Climate Change Research at JDSF

Adaptive Management Experiment (AMEX) potential in the coastal redwood forest type

Dr. Sarah Bisbing, University of Nevada, Reno

What is the AMEX?

The AMEX is a multi-decade study comparing management approaches to different climate change impact scenarios such as:

- Tree regeneration failure
- Shifts in species' ranges
- Drought mortality
- Increasing severity of disturbances: drought, insect damage, and fire

Adaptive Management utilizes a suite of approaches as a hedge against uncertainty. These treatments are:

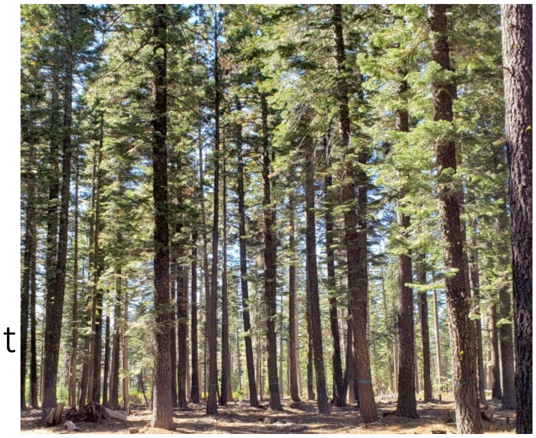
Resilience
- Creates stand conditions that will allow forests to recover to their pre-disturbance state
- Establishes a patchy, diverse forest structure while retaining locally rare species

Resistance
- Prepares a stand structure that is open, park-like, and forces fire to stay on the ground
- Favors large trees that can rapidly respond to release and increase in average diameter

Transition
- Helps forests adapt to a changing climate where they cannot recover without intervention
- Uses group selection to favor large, live trees but also create gaps for reforestation, ranging from ¼`- 1 acre and covering 10% of treatment area

Phase 1 (2023-2025)

- Perform research synthesis and organize listening sessions
- Collaboratively develop silvicultural prescriptions and determine experimental variables
- Explore potential study areas on JDSF and identify options for replication of the JDSF flagship study
- Install the AMEX plot network and complete pre-treatment sampling



AMEX THP

Intent of the Proposed Timber Harvest Plan

Introduction

Overview

The AMEX Timber Harvest Plan is a proposed experimental timber harvest and research project investigating how forest management practices and methods can be adapted to different climate change impact scenarios.

JDSF in collaboration with Dr. Sarah Bisbing, University of Nevada Reno, is preparing a multi-decade study to test four silvicultural prescriptions that will be replicated and monitored on JDSF with discussions under way to expand north and south across the redwood range. Climate change and the associated stresses on forest ecosystems are well established current research priorities for both JDSF and the larger academic community. Within this context, there is a need for the evaluation of management methods tailored to local forests and how these strategies may be used to mitigate or adapt to climate change scenarios in our region.

The Adaptive Management Experiment (AMEX)

The name AMEX stands for the Adaptive Management Experiment. AMEX was initially developed to test silvicultural alternatives across a wide range of future climatic stress scenarios in Sierra Nevada forests. The underlying principles of the study are:

1) recent climate change is anthropogenic.
2) climate change impacts are likely to threaten forest functioning in significant but uncertain ways.
3) silvicultural interventions will be necessary to maintain forest ecosystem functioning.

The project will include pre and post-treatment measurements and will be remeasured on a five-year basis for at least 20 years.

The JDSF Management Plan

CAL FIRE manages JDSF as a demonstration of sustainable forest management, as directed by statute, Board of Forestry policy and the JDSF Management Plan. The JDSF Management Plan identifies several detailed goals and objectives for the implementation and fulfillment of the established mission of the Demonstration State Forest Program. The number one goal established in this section is:

Goal #1 - RESEARCH & DEMONSTRATION: Improve the amount and quality of information concerning economic forest and timber management, forest ecosystem processes, watershed processes, performance of forest protection measures, that is available to the general public, forest landowners, resource professionals, timber operators, the timber industry, and researchers.[1]

The Research Plan (Appendix X of the JDSF Management Plan) is structured around four focus areas representing subject matter areas deemed to be of high interest and relevance to redwood forest management. Although there are a multitude of possible forest and ecosystem management subject areas for research, the four broad "Focus Areas" below were identified as priority subject areas for CAL FIRE-funded research:

1. Sustainable forestry;
2. Watershed science, restoration and aquatic habitat recovery;
3. Upland terrestrial habitat and forest structural relationships;
4. Managed redwood forests' climate change adaptations and role in carbon sequestration.

