



Beyond Slash-and-Burn: Fire, Fallow, Livelihoods, and Justice in Local Community Land-Use Systems – A Multidimensional Review of Ramifications and Context-Sensitive Mitigation

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ABSTRACT

Slash-and-burn agriculture remains one of the most contested land-use practices in tropical and subtropical regions. It is frequently associated with deforestation, biodiversity loss, greenhouse-gas emissions, soil degradation, haze, and public-health burdens, yet the term also encompasses long-established rotational systems in which local and Indigenous communities cultivate small plots temporarily before allowing secondary vegetation to regenerate during fallow periods. This qualitative literature review critically examines the multidimensional ecological, socioeconomic, cultural, health, and governance ramifications of community-based slash-and-burn and shifting cultivation and evaluates context-sensitive mitigation pathways. Contemporary evidence demonstrates that outcomes are governed not simply by the use of fire but by interactions among fallow duration, cultivation frequency, patch size, tree retention, soil and hydrological conditions, drought, livelihood dependence, market integration, tenure security, and customary institutions. Long-rotation systems may retain important food-security, agrobiodiversity, cultural, soil-recovery, and landscape biodiversity functions, whereas compressed fallows, permanent conversion, peatland drainage, and repeated uncontrolled burning can generate severe degradation and health externalities

INTRODUCTION

Slash-and-burn agriculture occupies an unusually contentious position in environmental and development debates. At one extreme, it is represented as an archaic and inherently destructive practice responsible for tropical deforestation, atmospheric emissions, soil impoverishment, biodiversity loss, and haze. At the other, it is interpreted as an adaptive form of rotational land management refined over generations by communities living in environments where capital-intensive permanent agriculture may be economically, ecologically, or culturally inappropriate. Both framings contain elements of truth, but neither adequately represents the diversity of systems grouped under the label “slash-and-burn.” A field cultivated temporarily and subsequently returned to secondary vegetation is fundamentally different from land permanently converted to a plantation, while a small controlled burn on mineral soil is fundamentally different from a fire entering deeply drained tropical peat. Treating these situations as a single causal category obscures the mechanisms determining environmental outcomes and may lead to poorly targeted policy responses (Bruun & Hepp, 2023; Goldstein et al., 2020; Mertz et al., 2021). Recent scholarship further shows a shift from blanket condemnation toward more differentiated analysis of swidden systems, while a 2026 perspective warns that conflating active fields, fallows, and forests in remote-sensing classifications can generate misguided deforestation estimates and misplaced blame (Hepp et al., 2026; Li & Nath, 2024).

Shifting cultivation, swidden agriculture, *jhum*, *ladang*, *kaingin*, *coivara*, and related regional systems generally involve a cycle in which vegetation is cut, biomass is allowed to dry, fire is used to prepare a cultivated field, crops are grown for a relatively short period, and the site is subsequently placed under fallow while cultivation moves elsewhere. The fallow stage is not merely “abandoned land”; it performs ecological and livelihood functions through vegetation succession, biomass recovery, nutrient cycling, weed suppression, collection of forest products, wildlife habitat, carbon accumulation, and sometimes tenure signaling. Secondary forests embedded within shifting-cultivation mosaics may therefore constitute functional components of the agricultural system rather than residual forest waiting to be permanently cleared (Borges et al., 2023; Mertz et al., 2021; Mukul et al., 2020).

The contemporary debate has intensified because these rotational systems are themselves changing. Population growth, market integration, infrastructure, restrictions on access to land, conservation regulations, cash-crop expansion, outmigration, and changing labor availability can shorten fallow periods or encourage permanent cultivation. In Laos, Myanmar, Northeast India, Nepal, and other regions, swidden systems have been undergoing agrarian transitions toward permanent cash crops, commercial plantations, sedentary agriculture, agroforestry, or mixed livelihood portfolios (Mukul & Byg, 2020; Pyone et al., 2024; Ramcilovic-Suominen & Kotilainen, 2020; Swe & Nawata, 2020). Remote-sensing work in Laos also illustrates both the continuing spatial significance of shifting cultivation and the methodological importance of distinguishing cyclical disturbances from permanent deforestation (Chen et al., 2023a; Chen et al., 2023b).

This distinction has major implications for climate policy. Burning vegetation releases greenhouse gases, and repeated forest clearing can reduce time-averaged biomass carbon when fallow periods become too short. Nevertheless, estimating the carbon footprint of shifting cultivation requires knowing whether forest actually regenerates, how much biomass is combusted, the length of the cultivation and fallow phases, soil-carbon responses, and whether the land eventually undergoes permanent conversion. Bruun and Hepp (2023) demonstrate that substantial uncertainties remain in all these components. Empirical studies reinforce this complexity: soil organic carbon remained comparatively stable across different rotation intensities in northern Laos, whereas intensified systems in other environments experienced fertility decline, greater weed burdens, biomass reductions, or slower ecosystem recovery (Abrell et al., 2024; Bruun et al., 2021; Nath et al., 2021).

The public-health dimension introduces another layer of complexity. Smoke from vegetation burning affects air quality, and escaped fires can destroy crops, forest resources, homes, and infrastructure. However, peatland landscapes deserve particular differentiation. Drainage lowers water tables, creates highly combustible peat and vegetation, and allows surface fires to develop into persistent subsurface combustion. Indonesian peat fires consequently produce exceptionally large smoke and health burdens. Studies have associated peat-fire PM_{2.5} exposure with mortality, respiratory illness, asthma, hospitalization, and productivity losses, while more recent monitoring of the 2019 Central Kalimantan fire episode showed extreme urban air-pollution exposure (Grosvenor et al., 2024; Hein et al., 2022). Such outcomes cannot reasonably be attributed to “traditional slash-and-burn” alone when hydrological alteration, drainage, plantation development, drought, fuel accumulation, and governance failures jointly create the underlying fire regime (Goldstein et al., 2020; Kiely et al., 2021).

There is also an environmental-justice problem. Smallholders are simultaneously users of intentional agricultural fire and victims of uncontrolled landscape fire. Carmenta et al. (2021a) document material and non-material burdens experienced by small farmers across tropical landscapes, including livelihood loss, damaged food security, health impacts, and restrictive fire regulation. In Indonesian Borneo, national burn restrictions introduced in response to catastrophic fires have affected communities practicing small-scale swidden farming on mineral soils, generating tensions between regulatory objectives and locally embedded agricultural systems (Daeli et al., 2021; Eilenberg, 2022). Hence, mitigation must address the difficult question not merely of how to reduce burning but of which fires, generated by which systems, under which conditions, should be reduced, modified, tolerated, or replaced.

