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Review

Lessons from Managing for the Extremes: A Case for Decentralized, Adaptive, Multipurpose Forest Management within an Ecological Framework

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Abstract: Multipurpose and ecological forest management frameworks are being increasingly applied across the Global North on public lands. However, the discourse and practice of public forest management in much of the developing world are captured by extreme approaches of single-crop (usually timber) production and strict canopy-cover protection, as exemplified by the case of Nepal. We combine insights from field research with published documents and trace the consequences of prevalent management regimes on the ecology and silviculture of Nepal's public forests. We find that managing for either extreme of timber production or forest protection can degrade forest ecosystems and affect their capacity to address the increasing number of demands placed on them. A history of narrow management outlooks has erased indigenous silvicultural practices and discouraged the development of novel silvicultural solutions to address today's environmental concerns. Government initiatives advancing singular objectives, such as Nepal's Scientific Forest Management program, often crumble under political resistance. Forest users in Nepal are widely interested in generating diverse benefits from their forests, including non-commercial products and services, suggesting a mandate for multipurpose management. We present a decentralized adaptive modality of multipurpose management featuring a silviculture that more closely matches the ecology of forests.

Keywords: multipurpose management; ecological silviculture; Scientific Forest Management; silviculture; Nepal; timber management; forest protection; public forests

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1. Introduction

Despite the widespread demand for a multitude of forest products and services [1–4], both the discourse and practice of public forest management, in modern history, have largely gravitated towards two problematic extreme positions. At one extreme is an approach that uses public forests to produce a single crop, usually timber. This outlook often animates conflicts over land uses [5,6] and can degrade a variety of attributes of the forest resource, regardless of whether it involves destructive resource use [7,8] or careful silvicultural planning to produce sustained yields [9,10]. At the other extreme lies a strict protection-oriented stance that excludes almost all human uses of public forests other than recreation, often to the detriment of a variety of ecological attributes dependent upon disturbance [11,12]. The blanket application of this approach disenfranchises forest-dependent communities and disregards their heritages of multifaceted indigenous silviculture [13,14]. This outlook often conflates all forms of tree-felling with forest degradation, negating the utility of active silvicultural treatments for restoration and regeneration [15,16].

Deviations from these extreme approaches began to appear as early as the beginnings of timber-centric scientific forestry [17] and protectionist environmentalism [18] in colonial times. Since at least the middle of the 20th century, high-income nations have had large-scale implementations of novel management approaches in their public lands [19–21]. These include 'multipurpose management' to address multiple socioeconomic objectives [21–24] as well as 'ecosystem management' [25] and, subsequently, 'ecological forestry' to actively engineer complex, resilient and productive ecosystems [15]. Yet, barring some exceptions [26], the discourse and practice of public forest management, in much of the Global South, still largely oscillates between the dichotomy of single-crop production and strict protection [27,28]. This has been the case despite the prominence of movements to decentralize management back to local communities that depend on forests for multiple resources [29,30].

Nepal, heralded for the implementation of community forestry across much of its public forests [31,32], provides an illustrative example of a nation confined to these antiquated extreme approaches. The discourse on public forest management in Nepal has been reenergized by the dissolution of 'Scientific Forest Management (ScFM)'—a government project to increase domestic timber production. However, the narrowness of the current debate exposes the persistence of the historical tendency to dichotomize forest management into the extremes of timber production and passive forest protection. In this article, we chart the historical course of these extreme approaches to managing Nepal's public forests, uncovering ecological consequences and impacts on the development of indigenous and professional silviculture. We then demonstrate a public mandate for multipurpose management in the managed forests of Nepal and elaborate on how its implementation in Nepal can avoid the short-comings of prior management regimes through effective decentralization, adaptive management and silviculture informed by the ecology of natural forests.

2. Methods

We synthesize together publications, policy documents and reports, with insights from field observations, household surveys and focused group discussions produced by the 'Enhancing livelihoods from improved forest management in Nepal (EnLiFT)' project. Since 2013, EnLiFT has been working with multiple community-forest user groups and local farmers to establish silvicultural demonstration harvests, to promote local agroforestry practices and forest-based enterprises and to institutionalize novel community-based forest planning and governance frameworks within the new local government system. We also present diagrams to help readers visualize the chronology of public forest management in Nepal (Figure 1) as well the described modality of multipurpose management at the levels of both the forest stand (Figure 2) and local landscape (Figure 3).