The proposed Timber Harvest Plan directly addresses these focus areas. The proposed project is a multi-decade study with an established university research program, based on a format that has been successfully implemented in the Sierra Nevada. Jackson Demonstration State Forest will be the flagship site for coastal AMEX, with ongoing relationship building, networking, and site visits scheduled for 2024 to identify paired core experiment sites (i.e., fully replicated) as well as companion sites (i.e., partially replicated).

---

[1] JDSF Management Plan pg 18.

AMEX THP

Executive Summary of the Proposed Timber Harvest Plan

Introduction

Overview

The AMEX Timber Harvest Plan is a proposed experimental timber harvest and research project investigating how forest management practices and methods can be adapted to different climate change impact scenarios.

JDSF in collaboration with Dr. Sarah Bisbing, University of Nevada Reno, is preparing a multi-decade study to test four silvicultural prescriptions that will be replicated and monitored on JDSF with discussions under way to expand north and south across the redwood range. This project will provide a scientifically rigorous evaluation of a suite of potential approaches forest managers may take to mitigate impacts on the ecological, economic, and social services provided by forest ecosystems.

Figure 1: Sierra Nevada AMEX sites. Larger icon represents flagship sites featuring all three management approaches.

The Adaptive Management Experiment (AMEX)

The name AMEX stands for the Adaptive Management Experiment. AMEX was initially developed to test silvicultural alternatives across a wide range of future climatic stress scenarios in Sierra Nevada forests. The underlying principles of the study are:

1) recent climate change is anthropogenic.
2) climate change impacts are likely to threaten forest functioning in significant but uncertain ways.
3) silvicultural interventions will be necessary to maintain forest ecosystem functioning.

This experiment compliments the ongoing national experiment, Adaptive Silviculture for Climate Change (https://www.adaptivesilviculture.org/) and the Sierra Nevada Adaptive Management Experiment (https://www.adaptive-forest-management-experiment.com/). The latter experiment includes LaTour and Mountain Home Demonstration State Forests as part of a north-south transect of sites across the Sierra Nevada Mountain Range and is also lead by Dr. Bisbing. Adaptive Management in the context of this Adaptive Management Experiment refers not only to climate change adaptation, but to the adaptation of management measures based on real world monitoring and measurement.

Why Here? Why Now?

Climate change and the associated stresses on forest ecosystems are well established current research priorities for both JDSF and the larger academic community. Within this context there is a demand for the localized evaluation of specific management methods and how these practices may be used mitigate or adapt to possible climate change scenarios.

JDSF staff and researchers from Dr. Bisbing's lab spent the summer of 2023 meeting with state, Tribal, non-profit, and private redwood forest managers on what they perceive as the biggest threats to the persistence of redwood forests and how they

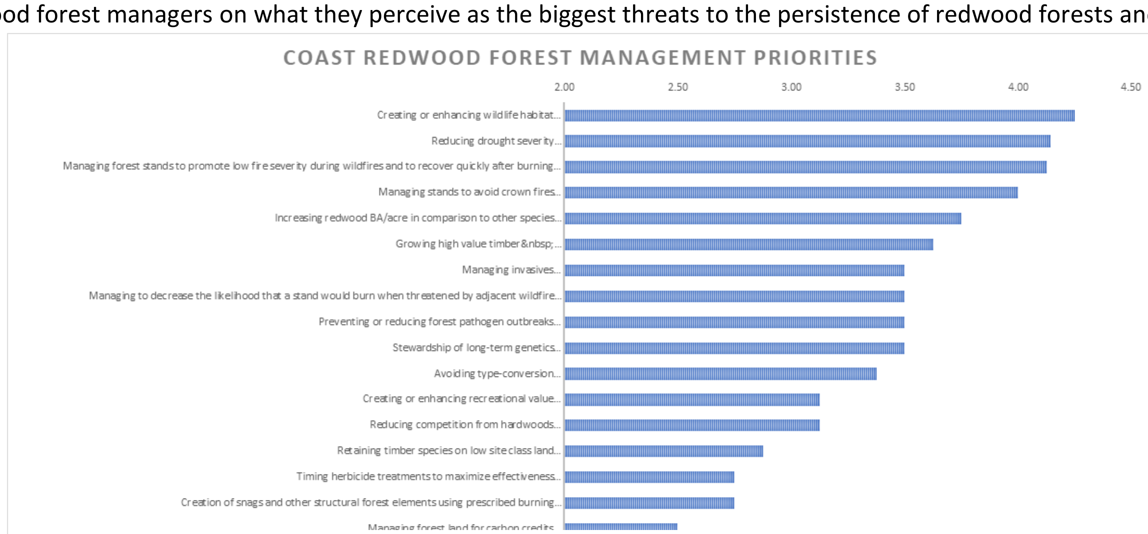


Figure 2: Respondents were asked to rate the importance of different management priorities on a scale of 1-5.

