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REVIEW

Community-Led Nature-Based Solutions for Climate Adaptation: Global Lessons and Governance Innovations

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ABSTRACT

Community-pioneered Nature-based Solutions (NbS) have become the main strategies in climate adaptation, although the evidence of their effectiveness and the governing conditions is still fragmented across hazards, ecosystems, and disciplines. The current review is a synthesis of the worldwide empirical research based on the concept of community-led NbS, meaning those interventions where communities have significant decision-making power and responsibility concerning the design, stewardship, sharing of benefits, and learning. On a taxonomy that differentiates between proximal ecosystem functionality and hazard modulation and distal human vulnerability reduction, and procedural, distributional, and recognition justice, we systematize the evidence-based findings according to hazard-ecosystem-intervention type (coastal storms and sea-level rise, flooding, drought and water insecurity, urban heat, and emerging compound risks) and we compare the outcomes. The results are reported to have the co-benefits of biodiversity gain, livelihood diversification, and better well-being, though they can be neutralized by elite capture, exclusion, tenure insecurity, as well as, in cities, green gentrification and displacement. The analysis of governance indicates repeating bundles related to longer-lasting and fairer results: hedge rights and tenure, community-enforceable and legitimizing representation institutions, financing institutions with longer horizons of maintenance and active adaptation, protection, and grievance, ethical supervision, and data governance. Our findings conclude that to scale

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community-led NbS, we need to switch the targets of areas to the target of governance quality and design of evaluation that would connect a change in the ecosystem to lived risk reduction and distributional change.

Keywords: Nature-Based Solutions; Community-Led Governance; Climate Adaptation; Environmental Justice; Evidence Synthesis

1. Introduction

Community-pioneered Nature-based Solutions have become the main strategies in climate adaptation, although the evidence of their effectiveness and the governing conditions is still fragmented across hazards, ecosystems, and disciplines [1]. The current review is a synthesis of the worldwide empirical research based on the concept of community-led NbS, meaning those interventions where communities have significant decision-making power and responsibility concerning the design, stewardship, sharing of benefits, and learning. On a taxonomy that differentiates between proximal ecosystem functionality and hazard modulation and distal human vulnerability reduction, and procedural, distributional, and recognition justice, we systematize the evidence-based findings according to hazard-ecosystem-intervention type (coastal storms and sea-level rise, flooding, drought and water insecurity, urban heat, and emerging compound risks) and we compare the outcomes. Most reliable records of ecological performance indicators, e.g., wave attenuation proxies, runoff control, soil-water storage, and urban cooling, have been in the evidence base, with less of the literature assessing avoided losses, recovery pathways, and long-term sustainability of extremes. The results are reported to have the co-benefits of biodiversity gain, livelihood diversification, and better wellbeing, though they can be neutralized by elite capture, exclusion, tenure insecurity, as well as, in cities, green gentrification and displacement [2]. The analysis of governance indicates repeating bundles related to longer-lasting and fairer results: Hedge rights and tenure, community-enforceable and legitimizing representation institutions, financing institutions with longer horizons of maintenance and active adaptation, protection, and grievance, ethical supervision, and data governance. Our findings conclude that to scale community-led NbS, we need to switch the targets of areas to the target of governance quality and design of evaluation that would connect a change in the ecosystem to lived risk reduction and distributional change.

The review is on community-led NbS as a way of adapting to climate change: interventions where communities undertake meaningful leadership, i.e., establishing priorities, influencing design, controlling key decisions, and/or controlling stewardship and benefit-sharing, instead of being involved in consultation or labor [3]. The distinction matters. Community-based and participatory strategies are frequently loosely applied, often covering up situations where power is retained by the authorities and the community contribution is restricted to confirming the existing answers. Community leadership, in practice, is found on a spectrum between the delegated power inherent in co-management, which can be seen at one end, and complete self-determination in self-governed stewardship (led by Indigenous people) [4]. At each end of this range, NbS led by communities may inculcate the concept of adaptation into the existing local governance systems, traditions of knowledge, and forms of social accountability. These aspects are commonly presumed to enhance efficacy and fairness; however, the data are still tied together in hazards, ecosystems, and areas, and are normally used with short-term or proxy measures.

This review is inspired by three relentless issues. To begin with, there is uneven evidence on the effectiveness of adaptation [5]. Numerous studies describe biophysical indicators of the required but not sufficient changes that include vegetation cover, infiltration rates, erosion change, or the modeled hazard attenuation, indicating a lower risk of climate. A much smaller number of studies quantify changes in vulnerability outcomes that are of greatest interest to individuals: avoided damages, increased water reliability, decreased heat stress, stable livelihoods, or increased preparedness and response capability. Moreover, it is hard to do causal attribution since NbS often co-exist with social programs, engineered defenses, governance reforms, or economic trends in general. Second, the results of equity and justice are often poorly specified [6]. Adaptation ben-

efits may be uneven across groups of people (depending on gender, age, ethnicity, caste, livelihood, and tenure), and projects may generate disabilities (maintenance tasks), opportunity costs, impeded access, or conflicts. Devoid of the vocational focus on procedural justice (who decides), distributional justice (who benefits), and recognition (whose knowledge and rights matter), NbS can turn into an instrument of some people adapting to changes instead of collective resilience. Third, governance inventions which facilitate community leadership, such as rights recognition, devolved finance, polycentric institutions, safeguards, and community-based monitoring, are on the rise, but the experience of what cross-contexts is diffused in case studies and policy reports [7].

It is on this basis that the current paper seeks to pull together international evidence on community-based NbS in respect of climate adaptation through an impacts-first prism where governance is considered as a moderator of impact [8]. In particular, our questions are as follows: (1) What are the reported outcomes of adaptation to community-led NbS, and what are the measures of them? (2) What are the scarcity informative differences in outcomes according to hazard types (coastal, flood, drought, heat, and compound risks) and classes of ecosystems/intervention (e.g., mangroves, wetlands, watersheds, agroforestry, rangelands, urban green-blue systems)? (3) What operating mechanisms of governance and finance are most likely to support community leadership, protect equity, and maintain functioning ecologically in the long run? Such an arrangement of evidence aims to go beyond such generic assertions that NbS work or participation matters, to a more practical sense of when, why, and to whom community-led NbS lowers the climate risk.

We call institutional and policy designs that change decision rights, accountability, financing, knowledge systems, and scaling pathways this, and we refer to them as governance innovations, which help community leadership sustain ecological integrity [9]. They can be customary tenure and stewardship laws and regulations; co-management institutions with active sanctions; and devolved adaptation funds and procurement restructuring that fund long-term maintenance and operation; share benefits and grievance frameworks that dilute elite capture and dispossession; and community surveillance systems in line with ethical data administration that, in some cases, also try to establish indigenous data sovereignty. Of significance, innovation does not mean newness everywhere: much of such arrangement represents old traditions of collective administration being recognized, codified, or reconfigured in the modern climate policy. The key question remains how these designs are standing the current day challenges, namely, accelerating extremes, land market, conservation wrangles, and disjointed public authority [10].

Another practical dilemma that has been addressed in this review is scaling, which is a challenge for policymakers, donors, and practitioners [11,12]. The demand to increase NbS investment tends to give preference to the uniformity of project templates and brief funding patterns that may weaken the leadership of the community and deliver shallow engagement. By comparison, community-led approaches are often described as slower or more difficult to control, and it takes time to build up trust and deliberate, and design locally. Those transaction costs can be the cost of durability, though, especially of those interventions in which the system must be supported by continuous custodianship and the establishment and enforcement of the legitimacy of rules. One significant input of the current paper would be thus to elucidate scaling pathways that are non-eroding of community authority: scaling out via networks and federations, and boundary organizations that extend technical assistance without usurping decision-making, and minimum standards of rights, representation, safeguards, and maintenance finance.

The article goes in the following manner. In Section 2, the conceptual core and an analytical framing are established between the community authority and rights, resources and knowledge and the results of adaptation with a theory of change, and the governance and contextual moderators are identified. Section 3 outlines the methodology of the review such as search strategy, inclusion criteria, and coding and quality appraisal, along with the evidence mapping process. Section 4 summarizes the world evidence base per hazard-ecosystem-intervention type, in which the strongest evidence gaps have been identified. Section 5 evaluates performance outcomes, among which are adaptation effectiveness, co-benefits, equity and justice dimension, and trade-offs, along with maladaptation risks, with consideration of measurement decisions as

well as attribution constraints. Section 6 looks at governance innovations and enabling conditions, finding some common bundles of institutional design features related to more sustained and fairer results. The limitations and drawbacks in the evidence base and practical use are discussed in Section 7, and provide future perspectives on the evaluation, money, protection, and extension to intensified climate extremes. Section 8 ends with transferable insights, design principles, and a focused research and policy agenda.

Comprehensively, the overarching hypothesis that is presented in this review states that community leadership represents not only a normative objective but also frequently a functional requirement for adaptation performance, in places where NbS rely on local stewardship, rule enforcement, and quick learning in the constantly shifting climate situations. Nevertheless, community leadership is not adequate but should be facilitated by secure rights, inclusive representation, sustained finance, strong safeguards, as well as legitimate institutions that can handle internal heterogeneity as well as external pressure. The proposed review will help to make community-led NbS of climate adaptation more effective, just, and durable by incorporating global lessons on hazards and ecosystems with an account of community leadership work focused on governance considerations.

2. Core Concepts and Analytical Framing

2.1. Defining Nature-Based Solutions for Climate Adaptation

Nature-based Solutions are becoming the focus of the central elements of climate adaptation, although their definition and scope vary across disciplines and policy spheres [13]. The concept of NbS in this review can be seen as ecosystem-based measures, whether protection, sustainable management, or restoration, that are purposeful, or can be reasonably anticipated to reduce climate-related threats to people and maintain ecological integrity and co-benefits to biodiversity and human welfare. This framing, which is oriented on adaptation, emphasizes the functional more than the label. An intervention that consumes at least one of the elements of climate risk, namely: hazard, exposure, sensitivity, or adaptive capacity, using discernible ecological pathways, is said to be adaptation-relevant.

Ecosystem-based adaptation, ecological restoration, green infrastructure, and climate-smart land management overlap in their definition, and the borders between the two groups are likely to be politically and institutionally significant [12]. Instead of trying to accommodate the conflicting terms, this review employs a functional method that focuses on mechanisms and durability. NbS adaptation is viewed as a category of interventions that relies on ecosystem functions in terms of water retention and infiltration, sediment stabilization, wave damping, evapotranspirative cooling, and microclimate control. Due to the dynamism of these processes, stewardship and maintenance are also considered part of the definition: temporary plantings or ad hoc projects of restoration that have no long-duration governance of caring may not be considered durable NbS to adaptation, even when they are called so.

