



ADAPTING TO A NEW **FIRE FUTURE**

Recommendations for fire management
on the Kaibab Plateau and the
Grand Canyon's North Rim

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GRAND CANYON
TRUST

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Conservation Science Partners is a 501(c)3 nonprofit organization working to apply human ingenuity to the preservation of nature using science, technology, and lasting partnerships with conservation practitioners.



The Grand Canyon Trust is a 501(c)3 nonprofit organization working to safeguard the wonders of the Grand Canyon and the Colorado Plateau, while supporting the rights of its Native peoples.

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Executive Summary

The Kaibab Plateau of northern Arizona is poised for substantial ecological change over the coming decades as a more arid regional climate, a century of fire exclusion, and an increasingly intense fire future converge. The long-term fire trajectory on the Kaibab Plateau foretells large, high-severity fires over the next one to three decades, short-interval reburns, and emerging vegetation shifts — all of which management can shape.

Given this trajectory, fire management grounded in proactive forest restoration, best available science, and Indigenous and local knowledge could lead to healthier, more climate-adapted forests. The 2025 White Sage and Dragon Bravo fires, which burned nearly 204,500 acres of public lands on the Kaibab Plateau, made clear that the time to act is now. These fires also highlighted the resilience of local communities and their reciprocal connection with the land, pointing to a strong foundation for future collaboration and forward-thinking actions.

The Kaibab Plateau is managed by the Kaibab National Forest, Grand Canyon National Park, and the Bureau of Land Management Arizona Strip Field Office. Its high-elevation forests include pinyon and juniper woodlands along its flanks, montane ponderosa pine woodland atop the plateau, and mixed conifer with spruce and fir at the highest

reaches. The region's complicated history of logging, periodic insect outbreaks, drought, and fire exclusion, and a recent dramatic escalation of wildfire activity overlay these multiple jurisdictions and forest types and underscore how critically important strategic and coordinated stewardship will be on the Kaibab Plateau in the coming decades.

The plateau holds rare old-growth ponderosa, biodiverse seeps and springs, key habitat for imperiled and endemic species, and more. And its cultural values are irreplaceable — from ancient archaeological artifacts and plants imbued with medicinal, ceremonial, or craft importance, to places of great cultural significance to local tribes. The plateau's cultural and ecological relevance is also a major factor in northern Arizona and southern Utah economies. As many as 400,000 visitors traverse the plateau en route to the north rim of the Grand Canyon annually.¹



PHOTO: JASON NEZ, NATIONAL PARK SERVICE

The decisions made now and following the inevitable next fires will shape the plateau for years to come.



PHOTO: ED MOSS

The 2025 White Sage and Dragon Bravo fires, which burned nearly 204,500 acres of public lands on the Kaibab Plateau, made clear that the time to act is now.

With these multiple jurisdictions, varied vegetation types, and landscape values in mind, this report sets forth 12 recommendations for supporting post-fire recovery and ongoing forest and fire management to sustain the ecological values and resilience of the Kaibab Plateau. To inform these recommendations, the report weighs future fire, forest, and climate trajectories. Recommendations are based on the three

dominant forest types: ponderosa pine, pinyon and juniper woodland, and mixed conifer. Management decisions must be grounded in local knowledge and meaningful engagement with tribes, and the public. Co-stewardship with associated tribes across planning and decision-making must be folded into the cross-agency collaboration needed to steward the Kaibab Plateau into the future, including leveraging beneficial fire. Because the landscape is divided among the Kaibab National Forest, Grand Canyon National Park, and the Bureau of Land Management Arizona Strip Field Office, managing future fire across it requires a planning framework intended to span boundaries. Monitoring and adaptive management are integral to the success of these recommendations.

The 2025 fires, which devastated the North Rim, are part of an accelerating trend of large, high-severity fire that is reshaping much of the western U.S. The decisions made now and following the inevitable next fires will shape the plateau for years to come. The most ecologically sound path forward in this warming and drying era is neither striving for past conditions that are no longer tenable nor doing nothing. Instead, that path calls for forward-looking, collaborative stewardship that reads the landscape closely, relies on the best-available conservation science joined with Indigenous knowledge, plans across boundaries, and embraces strategic reforestation and beneficial fire.

Wildfire smoke on the north rim of the Grand Canyon.
PHOTO: RAVEN CHAVEZ



Summary of Recommendations

These 12 proactive and scientifically grounded recommendations are designed to support post-fire recovery following the 2025 White Sage and Dragon Bravo fires and ongoing forest and fire stewardship to promote and sustain the ecological resilience of the Kaibab Plateau.

RECOMMENDATION 1:
Meaningfully include local tribes in co-stewardship of the Kaibab Plateau.

Supporting tribal co-stewardship calls on land managers to uphold tribal consultation but also to expand beyond “check-the-box” practices to fulfill the federal trust responsibility to tribal nations. This includes uplifting shared authority across planning, decision-making, implementation, and monitoring of forest and fire management actions.

RECOMMENDATION 2:
Retain use of beneficial fire as a key management tool and prioritize actions that move forests toward ecologically grounded fire regimes.

Land management objectives should strive to return more frequent, low-intensity fire patterns to ponderosa pine and dry mixed conifer forests using beneficial fire as a key tool. In pinyon and juniper forests, mitigation of invasive annual species should remain the priority while in more moist spruce and fir forests, patchy forest structure should be promoted.

RECOMMENDATION 3:
Pursue management actions that restore fire-resistant forest structure and heterogeneity and protect large and old trees.

Forest restoration actions that involve tree removal should focus on large and old tree retention, thinning from below, and heterogeneous forest-structure targets. They should be paired with prescribed or managed fire to achieve the greatest reductions in the risk of uncharacteristically severe wildfire.

RECOMMENDATION 4:
Consult with tribes to identify and safeguard cultural resources proactively and defensively.

Land managers cannot protect what they do not recognize. Managers should consult with tribes and conduct field visits to identify cultural resources and places that can be surveyed and protected in the event of fire.

RECOMMENDATION 5:
Protect and, where appropriate, restore wetlands and wet meadows to reduce severe wildfire risk, safeguard culturally important areas, and support overall forest health.

Wetlands and wet meadows should be proactively protected and restored for their fire break potential, water retention functions, and cultural significance. These ecosystems should be excluded, with buffers, from ground-disturbing management activities, including rerouting logging roads where needed.

RECOMMENDATION 6:
Apply specific safeguards to sensitive species with all forest restoration and fire management actions.

Forest thinning and other fire management actions should apply specific safeguards to sensitive, rare, and endemic species. This includes meeting forest-structure and tree-retention targets that support the habitat requisites of the American goshawk, Mexican spotted owl, pinyon jay, Kaibab squirrel, and others, as well as timing operations to avoid disruptions to breeding seasons.

RECOMMENDATION 7:

Minimize disturbance of post-fire forest structure to support early-stage recovery by native, fire-adapted plants and wildlife.

After fire, retaining surviving trees and other plants helps natural regeneration to take hold while retaining large, stable snags — standing dead trees — supports unique habitat for dependent wildlife. Intensive ground-disturbing actions soon after fire should be avoided as they can disrupt the regrowth of trees and other plants as well as negatively impact soils and site recovery.

RECOMMENDATION 8:

Define burned trees as hazardous based on public safety and infrastructure concerns, rather than by condition alone.

Public safety remains the top priority for post-fire land management. Standardized risk assessments should be used to evaluate the conditions of burned trees and identify those that pose a safety concern to ensure hazardous tree removal is targeted and efficient.

RECOMMENDATION 9:

Avoid broad-scale salvage logging and do not rely on it to reduce future fire risk.

Salvage logging should not be used as a general fire fuels-reduction tactic. Where tree removal is warranted, actions should be targeted and ecologically informed and follow best practices for minimizing impacts to habitats. Extensive salvage logging across a recovering landscape should be avoided and sensitive areas (e.g., wet meadows) should be entirely excluded.

RECOMMENDATION 10:

Pursue active reforestation where natural regeneration is unlikely and future climate conditions support native forest establishment.

Post-fire land management should allow for natural forest regeneration wherever it can occur. Where natural regeneration is unlikely, managers may consider planting native trees and leveraging on-the-ground assessments and decision support tools to locate sites and guide planting investments.

RECOMMENDATION 11:

Promote native plants and natural regeneration and mitigate invasive species spread in burned areas.

Best practices for mitigating invasive species, such as minimizing ground disturbance, should be applied throughout burned areas. Invasive species prevention should focus on on-the-ground monitoring as well as efforts to protect and restore biological soil crust and native plant species cover. Where natural understory regeneration is unlikely, seed with native-only mixes and avoid non-native seeding entirely.

RECOMMENDATION 12:

Manage public-land uses to support post-fire recovery and regeneration.

Because land uses of the Kaibab Plateau, such as recreation or grazing, can alter the recovery trajectory of post-fire landscapes, they should be limited around recovering burned areas. Monitoring post-fire vegetation recovery can inform and guide adaptive management.

PHOTO: CERISSA HOGLANDER

Background

The Kaibab Plateau of northern Arizona is one of North America's most ecologically distinctive high-elevation landscapes and a gateway to one of the seven natural wonders of the world, the Grand Canyon.

A forested “sky island,” it encompasses nearly 1,150 square miles entirely above 6,000 feet in elevation, with its highest point reaching 9,200 feet — well over a mile above the floor of the Grand Canyon. The plateau's minimum winter temperatures are below freezing while average summer maxima can climb well above 80°F. Most of the annual precipitation of 20-25 inches falls as winter snow or as rain during the summer monsoon. Its topography, climate, and geographic isolation compress considerable biodiversity and outstanding examples of old-growth ponderosa pine (*Pinus ponderosa*) into a relatively small area.

Seeps and springs are important centers of biodiversity on the plateau, as there are fewer than two miles of perennial streams across the entirety of the Kaibab National Forest.^{2,3} It is home to iconic species like the Kaibab squirrel (*Sciurus aberti kaibabensis*), California condor (*Gymnogyps californianus*), and mule deer (*Odocoileus hemionus*). Biodiversity exists within a mosaic of vegetation communities — from pinyon and juniper (*Pinus edulis* and *Juniperus* species) woodlands along the plateau's flanks to open ponderosa pine forests to mixed conifer and pockets of mesic subalpine spruce and fir forests (primarily *Picea engelmannii* and



The range of the once nearly extinct California condor includes the Kaibab Plateau. PHOTO: ANDREW ORR

Abies lasiocarpa). While the fire regimes across these vegetation communities have been disrupted by fire exclusion — in some contexts, dramatically — in the last 150 years, some of the more remote forested areas were spared, distinguishing the plateau from much of the American West and providing a reference for historic fire conditions.⁴⁻⁶

Indigenous peoples, including ancestors of the Kaibab Paiute whose word for “mountain lying down” informed the area’s current name, have inhabited the region for more than 10,000 years. A full account of Indigenous peoples’ past and enduring connections to the Kaibab Plateau is beyond the scope of this report. Prior to being displaced from their ancestral lands in the mid-1800s with Mormon colonization,⁷ the Kaibab Paiute occupied and moved throughout the plateau with seasonal food, shelter, and other needs. As was common to other Indigenous peoples in the region, their practices included setting and managing fires — for example, cyclical burns would promote

pinyon nut production and understory plants in the ponderosa pine forest.^{7,8} The curtailment of Indigenous burning coupled with the expansion of heavy livestock grazing changed the plateau’s forest structure and reduced fine fuels that had typically carried frequent, low-severity fires.⁸ Thus began the modern era of fire exclusion.