are actively preparing their forests for those threats. Listening sessions with land managers have been held in Santa Cruz, Mendocino, and the Humboldt/Del Norte area. A land manager survey was also conducted to gather information on how the wider land management community was approaching these challenges. Results from this survey are copied in figure 2.

Background

Site Selection

The preliminary listening sessions informed the selection of the proposed experimental site. JDSF evaluated four potential sites with different stand structures, species compositions, and harvest histories. Based on the information from the listening sessions the previously harvested Dunlap North THP (harvest year 2010) was selected as the proposed AMEX research area.

The Dunlap North area was last harvested in 2010 under the single tree selection silviculture. Prior to that there has not been a harvest entry since the original old growth harvests that took place in the early 1930's and 1970's. The stand structure in this area will serve as a good replicate of the interior coast redwood, Doug-fir, tan oak forest type typical of the interior Mendocino County redwood range, and the single previous harvest entry creates a management scenario common to area landowners. Included in figures 3 and 4 is stand inventory information collected by the AMEX research team.

Species	**Trees per Acre**	**Basal Area (ft^2/ac)**
redwood	55	114
Doug-fir	50	101
tan oak	103	78
grand fir	4	6
madrone	2	3
golden chinquapin	1	3
Total	**215**	**304**

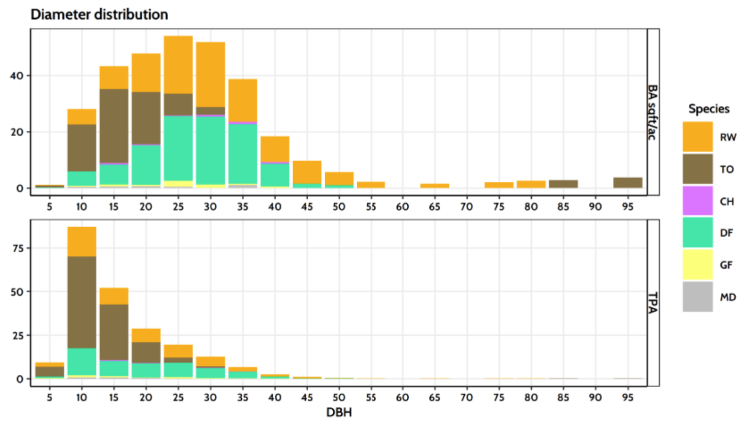


Figure 3&4: Inventory information from the AMEX fixed radius inventory plots.

Objectives and Management Actions

The JDSF Management Plan

CAL FIRE manages JDSF as a demonstration of sustainable forest management, as directed by statute, Board of Forestry policy and the JDSF Management Plan. The JDSF Management Plan identifies several detailed goals and objectives for the implementation and fulfillment of the established mission of the Demonstration State Forest Program. The number one goal established in this section is:

Goal #1 - RESEARCH & DEMONSTRATION: Improve the amount and quality of information concerning economic forest and timber management, forest ecosystem processes, watershed processes, performance of forest protection measures, that is available to the general public, forest landowners, resource professionals, timber operators, the timber industry, and researchers.[1]

The proposed project is a collaboration with an established university research program on an experiment format that has been successfully implemented in the Sierra Nevada. The project will include pre and post treatment measurements and will be remeasured on a five year basis for at least 20 years. Jackson Demonstration State Forest will be the flagship site for coastal AMEX, with ongoing relationship building, networking, and site visits scheduled for 2024 in order to identify paired core experiment sites (i.e., fully replicated) as well as companion sites (i.e., partially replicated).

The Research Plan

Silvicultures evaluated under this project are intended as potential management approaches to possible climate change pressures on redwood forest ecosystems. Anticipated impact scenarios include: tree regeneration failure, shift in species ranges, drought mortality, and increasing severity of disturbances (e.g. drought, insect damage, and fire). The proposed silvicultures have been assigned three descriptors based on the potential post-harvest stand structure and the type of climate change pressure they are intended to mitigate.

[1] JDSF Management Plan pg 18.

