Interconnectedness in Socio technical Design: A Systematic Review of Sustainable Community Forests Management in Nepal.

Abstract

Nepal's community forestry is a globally recognized model of participatory forest management, yet it faces persistent challenges related to knowledge asymmetries, multi-level governance fragmentation, institutional bricolage, and socio-ecological transformations. This systematic literature review synthesizes evidence from 36 peer-reviewed studies to examine how interconnectedness has been conceptualized in Nepal's community forest governance and to assess the potential of a sociotechnical design lens for improving sustainability outcomes. The review followed PRISMA guidelines, searching Scopus, Web of Science, Google Scholar, and CAB Abstracts. Thematic synthesis revealed four interconnected dimensions: knowledge–power dynamics (scientific forestry marginalizing local knowledge), multi-level governance networks (weak coordination post-federalisation), institutional bricolage (mixing, altering, or eroding formal and informal rules), and socio-ecological linkages (out-migration and human-wildlife conflict destabilizing forest–livelihood relations).

Crucially, none of the studies explicitly applied a sociotechnical design frameworktreating technical and social subsystems as jointly optimizablerepresenting a critical gap. The review concludes that technical interventions (e.g., forest inventories, monitoring tools) fail when designed in isolation from local social capacities and power structures. The single recommendation is that Nepal's Ministry of Forests and Environment mandate a sociotechnical co-design process for all community forest management plans, requiring every technical specification to be developed jointly with CFUG members through facilitated, equity-sensitive workshops, piloted in 20 CFUGs, and codified into revised guidelines. Without such integration, sustainability remains elusive.

Keywords: ***Community forestry, Interconnectedness, Sociotechnical design, Nepal, Forest governance.***

Introduction

Forest ecosystems play a central role in sustaining rural livelihoods, regulating climate, preserving biodiversity, and providing a wide range of material and non-material benefits to human societies worldwide (FAO, 2020). Globally, nearly 880 million people harvest fuelwood or make charcoal, and over 1 billion people rely on wild foods (Shackleton et al., 2011). Nepal's community forestry program stands as one of the world's most celebrated examples of participatory forest resource management (Acharya, 2002; Agrawal & Ostrom, 2001). Recognized globally as a pioneer in community-based natural resource governance, Nepal's model has successfully increased forest cover, restored degraded landscapes, promoted local democratic decision-making, and improved rural livelihoods over more than four decades of implementation (Gautam et al., 2004; Paudel et al., 2020).

Despite these achievements, Nepal's community forestry system faces mounting challenges that threaten its long-term sustainability and effectiveness. Rapid socio-economic transformations, including widespread out-migration and changing livelihood patterns, have profoundly altered the relationship between forest-dependent communities and the forests

they manage (Jaquet et al., 2015; Ojha et al., 2017). Since the early 2000s, out-migration of working-age adults from many parts of rural Nepal has led to declining collective action and passive forest management (Adhikari et al., 2019). At the same time, ecological dynamics such as increasing human–wildlife conflicts have emerged as significant threats to both forest conservation and agriculture-based rural livelihoods (Kandel et al., 2016; Thapa & Chapman, 2010). This problem has become particularly acute in mid-hill districts where community forestry programs have successfully restored forest cover alongside massive out-migration, destabilizing the historical coexistence between subsistence communities and local ecosystems (Paudel et al., 2020).

Furthermore, the progressive entrenchment of "scientific forestry" approaches has introduced expert-driven technical management frameworks that often underprivilege local traditional knowledge and weaken community decision-making autonomy (Gautam et al., 2018; Satyal Pravat & Humphreys, 2013). Under scientific forestry, professional and expert knowledge bolstered technical and bureaucratic power among forest authorities, which in turn not only marginalized traditional local knowledge but also undermined local decision-making autonomy in community forestry (Khatri et al., 2017). Research has revealed that community forest management plans are frequently employed as bureaucratic instruments to legitimize expert authority rather than as practical guides that genuinely assist local communities in managing their forests (Rabinowitz et al., 2018). The implementation of scientific forest management schemes has demanded high-level technical skills while simultaneously undermining local participation and autonomy (Paudel et al., 2019).

These interconnected governance, social, ecological, and technical dynamics foreground a critical observation: the sustainable management of community forests in Nepal cannot be understoodor effectively advancedby examining any single dimension in isolation (Ostrom, 2009; Poteete et al., 2010). The challenges and solutions alike lie at the intersection of multiple, mutually constitutive domains: local institutional arrangements, knowledge systems (both traditional and expert), social networks of forest users and government actors, technical tools for forest monitoring and planning, ecological processes, and shifting political-economic contexts (Baral et al., 2018; Ojha et al., 2016). Nepal's forest cover nearly doubled over the last three decades, driven primarily by community forest management and agricultural abandonment (DFRS, 2015), yet the governance outcomes of community forestry often fall short of expectations, raising questions about the effectiveness of existing institutional arrangements and the power dynamics among actors (Banjade et al., 2016).

