# Lake Tahoe West Restoration Partnership
# Science Team | Science Integration

## Study Goals and Research Questions

The goal of science integration for the Lake Tahoe West project was to evaluate tradeoffs among alternative strategies for promoting resilience of the terrestrial forests and associated social values on the west side of the Lake Tahoe basin. Our primary research question was which management strategies would best promote values important to land managers and stakeholders over time given a changing climate. The scenarios ranged from wildfire suppression only, thinning in the wildland-urban interface, thinning more intensively and beyond the wildland-urban interface, and an extensive prescribed burning with limited thinning near communities, To answer this question, we connected findings from both landscape-scale and fine-scale models to evaluate vegetation growth and mortality, air quality, water quality, wildfire outcomes and risks to property, wildlife habitat quality, and economics.

## Key Findings

- The management scenarios performed similarly in terms of overall vegetation development, total area burned by wildfires, areas dominated by old trees, and habitat for wildlife, including old-forest associated species. Because trees are maturing and increasing under moderate climate change, late-seral vegetation increased overall, but they were typically enhanced with higher levels of treatment. This finding is consistent with forest inventory data for the region, as well as stand-scale monitoring.
- Thinning in particular posed little risk to water quality and was expected to have nominal impacts to wildlife habitat even under Scenario 3 that allowed some removal of trees up to 38" DBH, thinning in wilderness, and mechanical treatments on slopes up to 50%.
- Management scenarios with landscape treatments reduced the extent and frequency of high-severity wildfires, and associated risk of property loss, extreme emission days, and large patches of high severity burns which can pose a challenge for reforestation.
- Prescribed burning has distinctive ecological benefits that are not readily reflected in modeling results.

### *Implications for Land Managers*

- Treatments, including thinning and prescribed burning reduced areas burned at high severity and risks from wildfires to properties and air quality, while promoting wildlife habitat diversity. Extending treatments into wildland areas enhanced these outcomes relative to treating only areas close to communities.
- Prescribed burning was effective as a cost-effective complement to thinning to reduce wildfire hazards and achieve special benefits of restoring fire. However, expanding burning over large areas could have water and air quality impacts, which warrants careful analysis, design, and implementation.
- Modeling suggested a very low risk of erosion from forest thinning activities; it may be possible to mitigate the somewhat greater risks associated with skidding on slopes above 30% and temporary increases in road use.

**Relevant Links:**

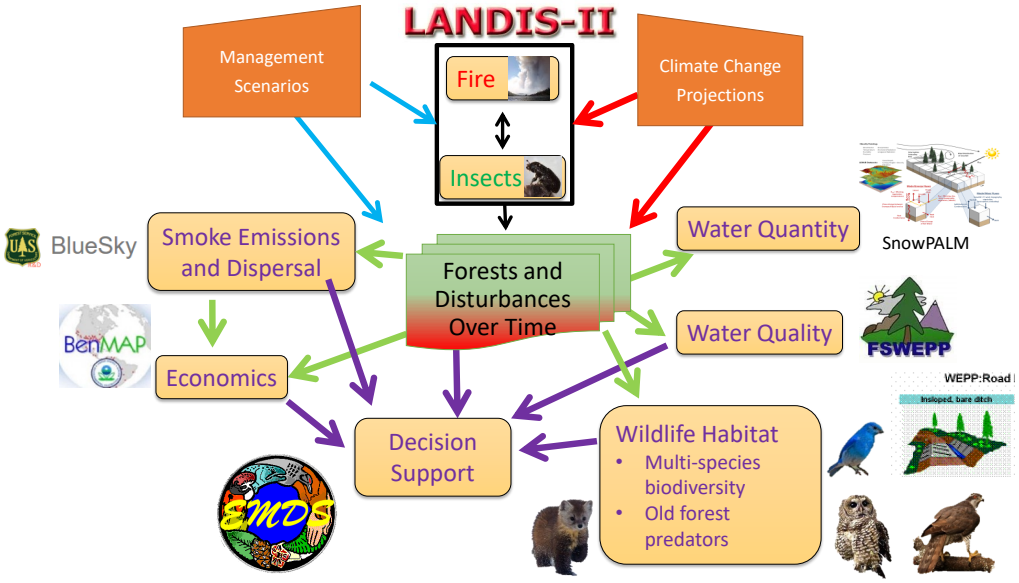
- https://www.fs.fed.us/psw/partnerships/tahoescience/

Contact: Jonathan.W.Long@usda.gov and Pat.Manley@usda.gov

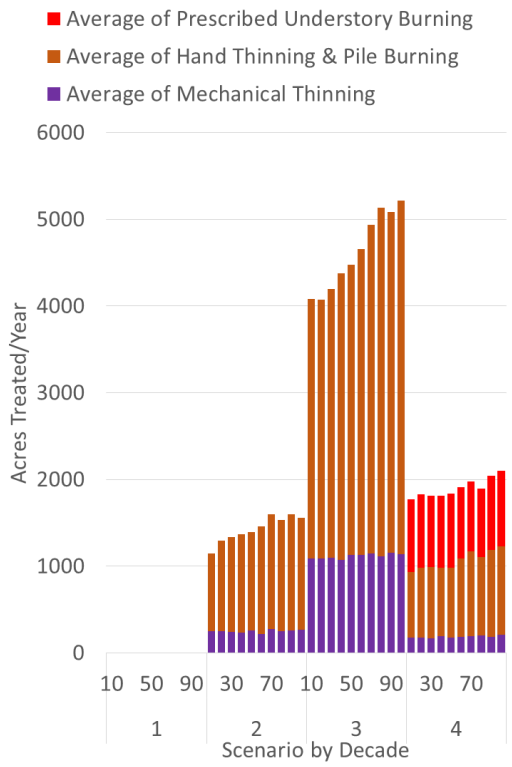
# Lake Tahoe West Restoration Partnership
# Science Team | Science Integration

## Model Description

The core modeling centered on century-long, landscape-wide results from LANDIS-II, for 4 management scenarios and 2 climate change emission estimates. We then linked those results to other models to evaluate particulate emissions, fine sediment and phosphorus loads, water yield, and wildlife habitat quality. We evaluated overall results by analyzing economic values and using an Ecosystem Management Decision Support Tool that scored performance of indicators selected by managers and stakeholders. For values such as health risks from smoke, we had to conduct snapshot analyses of representative events rather than comparing outcomes over decades.




*Interconnected landscape modeling tools*




*There was no active treatment under the first scenario, the most treatment under the third scenario, and comparable amounts of treatment under the initial runs of the second and fourth. The fourth scenario used understory prescribed burning in addition to thinning, and additional modeling is underway to evaluate more burning.*

## Summary of Results

The results support more active management across the Lake Tahoe West landscape beyond the borders of community areas. However, the decision about which strategy performs best is depends on the relative importance of resource costs and benefits.

Results suggested that business-as-usual approach (S2, treating only the WUI) to forest management will not achieve important social or ecological objectives. The value and impact of tactical implementation at project scales, such as diameter caps, operations on steep slopes, and road management, will need to be evaluated on a case by case basis to determine project specific costs and benefits.

While prescribed burning (and managed wildfire) at large scales can help to cost-effectively achieve goals for forest restoration, the modeling suggested that prescribed fire would have more risk and uncertainty in terms of air and water pollution than relying more heavily on thinning. The modeling may tend to overestimate these risks, since prescribed burns in particular can be managed to mitigate risks, and the models cannot capture the benefits of fire for some wildlife and understory plants. Rather than suggesting an optimal target for using fire, modeling results indicated adaptively managing fire for projects and across landscapes.

Contact: Jonathan.W.Long@usda.gov and Pat.Manley@usda.gov

# Lake Tahoe West Restoration Partnership
# Science Team Modeling | Vegetation Dynamics

## Study Goals and Research Questions

The goal of the landscape vegetation modeling team was to project changes in forest composition and structure under interacting disturbances, climate change, and different management strategies. These projections also included changes in the amount of carbon in the forest. Climate change is expected to increase fires and insect outbreaks. To project future forest conditions, it is important to consider all these interlinked disturbances along with management regimes.

## Key Findings

- Because the forests in the basin are continuing to recover from cutting since the Comstock era, they continued to add carbon and old, large trees increased in their occurrence through the end of the century.
- Climate change drove many changes in forest composition. Most projections showed a decrease in precipitation through time, while temperatures increased, resulting in more drought stress. These trends favored more drought tolerant pines; however, composition change was also mediated by disturbance.

*Patch that burned at high severity in the Gondola Fire 2001*

*Credit: Robert Scheller*

### *Implications for Land Managers*

- The amount of forest carbon and area dominated by old trees increased under any of the management scenarios, including increased thinning.
- Management may help to ameliorate shifts in composition that are driven by climate change; for example, selective thinning and other strategies can help sustain pines, red fir, and aspen.
- Management made a difference in affecting forest structure and composition over time, resulting in positive benefits for reduced large, high intensity fires.

