Fire-Driven Vegetation Type Conversion in Sierra Forests

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Vegetation Type Conversion (VTC)
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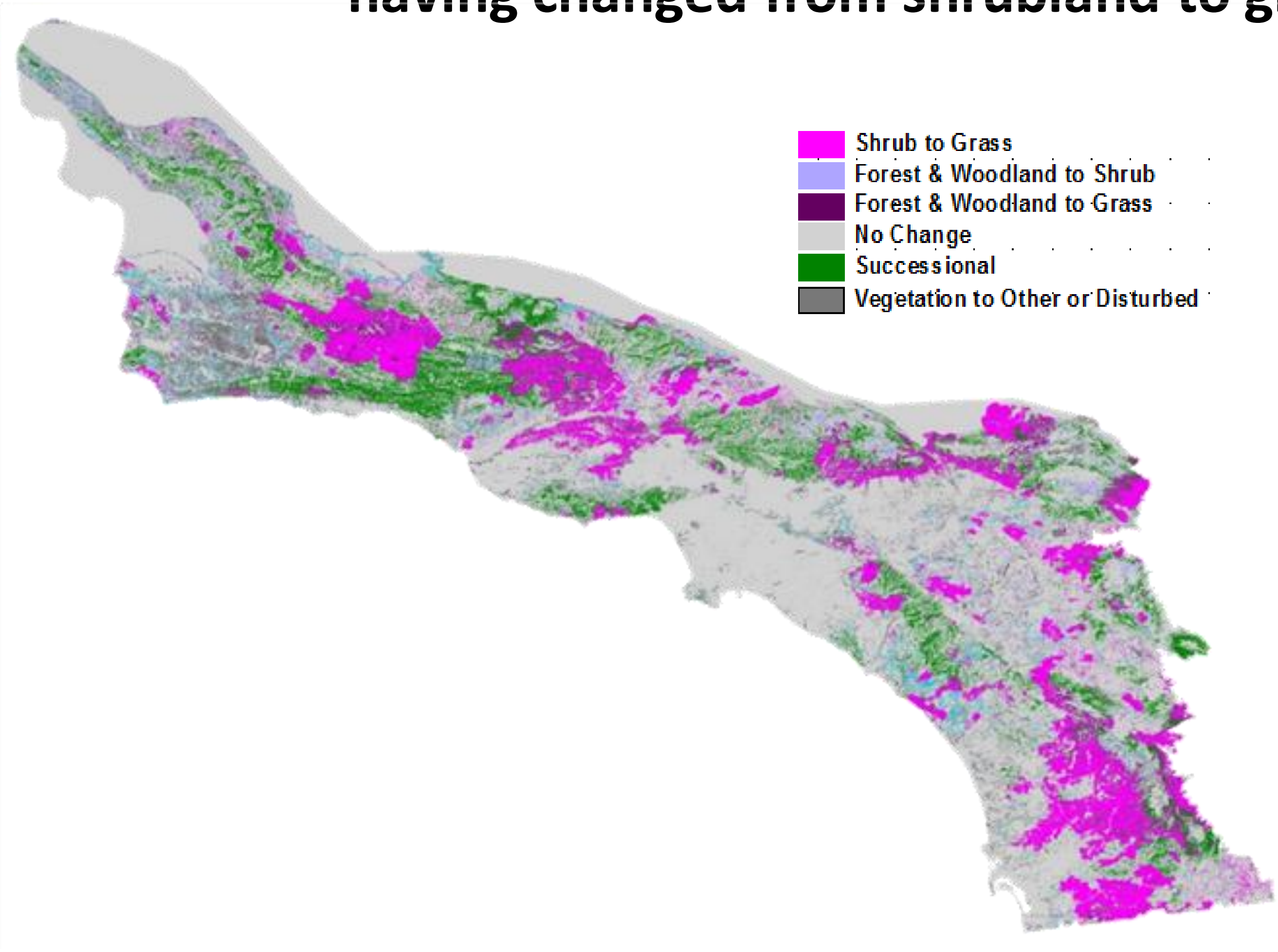
Highest historical fire frequency in those areas mapped as having changed from shrubland to grassland



(Syphard, Brennan & Keeley 2018)

In contrast to mixed conifer forests, drivers in shrublands are due to short fire-return intervals

But how short is short??

2020 Dolan Fire (Monterey Co) burned across 1987 unknown fire and 2008 Indians Fire

	Mature (33 yrs)			Immature (12 yrs)		
	% resprout	Prefire (shrubs/ha)	Seedlings /prefire shrub	% resprout	Prefire (shrubs/ha)	Seedlings /prefire shrub
Ceanothus cuneatus	0	15000	58.4	0	393	7.9
C. leucodermis subsp	0	1250	13.5	0	1668	0
Adenostoma fasciculatum	68	3690	7.8	43	12678	0.5
Quercus berberidifolia	100	1411	0	100	205	0

