Four-pillar synergy in spring-water conservation: An early-stage evidence mapping and evaluation protocol from Pasuruan, Indonesia

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Abstract. Spring-water conservation in tropical uplands often fails when interventions remain single-sector and monitoring is not embedded into local governance. This study aimed to present an early-stage evidence mapping of the Climate Action and Sustainable Landscape in Mountain Arjuna (CITASAMA) program in Prigen Subdistrict, Pasuruan (East Java, Indonesia) using a four-pillar synergy framework (education, ecology, social institutions, and local economy). A qualitative case-study was conducted using document-based analysis of the CITASAMA first-year report (May 2024–April 2025), Agropreneur Local Community cooperative materials, and the 2025 organizational evaluation. Reported indicators were extracted and coded into the four pillars, with explicit assessment of data completeness, uncertainty reporting, and verification limits. The documents report that the program reached approximately 36,105 beneficiaries and supported restoration activities involving more than 14,000 planted trees. They also present baseline discharge data for eight springs, measured using float and volumetric methods. In addition, the documents include biodiversity metrics based on the Shannon–Wiener index, showing very low tree diversity in a monoculture pine area (H'=0.154), as well as contrasting carbon stock estimates between areas classified as "high greenness" and "moderate greenness. Economic and inclusion indicators were reported through cooperative legality and employment at Wanawisata (70 workers, including persons with disabilities). These values were treated as reported baseline/process indicators. The current study proposes an evaluation protocol and a measurement timeline to enable future evidence-based assessment of hydrological, ecological, governance, and livelihood outcomes.
Key Words: evidence mapping, spring conservation, watershed rehabilitation.

Introduction. Spring-waters are the visible outlet of a wider hydrological system, and their discharge is shaped by infiltration processes, soil structure, vegetation cover, slope stability, land-use dynamics, and the governance of access and extraction (Shah et al 2022; Wang et al 2023; Xu et al 2024). In tropical upland landscapes, these biophysical determinants interact with climate variability and socio-economic pressures, producing complex risks for water security (Uriarte et al 2011; Vu et al 2014; Adeyeri 2025; Bojer et al 2025). Consequently, spring conservation cannot be reduced to a single technical action (for example, tree planting around a spring eye). Instead, it requires an integrated system that makes conservation ecologically functional, socially legitimate, and economically sustainable (Gann et al 2019; Pereponova et al 2023; Gürsu 2024).

The Climate Action and Sustainable Landscape in Mountain Arjuna (CITASAMA) initiative is an integrated climate action program that combines forest conservation, watershed rehabilitation, climate education, and sustainable agriculture. Implemented in the water-catchment context of the Prigen Subdistrict, the program explicitly frames conservation as cross-sector partnership action, bringing together multiple actors around a shared landscape agenda (Cempaka Foundation 2025a;2025b;2025c;2025d). However, a persistent weakness in conservation practice is an over-reliance on easily counted outputs, such as the number of seedlings planted, without ensuring long-term maintenance, institutional accountability, and continuous monitoring. This often produces "single-pillar fragility": planting declines after project cycles end, institutions struggle when livelihood incentives are absent, and education campaigns remain symbolic when communities lack practice spaces and sustained support (Gann et al 2019; Wibowo et al 2024; Chen et al 2025; Husamah et al 2025; Rahardjanto et al 2020a; Rahardjanto et al 2020b; Rahardjanto et al 2024; Rahardjanto et al 2025). In contrast, CITASAMA's documentation signals a shift toward indicator-based, multi-actor conservation by treating spring discharge measurement as baseline evidence and a benchmark for subsequent monitoring (Cempaka Foundation 2025b). The report also connects ecological rehabilitation to scientific collaboration involving three universities, aiming to strengthen evidence and impact measurement. Beyond technical indicators, organizational evaluation underscores the need for a clear backbone system to support scaling, explicitly stating that "System & Manual Book Must Be Done in 2025," indicating a deliberate move away from ad-hoc implementation toward standardized procedures and institutional memory (Cempaka Foundation 2025d).