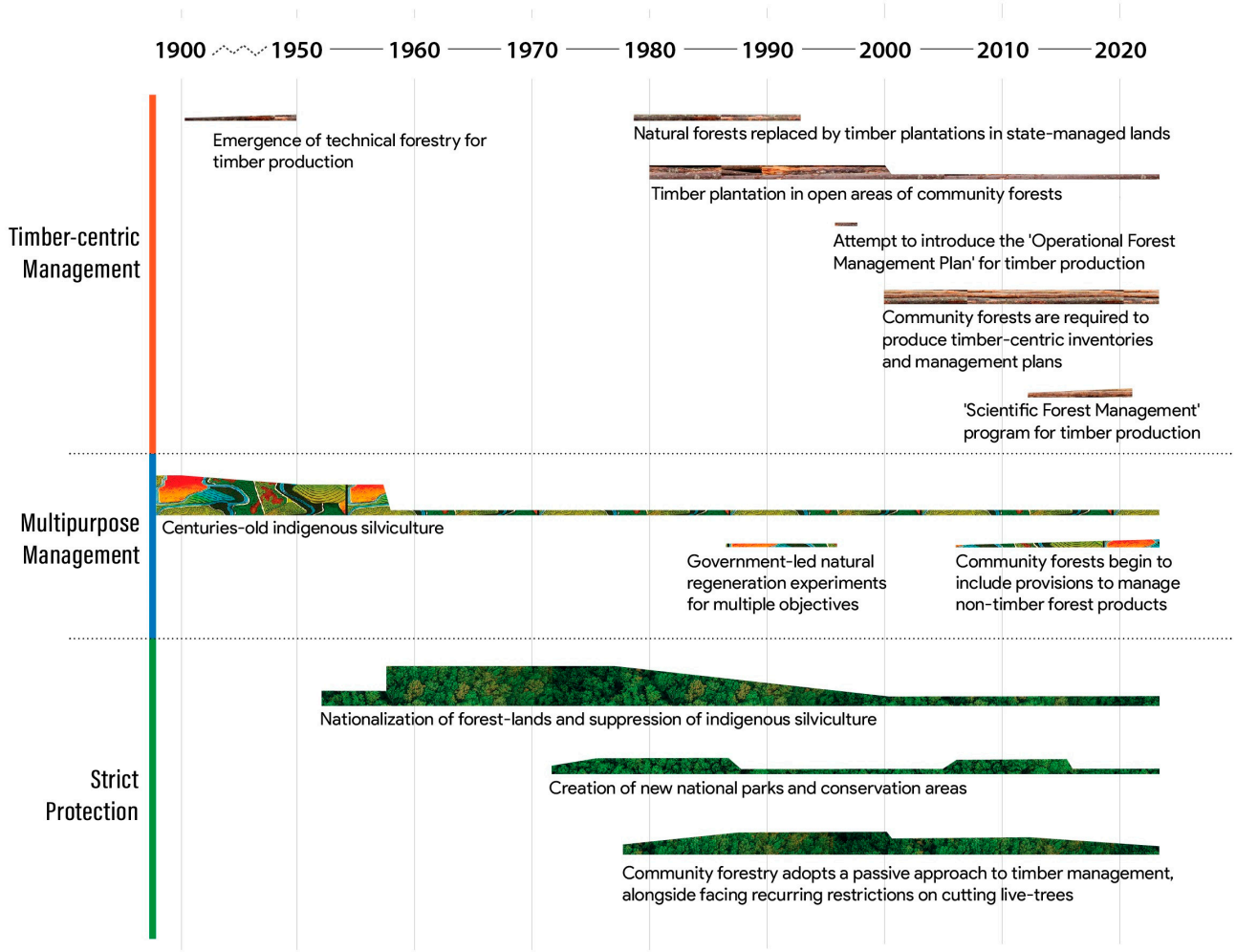

Figure 1. A historical timeline depicting the major events and outlooks prevalent in public forest management in Nepal. The width of the bars shows the relative spatial area across which an activity or approach was implemented.