These descriptors are based off concepts first put forth in the paper *"Climate Change and Forests of the Future: Managing in the Face of Uncertainty"*[2]. This paper posited three potential strategies as responses to different impact scenarios. The development of these concepts is predicated on the idea that no single solution will address all future climate challenges, and that different management approaches may be needed based on the resource values at risk and the goals of particular landowners. These concepts are not specific to forestry and have broad applicability across land and resource management.

- ***Resistance:*** Prepares a stand structure that is open, park-like, and forces fire to stay on the ground. Disconnects overstory trees from understory fuels and favors large trees that can rapidly respond to increased resource availability. This strategy may apply in parklands and the wildland urban interface where key management concerns include the persistence of large old trees and the control of disturbance impacts (e.g. overhead hazards from tree mortality, soil stability, infrastructure and housing loss, etc).
- ***Resilience:*** Creates stand conditions that will allow forests to recover from different possible disturbances (e.g. drought, fire, pests, and disease). Establishes a patchy, diverse forest structure while retaining locally rare species. This strategy may apply to industrial forests, small private ownerships, and less intensively managed public land where the goal is to improve the landscape's ability to rebound from a variety of potential disturbances.
- ***Transition:*** Helps forests adapt to a changing climate where they cannot recover without human intervention. Creates new openings for reforestation trials, ranging from ¼`- 1 acre and covering approximately 10% of treatment area. This strategy may be a last resort or further hedge against uncertainty depending on the goals of the land manager and the climate pressures on a particular landscape.
- ***Control:*** Take no action and allow natural processes to work without intervention.

Figure 4: Examples of the three different management approaches as applied at the Grouse Ridge site in the Sierras (From left: Resilience, Resistance, and Transition).

Climate Resilience and Carbon Management

The Natural and Working Lands Climate Smart Strategy (California Natural Resources Agency, 2022) and the Forest Carbon Plan (Forest Climate Action Team, 2018) are both State guidance documents that inform the development of climate change mitigation projects within State land management agencies.

The Forest Carbon Plan set several goals for forest management. One of the overarching goals set by this plan is to *"Expand and Improve Forest Management to Enhance Forest Health and Resilience".* Within this larger goal the plan also establishes the sub-goals of *"3.1.1 Improve Health and Resilience on Private and State/Local Public Forestland"* and "*3.1.4 Maximizing Forest Health Goals in Sustainable Commercial Timber Harvesting Operations".*[3]

The AMEX THP is proposed as a research and demonstration project to evaluate forest management practices that serve these larger goals.

Fire Resilience

The "Resistance" treatment is intended to promote resistance to the most damaging effects of high intensity wildfire. The exact treatments are still under review, but will likely include understory fuels management through some combination of chainsaw, mastication, and/or prescribed fire. The "Resilience" treatment will develop a patchy forest structure intended to limit the scale of high intensity burn impacts.

---

[2] Millar, C. I., Stephenson, N. L., and Stephens, S.L. 2007. Climate Change and Forests of the Future: Managing in the Face of Uncertainty. Ecological Applications. Pages 2145-2151

[3] Forest Climate Action Team. 2018. California Forest Carbon Plan: Managing Our Forest Landscapes in a Changing Climate. Sacramento, CA. pg 32.

The JDSF Fire Protection and Pre-Attack Plan guides the implementation fuels management and pre-attack planning on JDSF. Road 210 provides access to a trending east/west ridge that parallels Highway 20. The east end of this road intersects with the entrance road to the Chamberlain Fire Center. Important infrastructure and population centers within one mile of the proposed project area include the Chamberlain Creek Fire Center, Camp 20 Day-Use Area, Dunlap Campground, the Forest Learning Center, and the historic Little Red School House. A PG&E transmission line runs along the southern boundary of the proposed project.

Possible origin locations of human caused wildland fires include Highway 20, Dunlap Campground, power transmission lines, and the Camp 20 Day-Use Area. Lightning caused fires may also occur along the ridges. Under each of these potential fire scenarios road 210 is a potential access route and control line.

Roads, Recreation, and Restoration

Minimal new road construction will be required to harvest the THP area. Abandonment of Road 211, Road 212 and 212A occurred under the Dunlap North THP and involved the removal of culverts and associated fill at map points and at un-drained watercourse crossings. Other work included installing broad rolling dips, excavation of perched fill, watercourse re-alignment and installation of erosion control structures. This work will be reevaluated during the layout of the proposed project. Initial review indicates that the past road abandonment measures are functioning as intended.