This recognition has motivated a growing body of scholarship that explicitly adopts an interconnectedness lensa perspective that conceptualizes community forest governance as a multi-dimensional system wherein social, technical, institutional, and ecological elements are intrinsically linked and mutually influencing (Berkes, 2012; McGinnis & Ostrom, 2014). However, despite scattered applications across disciplines, there remains no systematic synthesis of how interconnectedness has been conceptualized, operationalized, and evaluated within the specific context of Nepal's community forestry (Gautam & Rana, 2019). In parallel, the field of sociotechnical designconcerned with the joint optimization of social and technical subsystems within complex organizational and environmental systems (Bostrom & Heinen, 1977; Trist & Bamforth, 1951)has seen limited and fragmented engagement with forest governance in the Global South (Johnson et al., 2021).

This systematic literature review therefore seeks to address two interlocking research objectives. First, it aims to trace and synthesize how the concept of interconnectednessacross its various theoretical registers (social-ecological, institutional, network-based, and

socio-technical)has been employed in studies of Nepal's community forest governance and sustainable management. Second, guided by this synthesis, the review seeks to examine the potential and limitations of sociotechnical design as an integrative framework for analyzing and improving the governance of community forests in Nepal.

Literature Review

Conceptual Foundations: Interconnectedness in Sociotechnical Systems

The concept of interconnectednessthe recognition that entities, actors, processes, and elements within a system are mutually linked and causally influence one anotherhas gained substantial traction across multiple scholarly traditions. Within sociotechnical systems theory, interconnectedness is not merely an optional analytical lens but a foundational axiom: sociotechnical systems are defined precisely by the entanglement of social and technical components, wherein the behavior of each is inseparable from and co-constitutive with the other (Trist & Bamforth, 1951; Walker et al., 2008). A sociotechnical system is a system that is both an engineered system and a social system, and understanding its performance requires treating both aspects as interdependent parts of a complex whole (Baxter & Sommerville, 2011).

Within sustainability transitions research, there has been a growing emphasis on multi-system innovation frameworks that broaden the conventional focus on single sociotechnical systems to encompass interactions across multiple, coupled systems (Geels, 2019; Markard et al., 2012). The field of sustainability transitions research emerged in the past two decades in the context of growing scientific and public interest in large-scale societal transformation toward sustainability, highlighting sociotechnical and socio-ecological approaches (Köhler et al., 2019). Key insights from this work include the importance of considering the overarching directionality of multiple sociotechnical systems and analyzing system configurations that examine value chains, sectoral characteristics, and interactions between complementary or competing technologies (Raven et al., 2012).

More recently, scholars have called for bringing technology into social-ecological systems research, arguing for a socio-technical-ecological systems (STES) approach that explicitly recognizes the technological mediation of human-environment relationships (Cash et al., 2016; Pahl-Wostl, 2019). Such an approach explicitly recognizes that technical infrastructures, governance arrangements, and ecological processes are co-produced and mutually shapinga perspective that resonates strongly with the complexities of community forest governance in Nepal (Johnson et al., 2021).

Taken together, these conceptual developments suggest that interconnectedness is not a monolithic concept but rather an analytical bridge constructone that connects actor-network perspectives, institutional analysis, social-ecological systems frameworks, and sociotechnical design approaches (Holling, 2001; Ostrom, 2009). In the specific domain of community forest governance, an interconnectedness lens holds particular promise precisely because community forests are quintessential hybrid systems: they involve social institutions (CFUGs, user committees, government agencies), technical elements (forest inventories, mapping tools, monitoring technologies), ecological processes (tree growth, biodiversity dynamics, carbon cycles), and governance arrangements (local rules, legal frameworks,

multi-level state structures) that cannot be meaningfully separated (Agrawal & Gibson, 1999; Nagendra & Ostrom, 2012).

The literature on Nepal's community forest governance reveals that interconnectedness manifests across at least four interrelated analytical dimensions: (1) knowledge and power dynamics, (2) multi-level governance networks, (3) institutional bricolage, and (4) socio-ecological linkages.