Against this background, this article develops a multidimensional qualitative synthesis of the recent literature. It asks: why do local communities retain or transform slash-and-burn systems; under what conditions are rotational systems relatively resilient or degrading; what ecological, livelihood, cultural, health, and governance consequences occur; and which mitigation pathways are effective, equitable, and realistic? Its primary argument is that outcomes are

determined less by the mere presence of fire than by the configuration of the wider social-ecological system. The article therefore moves beyond the binary question of whether slash-and-burn is “sustainable” or “destructive” and instead asks **which configurations of fire, fallow, livelihoods, hydrology, markets, and institutions produce which outcomes, for whom, and over what temporal scale.**

LITERATURE RIVIEW

1. Beyond a Single Definition of Slash-and-Burn

The term *slash-and-burn* describes a land-preparation technique rather than a complete land-use system. This distinction is essential. Fire may be used within rotational swidden, permanent agriculture, pasture establishment, plantation expansion, residue management, hunting, or deliberate landscape burning. Conversely, not every shifting-cultivation cycle produces an uncontrolled landscape fire. The environmental effects of burning therefore cannot be inferred reliably without understanding what precedes the fire, what follows it, and whether vegetation regeneration remains part of the system.

Traditional swidden systems frequently produce heterogeneous landscapes composed of active fields, young and mature fallows, remnant trees, forest patches, settlements, and uncultivated areas. These landscape mosaics can maintain more structural and biological heterogeneity than permanent monocultures. In Northeast India, for example, Borah et al. (2022) found that traditional non-intensive shifting cultivation retained substantial bird diversity, while similarity to old-growth forest increased with secondary-forest maturity. Studies in the Philippines likewise show substantial recovery of tree diversity in secondary forest after abandonment, although forest structure may recover more slowly than species richness (Mukul et al., 2020). These findings do not imply equivalence with old-growth forest; rather, they demonstrate that the ecological baseline chosen for comparison critically affects conclusions.

A particularly useful distinction is therefore between rotational disturbance and permanent conversion. Rotational clearing creates temporary reductions in vegetation followed by regrowth, whereas permanent conversion suppresses or removes the fallow phase. Remote sensing that detects canopy loss without adequately tracking subsequent regeneration risks categorizing rotational disturbance as deforestation. Chen et al. (2023a) demonstrate how Landsat time series can distinguish shifting cultivation, plantations, and deforestation more accurately, while Bruun and Hepp (2023) identify classification uncertainties as a central obstacle to estimating the climate impacts of swidden landscapes. Hepp et al. (2026) reinforce this concern by showing that robust deforestation attribution requires explicit separation of actively cultivated plots, fallows of different ages, plantations, and forest within dynamic shifting-cultivation landscapes.

2. Social-Ecological Systems and Resilience

A social-ecological systems perspective interprets shifting cultivation as a coupled system in which ecological processes and human institutions continuously influence one another. Fire releases nutrients and removes biomass; cultivation changes soil and vegetation; fallow permits succession; labor institutions determine when fields are cleared; customary rules can limit the scale

of disturbance; markets alter crop choice; and tenure security influences whether farmers invest in long-term vegetation recovery. Sustainability therefore emerges from interactions rather than from a single farming operation.

Resilience provides a useful way to interpret this dynamic. A rotational system is relatively resilient when cultivated plots can return toward a functional fallow state while households maintain acceptable food security and livelihoods. It becomes progressively less resilient when recovery time is insufficient, soil degradation accumulates, woody vegetation fails to re-establish, fire becomes more frequent, or household livelihood needs force increasingly intensive land use. Tverskoi and Scaggs (2025) add an important institutional dimension by modelling how reciprocity, normative reasoning, and sanctions can shape the intensity of swidden disturbance, illustrating that collective social institutions can influence ecological outcomes rather than merely responding to them.

3. Livelihoods and Agrarian Transition

For many remote communities, swidden is not simply an agricultural technology but one element of a diversified livelihood system. Access to land, forest products, labor exchange, hunting, gathering, livestock, cash income, and migration interacts with cultivation decisions. Paul et al. (2020) show that social and financial capital, livelihood diversification, extension, and market access substantially influence livelihood sustainability among shifting cultivators in Northeast India. Bos et al. (2020) similarly demonstrate that farmers' decisions concerning transitions away from shifting cultivation reflect livelihood strategies rather than only agronomic productivity.

Swidden decline therefore cannot automatically be interpreted as development. Transitions can generate higher cash incomes, but they may simultaneously increase dependence on markets, inputs, commodity prices, or land concentration. Polthanee et al. (2021), examining a transition toward rubber-based agriculture in Laos, demonstrate that changes from swidden to commodity production alter household food-security relationships. In Myanmar, Pyone et al. (2024) document a shift from Karen subsistence cultivation toward permanent cash cropping, while Swe and Nawata (2020) identify land conflict, migration, labor availability, and agricultural inputs as underlying factors in swidden-to-permanent-agriculture transitions.

4. Political Ecology and Environmental Justice

Political ecology contributes an analysis of power. What governments classify as “degraded land,” “forest,” “idle land,” “illegal burning,” or “modern agriculture” can determine who controls landscapes and who bears the costs of environmental regulation. Ramcilovic-Suominen and Kotilainen (2020) demonstrate in Laos that livelihood interventions designed to reduce shifting cultivation were mediated by visible and hidden power relations, affecting food security, resource access, and community resilience. Bauernschuster et al. (2022) likewise question assumptions that restricting shifting cultivation and intensifying permanent agriculture necessarily produce land-sparing benefits.

Environmental justice sharpens this argument by distinguishing distributional, procedural, and recognitional dimensions. Distributional justice concerns who bears smoke, fire, livelihood, and enforcement costs; procedural

justice concerns participation in decisions; recognitional justice concerns whether customary knowledge and identities are treated as legitimate. Carmenta et al. (2021a) show that tropical smallholders often experience the burdens of uncontrolled fire while simultaneously being represented as its principal cause. Daeli et al. (2021) demonstrate the practical consequences when fire prohibition collides with culturally embedded swidden practices.

5. Traditional Ecological Knowledge and Biocultural Landscapes

Local fire knowledge encompasses decisions about vegetation dryness, wind, humidity, ignition direction, field boundaries, firebreaks, timing, labor organization, and suppression. Such knowledge should not be romanticized as universally effective, especially where climatic and landscape conditions have changed. Nevertheless, exclusion of local knowledge can remove institutions historically used to manage fire.