2.2. What Counts as Community-Led

The term community-led NbS is often referenced in the context of adaptation discourse, but it is usually defined in loose ways, which can often be taken to mean participation, consultation, or implementation based on the community [8]. The term community-led NbS in this review signifies schemes where communities have a central decision-making role in important aspects of the NbS cycle, such as problem framing, selection of types and locations of interventions, the formulation of rules and regulations of access and utilization, benefit-sharing arrangements, implementation options, monitoring, and maintenance. The usage of community is in a place-based context, and it may involve Indigenous people, customary users, and locally organized groups whose existence and living conditions are directly associated with certain landscapes or seascapes [14]. Simultaneously, the communities are not considered as homogeneous actors in the review. It pays more attention to the governance relationships, designing the distribution of the power, duties, and responsibilities of the community members and external institutions. To ensure definitional transparency and reproducibility, we operationalize 'community-led' NbS using decision-authority and accountability criteria and specify coding anchors for governance reporting (**Table 1**).

Table 1. Operational definition of community-led NbS and coding anchors.

Dimension	Coding Anchor (What Counts)	Minimum Evidence in Study Text	Common Pitfalls to Flag
Decision authority	Community holds authority over at least one core decision domain (rules, resource allocation, enforcement, objectives, siting/design)	Explicit statements of who decides; governance charter; bylaws; meeting records	"Participation" described without authority; token advisory roles
Accountability	Community members can sanction/redirect leadership decisions	Elections, assemblies, customary governance mechanisms, recall or oversight committees	NGO/state accountability presented as community accountability
Scope of leadership	Leadership spans more than implementation labor (includes planning/monitoring/benefit-sharing)	Evidence of community role across ≥2 NbS phases	Communities hired as labor only
Representation	Decision forum includes mechanisms for broad inclusion	Representation rules, quotas, or documented inclusive processes	Elite capture; exclusion of women, migrants, landless groups
Rights/tenure	Rights enable stewardship and enforcement	Statutory/customary tenure recognition; co-title; stewardship agreement	Rights exist "on paper" but not enforceable
Benefit-sharing	Rules exist for distributing benefits and burdens	Written benefit-sharing plan; transparent allocation practice	Opaque distribution; burdens (maintenance) not acknowledged

Note: Overview of the criteria used in this review to classify NbS initiatives along a spectrum of community leadership, based on decision authority, governance accountability, and control throughout the project cycle. Coding anchors distinguish meaningful community leadership from limited participation, providing a consistent and transparent framework for interpreting cases across the literature.

The concept of community leadership is represented as a continuum, but not a dichotomy [15]. In other spheres, outside players maintain domination as communities are merely consulted or brought in as workers. Elsewhere, communities co-produce or co-manage power with state agencies, NGOs or private actors in co-production or co-management. At the local governance level, communities exercise delegated and enforceable decision rights or exercise self-determination via the Indigenous or local system of governance that establishes objectives, rules, and stewardship or provides resources or technical assistance without usurping the decision-making process. This continuum is a key element in the evidence synthesis of the review, as the extent of decision authority influences the possibility of maintaining stewardship over time and the probability of the intervention being consistent with the locally relevant risks and priorities [16,17]. We summarize this continuum of community authority and how it maps onto decision control across the NbS project cycle in **Figure 1**.

Internal power relations are also to be taken into consideration by the community-led framing. Organizations that fail to represent the marginalized groups well can claim leadership, and the attempts made by the community to lead something may replicate exclusion based on gender, social status, ethnicity, caste, livelihood, age, or migration status. This is why community leadership is being considered an empirical attribute of the arrangements of governance, which is based on the rights to make decisions and accountability, and not as the automatic proxy of equity.

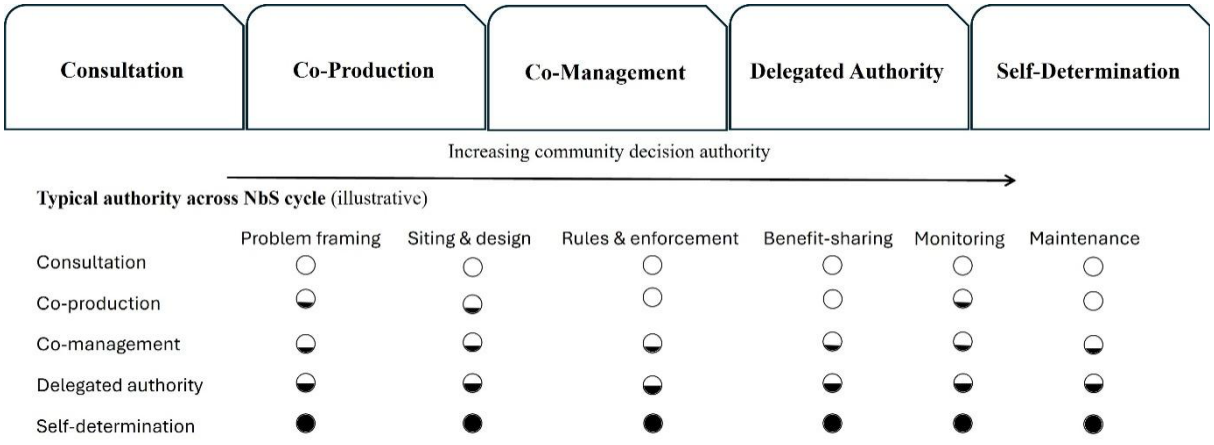

Figure 1. Continuum of community-led authority across the NbS project cycle.

2.3. Adaptation Outcomes and an Outcome Taxonomy for Synthesis

One of the shortcomings of NbS research studies is the recurrent problem of equating ecological change to the success of adaptation [18]. Most studies quantify shifts in ecosystem condition or biophysical proxy, e.g., vegetation cover, canopy density, or infiltration rate, and directly assume that risks have decreased without measuring whether people have become more vulnerable to climate. In order to facilitate synthesis between different study designs and contexts, this review uses an outcome taxonomy that differentiates between the outcomes of ecosystem function and hazard modulation, human risk and vulnerability outcomes, and equity and justice outcomes. This taxonomy allows making the evidence more interpretable and avoiding extrapolation of conclusions on the basis of partial indicators.

Ecosystem functioning and hazard modulation represent proximal processes that are likely to respond to hazards, such as wave attenuation, sediment retention, runoff reduction, slope stabilization, groundwater recharge and urban cooling. These outcomes are often reported since they are able to be tracked using ecological indicators, remote sensing, or models and they will give meaningful information on whether the interventions are working as they are supposed to be. Nevertheless, these proximal effects are not often in a linear relationship with lived risk. Functional performance may not be constant with the magnitude of events, seasonality, ecosystem maturity, and interacting stressors, and may not be maintained when it decays with time [19]. As a measure of adaptation, human risk and vulnerability outcomes are considered the fundamental ones. These encompass exposure, sensitivity, and adaptive capacity changes whereby floods in settlements have decreased, water reliability in times of drought has increased, exposure to heat has decreased, economic losses have been avoided, food security has been maintained, livelihood diversification, preparedness, and quicker recovery following shock. They are harder to measure, since these results need to be observed longitudinally, consider counterfactual conditions, and have the capability of isolating the effects of NbS and other drivers. However, the effectiveness of adaptation is tentative until evidence at this level is obtained.

Adaptation quality is considered to be dependent on equity and justice results instead of co-benefits. Procedural justice deals with the issue of inclusivity, transparency, and accountability of decision-making, and whether communities are the ones having real powers, not symbolic participation. Distributional justice is about the distribution of benefits and burdens, who is given protection, access, livelihood opportunities, and returns of financial benefits and who incurs opportunity costs, restrictions, and maintenance labor. Recognition justice is about the respect, institutionalization, and not marginalization or extraction of rights, identities, cultural values, and knowledge systems, especially of the Indigenous Peoples [20,21]. Inclusion of these dimensions is given the fact that the adaptation interventions may enhance inequity even when the aggregate measures of risks are enhanced.

2.4. Analytical Framing: Linking Community Leadership to Adaptation Performance

The analytical framing applied to such a review considers governance as an explanatory variable that preconditions whether NbS pathways lead to sustainable and equitable risk mitigation. The hypothesis is that community leadership has a role in determining adaptation performance based on mechanisms that take place at the design, implementation and maintenance stages [22]. Intervention design can be more applicable to local hazard regimes, micro ecology and livelihood activities when the communities are in decision authority. This kind of fit can minimize the risks of mismatch, including wetlands that are improperly located, improper choice of species, or urban greening, which do not consider the places and people at the greatest risk of heat and flooding.

Durability can also be determined by community leadership in the form of stewardship [23]. NbS interventions can demand extensive ongoing care and implementation of rules of access and use, and projects may fail when responsibilities are devolved without authority, resources, and legitimacy. In areas where processes of governance are locally legitimate, the rate of compliance can be greater, and conflict reduced, thus reinforcing protective ecosystem processes. Community monitoring and experiential knowledge can reinforce learning over time and allow adaptive management, especially when communities receive insti-

tutions that assist them by giving them technical assistance without appropriating decision-making. The framing does not presuppose the sufficiency of community leadership. Instead, it approaches leadership as an avenue whose success lies in the bigger institutional context, the availability of funds, and the availability of protective mechanisms that cushion against marginality and victimization. **Figure 2** illustrates the review's theory of change, linking community authority and governance enablers to mechanisms of performance and to adaptation and equity outcomes.

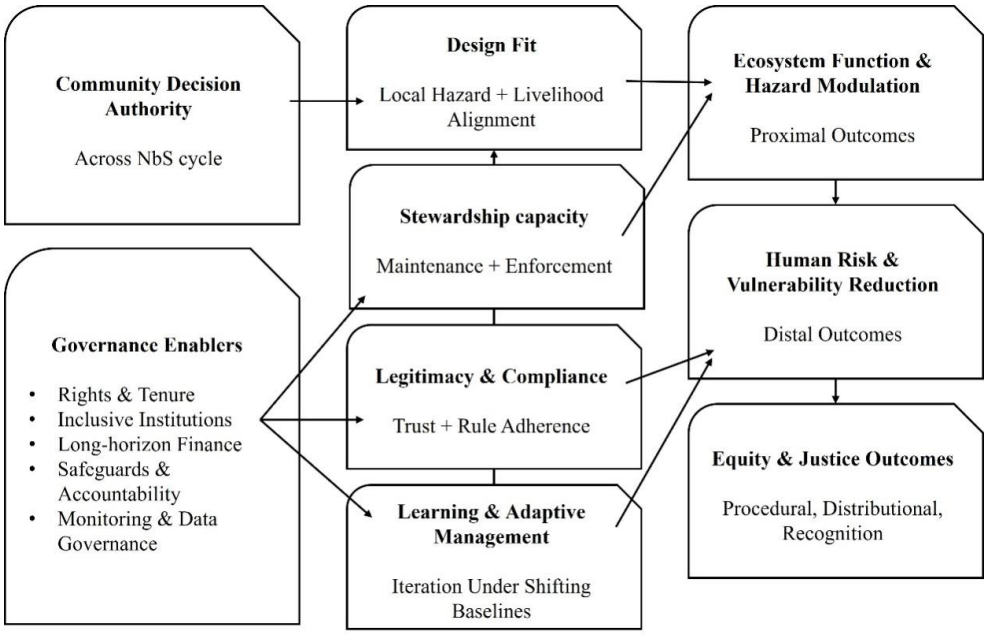

Figure 2. Conceptual framework and theory of change for community-led NbS adaptation.