Knowledge and Power Dynamics

Perhaps the most extensively documented expression of interconnectedness in Nepal's community forestry literature concerns the tension and interplay between scientific-technical knowledge and local-practical knowledge (Gautam et al., 2018; Satyal Pravat & Humphreys, 2013). A substantial body of research has traced how "scientific forestry"developed originally in the context of industrialized forestry in Western Europetraveled across the globe and became a dominant ideology and approach to forest management, including within Nepal's community forestry system (Khatri et al., 2017; Scott, 1998). Although the concept was formally introduced into Nepal's community forestry system beginning in the early 2000s (GoN, 2014), it fundamentally reshaped management priorities in community forests where local communities had historically managed forests primarily for subsistence livelihoods (Paudel et al., 2019).

Under the regime of scientific forest management (SciFM), professional and expert knowledge gained prominence, bolstering the technical and bureaucratic authority of forest officials while simultaneously underprivileging local traditional knowledge practices and undermining local decision-making autonomy (Karki et al., 2018). Empirical studies have provided granular evidence of this dynamic. A detailed investigation of SciFM plan preparation processes in two community forests in Kaski District found that forest technicians were consistently dominant over community forest users during the planning and decision-making phases (Rabinowitz et al., 2018). Crucially, while CFUGs played a leading role in implementing forest management activities (such as thinning, pruning, and other silvicultural operations), the majority of respondents (90%) considered SciFM to be excessively technical and reported being unable to effectively implement the management plans as designed (Paudel et al., 2019).

Multi-Level Governance Networks

A second analytical dimension of interconnectedness concerns cross-scale and cross-level governance processes. Community forestry in Nepal operates within a multi-level governance landscape that includes local CFUGs, municipal governments, district forest offices, provincial forest authorities, and federal ministries and agencies (Paudel et al., 2019; Shrestha & McManus, 2008). The successor failureof community forestry depends substantially on how actors across these levels interact, mobilizing their respective technical, civic, political, and administrative powers to influence both policy frameworks and on-the-ground practices (Ojha et al., 2016).

Recent research has mapped these multi-scalar processes, revealing how interactions between state and civil society, the interplay between scientific and popular knowledge, the influence of development assistance, decentralization policies, and scalar articulation all shape forest restoration outcomes and local livelihood implications (Adhikari et al., 2019; Banjade et al.,

2016). Nepal's 2015 Constitution marked a shift to federal governance, emphasizing cooperation among federal, provincial, and local levels (GoN, 2015), while the Local Government Operation Act 2017 and Forest Act 2019 outlined local government's collaborative roles in community forest management (GoN, 2019). Emerging tensions between newly established provincial forest authorities and local governments regarding regulatory authority over community forestry have added additional layers of complexity to these governance networks, with policy structures for intergovernmental dispute resolution frequently lacking the technical resources to address complex environmental challenges (Gautam & Rana, 2019).

Institutional Bricolage and Hybrid Governance

A third dimension of interconnectedness in the literature concerns institutional bricolagethe creative and often improvised processes through which local actors aggregate, articulate, alter, or erode institutional elements drawn from diverse sources (customary practices, state law, development project rules, scientific norms) to shape resource appropriation and management outcomes (Cleaver, 2012; de Koning, 2014). Institutional bricolage has gained attention in Global South contexts precisely because it captures the reality that formal institutional designs rarely operate as intended; instead, local actors actively combine, reconstruct, and sometimes subvert institutional components to address their immediate needs and navigate conflicting demands (Cleaver, 2017).

Drawing on two theoretical frameworksInstitutional Bricolage from Critical Institutionalism and Actor-Centered Powerrecent research has advanced the understanding of how actors blend or adapt formal and informal institutions in context-specific, often unplanned ways, while using power features such as coercion and incentives to shape forest governance outcomes (Banjade & Ojha, 2018). Despite extensive literature on Nepal's community forestry, there remains a lack of empirical evidence on how actorsthrough their interests and power resourcesreshape forest management institutions, reflecting a gap between institutional dynamics and actors' influence on forest resource appropriation (Gautam & Rana, 2019).

Socio-ecological Linkages and Emerging Transitions

A fourth dimension of interconnectedness concerns the reciprocal relationships between community actions and forest ecosystem outcomes, particularly in the context of rapid socio-economic and environmental change (Berkes, 2012; Paudel et al., 2020). The interplay between changing everyday dynamics of community forestry and associated socio-economic transformations in Nepal has been profound (Jaquet et al., 2015). Increased out-migration, growing wildlife depredation, NE liberalization of the commons, and the market integration of community economies have swiftly transformed rural communities' mode of economic production toward commercial endeavours and consumerism, thereby underutilizing and idling farmlands and forests (Adhikari et al., 2019; Ojha et al., 2017).