Primary recreation activities on the proposed project area are day-use activities (mushroom collecting, horseback riding, etc). The Camp 20 Day-Use Area and Dunlap Campground are within a mile of the proposed project. There are no official trails within the project area. The project area will be subject to temporary closure during implementation, but there will not be a lasting change to the recreational opportunities.

Coastal Adaptive Management Experiments (AMEX)
DRAFT Rx & Treatment Schedule – October 2024

Document Overview: AMEX was developed to test silvicultural alternatives across a range of climatic stress scenarios in Sierra Nevada forests. The underlying principles are: 1) climate change is anthropogenic, 2) impacts will threaten forests in significant but uncertain ways, and 3) silvicultural intervention will be needed to maintain forest functioning. AMEX is based on the climate change mitigation framework articulated by Millar et al. (2007) and DeRose & Long (2014), which propose testing “adaptive options” to prepare forests to resist, be resilient to, or accommodate change. The study intent is to generate research that informs sustainable forest management under climate change by “adapting” treatment types and intensities as we learn through experimentation. The overarching objective is to promote forest persistence into the future while continuing to meet desired objectives. Forest managers are therefore critical to design and application of treatments, including articulation of study questions, advising on adaptations to treatment type and timing as the study progresses, and maintaining study design integrity (i.e., implementing and maintaining treatments).

Here, we propose a prescription for California’s coast redwood forests that is based on these foundational principles but aligned with the ecology, management, and primary objectives for coast redwood ecosystems under current and future climatic and disturbance stress. Objectives and desired conditions were ascertained through a series of listening sessions, background research, discussions with land managers, and a web-based survey to listening session participants[1]. Coast redwood forests have been managed for many decades with the overarching objectives of providing long-term sustained yield timber while maintaining and promoting wildlife habitat through canopy retention and watershed protection. Climate change is impacting these forests by increasing the incidence and severity of novel and unprecedented wildfire, drought, and non-native pest and pathogen disturbances (e.g., Sillett et al. 2022, Potter 2023). Timber and wildlife conservation remain primary objectives in management, and climate change mitigation will thus be critical to maintaining desired objectives and conditions into the future

CAL FIRE’s Jackson Demonstration State Forest will be the flagship site for coastal AMEX, with ongoing relationship building, networking, and site visits scheduled for 2024 & 2025 to identify paired core experiment sites (i.e., fully replicated) as well as companion sites (i.e., partially replicated). As sites are considered for incorporation into AMEX, the Research Team and Forest Managers will maintain ongoing collaboration to ensure study integrity is maintained. To be designated a coastal AMEX participating site, managers must commit to maintaining study integrity over the long-term (up to 30 years). See AMEX MOU (signed Spring 2022) for details on this collaborative agreement.

[1] The top priorities identified were: 1) wildlife habitat and watershed protection; 2) wildfire mitigation; 3) ongoing sustained yield timber production; 4) climate change-driven disturbances (e.g., drought, pests, pathogens); and 5) climate change mitigation

EXPERIMENTAL DESIGN:

Core experimental sites include *resistance*, *resilience*, *transition*, and untreated *controls*. Treatment areas would ideally be laid out as a randomized block design with a minimum of three replicates per treatment (3 reps/treatment x 4 treatments = 12 units). The minimum size of each unit is 20 ac for a minimum total acreage of 240 ac (12 units x 20 ac = 240 ac), though we learned in Sierra AMEX that larger units are more favorable to layout and implementation (35-55 ac). Control units would ideally be included in the blocked design. Exceptions may be made for properties with area limitations. In these cases, control units may be installed on adjacent property of comparable pre-treatment composition and structure. We recognize that finding homogenous areas will be incredibly challenging, and flexibility is thus built into planning and experimental design. When mapping out the experimental design, pre-treatment data should be used to stratify the experimental unit by species composition and landscape factors to support replication within a forest condition and to accommodate the high topographic and landscape complexity of these systems. Coast redwood forests also have a high density of watercourses with high management constraints. WLPZs will be excluded from the experimental design and treated consistent with the goals of the forest manager. The research team will work closely with forest managers to identify a stratification that best fits the property. Among-site variation is expected treatment application due to different ecological and operational contexts.

Companion experimental sites are paired with the core experiment to replicate one or more treatments. Companion sites are often limited in treatment footprint area or bound by forest practices rules or other management plans/guidelines and unable to fully replicate the experiment. These sites increase the replication and statistical power around a given treatment type. In many cases, partners leverage an AMEX treatment type to test unconventional practices (e.g., marking to a lower BA or for larger group selections) before applying them at a larger scale and/or to gain a research exemption to allow for testing of boundary-pushing techniques.