### Relevant Links:

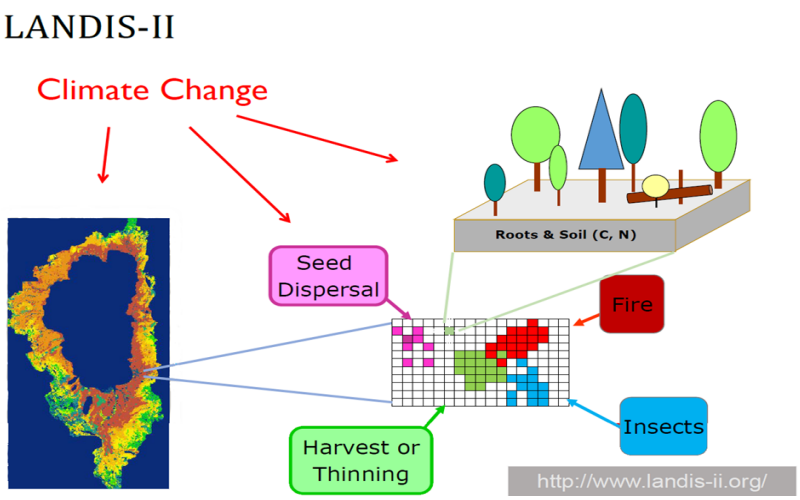
- More information about the model can be found at: http://www.landis-ii.org/
- Previous studies featuring LANDIS and the Basin can be found at: https://github.com/LANDIS-II-Foundation/Project-Lake-Tahoe-Basin-2010

Contact: Charles Maxwell, cjmaxwe3@ncsu.edu, Rob Scheller, rschell@ncsu.edu

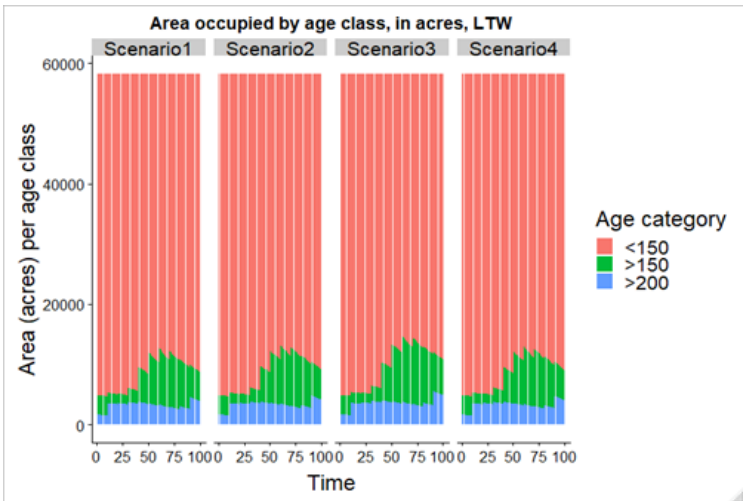
# Lake Tahoe West Restoration Partnership
# Science Team Modeling | Vegetation Dynamics

## Model Description

The LANDIS-II forest landscape model was used to simulate future forest conditions for a full century across the entire Lake Tahoe basin but based on management scenarios designed for the Lake Tahoe West landscape. The model simulates both aboveground forest growth and succession as well as tracks nutrient movement belowground, while incorporating the effects of a range of disturbances including fire, bark beetle, and forest management, in the face of projected changes in climate.



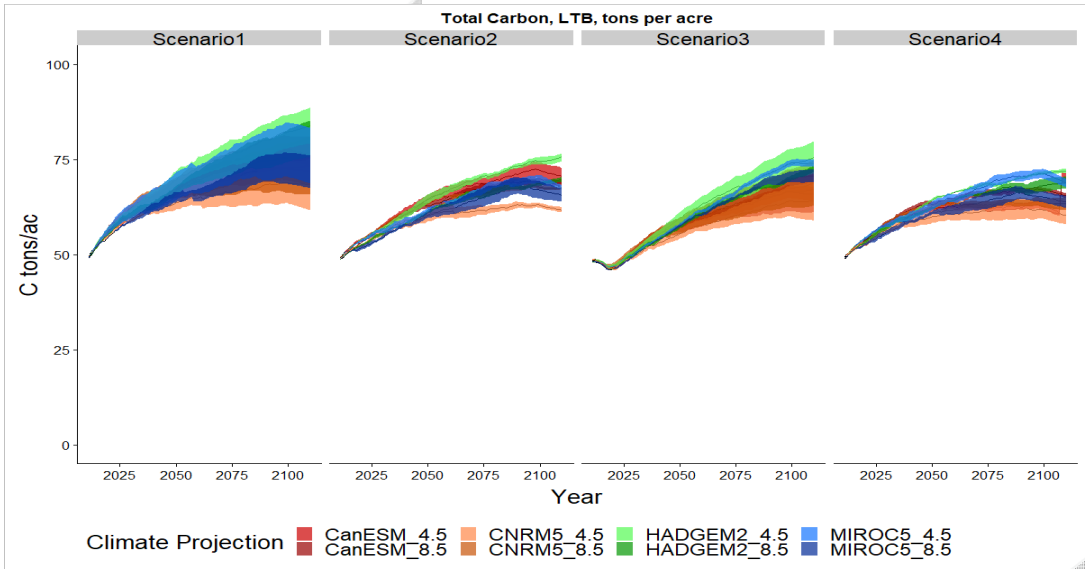

*LANDIS-II is a spatially explicit process based model capable of tracking forest dynamics, disturbances, and management under climate change*




## Summary of Results

Management activities had a positive role to play in shaping the carbon and fire trajectories of the forests. There is inertia in the system though, as the amount of in-forest carbon and area occupied by older trees will increase across all management scenarios. High levels of thinning treatments (Scenario 3) correlated positively with a number of desirable condition trends.

*Top: Old trees are accumulating over time — shown are number of acres in each age class. Right Carbon storage increases in all but the most extreme future climates — shown are projected total in-forest carbon (in megagrams C per hectare) through time by scenario and climate projection, shading represents +/- 1 s.d. among replicates.*




Contact: Charles Maxwell, cjmaxwe3@ncsu.edu, Rob Scheller, rschell@ncsu.edu

05/2019

# Lake Tahoe West Restoration Partnership
# Science Team Modeling | Water Quality

## Study Goals and Research Questions

The goal of the water quality modeling was to evaluate how four different management scenarios applied across the Lake Tahoe West landscape would affect water quality over 50 years considering disturbances including wildfire, prescribed fire, thinning, and managing the road system.

## Key Findings

- Management scenarios included fire suppression only (S1), thinning in the wildland-urban interface (S2), thinning across the landscape (S3), and prescribed fire across the landscape (S4).
- Scenarios 1, 2, and 3 had similar loads of fine sediment and phosphorus over time, suggesting that slightly increased loads associated with thinning were offset by reduced occurrence of large fires.
- Prescribed fires increased loads under Scenario 4 compared to the other scenarios, although there is uncertainty over the effects of such burns because we lack studies of their effects over large areas and on steep slopes; site-specific mitigation practices would likely reduce those risks.
- Responses are dominated by changes in the large watersheds with volcanic soils (Blackwood and Ward). Cascade Creek and Eagle Creek (steep watersheds) were also substantial contributing areas, but their loads did not vary much across scenarios.

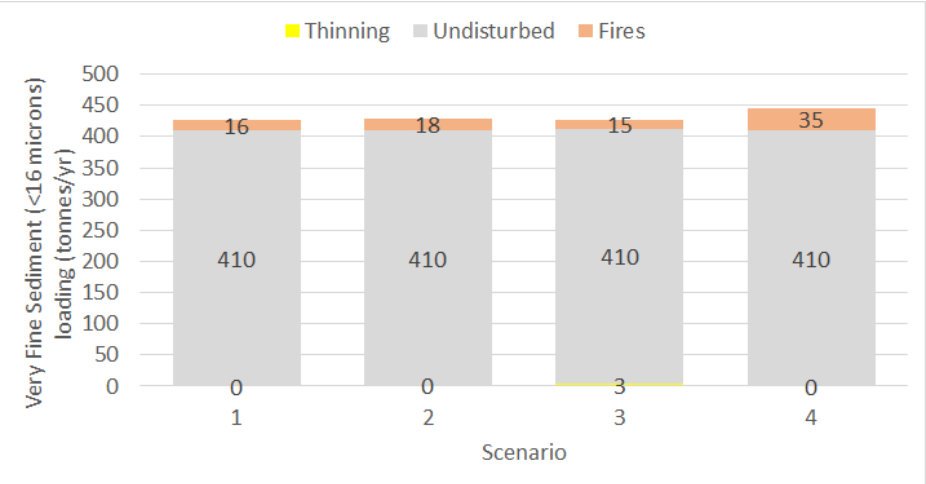



*Figure 1. Integrating WEPP water quality predictions with LANDIS projections of disturbance suggests that increased loads of very fine sediment from treatments from watersheds in Lake Tahoe West would be small compared to background loads.*

### *Implications for Land Managers*

- Thinning generally poses little risk to water quality when analyzed at large landscapes over long periods.
- Short-term risks associated with increased use of roads or thinning treatments in sensitive areas can be evaluated for mitigation options at project scales.
- Prescribed burning could pose risks to water quality; however, careful analysis, design, and monitoring specific to site conditions could help to mitigate risks and reduce the uncertainty associated with treatments.