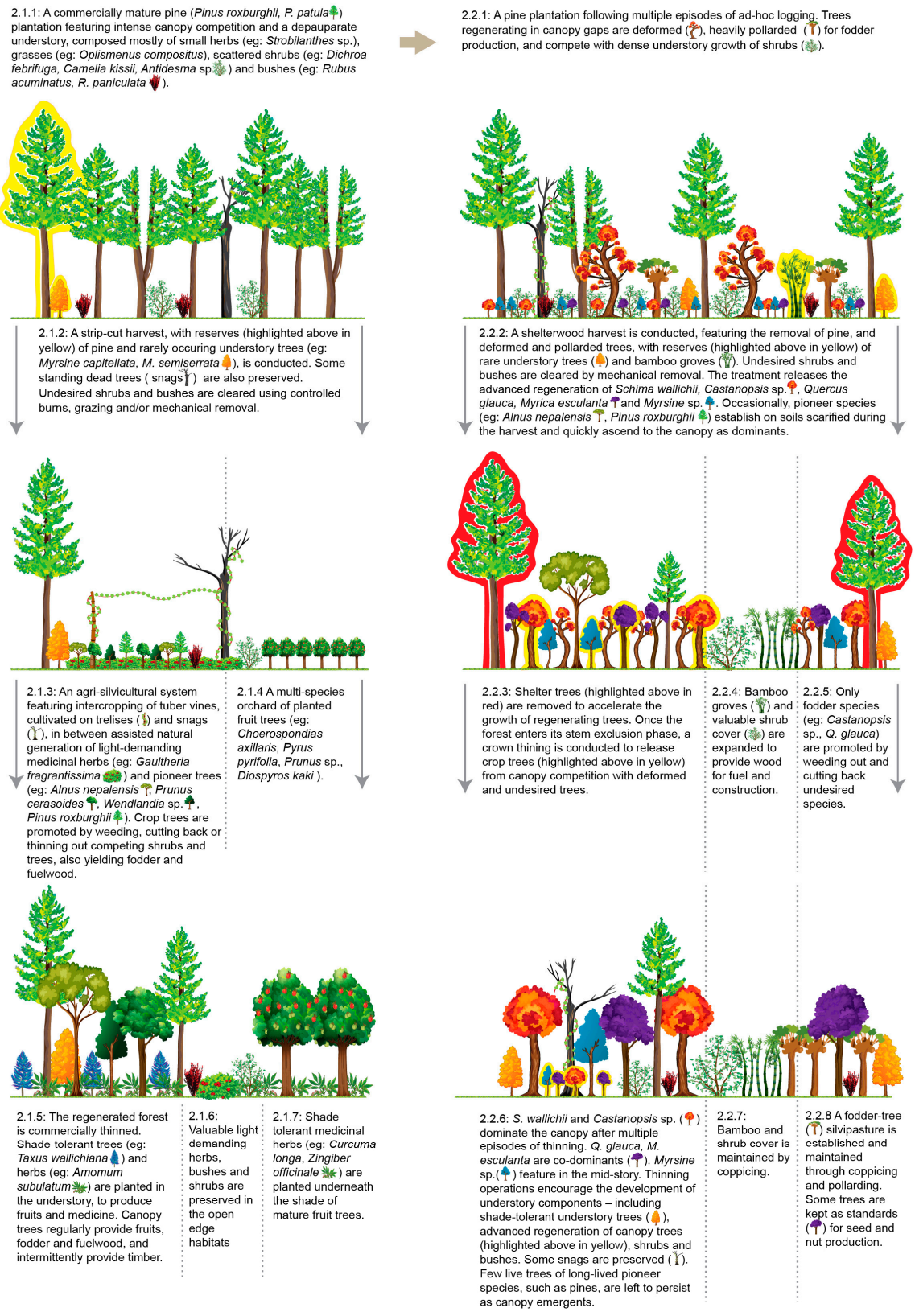

Figure 2. Pathways to convert pine plantations to natural broadleaf forests and agroforestry systems managed for multiple purposes. Silvicultural treatments and species mentioned are based on field work in mid-hill pine plantations adjacent to natural *Schima-Castanopsis* forests in Kavrepalanchowk and Sindhupalchwok districts.

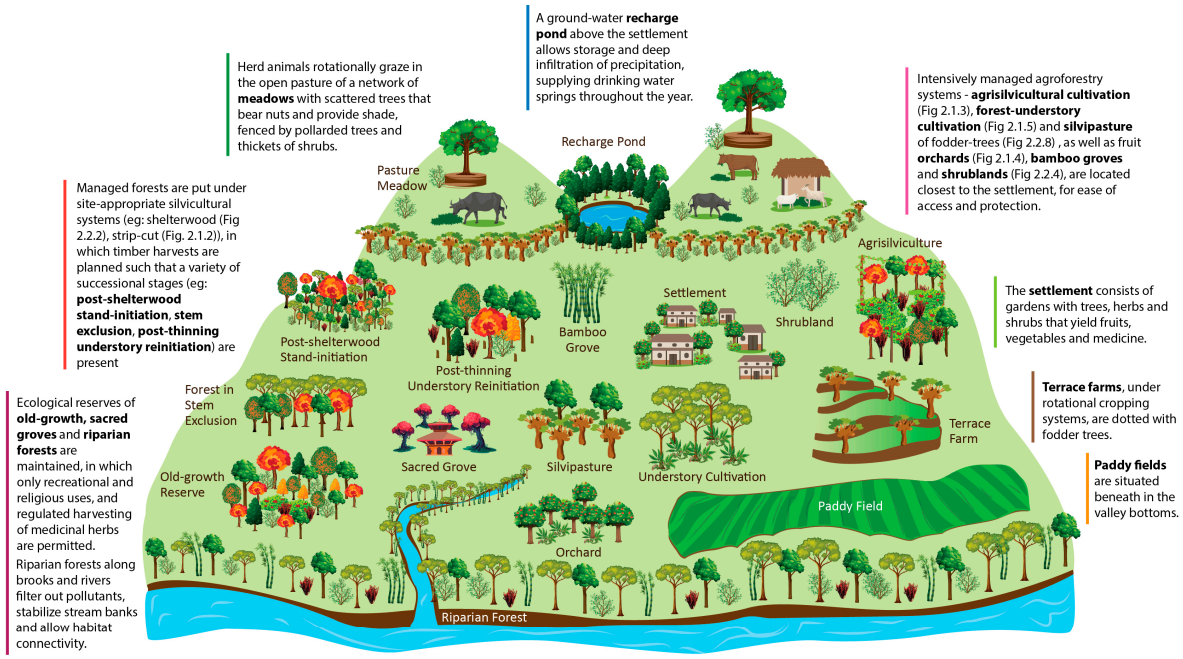

Figure 3. A schematic diagram of multipurpose management in an agrarian landscape in hilly Nepal, incorporating indigenous and local knowledge with ecological principles of land use.

3. Decline of Indigenous Silviculture

Up till the mid-20th century, most forests in Nepal were managed by village communities [33–35] using iteratively refined indigenous silvicultural practices to regenerate, protect and utilize multiple forest resources, such as fuel, fodder, medicine, food and timber [36]. In formal terms, indigenous silviculture prominently featured swidden cultivation (alternatively: shifting agriculture; locally: khoriya-kheti) [37,38] and various silvipastoral [39,40] and coppice systems [36].