The wider literature on Indigenous fire management demonstrates that cultural burning is not reducible to fuel disposal. It can integrate biodiversity, cultural obligations, landscape stewardship, and community authority. Smith et al. (2021) show that institutionalizing Indigenous fire management in Australia depends not merely on transferring technical knowledge but on sustained intercultural relationships and recognition of Indigenous environmental authority. More recent work by Beggs et al. (2025) similarly emphasizes governance, sovereignty, experimentation, and collaboration in cultural-fire programs. Indigenous-led research in Colombia further shows that cultural fire values are embedded in worldviews, identity, and forest governance rather than functioning only as a technical tool for vegetation management (Monsalve Cuartas et al., 2025). These lessons are relevant to swidden governance because effective fire policy frequently depends on institutional relationships, recognition, and co-produced knowledge rather than prohibition alone.

METHODOLOGY

1. Review Design

This study employs a qualitative integrative literature review. It is explicitly not a systematic literature review and does not claim exhaustive retrieval, PRISMA compliance, meta-analysis, or quantitative effect-size estimation. The purpose is interpretive synthesis: to compare findings from different disciplines, identify recurring and contradictory themes, explain why reported impacts differ between contexts, and develop an integrated conceptual framework for context-sensitive mitigation. This design is appropriate for a field in which the same broad label – slash-and-burn – covers heterogeneous land-use systems and where ecological and social outcomes are strongly context dependent.

A qualitative approach is particularly appropriate because the central problem crosses disciplinary boundaries. Soil scientists may evaluate organic carbon, nutrient availability, or aggregate stability; ecologists may analyze vegetation succession, birds, or biomass; anthropologists examine culture and reciprocity; development scholars focus on livelihoods and agrarian transitions; political ecologists study land control and marginalization; and public-health

researchers estimate smoke-related disease. A single outcome metric would therefore inadequately represent the object of analysis.

2. Literature Identification and Scope

Priority was given to peer-reviewed journal articles published from 2020 to 2026 and available through major scholarly publishing and indexing platforms. Search concepts combined terms including slash-and-burn, shifting cultivation, swidden, jhum, kaingin, local communities, Indigenous peoples, fire, fallow, soil, carbon, biodiversity, forest recovery, livelihood, food security, health, haze, governance, tenure, agroforestry, restoration, and mitigation. The review also used backward and forward citation tracing for conceptually important studies, with emphasis on recent empirical evidence and high-quality interdisciplinary synthesis. The objective was analytical coverage of the principal themes rather than exhaustive enumeration of every publication, which is consistent with the qualitative review design (Li & Nath, 2024).

The evidence base deliberately includes both studies directly examining shifting cultivation and contextual studies of landscape fire, peatland fire, Indigenous fire governance, agroforestry transition, and restoration where these help explain mechanisms relevant to mitigation. This is necessary because smoke impacts or peat-fire dynamics cannot be understood solely from agronomic studies, just as the social consequences of fire prohibition cannot be inferred from atmospheric science.

3. Thematic Coding and Synthesis

The literature was interpreted through first-cycle thematic codes covering: livelihood functions; food security; soil fertility; soil carbon; aboveground carbon; biodiversity; succession; fire escape; hydrology; peat; air pollution; health; culture; customary institutions; tenure; regulation; market integration; agrarian transition; agroforestry; restoration; and community fire management. These codes were subsequently consolidated into eight thematic dimensions: conceptual differentiation, livelihood functions, ecological ramifications, health and disaster ramifications, sociocultural ramifications, governance and justice, agrarian transition, and mitigation.

Contradictory evidence was treated analytically rather than regarded as error. For example, evidence that soil organic carbon remains stable under certain rotation intensities does not invalidate evidence of soil deterioration elsewhere. Instead, differences were examined in relation to soil type, fallow duration, slope, tree retention, cultivation frequency, climate, cropping systems, and study design. This comparative logic is central to the review's emphasis on **conditional sustainability**.

4. Limitations

Several limitations affect the literature. Terminology remains inconsistent, and “slash-and-burn” is sometimes applied to highly dissimilar systems. Geographic coverage is uneven, particularly between Southeast Asia, South Asia, Latin America, and Africa. Long-term studies tracking complete cultivation–fallow cycles remain limited, and recent Africa-focused synthesis also indicates substantial variation in biodiversity, soil, and livelihood effects across local systems (Kim, 2025). Studies disproportionately measure carbon, soil, and

biodiversity while cultural ecosystem services and gendered knowledge remain less frequently quantified (Mertz et al., 2021). Furthermore, remote-sensing classifications may detect vegetation removal more easily than subsequent regeneration, complicating assessments of permanent deforestation versus cyclical land use.

RESULT

1. Why Communities Continue to Use Fire-Based Rotational Agriculture

The persistence of swidden is best understood through livelihood functionality. Fire provides a relatively low-capital means of converting accumulated vegetation into a cultivable field, suppressing weeds, temporarily altering nutrient availability, and reducing the labor required for biomass removal. In environments with limited mechanization, difficult terrain, low access to credit, and restricted markets for external inputs, replacing fire can impose substantial labor or financial costs. Hazenbosch et al. (2021), working with swidden farmers in Papua New Guinea, found that soil amendments could increase crop yields but that farmer uptake depended on information, costs, field conditions, and labor considerations.

Land-use decisions are also strongly conditioned by alternatives. Mukul and Byg (2020) found that Indigenous Chepang farmers in Nepal were more dependent on swidden when alternative land uses and off-farm opportunities were limited. Phouyyavong et al. (2020) show how labor allocation in an upland Lao village increasingly encompassed cash crops and diversified livelihoods while swidden retained subsistence functions. The decision to abandon rotational cultivation is therefore neither purely environmental nor purely economic; it reflects household assets, land availability, market access, migration, risk, and cultural attachment.

Food security is particularly important because swidden fields frequently contain multiple crops rather than a single commodity. Agrobiodiversity can distribute production risk across varieties and seasons while supplying cereals, tubers, vegetables, fruits, and other foods. Changes toward monoculture or cash-crop agriculture may increase monetary income but also alter food purchasing requirements and exposure to commodity volatility. Evidence from Laos demonstrates that transitions from swidden-based production toward rubber can significantly reshape household food-security strategies (Polthanee et al., 2021).

The system also has social and cultural dimensions. Labor-intensive operations such as cutting and burning often rely on household cooperation or reciprocal labor institutions. Tverskoi and Scaggs (2025) illustrate theoretically how reciprocity and community norms can influence both production and ecological disturbance. Ethnographic evidence from India likewise indicates that shifting cultivation can remain deeply embedded in identity and ways of life even where its economic or ecological context is changing (Behera & Rout, 2025; Jagannath et al., 2025). Pandey et al. (2023) extend the analysis to psychological wellbeing, demonstrating that landscape transitions can affect Indigenous wellbeing as the relationships among land, livelihoods, culture, and community change.