### Relevant Links:

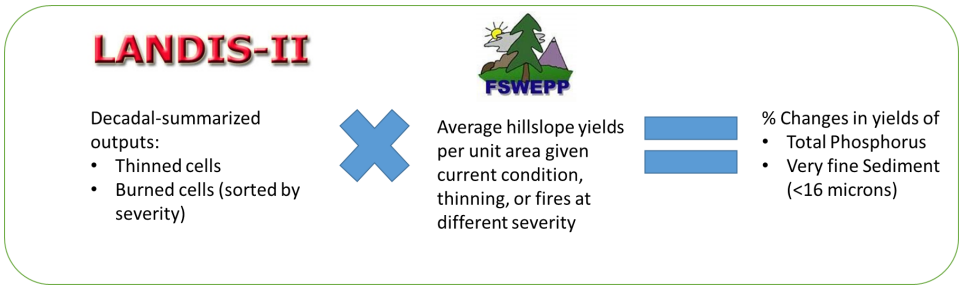
WEPP Project: for Lake Tahoe West landscape https://wepp1.nkn.uidaho.edu/weppcloud/lt

WEPP:Road and the Tahoe Basin Sediment Model tools for project analysis) https://forest.moscowfsl.wsu.edu/fswepp

Contact: Mariana Dobre, mdobre@uidaho.edu and Jonathan.w.long@usda.gov

08/2019

## Model Descriptions




Water quality impacts of various disturbances (thinning and different intensities of fire) were modeled using a WEPP interface that had been customized for 20 watersheds in Lake Tahoe West. The interface is available for use basin-wide and there are options for projecting future climate change. The outputs from these WEPP runs were combined with LANDIS model outputs to predict changes in total phosphorus and very fine (<16 micron) sediments.

The WEPP-road model was used to evaluate the current road network using conditions based upon current usage, expanded usage for thinning, and closure. In general, sediment yields from new or reopened roads were short-term in nature, and greatest in association with roads that were outsloped. Specific effects of individual scenarios could not be evaluated without site-specific proposals.

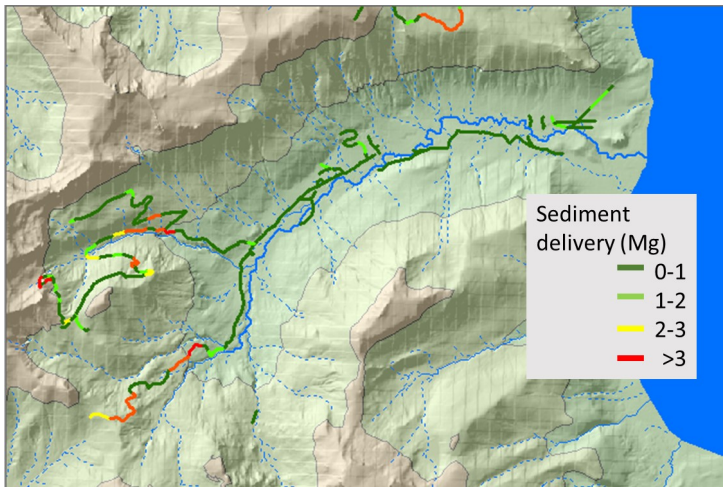



*Figure 2. Modeling of the road network in Blackwood watershed (the most important source of pollutant loads in Lake Tahoe West) identified segments that would temporarily increase sediment delivery if the roads were used to remove wood biomass as part of fuel reduction*

## Important Considerations

- The overlay analysis of LANDIS-II + WEPP results are useful for comparing effects of different management regimes over time. However, it is likely to overestimate the short-term impacts of disturbances by not accounting for the patchiness of disturbances, effects of including undisturbed buffers at the bottom of hillslopes, and the dynamic storage of eroded sediment in channel networks.
- Staging large-scale burns to follow efforts to restore stream channel connectivity to broad floodplains in meadows could further reduce the potential for sediments to enter the lake.
- The short-term effects of particular treatment scenarios could be better evaluated at a project-scale using the WEPP-based tool, the Tahoe Basin Sediment Model (see link on opposite page).
- Erosion risks may be somewhat greater when burning is conducted as a primary treatment, over larger areas, and on steep slopes, but such risks may be reduced when prescribed burning is implemented as a follow-up to thinning. Careful design and monitoring of such burns is a priority to better gage and mitigate the effects of such treatments.

CONTACT: MARIANA DOBRE, MDOBRE@UIDAHO.EDU AND JONATHAN.W.LONG@USDA.GOV

# Lake Tahoe West Restoration Partnership
# Science Team Modeling | Wildlife Habitat

## Study Goals and Research Questions

The purpose of the wildlife habitat modeling was to understand how forest management and natural disturbance processes (such as wildfire and bark beetle outbreaks) alter habitat for terrestrial vertebrate species over the next century on the west side of the Lake Tahoe Basin. Managers and stakeholders can use these modeling results to help predict how effective different fuel reduction prescriptions are in preserving habitat for native biodiversity. Although wildlife populations are susceptible to many stressors, we assumed that the probability of a species' persistence over the long-term would in part be determined by the maintenance and configuration of high quality reproductive habitat patches on the landscape.

## Key Findings

- Heterogeneity in forest conditions across the landscape are expected to increase as a consequence of both natural disturbance and fuel-reduction treatments.
- Growth and succession of mid-seral forests are predicted to outpace major disturbances resulting in greater amounts of late-seral habitat with large diameter trees.
- Forest thinning that extends into areas beyond the wildland-urban interface ultimately is expected to result in habitat configurations that benefited more wildlife species.

*California spotted owl, a species of concern*

### *Implications for Land Managers*

- Forest thinning was predicted to result in habitat structure that benefited wildlife species diversity. Prescribed fire can have positive effects on a variety of species in the short-term that were not accounted for in this study.
- Early-seral forest conditions are not predicted to increase on the landscape as a result of high severity fire. Thoughtful management of forest stands post-disturbance may be necessary to meet the needs of species dependent on early-seral habitat conditions.
- The number of California spotted owl, Northern goshawk, and Pacific marten territories supported is expected to increase over the next century. The elevation range of the California spotted owl is the most restricted, and attention will be needed to develop thinning approaches in lower elevation forests capable of maintaining and improving conditions for spotted owls.

**Relevant Links:**

http://www/landis-ii.org

Contact: Angela White, Pacific Southwest Research Station, angela.white2@usda.gov

08/2019

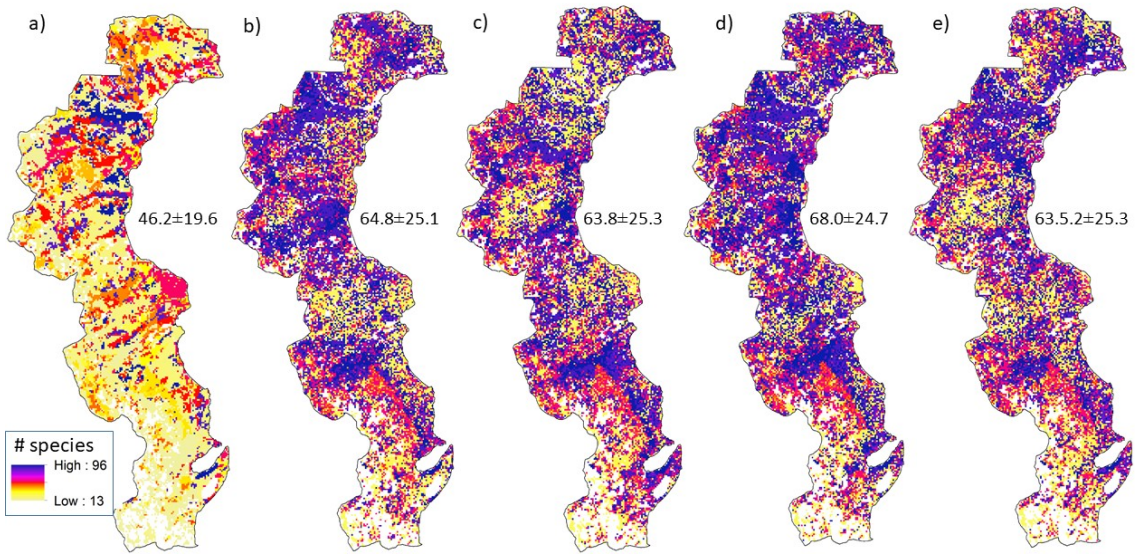
# Lake Tahoe West Restoration Partnership
# Science Team Modeling | Wildlife Habitat

## Model Description

We investigated potential impacts on the quantity and configuration of high-quality reproductive habitat for terrestrial vertebrate species that are known to occur in Lake Tahoe using outputs from the biomass extension in LANDIS-II, which provided age-based woody vegetation biomass estimates as a function of growth and succession of woody plant species. We assessed change in wildlife habitat conditions across the Lake Tahoe West landscape between 2010-2110 at decadal time steps as a result of natural disturbance processes and four different management scenarios that were modeled with LANDIS-II.