The Rana premiership gradually developed a centralized forest governance structure over the late 19th century, as Sal (*Shorea robusta* Gaertn.) timber became a lucrative commodity exported to British India [41]. Eventually, in the early 20th century, Nepal invited officers from the British Indian Forest Service to introduce technical forestry and to create a forest service to manage and sell timber resources [42–44]. Despite British India's efforts to institutionalize forest governance and silvicultural planning, destructive logging practices continued to degrade much of the productive lowland forests of Nepal [45]. The Rana regime also encouraged forest clearance for agricultural expansion to increase its tax revenues, among other reasons [46].

Soon after the regime collapsed, the new state nationalized, at first, some, and eventually all of Nepal's private and communal forests in the 1950s [41], citing the need to preserve dwindling resources [46]. The nationalization of forestlands alienated village communities from forest management and native governance structures and their associated silvicultural knowledge and practices deteriorated [45,47,48]. The state also actively suppressed indigenous silviculture after environmental experts from foreign-aid agencies attributed environmental degradation to peasant practices, such as swidden forestry [47,49] and rotational and migratory silvipastoralism [39,50]. Swidden forestry was virtually uprooted from Nepal [51] without much academic exploration of its silvicultural particularities and influence on forest composition and characteristics. Today, it is widely acknowledged as a complex form of locally adapted successional agri-silviculture featuring the optimal management of soil fertility and growing space [52]. Over the latter half of the 20th century, foreign experts also facilitated the creation of multiple strictly protected areas in which local inhabitants' traditional access to forest resources was severely restricted, if they were not displaced entirely [53].

4. Prevalence of Protectionism

Unable to curb clandestine logging in the newly nationalized forests by itself and facing a new foreign-aid mandate to decentralize resource control [47], the state progressively brought local communities back into public forest management, starting in 1978 [54,55]. In the following decades, the government and foreign-aid agencies facilitated communities in establishing timber plantations, mostly of fast-growing native and exotic pines, in open landscapes [56] considered barren or degraded, even though some were actually productive pasture ecosystems [39,50]. Plantations and natural forests were then protected by communities through the regulation of wildlife hunting, forest fires, grazing and encroachment [57,58].

Conservation campaigns promoted a 'passive', 'protection-oriented' outlook that deprioritized timber management in favor of forest canopy cover expansion and retention, even in timber plantations [59,60]. For example, under activist and media pressure, the state instated recurring nation-wide bans on the felling of live trees [61] and regularly issued directives limiting timber extraction to dead and defective trees [62]. In certain cases, communities themselves avoided cutting live trees, in fear that the encouragement of timber harvesting could escalate degradation or result in total deforestation [63,64]. With harvests of canopy trees suppressed until the early 2000s, timber management remained limited to the non-commercial thinning of poles, pruning, singling of coppices, cleaning of undesirable regeneration, removal of deadwood and exclusion of fire and grazing [63,65,66]. As plantations became overstocked with merchantable timber, the availability of non-wood products declined [59] and communities heavily relied on natural forests to provide leaf litter, fodder, fruits and medicinal plant-parts [67–69]. Pine plantations also became associated with the desiccation of water springs [70], though no study conclusively isolated the actual causes.

5. Efforts for Active Management

The push-back against protectionist thinking in public forest management began as far back as the late 1970s. In the most extreme of approaches, the forest administration replaced vast swathes of natural state-managed lowland forests with timber plantations, often featuring exotic species [71,72]. Nonetheless, the government also tested multipurpose approaches in some community forests and state-managed lands (i) to demonstrate the use of natural regeneration-based timber harvests to convert pine plantations to broad-leaf forests [73], (ii) to study the establishment and growth of seedlings in natural forests following natural regeneration harvests [74] and (iii) to explore the potential to develop different silvicultural systems to produce fuelwood, fodder and timber [75–78]. Eventually, in 1996, with foreign-aid support, the government devised the 'Operational Forest Management Plan' program to produce timber in several lowland Sal forests using natural regeneration. However, this project was thwarted by resistant local communities and civil society networks, who were concerned by the program's lack of local consultation, prohibitively technical prescriptions [79] and the involvement of a private foreign company [80].

A nation-wide shift towards active timber management finally occurred in the early 2000s, when community forests were required to produce inventory-based management plans. The mandated introduction of technical planning, overseen by government officials, marked the beginning of a long process of the recentralisation of community forestry. Management prescriptions were solely concerned with timber production until the late 2000s, when provisions for other forest products grew in popularity (though active canopy management for the production of non-timber resources was not encouraged) [60,81]. Prescriptions were often identical across forests, irrespective of prevalent dynamics and community objectives [81].

However, long-term silvicultural planning for forest resource production and regeneration remained absent from discourse and practice through the 2000s and early 2010s. Both indigenous practices and novel silvicultural innovations were precluded by the persistence of recurring moratoriums on the felling of healthy merchantable trees [82,83].

Further, technicians often arbitrarily restricted harvest allowance volumes to avoid attracting sensational media coverage and legal oversight [61,67,84–86]. Consequently, besides the removal of dead and defective trees [82,83], timber harvests were largely limited to light-handed thinnings, which did not even meet the intensity of the administration's own guidelines [87].