2.5. Governance Moderators and Enabling Conditions

Because the mechanisms above are contingent, the review tracks a set of governance moderators that appear repeatedly in the literature as determinants of success or failure. Rights and tenure shape whether communities can invest in long-term stewardship and defend ecosystems against external pressures. Where rights are insecure, NbS projects can intensify conflict, enable appropriation, or increase displacement risks when restored ecosystems raise land values. Institutional arrangements and representation shape whose voices are amplified and whose interests are protected, especially in contexts of internal heterogeneity. In practice, the design of decision rules and representation mechanisms can be as consequential as the formal label of "community-led" [24,25].

Finance and benefit-sharing also condition outcomes. Adaptation NbS often fails not because the ecological logic is flawed, but because funding is short-term, maintenance is under-resourced, and benefits are unevenly distributed. Financing arrangements that support long-term operations and maintenance, align incentives with stewardship, and create clear benefit-sharing rules can strengthen legitimacy and continuity. Accountability and safeguards further moderate outcomes by providing mechanisms for consent where relevant, for grievance and redress, and for reducing elite capture and exclusion. In urban contexts, safeguards against displacement and "green gentrification" are particularly important because NbS can increase amenity values and reshape access to land and housing. Finally, knowledge and monitoring systems matter not only for technical learning but for trust. Where community knowledge is instrumentalized, or data is extracted without reciprocity or control, participation can erode, undermining long-term stewardship [26].

2.6. Contextual Moderators and Boundary Conditions

Governance is involved in the wider ecological, social, and political frames of operation that define trans-

ferability and performance [27]. The time scales and magnitudes that NbS can offer protection, and the aspects of the occurrence of extreme events that can affect the provisions of NbS and the inefficiency of compound risks, may be of a nature that is not reflected in the average-condition measures. The recovery trajectories and the ecosystem condition identify how fast the protective functions are formed and remain during the stress. The state capacity, as well as policy coherence, has a bearing on the level of recognizing and enforcing community authority, whether cross-sectoral coordination is facilitative or discouraging of local stewardship. The existence of market pressures and land values may enhance the competition for land and resources, leading to risks of land grabbing, displacement, or unfriendly extraction. When there is conflict and social fragmentation, collective action may be undermined, and representation and enforcement may be complicated, in particular, when there is a contest between institutions of governance [28].

It is important to realize these borderline conditions to prevent overgeneralized prescriptions. The NbS that apply best when integrated in hybrid adaptation portfolios of ecosystem interventions with risk-sensitive land-use planning, early warning systems, targeted social protection and selective engineered actions might be best delivered by the community [29]. The review does not thus consider NbS as a separate category of solutions to risk but rather as a wider system of adaptation where the alignments in governance at different levels can dictate the realization and maintenance of risk reduction.

2.7. Implications for Synthesis in This Review

The idea of conceptual framing formulated here results in three commitments that permeate the rest of the article. To start with, the synthesis explicitly separates the proximal ecological performance and distal outcomes, which denote lived risk reduction, and makes the latter the most obvious indicator of adaptation success. Secondly, the issue of equity is approached as part of the quality of adaptation, and it is necessary to evaluate procedural, distributional, as well as recognition facets instead of assuming that community involvement will embrace fairness [30]. Third, governance is considered not only as a context of description but as a set of moderators and mechanisms that determine the achievement of NbS interventions in providing sustainable risk reduction in a changing climate. This would allow the review to recognize recurring governance bundles that seem to facilitate effective and fair results for hazards and ecosystems, together with identifying the circumstances under which community-led NbS might not work or cause harm.

3. Review Methods and Evidence Mapping

3.1. Review Design and Reporting Approach

The article has a systematic evidence synthesis of Nature-based Solutions of community-led nature-based solutions to climate adaptation, comprising a descriptive evidence mapping process and an interpretive synthesis of the governance mechanisms. The review design will support the methodological diversity of NbS research, where biophysical studies, social science case studies, mixed-method studies, and modeling studies are likely to exist in the same topical space. The review is conducted in accordance with a set of guidelines on systematic reviews and evidence syntheses that are scoping-based, with the reporting performed with Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA)-style guidelines whenever feasible. Since the goal is not to estimate some average effect of treatment, but to be able to describe how governance circumstances occur in various settings, the synthesis method focuses on structured comparison and mechanism-based explanation with descriptive statistics [31].

3.2. Search Strategy and Information Sources

An extensive literature search is carried out in a number of bibliographic databases to ensure the capture of peer-reviewed scholarship in the fields of environmental science, geography, development studies, public policy, and urban planning [32]. The search strategy will be able to detect terminological variation in that relevant studies could be indexed as Nature-based Solutions, ecosystem-based adaptation, green/blue infrastructure, ecological restoration, community-based adaptation, co-management, Indigenous-led stewardship, and commons governance. Search queries are made using three sets of concepts: the terms on adaptation

and climate risk, the terms on ecosystem intervention, and the terms on community leadership and governance. Each database has its own syntax needs (specialized to a particular database), and these strings are piloted to produce known sentinel papers before successively being refined to a balance between recall and precision.

Since NbS is an applied field, specific searches of the high-quality grey literature are also incorporated in the review, at which methodology description and outcome reporting are sufficiently clear to facilitate coding [1,33]. This encompasses reports by intergovernmental bodies, large development agencies, research consortia, as well as conservation or humanitarian organizations that regularly release evaluation-oriented publications. The backward and forward citation of the studies is employed to find other eligible studies that keyword searches have not covered, especially in areas that have weaker indices. All searches are recorded with date, database name, and search string, which is completed to make one replicate it.

3.3. Eligibility Criteria and Operational Inclusion Rules

Eligibility criteria have been established that include studies that will have a significant level of coverage about climate adaptation outcomes and enable the review to draw the line between community-led governance and more restrictive types of participation. The inclusion criteria are that the intervention is an ecosystem protection, management, or restoration intervention where the intervention is a primary mechanism examined and the intervention is considered to have a connection with the mitigation of climate risks, the reduction of vulnerability, or the increasing adaptive capacity [34]. Other studies that do not study the outcomes of sustainability in general without the possibility of an imaginable relationship to the climate risk pathways are not allowed to maintain analytic focus.

The rule of status based on community is an operating rule that is grounded in the decision authority and accountability. The studies are coded as community-led when they report that communities have significant power over at least one of the five domains of core decision-making: rule-making, resource distribution, enforcement, or the capacity to establish or change goals, and when they present data of an internal process of accountability according to which community members can affect or punish leadership or decisions. Research that characterizes consultation, awareness-raising, or labor participation, but does not specify authority of decision-making, is only held until relevant to produce some comparative worth of understanding the boundary between participatory and community-led NbS; such research is coded separately so that results about community-led NbS are not diluted by the broader category of participation [35,36].

The review covers both qualitative and quantitative and mixed-method studies, but also modeling studies with a clear assessment of NbS pathways of relevance to adaptation and enough context regarding governance arrangements. Conceptual papers are those that only inform framing (they do not feature in the empirical evidence map). The body of research that only focuses on mitigation results, including carbon sequestration, is not included unless the results are also addressed in terms of adaptation.

3.4. Screening and Study Selection

Search information is imported into reference management software and screening software, duplicates are filtered out, and the screening process is done in two phases: firstly, title -abstract screening, and then reviewing the content of the full-text. Screening is directed by a written decision log and a calibration exercise on a common subset of records in order to reduce selection bias and to provide the same interpretation of the inclusion rules. Conflicts are solved by discussing, and it may be stepped up to a third reviewer. Full-text screening involves checking the relevance of adaptation, ensuring the presence of NbS mechanisms, and determining whether the governance reporting is adequate to determine the level of leadership and code key moderators. The contents of the full-text level are noted to assist in transparent reporting as well as to explain the presence of evidence that might be there but not well documented to be synthesized.

3.5. Data Extraction and Coding Framework

A standardized coding framework is the framework of data extraction in which the characteristics of interventions, the context of hazard, the arrangement of governance, and outcome reporting are recorded. The model is

meant to facilitate the evidence map as well as the mechanism-oriented synthesis. Reported intervention variables are the type of ecosystem, type of intervention (protection, management, restoration, or hybrid), setting of intervention implementation (rural, peri-urban, urban), and maturity/time of implementation. The climate risk variables are the type of hazard, the nature of the events in case hazards are known, and the spatial magnitude of the outcome [37].

Governance variables include the extent of the decision-making authority of a community, the institutionalized form of leadership power, tenure and rights terms, features of representation, finance modalities, beneficial sharing plans, protective and accountability strategies, and monitoring or learning. The outcome variables are coded on the basis of the taxonomy in Section 2, which distinguishes between proximal ecosystem function and hazard modulation variables and human risk and vulnerability variables, and codes procedural, distributional, and recognition justice dimensions. In cases where multiple outcomes are reported in the study, they are coded with consideration of the measurement method and temporal horizon, and the degree of their relationship with a plausible causal pathway of the NbS intervention.

Since the NbS appraisals tend to have heterogeneous measures, the results are harmonized to be of similar categories but retain measurement specificity in the database [38]. As a coded example, flood outcomes can consist of modeled reduction in peak flow, depth of inundation observed, reported damages, or shifts in evacuation capacity; each of these is coded as a (non-conflating) outcome family.

3.6. Evidence Strength and Quality Appraisal

Since the types of study designs are varied, the review employs the fit-for-purpose quality appraisal method, which differentiates between the strength of evidence on ecological performance and the strength of evidence on human adaptation outcomes [39]. Quantitative appraisals are rated taking into consideration counterfactual logic, baseline comparability, temporal coverage, and confounding, where randomized designs are uncommon in this field. Pre-and post-studies and observational studies are under consideration in the question of the feasibility of the attribution and clarity of the methods. Qualitative research is evaluated based on clarity of case selection, triangulation, comprehensive description of governance, and validity of connecting the characteristics of institutions and the results. Transparency of assumptions, validation, and sensitivity analysis is evaluated, and it is also determined whether governance conditions are meaningfully represented or are exogenous [40].

Instead of reducing appraisal to one score, evidence is placed in tiers that are indicative of both methodological and applicability to particular outcome categories. This tiering facilitates subtle synthesis because it enables the review to provide information as to where evidence is strong to moderate hazards and weak to reduce vulnerability or equity, and where governance conclusions are mainly based on a qualitative inference.

3.7. Synthesis Strategy and Evidence Mapping

Synthesis occurs in two strands, which are integrated. The former is descriptive evidence mapping that defines the world distribution of studies in terms of hazards, ecosystems, regions, and the type of governance, as well as sums up the number of various outcome measures and the business plan of studies [41]. The mapping is employed to determine the concentrations of evidence, blind spots, and discrepancies between NbS promotion and empirical results. The evidence map also facilitates comparisons of how far the studies go in terms of proximal ecological indicators to distal human risk outcomes.

The second one is a mechanism-based synthesis that explains how the moderators of governance set the conditions in terms of outcomes [31,42]. This strand uses coded variables of governance to find repeated bundles of governance, including bundles of secure rights, inclusive representation, long-term finance, safeguards, and community monitoring. They are then compared in terms of hazard-ecosystem situations to determine whether higher-quality institutional arrangements are related to more sustainable and fair results, and to describe the usual failure modes of institutions, e.g., elite capture, maintenance burdens without power, tenure insecurity, or displacement risks in cities. All through, the synthesis is sensitive to context dependence and eschews expressions of universal transferability, making conditional speculations concerning what seems to work, with whom, and in what contexts.