## Summary of Results

**Biodiversity model:** Suitable reproductive habitat for terrestrial vertebrates was estimated at each decadal time step. The average number of species with high quality habitat was estimated to increase under all scenarios and was highest under the scenario with the most forest thinning (Scenario 3). Expanded thinning led to the highest performance of biodiversity metrics including maintaining species richness, redundancy in ecological function, and species diversity in early, mid and late seral habitat conditions.




*Number of species with high quality reproductive habitat a) present day (2010), and after a century (2010 to 2110) of management based on b) fire suppression only, c) thinning in the wildland-urban interface, d) thinning across the landscape, and e) prescribed fire across the landscape.*

**Species of management concern:** Species distribution models were also used to predict the number of territories supported across the Lake Tahoe West landscape for the California spotted owl, Northern goshawk and Pacific marten. The number of territories supported increased for all species regardless of management scenario, consistent with a predicted increase in late-seral conditions. Marginal differences observed among species and management alternatives can be explained by the current elevation limits of the owls and the extent to which each species was tied to current habitat structure.

Contact: Angela White, Pacific Southwest Research Station, angela.white2@usda.gov

# Lake Tahoe West Restoration Partnership
# Science Team Modeling | Water Quality

## Study Goals and Research Questions

The goal of the water quality modeling was to evaluate how four different management scenarios applied across the Lake Tahoe West landscape would affect water quality over 50 years considering disturbances including wildfire, prescribed fire, thinning, and managing the road system.

## Key Findings

- Management scenarios included fire suppression only (S1), thinning in the wildland-urban interface (S2), thinning across the landscape (S3), and prescribed fire across the landscape (S4).
- Scenarios 1, 2, and 3 had similar loads of fine sediment and phosphorus over time, suggesting that slightly increased loads associated with thinning were offset by reduced occurrence of large fires.
- Prescribed fires increased loads under Scenario 4 compared to the other scenarios, although there is uncertainty over the effects of such burns because we lack studies of their effects over large areas and on steep slopes; site-specific mitigation practices would likely reduce those risks.
- Responses are dominated by changes in the large watersheds with volcanic soils (Blackwood and Ward). Cascade Creek and Eagle Creek (steep watersheds) were also substantial contributing areas, but their loads did not vary much across scenarios.

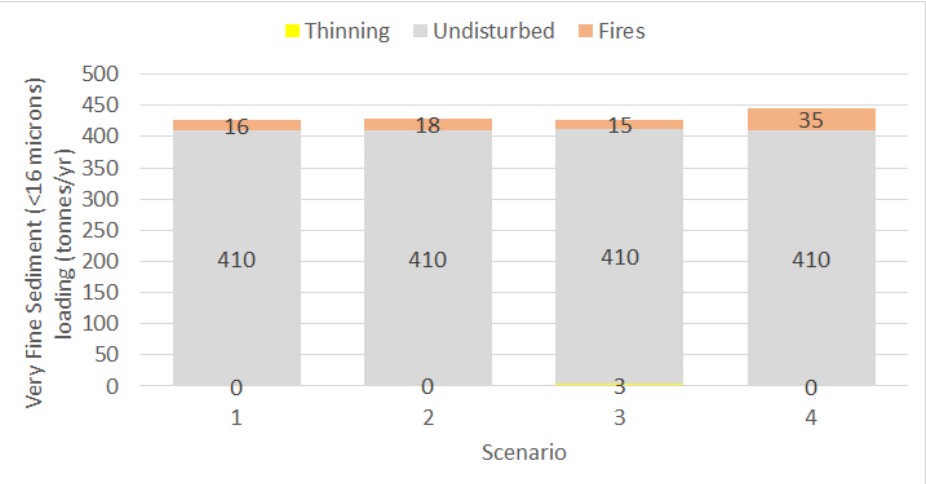



*Figure 1. Integrating WEPP water quality predictions with LANDIS projections of disturbance suggests that increased loads of very fine sediment from treatments from watersheds in Lake Tahoe West would be small compared to background loads.*

### *Implications for Land Managers*

- Thinning generally poses little risk to water quality when analyzed at large landscapes over long periods.
- Short-term risks associated with increased use of roads or thinning treatments in sensitive areas can be evaluated for mitigation options at project scales.
- Prescribed burning could pose risks to water quality; however, careful analysis, design, and monitoring specific to site conditions could help to mitigate risks and reduce the uncertainty associated with treatments.

### Relevant Links:

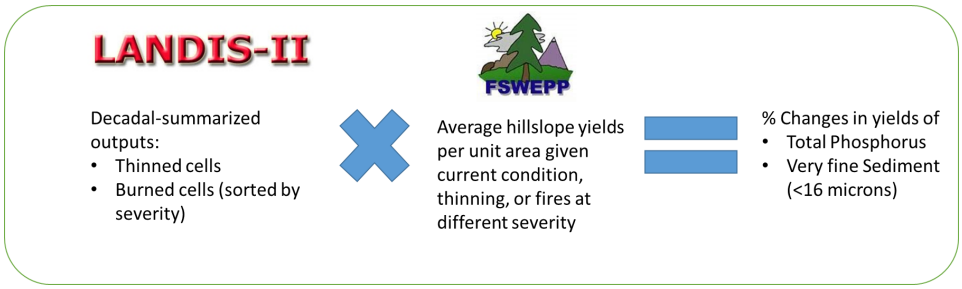
WEPP Project: for Lake Tahoe West landscape https://wepp1.nkn.uidaho.edu/weppcloud/lt

WEPP:Road and the Tahoe Basin Sediment Model tools for project analysis) https://forest.moscowfsl.wsu.edu/fswepp

Contact: Mariana Dobre, mdobre@uidaho.edu and Jonathan.w.long@usda.gov

08/2019

## Model Descriptions




Water quality impacts of various disturbances (thinning and different intensities of fire) were modeled using a WEPP interface that had been customized for 20 watersheds in Lake Tahoe West. The interface is available for use basin-wide and there are options for projecting future climate change. The outputs from these WEPP runs were combined with LANDIS model outputs to predict changes in total phosphorus and very fine (<16 micron) sediments.

The WEPP-road model was used to evaluate the current road network using conditions based upon current usage, expanded usage for thinning, and closure. In general, sediment yields from new or reopened roads were short-term in nature, and greatest in association with roads that were outsloped. Specific effects of individual scenarios could not be evaluated without site-specific proposals.

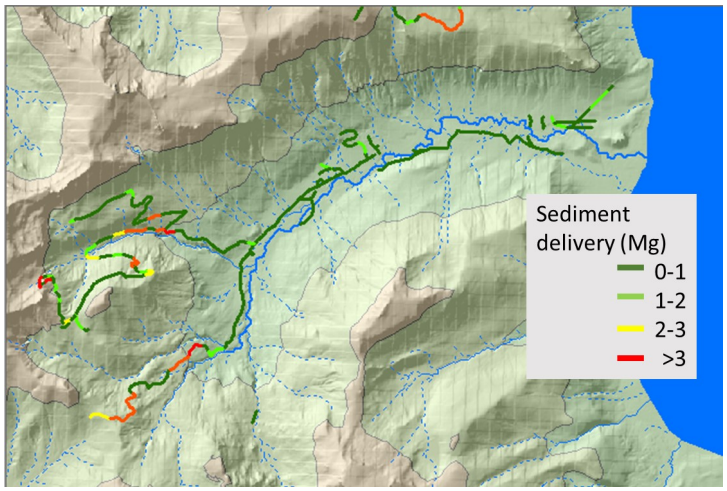



*Figure 2. Modeling of the road network in Blackwood watershed (the most important source of pollutant loads in Lake Tahoe West) identified segments that would temporarily increase sediment delivery if the roads were used to remove wood biomass as part of fuel reduction*

## Important Considerations

- The overlay analysis of LANDIS-II + WEPP results are useful for comparing effects of different management regimes over time. However, it is likely to overestimate the short-term impacts of disturbances by not accounting for the patchiness of disturbances, effects of including undisturbed buffers at the bottom of hillslopes, and the dynamic storage of eroded sediment in channel networks.
- Staging large-scale burns to follow efforts to restore stream channel connectivity to broad floodplains in meadows could further reduce the potential for sediments to enter the lake.
- The short-term effects of particular treatment scenarios could be better evaluated at a project-scale using the WEPP-based tool, the Tahoe Basin Sediment Model (see link on opposite page).
- Erosion risks may be somewhat greater when burning is conducted as a primary treatment, over larger areas, and on steep slopes, but such risks may be reduced when prescribed burning is implemented as a follow-up to thinning. Careful design and monitoring of such burns is a priority to better gage and mitigate the effects of such treatments.

CONTACT: MARIANA DOBRE, MDOBRE@UIDAHO.EDU AND JONATHAN.W.LONG@USDA.GOV

# Lake Tahoe West Restoration Partnership
# Science Team Modeling | Water Quantity

## Study Goals and Research Questions

Forests transpire water and they also intercept snow and rain, which are then subject to evaporation and sublimation losses. Warmer temperatures in the Sierra Nevada are affecting snow accumulation and melt, with significant ecological and economic impacts. This modeling was conducted to inform managers and others about the effects of forest thinning on snow accumulation and melt volume across the Lake Tahoe West landscape. Three questions were addressed: (1) what types of forest thinning are the most efficient to increase snow accumulation and melt volume, (2) where do they have the largest impact, and (3) what are the physical mechanisms driving these relationships?