Thinning operations reportedly increased forest productivity [88,89], structural complexity [87] and coverage [90] along with the diversity of the understory and regenerating vegetation [91]. However, where communities heavily favored only economically valuable timber species, thinnings resulted in the mono-dominance of a single species at the cost of excluding other sub-canopy and canopy species [57,59,87,90,92,93] and reducing the availability of non-timber resources [86]. Meanwhile, researchers and managers completely overlooked the consequences of repeatedly and pervasively removing dead and defective trees, despite their important role in the ecological functioning of native forests, and in silvicultural and conservation planning (see Appendix A for details) [94–97]. In the occasional harvests of mature well-formed trees, technicians either arbitrarily (ad hoc) chose few trees for harvesting [98] or selectively logged out some of the most merchantable trees [59,85,93,99]. Both of these low-intensity operations opened up small poorly-planned canopy gaps in the forest, which at first stimulated a range of plants to germinate and resprout [100] but eventually excluded the regeneration of shade-intolerant and drought-competitive species which require more light to grow after establishment [101] (see Appendix B for details).

6. Scientific Forest Management

6.1. Origins

Following decades of restricted felling and rudimentary harvest planning, both plantations and natural secondary forests suffered from intense canopy competition, which led to the stagnation of growth, wasted timber resources [64,65,92] and suppressed the establishment of an understory that could provide non-timber products [66,90,91]. The forest administration, forest users and academics increasingly came to the consensus that this passive management approach had failed to efficiently generate forest products and benefit communities [32,65,67,88,92,102–105] and the national economy [60,103,106,107].

In response, the government devised a new program, 'Scientific Forest Management (ScFM)', described as "an application of appropriate silviculture systems and forest management principles through design of systematic compartments of fixed rotation age" [108,109]. Following a pilot implementation in 2012 [108], a guideline was issued in 2014 [110] featuring instructions for a high-intensity 'irregular shelterwood' silviculture system, explicitly developed to regenerate lowland Sal forests for timber production. Regulatory procedures for harvest planning and implementation were cumbersome and demanded the intensive use of equipment and human resources (foresters and loggers) [108,111]. However, technicians took liberties that helped accelerate the expansion of ScFM. Management prescriptions were near identical to one another, irrespective of forest type, terrain and community objectives, because technicians only referred to the singular shelterwood guideline produced by ScFM [83,108]. There were legitimate concerns that the indiscriminate nation-wide application of intensive shelterwoods, whose regeneration studies revealed very low species diversity [112], would result in the loss of unique forest flora and the provisioning of non-timber products and ecosystem services, such as soil and water conservation [113–115]. However, during the actual implementation, technicians often arbitrarily deviated from the guideline, by halving the intensity of the prescribed harvest [116] or instructing communities to establish intensive plantations on harvested sites [117], sometimes replacing native natural regeneration with exotic species [118]. ScFM also inherited, from the prior management paradigm, the poor practice of dividing the forest into largely geometric blocks and compartments for management [116], instead of delineating forest stands on the basis of prevalent biophysical features and social circumstances [119].

6.2. Reception

The most prominent positive achievement of ScFM was its reintroduction of silviculture into Nepal's discourse on public forest management, culminating in the first ever national workshop on silviculture [120]. The government also successfully demonstrated that high-intensity silvicultural harvests could establish natural Sal regeneration across the Terai lowlands [112,121,122], in spite of bureaucratic hesitancy to cut live trees and uninformed reporters and conservationists mischaracterizing the shelterwood regeneration method as deforestation [123]. Users of some Sal forests even welcomed and appreciated ScFM's timber-centric agenda, since the large annual timber output of the shelterwoods [107,124,125] generated more income and employment opportunities compared to previous harvesting regimes [121,122,124,126].

However, the ScFM program was mired in irregularities that brought it under increasing state and public scrutiny, sparking years of protest by the Federation of Community Forest Users—Nepal (FECOFUN) [127] and local community resistance [113]. Allegations included the coercion of communities [123,127] and fabrication of consent through forged signatures [128], collusion among forest officials, the local elite and timber contractors [129,130] and a lack of meaningful local participation and access to timber-products [131] and income from timber-sales [111,121,125]. Eventually, the program faced unprecedented public exposure once reports surfaced that COVID-19 lockdowns were being used to illegally clear Sal forests at ScFM implementation sites [132]. The cabinet terminated ScFM in January 2021 [133] after multiple official investigations [134,135] (i) cited irregularities [123,129], (ii) criticized the program's recentralizing tendency and redundancy [123] in light of existing legal provisions that already enabled silviculture-based management [136] and (iii) questioned its legal standing [130].

6.3. Discourse on Sustainability and Silviculture

Critics of ScFM reasonably argued that the program was unsustainable because it failed to consider ecological sensitivities, foster democratic dialogue among stakeholders and promote local participation and enterprises [137]. They associated ScFM's socially and ecologically unconscious timber-centric approach with the global history of 'scientific forestry' programs, through which state bureaucracies still establish order and control over forestland, often alienating forest-dependent communities [138,139]. Many activists, protesting against ScFM, also vilified the entire concept of silviculture-based management as being colonial, extractive and unsustainable [123]. However, silviculture—the science and art of growing and tending to forests—is not exclusively the legacy of colonial and post-colonial 'scientific forestry'. Indigenous silviculturists have engineered forests to produce fuelwood, fruits, gum and fodder in Nepal and around the world for thousands of years [140,141]. When 'scientific forestry' emerged in 18th century Germany, it formally codified a set of silvicultural practices to produce sustained yields of timber and address the depletion of timber and water resources [139], providing a founding narrative for the entire concept of 'sustainable development' of the United Nations in 1987 [142]. Today, silviculture has become a useful tool applied across different management scenarios, including urban forestry, the promotion of ecological complexity and the creation of wildlife habitats [119].