3.8. Sensitivity, Transparency, and Limitations of the Method

Sensitivity analyses to check robustness are performed with the patterns being compared to the higher-evidence tiers by evaluating the patterns observed in the full dataset and patterns observed in higher-evidence tiers, and by evaluating whether the inferences are different when grey literature is not used. Checking against a stricter versus more inclusive threshold of classifying community-led governance is also checked by the review. Support of transparency is provided by documentation of search strings, screening decisions, and definition of codes, allowing replication and critique [43].

Meanwhile, the review has recognized the methodological limitations inherent to the evidence base. Attributes of governance tend to be underreported, and equity results may be unmeasured and implicit, which can hamper the accuracy of governance outcome assertions. Available evidence may also be biased by the publication of successful or donor-favored projects. Not only are these constraints seen as a limitation, but findings on the state of the field which informs the research agenda created later in the article.

4. Global Evidence Base by Hazard–Ecosystem–Intervention Type

4.1. Organizing the Evidence across Hazards and Ecosystems

Empirical studies on community-led Nature-based Solutions to climate adaptation cover a wide geographical range, a wide range of governance situations, and a wide range of ecological contexts, although unevenly distributed by the hazard types and types of interventions [18]. In order to render this diversity analytically manageable, three dimensions are repeatedly combined in this section to justify NbS in adaptation practice, which are the predominant climate hazard of interest, the ecosystem processes mobilized by the intervention, and the type of intervention perceived as protection, sustainable management, restoration or hybrid portfolios [44]. By structuring the evidence in this manner, it is able to identify where the literature mainly records the ecological functioning, where it can relate ecological change with human vulnerability consequences, and where the conditions of governance are reported in detail to be able to comprehend the role of community leadership.

In hazards, there is a general trend of studies demonstrating plausible roles of hazard regulation but providing slimmer evidence on the downstream mitigation of risks to households and communities [45]. Such an imbalance should not be seen as an insignificant technical problem; it determines the acceptability of the issue of adaptation and the viability of settling the community-led NbS by means of public finance and policy. The synthesis presented below, thus, focuses not only on what is written in interventions, but also on what types of outcomes are measured, to what extent evaluations are carried across the causal chain, and where evidence is still mostly inferential. We provide a structured evidence map of community-led NbS by hazard class and ecosystem setting, including typical outcomes and recurring gaps, to orient the synthesis that follows (**Table 2**).

Table 2. Distribution of evidence on community-led NbS across hazard types, ecosystems, and intervention strategies.

Hazard Class	Ecosystem/Setting	Typical Intervention Types	Most Common Reported Outcomes	Evidence Strength (Typical)	Frequent Evidence Gaps
Coastal storms & SLR	Mangroves, dunes, salt marsh, reefs	Protection; restoration; hybrid coastal buffers	Shoreline change; vegetation condition; modeled attenuation	Moderate for ecological function; low-moderate for human losses	Counterfactuals; extreme-event performance; distributional impacts
Flooding (riverine/pluvial)	Wetlands, floodplains, riparian zones, watersheds	Wetland restoration; riparian buffers; catchment restoration	Hydrologic proxies; modeled peak flow; sediment capture	Moderate for hydrologic proxies; low for avoided damages	Basin-scale attribution; upstream/downstream benefit-sharing
Drought & water insecurity	Drylands, agroforestry mosaics, rangelands, headwaters	Agroforestry; soil-water conservation; rangeland restoration	Vegetation/soil indicators; water reliability proxies; yields	Low–moderate; variable by design	Longitudinal outcomes; migration/livelihood pathways

Table 2. Cont.

Hazard Class	Ecosystem/Setting	Typical Intervention Types	Most Common Reported Outcomes	Evidence Strength (Typical)	Frequent Evidence Gaps
Heat (urban)	Urban green: blue systems	Shade corridors; tree stewardship; wetland/stream restoration	Surface/air temperature; canopy cover	Moderate for temperature proxies; low for health outcomes	Displacement/gentrification; equity of access
Compound risks	Fire–flood, cyclone: salinity cascades	Landscape restoration; slope stabilization; integrated portfolios	Mixed (often modeling and qualitative)	Low overall	Empirical extreme-event validation; thresholds/failure modes

Note: Mapping of the empirical studies reviewed by climate hazard, ecosystem setting, and intervention type. The overview highlights areas of concentrated evidence and identifies notable gaps, providing context for interpreting patterns discussed in the synthesis.

4.2. Coastal Hazards: Storms, Erosion, and Sea-Level Rise

One of the most evident strands of the available literature is community-led coastal NbS, an example of the historically existing mangrove, dune, and seagrass among other coastal ecosystems, community stewardship, and the increased focus on policy on coastal resilience [46–48]. The leading types of interventions are mangrove protection and mangrove restoration, community-owned coastal forests, dune stabilization and revegetation, and (in a less numerous group) coral reef restoration or reef-seagrass hybrid interventions. Such programs are normally put into perspective with the mitigation of storm surge effects, dampening waves, stabilizing coastlines, curbing erosion, and cushioning intrusion of salinity in the agricultural lands and fresh water.

Proximal indicators are often reported in the evidence provided in settings in the coastal context, like mangrove existence levels, modifications in canopy pressure, material accretion levels, or modeled wave dissolution. Studies, in a few instances, supplement such indicators with community reports of damages avoided or livelihood stability gained, especially the fisheries and coastal protection benefits associated. Nevertheless, comparatively little is done to measure human risk outcomes, including avoided losses of assets in case of similar storms, decreased displacement, or better recovery patterns. In the regions of such outcomes' reports, it is difficult to attribute them, considering known co-occurring engineered defenses, land-use changes, and artificial disaster response actions [46–48].

In the cases of governance of the coastal areas, tenure and enforcement capacity are frequently emphasized as the central issue. Wherever there is some form of authority that the communities have accepted to control harvesting, regulate access, or to enforce protection regulations, stewardship is likely to be put within a long-lasting context. However, in contrast to areas where commercial aquaculture, tourism development, or state-led conservation restrictions contest coastal commons, the literature can frequently record struggle, lower validity, and threats of non-inclusion. These trends indicate that the ecological suitability and extreme-event regimes are not only directly connected to the performance of coastal NbS but also to the ability of the institution to safeguard ecological recovery against established external forces [49].

4.3. Flood Hazards: Riverine, Pluvial, and Watershed-Mediated Risk

The community-led NbS that is related to floods is often reported in river basins and watersheds, and the interventions are intended to manage the runoff, enhance the flood storage, and decrease the level of downstream hazards. The most noticeable intervention types are wetland protection and restoration, creation of riparian buffers, floodplain reconnection and re-meandering of channels, upper catchment reforestation by communities, and watershed management plans that integrate a combination of numerous measures within the ecosystems. In less urban settings, the community stewardship can also be applied to green-blue infrastructure, including constructed wetlands, restoration of riverbanks, and community-controlled retention zones, although the evidence base in this case is less well-developed [50,51].

The flood literature tends to have fairly robust ecological and hydrological data, such as modeled peak flow decrease, alterations in infiltration, sediment capture, or capacity to withhold water. The translation into people reduction of risk is, however, less consistent in its measurements. There are also reports of a decrease in frequency or

depth of inundation in particular settlements or an increase in preparedness and early response mediated by an increase in local institutions, but many remain at the level of inferred benefits due to a change in hydrological behavior. In addition, the process of floods is very sensitive to the magnitude of events and land-use transformation across the basin, and as such, single-site analysis cannot be easily generalized [52].

Polycentric issues of coordination are often featured in governance narratives whenever it comes to flood and watershed cases [53]. The upstream interventions can create downstream effects in terms of incentives amongst the communities and the benefits sharing across communities. Community leadership is better documented in situations where watershed councils, basin committees, or inter-community agreements are established so as to coordinate activities and share costs and benefits. In the absence of such institutions, the literature tends to characterize disjointed initiatives, maintenance problems, and land and water rights contentiousness that are able to compromise ecological functioning as well as social authenticity.

4.4. Drought, Water Insecurity, and Dryland Climate Risks

NbS of drought and water insecurity. Community-based NbS usually focuses on water retention, groundwater recharge, soil stabilization, and livelihood diversification to mitigate variability in rainfall [54]. Some of the interventions in this category include agroforestry and farmer-managed natural regeneration, restoration of degraded rangelands and grasslands, community watershed restoration, which involves infiltration and recharge, preservation of springs and headwater catchments, rehabilitation of wetlands that support dry-season baseflows, and landscape-scale soil-water conservation interventions. In comparison with coastal and flood situations, mosaics of land-use practices are often a feature of NbS due to drought-related factors, making such systems rather difficult to measure and attribute, but perhaps more likely to capture the socio-ecological reality of dryland adaptation.

Observations in the drought situations usually document the alterations in the vegetation cover, soil organic matter, soil infiltration capacity, or signs of groundwater recharge. Agricultural productivity, food security proxies, or household surveys of the reliability of water access are sometimes used as livelihood and well-being outcomes, although they are often not standardized and very diverse [55]. Due to the time horizon effects and the mechanism of interactions between drought effects and market forces, migration, and policy changes, it is especially difficult to isolate the NbS effects of changes compared to the processes that involve the entire change.

The state of governance in cases of drought usually depends on joint actions in reference to common and mutual water resources. Management of grazing regimes, tree harvesting and cutting, and community-led management or water harvesting structures need to be legitimized and have the power to be enforced. Literature often indicates how local rules, conflict management, and culturally-based organizations are important to the maintenance of stewardship [56]. Meanwhile, it points to the frailty of such arrangements in the face of external land claims, commercial exploitation, or state-directed programs that may have goals that are inconsistent with local interests.

4.5. Heat Risk and Urban Climate Impacts

Urban heat has become a quickly emerging adaptation issue, and literature on community-based led urban NbS has increased. Some of the interventions are community-managed tree planting and management, neighborhood greening and shading, replenishing urban wetlands or riparian corridors, and taking care of parks and greenways to minimize heat exposure, stormwater management, and local microclimates [57]. Elsewhere, community-led efforts are also aimed at reinstating traditional water systems, enhancing urban biodiversity, or establishing cooling corridors, linking schools, transit lines, and public areas.

Localized temperature drop, canopy coverage expansion, or shifts in surface temperatures as a result of remote sensing are commonly reported as an indicator of an urban NbS. Nevertheless, the connection between these ecological and microclimate alterations and health effects, alleviation of heat stress on susceptible groups, or enhanced resilience to heat waves is rather scanty. The methodological nature of this gap is partially a result of the challenge of trying to isolate the effects of NbS on the health outcomes, but may also be viewed as a result of governance realities: urban NbS is often a part of complex property regimes and municipal planning frameworks with restricted community

authority [8,57].