Control: Controls are untreated units for testing the relative effects of paired treatments. Importantly, controls also represent the plausible alternative that a hands-off approach may, in some cases, be appropriate under certain climate scenarios or the default strategy of some managers. While the study context assumes management will be necessary to meet objectives and maintain ecosystem services into the future, it is also critical to actively test a broad set of techniques, including a hands-off approach. Controls are to remain untreated over the 30-year study timeframe. However, given the experiment occurs on working forests, some treatments are allowable if they meet forest objectives and would be applied across the entire forest/AMEX units. At JDSF, invasive weed management, for instance, occurs on all tracts of land. Additionally, salvage of bark-beetle killed trees is an allowable exemption from the no-treatment rule if the practice is critical to forest management and being applied across the property[2].

[2] Exception agreed to and voted on by AMEX Research Team & Cooperators at 11/1/23 planning meeting.

Resistance: The treatment favors retention of large, vigorous trees to meet a twofold purpose – foster development of late seral tree- and stand-level structures, specifically the large tree component, and promote resistance to canopy mortality in a wildfire. Although treatments will not lead to the immediate development of complex tree and stand-level structures, we anticipate the first-entry to initiate the development of complexity and serve as a waypoint toward this desired condition. Adaptive management and follow-up treatments will be required to push stands toward this desired condition. Treatments will also maintain and grow carbon reserves while protecting and improving wildlife habitat. This treatment type balances the critical need to mitigate the risk of a high-severity crown fire by reducing fuels and breaking up canopy continuity while simultaneously promoting growth and structural development of the canopy. Treatments change stand structure by promoting residual growth of retention trees, removing ladder fuels, increasing spacing among trees, and maintaining low surface fuels. Marking should be non-uniform to avoid creating an even-aged forest and to maintain natural structure, though we anticipate a canopy layer dominated by larger redwood trees. Regeneration is not a treatment objective; however, we anticipate natural regeneration due to canopy opening and sprouting responses of local species. The intent is to create a forest structure where, when wildfires occur during extreme weather conditions, they have a high probability of being low severity. Likewise, mortality is expected to be low during extreme drought. Resistance is expected to be achieved by reducing tree densities (trees per acre) and surface fuel loads while maintaining high stand basal area (BA). While some post-disturbance change is expected, the change will ideally be small enough that the fundamental structure and composition needed to resist future disturbances remain intact. This treatment is a management-intensive approach that will require regular fuel treatments to maintain open, park-like conditions once overstory retention targets are met.

<u>This treatment has a 30% canopy reduction target with a residual BA of 150 ft^2/ac</u> (125 to 175 range) following the first round of treatments (if possible, with flexibility based on property). Redwood clumps will be targeted for thinning down to 1-3 dominant trees, and 4-6 PETs (potentially elite trees) will be retained per acre. Follow-up treatments are designed to reduce surface fuel loads to levels that are expected to result in low- to moderate-severity fires during extreme fire weather conditions. Target retention is 75% redwood, 15% Douglas-fir and white woods, and 10% hardwood.

Treatments include: (1) a canopy **harvest** paired with a **heavy thin-from-below** to reduce stocking and promote tree vigor, (2) **targeted thin around PETs and other selected retention trees** to promote accelerated growth and late seral trait development, (3) a post-harvest **pile burn** with thinned material, and (4) **a broadcast burn, or equivalent treatment,** within one to four years of harvest to reduce ladder fuel development. Ladder fuels and understory vegetation may be removed or controlled with other means (e.g., mastication, chipping, hand pile and burn, or herbicide) if operationally feasible or necessary to protect other values. For this scenario, it is assumed that management interventions sufficient to resist climate impacts require relatively frequent interventions (~5–10-yrs). The treatment aim is to achieve and then maintain low stocking, high tree vigor, and a distinct separation between surface and canopy fuels.