2021 French Fire (Kern Co) burned across mature and immature stands

	Mature 1966 unknown fire (55 yrs)			Immature 2003 Rx fire (18 yrs)		
	% resprout	Prefire (shrubs/ha)	Seedlings /prefire shrub	% resprout	Prefire (shrubs/ha)	Seedlings /prefire shrub
Ceanothus cuneatus	0	568	169	0	1406	0.27
Fremontodendron californicum	0	938	76	33	18	18.3
Quercus berberidifolia	83	1875	0	75	375	0

Forest Ecology and Management 512 (2022) 120129

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Tamm reviews

Mechanisms of forest resilience

Donald A Falk [a,e,*], Philip J van Mantgem [b], Jon E Keeley [c], Rachel M Gregg [d], Christopher H Guiterman [e,1], Alan J Tepley [f], Derek JN Young [g], Laura A Marshall [h]

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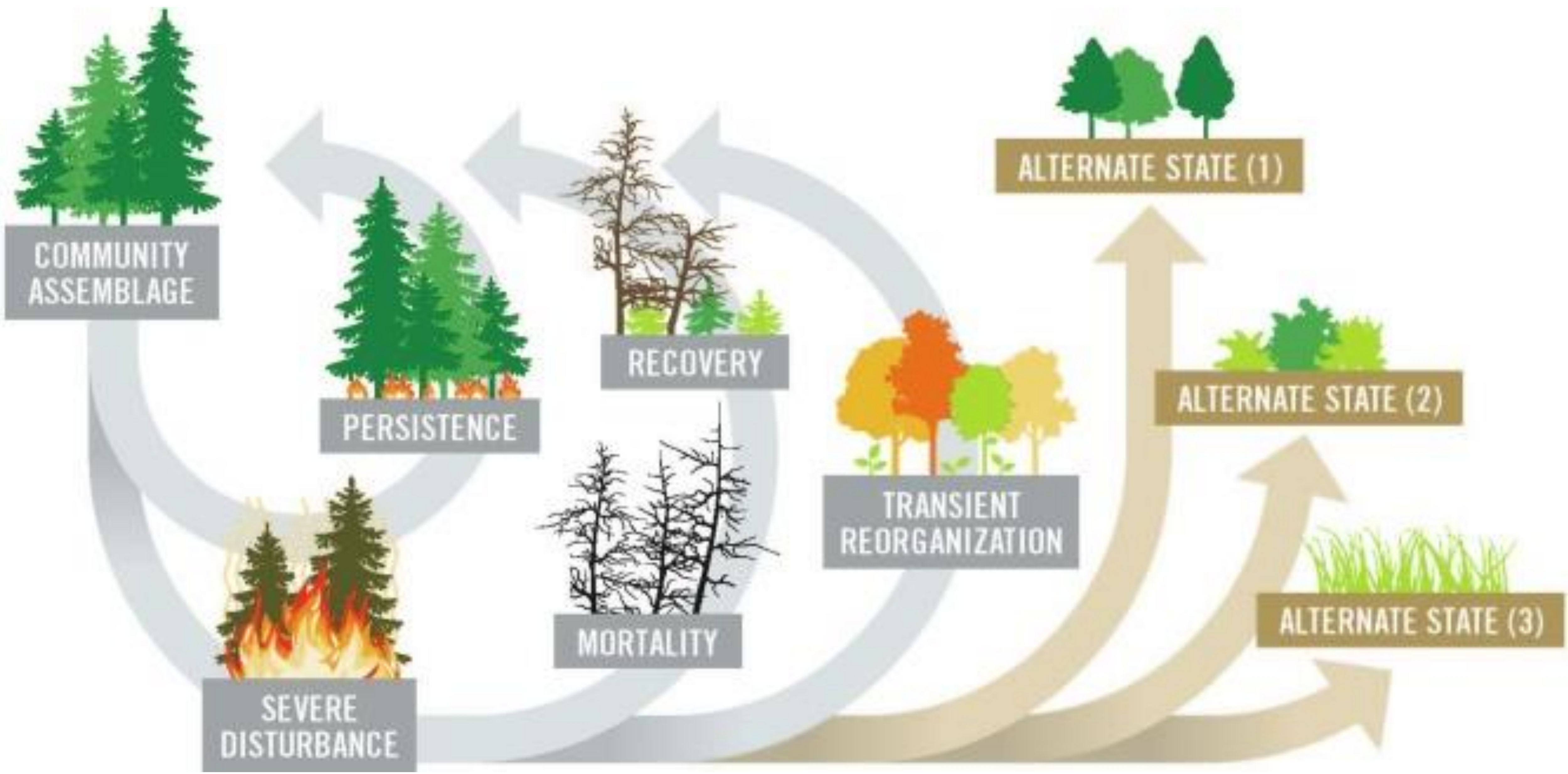
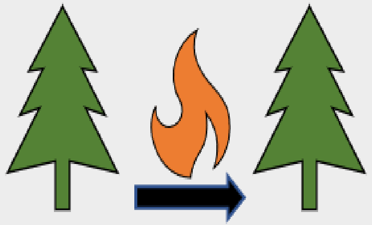
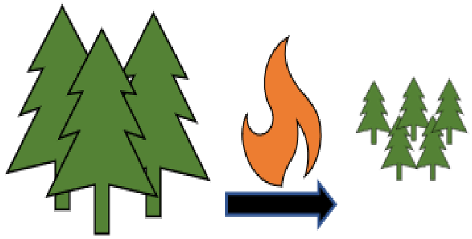
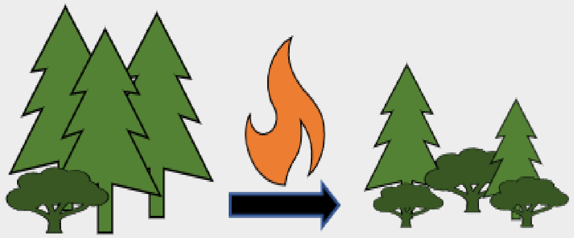
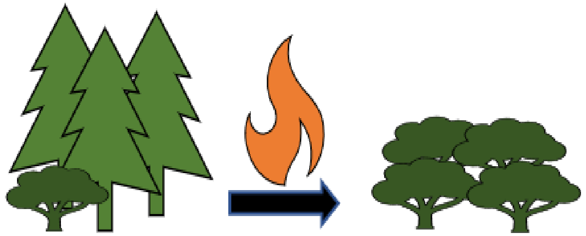
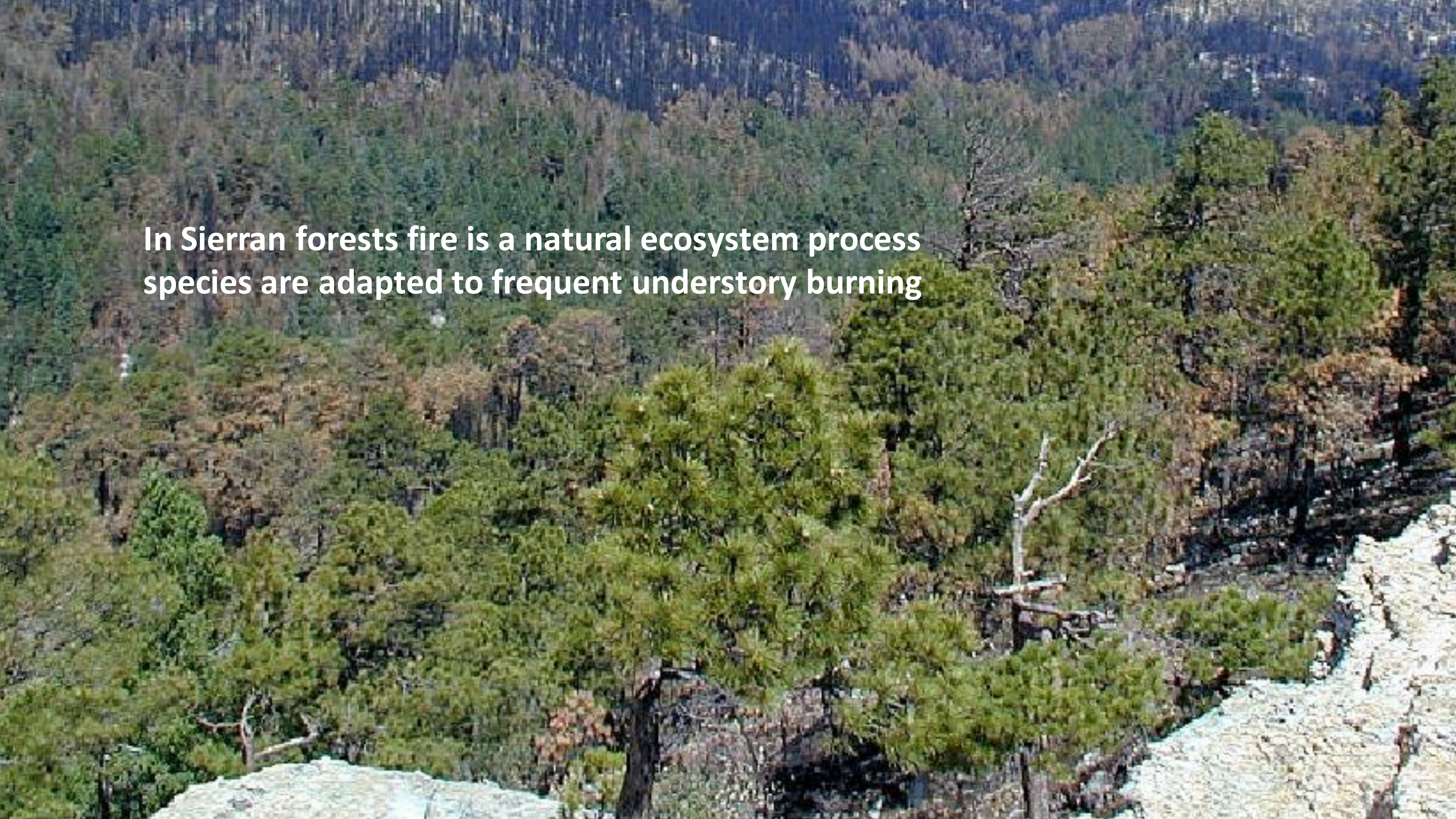