Against this background, the present study documents and analyzes spring-water conservation in Pasuruan as a good-practice case using a four-pillar synergy framework: education–ecology–social institutions–economy. The study synthesizes evidence-centered indicators from program documentation, including spring discharge, biodiversity indices, carbon storage potential, and agroforestry baselines. Second, it clarifies an institutional pathway by showing how diversified local organizations function as governance infrastructure for collective action and agroforestry scaling. Third, it documents how cooperative and social-enterprise elements are positioned to finance stewardship and promote inclusive benefit distribution, thereby strengthening the economic pillar of conservation. Finally, it derives transferable design principles that may inform spring and watershed conservation programs in comparable tropical upland contexts.

Spring systems are classic socio-ecological commons where water security depends not only on biophysical restoration but also on rules, legitimacy, monitoring, and incentives. Accordingly, integrated conservation frameworks should be positioned within established theory on collective action and adaptive management, including design principles for governing common-pool resources and mechanisms for learning through iterative monitoring and feedback. In practice, however, many conservation manuscripts over-report outputs (e.g., number of seedlings planted) and under-report causal logic, uncertainty, and counterfactual comparison. This gap is particularly visible in early program phases when ecological outcomes are not yet expected to manifest. Therefore, rather than claiming impact, this study contributes by mapping the available first-year evidence and by specifying an evaluation protocol that links the four-pillar synergy approach to measurable indicators, verification steps, and a multi-year monitoring timeline. The research questions are: (1) What baseline and process indicators are reported across the four pillars in the first-year documentation? (2) What are the key evidence gaps that prevent causal inference? and (3) What monitoring design can enable a future outcome-based assessment?

Material and Method

Study design. A qualitative case-study was conducted with document-based analysis to produce early-stage evidence mapping and to develop an evaluation protocol for outcome-based monitoring. The case was selected as an information-rich, partnership-driven initiative (CITASAMA) operating in a tropical montane catchment. The non-random selection of sites and the resulting limitations for generalization are explicitly acknowledged.

Data sources. The primary documents include: (1) CITASAMA Report First Year (May 2024–April 2025), (2) Agropreneur Local Community (ALC) cooperative and sociopreneurship materials, and (3) the 2025 organizational evaluation. These sources are program-produced documents; therefore, they are treated as self-reported evidence. To address verification limits, a planned triangulation layer for resubmission was added: public hydrometeorological records (rainfall proxies), satellite-derived vegetation indices, and, where available, government water-resource records (details provided in the Evaluation Protocol).

Data extraction coding, and evidence grading. Extracted statements and numeric values were coded into the four-pillar synergy domains (education, ecology, social institutions, economy). Each numeric indicator was additionally graded for evidence completeness using a checklist: (i) measurement date/season, (ii) replication and sampling effort, (iii) uncertainty quantification (e.g., SD/SE/CV), (iv) quality assurance procedures, and (v) availability of counterfactual or historical comparison. Missing fields were explicitly marked as "not reported" to prevent over-interpretation. An evaluation matrix was developed that distinguishes claimed/expected outcomes from measurable indicators and specifies the minimum evidence requirements needed for outcome-based inference (e.g., replication across wet–dry seasons, uncertainty quantification, and verification). This matrix also helps prevent over-interpretation of self-reported outputs by explicitly marking which indicators are available in first-year documentation and which require future monitoring. Table 1 summarizes the matrix across the four pillars.

Table 1

Claimed outcomes and measurable indicators (evaluation matrix)

Pillar	*Claimed/expected outcome*	*Measurable indicator*	*Minimum evidence required*	*First-year status*
Spring-water	Improved water security	Discharge (L s^{-1}) + seasonal CV; water quality (basic parameters)	Wet–dry season repeated measures; uncertainty; QA replication	Discharge reported; season/uncertainty not reported
Ecology	Improved infiltration/vegetation function	NDVI/greenness trend; tree survival; plot-based diversity	Baseline + annual trend; plot design; allometry/NDVI thresholds	Carbon/greenness reported; methods incomplete
Social institutions	Stronger governance & compliance	Rules/SOPs; participation; monitoring routines	Documented rules + independent confirmation	Reported in documents; verification limited
Economy	Sustainable financing & livelihoods	Cooperative net benefit (USD); conservation cost coverage	Transparent accounting; trend; cost-benefit	Cooperative Net Surplus (CNS) reported (IDR) needs USD conversion + interpretation

Results

Case setting and evidence window. CITASAMA is reported to operate across five villages (Dayurejo, Ledug, Pecalukan, Prigen, and Sukolelo) with a reported total of ~36,105 beneficiaries. The target landscape is the Upper Kedunglarangan Watershed (1,108 ha), consisting of 804.38 ha protected forest and 303.46 ha production forest. The evidence summarized below derives from the first-year documentation window (May 2024–April 2025) and is therefore interpreted primarily as baseline and process information, not as outcome evidence (Table 2).