Summary of objectives & treatments:

- Objectives
  - Foster the development of late seral tree- and stand-level structures
  - Promote resistance to canopy mortality in the event of a wildfire
  - Create an open, park-like structure with discontinuity among canopy trees and between surface and canopy fuels
  - Through periodic treatments, allow for stand development toward larger tree sizes while maintaining low fire hazard and high tree vigor.
- Treatments (<u>initial target residual BA of 175 ft^2/ac, ~30% canopy removal)</u>
  - Entry 1: Canopy harvest and heavy thin-from-below (year 1)
    - Range of 150 - 200 ft^2/ac, aiming for lower end of BA range
    - Retention of 4-6 PETs per acre to promote accelerated growth & LSD
    - Post-harvest pile burning to treat slash
  - Entry 2: Immediately followed by ladder fuel removal (years 1-4)
    - Broadcast burn or equivalent treatment of ladder fuel
  - Entry 3: Periodic follow-up maintenance may need to occur once shrub and small tree cover develops to a level where it could contribute to tree mortality under extreme wildfire conditions. Generally, shrub cover is desired to be <30%. Sprout thinning to accelerate development of conifer and hardwoods based on managers objectives may be part of this treatment.
  - Intermediate treatments (entries 2 & 3) may need to be repeated between harvests as the understory redevelops and fuels recover/accumulate in order to maintain the desired low-fuel stand condition.
  - Harvest re-entry will depend on site productivity and whether 175 ft^2/ac target was met during. It is expected that harvests will open the canopy sufficiently such that harvests will shift from ~12-20 to ~20-30 years, though fuel reduction may be required ~5-10 years to maintain low fuel conditions.

Resilience: These treatments push the boundaries of business-as-usual, multi-aged redwood silviculture by leveraging single-tree selection but doing so with increased management intensity (~125 ft^2/ac and/or ≥40% BA reduction). Treatments are designed to meet ongoing sustained timber yield while simultaneously creating sufficient compositional and structural heterogeneity that stands remain forests following a disturbance (i.e., no type conversion). Stands are marked through a lens of high structural heterogeneity and species diversity that retains a higher hardwood component as well as locally rare species (e.g., madrone and chinquapin). Increasing complexity across all aspects of forest composition and structure is likely to increase resilience to any given disturbance. However, shifts in species or structures are anticipated, as climate-driven disturbances are likely to be more intense, and thus more severe, than historical disturbances. Through survival of mature trees, this treatment will determine whether using traditional techniques is compatible with forest persistence. <u>This treatment has high structural variability at local scales (<0.50 ac)</u>, with an average <u>residual BA of 125 ft^2/ac</u>. Average BA should fall within 25 ft^2/ac of target BA, with higher and lower BAs expected to create low- and high-density patches (0.25-0.50 ac patches). Relative stand-level species diversity should increase after initial treatment. This prescription does not preclude harvesting of less desirable species, though marking should retain or increase compositional diversity. Hardwood densities may be reduced by retaining only the largest individuals. Target retention is 60% redwood, 30% Douglas-fir and white woods, and 10% hardwood. Fuel treatments are not anticipated except for post-harvest slash reduction, although second entries harvests may be required to meet targets.

Here, (1) **harvest** involves single-tree and cluster selection that produces small gaps and high BA diversity in small-patches (0.25-0.50 ac). No follow-up treatments are included. Resilience treatments are comparable to conventional density management in the redwood forest, where stocking is managed but no ladder or surface fuel treatments occur. The goal is structural and compositional heterogeneity, and, where BA targets/reductions may be too low for a particular site, the local forester must determine the appropriate BA while maintaining study integrity.

Summary of objectives & treatments:

- Objectives
    - Meet ongoing sustained timber yield needs
    - Promote resilience via high structural, species, and age-class diversity and "options" for forest recovery following disturbance
    - Modify business-as-usual techniques to develop multi-aged structure
- Treatments (<u>initial target residual BA of 125 ft^2/ac)</u>
    - Entry 1: Harvest – single-tree selection with small gaps (year 1). Sprout thinning to accelerate development of conifer and hardwoods based on managers objectives may be done as an intermediate treatment.
    - Repeat above as needed to maintain basal area within a density management zone from 200 to 250 ft^2/ac), which may be ~12-20 or up to 30 years.

Transition: Transition treatments represent the scenario where Resistance and Resilience treatments, despite their proactive contexts, are not sufficient for maintaining or restoring forests, and forests cannot recover because of high tree mortality and subsequent regeneration failures. We propose a prescription that mimics a mixed-severity fire by incorporating variable-sized gaps (1/4 ac to 2.5 ac), as desired and allowable by Forest Practice Rules, via group-selection harvest into a heavy thin-from-below prescription to create an open, heterogenous post-harvest environment. This treatment will then be followed by broadcast burning. Where possible, large gaps will be planted post-fire with a variety of species and seed lots from both local and non-local seed sources to test optimal planting stock under future climate change scenarios.