## Key Findings

- Reductions in forest canopy generally increased snow accumulation and melt due to reduced sublimation of snow in canopies.
- Relatively dense stands (>3 $m^2/m^2$) between 5-15m tall (typically found at low to mid elevations) showed the greatest response to thinning, with increases in peak snow accumulation (400-450mm) and average melt volume (500-600mm).
- At high elevations, the largest changes to incoming radiation were observed.
- Changes in water volume were most pronounced in stands that were more dense before treatment

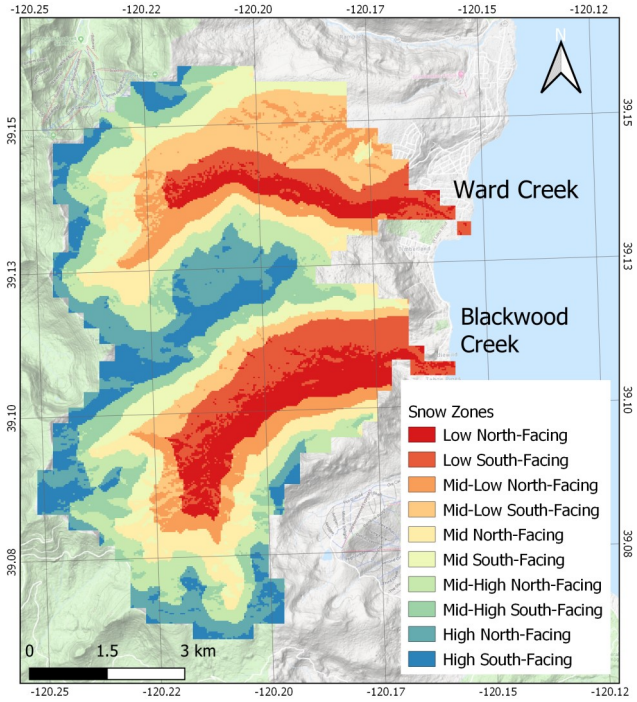



*Figure 1. Snow retention zones for two watersheds in the Lake Tahoe West landscape.*

### *Implications for Land Managers*

- Treating dense and 5-15m tall forest stands is particularly effective in increasing water quantity, and in the LTW landscape they were mostly located in valley-bottoms and the wildland-urban interface.
- Both snow accumulation and snow melt will benefit from thinning; however, snow persistence and the number of snow-covered days increased and decreased inconsistently in response to thinning.
- Low elevation hillslopes had the largest increase in snow accumulation and melt, as this areas are denser and more sheltered to increasing solar radiation.
- Higher elevations hillslopes have more snow but also a sparser forest cover, resulting in smaller increase in snow accumulation and melt due to increasing incoming radiation.

**Relevant Links:**

- https://naes.unr.edu/harpold/

Contact: Adrian Harpold, University of Nevada, Reno, aharpold@cabnr.unr.edu 08/2019

## Model Description

We used the Snow Physics and LiDAR Mapping (SnowPALM) model to evaluate the effects of thinning:

- The effect of forest interception of snowfall and solar radiation are represented at a fine-scale—high-resolution (1-m) model that can explicitly represent the snow-forest interaction at the tree-scale.
- The model simulates the energy and mass budget at the tree and snowpack, allowing a robust representation of the effect of forest removal on snow accumulation and melt.
- Existing vegetation height and density from LiDAR estimates at 1-m resolution were used at inputs.

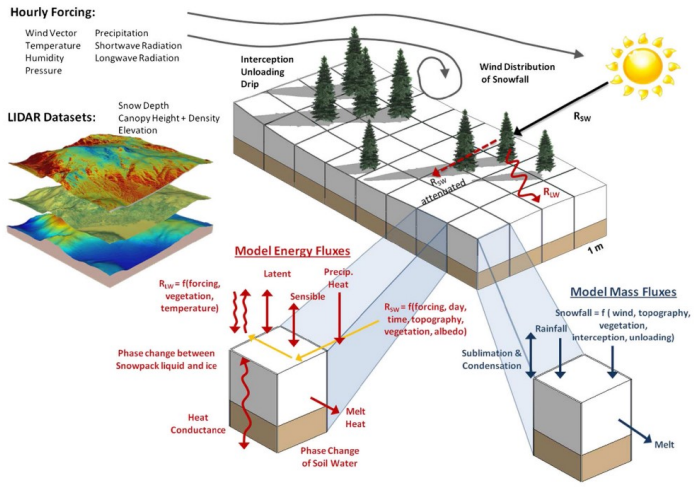



*Figure 2: Overview of the SnowPALM model showing included physical processes and required input data (Broxton et al., 2015)*

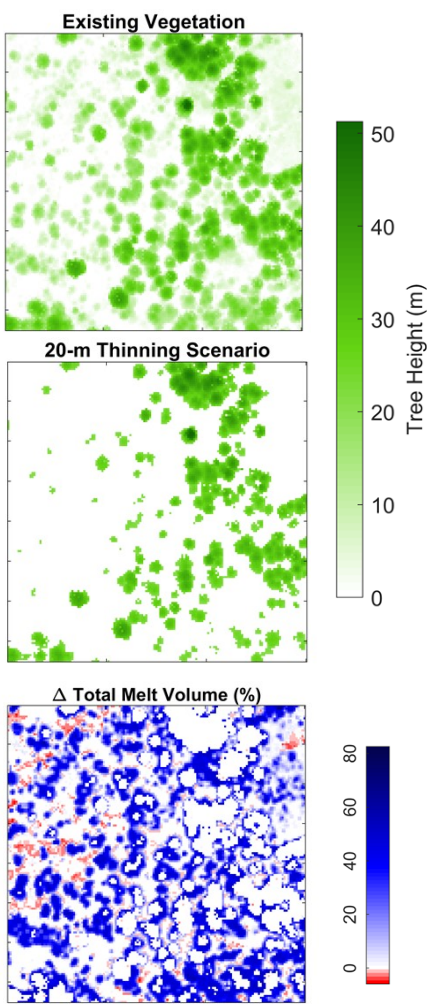



*Figure 3: Change in vegetation and melt volume at a low elevation and north facing slope at 1-m scale.*

## Summary of Results

Model validated well against snow depth and surface temperature in open and closed canopy sites, and against snow water equivalent.

Large spatial variability on the impact of forest thinning on snow accumulation and melt was observed at a 1-m scale (Figure 3), with the largest increase found around existing forest tree clusters.

Decreasing melt volume was only found in open areas that did not benefit from decreasing canopy interception of snowfall, and the increase in solar exposure was most prejudicial to total melt volume.

Most vegetated areas were found to benefit from thinning, increasing average melt volume and snow accumulation up to 500-600 mm and 400-450 mm, respectively, at forest patches with relatively high mean LAI (>3 $m^2/m^2$) and between 5 to 15 m tall.

Solar radiation increased, longwave radiation decreased, sensible heat increased and latent heat both increased and decreased across the domain.

At high elevation Snow Zones, changes to incoming radiation (shortwave and longwave) were the largest, as there were sparser vegetation and steeper slopes at times of low solar angle.

CONTACT: ADRIAN HARPOLD, UNIVERSITY OF NEVADA, RENO, AHARPOLD@CABNR.UNR.EDU

# Lake Tahoe West Restoration Partnership
# Science Team Modeling | Aspen Restoration and Fire

## Study Goals and Research Questions

The goal of the aspen and fire spread modeling team was to project changes in forest composition and structure and fire behavior in response to different thinning prescriptions. Restoration thinnings alter the structure and composition of forest stands to promote desired conditions, like promoting aspen stands, and desired processes like wildfires burning at low to moderate severity. Fine-scale interactions between individual trees and the physical environment affect outcomes, so thinning treatments need to account for the spatial distribution of trees. This study used three, 1-ha (~2.5 ac) sites in the Lake Tahoe Basin where all trees were mapped, and simulated light (<14" DBH) and heavy (<30" DBH) thin-from-below conifer removals to examine predicted changes in shading and spatially explicit fire spread behavior.

## Key Findings

- Both light and heavy thinning treatments promoted increased gaps and clumps of conifers (2-9 trees).
- Lighter and heavier thinnings increased understory fuel cover of aspen from 53% to 62% and 98%, respectively.
- Light thinnings marginally decreased shading on aspen relative to heavy thinning.
- Both thinning intensities reduced canopy consumption by fire, but heavy thinnings yielded much greater reductions.
- Only heavier thinning reduced rate of fire spread, and only during severe fire weather conditions.