Drawing on historical materialism and conjunctural analysis, recent scholarship has explored how community and forest transitions are shaped by the conjuncture of forces such as out-migration, market interventions, urbanization, consumerism, and the neoliberal restructuring of the rural economy (Paudel et al., 2020). Remittances, decreased farm production, energy use shifts, increased need for cash, climate change, and disasters have resulted in weak collective action, passive forest management, and a shifting perception of forests from resource to risk (Kandel et al., 2016; Thapa & Chapman, 2010).

The problem of human-wildlife conflict has become acute in mid-hill districts where community forestry programs have contributed to restoring forest cover over the past decades (Kandel et al., 2016). In these regions, subsistence farming practices are substantially declining and the trend of abandoning farmlands is increasing (Jaquet et al., 2015). Wildlife invasion into farmlands has emerged as an acute problem in the Himalayas, threatening farm-based livelihood systems of smallholder rural communities (Thapa & Chapman, 2010). The problem is severe in areas where successful forest restoration has been achieved by community forestry programs alongside massive out-migration, creating new conceptual and empirical discourses on conservation, nature-society relations, and human-wildlife interactions as some wild animals have become pests for farming communities (Paudel et al., 2020). Consequently, the historical co-existence and relationships between subsistence communities and local ecosystems have been destabilized (Ojha et al., 2017).

Methodology

This systematic literature review follows the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021) to ensure transparency, reproducibility, and rigor. The review protocol was not pre-registered, but the procedures described below were followed consistently.

Research Questions

The review was guided by the following primary research questions:

1. How has interconnectedness been conceptualised and operationalised in the literature on sustainable forest management in Nepal's community forests?
2. What insights does a sociotechnical design lens offer for understanding and improving governance of Nepal's community forests as socio-technical-ecological systems?

Search Strategy

A systematic search was conducted in four electronic databases: **Scopus**, **Web of Science**, **Google Scholar**, and **Forest Science Database** (CAB Abstracts). The search was performed in March 2026. The search string combined terms related to (a) community forestry in Nepal, (b) interconnectedness or sociotechnical concepts, and (c) governance or management outcomes.

Table 1: Search String Components

Concept	Keywords (Boolean OR)
Context	"Nepal" AND ("community forest*" OR "CFUG*" OR "community based forest management" OR "participatory forest

	management")
Interconnectedness	"interconnected*" OR "sociotechnical" OR "socio-technical" OR "social-ecological" OR "multi-level governance" OR "network*" OR "institutional bricolage" OR "knowledge–power"
Outcome	"sustainable forest management" OR "forest governance" OR "collective action" OR "livelihood*" OR "forest restoration" OR "human–wildlife conflict"

The full search string (adapted for each database) was:

("community forest" OR "CFUG*" OR "community-based forest management") AND Nepal AND (interconnected* OR sociotechnical OR "socio-technical" OR "social-ecological" OR "institutional bricolage") AND (governance OR management OR sustainable)*

Additional records were identified through backward snowballing (reference lists of included articles) and forward citation tracking (using Google Scholar) of key seminal papers (e.g., Agrawal & Ostrom, 2001; Ojha et al., 2016; Paudel et al., 2020).

Inclusion and Exclusion Criteria

Studies were considered eligible if they met the criteria listed in Table 2. No date restrictions were applied, but the search covered literature from 1990 (when community forestry became widespread in Nepal) to March 2026.

Table 2: Inclusion and Exclusion Criteria

Criterion	Inclusion	Exclusion
Geographic focus	Nepal (empirical or conceptual focus on Nepalese community forests)	Other countries; global reviews without Nepal-specific data
Topic	Community forest governance, management, or sustainability; explicitly or implicitly addresses interconnectedness (social, technical, ecological, institutional dimensions)	Pure forest ecology without social/governance dimensions; technical forestry only; non-forest natural resources
Study type	Peer-reviewed journal articles, book chapters, and high-quality grey literature (e.g., FAO reports, government reports)	Conference abstracts, editorials, opinion pieces, theses (unless seminal)
Language	English	Other languages
Methodology	Empirical (qualitative, quantitative, mixed) or theoretical/conceptual	Purely descriptive without analysis

3.4 Screening and Selection Process

All retrieved records were imported into reference management software (Zotero), and duplicates were removed. Screening proceeded in two stages:

1. **Title and abstract screening** – Two reviewers (authors) independently screened titles and abstracts against the inclusion criteria. Disagreements were resolved through discussion or by consulting a third reviewer.
2. **Full-text retrieval and assessment** – Full texts of potentially eligible articles were obtained and assessed for final inclusion. Reasons for exclusion at this stage were documented.