These findings suggest that policies designed to remove fire without understanding its functions can produce unanticipated trade-offs. If mechanized clearing, fertilizers, herbicides, permanent cash crops, or purchased food replace the functions previously provided through rotational land use, environmental burdens may be displaced rather than eliminated. An appropriate comparison is therefore not simply “swidden versus untouched forest” but frequently “swidden versus the land-use system likely to replace it.”

Figure 1 illustrates why fire should be analyzed as one component within a larger social-ecological causal chain rather than as an isolated driver of environmental degradation. The figure links structural drivers and system configuration to biophysical context, ecological processes, human outcomes, and governance feedbacks, thereby making the article’s central causal argument explicit.

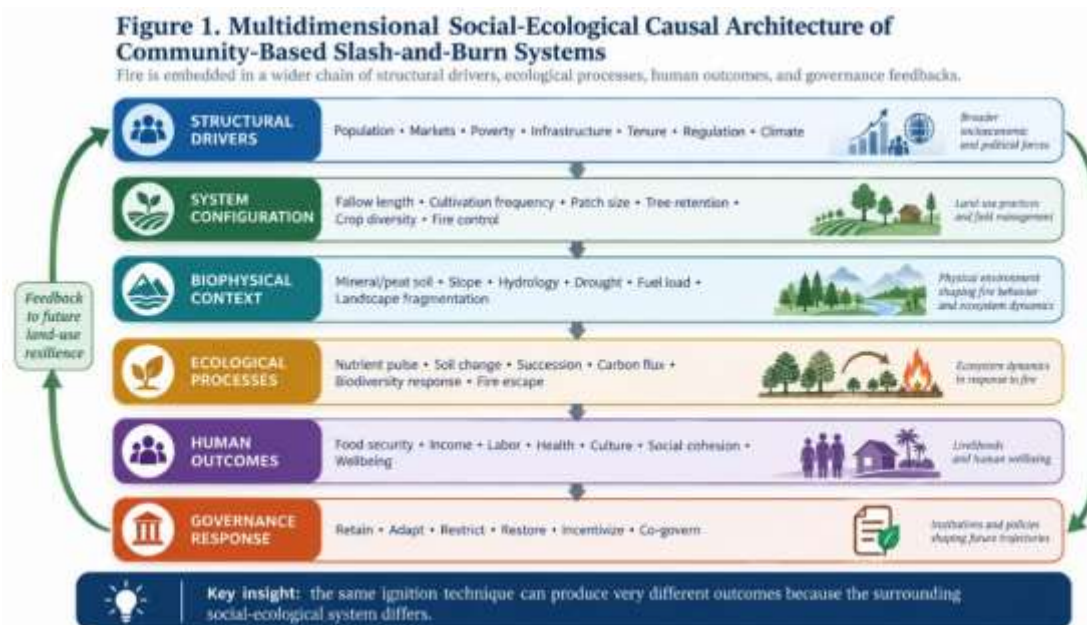


Figure 1. Multidimensional Social-Ecological Causal Architecture of Community-Based Slash-and-Burn Systems

Figure 1 emphasizes feedback. A shortened fallow, for example, can reduce vegetation recovery and increase weed pressure; higher labor requirements can then encourage herbicide use, permanent crops, or further clearing. Conversely, secure tenure and community institutions may enable longer rotations, tree retention, or collective fire control. The same ignition technique can therefore produce markedly different outcomes because the causal variables operating before and after burning differ.

2. Soil Fertility, Nutrient Dynamics, and Fallow Recovery

Fire immediately alters soil chemistry by converting part of the standing biomass and litter into ash, producing a temporary nutrient pulse and often increasing surface-soil pH. Whether this constitutes sustainable fertility management depends on what happens during subsequent cultivation and fallow. Nutrients can be removed in harvests, lost by erosion or leaching,

immobilized during vegetation recovery, or replenished through organic inputs and deeper-rooted vegetation.

Evidence does not support a universal trajectory of soil collapse. Lintemani et al. (2020) found that long fallows in a Brazilian slash-and-burn system could restore several physical and chemical soil characteristics, with approximately 15 years of fallow producing strong recovery for the variables examined. Pinho et al. (2023), studying Indigenous swidden fields and fallows in northern Amazonia, found relatively stable soil acidity and fertility patterns in long-managed forest islands and emphasized that fallow also maintained environmental and social functions beyond simple nutrient restoration. Fachin et al. (2024) further demonstrated resilience in several soil physical properties under a long history of Atlantic Forest slash-and-burn management.

However, resilience is not unlimited. Sharma et al. (2022) observed reduced soil fertility under shortened fallow cycles in Mizoram, while Laskar et al. (2021) demonstrated significant relationships among fallow chronosequence, soil aggregation, depth, and soil organic carbon in Northeast India. Abrell et al. (2024) found that intensified cultivation in the eastern Amazon was associated with declining soil fertility and increased weed pressure, creating additional labor demands. Consequently, shortening a rotation can undermine precisely those regenerative functions that made a low-input shifting system viable.

The importance of vegetation structure is particularly evident in African miombo landscapes. Magalhães (2023) found that maintaining trees within shifting-cultivation landscapes helped preserve soil organic carbon following woodland conversion, whereas treeless systems experienced greater carbon loss. Tree retention therefore deserves greater emphasis as a practical design variable. The relevant management question is not solely how long land remains fallow but what type of vegetation develops during that period and how much woody biomass is retained during cultivation.

3. Soil Carbon, Biomass, and Climate Implications

Carbon consequences are frequently invoked to justify restrictions on swidden, yet the evidence is highly dependent on system boundaries. Burning releases carbon rapidly, but regenerating vegetation subsequently absorbs carbon. Aboveground stocks fluctuate through the rotation, while belowground and soil-carbon responses may follow different trajectories. Carbon accounting must therefore incorporate cultivation length, fallow length, biomass accumulation, combustion completeness, frequency of burning, soil-carbon response, and permanent-deforestation risk (Bruun & Hepp, 2023).

Bruun et al. (2021) found no clear depletion of soil organic carbon across the shifting-cultivation intensities examined in northern Laos, challenging generalized narratives that shortening fallow inevitably produces immediate SOC loss. Mukul et al. (2022) similarly found limited differences in several soil carbon and nutrient indicators across regenerating secondary forests in the Philippines, with patch size, slope, and fallow age helping explain variation. In contrast, Nath et al. (2021) found that ecosystem carbon stocks increased with fallow age but remained below natural-forest values even in older fallows. These

apparently conflicting findings illustrate that soil carbon and whole-ecosystem carbon are not interchangeable outcomes.