*Thinning treatments can decrease crown fuels and promote aspen-based fuels, leading towards reductions in wildfire hazard*

### *Implications for Land Managers*

- Thinning treatments are an effective means to promote residual & suckering aspen and modify fire behavior.
- Thinning from below may restore natural spatial pattern of conifers commonly sought in restoration treatments
- Though heavy thinning reduced rate of spread (ROS) under severe fire weather, ROS is more impacted by fire weather, hence other measures of performance (e.g., canopy consumption) may be better indicators of treatment effectiveness
- Heavy thinning can not only dramatically reduce crown fuel loads but can greatly reduce canopy consumption by shifting to less hazardous aspen-based surface fuels
- Results suggest that heavier thinning not only improves growing conditions for aspen, but can also considerably reduce wildfire hazard

### Relevant Links:

- More information about the fire model, Wildland-urban interface Fire Dynamics Simulation can be found at: www.fs.fed.us/pnw/fera/research/wfds/

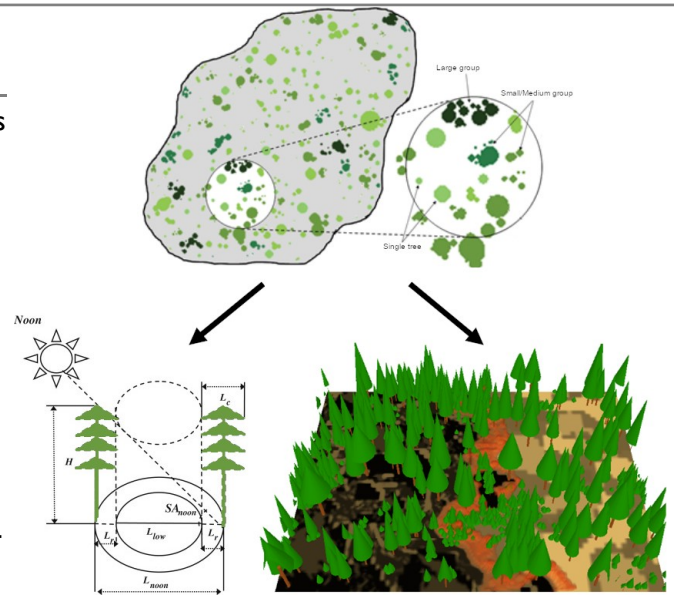
Contact: Chad Hoffman, c.hoffman@colostate.edu or Justin Ziegler, justin.ziegler@colostate.edu

# Lake Tahoe West Restoration Partnership
# Science Team Modeling | Aspen Restoration and Fire

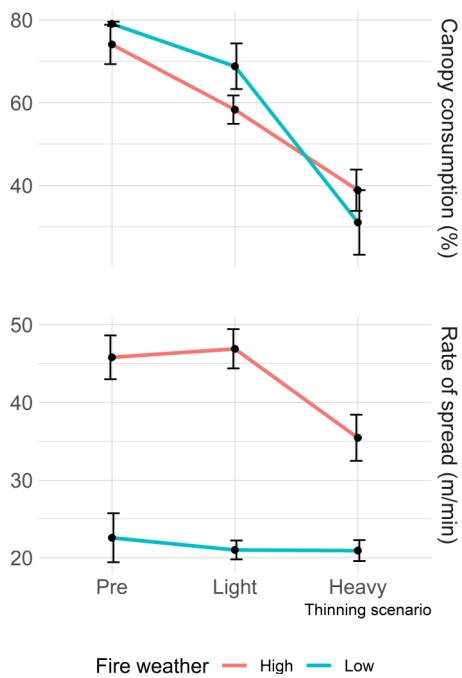
## Model Description

We used three, 1-ha plots from mixed conifer-aspen stands whose trees had previously been mapped. We simulated light and heavy thinning treatments to evaluate responses:

1. Quantified the proportion of conifer trees in various sized tree clumps, and the area that was at least 20 ft from a conifer tree;
2. Calculated the degree of shading on aspen crowns and the forest floor around aspen trees; and
3. Using projected changes in overstory and understory surface fuels, simulated fire behavior using WFDS - a 3-D physics-based model for two fire weather scenarios: low (1.1 mph 6 ft AGL wind speed, 10% surface fuel moisture) and high (3.4 mph 6 ft AGL wind speed, 5% surface fuel moisture).




*Spatially explicit modeling framework from structure (top) to shading (bottom left) to fire behavior (bottom right). Image credits: Wade Tinkham, Jiaojun Zhu*




*Heavy thinning reduced canopy consumption much more than light thinning (top). Only heavy thinning at high fire weather conditions, reduced rate of fire spread.*

## Summary of Results

Though light thinning (< 14" DBH) removed over half of all conifers, these treatments had a much lower impact than heavy thinning (< 30" DBH). This included all measures: overstory cover and surface fuel type area of aspen, areas free from the direct influence of conifers, tree group sizes, light availability, and fire behavior. In addition, though heavy thinning can yield a measurable reduction in rate of spread under high fire weather conditions, the effect of burning conditions themselves can be more impactful. We did not find that opening up the stands exacerbated fire behavior because any mid-flame wind speed increases were counterbalanced by shifts towards aspen fuels.

In summary, the effectiveness of restoration treatments can be hindered by diameter cap constraints. Future work in this study will include:

- Additional fire modeling of real-world implemented treatments
- Simulations of pile burning with/without broadcast fire

| Thinning | Basal area ($ft^2$/ac) | Open (> 20' from conifer) area (%) | # of Tree groups | | | | | % Shaded | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Single | 2-4 | 5-9 | 10-19 | 20+ | Forest floor | Aspen trees |
| Pre | 227 | 31 | 31 | 21 | 7 | 3 | 2 | 70 | 24 |
| Light | 193 | 48 | 29 | 17 | 3 | 1 | 0 | 60 | 22 |
| Heavy | 109 | 93 | 7 | 1 | 0 | 0 | 0 | 14 | 4 |

Contact: Chad Hoffman, c.hoffman@colostate.edu or Justin Ziegler, justin.ziegler@colostate.edu

08/2019

# Lake Tahoe West Restoration Partnership
# Science Team Modeling | Air Quality Modeling

## Study Goals and Research Questions

The goal of the air quality modeling was to evaluate how different forest management regimes within Lake Tahoe West landscape would generate smoke and affect air quality across the basin and the larger region

## Key Findings

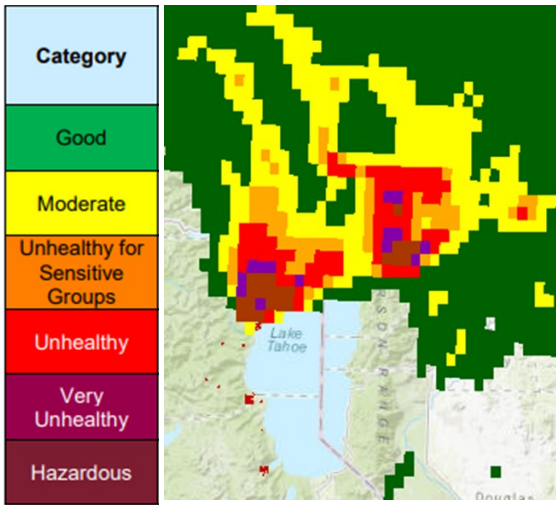
- Treatments reduced fuel consumption, emissions from wildfires, and days of high emissions, which in turn reduce the risk of public health and economic impacts; specifically, the management scenario with the most thinning reduced the risk of very high emission days, and the scenario with no treatment greatly increased that risk.
- Weather conditions greatly influenced the impacts of high daily emissions on downwind populations.
- Pile burning generated many days of low emissions but did not result in high daily emissions.
- Frequent, large prescribed burns could have substantial smoke impacts. Timing and fire management can reduce smoke impacts.
- Additional analysis is needed to inform how to most effectively use frequent, low emissions fires to reduce the incidence of infrequent, high emissions wildfires.

## *Implications for Land Managers*

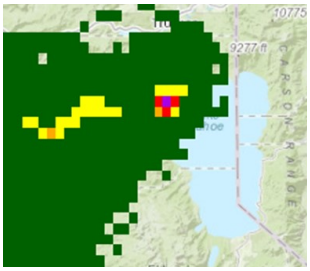
- Both thinning and prescribed burning are effective and complementary treatments in reducing the consumption of forest fuels during wildfires.
- Single extreme wildfires could cause $6 and $80 million of economic losses based upon health risks alone.
- To effectively mitigate smoke impacts through the use of prescribed understory fires will depend on careful planning, monitoring, and proactive engagement with downwind and smoke-sensitive communities.

