northlab.faculty.ucdavis.edu/