Aboveground recovery is generally more visibly dependent on fallow length. Borges et al. (2023) found that different ecosystem attributes in Brazilian swamp gallery forests recovered at very different rates following cultivation; diversity could recover substantially earlier than biomass. Reang et al. (2021) showed that Indigenous pineapple agroforestry systems could rebuild ecosystem carbon over time and approach natural-forest stocks more closely in older systems. Hazarika et al. (2024) likewise identified long-established pineapple agroforestry as a potential land-restoration pathway in the Eastern Himalayas. These findings imply that agroforestry transitions can reduce pressure for repeated clearing while retaining productive functions.

Model-based evidence also demonstrates the importance of rotation design. Primo et al. (2023) simulated long-term carbon outcomes under slash-and-burn and agroforestry scenarios and found that absence of adequate fallow can strongly reduce SOC, whereas agroforestry rotations can improve sequestration. Such results reinforce the argument that carbon policy should focus on **rotation intensity and permanent conversion**, not simply the binary existence of fire.

4. Biodiversity and Secondary-Forest Succession

Shifting-cultivation landscapes can generate both biodiversity loss and biodiversity habitat depending on the baseline, rotation intensity, and surrounding forest. Conversion of intact old-growth forest to agriculture clearly reduces many ecological values, especially where repeated cultivation prevents recovery. Yet a mature swidden mosaic containing old fallows, remnant trees, active fields, and forest patches can contain substantially greater habitat heterogeneity than a landscape converted to permanent monoculture.

Borah et al. (2022) found that traditional non-intensive shifting-cultivation landscapes in Northeast India provided important bird habitat, with secondary-forest maturation increasing resemblance to old-growth communities. Mukul et al. (2020) observed relatively rapid recovery of tree diversity in Philippine fallows, although structural characteristics recovered more slowly. Sharma et al. (2022) similarly showed progressive shifts from herbs and shrubs toward greater tree representation with increasing fallow age. These findings demonstrate that fallow is a biodiversity process rather than simply a period of agricultural inactivity.

Baul et al. (2023), however, illustrate that shifting cultivation interacting with forest fragmentation can reduce soil carbon and nutrient stocks relative to intact forest. Wang et al. (2023) likewise found that forest disturbance from logging and shifting cultivation changed soil-carbon functional groups in Hainan's tropical rainforest, even where subsequent recovery occurred. The appropriate conclusion is therefore neither that swidden conserves biodiversity universally nor that it destroys biodiversity universally. Ecological value depends strongly on whether old-growth forest continues to be cleared, whether fallows mature sufficiently, and what alternative land use follows agricultural transition.

Mertz et al. (2021) provide a particularly useful comparative insight: secondary forests in shifting-cultivation landscapes generally provide lower carbon storage and biodiversity than old-growth forests but can outperform agricultural alternatives for many ecosystem services. This implies that policy evaluation should compare realistic alternatives. Replacing a swidden mosaic with permanent plantation agriculture may increase one service, such as cash income, while reducing habitat heterogeneity, provisioning diversity, or cultural values.

Figure 2 conceptualizes swidden sustainability as a continuum governed by regeneration capacity, land-use permanence, and fire risk rather than as a binary classification. The gradient clarifies why long-fallow rotational systems, pressured transitions, degrading systems, and critical peat-fire landscapes require progressively different forms of intervention.



Figure 2. The Conditional Sustainability Continuum

Figure 2 highlights that a management intervention appropriate at one end of the continuum can be inappropriate at another. A rotational system with adequate regeneration on mineral soil may principally require improved fire control and tenure security. A compressed-fallow system may require agronomic adaptation or agroforestry. Drained peat, by contrast, often requires hydrological restoration and major reduction of ignition sources because even small surface fires can become exceptionally damaging.

5. Peatlands, Hydrology, and the Limits of Generalized Fire Narratives

Tropical peatlands demonstrate most clearly why all agricultural fires should not be treated alike. Peat soils store very large amounts of carbon in partially decomposed organic matter. When drained, the water table falls, peat oxidizes, subsides, and becomes increasingly susceptible to combustion. Surface fire entering dry peat can persist below ground, becoming difficult to detect and

suppress while releasing large quantities of particulate matter and greenhouse gases.

Goldstein et al. (2020) show that the transition from surface to subsurface peat fire in Central Kalimantan is produced through interactions among hydrological modification, fuel conditions, human activities, and landscape history. This challenges explanations that reduce Indonesian peat fire simply to slash-and-burn behavior. Dhandapani and Evers (2020) experimentally documented substantial post-fire changes in greenhouse-gas emissions, nutrients, and peat properties in an oil-palm-associated tropical peatland, demonstrating why peat combustion carries impacts qualitatively different from a shallow vegetation burn on mineral soil.

Restoration therefore requires more than policing ignition. Rewetting, canal blocking, vegetation restoration, land-use adaptation, fire preparedness, and community engagement need to operate together. Carmenta et al. (2021b) found that successful peat-fire prevention emerged from combinations of interventions whose effectiveness depended on landscape and social context. Robins et al. (2022) similarly emphasize knowledge-system integration and stakeholder engagement in community fire management and peatland restoration. Participatory action research in Riau further indicates that durable fire prevention and peatland restoration depend on political support, community leadership, social capital, institutional strengthening, and viable livelihood models rather than on technical restoration alone (Purnomo et al., 2024). This reinforces a general lesson for mitigation: interventions should be designed as context-specific bundles rather than as single universally applicable instruments.

6. Smoke, Public Health, and Disaster Burdens

Smoke creates an externality extending far beyond the cultivated field. Fine particulate matter can travel across communities and national borders, and severe episodes can affect respiratory and cardiovascular health, schools, transportation, labor productivity, and economic activity. The magnitude varies greatly according to fuel type, area burned, atmospheric conditions, peat involvement, and population exposure.

Hein et al. (2022) estimated substantial long-term mortality, childhood asthma, hospitalization, and lost-workday burdens attributable to Indonesian peat-fire PM_{2.5}. Grosvenor et al. (2024) documented exceptionally severe air-quality impacts during the 2019 Central Kalimantan fires and estimated substantial excess mortality. Kiely et al. (2021) integrated economic and atmospheric modelling to demonstrate the high costs of Indonesian fires and the potential benefits of peatland restoration. These studies strongly justify aggressive prevention in high-risk peat landscapes but simultaneously demonstrate why health evidence from peat megafires should not be indiscriminately used to characterize every smallholder swidden burn.