### Relevant Links:

- General framework: *Aligning smoke management with ecological and public health goals*, J. of Forestry 116(1): 76-86. https://www.fs.usda.gov/treesearch/pubs/53771
- LANDIS: http://www.landis-ii.org/
- BlueSky: https://cools.airfire.org




**Air Quality Index** **900 acre summer wildfire**



**100 acre fall prescribed burn**

*Projected concentrations of fine particulates under an extreme wildfire in a scenario with no treatment (left) compared to a prescribed burn in a scenario that uses prescribed fires to reduce fire risk (right). The colors in the legend indicate general air quality conditions to illustrate how such outcomes could impact downwind populations. However, air quality conditions from actual fires would vary widely depending on actual weather conditions and other factors.*

Contact: Stacy.A.Drury@usda.gov and Jonathan.W.Long@usda.gov

08/2019

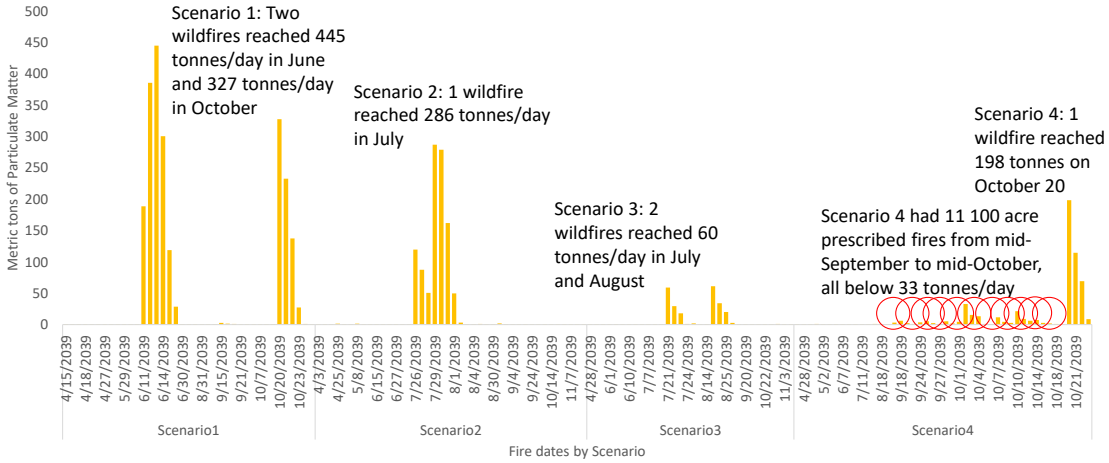
# Lake Tahoe West Restoration Partnership
# Science Team Modeling I Air Quality Modeling

## Model Description

Daily emissions are a useful proxy indicator for health impacts, which vary with weather and can be challenging to model accurately. We used landscape model outputs from LANDIS-II to estimate daily emissions of fine particulate matter (less than 2.5 microns) from wildfires and prescribed burns for a future fire year (2039). We then used the BlueSky modeling framework and recent historical weather data to project downwind levels of fine particulate matter. We analyzed resulting maps as inputs to the BenMAP model to estimate potential smoke impacts on communities.

| **Framework Step** | 1) Landscape modeling of emission from wildfires and prescribed burns | 2) Smoke dispersion modeling | 3) Smoke impacts (health and economics) modeling |
|---|---|---|---|
| **Modeling Tools** | LANDIS-II | BlueSky, DRI, CMAQ | BenMAP |
| **Temporal Scope** | Broad-scale (full century) with daily data | Snapshot events from 2039<br>Single multi-day events<br>Working toward multiple months | |

*Right: Example of daily emissions from fires under 4 management scenarios for a modeled future year. Suppression-only management (Scenario 1) generally resulted in the most extreme emissions days, while the most intensive treatment (Scenario 3) avoided extreme emissions. Use of prescribed burns (Scenario 4) resulted in more frequent, low-level emissions, but wildfire emissions remained similar to those under WUI-focused thinning (Scenario 2).*




## Summary of Results

- Modeled treatments reduce fuel consumption, leading to lower overall emissions and fewer days of high emissions, but there was much variation in individual smoke events and resulting impacts.
- Smoke emissions and potential impacts commonly extend far beyond the basin
- Pile burning was a minor contributor to days with high emissions, although it represented many burn days and total emissions of fine particulate matter.
- Prescribed burning resulted in moderate emissions, which could have measurable impacts even while if they remain within regulatory limits if conducted for many days over the course of a year.
- Timing and management of prescribed fires can minimize impacts in ways that broad-scale modeling can't capture well.

Contact: Stacy.A.Drury@usda.gov and Jonathan.W.Long@usda.gov

# Lake Tahoe West Restoration Partnership
# Science Team Modeling | Economic Impacts

## Study Goals and Research Questions

The goal of the economics modeling group was to deliver information to managers and stakeholders on the socioeconomic costs and benefits of different forest management scenarios. For each management scenario, the team quantified a variety of indicators including the cost of implementing fire risk reduction treatments and fire suppression, the risk of wildfire to residential properties, and the public health impacts from the smoke from wildfires. Economic impacts are also expected in other sectors that are not covered in this brief, in particular, the impact that smoke may have on recreation and tourism, changes in the cost of maintaining water quality, and effects on water availability for agriculture and municipal use. downstream.

## Key Findings

- Increased intensity of forest management reduced (by more than half the number) the properties at risk from medium and high intensity wildfires.
- Due to an emphasis on removing mostly small trees, revenue from timber and biomass sales was a relatively small component of overall management costs.
- Increased forest management, particularly use of prescribed fire, reduced wildfire suppression costs by more than $400,000 per year.
- Increased use of prescribed fire appeared to be one of the most cost-effective interventions available, as a scenario that used prescribed fire cost about half the amount of one focused on greatly increased thinning–while also substantially reducing wildfire risks in residential areas.
- Carbon storage in wood products and in fossil fuel displacement was highest under more intensive management, but total carbon sequestration–and thus overall climate mitigation–was highest under a suppression-only management scenario.
- Reducing fuel loads reduced the health impacts of large wildfires, although there was considerable uncertainty based on prevailing weather conditions. The impact of prescribed fires on public health appeared to be relatively small although both individual burns and the collective effects of multiple burns could have impacts on nearby communities.

### *Implications for Land Managers*

- Trade-offs exist among different economic values associated with forest management in the Lake Tahoe West landscape. While climate benefits were highest under less-intensive management, more intensive management resulted in significant reductions in fire risk and property damage.
- Prescribed fire can reduce wildfire risk to property at a much lower cost than thinning, although it can also cause smoke impacts.
- Because smoke impacts are very dependent on population exposure, wind and weather conditions, negative health impacts of prescribed fire can be mitigated by both careful timing and control of burns as well as proactive mitigation actions during burn events.

**Relevant Links:**

Potts Research Group:

https://nature.berkeley.edu/pottslab/

Contact: Matthew Potts, mdpotts@berkeley.edu, Sam Evans, Tim Holland

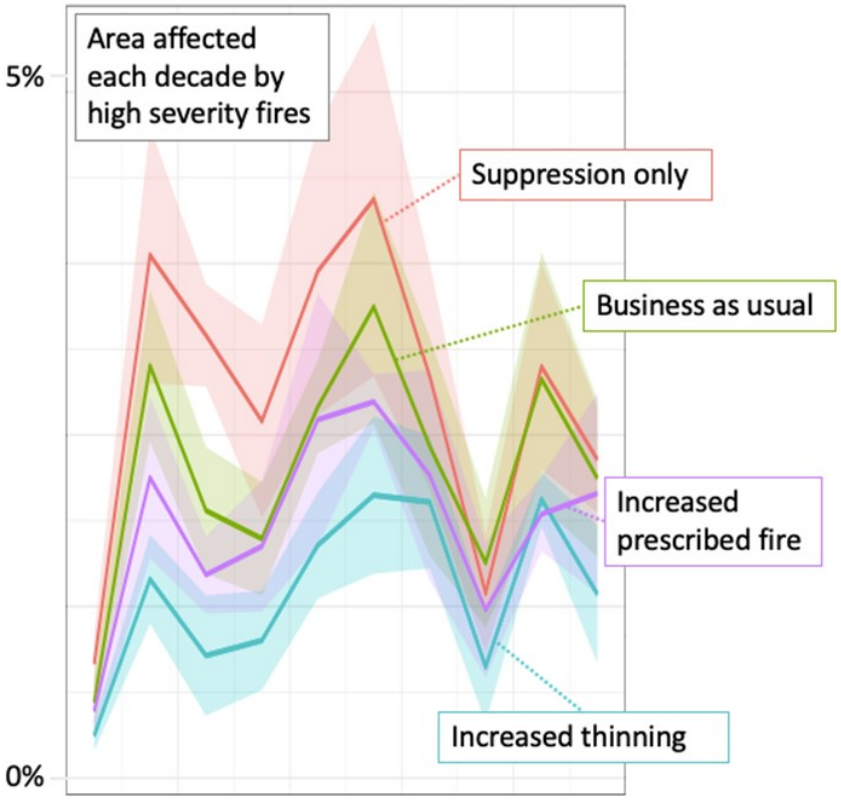
08/2019

## Model Description

The economic framework combined several methodological approaches to determine the relative costs and benefits for each scenario, including: implementation expenditures, revenues from restoration by-products, fire suppression, wildfire risk to residential properties, health costs of smoke, social costs of carbon emissions. When possible, economic impacts are expressed in dollars. Existing modeling frameworks were leveraged for assessing the management costs (USFS's BioSum OpCost model) and health impacts (EPA's BenMap Model). These models were modified to represent conditions in the LTW assessment area. For other components, such as fire management, greenhouse gas accounting, and property

## Summary of Results

Increases in treatments greatly reduced the risk of residential properties being exposed to medium and high intensity fires—from hundreds of residences in a suppression-only scenario and a business-as-usual scenario focused on thinning in the WUI, to only a few dozen (in the scenario with modest thinning and prescribed burning) or even none (under greatly increased thinning).