The Kaibab National Forest was established in 1908 under President Theodore Roosevelt, who also designated what would later become Grand Canyon National Park in 1919. This coincided with the widespread adoption of fire suppression across forests, which remained the prevailing fire management paradigm across the nation until recent decades. Old lookout trees — trees outfitted with high platforms from which occupants could scan the forest canopy for fires — suggest the Kaibab Plateau, despite its relative isolation, saw active fire suppression efforts very early in the century.^{8,9} Industrial forestry came comparatively late to the plateau, as its distance from transcontinental

railroads spared it the heavy logging that reshaped forests elsewhere in the region. Timber harvesting remained relatively limited until after World War II, when postwar lumber demand prompted the district’s first timber management plan and, in 1950, its first large sale. Early cuts were selective, concentrating on old and less vigorous trees, but the 1980s brought a sharp shift toward even-aged harvesting.^{9,10} Between the 1920s and the closure of the Fredonia mill in 1992, roughly 1.8 billion board feet — about 80% ponderosa pine — were removed from nearly 200,000 acres of the North Kaibab Ranger District. This left a patchwork of older, multi-aged forest stands punctuated by young, even-aged regeneration and, at the higher elevations, a steady increase in shade-tolerant species like fir and spruce.⁹⁻¹¹ This logging, coupled with periodic insect outbreaks (e.g., *Ips* beetles) exacerbated by drought and a legacy of fire exclusion, has contributed to contemporary forest conditions across the plateau’s ponderosa pine and lower-elevation mixed conifer forests in particular.^{3,11,12}

This layered, complicated history underscores how critically important strategic and forward-thinking stewardship will be on the plateau in the coming decades. Its ecological values remain considerable — rare old-growth ponderosa, biodiverse seeps and springs, key habitat for imperiled and endemic species, and more. And its cultural values are irreplaceable — from ancient archaeological artifacts and plants imbued with medicinal, ceremonial, or craft importance, to locations and landscape features of great cultural significance to local tribes, including the Kaibab Band of Paiute Indians, Hopi Tribe, Pueblo of Zuni, Navajo Nation, and others. The plateau’s cultural relevance has grown in other ways too. Up to 400,000 visitors traverse the land annually en route to the North Rim of the Grand Canyon,¹ where numerous historic buildings were lost in the 2025 Dragon Bravo blaze. The deep, enduring ecological, cultural, and historical significance of the Kaibab Plateau makes clear the need for a holistic, inclusive, and strategic approach to stewarding the landscape into an uncertain future.



Ponderosa pine trees felled in 1924 for bark beetle control in the Kaibab National Forest. PHOTO: USDA FOREST SERVICE, PACIFIC NORTHWEST REGION



Aerial view showing the southwest corner of the Bright Angel Peninsula that burned in the Dragon Bravo Fire, including the site of the former Grand Canyon Lodge. PHOTO: MATT JENKINS, NATIONAL PARK SERVICE

Forest and Fire Management on the Kaibab Plateau

The jurisdiction and management of the Kaibab Plateau that is the focal area of this report is chiefly shared by the National Park Service, which manages Grand Canyon National Park along the north rim of the Grand Canyon, and the U.S. Forest Service, which manages the Kaibab National Forest North Kaibab Ranger District. The Bureau of Land Management (BLM) manages the Arizona Strip Field Office surrounding the northern portion of the plateau with only a small sliver overlapping. Parts of the Kaibab Plateau are managed as the Baaj Nwaavjo l'tah Kukveni — Ancestral Footprints of Grand Canyon National Monument. The entire plateau falls within Arizona's Coconino County while maintenance for the Kaibab Plateau's main highway corridors is led by the Arizona Department of Transportation.

Forest and fire management on the Kaibab Plateau is guided primarily by the Kaibab National Forest's 2014 Land and Resource Management Plan (hereafter, KNF Forest Plan)² and its associated final environmental impact statement,³ by Grand Canyon National Park's 2025 Fire Management Plan¹³ (updated annually), and by the BLM's 2008 Arizona Strip Field Office Resource Management Plan.¹⁴ While not covered directly in this report, desired conditions and ecological goals set for

the small portion of BLM's Arizona Strip Field Office on the Kaibab Plateau are similar to those set by the U.S. Forest Service and Grand Canyon National Park (e.g., to achieve fire return intervals appropriate for the ecological site through mechanical thinning and prescribed fire).

Fire is a natural component of the Kaibab Plateau landscape and its management as such is reflected in agency management plans, with desired conditions to move toward restoring more natural fire regimes. For example, the KNF Forest Plan identifies desired conditions for ponderosa pine and drier mixed conifer forests and states that fire-only management actions may be appropriate for fire fuel reduction in areas with open forest canopies and low fuel loads, but indicates mechanical fuel-reduction (i.e., thinning) is needed in many areas before fire can be safely reintroduced.²

Similarly, the Grand Canyon National Park Fire Management Plan prioritizes prescribed burns and mechanical thinning based on site-specific conditions to restore ecosystems to healthy natural conditions that are within the range of the plan's desired conditions and goals. For both land management agencies and across forest types, selection of forest restoration methods in designated wilderness must be consistent with minimum tool requirements and non-impairment standards. Based on a review of Treatment and Wildfire Interagency Geodatabase (TWIG 1.0; 2026) data, since 1987, about 325,000 acres of forest and woodlands have been mechanically thinned, and almost 360,000 acres have experienced prescribed burns on the plateau. Even so, the pace and scale of thinning and burning treatments, which are constrained by cost and access, among other factors, may not be meeting the need to keep forests within the range of desired conditions.²

PHOTO: GRAND CANYON NATIONAL PARK



National policies, plans, and practices can also affect fire management in the region and may shape the degree to which beneficial fire — including prescribed fire and managed wildfire — plays out. For example, the National Cohesive Wildland Fire Management Strategy (2014, 2023) is a national strategic framework established by the congressionally created Wildland Fire Leadership Council to address national wildland fire issues, and its goals include restoring and maintaining resilient landscapes. This is also overlaid with more recent directives, including 2025 Executive Order 14225 (“Immediate Expansion of American Timber Production”), which directs federal agencies to establish annual timber volume targets and accelerate timber projects (in part by bypassing some protections under the Endangered Species Act of 1973), and a 2025 secretary of agriculture memo, which allows rapid implementation of tree removal projects on U.S. Forest Service lands associated with fire risk (in part by authorizing exemptions from the National Environmental Policy Act of 1970).

One cross-cutting feature of forest and fire management across the plateau is collaboration. The 2009 Kaibab Forest Health Focus¹⁵ was a multi-stakeholder effort that sought to develop consensus on forest restoration guidance and priority areas on the plateau through a collaborative, science-based process, yielding a landscape assessment and a prioritization framework that remain relevant to collaborative forest management today. In addition, the North Zone Interagency Fire Management Program is a collaborative wildland fire organization that integrates personnel and resources from the Kaibab National Forest and Grand Canyon National Park to carry out, for example, prescribed burns across both landscapes.

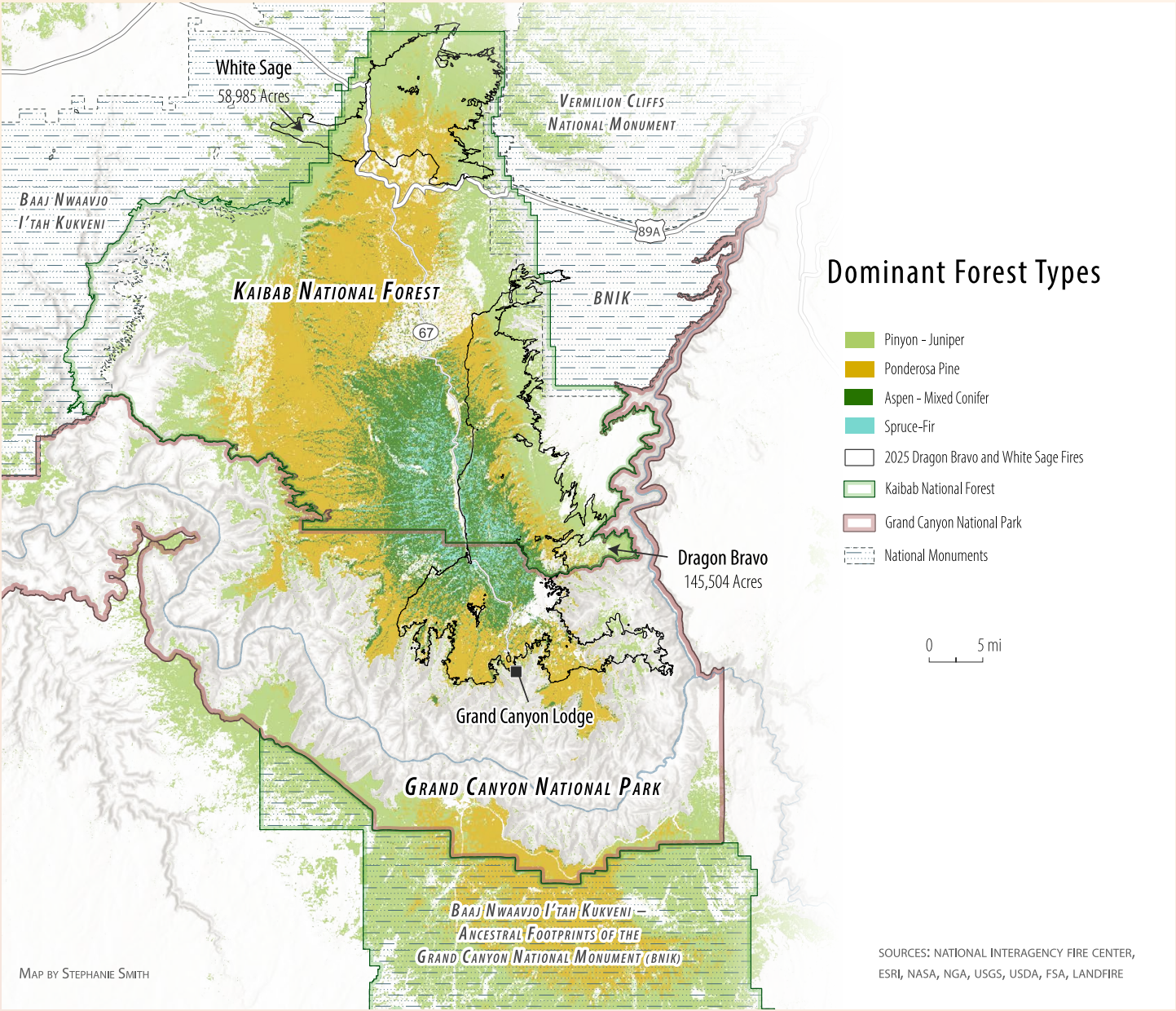
Another important component of both the KNF Forest Plan and the Grand Canyon National Park Fire Management Plan is coordination with local and regional tribes — in particular the Kaibab Band of Paiute Indians — who formally consult with both the U.S. Forest Service and National Park Service, often integrating traditional ecological knowledge into projects and identifying sensitive cultural and archaeological sites prior to management actions. According to the U.S. Forest Service, National Park Service, and BLM, the three agencies consult with 18 separate tribes (the Ak-Chin Indian Community, Fort McDowell Yavapai Nation, Gila River Indian Community, Havasupai Tribe, Hopi Tribe, Hualapai Tribe, Kaibab Band of Paiute Indians, Las Vegas Paiute Tribe, Moapa Band of Paiute Indians, Navajo Nation, Paiute Indian Tribe of Utah, Pueblo of Zuni, Salt River Pima-Maricopa Indian Community, San Carlos Apache Tribe, San Juan Southern Paiute Tribe, Tonto Apache Tribe, White Mountain Apache Tribe, and Yavapai-Apache Nation).

Fire is a natural component of the Kaibab Plateau landscape.

PHOTO: LAUREN CISNEROS

Forest and Fire History

The forests of the Kaibab Plateau include pinyon and juniper woodlands along its flanks and montane ponderosa pine forests atop the plateau that transition into more closed-canopy mixed conifer with spruce and fir components at the highest reaches. This broad gradient is punctuated by more localized patterns — north facing slopes of drainages host more mesic communities, for example. Broadly, much of the plateau’s ecosystems have always been — and will continue to be — shaped by fire.



This map depicts the three dominant forest types of the Kaibab Plateau: pinyon and juniper, ponderosa pine, and aspen-mixed conifer.

Pinyon and juniper woodlands

The pinyon and juniper woodlands fringing the plateau are dominated by two-needle pinyon and juniper species and tend to have denser canopies (>50% canopy cover) than elsewhere in the region. Historically, these pinyon and juniper woodlands experienced infrequent (>250 year interval) and high-severity fires.^{16,17} There is minimal evidence that low-severity fire historically played a role in these woodland systems.^{16,18} Thus, the present-day condition of the plateau’s pinyon and juniper woodlands may reflect historic fire suppression but perhaps to a lesser degree than, for example, ponderosa pine forests where frequent fire is (or

was, historically) more typical. Rather than fire, drought compounded with bark beetle outbreaks has been identified as a dominant force shaping pinyon and juniper woodlands.¹⁹ That said, the ongoing invasion of cheatgrass (*Bromus tectorum*), among other non-native species such as Russian thistle (*Salsola* species), onto the plateau has created an abundance of fire fuels and fuels connectivity that likely contributed a great deal to the fire connectivity, severity, and sheer area burned in the 2025 White Sage Fire, which grew from the pinyon and juniper woodlands into the ponderosa pine forest.



The pinyon and juniper woodlands fringing the plateau have historically experienced infrequent fire but non-native species like cheatgrass create an abundance of fire fuels in this forest type. PHOTO: ED MOSS

Ponderosa pine forests

Ponderosa pine forests historically blanketed the central part of the Kaibab Plateau. The dominant pattern was open and park-like — large, widely-spaced pines in uneven-aged clumps over a productive bunchgrass understory interspersed with denser pockets. The first known timber reconnaissance report in the early 1900s documented approximately 50 pines >6” in diameter per acre,²⁰ though the report may not have inventoried all aspects of forest structure and composition. Tree-ring reconstructions of late 1800s conditions at unharvested North Rim sites (e.g., Powell Plateau) yielded similar values of roughly 50-60 larger pines per acre.^{21,22} That first timber reconnaissance described the forest as having “all age classes in varying density and proportions, but nowhere fully stocked.”²⁰ At the time, forest structure had been maintained by frequent, low-severity surface fires that recurred on average every three to five years and more widespread fires that occurred every six to nine years.⁴ Surface fires cleared seedlings, litter, and fine fuels, while thick-barked, tall-crowned overstory pines persisted. The

frequent fire regime was a function of both lightning ignitions and intentional burning by Indigenous peoples who lived across the plateau.²³

Indigenous fire use likely ceased with the displacement of the Kaibab Paiute in the late 19th and early 20th centuries. The prevailing fire regime was further disrupted in the late 1800s by the arrival of large cattle operations, which substantially reduced the grasses and other fine fuel sources important to low-severity surface fires, and by the formal fire suppression activities that followed soon thereafter. More than a century of fire exclusion and alternating periods of selective logging and even-aged management has shifted ponderosa forests toward denser and more uniform stands with abundant small-tree ingrowth — including Douglas fir (*Pseudotsuga menziesii*) and white fir (*Abies concolor*) — and more continuous surface and canopy fuels.²⁴ The average fire-return interval across ponderosa communities in the greater Grand Canyon landscape is now 50 years — roughly seven to eight times longer than the historical interval.⁵ Stand densities in some areas are well over twice the densities in reference areas where fire has not been excluded.²⁵ Fire modeling indicates that the share of North Rim forests vulnerable to stand-replacing fires rose from 6% in the late 1800s to 33% by 2000.²⁶

In ponderosa pine forests, recent fire history has exemplified this trend. The 2006 Warm Fire burned across 59,000 acres in massive, high-severity patches and the 2020 Mangum Fire burned 71,450 acres mostly in ponderosa pine forest and pinyon and juniper woodland. Very large fires with high-severity patches have continued in the 2025 fire season. The degree to which these forests have departed from their historical structure and dynamic suggests a key role — and even need — for ecologically grounded restoration actions that include beneficial fire.

The endemic Kaibab squirrel depends on the Kaibab Plateau's dense interlocking ponderosa pine canopy. PHOTO: KAIBAB NATIONAL FOREST



Mixed conifer forest covers the plateau's higher and more moist slopes, with important components of spruce, fir, and aspen. PHOTO: CERISSA HOGLANDER

Mixed conifer with aspen, spruce, and fir components

Grading into and above the ponderosa belt, mixed conifer forest covers the plateau's higher and more moist slopes, with components of spruce, fir, and aspen (*Populus tremuloides*) throughout. Here, ponderosa intermixes with Douglas fir and white fir, with stands of Engelmann spruce, blue spruce (*Picea pungens*; to a much lesser degree), and subalpine fir at the highest and coolest elevations. Aspen runs this whole gradient, typically coming in after fire.^{23,27}

The mixed conifer gradient historically burned under a mixed-severity regime — frequent, low-severity surface fires on warmer south-facing slopes alongside patches of higher-severity on cooler aspects.²⁸ The mixed conifer historically has had fire-return intervals of 20-30 years,²⁹ when high-severity patches may have been a less common occurrence. At the highest elevations, spruce and fir would have burned infrequently — on the order of every 70-250 years — but tended toward higher-severity, stand-replacing fires when they did.³⁰

Fire largely disappeared from these forests by the early 1900s. Forest stands that had been ponderosa

pine — with white fir largely absent — are mixed conifer today.³¹ Mixed conifer density on the plateau was about six times higher by 1990 than in 1909, with fir and spruce densities up by more than 600%, while ponderosa densities only modestly increased.¹¹ The replacement of ponderosa and subsequent infilling of smaller, shade-tolerant but less fire-tolerant conifers has altered the forest canopy in ways that make it susceptible to carrying crown fire in severe fire weather conditions.¹¹ Recent fires like the 2000 Outlet and 2025 Dragon Bravo fires reflect a shift toward larger, more severe patches than the past mixed-severity fire patches with which these forests likely evolved.

That said, fire regime variability in mixed conifer forests is more challenging to determine than in open ponderosa forests with more frequent surface fires.^{27,28} Spruce and fir dynamics are perhaps least certain of all. Thus, management recommendations for these forest types are best framed around restoring the ecological processes and complexity.^{11,27,28,31}

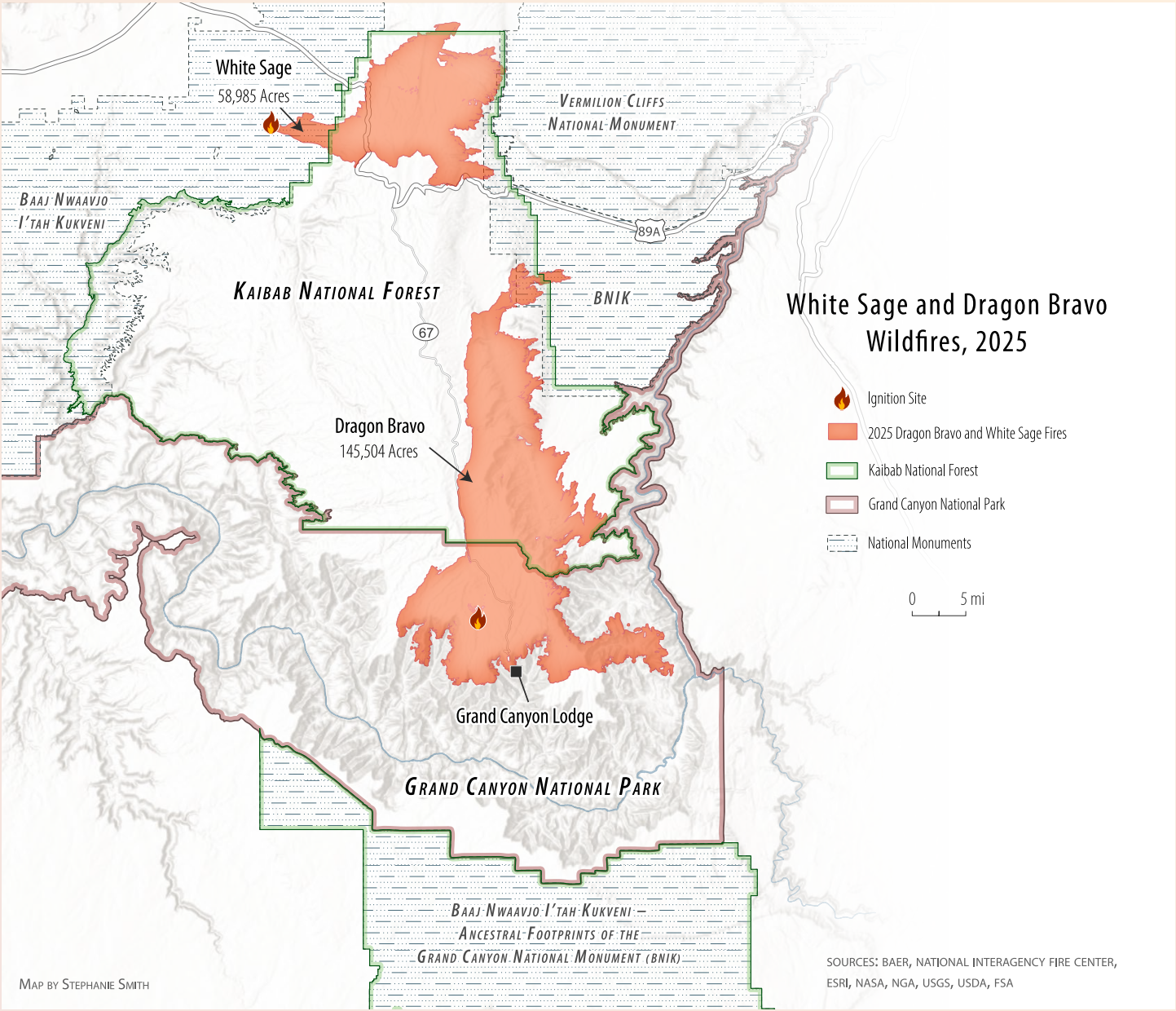
Recent fire trends

The dramatic escalation of regional wildfire activity across these forest types in recent decades underscores a clear departure from historical fire regimes, on the plateau and beyond. Recent trends are telling. Between 1984 and 2015, fuel aridity has led to increased burn areas,³² and areas burned at high severity in western U.S. forests increased eight-fold.³³ In Arizona and New Mexico alone, fires over the past three decades have

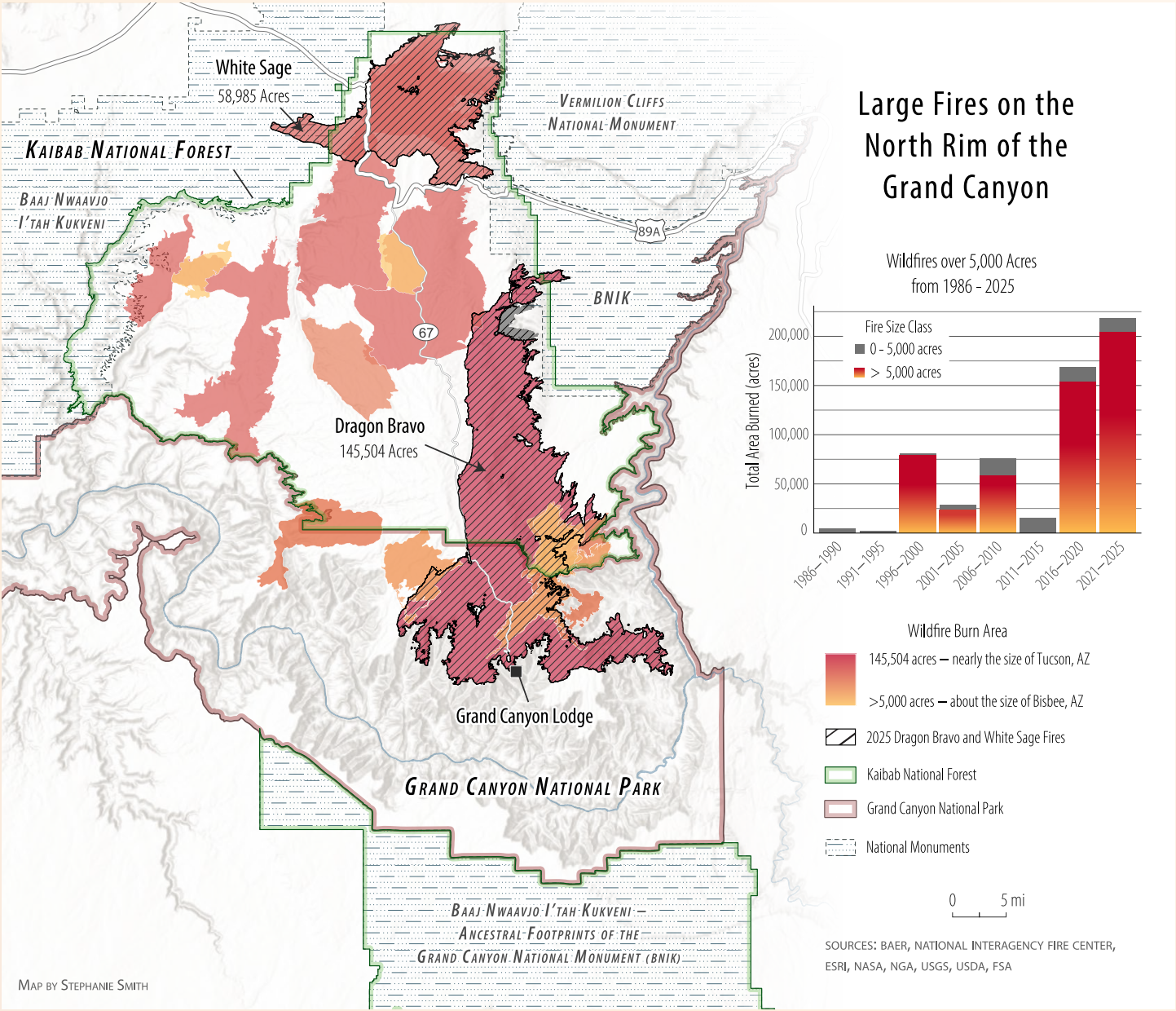
been more frequent, larger, and more severe across all forest and woodland types, and the relationship between advancing climate change and increasing fire severity in the Southwest has been steadily strengthening.³⁴ Fire activity on the Kaibab Plateau vividly illustrates these regional trends. The most extensive fires this

century include the 2006 Warm Fire and the 2020 Mangum Fire while the 2025 fire season saw the simultaneous burning of the Dragon Bravo and White Sage fires across nearly 204,500 acres of the plateau. The White Sage fire burned 58,985 acres north of Jacob Lake, Arizona, and largely in pinyon and juniper, with its rapid expansion facilitated in part by surface fuel continuity due to invasive cheatgrass. Farther

south, the Dragon Bravo surged to become a megafire, burning just over 145,500 acres of ponderosa, mixed conifer, and spruce and fir forests on the Kaibab National Forest and Grand Canyon National Park, as well as the historic Grand Canyon Lodge. Although the distressing 2025 fire season might be deemed unprecedented on the plateau, it may well become something closer to the norm in years to come.



This map shows the ignition points and extents of the 2025 Dragon Bravo and White Sage fires on the Kaibab Plateau that together burned nearly 204,500 acres.



Fire has long shaped the Kaibab Plateau. This map shows wildfires that occurred between 1986 and 2025 and burned more than 5,000 acres, including the 2025 Dragon Bravo and White Sage fires.

The Future of Forests and Fire on the Kaibab Plateau

The Kaibab Plateau is likely poised for substantial ecological change over the coming decades given multiple converging forces, including the lasting effects from over a century of fire exclusion, a more arid regional climate, and the acceleration of larger, hotter fires. Based on the best available science, what may be expected for forests of the Kaibab Plateau in the coming decades is a period of considerable disturbance followed by a transition into different forest, woodland, and other plant community patches — particularly along the lower-elevation and northern margins of the plateau.

Climate trajectory

The greater Grand Canyon landscape has been warming considerably for over a century and is widely anticipated to continue warming by as much as 9°F by 2050, while precipitation projections anticipate annual precipitation may modestly increase by 2050, falling more in sporadic and intense rainstorms and less as snow.³⁵

Despite precipitation projections, the plateau faces a net drying risk because warmer temperatures cause more moisture to be taken up by the surrounding atmosphere, which limits available water for plants.^{36,37} With this warming and drying trend, the number of days each year with snowfall could drop by more than half,³⁵ shortening the critical winter season on the



The 2006 Warm Fire burned nearly 59,000 acres in the Kaibab Forest, transitioning the area from largely ponderosa pine to mostly aspen and New Mexican locust. PHOTO: U.S. FOREST SERVICE, SOUTHWESTERN REGION, KAIBAB NATIONAL FOREST

Kaibab Plateau that sustains soil moisture, recharges groundwater, and limits fire spread as snowpack melts through the spring. These projections sit within a broader drying trend across the Southwest. The megadrought beginning in 2000 is the driest period in at least 1,200 years,^{38,39} resulting in dramatic flow reductions in both local springs and major river basins.

The Kaibab Plateau's future is one of more climatic extremes, including more variable and sustained droughts.^{40,41} How the region's warming and drying affect localized precipitation patterns, including the region's vital summer monsoon rains, remains to be seen. Summer monsoons deliver a substantial fraction of the plateau's precipitation, yet its future is among the least resolved aspects of regional climate, with no current consensus on its 21st century trajectory.^{35,42} Operating at a less frequent cadence, the El Niño-Southern Oscillation and Pacific Decadal Oscillation drive substantial variability in winter precipitation, but how these modes may evolve remains unclear.⁴³ This will undoubtedly make the weather and climate modeling that is integral to fire response and management planning all the more challenging, yet all the more critical.

Fire regime trajectories

Research shows a near-term fire trajectory of hotter, drier, and longer fire seasons layered onto uncharacteristically dense forests and fuel accumulation that will continue to support very large and high-severity fires.^{33,34} Even as more and higher-severity fire activity is anticipated in the coming decades, longer-term fire dynamics may be shaped by negative feedback between fire severity and frequency on the one hand, and vegetation type and growth on the other. Across the western U.S., projected climate-induced reductions in vegetation growth — and therefore fuel availability — may ultimately attenuate severity across a substantial fraction of conifer forests under continued warming.^{44,45} This potential attenuation depends on vegetation and fuel loads shifting in parallel with climate. An alternative trajectory may include both high fire frequency and high fire severity, perpetuated by a transition from conifers to broadleaf species like aspen with fire-resilient traits (e.g., resprouting).^{45,46}

Another increasingly important component of the emerging fire regime is reburns, or areas that burn two or more times in close succession. Extreme fire weather may eliminate any moderating effect previous burns have on reburns.⁴⁷ In summary, the long-term future of fire on the Kaibab Plateau remains complex. There is an increasing risk of large, high-severity fires over the next one to three decades, but long-term fire dynamics will likely be determined by a patchwork of burn severities, short-interval reburns, and shifts in emergent vegetation — each of which can be shaped by restoration and management.

From 1895 to 2020, the annual mean temperature within Grand Canyon National Park increased at a rate of nearly 2°F/century, accelerating to 6.3°F/century since 1970.

A synthesis of 20 climate projections for the greater landscape found total agreement that temperatures will continue to rise.

Temperatures may increase as much as 4.0-4.2°F or 8.8-9.3°F by mid-century and 6.5-6.6°F or 14.2-14.8°F by late-century, relative to a 1981-2010 baseline, with summer temperatures increasing the most. Models varied more with projected changes in annual precipitation, ranging from increases of 0.9-2.7 inches or 0.1-0.5 inches by mid-century to increases of 2.4-5.1 inches or even slight decreases of -0.1-0.7 inches by late-century, depending on elevation.³⁵

Forest type trajectories

Even as it is challenging to predict precisely how future fire dynamics will unfold on the plateau, fire-catalyzed changes in vegetation composition are virtually assured. High-severity fire, followed by drought, is the primary driver of numerous vegetation type conversions across the Southwest, like ponderosa and pinyon and juniper woodlands converting to shrubland or grassland.^{39,48,49} Across the Colorado Plateau, climatically suitable forest area is projected to shrink by roughly 40% by mid-century.⁵⁰ For practically all ecosystem types, climatic suitability is projected to shift substantially upward in elevation and latitude.⁵¹

Pinyon and juniper woodlands are projected to expand upwards, along the edges of the plateau, with dry shrubland increasing in some areas,^{52,53} however, pinyon and juniper expansion is not a given. These pinyon and juniper woodlands have proven highly vulnerable to drought- and beetle-induced mortality across the Southwest with some areas experiencing upwards of 90% mortality.^{54,55}

Ponderosa pine will likely see an expansion into formerly cooler and more moist zones at upper elevations,^{56,57} coupled with erosion at its lower margin, where fire-driven conversion to shrubland or grassland is likely.^{48,49} Mesic mixed conifer and

spruce and fir are anticipated to contract upslope with virtually no regeneration,^{56,57} and they may be replaced by ponderosa and drier mixed conifer species.^{52,53}

Sudden vegetation transitions will be catalyzed by fire, with post-fire conifer regeneration failure being a contributing factor. Another complicating factor in vegetation recovery is invasive annual grasses. Cheatgrass regenerates rapidly, outcompeting many native grasses and herbaceous species, and creates a dense carpet of fine fuels that senesces each spring, thereby lengthening the fire season. The resultant self-reinforcing grass-fire cycle can amplify fire risk^{58,59} and further preclude conifer regeneration.^{60,61} The implication for the Kaibab is that the plateau's northern edge and transitional belt between pinyon and juniper woodland and ponderosa are likely at highest risk for fire-catalyzed transformation compounded by invasive-grass feedback, though proactive control may help disrupt this feedback.

Taken together, continued high-severity fire, regeneration failure, and invasive annual grasses suggest that the vegetation of the Kaibab Plateau in mid- to late-century may be transformed. The plateau will likely retain conifer forest and woodland, but mesic mixed conifer will likely be confined to the highest elevations. Ponderosa pine will hold more terrain at upper elevations than it does today, but its lower margin may erode through repeated fire followed by chronic regeneration failure, ceding ground to aspen, oak-shrub assemblages, and possibly pinyon and juniper. The 2025 burn footprints, together with earlier large fires like the 2006 Warm Fire, will likely serve as templates for plausible vegetation futures. Importantly, management choices made in the wake of these fires can strongly influence which areas cross irreversible thresholds and which retain the capacity to support forests and woodlands into the future.

Burned aspen trunks inside the Dragon Bravo Fire perimeter exemplify a high-severity burn area. PHOTO: AMY MARTIN



Recommendations

12 recommendations for supporting post-fire recovery and ongoing forest and fire management to sustain the ecological values and resilience of the Kaibab Plateau.



PHOTO: NATIONAL PARK SERVICE

RECOMMENDATION 1

Meaningfully include local tribes in co-stewardship of the Kaibab Plateau.

- Uphold and expand tribal consultation beyond “check-the-box” consultation and fulfill the federal trust responsibility to tribal nations.
- Support tribal co-stewardship across planning, decision-making, implementation, and monitoring.
- Work with tribes to leverage beneficial fire, including cultural burning.

Indigenous people have occupied and cared for the Kaibab Plateau since time immemorial. Part of this traditional stewardship across the Southwest has included managed fire (both fire manipulation and ignition).^{62,63} Specifically, Indigenous people carried out cyclical burns to promote pinyon nut production and understory plants in the ponderosa.⁸ Studies from as close as the south rim of the Grand Canyon show that Indigenous food sources came from species

that thrived in fire disturbance, another indicator of the close traditional ties between Indigenous practices and fire.⁶²

Settler colonialism displaced Native peoples of the Southwest and disrupted traditional practices like cultural burning,⁶² among other harms. But traditional Indigenous practices like cultural burning are ongoing — not just historical — in many places

across the continent,⁶² and the burden is on land management agencies to ensure that traditional uses and stewardship of the Kaibab Plateau may continue and grow.

All three federal land management agencies of the Kaibab Plateau have tribal consultation responsibilities under Section 106 of the National Historic Preservation Act, but this can and should be taken further. More and more, there is growing recognition that for the federal government to fulfill its trust responsibility to tribal nations, it must do more than “check-the-box” consultation. Successful co-stewardship, which can include co-management, is shared stewardship between tribes and agencies that recognizes, honors, and effectuates an alignment of needs, values, relationships, and authorities.⁶⁴ Fire management of the Kaibab Plateau is ripe for co-stewardship that integrates local and affiliated tribes in planning, decision-making, implementation, and monitoring.⁶⁵

What’s more, Indigenous knowledge and Indigenous practices can build ecological resilience, as traditional fire management practices (e.g. cultural burning) can “support ecological processes, such as nutrient cycling, habitat renewal, structure protection...[and] maintaining biodiversity.”⁶² Research shows that Indigenous occupation and associated fire management buffer the fire-climate relationship, though the result is scale-dependent.⁶³ According to Diné forestry specialist Lionel Whitehair, “[e]xpanding Indigenous-led collaborations and reforming land governance could strengthen the resilience of landscapes and communities to fire while supporting cultural revitalization. Embedding Indigenous stewardship in land management offers a tangible path toward inclusive, adaptive fire policy.”⁶²

THE KAIBAB NATIONAL FOREST LISTS THE FOLLOWING TRIBAL PARTNERS:

- The Havasupai Tribe
- Hopi Tribe
- Hualapai Tribe
- Kaibab Band of Paiute Indians
- Navajo Nation
- Pueblo of Zuni
- San Juan Southern Paiute Tribe
- Yavapai-Prescott Indian Tribe

GRAND CANYON NATIONAL PARK RECOGNIZES THE FOLLOWING TRADITIONALLY ASSOCIATED TRIBES:

- The Havasu 'Baaja (Havasupai Tribe)
- Hopi Tribe
- Hwal'bay (Hualapai Tribe)
- Nungwu (Kaibab Band of Paiute Indians)
- Las Vegas Paiute Tribe
- Moapa Band of Paiute Indians
- Diné (Navajo Nation)
- Paiute Indian Tribe of Utah
- San Juan Southern Paiute Tribe
- A:shiwi (Pueblo of Zuni)
- Yavap'e - Nnéé (Yavapai-Apache Nation)



PHOTO: CERISSA HOGLANDER

RECOMMENDATION 2

Retain use of beneficial fire as a key tool and prioritize actions that move forests toward ecologically grounded fire regimes.

- Prioritize management actions that work to restore frequent, low-intensity fire in ponderosa pine and dry mixed-conifer forests.
- In more moist, infrequent-fire forest types, favor forest-structure heterogeneity and protect wet meadows.
- In pinyon and juniper woodlands, prioritize invasive annual grass mitigation to reduce fine fuels and consider thinning with caution.

In ponderosa pine and dry mixed-conifer forests with ponderosa and Douglas fir, restoring frequent, low-intensity fires should continue to be a primary goal across the Kaibab Plateau, using beneficial fire of all forms — cultural fire, agency-led prescribed fire, and managed or resource-objective wildfire. These forest types are where southwestern restoration science is perhaps deepest and where Indigenous fire stewardship is most directly documented in the fire-scar record, not only inferred from it.^{66,67}

We recommend developing prescriptions and monitoring together with tribal partners whose fire stewardship in these forest types is centuries old. In ponderosa pine forest types, continued cultural burning and fire stewardship can be a model for restoring fire regimes, not only as a historical data point.^{68,69} Beyond cultural burning, there is clear evidence of the effectiveness of prescribed fire following forest thinning in mitigating subsequent fire severity in ponderosa pine forests.⁷⁰⁻⁷² Importantly, thinning alone is often less effective than thinning paired with prescribed fire, or prescribed fire alone.⁷³ South of the Grand

Canyon, the landscape-scale Four Forest Restoration Initiative project provides an in-progress example validating the importance of using beneficial fire in combination with small-diameter thinning for forest restoration.⁷⁴ Managed wildfire in ponderosa and dry mixed-conifer may confer benefits similar to prescribed fire, but carries trade-offs as it may reduce the proportion of high-severity fire while increasing total area burned and absolute high-severity area.⁷⁵

More moist mixed-conifer and spruce-and-fir forests at the highest elevations on the Kaibab Plateau call for a different approach than ponderosa pine and dry mixed-conifer types, as these forests historically burned less frequently with large, stand-replacing patches.³⁰ Relative to ponderosa pine forests, there is far less evidence in these forest types; indeed, the KNF Forest Plan for these forest types mentions limited beneficial fire but proposes experimental, closely monitored thinning and burning.²

Where targeted intervention is needed, consider accepting some high-severity burned patches in these forest types as characteristic and, where historical

forest patchiness no longer exists, consider deliberate patch-creation to restore structural heterogeneity.⁷² Importantly, natural fuel breaks already exist in these forest types. Wetlands and wet meadows hold more soil moisture and serve as effective natural fuel breaks and should be a protection priority here and across the Kaibab Plateau (see Recommendation 5).

As with wetter mixed conifer and spruce and fir, the evidence base for actively restoring ecologically grounded fire regimes in pinyon and juniper and reducing the risk of uncharacteristically severe wildfire remains far less developed than for ponderosa pine. After all, pinyon and juniper woodlands historically experienced infrequent, high-severity fire such that the present-day structure of the plateau's pinyon and juniper — invasives notwithstanding — are less departed from historical conditions.¹⁶ That said, mounting observations of density-dependent mortality during drought^{76,77} and concern over uncontrollable wildfire have spurred efforts to reduce

competition and fire risk through thinning and, in some cases, prescribed fire.⁷⁸ The effectiveness of this is mixed and the degree to which subsequent fire severity may be moderated largely remains an open question.^{79,80} Further, the intensity of operations matters in other ways: seedling recruitment, biological soil crusts, soil retention, and the occurrence of pinyon and juniper specialists like pinyon jay (*Gymnorhinus cyanocephalus*; see Recommendation 6) may be negatively affected,^{80,81} especially with indiscriminate pinyon and juniper removal.

Thus, with limited evidence for using intensive interventions to achieve ecologically grounded fire regimes, we recommend treating any pinyon and juniper restoration as a closely monitored, lower-intensity intervention; prioritizing control of cheatgrass and other invasive annuals to reduce continuous fuels; and ensuring any restoration targets serve cultural harvest goals alongside drought and fire-risk reduction.



Prescribed fire is a critical tool in moving fire-adapted forests toward ecologically grounded, low-intensity fire regimes. PHOTO: NATIONAL PARK SERVICE

RECOMMENDATION 3

Pursue management actions that restore fire-resistant forest structure and heterogeneity and protect large and old trees.

- Thin from below, targeting small-diameter trees first, and reduce ladder fuels.
- Set explicit upper-diameter limits and “old tree” definitions to exclude large and old trees from removal.
- Pursue forest restoration approaches that move toward heterogeneous forest structure.

Across all Kaibab Plateau forest types, retaining and protecting old-growth forest characteristics are critical for fire and forest resilience. Old trees and old-growth characteristics are uncommon across the Southwest largely due to an intensive logging history in the late 1800s and 1900s that removed much of the region’s old-growth ponderosa pine and, in more recent decades, instances of indiscriminate pinyon and juniper woodland cutting that did not distinguish sometimes centuries-old pinyon and juniper trees from younger individuals. Loss of old trees, typically trees more than 150 years old that pre-date fire exclusion management practices, results in loss of habitat quality, forest fire resilience, and locally adapted seed sources. Because of its relatively

remote location, the Kaibab Plateau has some of the Southwest’s best examples of old trees, particularly ponderosa pines. Retaining these trees should be a priority in both proactive severe fire risk-reduction efforts and post-fire management actions.

Old ponderosa pine trees have key adaptations like thick bark and high crowns that give them the capacity to resist most fire, support an array of wildlife, and carry well-established seed sources that support natural regeneration.^{72,82} With the rising density of these forests driven by historic fire suppression, cessation of cultural burning, and overgrazing, the risk of severe fire has increased in this fire-adapted forest type. It is well established

that strategic, small-diameter forest thinning can be highly appropriate for reducing fire severity in fire-adapted forests. Here, operations ought to focus on large and old tree retention and thinning from below, i.e., removing the smallest diameter trees first until density goals are reached.^{24,83} Crucially, any forest thinning must avoid “high-grading” — the selective removal of the largest or most valuable trees for commercial gain — as this practice strips the stand of its most fire-resilient structures, leaves more flammable young trees, and is fundamentally incompatible with ecological restoration objectives.⁷² Moreover, as we detail in Recommendation 6, forest-structure targets must be adapted to the habitat needs of sensitive and other forest-dependent native species, particularly the American goshawk (*Astur atricapillus*; formerly northern goshawk) and the Mexican spotted owl (*Strix occidentalis lucida*), among others.

The Four Forest Restoration Initiative’s Old-Growth Protection and Large Tree Retention Strategy codifies old and large tree retention and makes clear the importance of adopting an explicit upper-bound diameter limit to protect large trees rather than relying on discretion.⁷⁴ Still, strictly applied diameter caps can come with trade-offs. They potentially limit the degree to which structural heterogeneity may be achieved within a stand or competition with the oldest of trees may be reduced, among other trade-offs^{84,85} — such that specific, narrowly-defined ecological exceptions to diameter caps may warrant consideration.^{86,87} As detailed in Recommendation 2, thinning in ponderosa and dry mixed conifer ought to be paired with prescribed fire to achieve the greatest reductions in subsequent fire severity.^{73,88}

Across all Kaibab Plateau forest types, retaining and protecting old-growth forest characteristics are critical for fire and forest resilience.

PHOTO: CERISSA HOGLANDER

Old ponderosa pine trees, typically over 150 years old, have key adaptations like thick bark and high crowns that give them the capacity to resist most fire. PHOTO: CERISSA HOGLANDER

RECOMMENDATION 4

Consult with tribes to identify and safeguard cultural resources proactively and defensively.

- Consult with tribes and conduct field visits to identify cultural resources and places that can be surveyed and protected in the event of fire.

The Kaibab Plateau shelters centuries of cultural resources, including lithic scatters, wooden and masonry structures, rock imagery, historic sites, traditional cultural properties, and plants imbued with medicinal and ceremonial value. These cultural resources are vulnerable to fire² and once lost, cannot be replaced.

Both the U.S. Forest Service and the National Park Service seek to preserve, protect, and restore

cultural resources, with the Grand Canyon National Park Fire Management Plan giving explicit guidance that fire management tools can be used to maintain and protect cultural resources.¹³ Agency tribal liaisons and fire archaeologists play a critical role in cultural resource preservation in the event of fire and should continue to be resourced agency roles. But what is key to preservation is identification, as managers cannot protect what they do not recognize.

As of 2014, 30% of the Kaibab National Forest, including the North Kaibab Ranger District, was inventoried for cultural resources.² Oftentimes, cultural resources are identified in real time as archaeologists walk ahead of a fire break while it is being dug during a fire. Furthering cultural resource surveys (i.e., through Section 110 of the National Historic Preservation Act) — done in consultation with tribes, in the field when possible — is paramount to knowing the location and significance of cultural resources and places so they can be proactively and defensively protected in the event of fire — managed, beneficial, or other.

What is key to preservation is identification, as managers cannot protect what they do not recognize.

On page 31: Land managers proactively cleared brush and branches to protect the integrity of this traditional Paiute shelter during the 2025 White Sage Fire. Tribal consultation helps agencies manage fire across a cultural landscape. PHOTO: MILLIE SMALLCANYON ROSE



RECOMMENDATION 5

Protect and, where appropriate, restore wetlands and wet meadows to reduce severe wildfire risk, safeguard culturally important areas, and support overall forest health.

- Proactively protect and restore wetlands and wet meadows for their fire-break potential, water-retention functions, and cultural significance.
- Exclude these ecosystems, with buffers, from ground-disturbing management activities, including rerouting roads out of ephemeral stream channels and drainages where needed.
- Work with tribes, as appropriate, to plan and implement springs protection and restoration.

The Kaibab Plateau’s geology and hydrology support numerous seeps, springs, sinkhole wetlands, and ephemeral streams that are disproportionately important, supporting significant biodiversity and providing critical water resources in an otherwise arid landscape. Across the region, many springs have deep social and cultural significance and many are considered sacred to Native peoples. The relationship between these ecosystems and fire risk runs in two directions. First, wetlands and wet meadows — impacted by overgrazing, drought, and direct manipulation like excavation or road development — become eroded, disconnected from flows, and no longer retain the concentrated amounts of soil moisture that support biodiversity, groundwater recharge, and fire buffers. Conversely, intact wetlands and wet meadows can actively resist burning and function as fire refugia even under severe fire weather.⁸⁹⁻⁹¹

We recommend protecting these ecosystems from overgrazing, harmful manipulation, and disconnection from flows which contribute to erosion, channelization, and dewatering — impacts that are compounded by advancing climate change. Where such ecosystems are impacted, process-based restoration techniques that slow down flowing water and collect sediment — such as one-rock dams or log run-downs⁹² — can help raise the water table, reconnect flows, and reduce wildfire risk, and can be built effectively with rock or slash from fire management activities.^{91,93} Examples of erosion-control structures are already present across northern Arizona’s national forests, and have seemed to enhance wet meadow habitat pre-fire, provide natural fire breaks during fire, and mitigate the impacts of post-fire flooding, erosion, and ash flows.

Additional restoration opportunities include building protective exclosures to halt overgrazing,

planting native riparian vegetation, and removing encroaching young conifers which establish in drying meadows and reduce fire break potential.^{94,95} Finally, exposed, burned ground — often unconsolidated mineral soil — can rapidly erode into these features; adding cover such as downed wood or mulch may reduce that sedimentation risk.^{96,97}

Erosion control measures like this one-rock dam can help retain water in wet meadows. PHOTO: CERISSA HOGLANDER



Volunteers support wet meadow recovery in the Dragon Bravo Fire burn area. PHOTO: NICK PANE

RECOMMENDATION 6

Apply specific safeguards to sensitive species with all forest restoration and fire management actions.

- Pursue forest-structure and tree-retention targets that support the habitat requisites of the American goshawk, Mexican spotted owl, pinyon jay, and Kaibab squirrel.
- Time management action operations to avoid disruptions to species-specific breeding seasons.

Preventative and post-fire management should take particular care around sensitive, rare, and endemic species. The Kaibab Plateau is home to an array of sensitive species including the iconic California condor, endemic Kaibab tree squirrel^{2,3} and small, slow-growing, and narrowly distributed plants like the Kaibab plains cactus (*Pediocactus paradinei*), Kaibab paintbrush (*Castilleja kaibabensis*), and Kaibab

bladderpod (*Physaria kingii* subspecies *kaibabensis*).^{6,98} Preemptive protection of sensitive species should be prioritized by mapping occurrences and suitable habitat in advance and excluding these areas from ground-disturbing activities.

As is built into the KNF Forest Plan, specific fire and forest structure targets should continue to



Thinning in pinyon and juniper woodlands, and specifically removal of pinyon pine, has been shown to measurably reduce the number of pinyon jays and their available habitat. PHOTO: MARIE READ

be grounded in habitat needs and safeguards for ponderosa pine and mixed conifer-dependent species, particularly the American goshawk, considered a sensitive and management indicator species for the Kaibab National Forest, and the Mexican spotted owl, which is federally threatened under the Endangered Species Act, as well as for the Kaibab squirrel.

Goshawks require old, large trees with complex canopies but can benefit from an open, interspersed structure,⁹⁹ while Mexican spotted owls require a habitat of forest conditions that are denser than pre-fire-exclusion estimates.¹⁰⁰ The Mexican spotted owl recovery plan reconciles this tension by establishing clear diameter caps within Mexican spotted owl critical habitat with canopy and density targets higher than in the surrounding forest.¹⁰¹ For both species, advancing climate change and high-severity fire risk threaten the forest structure and the large, old trees the species depend on.¹⁰²⁻¹⁰⁵ For any management actions, spatially bounded forest-structure targets for goshawk and Mexican spotted owl are critical while allowing for broader restoration of ecologically grounded fire regimes in ponderosa pine and dry mixed conifer. Similar to goshawk and Mexican spotted owl, the habitat of the Kaibab squirrel is at risk from high-severity fire and intensive logging, as it depends on the Kaibab Plateau's dense interlocking ponderosa pine canopy.¹⁰⁶ Maintaining canopy corridors is critical for ensuring this endemic species' habitat needs are met.^{107,108}

In the pinyon and juniper woodlands of the Kaibab Plateau, safeguards should also be in place for pinyon jay, a candidate for listing under the Endangered Species Act and a bird experiencing steep, long-term decline. Thinning in pinyon and juniper woodlands, and specifically removal of pinyon pine, has been shown to measurably reduce the number of pinyon jays and their available habitat.⁸¹ Conservation strategies for this pinyon and juniper woodland-

dependent species advise focusing any thinning in lower-value habitat (i.e., retaining old trees) or woodlands that are already quite open, leaving dense nesting and seed-caching patches untreated.¹⁰⁹⁻¹¹¹



The Kaibab Plains cactus is a rare, endemic species of concern on the Kaibab Plateau. PHOTO: CLARE ASLAN

Preemptive protection of sensitive species should be prioritized by mapping occurrences and suitable habitat in advance and excluding these areas from ground-disturbing activities.

RECOMMENDATION 7

Minimize disturbance of post-fire forest structure to support early-stage recovery by native, fire-adapted plants and wildlife.

- Retain surviving trees and plants to support natural regeneration and increase seed sources for regrowth.
- Retain large, stable snags — standing dead trees — across burned areas to support dependent wildlife.
- Avoid intensive ground-disturbing actions, like widespread and intensive logging, which can impede early-stage forest recovery, especially after severe fire.

After fire, managers should consider the burned forest areas as unique, transient habitats that support a comparatively unique set of species rather than solely a site awaiting recovery. After severe, stand-replacing fire, surviving trees and standing snags

are biological legacies that can structure forest and woodland recovery for decades. However, the unique forest structure and conditions in this early, post-fire stage can be impeded by intensive management actions following fire, such as



Bluebirds on a ponderosa pine in Grand Canyon National Park. PHOTO: MATT JENKINS, NATIONAL PARK SERVICE

In the Southwest, more than 75 distinct animal species rely on standing dead trees for habitat.

intensive logging.¹¹² Snags that are created by severe fire can become a key part of the post-fire forest structure for bats, birds, and other wildlife: in the Southwest, more than 75 distinct animal species rely on these standing dead trees for habitat,¹¹³ including many species on the Kaibab plateau.¹¹⁴ Furthermore, different bird species use the post-fire landscape at different times after fire, such that avian communities may shift from one year to the next as the forest recovers.¹¹⁵ Over the long term, bird species diversity has been found to be higher in areas that burn with mixed fire severity (low, moderate, and high) compared to unburned areas.^{116,117}

In a forest’s understory, early regenerating native species that survive or emerge after severe fire often reflect the most important disturbance-adaptation characteristics for natural recovery, including drought and stress tolerance and the capacity to compete with invasive species,¹¹⁸ and are key seed sources. On the Kaibab Plateau, species like the scarlet globemallow wildflower (*Sphaerelcea coccinea*) in pinyon and juniper woodlands and bottlebrush squirreltail grass (*Elymus elymoides*) in ponderosa pine forests can often emerge first as mid- and later-stage native species — including other grasses, shrubs, and trees — re-establish.¹¹⁸ For example, one year after the Dragon Bravo Fire, high-severity burn areas already feature resprouting aspen and an array of native wildflowers, including lupine, skyrocket, and paintbrush species. Minimizing intensive management actions following fires can allow for robust natural forest regeneration and promote habitat for fire-adapted species.



Top Right: Tree cavities, burned or not, are important habitats for animals. **Bottom Right:** Snags like this are a key part of the post-fire forest structure for wildlife. PHOTOS: KAIBAB NATIONAL FOREST

RECOMMENDATION 8

Define burned trees as hazardous based on public safety and infrastructure concerns, rather than by condition alone.

- Use standardized risk assessments that evaluate hazardous trees by both condition and threat.
- Use best management practices to address hazardous trees in an expedited manner.



Public safety in burned forests is the top priority for land management agencies on the Kaibab Plateau, including threats like fire-killed falling trees, that necessitate swift assessment and action after a fire. We acknowledge the importance of land managers acting expeditiously to address such concerns.

A hazardous tree is conventionally defined by land managers as the co-occurrence of two factors: a defect or mortality that raises the likelihood of falling plus a safety concern or target the falling tree could strike (e.g., buildings or main roads).^{119,120} If either one of those factors is missing, a hazardous designation should not necessarily apply. For example, a partially burned, surviving tree; a stable, burned tree that is unlikely to fall within a few years; or a structurally compromised tree that would

Retaining stable, partially burned trees like this ponderosa pine provides key habitat structure in the short term, post-fire, and seed sources for forest regrowth. PHOTO: CERISSA HOGLANDER

not cause harm if it fell would likely not be designated as hazardous.

Adopting target-based definitions and conducting meaningful assessments is important because, absent an explicit standard, widespread burned tree removal in a post-fire context can duplicate the harmful effects of salvage logging (see Recommendation 9). As detailed in Recommendation 3, retaining stable, partially burned trees that survive fires provides key habitat structure in the short-term, post-fire, and seed sources for forest regrowth over the long term. Because large, stable snags are a limited and valuable resource, post-fire management should seek to retain them in a varied distribution across the

Trees burned by the Dragon Bravo Fire in Grand Canyon National Park along Highway 67 may constitute hazardous trees. PHOTO: AMANDA PODMORE



landscape to support key habitat structure, including for cavity-nesting wildlife. Operationally, this means assessing public safety concerns, defining removal buffers around at-risk values (e.g., within striking distance of main roads or infrastructure), and other established best practices,¹¹⁹ to support the health of forest-dependent species in burned areas.

Retaining stable, partially burned trees that survive fires provides key habitat structure in the short-term, post-fire, and seed sources for forest regrowth over the long term.

PHOTO: AMANDA PODMORE

RECOMMENDATION 9

Avoid broad-scale salvage logging and do not rely on it to reduce future fire risk.

- Avoid extensive salvage logging across the recovering landscape and entirely exclude sensitive areas (e.g., wet meadows).
- Do not treat salvage logging as a general fire fuels-reduction tactic.
- Where tree removal is warranted, ensure activities are targeted and ecologically informed and follow best practices for minimizing impacts to wildlife habitat and forest regeneration.

Salvage logging is the practice of harvesting merchantable trees (e.g., ponderosa pine) in a burned area as one way to reduce the economic losses of a timber sale impacted by wildfire. Because of concerns with insect and other pathogen spread among burned trees, this practice is typically done

in the first few months or years following a fire.¹²¹ However, the modest recuperation of timber revenue can come at the cost of substantial disruption of ecological recovery and long-term forest health impacts. Salvage logging tends to worsen erosion and post-fire flooding impacts, degrade soil health, and reduce native biodiversity.^{121,122} Such a practice is sometimes promoted as essential for post-fire forest recovery, particularly in high-severity burn areas, but can instead set such recovery back. Salvage logging has been shown to compromise post-fire tree and other native plant establishment through soil compaction and loss, damage to seedlings, and other disturbances.^{123,124}

Salvage logging is also undertaken to reduce subsequent fire risk by removing fuels, but the efficacy of this practice is more nuanced. While salvage logging does reduce the number of burned trees that can contribute to coarse fuels if they fall, it

Minimizing tree removal in burned areas remains the most reliable way to ensure natural regeneration can hold after fire. Any tree removal should prioritize hazard trees like this one.
PHOTO: AMANDA PODMORE



also adds a pulse of finer fuels, such as twigs.^{123,125,126} The reduction in coarse fuels does not reliably translate into lower burn severity in future fires; salvage-logged areas appear about as likely to reburn at high severity as areas not salvage logged.^{46,126-128}

Minimizing tree removal in burned areas is one way to ensure natural regeneration can take hold after fire. That said, where there are specific fuel reduction needs,¹²⁹ there may be a role for targeted alternatives to uniform, broad-scale salvage logging. Because snags carry substantial wildlife value¹³⁰ — including for many bird species on the Kaibab Plateau¹¹⁴ — and downed wood can aid natural regeneration by moderating microsite conditions,^{131,132} any post-fire timber harvesting must be carefully implemented to avoid impacts to wildlife habitat and overall forest health. Targeted post-fire timber harvests should be site-specific and exclude sensitive areas (e.g., wet meadows, steep slopes), minimize logging machinery pathways to reduce the extent of disturbance, and follow best practices to minimize erosion and wildlife habitat impacts.¹²⁴ Any tree removal should prioritize hazard and small-diameter trees first (e.g., thin-from-below), have clear snag retention targets for wildlife, and vary the density and intensity of removal to promote multi-scale spatial heterogeneity.¹³³⁻¹³⁵



Recently removed hazard trees are piled along a main road in Grand Canyon National Park after the Dragon Bravo Fire while stable, burned trees remain in the background to support snag-dependent wildlife and limit ground disturbance. PHOTO: AMANDA PODMORE

The modest recuperation of timber revenue can come at the cost of substantial disruption of ecological recovery and long-term forest health impacts.

RECOMMENDATION 10

Pursue active reforestation where natural regeneration is unlikely and future climate conditions support native forest establishment.

- Prioritize natural forest regeneration after fire wherever it can occur.
- Where adequate natural forest regeneration is unlikely to occur, plant native trees where surviving seed sources are too distant and projected climate still supports establishment.
- Leverage decision support tools and on-the-ground assessments to locate seed source and reforestation sites and guide planting investments.

Active reforestation is one of several tools for supporting forest recovery after fire and may become increasingly important in high-severity burn areas. While the majority of post-fire forest recovery occurs — and should be allowed to occur — through natural regeneration from surviving trees, targeted planting may be warranted where natural recovery is unlikely to succeed. Natural conifer regeneration in large, treeless patches is chiefly limited by distance to surviving seed trees and, increasingly, by climatic conditions untenable for establishment.^{136,137} These two constraints ought to guide active reforestation sites, pointing to locations too far from seed sources and where climatic conditions are — and will be — still suitable habitat for those tree species.

For any tree seeding or planting efforts, we recommend using decision support tools that leverage the best available science and on-the-ground forest assessment information and promote resilient forests and native biodiversity. For example, RegenMapper¹³⁸ — the West-wide complement to

the Southern Rockies Reforestation Tool¹³⁹ — maps exactly this, predicting natural regeneration probability and climatic suitability for multiple western conifers under both current and mid-century conditions on any fire footprint, including reforestation mandates for national forest lands (e.g., National Forest Management Act 36 Sec. 219.11).

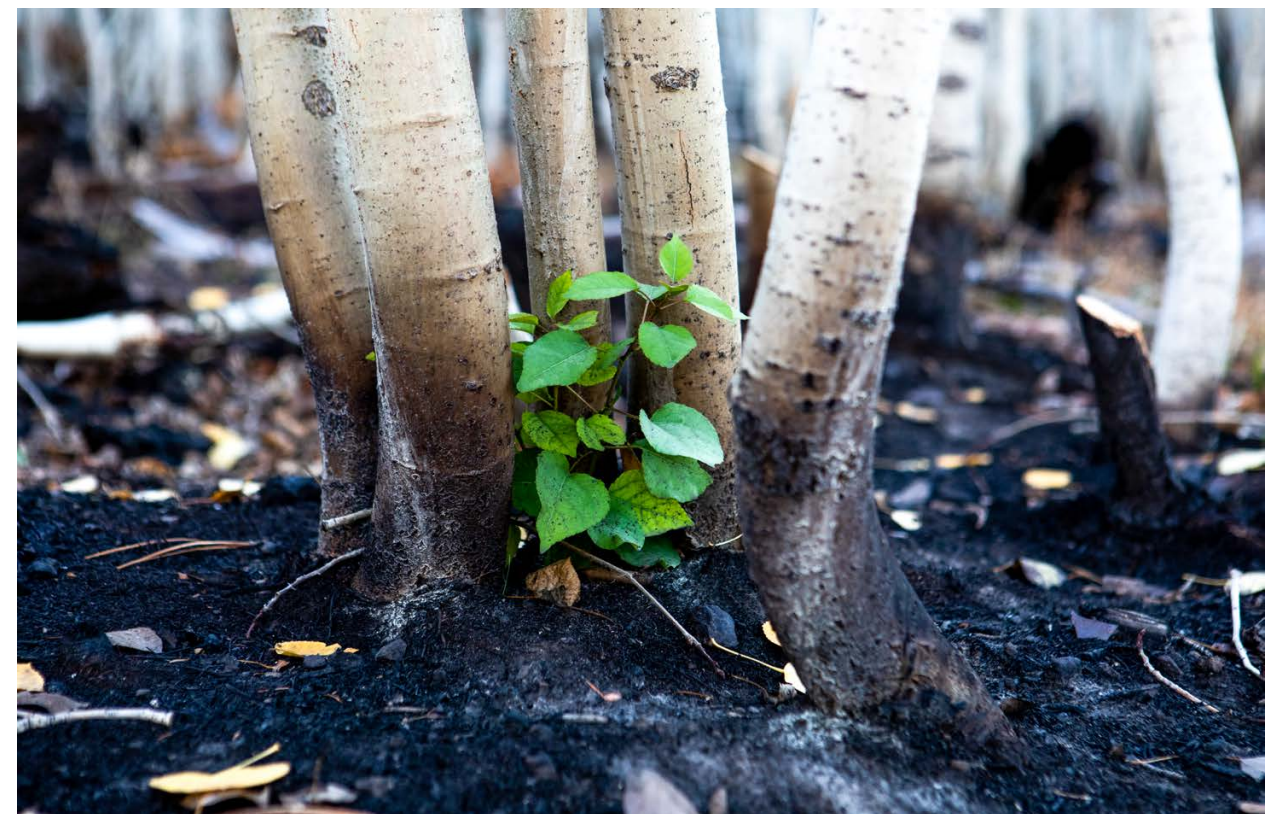
For regeneration of specific native species, the RegenMapper tool models ponderosa, Douglas fir, and higher-elevation conifers including Engelmann spruce and subalpine fir, but not pinyon pine or juniper. In pinyon and juniper woodlands, recovery after high-severity, stand-replacing fire can be exceptionally slow. In pinyon and juniper areas projected to lose climatic suitability, protecting surviving seed trees is likely to be most effective,^{140,141} and replanting should be prioritized in areas of cultural importance that will remain climatically suitable.¹⁴² In the Kaibab Plateau's highest elevation and most climate-constrained forest type, Engelmann

spruce and subalpine fir have no higher ground to retreat to as the climate warms.¹⁴³ A mixed strategy of targeted replanting of these species alongside acceptance of a compositional shift toward more future-climate adapted tree species may be appropriate at higher elevations.

Pursuing local seed sources for native plant establishment has historically been the preferred choice in forest restoration efforts, but with a warming climate, sourcing strictly local seed means plantings may be adapted to climatic conditions that are disappearing.^{144,145} Where a planting site is situated within a species' range should guide application of this strategy. Toward the cooler edges of a range (e.g., at higher elevations) sourcing seed from warmer parts may improve future fit, whereas at the trailing edge of a species' range, local or mixed sourcing is the only option.^{146,147} Climate-matching resources such as the Seedlot Selection Tool,¹⁴⁸ which

maps the climatic match between a planting site and candidate source locations under current or projected future climates, can be used to pinpoint places where climatically suitable seed may be collected.

Across all tree species on the Kaibab Plateau, seedling survival over the first few years is governed largely by available soil moisture. In addition to planning plantings around peak moisture periods, consider standing or downed dead wood, shrubs, and rocks as microhabitat features that can buffer soil temperatures, trap moisture, and reduce wind exposure, thereby improving seedling establishment likelihood.¹⁴⁹ As these microhabitat features can substantially increase seedling establishment for pinyon pine, spruce, and fir trees,^{132,150} broad-scale salvage logging or other intensive, post-fire disturbance should be avoided, especially in reforestation areas, so as not to compromise these key reforestation components.¹⁵¹



Aspen shoots emerge within months of the Dragon Bravo Fire. PHOTO: AMY MARTIN

RECOMMENDATION 11

Promote native plants and natural regeneration and mitigate invasive species spread in burned areas.

- Prioritize prevention and early detection of invasive species and implement best management practices for invasive species mitigation in burned areas.
- Protect and restore native plant species cover and biological soil crusts and prioritize natural understory regeneration wherever it can occur.
- Where adequate natural understory regeneration is unlikely to occur, use native-only seed mixes, prioritizing locally adapted seed sources and avoiding non-native seeding entirely.

Forest conditions in severely burned areas — bare, disturbed soil with an open canopy — can favor non-native, invasive species. One primary concern is the invasive annual grass, cheatgrass, which returns quickly after fire and dies back during peak fire season in a self-reinforcing grass-fire cycle that competes with native species and promotes fire spread.^{152,153} We recommend monitoring plant composition post-fire to facilitate early detection of invasive species. We also recommend protecting intact native plant cover and biological soil crusts which increase a landscape’s resistance to invasion while reducing erosion and retaining soil moisture.^{153,154} For cheatgrass in particular, post-fire spread of this invasive species is more likely in pinyon and juniper woodland and mid-elevation ponderosa pine forest types.

In susceptible burned areas, post-disturbance seeding with a weed-free mix of native shrub, grass, and forb species has been shown to reduce cheatgrass abundance, among other approaches.^{155,156} Seeding native species should also be considered where

natural understory regeneration is unlikely to occur, or unlikely to occur at the rapid rate needed to mitigate soil erosion threats. Seeding exclusively with seeds native to the forest type and region, ideally locally sourced, should be considered.

In practice, we recommend banking local and climate-adapted seed as soon as possible and building that capacity in anticipation of the next “unprecedented” fire year. Importantly, non-native seed should be avoided as it has lasting effects on forest health and fire resilience even if there may be some limited, short-term benefits in soil retention. Intentional post-fire seeding with non-native species can suppress native recovery, especially over the long term, without reliably delivering the erosion control it is intended to provide;^{155,156} and, incidental spread may occur during restoration operations,¹⁵⁷ causing establishment long term.

Best practices for post-fire activities in burned areas — whether planting or hazard tree removal — center

on prevention of invasive spread first and foremost. Limiting new roads and pathways reduces invasive seed traffic, and minimizing unnecessary ground disturbance reduces invasive seed bank activation. Land managers across the Kaibab Plateau are keenly aware of the consequences of invasive species and already have established best practices, or even an integrated management plan for mitigating spread (e.g., KNF Forest Plan), and we appreciate continued, critical efforts in this arena to support native biodiversity and reduce uncharacteristically severe wildfire risk.



Invasive cheatgrass competes with native species and promotes fire spread.
PHOTO: SUZANNE ALLMAN, COURTESY OF THE BUREAU OF LAND MANAGEMENT



Targeted planting may be warranted where natural recovery is unlikely to succeed and planted species will adapt to the projected warmer, drier, and more fire-prone future. PHOTO: BILL FERRIS

RECOMMENDATION 12

Manage public-land uses to support post-fire recovery and regeneration.

- Limit recreation, grazing, and other managed land-use activities around recovering burned areas.
- Monitor post-fire recovery of vegetation to inform adaptive management of recreation, domestic and wildlife grazing, and other managed land uses.

Land uses of the Kaibab Plateau, from livestock and wild ungulate grazing to recreation, can alter the recovery trajectory of post-fire landscapes. For example, conifer seedlings are susceptible to damage and trampling by large ungulates (e.g., bison or cattle) which may also promote the spread of invasive species.^{158,159} There is a common practice of deferring livestock grazing for at least two growing seasons following wildfire to promote natural regeneration, reduce soil compaction and erosion, and mitigate

invasive species spread.¹⁶⁰ This practice may also improve the likelihood of establishment after seeding or planting. However, regionally relevant studies are lacking,¹⁶⁰ and the benefits are expected to be species-, timing-, and precipitation-dependent as the Kaibab’s diversity of plant species leaf out at different times and are not uniformly palatable for bison and cattle.

That said, research from other regions indicates that impacts to plants may be minimized if herds are small and dispersed (e.g., by encouraging multiple watering areas),^{161,162} though this practice may be less practical for implementation with the Kaibab Plateau bison herd. Still, trampling potential and other impacts of grazing in forests and woodlands too soon after fire — soil compaction, invasive facilitation, altered native vegetation — suggest that deferred grazing after planting is warranted,^{157,163} particularly in wetland or riparian areas. We recommend that the duration of grazing rest should be guided by monitoring on-the-ground

conditions and informed by the rate and composition of post-fire plant recovery and seedling establishment rather than at a fixed interval.

A pause from other managed land uses may be warranted as well after fire — for example, limiting or rerouting recreational activities such as dispersed camping and off-road vehicles not only for public

safety but also to safeguard seedling growth and survival and minimize erosion, particularly around wetland and riparian areas.^{164,165} Many of these approaches are already embedded within agency management plans on the Kaibab Plateau (e.g., KNF Forest Plan) and we encourage continued implementation of these best practices while also increasing on-the-ground monitoring to inform adaptive management.



Deferred grazing on replanted areas can help with post-fire recovery. PHOTO: CERISSA HOGLANDER



Looking south on Highway 67 in the Dragon Bravo Fire burn area. PHOTO: MATT JENKINS, NATIONAL PARK SERVICE

Land-use management should be guided by monitoring on-the-ground conditions and informed by the rate of plant recovery.

Looking Forward

A Collaborative and Informed Approach to Forest and Fire Management

The recommendations in this report are not a uniform prescription but instead are a science-driven set of values we present as core to forest health and resilience on the Kaibab Plateau. Across the region, fire seasons are becoming longer with more acres burning and at higher costs than ever before. Forest conditions and fire behavior are only expected to depart further from historical patterns. The recommendations here reflect the fact that some of the most substantive levers land managers hold to reduce uncharacteristically severe wildfire risk are through proactive forest restoration, pairing beneficial fire with strategic and small-diameter thinning to achieve resilient landscapes with diverse habitats and abundant native species. These efforts can reinforce — and indeed can be reinforced by — comprehensive watershed restoration and wetland protection. This active stewardship must be grounded in the best available conservation science and condition monitoring to ensure actions are well-informed, targeted, and effective, and must be implemented with best practices to safeguard key forest values, from sensitive species to old, fire-resilient trees.

Importantly, while land managers must uphold their role as stewards of these public lands — and must have the resources to do so — a foundation for coordination and collaboration helps to guide

the path forward. Engaging with tribes — beyond consultation — and pursuing co-stewardship opportunities should remain a top priority for land managers, particularly in beneficial fire and forest restoration actions. In addition, local and regional stakeholders remain invested in the long-term health of the Kaibab Plateau, ready to build off of past collaborative efforts which have bolstered information-sharing and built strong support for ecologically driven management actions that support the forest and the communities that depend on it.

The 2025 fires may be viewed as a major loss — especially to the North Rim — and as contributing to an accelerating trend of large, high-severity fire that is reshaping much of the western U.S. But the 2025 fires also represent a management juncture, as decisions made now (and following the inevitable next fires) will shape the plateau for years to come. The most ecologically sound path forward in this warming era is neither striving for past conditions that are no longer tenable nor doing nothing. Instead, that path calls for forward-looking, collaborative stewardship that reads the landscape closely, relies on the best available science joined with Indigenous knowledge, plans across boundaries, embraces beneficial fire and strategic reforestation, and shares both the work and authority to do so.

We look forward to continuing this important work together.

On page 48: Tribal co-stewardship and public engagement must be folded into the cross-agency collaboration necessary for stewarding the Kaibab Plateau into the future. PHOTO: NICK PANE



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Fireweed grows back within the Dragon Bravo burn.
 PHOTO: NATIONAL PARK SERVICE





PHOTOS: **TOP** CERISSA HOGLANDER; **ABOVE LEFT** AMY MARTIN; **ABOVE RIGHT** ED MOSS