COMMUNITY ASSEMBLAGE
PERSISTENCE
RECOVERY
SEVERE DISTURBANCE
MORTALITY
TRANSIENT REORGANIZATION
ALTERNATE STATE (1)
ALTERNATE STATE (2)
ALTERNATE STATE (3)

		Description	Examples
Persistence		The ability of an individual organism (e.g. a single shrub or tree) to survive a disturbance	Thick, insulating bark prevents fire injury; self-pruning of dead branches; capacity to resprout from roots, trunk, or branches; drought-resistant xylem/hydraulic systems; managers protect a culturally important site from fire
Recovery		The replacement of the pre-disturbance population through recruitment or colonization	Seeds in the soil or in cones germinate after a fire, triggered by heat or smoke; seeds or other propagules are dispersed into the area by wind, water, or animals; managers plant trees following high severity fire
Reorganization		A community of species continues to exist post-disturbance but no longer resembles the pre-existing community in one or more ways	Species composition changes due to a warmer, drier temperatures; increased forest density following fire exclusion; managers plant drought-tolerant species after fire
Vegetation type conversion		A special case of reorganization in which the change in community type and dominant plant functional types are extensive, and the alternative state is persistent and reinforced by novel interactions among climate, vegetation, and disturbances	A forest converts to a shrubland after trees fail to recover after a large wildfire; a shrubland converts to a grassland after frequent fire and introduction of invasive annual grasses

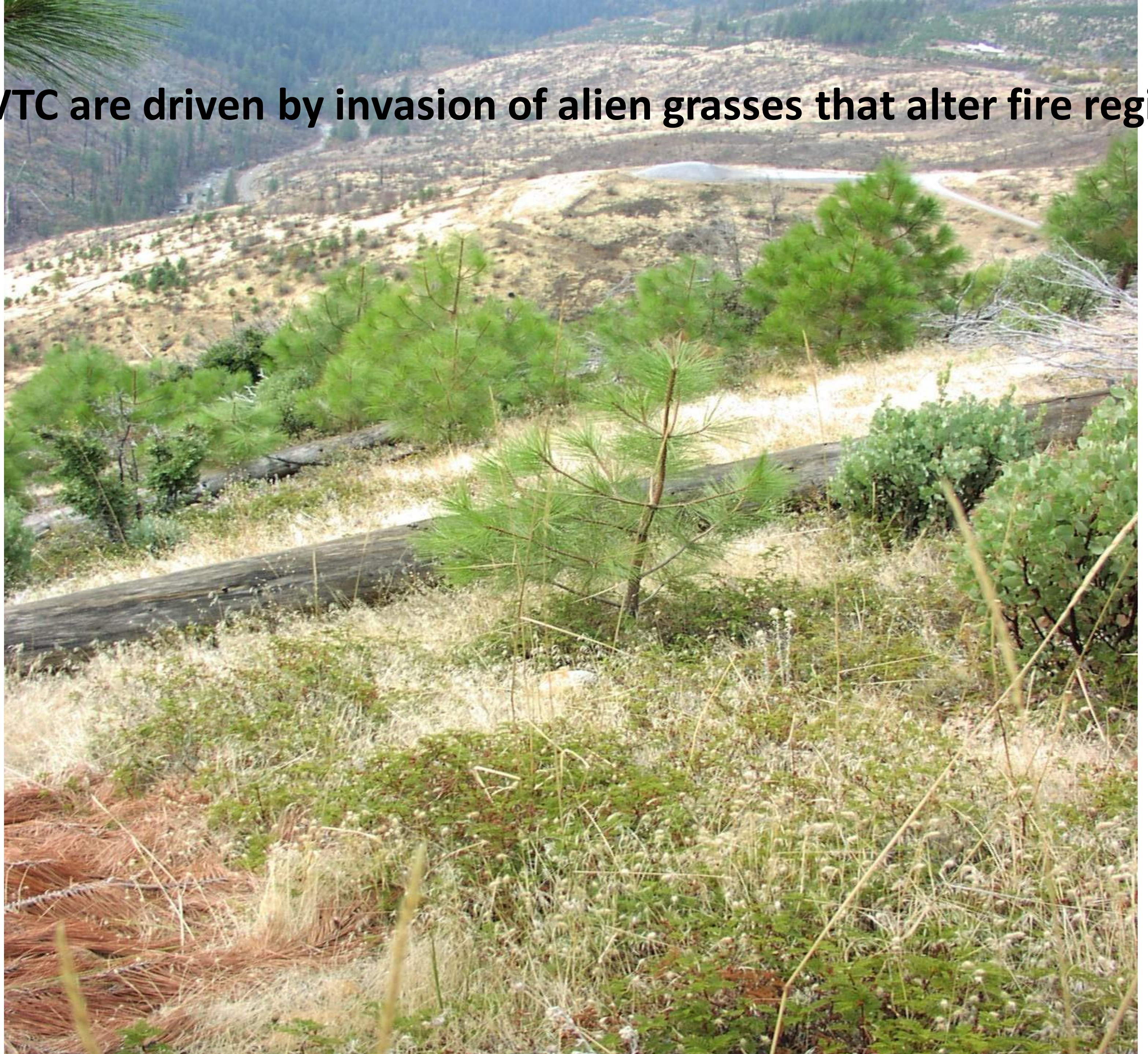

In Sierran forests fire is a natural ecosystem process
species are adapted to frequent understory burning

However, humans have perturbed the natural fire regime by producing longer intervals resulting in huge increases in fuels, thus changing the regime to one of high intensity crown fires

How does this forest recover from such extreme events?

Often times these VTC are driven by invasion of alien grasses that alter fire regimes

Former ponderosa pine forest in Eldorado County after 1991 fire that removed the forest, then cheatgrass invasion that carried a repeat fire in 8 years



Guiterman *et al. Fire Ecology* (2022) 18:6
https://doi.org/10.1186/s42408-022-00131-w

Fire Ecology

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Vegetation type conversion in the US Southwest: frontline observations and management responses

Christopher H. Guiterman[1,2,3*], Rachel M. Gregg[4], Laura A. E. Marshall[5,6], Jill J. Beckmann[7,8], Phillip J. van Mantgem[7], Donald A. Falk[1,5], Jon E. Keeley[9,10], Anthony C. Caprio[11], Jonathan D. Coop[12], Paula J. Fornwalt[13], Collin Haffey[14], R. Keala Hagmann[15,16], Stephen T. Jackson[17,18], Ann M. Lynch[19], Ellis Q. Margolis[20], Christopher Marks[21], Marc D. Meyer[22], Hugh Safford[23,24], Alexandra Dunya Syphard[25,26], Alan Taylor[27], Craig Wilcox[28], Dennis Carril[29], Carolyn A. F. Enquist[17], David Huffman[2], Jose Iniguez[30], Nicole A. Molinari[31], Christina Restaino[32] and Jens T. Stevens[20]

Abstract

Abstract

Background: Forest and nonforest ecosystems of the western United States are experiencing major transformations in response to land-use change, climate warming, and their interactive effects with wildland fire. Some ecosystems are transitioning to persistent alternative types, hereafter called "vegetation type conversion" (VTC). VTC is one of the most pressing management issues in the southwestern US, yet current strategies to intervene and address change often use trial-and-error approaches devised after the fact. To better understand how to manage VTC, we gathered managers, scientists, and practitioners from across the southwestern US to collect their experiences with VTC challenges, management responses, and outcomes.

Results: Participants in two workshops provided 11 descriptive case studies and 61 examples of VTC from their own field observations. These experiences demonstrate the extent and complexity of ecological reorganization across the region. High-severity fire was the predominant driver of VTC in semi-arid coniferous forests. By a large margin, these forests converted to shrubland, with fewer conversions to native or non-native herbaceous communities. Chaparral and sagebrush areas nearly always converted to non-native grasses through interactions among land use, climate, and fire. Management interventions in VTC areas most often attempted to reverse changes, although we found that these efforts cover only a small portion of high-severity burn areas undergoing VTC. Some areas incurred long (>10 years) observational periods prior to initiating interventions. Efforts to facilitate VTC were rare, but could cover large spatial areas.

Conclusions: Our findings underscore that type conversion is a common outcome of high-severity wildland fire in the southwestern US. Ecosystem managers are frontline observers of these far-reaching and potentially persistent changes, making their experiences valuable in further developing intervention strategies and research agendas. As its drivers increase with climate change, VTC appears increasingly likely in many ecological contexts and may require

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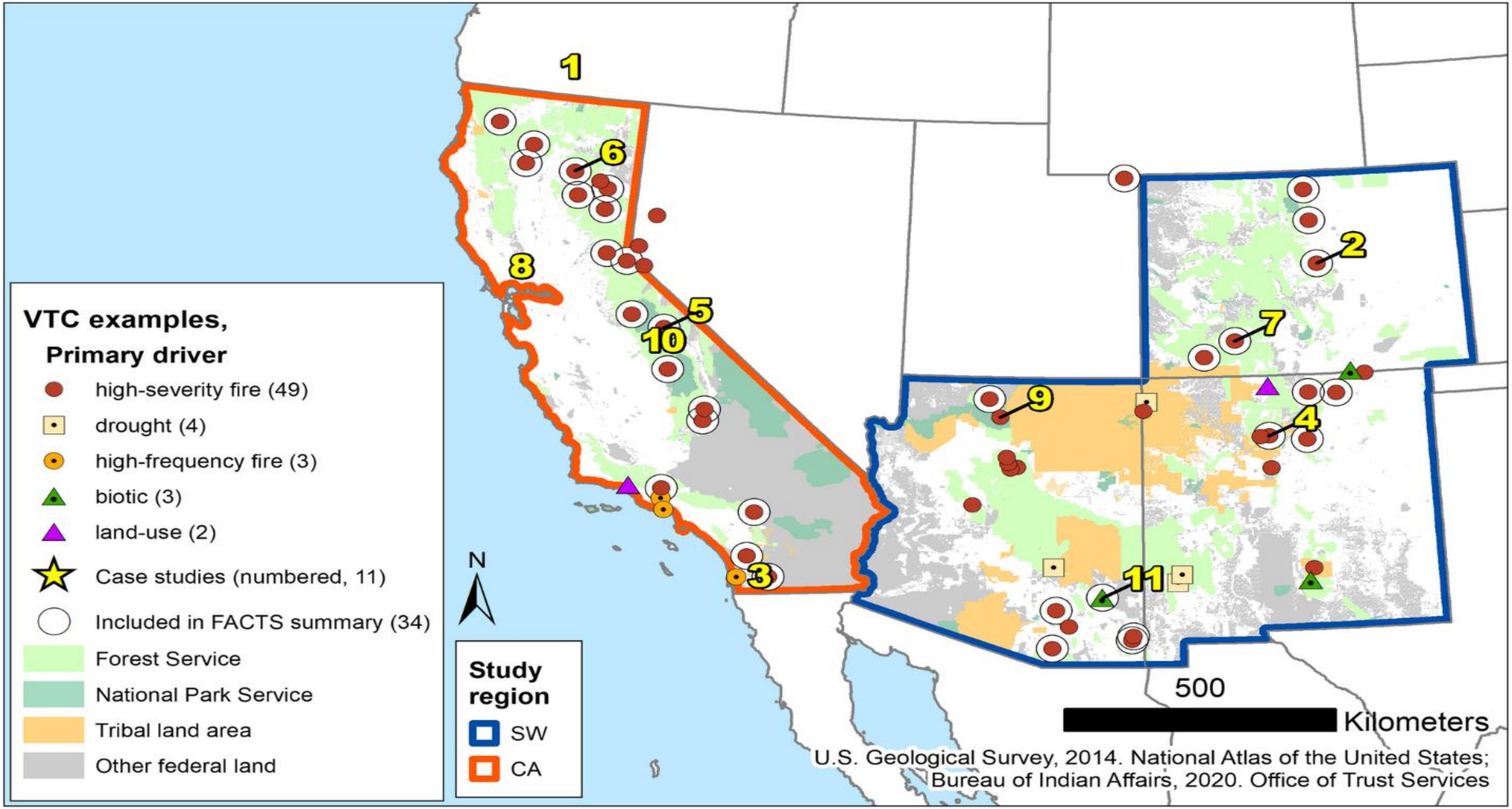
1
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8
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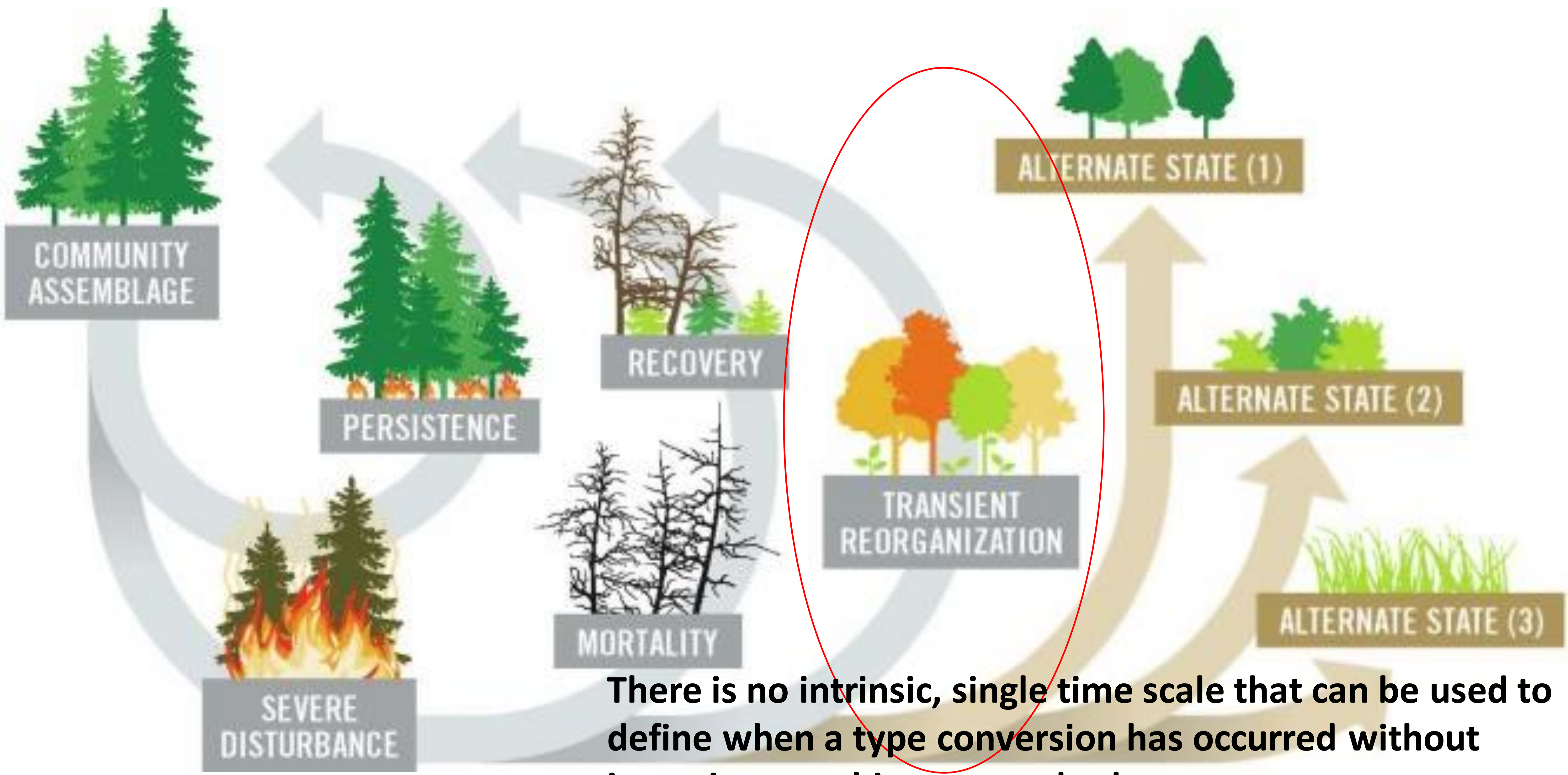
10
11
VTC examples,
Primary driver
high-severity fire (49)
drought (4)
high-frequency fire (3)
biotic (3)
land-use (2)
Case studies (numbered, 11)
Included in FACTS summary (34)
Forest Service
National Park Service
Tribal land area
Other federal land
N
Study region
SW
CA
500
Kilometers
U.S. Geological Survey, 2014. National Atlas of the United States;
Bureau of Indian Affairs, 2020. Office of Trust Services

Table 1 Descriptions of management responses to VTC from workshop participants along with case study examples

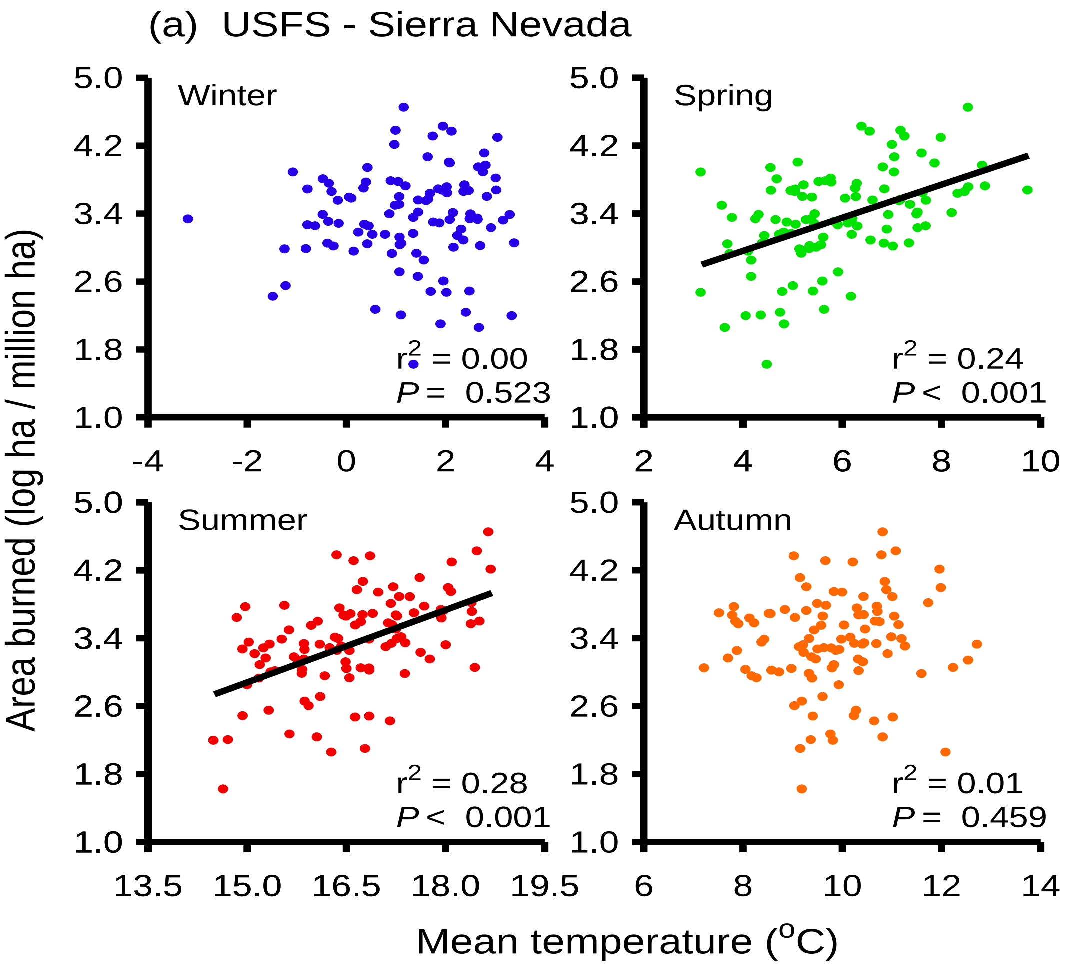
Management response	Description	Case study examples
Reverse change	Actively try to reverse change via: • Coupled thinning and prescribed fire treatments to reduce fuel loads and fire severity and promote fire-dependent species and ecosystem recovery (Stephens et al. 2009) • Planting or seeding pre-VTC species • Removing or managing new or undesirable species (e.g., non-native grasses and shrubs that may increase fire frequency and/or severity) • Fire suppression to reduce fire extent and allow for recovery time • Preventing post-disturbance soil loss to sustain ecological functions	1. Klamath Reservation, southern Oregon 2. Southern Front Range, Colorado 3. Laguna Mountain, California
Observe change	Take no active intervention measures and adopt monitoring to assess ecosystem trajectory over time. This approach may be most appropriate where there is: • Limited management capacity (e.g., high upfront and maintenance costs of active intervention, limitations to access in sites such as those in wilderness or roadless lands) (Rother et al. 2015; Aplet and Mckinley 2017) • High uncertainty of unintended consequences of active intervention (e.g., one workshop participant noted that "sometimes doing something is worse than doing nothing") (Landres 2010). This approach is consistent with restoration paradigms emphasizing a spectrum of approaches to spread risk (Aplet and Mckinley 2017).	4. Eastern Jemez Mountains, New Mexico 5. Devils Postpile National Monument, California 6. Lassen Volcanic National Park, California 7. San Juan Mountains, Colorado 8. Inner Coast Range, northern California
Facilitate change	Actively direct system toward alternative and/or novel acceptable conditions by: • Planting or seeding with focus on more drought- and fire-tolerant species compared to pre-disturbance species (e.g., assisted gene flow; Young et al. 2020) • Follow-up wildfires with ecologically-credible fuel reduction activities	9. North Rim of the Grand Canyon, Arizona 10. Southern Sierra Nevada, California 11. Pinaleño Mountains, Arizona



There is no intrinsic, single time scale that can be used to define when a type conversion has occurred without imposing an arbitrary standard.


Potential Climate Change Impacts

Fire regimes



1910 – 1959 0.42 - Ppt spr - Ppt win

1960 - 2013 0.52 Temp spr + Temp sum

Keeley & Syphard 2017

Postfire recovery

Elevated temperatures increase water deficits, favoring invasive grasses over tree seedlings

This leads to VTC feedbacks that further alter fire regimes

Wildfires and climate change push low-elevation forests across a critical climate threshold for tree regeneration

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Edited by Christelle Hély, Ecole Pratique des Hautes Etudes, Montpellier, France, and accepted by Editorial Board Member Robert J. Scholes January 31, 2019 (received for review August 31, 2018)

Climate change is increasing fire activity in the western United States, which has the potential to accelerate climate-induced shifts in vegetation communities. Wildfire can catalyze vegetation change by killing adult trees that could otherwise persist in climate conditions no longer suitable for seedling establishment and survival. Recently documented declines in postfire conifer recruitment in the western United States may be an example of this phenomenon. However, the role of annual climate variation and its interaction with long-term climate trends in driving these changes is poorly resolved. Here we examine the relationship between annual climate and postfire tree regeneration of two dominant, low-elevation conifers (ponderosa pine and Douglas-fir) using annually resolved establishment dates from 2,935 destructively sampled trees from 33 wildfires across four regions in the western United States. We show that regeneration had a nonlinear response to annual climate conditions, with distinct thresholds for recruitment based on vapor pressure deficit, soil moisture, and maximum surface temperature. At dry sites across our study region, seasonal to annual climate conditions over the past 20 years have crossed these thresholds, such that conditions have become increasingly unsuitable for regeneration. High fire severity and low seed availability further reduced the probability of postfire regeneration. Together, our results demonstrate that climate change combined with high severity fire is leading to increasingly fewer opportunities for seedlings to establish after wildfires and may lead to ecosystem transitions in low-elevation ponderosa pine and Douglas-fir forests across the western United States.

ecosystem transition | climate change | wildfire | ponderosa pine | Douglas-fir

juveniles of the same species (6, 14, 15). Disturbance-catalyzed change at lower treeline, where trees grow at the warm, dry margin of their climatic tolerances, may be one of the first visible signs of forest ecosystems adjusting to new climate conditions. Recent evidence suggests that wildfires may already be catalyzing vegetation shifts in forests across the western United States (16), with limited tree regeneration following fires in recent decades (e.g., refs. 17–19). This is particularly acute in low-elevation forests (17, 20–23), implicating climate change as an important driver of regeneration failures. However, the annual climate conditions which limit tree regeneration are poorly resolved, and potential thresholds to regeneration have not been identified. Understanding if recent reductions in postfire tree regeneration signal an ecosystem transition (e.g., to a nonforested state) requires a quantitative understanding of how seasonal to interannual variations in climate impact tree seedling germination and establishment.

Here we demonstrate that dry low-elevation *Pinus ponderosa* (ponderosa pine) and *Pseudotsuga menziesii* (Douglas-fir) forests of the western United States have crossed a critical climate threshold for postfire tree regeneration. We focused on ponderosa pine and Douglas-fir because they are widespread ecologically and

Significance

Changes in climate and disturbance regimes may cause abrupt shifts in vegetation communities. Identifying climatic conditions that can limit tree regeneration is important for understanding when and where wildfires may catalyze such changes. This study quantified relationships between annual climate conditions and