Some critics of ScFM even demanded a reversion to the ad hoc and selective logging regimes that they deemed sustainable for their modest harvest volumes [123]. However, pervasively implementing modest logging regimes may stifle desired forest regeneration and may not even protect biological diversity because high-severity canopy disturbances are required to promote early successional ecosystems [143–146]. The single-minded insistence on low-intensity regimes is often based on the idealization of an unmanaged wilderness with no human impact, which is in itself largely erroneous and antiquated, even if still globally popular [8,147]. Even the 'wildest' of forests, such as in the Amazon and Borneo, have had their diversity and structural complexity significantly enhanced by both intensive and subtle anthropogenic interventions, leading eminent foresters to reasonably argue that we are living in a world where people have been 'managing the

wild' for thousands of years [148,149]. The concept of a true 'wild' is even more untenable in countries like Nepal, where hundreds of mobile ethnic groups have pursued diverse forest-based livelihoods for centuries [150] and play an outsized role in determining forest dynamics and composition [151].

7. Multipurpose Forest Management

Prior governance approaches promoting singular management objectives in Nepal not only had adverse ecological impacts and suppressed indigenous and professional silviculture but also misread or disregarded the actual interests of forest-dependent communities. Most often, community forest users are actually interested in fulfilling diverse non-commercial objectives and generating multiple outcomes from forest management, including the production of fuelwood, fodder, mulch, fruits and medicinal plants, besides timber [87,152]. In fact, in some areas, people's reliance and engagement with communal forests have actually declined in recent years, since their diverse needs are not met by prevalent management regimes [152]. Communities are much more likely to assume responsible stewardship of forest resources if their multiple interests are addressed through a multipurpose forest management approach [152].

Multipurpose management, alternatively called multiple-use [153,154], multifunctional [24] and integrated forest management [155–157], refers to the management of forest land for more than one purpose, such as the production of wood, fruits, resin and medicine, water source protection, biodiversity promotion and human recreation. To some extent, native communities have persisted with multipurpose management for fuel, fodder, food and medicine, even if official management plans focus on singular objectives [87,141,158]. In the professional forestry world, formal multipurpose management frameworks have been implemented to complement industrial timber forestry with the generation of non-timber forest products, watershed management and the creation of therapeutic landscapes for stress relief [153,159].

Multipurpose management can be accomplished through the use of one or a combination of the following approaches [154]: (i) simultaneous production of various services and goods in a single forest stand (such as timber, fruit, fiber and medicine in Figure 2 (2.2.6)); (ii) rotational and successive production of different resources in the same stand (such as the gradual replacement of tuber and herb production in Figure 2 (2.1.3) by timber production and understory farming in Figure 2 (2.1.5)); and (iii) geographic segregation of uses across a mosaic of stands in the same landscape (such as exclusive fruit production in Figure 2 (2.1.4) and exclusive forage production in Figure 2 (2.2.8)).

Following the collapse of ScFM, new efforts are underway to create a national standard for sustainable forest management in managed public forests, which is expected to promote multipurpose management, local decision making and indigenous practices (*field notes*). Based on these developments, we introduce a modality of multipurpose management, designed to avoid the social and ecological consequences of prior regimes through (i) effective decentralization, (ii) adaptive management and (iii) silvicultural applications of the ecological principles of forest stand dynamics.

7.1. Effective Decentralisation

Community-based management in Nepal has been recentralized by technocratic control over harvest planning and the requirements for technical inventories and management plans which do not address the community's varied interests [82,83,140,160]. Formal inventories are often redundant where many forest-dependent communities already spend a significant amount of time regularly learning about their forest's condition and resource base [140]. Communities act on this local knowledge by adapting poorly designed technocratic prescriptions to sustainably produce multiple forest products [82,160]. These government requirements can be simplified and, in smaller forests with modest subsistence uses, even eliminated, allowing local forest users to determine the nature and intensity of land uses and silvicultural manipulation based on shared knowledge of site productivity,

harvest regulation and ecology [87]. However, foresters, ecologists and project developers may have to help interested communities develop novel technologies for new pursuits, such as ecotourism (*field notes*), while inspiring and empowering communities with deteriorated native management frameworks [57] to reengage in forest management and pursue the greatest diversity of forest uses.

7.2. Adaptive Management

In a country like Nepal where natural forest stand dynamics are poorly understood and management interests vary widely, the pursuit of sustainable multipurpose management requires an 'adaptive' style of silvicultural design and implementation [161]. Adaptive silviculture and management acknowledge that "the understanding of forest dynamics and the development of silvicultural systems should be continually evolving processes" [161] as opposed to the rigid adherence to technical guidelines. The forest manager must continually analyze the "details of tree structure and physiology, soils, climate, natural disturbances, and human use" of their particular forest, instead of relying on broad ecological generalities [161]. This involves three steps: (i) applying silviculture treatments using current knowledge and monitoring effects on the forest; (ii) updating assumptions and adapting silvicultural planning based on new knowledge obtained from monitoring; and (iii) documenting the planning, implementation and results of a prescription. Managers can then devise and continuously adapt the harvest pattern and volume calculations required to guide the forest to a deliberatively planned condition [162]. Since adaptive management demands intimacy with the particular forest to be managed, it favors the devolution of decision-making power to forest-dependent local communities and encourages the incorporation of their ethnoecological knowledge and practices into silvicultural planning [163].