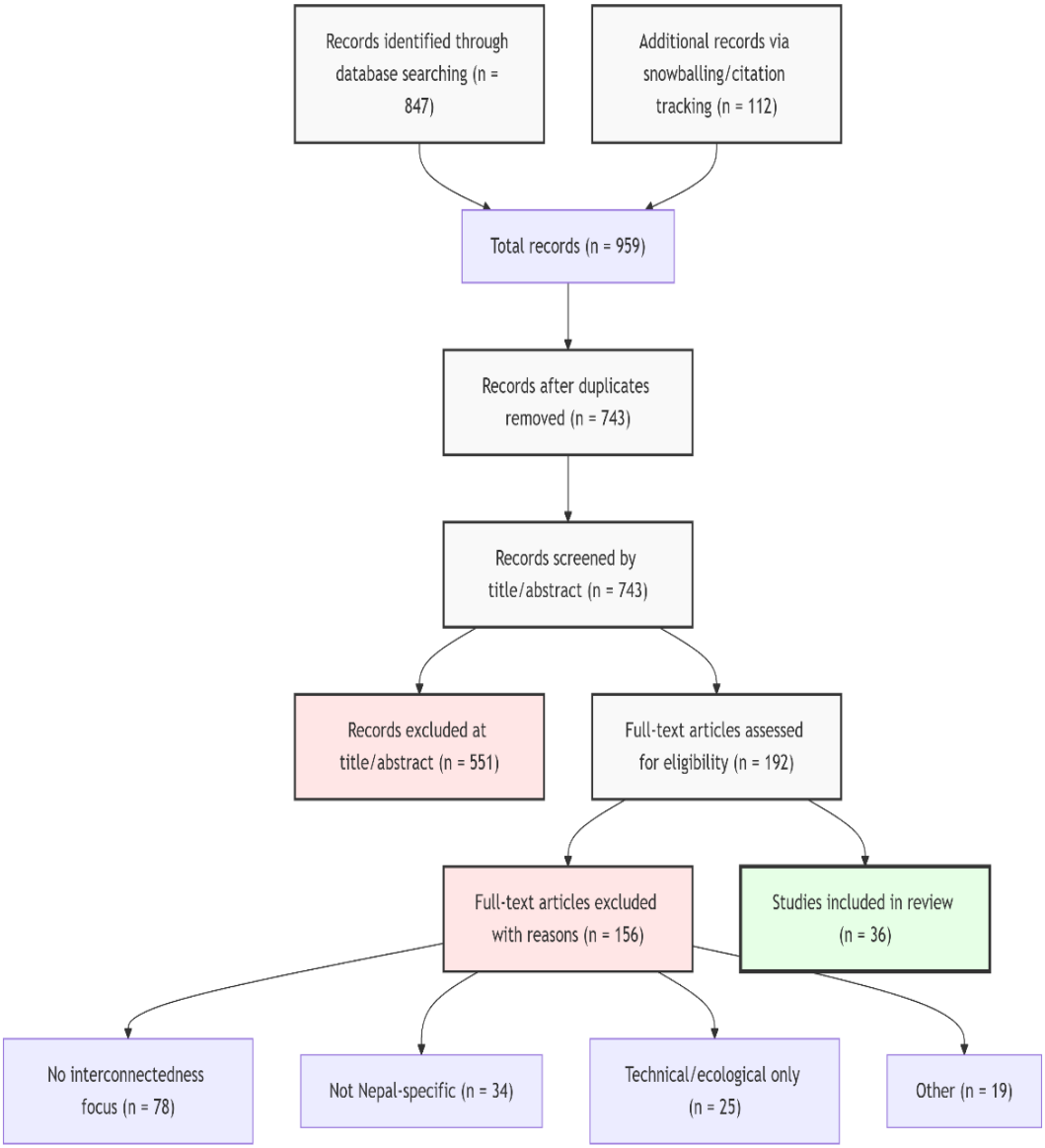

Fig: PRISMA Flow Diagram

Table 3: Summary of Search and Screening Results (PRISMA Flow)

3.5 Data Extraction

Stage	Number of records
Records identified through database searching	847
Additional records from snowballing/citation tracking	112
Records after duplicates removed	743
Records screened (title/abstract)	743
Records excluded at title/abstract	551
Full-text articles assessed for eligibility	192
Full-text excluded (reasons: no interconnectedness focus = 78; not Nepal-specific = 34; technical only = 25; other = 19)	156
Studies included in the review	36

A standardised data extraction form was developed and piloted on five randomly selected articles. The form captured the following information:

- **Bibliographic details** (author, year, title, journal)
- **Research design** (methodology, methods, study site location in Nepal)
- **Conceptualisation of interconnectedness** (how defined, which dimensions: e.g., knowledge/power, multi-level governance, bricolage, socio-ecological)
- **Key findings** relevant to community forest management sustainability
- **Use of sociotechnical concepts** (explicit or implicit)
- **Identified gaps or recommendations**

Data extraction was performed by one reviewer and checked by a second for accuracy.