The risks outlined in governance discourse in urban scenarios restate those that are less conspicuous in rural and coastal commons, especially green gentrification and displacement. Community-based stewardship can enhance the quality of the local environment and decrease the heat exposure, but it might also lead to an increase in rent unless it is accompanied by rigorous anti-displacement controls. Procedural justice and benefit distribution may be particularly central in urban NbS, where a particular intervention can be both beneficial and harmful to low-income residents by decreasing their exposure to climatic factors and increasing housing insecurity at the same time [6].

4.6. Compound and Cascading Risks: Emerging Evidence and Methodological Challenges

A lesser though increasing body of literature focuses on compound and cascading risks, e.g., the interrelationship between wildfire and post-fire flooding and debris flows, cyclone occurrences that cause salinity intrusion and agricultural regression, or drought contexts that predispose the occurrence of landslides following the experience of heavy rainfall. The NbS is also a community-based undertaking in these settings, typically consisting of landscape-scale recovery, fuel management via ecological stewardship, or combined watershed and slope stabilization endeavors [58,59]. These examples are important since climate change is raising the probability of extreme events, and NbS performance in this situation is a key test of adaptation resistance.

The evidence in this category is scarce and can frequently be based on modelling or qualitative inference as opposed to long-term empirical validation of the evidence of several extreme events. These studies are, however, useful in establishing the NbS potential limits, the need to adopt hybrid strategies, and the governance systems to facilitate fast learning and adjustment. They also depict the significance of NbS as components of larger risk management systems, but not isolated projects.

4.7. Cross-Cutting Patterns in Intervention Types and Leadership Arrangements

The evidence base across the categories of hazard documents indicators of archetypal interventions. Protective strategies aim at avoiding the further degradation of this ecosystem, usually by means of community regulations and implementation. Restoration methods are aimed at reclaiming lost ecological processes, and they need to be sustained and given time to mature [60]. With sustainable management strategies, resource use regimes are adjusted to sustain ecosystem functions in times of stress, which are often dependent on commons governance. Hybrid strategies are a mixture of these factors, and they may incorporate careful measures that are engineered, especially when the place is densely populated or valuable.

The records of the community leadership also have systematic differences among the hazards. The cases of ocean and dryland commons tend to be more descriptive of tenure, customary institutions and collective rules due to the extensive history of local stewardship. The cross-scale coordination and the issue of aligning the upstream and downstream in their incentives are often highlighted in flood and watershed cases. In urban cases, there is a common sense of community stewardship in systems that are dominated by the municipality, where leadership can be more restricted and reliant upon alliance, land access, and the political economy of city building [61].

4.8. What the Evidence Base Reveals About Measurement and Knowledge Gaps

One of the key results of organizing the evidence on a hazard- and ecosystem-centric basis is the strong tendency of the literature to focus on ecological condition and hazard modulation, weaker on household-level and community-level vulnerability outcomes, and weaker on distributional equity impacts and long-term sustainability in extremes. There is a policy and scientific impact of this trend. Lived risk outcomes can only be measured consistently without the capacity to compare community-led NbS to other adaptation measures and to rating by scaling using public adaptation finance. Internal exclusions or external harms are hard to ensure without an equity-sensitive assessment, that is, the avoidance of community-led framing obscuring these issues [62,63].

Meanwhile, the hazard-ecosystem organization demonstrates the zones of research investments, which might bring the most significant marginalized benefit. An

elevated association between the measurements of hazard attenuation and the prevented destructions during similar occurrences in coastal and flood environments would reinforce cause-and-effect assertions. In dryland and drought conditions, long-term and mixed-method designs linking ecological change to the issue of water reliability, livelihood stability, and the process of migration would resolve significant attribution issues [64]. The increased incorporation of heat exposure mapping, health and well-being indicators, and governance analysis that is sensitive to displacement is needed in urban environments to determine whether community-led NbS can be used to build resilience and justice at the same time.

Combined, these trends encourage the outcome-oriented synthesis in Section 5 that evaluates what the evidence indicates regarding effectiveness, co-benefits, equity, and trade-offs and the governance-oriented synthesis in Section 6 that analyzes which elements of institutional designs and innovations seem to deliver more stable and equitable results on lasting and satisfactory outcomes in adapting.

5. Outcomes Synthesis: Effectiveness, Co-Benefits, Equity, and Trade-Offs

5.1. Interpreting "Effectiveness" in Community-Led NbS for Adaptation

The notion of the effectiveness of climate adaptation is frequently stated as an obvious outcome, although the literature on community-led Nature-based Solutions exposes considerable differences in terms of measures and implications [65]. Effectiveness in this review will be the degree to which a community-driven NbS intervention helps to achieve long-term mitigation of climate-related risk to people, whether through attenuation of danger, decrease of exposure, decreased sensitivity, or increased adaptive power. This sense necessitates following a causal pathway of outcomes that start with the ecological change and end with human enhancement of well-being in climate stress. The density of evidence base, however, is likely to be concentrated at the start of that chain. Evidence of ecological recovery or hazard control follows many studies that present convincing evidence, and few studies indicate that such shifts are reflected in quantifiable losses, disruption, or susceptibility reduction [66]. Consequently, there is a tendency to have strong statements in the literature regarding functional potential and weak statements regarding achieved risk reduction. To avoid conflating proximal ecological metrics with adaptation success, we apply an outcome taxonomy that distinguishes ecosystem function, human vulnerability outcomes, and equity/justice outcomes, alongside illustrative indicators and methods (**Table 3**).

Another complication is the fact that community-led NbS hardly ever functions independently [67]. The interventions often overlap with a planned intervention, social protection programs, land-use alteration, investment in disaster response, or more general economic and demographic changes. Such co-occurrence is not a practice shortcoming, but it makes attribution in research difficult. The most plausible studies are therefore those with explicit comparison of sites or periods, those with triangulation of evidence in methods, or those that are keen to define plausible mechanisms and boundary conditions on which NbS is likely to have an effect. All these characteristics determine the degree to which one can conclude on effectiveness, and they contribute to the explanation of why evidence tends to be much more assured on some types of outcomes compared to others.

Table 3. Outcome taxonomy and illustrative indicators for evaluating community-led NbS adaptation effectiveness.

Outcome Domain	Sub-Domain	Example Indicators (Illustrative)	Typical Methods	Interpretation Cautions
Ecosystem function/ hazard modulation (proximal)	Coastal buffering	shoreline position; erosion/accretion; modeled wave reduction; canopy density	remote sensing; field transects; models	Does not equal avoided losses without linking to exposure/vulnerability
	Flood regulation	infiltration; storage volume; peak flow proxy; sediment retention	hydrologic monitoring; models	Basin confounding; event magnitude sensitivity
	Drought buffering	soil moisture; groundwater proxy; vegetation cover; baseflow	soil sampling; remote sensing; stream gauges	Long time horizons; multiple drivers
	Urban cooling	air/surface temperature; canopy cover; thermal comfort proxy	sensors; satellites; surveys	Heat benefits depend on access and use patterns

Table 3. *Cont.*

Outcome Domain	Sub-Domain	Example Indicators (Illustrative)	Typical Methods	Interpretation Cautions
Human risk/vulnerability (distal)	Exposure & sensitivity	inundation depth in settlements; heat exposure index; water reliability	geospatial + household data	Requires counterfactual reasoning
	Losses and recovery	avoided damages; downtime; recovery time; displacement	event-based analysis; surveys	Rare extremes; attribution challenges
	Adaptive capacity	diversification; preparedness; collective action capacity	mixed methods	Risk of self-report bias
Equity & justice (cross-cutting)	Procedural	decision authority; inclusion; transparency; consent processes	governance analysis; interviews	"Participation" may be performative
	Distributional	benefit incidence; burden incidence; labor/time costs	disaggregated surveys	Needs subgroup disaggregation
	Recognition	rights upheld; knowledge legitimacy; cultural values protected	qualitative + legal analysis	Often underreported; context-specific

Note: Taxonomy distinguishing ecosystem outcomes, human vulnerability outcomes, and equity outcomes used to evaluate NbS performance. Example indicators illustrate how adaptation effectiveness is assessed, highlighting the distinction between ecological proxy measures and direct evidence of risk reduction.

5.2. Adaptation Effectiveness: From Hazard Modulation to Reduced Vulnerability

The strongest consistent evidence in support of the hypothesis of community-led NbS, across the hazard types, has to do with the fact that community-led NbS preserves or recovers the functions of the ecosystem that are relevant to the hazard modulation [68]. Cases along the coastline are frequently recorded to show signs of wave attenuation, stabilization of the shoreline, and less potential erosion. Changes in flood and watershed cases are often reported, which can be attributed to either high infiltration, low runoff maximums, or high flood storage. Proxies of vegetation cover, soil condition, and water retention are generally improved in drought and dryland cases, and local cooling and enhanced stormwater retention using green-blue infrastructure are common in urban cases. These proximal outcomes are important as they precondition any downstream risk reduction, and they have a mechanistic foundation for the claims of adaptation.

The process of hazard modulation to lower vulnerability is less well-illustrated in translation. Where household or community results are mentioned in the studies, they tend to say water reliability, agricultural stability, or local preparedness and response capacities. The qualitative descriptions in certain environments show less disruption during storm or flood events, quicker recovery, or better livelihood sustenance. The evidence has unequal capability to quantify the losses avoided or to compare the results of outcomes to realistic counterfactuals. Such a gap is especially significant since the decisions related to adaptation are usually subject to trade-offs between NbS and other types of investments, with a financial constraint [13,69].

One of the recurring themes is that vulnerability outcomes are more prevalent when community-led NbS are bound with larger systems of adaptation [68]. Between NbS and risk-sensitive land-use planning, early warning systems, livelihood diversification programs, or selective engineered defenses, the ecological-to-lower losses pathway is more evident. In contrast, in cases where NbS is introduced as an independent project with no governance support, the financing of the maintenance and additional steps and the indications of the risk mitigation are less powerful, and the sustainability of the project is less predictable. This trend supports the idea that the effectiveness of NbS needs to be implemented in a portfolio and not as a single intervention, and that community leadership could play the most significant role in the alignment and sustainability of that portfolio over the long term.

5.3. Co-Benefits and Synergies: Why Community-Led Framing Often Matters

The appeal of NbS in the policy of adaptation is that it can create co-benefits that are not easily offered by conventional protective infrastructure. Co-benefits in terms of biodiversity, ecosystem services, livelihoods, and social well-being are common in the literature on community-led NbS [70]. These co-benefits are not bystanders merely; these can be part and parcel of the political and social sustain-

ability of adaptation. Where families are benefiting in a real way in terms of livelihood or well-being, there may be readiness to invest in labor and in investments in adhering to stewardship regulations, which enhance the sustainability of ecosystem processes that form the foundation of protection.

The co-benefits of livelihoods in rural and coastal commons can be in the form of fisheries enhancement, enhanced grazing conditions, or diversified agroforestry products. Water quality and more predictable baseflows can be useful in watershed contexts for domestic use and agriculture. Urban interventions, Greening can enhance mental health, access to recreation, and neighborhood connectedness, along with lessening exposure to heat and stormwater. Notably, the governance at the community level can influence the realization and the retention of co-benefits at the local level [71]. Where priorities are set, and control of benefit-sharing is done at the community level, NbS is perhaps more associated with the locally valued services compared to externally important measurements like carbon storage or others. In this context, community leadership may be used not only to affect the presence or absence of co-benefits but also to affect the benefits aimed at, beneficiaries, and benefits to increase or decrease the long-term adaptation capacity.

5.4. Equity and Justice Outcomes as Central Adaptation Results

Equity is frequently invoked in discourse on community-led adaptation, yet the empirical literature shows that equity outcomes must be demonstrated, not assumed [72]. Procedural justice outcomes are most directly linked to the concept of community-led governance because they concern authority, voice, and accountability. Studies that document genuine decision authority, transparent deliberation, and accountable leadership structures tend to describe greater legitimacy and stronger compliance with stewardship rules. In such cases, procedural justice appears to function as both a normative outcome and an instrumental mechanism that supports durability.

Distributional justice outcomes are more variable and depend on benefit-sharing arrangements, labor burdens, and how protective benefits intersect with spatial patterns of exposure. Even where a community collectively benefits from reduced hazard impacts, burdens may fall unevenly through unpaid maintenance work, restricted access to resources, or opportunity costs borne disproportionately by specific groups. Gendered patterns are particularly salient, as stewardship labor and resource access are often structured by gender norms. Recognition justice is most prominent in cases involving Indigenous stewardship, where outcomes include not only material risk reduction but also the affirmation of rights, governance authority, and knowledge systems. Where recognition is weak, studies frequently note distrust, contestation, and the risk that NbS becomes a vehicle for external agendas that reconfigure land and resource control. A critical implication is that community-led NbS cannot be evaluated solely by aggregate risk reduction metrics. Evaluations need to ask whose risks are reduced, whose livelihoods are stabilized, and whose burdens increase. Without this distributional lens, projects can be labeled successful while intensifying marginalization for specific subgroups. The literature suggests that equity outcomes are most favorable where governance includes inclusive representation, transparent decision rules, enforceable benefit-sharing, and accessible mechanisms for grievance and redress [73].

5.5. Trade-Offs, Unintended Consequences, and Maladaptation Risks

It is also recorded in the outcomes literature that there have been various trade-offs and unintended consequences, some of which may have been maladaptation when they make people more vulnerable or redistribute risks among people who already face them. One repeated device forming the repeated form of inequality is the process of elite capture known as the inclusion of decision authority, resources, or gain by local or external elites, which subverts both equity and ecological stewardship. A second typical trade-off could be presented by protective ecosystem activities that limit access to livelihood-supporting resources, e.g., fishing areas, fuelwood, or grazing lands, and do not replace such access with fair compensation. Under these circumstances, communities can suffer short-term losses that diminish the support for stewardship and result in conflict or noncompliance [74].

The city environment poses unique risks, particularly where greening adds amenity value and causes displace-

ment or housing insecurity for low-income earners [75]. In such environments, NbS could decrease heat exposure and the risk of floods and enhance social vulnerability by raising the cost of living and place-based networks. The dynamic highlights the fact that adaptation can never be taken as simply a reduction of hazards only, but should consider the socio-economic trajectories that combine to define vulnerability. The lack of anti-displacement protection and equity-focused planning can also cause the community-led initiatives to perpetuate green gentrification even when locally motivated.

The biophysical trade-offs and restrictions are also found in the literature [76]. Certain interventions could cause ecosystem services, including water use by some species of trees in water-deficient areas or the risk of wildfires due to poorly managed vegetation. Other forms fail when ecosystems are not mature enough or when climatic extremes are surpassed. Those risks do not need to be countered by NbS, but note the relevance of careful species selection, assessment of the appropriateness of the site, and adaptive management, which takes into account an evolving baseline.

5.6. Measurement Patterns and What They Imply for Synthesis

This heterogeneity in results found in the literature is a consequence not only of the interdisciplinary nature of NbS research but also of the institutional incentives governing evaluation. The reason why proximal ecological metrics are prevalent is that they can be measured in short project cycles, and they agree with expert knowledge in ecological monitoring [77]. The vulnerability outcomes and equity outcomes are less prevalent since they involve a longer time frame, social data, and consideration of counterfactual conditions. What has been produced is a literature that tends to validate assertions regarding functional plausibility and is unclear on the extent, sustainability, and distribution of benefits.

There are two implications in the interpretation of this pattern of measurement. The first is that in synthesis, proxy indicators should not be considered to be equal to reduced risk despite strong ecological logic. Second, there is no even distribution of evidence gaps; rather, the gaps accumulate in areas where measurements of outcomes are most difficult, that is, in areas where there are avoided losses in times of rare extremes, long-term maintenance performance, and distributional effects in heterogeneous communities. These gaps are imperative to sound policy translation whenever a program of translating NbS is being scaled with climate finance practices requiring quantifiable performance/output and safeguards [78].

5.7. Summary of Outcome Insights Guiding the Next Section

Combined, the body of evidence on outcomes indicates that community-led NbS often exhibits plausible ecological mechanisms through which to lessen climate threats and is able to augment the adaptive capacity by co-option of livelihood and social advantages. The evidence to support direct loss or vulnerability reductions is also less consistent and is of thin coverage regarding long-term sustainability at extremes, however. The result of equity is very reliant, and it is based on the representation, sharing of benefits, protection, and overall political economy of land and resource control. The commonality of trade-offs and the threat of maladaptation is high enough that it can be the subject of systematic consideration, especially within a context of tenure insecurity, intense market forces, or city-building processes [79]. The results encourage the governance-oriented discussion in Section 6, which entails the analysis of which institutional designs and innovations most regularly lead to lasting and equitable results and whether certain pathways of failure tend to be common irrespective of hazard-ecosystem setting.

6. Governance Innovations and Enabling Conditions

6.1. Why Governance Is Treated as a Determinant of Outcomes

The evidence collected and integrated in the above sections indicates that adaptation approaches of Nature-based Solutions (NbS) led by communities are not often constrained by ecological logic only [80]. Rather, the stability of ecosystem operation, the plausibility of risk-minimizing agendas, and the distribution of gains and losses will revolve around the organization and the arranged structure of authority, resources, and responsibil-

ity. Here, therefore, governance is seen as a predictor of results and not background context. The design fit, stewardship, compliance, and learning can be facilitated by community leadership but it may be compromised when the leadership position is symbolic, the funding is short-term, the rights are not secure, and the internal inequities are not addressed. The governance innovations presented in this section are perceived as institutional designs and policy mechanisms that extend or guard decision authority of communities, guarantee incentives for stewardship, and align objectives of adaptation and equity, and ecological integrity.

6.2. Rights and Tenure Innovations: Securing the Foundations of Stewardship

In hazards and ecosystems, rights and tenure are enabling conditions since they define incentives and the ability to engage in long-term stewardship. In locations where communities have secure and enforceable land, water, forest, rangelands, or coastal commons possession, the literature is more likely to describe permanent upkeep and the capability of thwarting external deterioration drives on restored ecosystem locations. On the contrary, since rights are unclear or disputed, even technically competently designed NbS may not be effective because communities are extracted by external institutions, negatively affected by development contexts or conservation limitations, and the consequent local legitimacy is diminished [46–48].

Statutory acknowledgment of customary tenure, legal reform that formalizes the community stewardship rights and co-title structures that share power throughout the community and state without undermining the local governance autonomy, are some of the governance innovations in this area. In other contexts, recognition may be in the form of community conserved areas or Indigenous territories, which connect the results of adaptation to larger-scale self-determination and culture. Rights-based innovation also involves mechanisms that explain control and exclusion criteria on commons and therefore ease tension and establish binding terms on collective action. Significantly, the evidence suggests that recognition of rights is not just a juristic goal, but a practical potential; rights that exist on paper but are loosely observed do not normally give the sense of stewardship that the community-led NbS needs [8,81].

6.3. Institutional Arrangements That Make Community Authority Operational

NbS, based on the communities, relies on institutions that convert authority into the practice of decision-making throughout the intervention life cycle. In the literature, there are reports of various institutional forms, such as customary councils, community forestry committees, fisher associations, rangeland cooperatives, watershed councils, and co-management boards of a specific area or coastal zone. These institutions differ in terms of the distribution of power, the structure of representation, and the enforcement of decisions. The enabling institutional arrangements are not known by their formal name, but the capacity to decentralize actual decision-making to communities and still have access to a means of coordination with other agents acting at other levels, including a municipality, basin authority, or national agency.

Co-management is often brought forth as an innovation in governance since it forms formal systems of joint power [82]. The evidence does, however, also indicates that co-management can also create asymmetries in the case of decisive control by state agencies and the main contribution of labour or legitimacy by communities. The co-management that is correlated with long-term effects is more frequently related to the situation when the community establishes enforceable rights to rule-making, monitoring, and distribution of benefits, as well as when the process of decision-making is transparent and procedurally fair. The same dynamic is depicted by watershed institutions. Since upstream activities may produce downstream benefits, some efficient community-based watershed NbS may need institutions without borders across communities and jurisdictions. Governance innovations in this case are basin committees, which contain rules of representation that minimize upstream-downstream conflict and benefit-sharing mechanisms that factor in different costs and benefits [83].

The urban environment is a unique institutional challenge due to the lack of the ability of the communities to have control over land and space [84]. Their particular innovations of significance to cities in this regard are therefore community stewardship arrangements, community land trusts, and formal partnerships that confer long-term man-

agement rights over green spaces. In the absence of such arrangements or on a short-term basis, such a pattern of episodic planting with non-maintenance is often characterized in the literature as a form of limited control over where to plant and is susceptible to any redevelopment pressures that might destroy any gains achieved in adaptation.

6.4. Finance Innovations: Devolved Funding, Long-Horizon Maintenance, and Incentive Alignment

The issue of financing is consistently cited as a veto of community-led NbS, especially since the returns on ecosystem restoration and ecosystem maintenance have long-term payoffs, when decisions to fund the ecosystems tend to be short-term and capital-driven. Funding modalities that fund the rapid disbursement and the standardized outputs put the interested community at a disadvantage, thus promoting the appearance of the action rather than long-term stewardship. The governance literature thus focuses on financial innovations that devolve the decision authority, fund maintenance, and monitoring, and cut administrative and administrative burdens which lock out smaller community organizations [85].

Small-grants windows and devolved adaptation funds are the features that stand out since they have the potential to bring more control over priorities and resource allocation closer to communities. At locations where they are successful, it is indicated that they incorporate unambiguous eligibility guidelines, predictable schedules of disbursement, and provision of administrative capacity instead of considering overhead as a waste. Long-horizon financing is also important. Community-based NbS may have multi-year operation and maintenance support, among other requirements, such as adaptive management and local monitoring of the operation. Continuity can be maintained with accountability as mechanisms like stewardship contracts, tranches based on a performance strategy tied to mutually defined indicators, and pooled finance administered by trusted intermediary institutions can be used [86].

The increasing confusion between NbS to address adaptation and finance associated with ecosystem service markets, such as payments for ecosystem services and carbon-related finance, is also discussed in the literature [87]. These mechanisms are capable of both providing new resources and may also lead to the distortion of priorities when mitigation measures take over or when market engagement creates new forms of inequality. Governance options in this sector are thus centered around benefit-sharing regulations, safeguarding against land grabbing, and the preservation of local decision-making so that finance supports the provision of the ecosystem's functions and services that are relevant to the traditions and thereby locally treasured instead of introducing externally relevant performance logics.

6.5. Safeguards, Accountability, and Conflict Resolution as Core Governance Components

According to the literature available, the threats of exclusion, elite capture, and displacement are not exceptional occurrences; they are general trends that need specific governance reactions. Protective measures and control systems thus act as facilitating factors for ethical and sustainable community-based NbS, rather than ancillary services. In places where communities have authority, internal accountability mechanisms influence the decision-making process of whether decisions are based on the broad interests of the communities or the narrow elites. In cases where external actors have financed or technically assisted the community, accountability is what makes the difference between instrumentalizing and respecting the leadership of the community [88].

Innovations in governance in this sphere are grievance and redress systems that are available and credible, transparency conditions of benefit-sharing and funds distribution, and procedural safeguards of consent where applicable. Urban amenity values and rent increases, as well as redevelopment pressures, can cause displacement through greening interventions, particularly in urban areas, where such protection is especially needed. The evidence indicates a greater likelihood of just adaptation pushing ahead in cities when given in association with institutional interventions, including anti-eviction laws and controls on trans-community land forms or instruments to control planning that sustains affordability and residents' right to stay [89].

Conflict resolution institutions are also becoming very important, particularly in common-pool situations in which resource regulations may subject livelihood strategies to temporary limitations. The non-observance of rules, which are seen as obtrusive or unjust, may threaten the ecological performance and the social unity. Good community-based arrangements are likely to contain believable procedures for updating rules, resolving disputes, and responding to evolving circumstances, and this is close to the bigger picture of adaptive governance [90].

6.6. Knowledge Co-Production, Monitoring, and Data Governance

One of the unique aspects of community-led NbS is the possibility to combine the experience, local and indigenous knowledge with scientific and technical knowledge. According to the literature, this type of integration can positively influence design fit, monitoring of ecosystem condition, and learning in a changing climate baseline. The community-based monitoring and citizen science techniques are often referenced as innovative methods that offer a wider spatial and temporal reach of the information and enhance local stewardship. Communities can also help to make ecological change more legible, locally significant, and adaptive management decisions can be based on community-generated evidence as well as offered by external assessments [91].

Simultaneously, it is also observable in the literature that there are also tensions concerning the data ownership, extraction, and use of knowledge [92]. Trust may dissipate, and the participatory level may be transactional, where external actors gather data that may lack any form of reciprocity or control. The governance innovations in this area are agreements to define the rights to use data, protocols designed to guard sensitive knowledge, and, in Indigenous contexts, methods associated with the principles of Indigenous data sovereignty. Such arrangements are not only ethical, but they have implications for the long-term monitoring viability and legitimacy of the adaptive management.

6.7. Scaling Pathways That Preserve Community Leadership

One main policy goal of NbS is scaling, although it is also a main administration risk. Common protocols and blistering development can water down the leadership of communities, making a community-focused approach a meaningless brand name where power is concentrated among donors and nongovernmental organizations or with state institutions. The literature thus differentiates between scaling that enhances the number or territory of NbS interventions and scaling that does not qualify to alter the institutional attributes, contesting community-based solutions to be not only impactful but also righteous [93].

It has been observed in further journeys to scale, such as to maintain leadership, that scaling can proceed via peer learning networks and federations of community organizations, in which mutual accountability and scaling out through networks and federations assist in the refraining of exemplars of a single model. The scaling can also be provided with the help of a boundary organization plus using intermediaries that can assist with technical support, finance management, and monitoring, and keeping the right of the community to decide. The other recurring innovation is the emergence of minimum governance principles of the community-led NbS, such as those of decision rights, representation, benefits-sharing transparency, operation protection, and maintenance finance. These standards have the potential to make sure that scaling does not replace procedural legitimacy with formal participation [73].

6.8. Governance "Bundles" and Recurring Failure Modes

In the evidence base, there are seldom situations in which governance conditions can stand alone. Long-term and sustainable results are more commonly linked with collections of empowering characteristics that mutually enhance each other [94]. Authorities on securing rights render the incentives of stewardship credible, operationalize the decision-making authorities in institutions, supply financing to maintain the asset repairs over the long run, guard against damages and alienation, and tracking contributes to learning and adjustment. The absence of one component may weaken the whole system. Indicatively, devolved finance with no protection can worsen the level of elite capture; realized rights not followed through may not help in safeguarding ecosystems against extraction; authority by community without finance over the long run may cause

a maintenance trap, which reduces support in the medium term; and undisciplined surveillance may damage trust and participation. These enabling bundles, along with the risks and protections that accompany them, were summarized by us into a limited set of settings of design relevance governance (**Table 4**).

Repeat failure modes are evident throughout the hazards as well as the ecosystems. They are participation-washing, in which the community is promoted, but the power is external; short-term project rotations, in which the plants are funded but not maintained; institutional designs that shut out the marginalized groups; benefit-sharing, which is obscure or inequitable; and scaling, in which targets on area rather than on quality governance are the focus [73]. The urban cases contribute a unique mode of failure whereby the NbS ameliorates environmental conditions and escalates the pressure of displacement, thus making people more vulnerable due to the socio-economic pathways. It is critical to identify these failure modes so as to be able to translate the findings of the review into sound policy advice.

Table 4. Governance innovation bundles supporting durable community-led NbS implementation.

Governance Bundle	What It Looks Like in Practice	Why It Matters (Mechanism)	Common Failure Mode	Safeguard/Design Response
Rights & tenure security	customary/statutory recognition; stewardship agreements; co-title	increases stewardship incentives and enforcement legitimacy	"Paper rights" unenforced; land grabs after value increases	enforceability; boundary clarity; legal aid; anti-grab provisions
Inclusive institutions	representative councils; transparent rules; dispute resolution	reduces elite capture; strengthens legitimacy & compliance	exclusion of women/landless/migrants	quotas/representation rules; public deliberation; grievance channels
Long-horizon finance	O&M funding; stewardship contracts; devolved grants	sustains maintenance and adaptive management	capex-only funding; burnout; project decay	multi-year tranches; budget for maintenance/monitoring; overhead support
Accountability & safeguards	grievance mechanisms; benefit-sharing rules; FPIC where relevant	prevents harm; enables course correction	participation-washing; opaque benefit distribution	independent audits; public reporting; enforceable benefit-sharing
Monitoring & data governance	community monitoring; co-produced indicators; data rights protocols	supports learning; builds trust; improves fit	data extraction; mistrust; unused data	data-sharing agreements; local control; feedback loops to decisions
Scaling with integrity	networks/federations; boundary org support	spreads practice without eroding authority	standard templates override local priorities	minimum standards for authority/safeguards; flexible design menus

Note: Summary of governance elements commonly found in successful community-led NbS, such as tenure security, inclusive institutions, long-term finance, and accountability mechanisms and the risks that emerge when these elements are absent. The synthesis illustrates how governance conditions interact to influence implementation durability and equity outcomes.

6.9. Transition to Limitations and Prospects

The reviewed governance innovations explain the reasons why community-led NbS can provide lasting adaptation results and why it can occasionally fail or may cause harm [68]. They also inform us that the idea of community leadership is best thought of as an institutional accomplishment, built by rights, finance, safeguards, and accountable decision-making, and not as an intrinsic project characteristic dubbed as community-based. These understandings pre-establish the ensuing discussion that explores shortcomings in the evidence base and practice, recognizes disadvantages and boundary cases, and provides future opportunities towards evaluation, finance, and governance reforms that can support community-led NbS in the increasing climate risks. This is summarized in **Figure 3** under the interaction of governance bundles to influence quality of implementation, durability, equity outcomes, and repeat failure modes, in the absence of key enabling conditions [95].

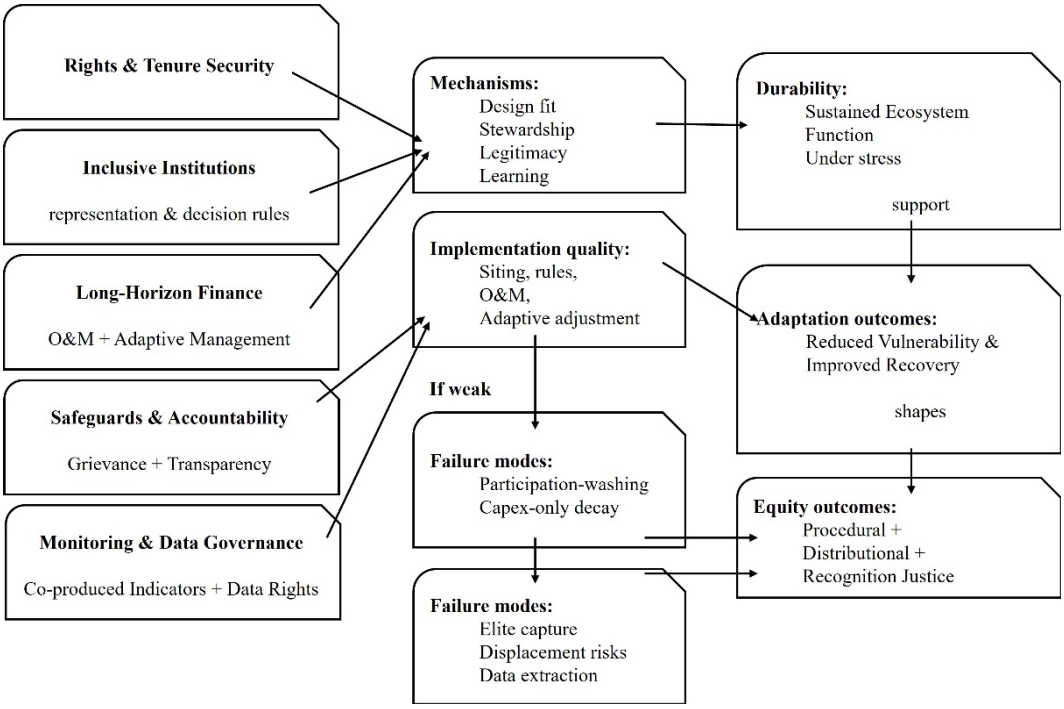

Figure 3. Governance "bundle" model linking innovations to outcomes and failure modes.

7. Limitations, Drawbacks, and Prospects

7.1. Limits of the Current Evidence Base

Although the literature on community-led Nature-based Solutions (NbS) to tackle climate adaptation has grown at a very fast pace, the evidence base is skewed in a manner that limits the ability to make inferences with confidence [13]. One of the key weaknesses of the studies is that most of them reveal proximal ecological transformation and scant evidence of downstream losses in human susceptibility. The given pattern demonstrates the relative tendencies of measuring systems that indicate the ecosystem and the challenge in attributing the changes in the losses, well-being, or recovery paths to NbS in the context of complex social-ecological systems. Practically, NbS interventions often overlap with engineered defenses, land-use change, livelihood programs, and the disaster risk management intervention, making it difficult to isolate the effect without a robust counterfactual logic, extended time series, or comparative designs. This has led to the fact that much of the literature does not endorse sound estimates of magnitude, durability, and allocation of benefits but conjectures risk-reduction mechanisms [96].