The reduced rates of wildfires are also associated with significant reductions in the health costs of wildfires. These values depend on fire location, exposed populations, and prevailing weather and wind patterns at the time of the burn, and so can vary greatly; however, the economic costs of the health impacts of a single wildfire in the Basin could be on the order of $5-70 million.

The overall budgetary costs of the four scenarios vary from a low of $1.7 million annually for the suppression-only scenario (only the cost of fire suppression) to a high of $5.4 million annually for the scenario that greatly increases thinning. The scenario that includes prescribed burning is slightly less expensive than the WUI-focused scenario ($2.6m vs $3.2m annually) because the relatively low cost of prescribed burning is more than compensated by the reductions in thinning and fire suppression costs.

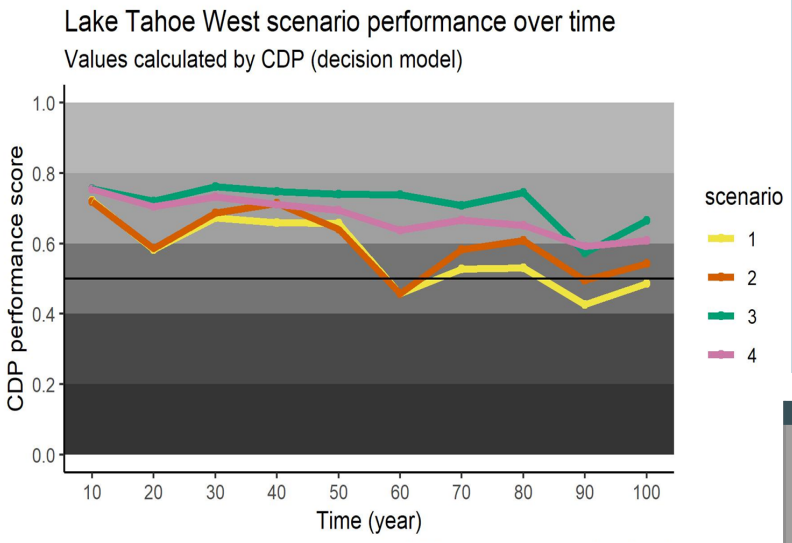
CONTACT: MATTHEW POTTS, MDPOTTS@BERKELEY.EDU, SAM EVANS, TIM HOLLAND

## EMDS Introduction

Significant challenges accompany assessing large and complicated environmental problems with many moving parts, stakeholders and scales. The Ecosystem Management Decision Support (EMDS) tool is designed to facilitate such projects. EMDS will provide the following contributions to the Lake Tahoe West project. First, it acts as a central repository for approximately 60 different modeled data outputs across four management scenarios and 10 decadal times-steps. Second, it integrates and assesses modeled data provided by LANDIS and interpretations thereof to evaluate the overall performance of management scenarios. Finally, EMDS provides perspective on the degree to which each management scenario meets desired objectives by enabling managers to consider biophysical conditions along with societal goals and priorities. EMDS incorporates this "human" perspective and then automates the process—by integrating many data inputs over many time points EMDS can synthesize many data inputs and provides evaluation and guidance for making decisions.

## Key Findings

- Management activities improve modeled forest conditions over time.
- Scenarios 3 and 4 (scenarios with management) have reduced forest condition variation over time.
- Management activities associated with scenario 3 achieved the best forest conditions over time.




*Scenario performance by decade: on the X-axis is time (from present day to 100 years in the future) and on the Y-axis is scenario performance. This figure shows how the different scenarios perform both in comparison to each other and across time.*

### *EMDS facilitates decision making*

EMDS provides a lens to examine different management strategies (at any given moment in time) and to assess performance of strategies over time. EMDS provides output that is comparable across spatial and temporal scales to allow managers to easily examine the implications of differing management strategies.

A hierarchical model (figure 1) permits the exploration of exactly what contributes to each resilience assessment. Interested parties can then utilize the model to examine the relationship between all included values/indicators to discover which variables are driving the success (or failure) of a management scenario at any given point in time.

**Relevant Links:**

**- EMDS website: https://emds.mountain-viewgroup.com/**

CONTACT: ERIC ABELSON, USFS PSW, EABELSON@FS.FED.US

## Model Description

EMDS relies upon a hierarchical model that depicts the topics and weightings that mirror those that a decision maker would consider when examining data.

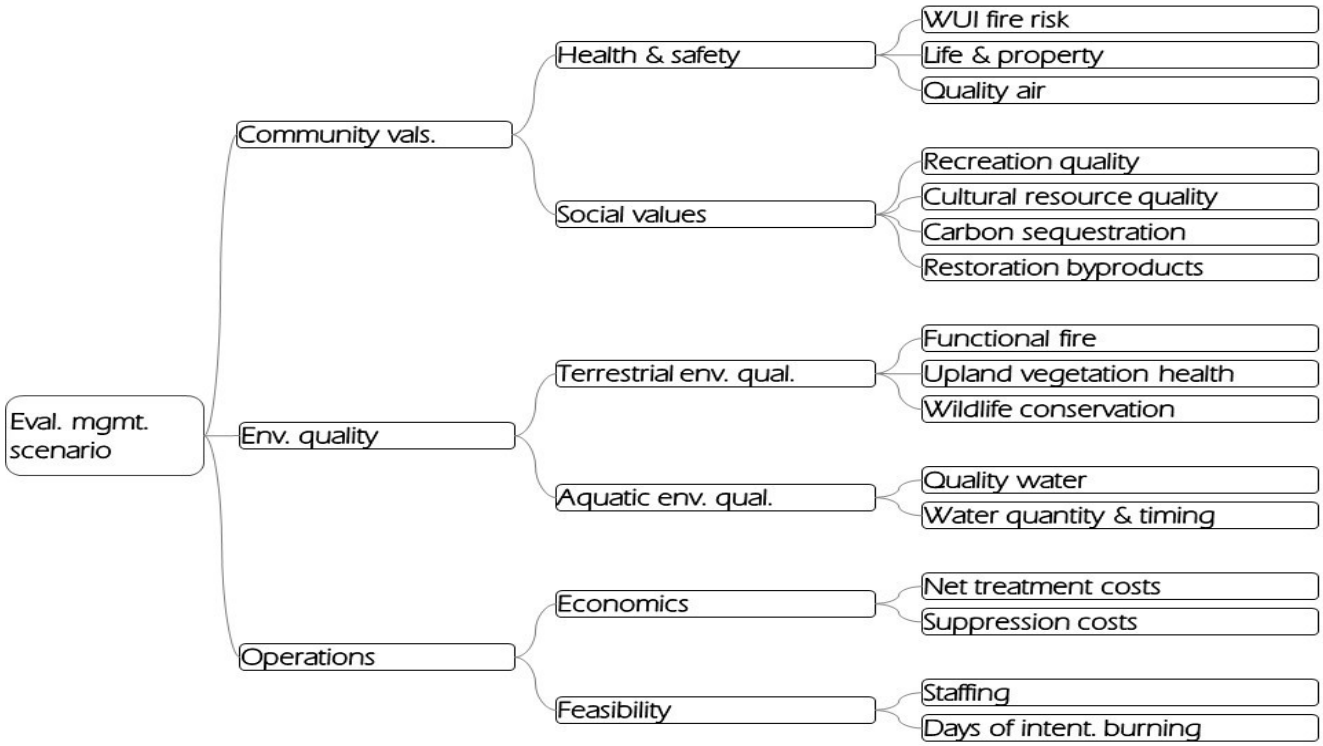



*Figure 1. EMDS topic hierarchy for evaluating management scenarios*

## Summary of Results

EMDS evaluated 16 main topic areas and generated scenario performance for each decade over 100 years (16 topics are listed in the right-most column of Figure 1. Of the 16 topic areas, some topic areas had considerable variation between decades. These included (followed by the best performing scenario): quality water (most scenarios were roughly equal and performed very well with the exception of Scenario 4 that performed poorly over time), quality air (S3 best), WUI fire (all scenarios performed intermediately to poorly — generally speaking S3 & S4 outperformed S1 & S2), recreation (S3 best), water quantity and timing (S3 bset), life and property (S4 best), suppression cost (S4 best). The remaining topic areas had little between-decade variability in terms of the best performing scenario: cultural resource quality (S3), upland vegetation health (S3 & S4 were roughly equal), functional fire (S3 & S4 were roughly equal), wildlife conservation (all scenarios were roughly equal), net treatment cost (S1), restoration by-product (S3), carbon sequestration (S1), days of intentional burning (S1), and staffing (S1). In sum EMDS finds that scenarios with more management activities lead to forest conditions that are closer to the pre-defined optimal conditions. In many decades Scenario 3 & 4 performed similarly, though, when there was some differentiation, S3 outperformed S4. In absolute terms, S3 & S4 performed very well (performance scores 0.6-0.8) while S1 & S2 ranged from intermediate to very good (scores 0.4-0.8); however, performance values decrease slightly over time for all scenarios. Finally, stable performance over time can be important — S3 & S4 led to stable and predictable results over time while S1 & S2 had greater between-decade variation.