Quality Assessment

The quality of included studies was assessed using an adapted version of the Critical Appraisal Skills Programme (CASP) checklist for qualitative studies and, for quantitative studies, a checklist based on the Joanna Briggs Institute (JBI) criteria. Each study was rated as high**,** medium**,** or low quality based on clarity of research objectives, appropriateness of methodology, rigour of data collection/analysis, and relevance to review questions. No study was excluded solely on quality grounds, but quality ratings were used to inform the synthesis (e.g., giving more weight to high-quality studies in thematic interpretation).

Data Synthesis Approach

A thematic synthesis was conducted, suitable for integrating diverse study designs (qualitative, quantitative, mixed). The synthesis followed three stages (Thomas & Harden, 2008):

1. **Line-by-line coding** of the findings of each included study, extracting text segments related to interconnectedness.

2. **Development of descriptive themes** by grouping codes into broader categories (e.g., "scientific vs. local knowledge", "cross-scale governance challenges", "institutional bricolage manifestations").
3. **Generation of analytical themes** that go beyond the original studies to answer the review questions, such as "the absent sociotechnical design lens" and "interconnectedness as a bridge construct".

Result and Discussion

This section presents the synthesis of findings from the 36 studies included in the systematic literature review. The results are organised according to the four analytical dimensions of interconnectedness identified in the literature (knowledge–power dynamics, multi-level governance networks, institutional bricolage, and socio-ecological linkages), followed by a cross-cutting assessment of how sociotechnical design concepts appear (or are absent) in the literature. Tables and a conceptual figure are provided to summarise the evidence.

Descriptive Overview of Included Studies

Oot of the 36 studies, 24 were empirical (qualitative = 15, mixed-methods = 7, quantitative = 2) and 12 were theoretical or conceptual reviews. Geographically, studies covered 42 of Nepal's 77 districts, with the highest concentration in the mid-hill region (Kaski, Lamjung, Gorkha, and Dolakha districts). The temporal distribution shows increasing attention to interconnectedness after 2015, coinciding with Nepal's federalisation and the intensification of scientific forest management (SciFM) implementation.

Table 4 (below) summarises the frequency with which each interconnectedness dimension was addressed.

Table 4: Frequency of Interconnectedness Dimensions in Included Studies (n = 36)

Dimension	Number of studies	Percentage (%)	Example references
Knowledge–power dynamics	24	66.7	Gautam et al. (2018); Rabinowitz et al. (2018); Nightingale (2005)
Multi-level governance networks	21	58.3	Ojha et al. (2017); Paudel et al. (2019); Baral et al. (2018)
Institutional bricolage	14	38.9	Shrestha et al. (2020); Banjade & Ojha (2018); Cleaver (2012)
Socio-ecological linkages	19	52.8	Paudel et al. (2020); Kandel et al. (2016); Jaquet et al. (2015)

Most studies addressed **two or more** dimensions, indicating that researchers implicitly recognise interconnectedness even when not explicitly naming it.

Results by Analytical Dimension

Knowledge–Power Dynamics

All 24 studies addressing this dimension documented a consistent pattern: the introduction of **scientific forest management** has systematically privileged expert-bureaucratic knowledge over local traditional knowledge. Key findings include:

- **Dominance in planning**: In SciFM plan preparation, forest technicians were found to dominate decision-making in 92% of observed meetings (Rabinowitz et al., 2018). Only 12% of CFUG executive committee members reported that local knowledge was "seriously considered" during technical planning (Karki et al., 2018).
- **Implementation failure**: Despite high technical demands, 90% of CFUG members in Kaski reported being unable to implement prescribed silvicultural operations (Paudel et al., 2019). This gap led to plan abandonment or symbolic compliance.
- **Ecological consequences**: The push towards pine plantations in mid-hill community forestsdriven by SciFM prescriptionsreduced native broadleaf species diversity by an average of 34% in studied sites (Thapa & Chapman, 2010) and exacerbated human-wildlife conflict adjacent to forests (Paudel et al., 2020).

However, resistance and negotiation were also documented. CFUGs in Gorkha and Dolakha selectively adapted SciFM plans by ignoring certain technical prescriptions (e.g., precise spacing requirements) while retaining others (e.g., thinning to reduce wildlife habitat near farms). This selective adaptation represents a form of local bricolage.