The second weakness is that there is inconsistent reporting of the governance conditions. Research usually explains that there was community participation but fails to state clearly what the decision authority was, how the representation was implemented, and how the benefits and responsibilities were distributed. This vagueness is significant since the main assumption of the review is that the leadership of the community modulates the outcomes. In instances where authority and accountability are not sufficiently reported, statements on the effectiveness of governance have to be cast based on inference and not on direct evidence, and the comparisons across cases are not as precise. Similarly, the term community is often discussed as an active entity, which covers the inner heterogeneity and power relations that define the participants and beneficiaries. This adds to an evidence base that can inflate the effects of equity in situations where intra-community exclusions are large but under-researched [97].

The distribution of studies in geography and language is also uneven. Areas that have good research institutes, or have donor funding, or have an existing conservation program, tend to be overrepresented, whereas those regions with less represented in the indexed journals, but where community stewardship is extensive, may

be underserved. Grey literature partially balances this imbalance out, but it has other limitations, such as inconsistent transparency of methodology and incentives to report success. Publication bias is thus an unending issue, especially since NbS is usually touted as a win-win technique. Losses, disagreements and ill-distribution outcomes are less prone to be reported in peer-reviewed sources, although they are vital towards learning and formulating protective measures.

Lastly, there is a low level of evidence base that can assess performance in terms of increasing climate extremes and changing baselines [98]. Most NbS interventions take time to develop, and most of the evaluations are made in the short term, which fails to reflect extreme events or the long-term maintenance dynamics. This leaves one wondering how long-term protection can be guaranteed, particularly in situations in which ecological limits can be violated, when risks of compounds are becoming more frequent, or when social and economic tension on land and resources is increasing.

7.2. Practical Drawbacks and Boundary Conditions in Implementation

In addition to limitations on evidence, community-led NbS has more practical disadvantages that can influence results even in cases of a proper ecological design. The common problem is that of time and labor in many instances. Community leadership and stewardship tend to be very deliberate, involve a lot of coordination, and constant maintenance. Community-led NbS may go extractive when the demands are not accompanied by a sufficient amount of resources, capacity support, and acceptable compensation, based on unpaid labor, triggering fatigue or burnout. This relationship may undermine the legitimacy in the long term, and may diminish the disposition to support the benefits of restorations at the end of the external project cycles [99].

Boundary conditions also persist in the representation and internal equity. Community-led governance may be susceptible to elite capture, marginalization of the disadvantaged groups, and making decisions that favor those with higher social status, landholdings, or political affiliations. The given dynamics cannot be considered peculiar to NbS, yet they are especially drastic when interventions change access to resources or redistribute protective benefits. Unless the community establishments are set to tackle the hyper heterogeneity and unequal power balance, it means that community-led NbS may create unequal results yet still save the facade of credibility through local branding [8].

The other significant limitation would involve tenure insecurity and claims on land and resources. Where communities do not have secure tenures or owners and managing communities have a number of parties exerting their authority over commons, NbS interventions may introduce conflict, facilitation of appropriation or a focus on displacement in the event that land value is escalated by restoration. In these situations, community-based NbS can turn into a place of political conflict as opposed to a path to resilience, particularly when outside forces inject streams of finance that exacerbate the level of competition. These processes emphasize that the NbS is not apolitical; it rationalizes reward and dominance by land, water, and ecosystem services [100].

City environments have their own unique disadvantages. Although it is causing the environment to be less exposed to heat or increasing the stormwater levels with improved management, the amenity returns can fuel gentrification forces, even at the expense of ensuring the low-income locals can still stay there and produce the advantages. These environments do not permit the evaluation of NbS as a tool of adaptation that is not contingent on housing policy, land markets, and development processes. Community-led initiatives can be helpful in reducing certain risks by deciding the siting and stewardship, yet unless incorporating robust measures that discourage displacement and establish effective anti-displacement mechanisms that focus on preserving affordability, NbS will be self-contradictory in causing vulnerability through systemic socio-economic processes.

Ordinances on the ecological borders also restrict the universality of community-led NbS [70]. The recovery of an ecosystem is a process that does not happen quickly; it may not be effective to protect under the influence of very large events, and some interventions will not work effectively when climatic conditions change very fast. Misuse or mismatch between the regime of intervention and a species can decrease effectiveness or cause ecosystem disser-

vices, such as poor species selection or poor maintenance. In arid areas, such as some types of afforestation may distort hydrological conditions, which damage water security. These environmental constraints do not diminish the usefulness of NbS but they strengthen the necessity to design and manage them carefully and even utilize hybrid portfolios combining NbS and engineered and social actions in most settings.

7.3. Future Prospects: Methodological Advances That Could Strengthen Inference

The future direction of the study of community-led NbS as an adaptation strategy is probably influenced by the evaluation methods that will shift away from short-term proxies and toward a more robust causal inference and distributional analysis. It has methodological perspectives to use broader application of quasi-experimental designs, comparative case design, and mixed-method methods of assessment, which would incorporate ecological monitoring and household and community social realities. Repeated surveys and panel data are longitudinal designs, which can be better used to understand adaptive capacity changes and the recovery patterns, whereas event-based analyses can be used to understand the NbS response under and following extremes. The improvement in remote sensing and geospatial analysis has the potential to provide better measurements of ecological and exposure measures, although they will require social data to prevent overstating the success of adaptation using biophysical proxies [101].

One of the most significant opportunities is that standardized and equity-oriented sets of indicators are being created and used in adapting NbS [102]. Ecological functional and vulnerability reduction would be differentiated through such suites and procedural, distributional, and recognition dimensions would accompany them as the key measures. Standardization does not require uniformity but may help to create comparability and still give the area indicators an opportunity to be locally shaped in order to capture local context and local priorities. When this change is accompanied by clear reporting of governance provisions, it would go a long way in enhancing the field's ability to do cross-case learning and to scale with integrity.

7.4. Future Prospects: Governance and Finance Reforms for Durable Community Leadership

Better institutional and financial reforms based on the alignment of incentives with long-term stewardship are also prospects of stronger community-led NbS. Devolved adaptation funds, streamlined access by community organizations and financing arrangements that will facilitate operations and maintenance and not installation alone, are bound to become more important. Through governance reforms that clarify and enforce rights and tenure, is equally critical, so as to enable communities to prevent external degradation of restored ecosystems, and so that the community can gain the benefits of stewardship. In most situations, the future of community-led NbS is either going to depend less on technical advice on restoration or on the political and legal legitimization of community power [8].

Protective and responsibility frameworks are also most likely to be updated as NbS will be characterized by closer interactions with climate funds and performance indicators [38]. The risks of elite capture, displacement, and participation-washing are increasing with the level of funding. The innovations in governance in the future will thus require the adoption of grievance and redress mechanisms, open systems of sharing benefits and safeguarding the vulnerable segments of society, especially in cities where the pressure of displacement is high. Increasing the focus on data and monitoring will increase the relevance of ethical data governance as well. Learning and legitimacy can be reinforced by community monitoring, but that demands communities maintain control over data use and that monitoring is associated with decision-making controlled by communities.

Another significant opportunity is scaling the pathways that maintain the leadership within a community. Instead of scaling using the standardized templates, it has been shown that scaling out to the networks, federations, and peer learning could be more effective in preserving the local authority and allowing the diffusion of practice. This can be facilitated by the boundary organizations and intermediaries who can offer technical assistance, financial management, and monitoring infrastructure as such, however, the challenge in design will be to make sure that these intermediaries complement, and not substitute, the

community decision-making [103].

7.5. Future Prospects: Adaptation under Compounding Extremes and Shifting Baselines

The frequency of the compound and cascading hazards is rising as a result of climate change, and the future perspectives of community-led NbS will be determined by the quality of these interventions in relation to the stress and the rate of learning and adaptation in the governance systems. This will necessitate the stress testing of NbS designs to the extreme event conditions, determine the ecological thresholds and failure conditions, and incorporate adaptive management triggers to trigger action where there is a change in conditions. This rather speculative opportunity is that NbS will not avoid risk, but that community-based governance can allow adaptive responses to vary both restoration and management strategies as baselines vary. Practically, community-led NbS will probably be based on hybrid adaptation systems that will integrate ecosystem interventions with engineered measures, land-use planning, early warning systems, and social protection. The key to community leadership staying central in such systems can be through recognition of decision authority and the ability of communities to influence how portfolios are formed, sustained and evolved. In this regard, the future of community-based NbS cannot be seen outside of more general waves of change in adaptation governance to polycentric coordination, justice-based planning, and long-term investment [104,105].

7.6. Implications for the Review's Overall Argument

These limitations and drawbacks do not undermine the relevance of community-led NbS; on the contrary, they shed more light on the circumstances in which the latter may plausibly provide climate adaptation, and what risks need to be addressed as NbS becomes larger. The strongest evidence base is now the ecological functioning and the weaker base is long-term vulnerability reduction and equity outcomes, whereas practice is limited by the insecurity of tenure, temporary funding, the problem of representation, and, in the urban setting, the dynamics of displacement [106]. The way forward is the ability to enhance the methodology to make causal inference and distributional analysis more robust and governance and finance reforms to ensure rights, finance maintenance, introduce safeguards and scale via mechanisms that maintain community authority. These reflections precondition the final part, where a synthesis of the transferable lessons of the review and the statement of the design principles and research priorities for further developing community-led NbS as a sustainable and equitable response strategy.

8. Conclusion

This review highlights an important but often overlooked insight in the literature on nature-based solutions (NbS): community leadership alone does not guarantee effective or equitable adaptation outcomes. While community-led approaches are frequently associated with stronger stewardship, local legitimacy, and improved contextual fit, the evidence suggests that these advantages translate into durable adaptation benefits only when they are embedded within enabling governance conditions. In particular, secure tenure or resource rights, long-term financing arrangements, and accountability mechanisms consistently emerge as critical complements to community leadership. Where these conditions are absent, NbS initiatives—even when participatory—may struggle to maintain ecological performance over time or may reproduce existing inequalities through elite capture or uneven benefit distribution.

A second key insight is that governance conditions operate as mutually reinforcing "bundles" rather than as isolated design features. Successful community-led NbS rarely depend on a single institutional innovation; instead, they combine multiple elements, including inclusive decision-making structures, sustained financial support for maintenance and monitoring, and mechanisms that ensure transparency and grievance redress. These institutional combinations appear to enable not only better ecological management but also stronger social legitimacy and long-term stewardship. Conversely, interventions that prioritize ecological design while neglecting institutional arrangements often show weaker evidence of sustained adaptation benefits.

Together, these findings suggest that the effectiveness of community-led NbS should be understood less as

a function of participation alone and more as an outcome of institutional alignment between local authority, resources, and accountability. Future research and policy efforts should therefore move beyond the simple promotion of "community-led" approaches and focus instead on identifying the governance configurations that allow local leadership to translate into durable, equitable adaptation outcomes.

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Conflicts of Interest

The authors declare no conflict of interest.

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