Smallholders themselves frequently bear significant fire burdens. Carmenta et al. (2021a), drawing on cases in Brazil, Madagascar, and the Philippines, show that uncontrolled fire damages local livelihoods, food security, health, and social relations. Farmers who intentionally use controlled fire therefore have incentives to avoid escaped fire, although changing climate

conditions, landscape fragmentation, fuel accumulation, and weakening institutions can reduce their capacity to do so.

7. Sociocultural Ramifications

Swidden landscapes can embody cultural histories, institutions, ecological knowledge, and social identity. The sequence of cutting, drying, burning, planting, harvesting, and fallowing may structure seasonal calendars and cooperative labor. Crop varieties and associated wild resources form part of local food cultures, while customary rules influence access to plots and fallows.

Jagannath et al. (2025) emphasize how crop selection, rotation, and management in Nagaland are shaped by socio-ecological drivers and Indigenous knowledge. Behera and Rout (2025) describe shifting cultivation among Kandha communities as a way of life facing significant contemporary pressures. Tverskoi and Scaggs (2025) show theoretically how reciprocity and normative sanctions can help govern collective land use. These findings suggest that replacing swidden is not simply an agronomic substitution: it can restructure social relations and weaken institutions that formerly coordinated labor and resource use.

Psychological and wellbeing impacts also deserve attention. Pandey et al. (2023) found that transformations in shifting-cultivation landscapes in the Indian Himalayas were associated with changes in Indigenous psychological wellbeing. These effects are difficult to capture in conventional carbon or productivity assessments but matter for recognitional justice and sustainable development.

8. Governance, Criminalization, and Misplaced Responsibility

Fire governance often intensifies following catastrophic haze events, yet regulation developed for extreme fires can affect small-scale systems far removed from the conditions generating those disasters. Daeli et al. (2021) show how Indonesia's burn ban produced conflict with customary swidden practices in West Kalimantan. Eilenberg (2022) places this within longer histories of frontier governance, arguing that haze crises can reinvigorate narratives of supposedly backward agriculture and justify agricultural modernization and enclosure.

Alam et al. (2023) similarly highlight the challenge of governing traditional farming within transboundary haze regimes. The problem is not that agricultural fire requires no regulation; rather, the governance scale must correspond to causal responsibility. A differentiated policy would distinguish small mineral-soil burns with effective containment from fires on drained peat, plantation clearing, deliberate illegal burning, or burning during extreme drought.

Land-tenure policy is equally influential. Insecure land rights can discourage long-term fallow management and tree investment while increasing incentives for visible land clearing to demonstrate occupation. Policies designed to stabilize cultivation can also generate unintended outcomes. Bauernschuster et al. (2022) found that agricultural intensification in Laos did not automatically produce the expected land-sparing outcomes and that greenhouse-gas and food-security trade-offs remained. Ramcilovic-Suominen and Kotilainen (2020) likewise demonstrate that interventions intended to restrict shifting cultivation can distribute benefits and costs unevenly through existing power relations.

DISCUSSION

1. Why the Evidence Appears Contradictory

The literature contains studies concluding that shifting cultivation causes ecosystem degradation and others demonstrating substantial ecological resilience. This contradiction is largely resolved once the system is disaggregated. Fallow duration, cultivation frequency, tree retention, soil type, topography, climate, and prior land-use history change the direction and magnitude of outcomes.

Long fallow can restore soil aggregation, nutrient cycles, woody biomass, and vegetation structure, but ecological components recover at different rates. Soil characteristics may recover within a moderate period while aboveground biomass requires several decades. Species richness may recover before community composition. Soil organic carbon may remain stable even while total ecosystem carbon declines because aboveground biomass has been removed. Consequently, sustainability cannot be inferred from one indicator.

This helps explain why Bruun et al. (2021) detected no major SOC loss under the Lao rotation intensities studied, whereas Nath et al. (2021) identified substantial ecosystem-carbon differences among fallow stages and natural forest, and Abrell et al. (2024) documented soil-fertility and weed problems under intensified Amazonian cultivation. The studies measure different ecological components under different systems rather than offering mutually exclusive conclusions.

The same reasoning applies to biodiversity. A shifting-cultivation mosaic compared with primary forest may show reduced habitat quality for old-growth specialists. The same mosaic compared with permanent monoculture can simultaneously provide greater landscape heterogeneity and habitat. Borah et al. (2022) and Mukul et al. (2020) demonstrate substantial biodiversity value in regenerating fallows, while Mertz et al. (2021) cautions that secondary forest usually remains inferior to old-growth forest for several services. The appropriate policy inference is conservation of remaining old-growth forest **plus** improved management of human-modified mosaics, rather than treating the two categories as interchangeable.

2. Fallow as the Missing Variable in Many Policy Narratives

Fallow is the central regenerative mechanism of rotational swidden. Yet policy narratives often focus on cutting and burning while paying comparatively little attention to what happens during the years when vegetation regrows. The sustainability of the system can therefore deteriorate even if burning technique itself remains unchanged.

Population pressure is one cause of shorter fallows, but it is not the only one. Land enclosure, protected-area restrictions, plantation concessions, insecure tenure, road development, cash-crop opportunities, and labor shortages can reduce the land or time available for rotation. In some circumstances, therefore, policies intended to protect forests can indirectly compress cultivation into smaller areas and accelerate rotation.

The policy objective should consequently include maintaining or reconstructing regenerative functions. Where long fallows are no longer possible,

improved fallows, nitrogen-fixing vegetation, tree retention, compost, manure, targeted fertilizer, cover crops, or agroforestry may partially substitute for ecological processes formerly supplied by longer secondary succession. Hazenbosch et al. (2021) show that locally accessible fertility management can improve yields, while Hazarika et al. (2024), Reang et al. (2021), and Mathur and Bhattacharya (2022) demonstrate the potential of agroforestry transitions to combine livelihood and restoration objectives.

3. Agrarian Transition is Not Automatically an Environmental Improvement

Transitions toward permanent agriculture are frequently presented as modernization. Yet permanent cultivation can require more fertilizer, herbicide, mechanization, irrigation, and market dependence. Commercial crops may generate higher cash income but reduce subsistence production and expose households to price volatility. The land-use replacement may also store less carbon or support less biodiversity than mature swidden fallows.