Figure 1 summarizes the program phases and the documentation window used in this manuscript. Because hydrological regulation and ecological recovery usually require multi-year observation, the first-year evidence is treated as baseline and process information. Causal inference would require repeated measurements across wet and dry seasons, uncertainty analysis, quality assurance, triangulation with independent sources, and comparison with counterfactual or historical data.

Table 2

Program context (CITASAMA)

Component	*Evidence from documents*
Location	Prigen Subdistrict, Pasuruan, East Java (Indonesia)
Villages	Dayurejo, Ledug, Pecalukan, Prigen, Sukolelo
Reported beneficiaries	~36,105 people
Duration	2023–2026; Report period May 2024–April 2025
Core focus	Forest conservation, watershed rehabilitation, climate change education, sustainable agriculture
Target landscape	Upper Kedunglarangan watershed (1,108 ha; protected + production forest)

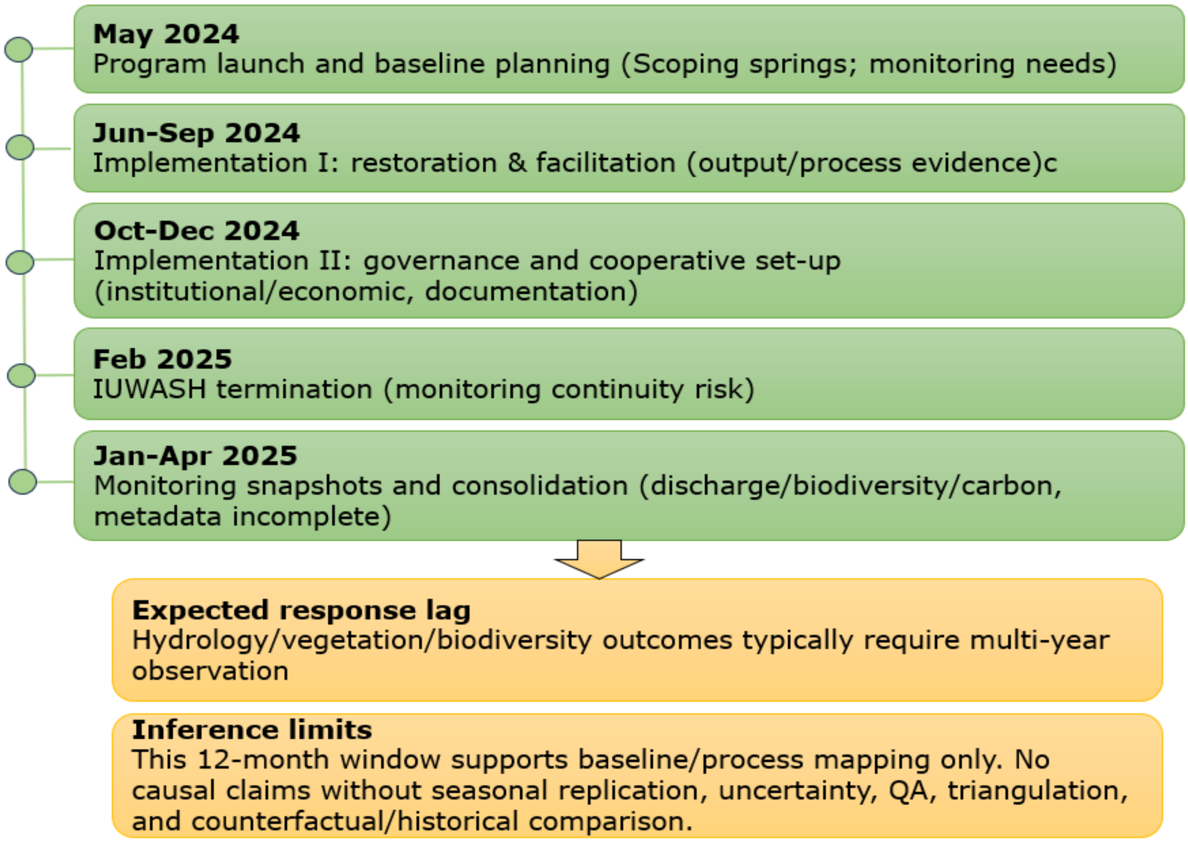

Figure 1. Activity–measurement timeline, expected response lag, and inference limits (May 2024–April 2025).