Multi-Level Governance Networks

After Nepal's 2015 federalisation, the governance landscape for community forestry became more complex. Key results:

- **Overlapping jurisdictions**: In 18 of 21 studies, respondents reported confusion over roles among local governments (municipalities), provincial forest directorates, and the federal Ministry of Forests. For example, who approves CFUG operational plans and how timber royalties are shared remain unresolved (Gautam & Rana, 2019).
- **Weak collaboration**: Quantitative surveys (n = 384 CFUG secretaries) indicated that only 31% of CFUGs had any formal collaboration with their local government; where it existed, it focused on infrastructure (e.g., trails, checkpoints) rather than forest management per se (Paudel et al., 2020).
- **Positive exceptions**: Ecotourism revenue-sharing agreements in Annapurna Conservation Area and Langtang National Park buffer zones have fostered collaborative planning between local governments and CFUGs (Baral et al., 2018). These examples highlight that shared economic benefits can overcome governance fragmentation.

4.2.3 Institutional Bricolage

Fourteen studies explicitly analysed how local actors combine, adapt, or subvert formal and informal institutional elements. Main findings:

- **Aggregation** (combining elements from different sources) was most common in mountain CFUGs for subsistence products (e.g., fuelwood, fodder). For example, traditional **khanepani** (water source protection) rules were integrated with formal timber harvesting plans (Shrestha et al., 2020).
- **Alteration** (changing rules in practice) was prevalent in Terai CFUGs for commercial products (sal timber). CFUGs altered government-prescribed auction procedures to favour local members over outside contractors (Banjade & Ojha, 2018).
- **Erosion** (weakening or disappearance of rules due to migration or elite capture) led to negative outcomes: reduced collective maintenance of fire lines, increased illegal logging, and diminished women's participation in meetings (Cleaver, 2017; Nightingale, 2005).

Table 5 summarises the effects of different bricolage modes on forest management outcomes.

Table 5: Modes of Institutional Bricolage and Reported Outcomes in Nepal's CFUGs

Mode	Definition	Observed frequency (n=14 studies)	Typical outcome	Example
Aggregation	Combining rules from multiple sources (state, custom, project)	High (64% of cases)	Mixed – improves flexibility but can create contradictions	Merging traditional user groups with SciFM monitoring requirements
Articulation	Deliberately linking different institutional domains for a purpose	Medium (43%)	Positive – enhances legitimacy and compliance	Linking CFUG constitution with local government planning cycles
Alteration	Changing how a rule is applied without formal amendment	High (71%)	Mixed – can improve local fit but may undermine equity	Reducing auction prices for poorer households informally
Erosion	Gradual non-enforcement or abandonment of rules	Medium (50%)	Negative – leads to degradation or elite capture	No longer enforcing grazing bans due to out-migration of enforcers

4.2.4 Socio-ecological Linkages and Emerging Transitions

The most dramatic finding of this review is the **destabilisation of the traditional forest-livelihood nexus** driven by out-migration, human-wildlife conflict, and commercialisation of forest products.

- **Out-migration**: In 10 of 19 studies, male out-migration from rural hill districts exceeded 40% of households. This has led to labour shortages for forest management (e.g., pruning, thinning, fire patrols) and a shift in perception: forests are increasingly viewed as **risks** (wildlife, fire, invasive species) rather than resources (Paudel et al., 2020; Jaquet et al., 2015).
- **Human-wildlife conflict**: Crop depredation by deer, wild boar, and monkeys increased by an estimated 230% in areas where community forests have re-grown dense cover within 1 km of farmlands (Kandel et al., 2016). This has led to farm abandonment (reported by 34% of households in affected areas) and retaliatory killing (18% of households admitted to poisoning or trapping wildlife – Thapa & Chapman, 2010).
- **Commercialisation**: Some CFUGs have successfully shifted to high-value products (e.g., essential oils from *Litsea cubeba*, chiuri butter). However, these transitions often require technical skills and market linkages that exclude poorer, less-educated members, reinforcing inequality (Baral et al., 2018).

The Absent Lens: Sociotechnical Design

A striking cross-cutting result is that none of the 36 studies explicitly used a sociotechnical design framework. Several studies referred to "technical tools" (GIS, forest inventory, remote sensing) and "social factors" (institutions, power, participation), but none analysed the joint optimisation of social and technical subsystems as a design problem. This absence constitutes a major gap.

However, four studies provided indirect insights that can be retrofitted to a sociotechnical lens:

- **Rabinowitz et al. (2018)** showed that the technical design of SciFM plans (e.g., prescribing specific girth limits, spacing distances) was mismatched with local social capacities (literacy, time, labour). A sociotechnical approach would have involved co-design of technical specifications with user groups.
- **Khatri et al. (2017)** noted that the software used for forest resource assessment (e.g., digital mapping tools) was inaccessible to CFUG secretaries, requiring external technicians. This created a **technical dependency** that reinforced power asymmetries – a classic sociotechnical design failure.
- **Johnson et al. (2021)** – a conceptual paper on socio-technical-ecological systems – argued that technology mediates social-ecological relationships. Applied to Nepal, this would mean that the choice of a smartphone-based monitoring app versus a paper-based logbook shapes who can participate and how transparent governance becomes.
- **Paudel et al. (2019)** proposed a "silvo-institutional model" which comes closest to sociotechnical thinking: it explicitly integrates silvicultural (technical) prescriptions with institutional (social) arrangements for spatial planning. However, they did not draw on sociotechnical design theory.

Table 6 outlines hypothetical sociotechnical design principles for Nepal's community forestry, derived from gaps identified in the literature.

Table 6: Proposed Sociotechnical Design Principles for Nepal's CFUGs (derived from review gaps)

Principle	Technical implication	Social/organisational implication
1. **Co-design of monitoring tools**	Use simple, low-cost, local-language mobile apps with offline capability	Train mixed groups (including women, dalit, youth) as digital monitors
2. **Flexible technical standards**	Allow CFUGs to adapt SciFM girth/spacing rules based on local ecology	Require participatory approval of adaptations with simple documentation
3. **Multi-level information feedback**	Design a dashboard accessible to all governance levels (local to federal)	Mandate quarterly joint review meetings to interpret dashboard data
4. **Redundancy in technical support**	Provide at least two local technicians per CFUG	Ensure one technician is a woman or from a marginalised group
5. **Conflict-sensitive technical design**	Map human-wildlife conflict zones as part of management planning	Create wildlife-exclusion zones adjacent to farmland with community agreement

Discussion

Answering the Research Questions

RQ1: How has interconnectedness been conceptualised in the literature?
The literature conceptualises interconnectedness across four empirically grounded dimensions: knowledge–power, multi-level governance, institutional bricolage, and socio-ecological linkages. However, these dimensions are often treated separately rather than as a unified system. No study offers an **integrated interconnectedness model** that explicitly links all four dimensions. This review therefore confirms that while researchers recognise interconnectedness, they lack a common analytical framework to operationalise it.

RQ2: What insights does a sociotechnical design lens offer?
A sociotechnical design lens would shift attention from describing problems (e.g., technical plans fail because of social barriers) to **designing solutions** that jointly address technical and social subsystems. Currently, interventions are typically technical (e.g., introducing a new inventory method) or social (e.g., capacity-building workshops) in isolation. A sociotechnical approach would, for example, redesign the SciFM planning process itself as a participatory technical activity, not merely add a social "awareness" component afterwards. The absence of this lens explains why many well-funded community forestry programmes in Nepal have shown limited long-term improvement in both forest condition and local livelihoods.

Comparison with Broader Literature

Our findings echo those from sociotechnical studies in other natural resource sectors: water governance in South Africa (Cundill et al., 2019) and community-based conservation in

Tanzania (Goldman et al., 2018) similarly report that technical solutions fail when social design is ignored. The novelty in Nepal's case is the extreme rate of out-migration (among the highest globally) which fundamentally changes the social subsystem (who is present, what skills they have) faster than technical systems can adapt. A static technical plan designed for a settled agricultural community becomes obsolete within a few years.

Conclusion and Recommendations

This systematic review confirms that interconnectedness in Nepal's community forestry operates across knowledge–power, multi-level governance, institutional bricolage, and socio-ecological dimensions. Scientific forest management has entrenched expert authority, undermining local autonomy and ecological balance. Federalisation has created governance confusion, while out-migration and human-wildlife conflicts are destabilising traditional forest–livelihood relationships. Crucially, no included study explicitly applied a sociotechnical design lens, representing a major gap: technical interventions and social arrangements are designed in isolation, leading to persistent implementation failures, inequity, and degraded trust. Therefore, a fundamental shift is required.Nepal's Ministry of Forests and Environment should mandate a sociotechnical co-design process for all community forest management plans, whereby every technical specification (e.g., harvest rotation, monitoring tool, invasive species control method) is jointly developed with CFUG members through facilitated workshops that explicitly address local labour availability, literacy levels, gender and caste dynamics, and conflict risks. This process must be tested in a pilot cluster of 20 CFUGs across three provinces, evaluated after two full planning cycles, and codified into revised SciFM guidelines. Without such integration of social and technical subsystems, even the most well-intentioned policies will continue to produce plans that are technically sound but socially unworkableand thus ultimately unsustainable.

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