In Myanmar, Pyone et al. (2024) show that community landscapes are shifting toward cash cropping under interacting social, political, and economic drivers. Swe and Nawata (2020) similarly document movement toward permanent agriculture among Karen communities. In Laos, Phouyyavong et al. (2020) demonstrate increasing livelihood diversification, while Polthanee et al. (2021) identify important food-security effects from rubber-oriented transitions. Agrarian transition should therefore be assessed according to multiple outcomes, not measured merely by a reduction in visible shifting cultivation.

Moure et al. (2024) add an important behavioral dimension: swidden and agroforestry farmers can perceive causes, risks, uncertainties, and adaptation options differently. Programs that assume farmers will adopt agroforestry simply because researchers identify aggregate environmental advantages may fail if the transition creates unfamiliar risks or does not fit household decision models.

Hands (2021) provides another example through the Guama Model and *Inga* alley cropping, designed to provide sustainable food production while reducing repeated slash-and-burn clearing. Its broader lesson is not that one particular technology should replace swidden everywhere but that credible alternatives must perform the functions households need—food, soil management, risk reduction, income, and manageable labor—rather than merely satisfying an external environmental objective.

Figure 3 summarizes why any evaluation of swidden or its replacement must simultaneously consider ecological, economic, health, social, and cultural outcomes. By placing potential benefits and potential costs side by side, the matrix makes visible the trade-offs that can be obscured when sustainability is judged by a single indicator such as carbon, yield, or forest cover.



Figure 3. Multidimensional Trade-off Matrix

Figure 3 also demonstrates why an apparently successful intervention can create new problems. Eliminating fire may improve local air quality but increase household expenditure on herbicides or mechanized clearing. Replacing food crops with rubber can raise income while increasing purchased-food dependence. Increasing agricultural intensity may reduce area per unit output while also increasing fertilizer-related emissions. A genuinely multidimensional assessment therefore requires explicit recognition of trade-offs.

4. Environmental Justice: Who Causes Fire and Who Bears Its Costs?

The distribution of responsibility is one of the most neglected aspects of fire policy. Local communities may ignite fires, but ignition is only one element of wildfire risk. The probability that a fire escapes and the magnitude of resulting damage depend on drought, drainage, vegetation structure, adjacent land uses, fuel connectivity, road access, firefighting capacity, and institutional coordination.

This is especially important in Indonesia. Goldstein et al. (2020) show how peat-fire vulnerability results from historically produced hydrological and vegetation conditions. Carmenta et al. (2021b) show that prevention outcomes depend on combinations of social and landscape conditions. It is therefore analytically weak to treat ignition behavior as the sole causal variable while disregarding the creation of highly combustible landscapes.

At the same time, communities should not be exempt from responsibility where burning generates avoidable harm. Environmental justice requires neither romanticization nor criminalization. It requires proportionality: responsibility should correspond to actual risk creation, ability to prevent harm, and control over landscape conditions. Larger actors that drain peat, alter hydrology, or create extensive flammable landscapes should bear responsibilities commensurate with those impacts, while local burning should be governed

according to patch size, soil type, weather, containment capacity, and nearby vulnerability.

5. Community-Based Fire Management and Co-Production of Knowledge

Community-based fire management provides an alternative to purely punitive regulation. It combines prevention, preparedness, early detection, firebreaks, equipment, monitoring, suppression, local knowledge, and coordination. However, labeling a program “community-based” does not automatically make it participatory. Communities require meaningful decision authority, adequate resources, incentives, recognition, and compatibility with livelihood calendars.

Robins et al. (2022) demonstrate that knowledge-system approaches can improve peat-fire-management projects by identifying stakeholder relationships and pathways through which knowledge affects action. Carmenta et al. (2021b) similarly show that intervention bundles work differently under different conditions. Agricultural extension can support these transitions, but Tran and Touch (2024) caution that extension institutions themselves must adapt to rapidly changing agrarian systems.

Lessons from Indigenous fire management elsewhere reinforce the importance of institutional design. Smith et al. (2021) found that the revival of Indigenous burning in southern Australia depends heavily on relationship-building and institutional legitimacy. Beggs et al. (2025) show that collaborative cultural-fire governance is also connected to Indigenous authority and sovereignty. Evidence from a Mexican tropical biosphere reserve likewise suggests that integrated fire management can be strengthened through community participation, local agreements, and combined cultural and physical prevention measures (Neger et al., 2024). Participatory peatland work in Indonesia similarly emphasizes institutional strengthening and collective action as prerequisites for durable outcomes (Purnomo et al., 2024). Together, these studies suggest that successful fire management requires co-production rather than simply extracting local knowledge and inserting it into externally designed programs.

6. Mitigation Options Along a Risk Gradient

A useful mitigation strategy should match intervention intensity to actual risk. Where traditional rotational systems operate on mineral soils, retain substantial fallows, conserve old-growth forest, and maintain effective fire-control institutions, complete elimination of fire may produce little additional benefit relative to its livelihood costs. Risk reduction may instead focus on firebreaks, weather-based burning, collective supervision, patch-size limits, emergency suppression, tree retention, and protection of sensitive areas.

Where fallows are shortening and productivity declining, adaptation should target the causes of intensification. Improved fallows, agroforestry, locally appropriate fertilizers, compost, tree retention, erosion control, diversified income, and extension can increase productivity without forcing abrupt livelihood displacement. Mathur and Bhattacharya (2022) found substantial agroforestry adoption among former or continuing shifting cultivators in Tripura, while Hazarika et al. (2024) demonstrate the potential for mature agroforestry to recover important soil properties.

Where permanent conversion or repeated burning is degrading forest, stronger land-use controls may be necessary, especially where old-growth forest remains at risk. Where peat has been drained, however, the intervention hierarchy changes fundamentally. Hydrological restoration, rewetting, canal management, fire exclusion under high-risk conditions, alternative wetland-compatible production, and large-scale prevention become central. Kiely et al. (2021) demonstrate that restoration can generate substantial avoided-fire benefits.

Figure 4 translates the review findings into a three-pathway mitigation hierarchy. It operationalizes the article's Retain-Adapt-Transform framework by linking diagnostic conditions to proportional responses ranging from risk reduction to agroecological adaptation and, where thresholds are exceeded, ecological restoration and livelihood transition.



Figure 4. Retain-Adapt-Transform: A Context-Sensitive Decision Framework

The principal advantage of Figure 4 is that it avoids two policy errors: universal prohibition and universal tolerance. Both are inappropriate because social-ecological contexts vary dramatically. The framework treats mitigation as a diagnostic process in which the objective is to preserve beneficial functions where possible, adapt systems approaching ecological thresholds, and transform systems where risks have become unacceptable.