Figure 1 clarifies that the reporting window largely captures implementation and snapshot measurements, while hydrological and ecological outcomes typically require multi-year observation. This framing guides how the reported indicators are interpreted in subsequent subsections (baseline/process vs outcome inference).

Spring-water pillar: reported baseline discharge and evidence completeness. The program documents report baseline discharge values for eight springs, measured using float and volumetric field methods and presented as baseline evidence for subsequent monitoring. To avoid over-interpretation, these values are presented as reported snapshots and simultaneously disclose evidence completeness (date/season, replication, uncertainty, QA), which is required for outcome-based inference (Table 3).

Table 3
Baseline discharge of eight springs and potential recipients (reported snapshots) with evidence completeness fields

Spring name	*Discharge (reported)**	*Potential recipients (pers day⁻¹)***	*Measurement date/season*	*Replicates*	*Uncertainty (SD/SE/CV)*	*QA/notes*
Watu Pereng	0.037	53	Not reported	Not reported	Not reported	Reported snapshot only
Curah Tangkil	0.175	251	Not reported	Not reported	Not reported	Reported snapshot only
Bulurancang	17.516	25,223	Not reported	Not reported	Not reported	Reported snapshot only
Jenglong	3.161	4,551	Not reported	Not reported	Not reported	Reported snapshot only
Talang Watu	0.526	757	Not reported	Not reported	Not reported	Reported snapshot only
Sapen	0.591	850	Not reported	Not reported	Not reported	Reported snapshot only
Dawuhan	30.667	44,161	Not reported	Not reported	Not reported	Reported snapshot only
Lajer	0.728	1,049	Not reported	Not reported	Not reported	Reported snapshot only

*Discharge values are reported in program documents; the excerpt does not consistently specify measurement metadata required for seasonal or trend inference. **Potential recipients are reported using a domestic-use assumption of 60 L day^{-1}.

Ecology pillar: restoration outputs, biodiversity indices, and carbon/greenness screening estimates. Restoration outputs are reported in the first-year documentation, which states that more than 14,000 trees were planted in the Kedunglarangan watershed. In this study, planting is treated as an implementation output rather than an ecological outcome because survival, growth, and maintenance rates are not provided in the extracted evidence.

Biodiversity conditions are reflected in the reported Shannon–Wiener diversity index (H’) values, which are generally moderate (1<H’<3) but vary from low to high across sites and taxa. A notable risk signal is extremely low tree-stand diversity in Ledug production forest (H’=0.154), consistent with monoculture pine dominance, while Pecalukan production forest is reported to have higher tree-stand diversity (H’=2.536). Because the extracted documentation does not specify plot design, sampling effort, taxonomic scope, or protocol consistency for tree-stand assessment, these indices are presented as indicative reported values motivating standardized plot-based monitoring.

Carbon stock and greenness estimate also appear in the documents, which report average carbon stocks of 31.7 ton C ha^{-1} in high-greenness areas and 1.98 ton C ha^{-1} in moderate-greenness areas. However, the extracted evidence does not specify greenness classification thresholds (e.g., NDVI cut-offs), the carbon pools included, or the allometric equations used. These values are treated as screening estimates and not interpreted as program impact.

Figure 2 summarizes how reported indicators in the documents align with each pillar (spring-water, ecology, social institutions, economy, and education). The figure is used for interpretive clarity, it shows which indicators are available in year one and where evidence gaps remain.

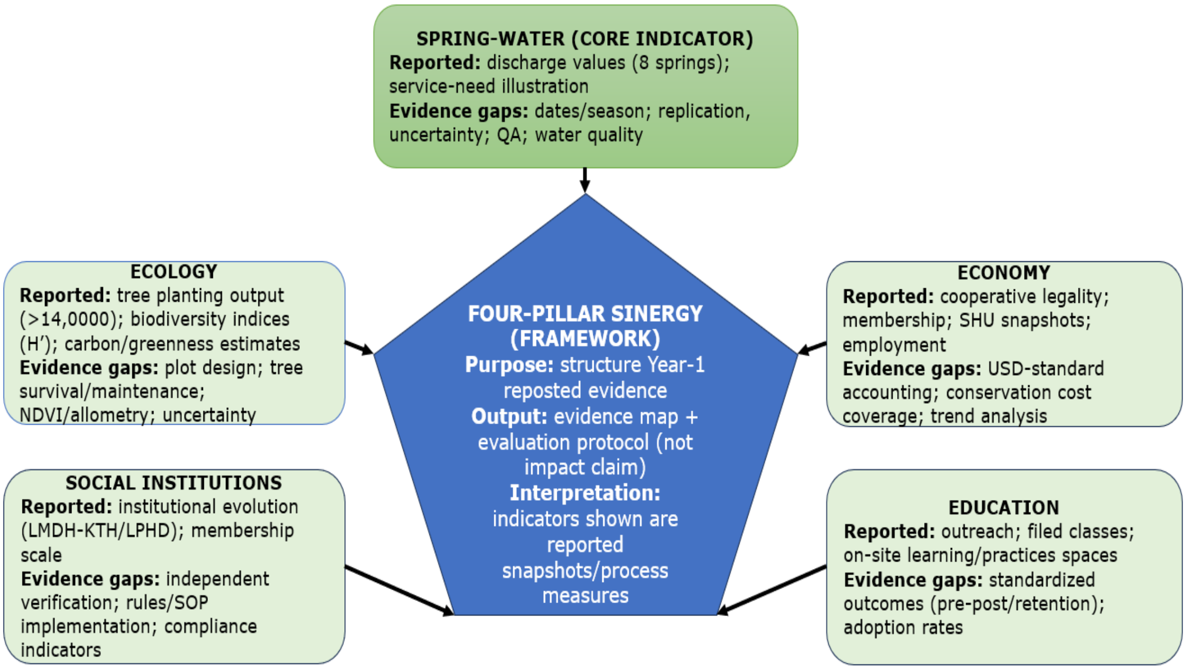

Figure 2. Four-pillar synergy framework linked to reported baseline/process indicators (first-year evidence mapping).

Social-institutional pillar: reported governance evolution and participation scale. The documents describe institutional evolution from centralized Forest Village Community Institution (FVCI) structures toward diversified organizations (including Forest Farmers Group (FFG) and Village Forest Management Institution (VFMI)) associated with commodities and management blocks. They report membership expansion with approximately 583 members across FFG/VFMI groups and around 5,500 persons in FVCI, supporting a target of 6,000 village farmers involved in agroforestry practices. These are presented as reported institutional scale indicators; independent verification is not available within the extracted evidence.

Education pillar: reported capacity-building activities (process indicators). Capacity building is described through public outreach, four field-class sessions, and on-site visits connected to practice spaces (e.g., composting and plot-based learning). These are reported as education process indicators. The extracted evidence does not provide standardized learning outcome metrics (e.g., pre–post scores, retention). Therefore, effectiveness claims are not made in the Results section.

Economy pillar: cooperative legality, reported CNS, membership, and inclusive employment. The ALC materials report cooperative legality – notary deed, business legal deed (AHU), and business identification number (NIB), membership – 93 members, 6 micro, small and medium enterprises (MSMEs), and inclusive employment at the Wanawisata unit – 70 workers including persons with disabilities. These are treated as reported governance/economic process indicators.

The documents report cooperative CNS values of IDR 213,164 (2023) and IDR 176,329 (2024). Using a 2024 average exchange rate of approximately 1 USD ≈ 15,866 IDR, these correspond to ~USD 13.44 and ~USD 11.11, respectively (standardized using the same conversion basis). The decline indicates that financial performance cannot be presented as unequivocal success without transparent accounting and conservation cost coverage (Table 4).

Table 4

Economic and governance indicators (reported) with USD conversion for CNS

Indicator	*Reported value (documents)*	*Notes for inference (this study)*
Cooperative legality	Notary deed, AHU, NIB listed	Reported governance status
CNS update	2023: IDR 213,164 (~USD 13.44); 2024: IDR 176,329 (~USD 11.11)	USD conversion uses 2024 avg rate (1 USD ≈ 15,866 IDR); interpretation requires accounting scope
Members and MSMEs	93 members; 6 MSMEs	Reported snapshot
inclusive employment	70 workers; includes persons with disabilities	Reported inclusion snapshot

AHU-business legal deed; NIB-business identification number; CNS-cooperative net surplus; MSMEs-micro, small and medium enterprises.

Agroforestry baseline: reported practice differences across villages (targeting signals). The documents provide a baseline comparison of agroforestry practices across villages (land clearing, soil conservation, fertilizing, and synthetic agri-chemical use). These differences are retained as baseline targeting signals (e.g., higher synthetic chemical use in Ledug), rather than outcomes (Table 5).

The documents also identify Prigen as the "readiest" area for prioritization due to maturity and facilitation, indicating non-random prioritization. In Results, this is reported as a site-selection characteristic relevant to inference limits rather than evidence of differential program impact.

Table 5

Current agroforestry practices across villages (baseline; reported)

Practice	*Prigen*	*Pecalukan*	*Sukolelo*	*Dayurejo*	*Ledug*
Land clearing	Manual; no chemical	Manual; no chemical	Manual; no chemical	Manual; no chemical	81% manual; 19% herbicide
Soil conservation	82% terracing	Terracing+ weed planting	Tree planting+ soil bund	76% terracing+ ditch	73% terracing
Fertilizing	Manure+ compost	Natural decomposition	80% organic fertilizer	53% organic fertilizer	45% organic fertilizer
Synthetic agri-chemical use	No	23%	47%	41%	91%

Managing shocks and monitoring continuity: IUWASH termination risk. The documents report that Urban Resilient Water, Sanitation, and Hygiene (IUWASH) "Tangguh" (program initiated by USAID Indonesia) ended activities in February 2025, creating a gap in hydrological assessment support and multi-stakeholder facilitation. The reported recommendation is that Cempaka Foundation assumes responsibility for hydrological research and intensifies coordination while seeking new technical partnerships. This is presented as a reported continuity risk and mitigation plan, relevant for interpreting monitoring consistency during the first-year evidence window.

Discussion. This study should be interpreted as early-stage evidence mapping derived from first-year documentation (May 2024–April 2025), rather than a demonstrated conservation impact. Within this boundary, the reported indicators still provide useful signals for risk prioritization and for designing a monitoring system that can later meet evidence-based standards. A key implication is that "green cover" should not be equated with ecological resilience: monoculture stands may stabilize certain erosion risks but can weaken biodiversity-linked functions and adaptive capacity, which is consistent with the very low tree-stand diversity reported for Ledug (H’=0.154). These values are therefore best read as risk flags motivating enrichment planting and habitat integrity measures, not proof of restoration success (Zou et al 2024; Mihrete & Mihretu 2025; Pusparini et al 2023; Zyambo et al 2024; Schneider et al 2025).

A second contribution is the practical logic of combining hydrological and ecological indicators into a communicable dashboard. Carbon/greenness and biodiversity snapshots can complement discharge monitoring to support multi-stakeholder planning and accountability, but only after methods are transparent (e.g., greenness thresholds, carbon pools, and conversion factors) and uncertainty is reported (Button et al 2022; Chaplot & Smith 2023; Peri et al 2024; Liang et al 2025; Yuniarti et al 2023; Alotaibi et al 2024). Regarding spring-water, the reported discharge distribution is highly skewed, implying that a few large springs dominate water-service potential; this supports a rational basis for protection zoning and investment prioritization. Discharge monitoring can also anchor governance rules and demand management, but the current evidence should be treated as baseline snapshots because seasonal replication, uncertainty quantification, and quality assurance are not reported (World Water Council 2004; Weber & Bergan 2006). Institutionally, the documented diversification of local organizations (FVCI/FFG/VFMI) can be advantageous if coordination mechanisms, role clarity, and monitoring discipline are strengthened; this aligns with arguments on institutional diversity and long-term governance performance (Andersson et al 2014; Fischer et al 2023; Arts et al 2024; Baldwin et al 2024).

The IUWASH termination in February 2025 further highlights the need for “backbone system” capacity (SOP/manual book and data routines) so that monitoring and facilitation functions remain continuous despite partner exits. Finally, the education and economy pillars should be interpreted as maintenance infrastructure rather than outcome evidence. Practice-based learning is relevant for sustaining soil conservation, reduced chemical dependence, and collective monitoring routines (AlAli et al 2025; Fahmy & Thamarat 2025; Nurwidodo et al 2023; Ramdiah et al 2018; