Bridging Ancestral Fire Stewardship and Climate Mitigation: Cultural Burning as an In-Situ Pathway for Biochar Production and Ecosystem Resilience

By Johnny Appleking.

Abstract

Modern wildfire management is increasingly confronted with the limits of suppression-oriented, hazard-reduction paradigms in the face of anthropogenic climate change. This paper examines Indigenous cultural burning as a sophisticated, trans-hemispheric pyrotechnology that functions as an *in-situ* (on-site) pathway for biochar production and ecosystem restoration. Drawing on comparative analysis between the Noongar of Southwest Australia (*Nungar Budja*) and the North Fork Mono of Northern California, we demonstrate how low-intensity, human-led fire alters local soil chemistry and hydrology.

Unlike high-intensity agency-prescribed burns, traditional cultural burning operates at low temperatures ($\le 350^\circ\text{C}$), initiating low-temperature pyrolysis that yields highly porous, tar-free carbon—an *in-situ* biochar that fosters deep pedogenesis (soil formation) and provides micro-habitats for soil microbiota. Furthermore, we analyze how these practices initiate rapid hydrological recovery by removing water-intensive understory encroachers, causing local aquifers and springs to rebound. By bridging Indigenous epistemologies with quantitative biogeochemistry, this paper argues for a paradigm shift: reframing Indigenous fire stewardship not merely as fuel management, but as a critical, reciprocal negative-emissions technology capable of restoring ecological equilibrium in a warming world.

I. Introduction: The Cosmological and Colonial Geographies of Fire

In the oral history of the Noongar people of Southwest Australia, the ecological mandate of humanity begins with a primordial fire:

"This great tall spirit woman... She built this fire. To the beautiful, orange glowing fire she said, 'I'm now going to collect the little children.' And she started gathering from her long white hair... placing them around this fire, she gave instruction... 'You have won the right to care for everything on earth.'"

This ancestral narrative establishes a foundational tenet shared by many Indigenous societies: fire is not an exogenous hazard to be feared or suppressed, but an active partner in a reciprocal relationship of care. Under this framework, human agency is structurally integrated into the ecosystem. Pyro-stewardship is the physical expression of this "right to care," a highly specialized, localized management system designed to maintain balance, harmony, and abundance.

The onset of European colonization, however, fractured this relational geography. Across the entire globe, settler-colonial administrations imposed extractive, agronomic models of land management that treated fire as an absolute threat. As Noongar elders observe:

"To be fair to them, they did not understand. They thought this place was like England, where you just clear it and plow it and crop it."

This Eurocentric "clearing and plowing" model relied on the complete exclusion of fire. By treating complex, fire-adapted landscapes as blank slates for pastoralism, agriculture, and industrial timber extraction, colonizing forces dismantled the pyrosocial systems that had stabilized these ecosystems for millennia.

The consequences of this historical rupture are now manifest in the contemporary global wildfire crisis. In Southwest Australia, the montane forests of Northern California and beyond, more than a century of active fire suppression has altered forest structures, leading to dense, choked understories and massive fuel accumulation. When combined with the warming and drying trends of anthropogenic climate change, these conditions yield catastrophic, high-severity wildfires. These modern conflagrations do not heal; they sterilize the soil, destroy the seed bank, and vaporize vast pools of biogenic carbon into an already overloaded atmosphere.

[Colonial Fire Exclusion] ──> Dense Ladder Fuels ──> High-Severity Wildfires ──> Atmospheric Carbon Spikes
[Indigenous Stewardship] ──> Cool "Trickle" Burns ──> In-Situ Biochar Yields ──> Deep Soil Carbon Drawdown

To resolve this crisis, modern conservation science must move beyond the reductive boundaries of Western fire management. Traditional agency-led "hazard reduction" burns often mimic the intensity of wildfires, occurring outside of natural seasonal cycles and burning at temperatures that cook the soil profile.

This paper argues that returning to Indigenous cultural burning offers a viable, scalable, and scientifically verifiable pathway for climate mitigation and ecosystem resilience. By comparing the ancestral practices of the Noongar of *Nungar Budja* and the North Fork Mono of Northern California, we demonstrate how traditional burning acts as an *in-situ* biochar generator. When applied correctly, this low-intensity pyrotechnology converts volatile biomass into stable, recalcitrant carbon, actively "singing the carbon down" into the earth while triggering rapid ecological and hydrological recovery.

II. Trans-Hemispheric Pyrotechnologies: Comparative Case Studies

Indigenous fire stewardship is not a uniform, static practice, but a collection of highly localized, empirically driven pyrotechnologies. To appreciate how cultural burning operates as an *in-situ* biochar engine across different biomes, we compare the practices of the Noongar in Southwest Australia with those of the North Fork Mono in the Sierra Nevada foothills of Northern California.

The Noongar of Southwest Australia (*Nungar Budja*)

The Noongar region, spanning the biodiverse jarrah (*Eucalyptus marginata*), karri (*Eucalyptus diversicolor*), and banksia woodlands of Southwest Australia, is managed according to a complex, six-season calendar: *Birak, Bunuru, Djeran, Makuru, Djilba,* and *Kambara.* Noongar fire stewardship is deeply attuned to these cycles.

Rather than executing broad-scale burns to consume all fuel, Noongar practitioners apply "cool" or "trickle" fires primarily during *Birak* (December/January) and late *Djeran* (April/May), when specific seasonal indicators—such as the flowering of the West Australian Christmas tree (*Nuytsia floribunda*) or changes in wind directions—signal optimal moisture levels.

These burns are characterized by a slow-moving, low-flame height "cool fire" that trickles through the understory. This selective approach leaves the canopy intact, burns in a mosaic pattern that allows wildlife to find refuge, and leaves behind a charred, carbon-rich residue instead of consuming all biomass to mineral ash.

The North Fork Mono of Northern California

In the montane oak woodlands and mixed-conifer forests of the Sierra Nevada, the North Fork Mono Tribe utilizes fire as a precise tool for material harvesting, food security, and water management. A central element of North Fork Mono pyrotechnology is the revitalization of culturally significant understory species, such as *Tashin* (sourberry, *Rhus trilobata*) and Redbud (*Cercis occidentalis*).

Mono practitioners burn during the late fall and early winter when atmospheric humidity increases and soils are damp. By executing low-intensity understory burns, they remove dead material, stimulate the epicormic sprouting of straight, flexible shoots necessary for basketry, and clear out encroaching shade-tolerant conifers like white fir (*Abies concolor*).

Crucially, Mono fires are localized, slow, and frequently managed in small heaps or patches. This prevents the fire from escaping into the crown of dominant black oaks (*Quercus kelloggii*) and ponderosa pines (*Pinus ponderosa*), and ensures that the organic matter on the forest floor undergoes incomplete combustion, preserving carbon on-site.

III. The Biogeochemistry of Low-Temperature *In-Situ* Biochar

To understand how cultural burning acts as an *in-situ* carbon-capture system, we must examine the physical and chemical transitions that occur when biomass is heated.

In Western industrial carbon management, biochar is produced through pyrolysis—the thermal degradation of organic matter in the absence of oxygen—within closed, high-temperature reactors (> 500°C). Cultural burning, however, represents an open, *in-situ* pyrotechnic system that achieves similar chemical outcomes through a micro-stratified combustion gradient on the forest floor.

Thermal Dynamics and Yield Kinetics

During a high-severity wildfire or a high-intensity prescribed agency burn, soil surface temperatures frequently exceed 600°C to 800°C. At these temperatures, the combustion reaction goes to completion in the presence of atmospheric oxygen, converting almost all plant biomass (cellulose, hemicellulose, and lignin) into carbon dioxide (CO_2) gas and mineral ash (K_2CO_3 and $CaCO_3$, etc.), leaving behind sterile, hydrophobic soil that is prone to erosion.

In contrast, cultural burns are purposefully ignited under high fuel-moisture and cool atmospheric conditions. The fire behaves as a "back-burn" or "creeping fire," where the temperature at the fuel-soil interface is strictly limited to greater than or equal to 350°C. This creates an incomplete combustion zone. The moisture inside the forest litter vaporizes, consuming latent heat and preventing the temperature from rising further.

Within this boundary layer, oxygen is depleted by the rising flame front, establishing localized, anaerobic conditions. The biomass undergoes low-temperature, slow pyrolysis. Under these conditions, the conversion efficiency of volatile carbon to solid, stable elemental carbon is maximized, yielding up to 30–45% of the initial biomass as a highly stable char, compared to less than 5% in high-severity wildfires.

Chemical Composition and Recalcitrance

The low temperatures of cultural burning produce a biochar with distinct chemical properties:

1. **Preservation of Functional Groups:** High-temperature industrial pyrolysis cooks away volatile organic compounds, leaving behind a highly condensed, chemically inert aromatic carbon skeleton. At greater than or equal to 350°C, however, the resulting *in-situ* biochar retains oxygenated functional groups, particularly carboxylic acid groups and phenolic hydroxyl groups
2. **Cation Exchange Capacity (CEC):** The presence of these oxygenated functional groups gives the biochar a highly active surface charge. Over time, as the biochar undergoes natural abiotic weathering in the soil, these groups deprotonate, drastically

increasing the soil's Cation Exchange Capacity (CEC). This negative charge allows the soil to bind and retain crucial cationic plant nutrients such as ammonium, calcium, magnesium, and potassium, preventing them from leaching out during heavy rains.

3. **Porous Structure and Microbial Habitats:** Low-temperature biochar retains the cellular structure of the parent wood and foliage. This yields a highly porous material dominated by micro- and macro-pores.

The intra-pore spaces of biochar particles act as capillary water reservoirs, vastly increasing the overall water-holding capacity of the soil.

Furthermore, these porous structures serve as perfect microbial refugia. Soil microbiota, particularly mycorrhizal fungi and nitrogen-fixing bacteria, migrate into the micro-pores. Safe within these cavities, they are protected from predators (like protozoa) and environmental desiccation, accelerating the rate of pedogenesis (soil building) and organic nutrient cycling.

IV. Eco-Hydrological Rebound: Understory Management and Hydrology

Beyond carbon capture, the immediate, tangible benefit of cultural burning observed by Indigenous practitioners is the physical return of water to the landscape. For generations, both Noongar and Mono elders have maintained that "bringing fire back brings the water back." Modern hydrologic monitoring is now validating this ancestral ecological knowledge.

The Mechanics of Encroachment and Water Loss

In the absence of frequent, low-intensity fire, both Southwest Australian woodlands and Northern Californian mixed-conifer forests undergo rapid understory encroachment. In California, fire suppression allows millions of shade-tolerant, water-intensive white fir and incense cedar saplings to choke the forest floor. In Southwest Australia, fire exclusion leads to dense, overgrown stands of woody shrubs.

This dense understory acts as a massive straw, drawing water from shallow aquifers and transpiring it into the atmosphere. The ecosystem's water balance can be represented by the hydrologic equation:

```
P = ET + Q + Delta S
```

Where:

- P = Precipitation
- ET = Evapotranspiration (water lost to the atmosphere via plants and evaporation)
- `Q=Runoff/Streamflow`
- ΔS `= Change in Soil and Aquifer Water Storage`

When decades of fire suppression cause ET to spike due to unchecked understory biomass, the available water for streamflow (Q) and ground-water storage (ΔS) plummets. Springs dry up, meadows turn to dry upland brush, and soils lose their moisture.

Hydrological Recovery via Cool Fire

Cultural burning acts as a selective thinning mechanism. Because the fire is low-intensity, it lacks the energy to ignite the thick bark of mature canopy trees (like black oaks or ponderosa pines), but easily consumes the thin-barked, water-guzzling understory saplings and woody shrubs.

[Low-Intensity Burn] ──> Understory Thinned ──> Transpiration (ET) Drops ──> Water Rebounds to Springs (Q) ──> Biochar Produced ──> Soil Moisture Storage (ΔS) Increases

When cultural burning thins this understory, the immediate reduction in plant transpiration causes a rapid hydrological rebound:

1. **Spring and Aquifer Recharge:** With understory transpiration shut down, water that would have been lost to the atmosphere remains in the shallow water table. This increases groundwater storage (ΔS), causing dormant springs, creeks, and wet meadows to flow once more, even during the dry summer months.
2. **Mitigating Soil Hydrophobicity:** High-severity wildfires vaporize organic compounds on the forest floor, forcing them down into the soil profile where they condense and form an impermeable, hydrophobic (water-repellent) barrier. This barrier prevents infiltration, causing severe erosion and mudslides when rain returns. Cool cultural burns, operating under 350°C, do not reach the thermal thresholds required to volatilize these organic lipids. The soil structure remains porous and open, allowing immediate rainwater infiltration and groundwater recharge.

V. Epistemological Integration, Policy, and Sovereign Stewardship

For cultural burning to be scaled successfully as a global climate mitigation tool, Western scientific and administrative frameworks must undergo a profound shift. Historically, Western conservation science has attempted to compartmentalize Indigenous practices—extracting the "technique" of burning while discarding the relational, spiritual, and sovereign contexts in which those practices exist.

Epistemological Barriers

Western environmental management operates on an extraction-preservation binary. Land is either utilized for capital extraction (logging, mining) or locked away in "wild preserve" states where natural processes, including fire, are suppressed.

Indigenous epistemologies reject this binary. The Noongar concept of “*caring for country”* and the Mono system of “reciprocal gathering” treat humans as necessary, active participants in the life cycle of the forest. Fire is not a destructive intervention, but a relational duty.

To evaluate cultural burning purely through the lens of modern carbon accounting—measuring exact metric tons of CO2 equivalent sequestered per acre—risks reproducing colonial patterns of exploitation. A truly integrated approach must respect that the carbon-sequestration capacity of cultural biochar is a natural byproduct of a holistic, relational practice, not its sole driver.

Policy and Administrative Hurdles

Currently, several institutional barriers prevent the wide-scale implementation of cultural burning:

Barrier Category	United States (e.g., California)	Australia (e.g., Southwest Australia)
Air Quality & Emissions	Strict EPA and Air Resources Board regulations treat cultural burn smoke identically to industrial pollution, limiting burn windows.	State-level Environmental Protection Authorities tightly restrict seasonal burn periods, often ignoring traditional calendar indicators.
Liability & Insurance	Private burn bosses and Tribal practitioners face high insurance premiums and legal liability if a burn escapes.	Complex public liability insurance structures make it difficult for traditional owners to burn without state-agency supervision.
Jurisdictional Fragmentation	Land is divided among federal (USFS, BLM), state (CAL FIRE), and private entities, preventing contiguous landscape-scale burning.	Overlapping state forestry departments, national parks, and private agricultural leases restrict Noongar access to ancestral lands.

Overcoming these barriers requires a shift from agency-dominated "prescribed fire" to true **sovereign co-management**. Policies must be rewritten to recognize Tribal sovereign rights to manage ancestral lands, establish dedicated insurance pools for cultural practitioners (like California has done with Senate Bill 332), and carve out specific air quality exemptions for traditional, low-emission cool burns.

VI. Conclusion

The contemporary wildfire crisis is not an inevitable consequence of a warming planet, but the predictable end-state of over a century of colonial fire suppression. As global temperatures rise, the traditional Western model of fire exclusion and high-intensity, mechanical hazard reduction has proven both ecologically destructive and financially unsustainable.

Bridging ancestral fire stewardship with modern biogeochemical science offers a profound path forward. Cultural burning is a highly sophisticated, trans-hemispheric pyrotechnology. By utilizing low-temperature, slow-pyrolysis burns, cultural fire practitioners safely thin the forest understory while converting volatile biomass into highly stable, porous, and chemically active *in-situ* biochar. This biochar acts as a long-term carbon sink, enhances soil fertility and microbial diversity, and prevents soil hydrophobicity. Simultaneously, the reduction of water-intensive understory vegetation restores local water balances, recharging aquifers and reviving dry springs.

To fully harness this negative-emissions technology, we must move beyond treating cultural burning as a mere fuel-management technique. It must be recognized as a sovereign, relational system of ecological care. By restoring the "right to care" to cultural Fire practitioners, modern society can transition from a paradigm of fighting fire to one of working with fire—using her to sing the carbon back down into the earth, and in so doing, restoring the balance of our shared biosphere.