7. Toward a Differentiated Fire-Governance Framework

The evidence synthesized in this review supports five overarching governance principles. Together, these principles translate the conditional-sustainability argument into a practical governance sequence that differentiates fire types, protects regeneration, addresses hydrology, aligns alternatives with livelihood functions, and recognizes local institutions.

First, **differentiate fire types before regulating them**. Policies should distinguish controlled agricultural burning, escaped vegetation fire, peat fire, plantation clearing, and wildfire. The term *slash-and-burn* is too broad to serve as a sufficient regulatory diagnosis.

Second, **protect ecological regeneration, not merely forest cover at one moment in time**. Monitoring systems should identify both clearing and regrowth. Chen et al. (2023a, 2023b) show that time-series approaches can substantially improve understanding of shifting-cultivation dynamics. Policies should particularly discourage expansion into remaining old-growth forest while recognizing fallow as part of existing agricultural landscapes.

Third, **govern hydrology as well as ignition**. In peatlands, preventing individual ignitions without reversing drainage leaves the underlying landscape highly flammable. Restoration therefore requires rewetting and vegetation management alongside community fire prevention.

Fourth, **align alternatives with livelihood functions**. A technically superior agricultural system will not be adopted if it is more expensive, exposes farmers to unfamiliar risks, increases labor beyond household capacity, or undermines food security. Evidence from Hazenbosch et al. (2021), Moure et al. (2024), and Paul et al. (2020) supports the importance of farmer capabilities, uncertainty, extension, and livelihood assets.

Fifth, **recognize local institutions but evaluate outcomes empirically**. Traditional ecological knowledge can improve fire timing, coordination, and landscape stewardship, yet climatic and social conditions are changing. Co-governance should combine community knowledge with meteorological forecasts, remote sensing, soil assessment, air-quality data, and modern fire-suppression capacity.

8. Research Gaps

Several major gaps remain. The first concerns terminology and measurement. Comparative studies need standardized reporting of cultivation duration, fallow duration, number of rotations, field size, vegetation type, soil classification, slope, fire intensity, and whether old-growth or secondary vegetation is cleared. Without such data, apparently conflicting findings remain difficult to reconcile.

Second, carbon accounting remains incomplete. Bruun and Hepp (2023) emphasize uncertainty in fallow biomass, combustion completeness, belowground carbon, rotation intensity, and permanent-deforestation attribution. Research should therefore measure complete landscape rotations rather than relying solely on plot-level emissions immediately after fire.

Third, social outcomes remain understudied relative to ecological indicators. Mertz et al. (2021) found that ecosystem-service studies disproportionately emphasize carbon, biodiversity, and soil while provisioning and cultural services receive much less attention. Food security, women's knowledge, labor reciprocity, youth aspirations, migration, mental wellbeing, and cultural identity deserve systematic empirical attention.

Fourth, health research should differentiate fuel sources and exposure pathways. Peat smoke, forest biomass, crop residues, and small controlled burns

differ substantially in emission factors and population exposure. Treating all agricultural burning as a homogeneous health exposure could generate misleading policy recommendations.

Fifth, research on mitigation should compare intervention packages rather than individual technologies. Community fire management, agroforestry, improved fallow, tenure reform, restoration incentives, and early-warning systems interact with one another. Experimental and quasi-experimental studies should examine not only environmental effects but adoption, distributional outcomes, gender, transaction costs, and durability.

Finally, improved remote sensing should be combined with participatory landscape mapping. Local communities can often distinguish active fields, recent fallows, mature fallows, sacred forests, production forests, and customary boundaries that may appear similar in satellite classifications. Combining these knowledge systems could reduce both mapping error and governance conflict.

CONCLUSIONS AND RECOMMENDATIONS

Slash-and-burn is not a single environmental phenomenon. It is a technique embedded within land-use systems ranging from relatively low-intensity rotational cultivation with long fallows and strong customary regulation to shortened-fallow agriculture, permanent commodity conversion, and highly hazardous burning in drained peatlands. The environmental and human consequences differ correspondingly.

The literature demonstrates that fire itself is an insufficient explanatory variable. The critical determinants include fallow duration, cultivation frequency, woody-vegetation recovery, patch size, old-growth clearing, soil properties, hydrology, drought, fuel continuity, crop systems, household dependence, market integration, tenure, and institutional capacity. Some rotational landscapes retain meaningful biodiversity, soil, food-security, and cultural functions, whereas ecological performance declines when regenerative processes are compressed or eliminated.

Fallow deserves particular recognition because it performs many of the ecological functions commonly attributed to external agricultural inputs. Where adequate fallows remain possible, protecting regeneration can sustain soil and landscape functions. Where land pressure or agrarian change has shortened rotations, improved fallows, agroforestry, fertility management, extension, diversification, and tree retention provide more constructive responses than abrupt prohibition.

High-risk peat landscapes require a different policy regime. Drainage changes the physical properties of the landscape such that relatively small ignitions can generate deep, persistent, smoke-intensive fires. Rewetting, hydrological restoration, ignition control, vegetation management, community fire preparedness, and livelihood transition should therefore operate together. Governance should also avoid transferring responsibility disproportionately to communities that have limited control over the structural drivers of fire risk. Smallholders can be both users of intentional fire and victims of uncontrolled fire. Environmental justice requires proportional regulation, recognition of customary

institutions, meaningful participation, and accountability for actors responsible for drainage, permanent conversion, or creation of highly combustible landscapes.

The synthesis therefore supports a Retain–Adapt–Transform framework. Viable rotational systems with adequate regeneration and controllable fire can be retained while reducing risk. Systems undergoing fallow compression, productivity decline, or rising fire risk should be adapted through agroecological, institutional, and livelihood interventions. Systems characterized by drained peat, chronic uncontrolled burning, permanent deforestation, or severe ecological degradation require transformation and restoration.

The broader policy principle can be summarized as Differentiate → Diagnose → Co-govern → Adapt → Monitor. Sustainable land and fire governance should replace the simplistic sequence Identify fire → Prohibit fire. By distinguishing the social-ecological contexts in which fire is used, policymakers can more effectively protect forests, climate, biodiversity, health, and public safety while respecting the livelihoods, knowledge, and rights of communities whose agricultural landscapes have developed through generations of interaction with fire and fallow.

FURTHER STUDY

This research still has limitations, so further studies on the topic Beyond Slash-and-Burn: Fire, Fallow, Livelihoods, and Justice in Local Community Land-Use Systems – A Multidimensional Review of Ramifications and Context-Sensitive Mitigation are needed to improve this research and provide more insights for both the author and the readers.

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