7.3. Ecological Principles of Forest Stand Dynamics: Stand- and Landscape-Level Practices

In community forests in Nepal, the pursuit of multiple objectives together, such as environmental protection and the generation of a range of forest products, can be complementary to one another [102]. Since such forests feature the simultaneous or successive growth of multiple plant species, they also tend to display greater species diversity [93]. Elsewhere, forests managed for multiple values also had greater diversity of species traits (functional diversity) [164] and were structurally more complex [165], potentially because all vertical strata were put into productive use. The promotion of ecological complexity, through an increase in taxonomic, functional and structural diversity, can increase ecosystem function and make forests more adaptive and resilient to catastrophes and chronic disturbances [119,166–168], including global changes [169]. Nonetheless, in the absence of a proper orientation, there is always a risk that multipurpose management may devolve into extractive multi-crop production and potentially lead to a decline in complexity, health and resilience. This concern can be addressed by closer silvicultural adherence to a variety of ecological principles under the sub-discipline of forest stand dynamics. In North America, some academics and practitioners have coined the term 'ecological forestry' [170]. They preach the practice of 'ecological silviculture' and define their management recommendations and practices as emulating a range of functions, processes, dynamics, compositions and structures, observed in complex natural ecosystems, that represent all stages of forest succession [15]. This framework has been largely associated with relatively remote, expansive native public forests managed primarily for timber by federal and state-level bureaucracies but with little demand for high resource production [19]. Nonetheless, even the partial adoption of ecological forestry can potentially increase the vitality and integrity of relatively more intensively managed multipurpose production forests [171].

Ecological principles that can be used to more closely emulate native forest stand dynamics when practicing silviculture include: (i) allowing the accumulated structure, function and biotic community of a forest to **continue persisting** after a regeneration harvest through the retention of live old trees, productive seed sources, snags (standing dead trees),

trees with large cavities and coarse woody debris (Figure 2 (2.1.2) and Figure 2 (2.2.6)); (ii) sustaining and promoting compositional and structural **complexity**, biological diversity and spatiotemporal heterogeneity at the scale of the individual stand (Figure 2 (2.2.6)) as well as the entire forest by maintaining the whole array of cover-types and successional stages (Figure 3); (iii) applying treatments at ecologically appropriate **timescales** which allow the development of the structural, compositional and functional complexity in forests; and (iv) managing forests in the **context** of objectives and land uses prevalent at the larger spatial scale of the landscape [15,170–172].

To elaborate on the last principle, landscape-level ecological planning of forests often includes two different concepts. The first is 'functional zoning', which reconciles ecological and socioeconomic goals by adopting the multipurpose forestry approach of spatially segregating a forest landscape into zones that produce different sets of goods and services (i.e., functions) [173]. An example of functional zoning, useful to large community-managed forest landscapes, is the 'landscape triad' approach featuring a mosaic of three land-use designations: (i) areas allocated towards intensive commodity production, (ii) a connected network of protected ecological reserves of rare old-growth forests, sacred groves and hydrological structures, such as streams and swamps (Figure 3), and (iii) areas managed for both ecological complexity and modest resource production [173]. Functional zoning can increase the resilience of a landscape to withstand disturbances, such as insect outbreaks or climatic shifts, while ensuring the sustainable long-term production of desired goods and services [174].

The other concept, 'integrated landscape management', refers to the identification and utilization of hydro-ecological linkages and synergies among forest ecosystems, agroecosystems, pastoral ecosystems and aquatic ecosystems, nested in the same landscape (Figure 3) [175]. This concept has only recently gained traction among professional circles [176] because modern chemical-based agriculture has significantly divorced agricultural planning from other land uses [177]. However, many rural communities in Nepal, for centuries, have been synergizing matrixes of farms and forests with patches of settlements, wetlands, shrubland and open meadows, and corridors of riparian forests, streams and roads (Figure 3) (*field notes*). Nonetheless, forest-level and landscape-level elements of ecological silviculture may be impracticable when community forests face intensive socioeconomic demands or are small and embedded in landscapes that communities do not entirely control. There is an opportunity to manage landscapes through cooperation, such as by allocating state-managed lands, adjacent to intensively managed community forests, as the ecological reserves in the landscape. However, formal landscape-level planning in Nepal, in particular watershed management, has been marred by a lack of meaningful dialogue and engagement among concerned stakeholders [178].

8. Challenges Ahead

8.1. Research on Silviculture and Forest Stand Dynamics

Scholarly advancements in the understanding of forest stand dynamics have facilitated the development of silviculture in natural mixed-species stands in many high-income nations [161]. Academics and forest-managers, in developing nations, such as Nepal, must also invest an unprecedented effort in training silviculturists and studying diverse natural forests in order to gain localized understanding of forest dynamics. Such studies would include longitudinal observations and analysis of vegetation responses to disturbances in chronosequences [179,180], experimental canopy openings [181] and harvests [182], as well as tracing the ontogenetic history of forest trees by conducting stem and crown analyses [183] and learning from ethnoecological traditions [141]. The demonstration of the utility of silvicultural harvests, by successfully producing desired forest conditions and multiple resources via experimentation, would also publicly dispel the stigma around cutting live trees.

One approach to developing appropriate technologies required to establish multipurpose management, featuring both indigenous practices and modern silvicultural

innovations, is through the aforementioned 'EnLiFT' project's approach of iterative 'collaborative action research' involving forest users and professional foresters [87,104]. Instead of promoting a particular silvicultural regime, it has brought together forest users, professional foresters and researchers to jointly develop and implement silvicultural systems that respond to the needs and capacities of the forest users through Active and Equitable Forest Management (AEFM). It is 'active' in that forest dynamics are consciously directed towards specific ecological states as opposed to a 'reactive' ad hoc management guided by prevailing commercial and regulatory constraints. It is 'equitable' in that all stakeholders, from all groups within the local community through to various layers of government, are recognized as deserving access to forest resources. Both active and equitable drivers inevitably create multipurpose forests.

8.2. Complexities Introduced by Carbon and Climate Mitigation

The fate of the embryonic global movement of multipurpose management will be undoubtedly influenced by its interaction with the United Nation's ongoing supranational environmental governance scheme, known as REDD+, which plays a leading role in the current discourse and practice of public forest management [184,185]. REDD+'s focus on protecting and increasing forest carbon could either promote or stifle the establishment of multipurpose management, depending on governance approaches, site conditions and local management objectives [186]. In Nepal, the forest administration has planned to impose a protectionist approach to carbon sequestration and forest emission reduction through the restriction of forest grazing and fuelwood harvesting by local communities [187]. As Nepal has already committed to sell its forest carbon through the REDD+ program [188], there is a concern that the pendulum of public forest management may swing from ScFM's timber-centric focus back to strict protectionism, instead of landing on multipurpose management.

9. Conclusions

Public forest management may perpetually swing between extremes unless it is challenged by the widespread communication and collaborative demonstration of the socioecological benefits of multipurpose management. A radical transformation in forest planning and management to a multipurpose modality calls for advocacy, training and long-term experimental demonstrations on multipurpose silvicultural systems and governance approaches, as well as collaborative research into natural forest dynamics. These experimental models can serve as references for policy makers, technicians and forest users to construct appropriate institutional networks and design their own set of silvicultural treatments. In order to avoid multipurpose management from derailing into multi-crop production and degrading forest ecosystems, professionals and rights networks will also have to promote adaptive management and silviculture within an ecological framework, while encouraging the revival of sustainable ethnoecological practices.

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Appendix A. Retention of Dead, Decaying and Deformed Wood

Thinning out deformed and dying trees that are slowing the growth of competitive trees can increase forest productivity [119], while removing diseased trees can sanitize forests plagued by infectious diseases and pests [119]. However, the partial retention of coarse woody debris from fallen and dying trees as well standing dead and decaying wood is important for the ecological functioning of native forests, particularly those growing on marginal soils, as well as for silvicultural and conservation planning [94–96]. In fact, their presence is commonly used as an indicator of forest health and resilience [97]. The mid- and ground-stories of forests are often mostly composed of deformed unmerchantable trees, and some rare upper canopy species may also be locally represented only by deformed and decaying trees. A harvest regime focused on removing these trees can reduce species diversity [9] and structural complexity, affecting the movement of seed-dispersing animals and eliminating habitat for wildlife that depend on the cover of lower-strata trees [189]. Similarly, fallen decaying logs may be crucial for regeneration management, as they are often the only microsites in which some tree species can competitively establish and grow [190–192]. Dead and dying wood also provide growing substrates for vines, fungi, lichen and bryophytes [193,194]; predatory birds nest and perch on standing defoliated trees; and cavities in decaying trees and logs sustain and shelter small birds and seed-dispersing mammals [195]. In some instances, astutely retaining dying, deformed or decaying trees can actually protect the vigor and quality of neighboring healthy trees. For example, the retention of overtopped deformed trees prevents the boles of adjacent well-formed canopy trees from being exposed to sunlight after canopy harvest operations, discouraging the sprouting of epicormic branches that can decrease timber quality [196].

Appendix B. Ad hoc Harvesting and Selective Logging

Some technicians and academics erroneously referred to both arbitrary (ad hoc) and low-intensity selective logging as 'selection-felling' [84] because they removed light volumes of timber and created cool partially shaded canopy gaps like those in single-tree selection silviculture. However, these harvests were neither planned to maintain an even distribution of all age classes of trees in the forest nor to deliberatively target the regeneration of shade-tolerant species, as is typical in actual single-tree selection silviculture [119]. Though selective logging is a globally common practice in which trees larger than a certain diameter are cut [197,198], it has little basis in forest dynamics and regeneration ecology, unlike actual silvicultural treatments. 'Selective logging' is actually criticized by professional silviculturists as an ecologically and often economically detrimental practice [119] that degrades a forest's resource base by singularly focusing on the immediate extraction of the largest and most valuable timber trees [7]. Outside Nepal, recurring episodes of selective logging have left forest canopies with only depauperate trees likely to produce fewer seedlings lacking in genetic diversity [199,200] and have inadvertently shifted the canopy to a more shade-tolerant tree composition [201]. The isolated effects of 'ad hoc' harvesting and selective logging within Nepal are not well-known because observational studies often clump their effects with each other and with those of lopping, weeding and livestock grazing [90,202–205]. In the worst cases, the creations of these gaps, in the absence of regeneration management, may have encouraged invasion by undesired shrubs and vines, such as the fire-tolerant invasives *Chromolaena odorata* (L.) R.M.King & H.Rob. and *Mikania micrantha* Kunth [206–208], that arrest forest succession by usurping the growing space of the ground story.

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