Single-tree and group selection harvest will be paired with a heavy thin-from-below to create a low-density matrix (150 ft^2/ac) with large gaps to mimic mixed-severity fire effects. Redwood will be preferentially retained with residual BA distributed as 40% redwood, 30% Douglas-fir and white woods, and 30% hardwoods. A broadcast burn will be applied following harvest.

Provenance trials nested within or adjacent to transition treatments are in line with the conceptual framing of transitioning a forest to a more climate-adapted state. Here, gardens are planted to test and identify ideal planting stock to support strategically shifting to climate-adapted species composition before a disturbance catastrophically changes the composition and structure of the forest (i.e., type conversions from forest to shrub/grasslands). In the redwood system, we will aim to select a total of five species (redwood, 2 white woods, and 2 hardwoods) for testing planting stock, with 3-5 lots of each species selected from across the redwood range (e.g., N to S, W to E to test climate tolerances of species and populations). Provenance trial planting will occur in larger gaps (1 to 2.5 ac) in the spring following the prescribed fire (year 2), and planting strategy will have to work with existing sprouting system (i.e., pines in lines challenging). All gaps will be stem mapped in order to track natural vs. artificial regeneration over time. In subsequent years, naturally regenerating sprouts can be controlled with herbicide or chainsaws in order to limit redwood and tanoak regeneration densities

During treatment (1) a group selection **harvest** and paired heavy thin from below will favor retention of large trees while also <u>creating distinct gaps for reforestation</u>. A follow-up (2) **mastication** (or equivalent ladder fuel treatment) will reduce surface and ladder fuels and bring the forest to a target <u>BA of 175 ft^2/ac</u>. A subsequent (3) **prescribed fire** will further reduce fuels, and maintenance burns will occur with enough frequency to maintain surface fuel loads low enough to maintain low probabilities of high severity fire during extreme fire weather conditions. It is assumed that relatively intensive and possibly frequent interventions will be necessary (re-entry every ~5-10 years) to maintain low surface fuel loads. Density management of the mature overstory should be similar to Resistance in terms of scheduling of harvests. Finally, within openings of sufficient size, (4) **gap reforestation** will be implemented using a provenance testing methodology.

Summary of objectives & treatments:

- Objectives
    - Test the potential for transition-in-action following a severe wildfire
    - Practice adaptive management to determine series of treatments and next steps in order to meet forest management objectives.
    - Identify steps required for transition of species composition under extreme climate stress conditions
    - Intervene in forest recovery by assisting migration or gene flow via planting of non-local species or genotypes better adapted to current and future climate conditions; this is adjusted with each entry that creates new canopy gaps

- Treatments (residual BA of 175 ft^2/ac in matrix forest between gaps)
    - Entry 1: Harvest with group selection and heavy thin-from-below (year 1)
    - Entry 2: Mastication or other ladder fuel removal treatment (years 1)
    - Entry 3: Prescribed fire in (year 1 following ladder fuel removal, or within the same year as mastication if doing a winter burn)
    - Entry 4: provenance trial
    - Entries 1, 2, and 3 may need to be repeated regularly to maintain low fuel loads and reduced competition. It is generally expected that harvests will occur every 20 to 30 years.

Literature Cited

DeRose, R.J. and Long, J.N., 2014. Resistance and resilience: a conceptual framework for silviculture. *Forest Science*, *60*(6), pp.1205-1212.

Millar, C.I., Stephenson, N.L. and Stephens, S.L., 2007. Climate change and forests of the future: managing in the face of uncertainty. *Ecological applications*, *17*(8), pp.2145-2151.

Nagel, L.M., Palik, B.J., Battaglia, M.A., D'Amato, A.W., Guldin, J.M., Swanston, C.W., Janowiak, M.K., Powers, M.P., Joyce, L.A., Millar, C.I. and Peterson, D.L., 2017. Adaptive silviculture for climate change: a national experiment in manager-scientist partnerships to apply an adaptation framework. *Journal of Forestry*, *115*(3), pp.167-178.

Potter, C. 2023. Impacts of the CZU Lightning Complex Fire of August 2020 on the forests of Big Basin Redwoods State Park. California Fish and Wildlife Journal 109:e1

Sillett, S.C., Antoine, M.E., Carroll, A.L., Graham, M.E., Chin, A.R. and Van Pelt, R., 2022. Rangewide climatic sensitivities and non-timber values of tall Sequoia sempervirens forests. *Forest Ecology and Management*, *526*, p.120573.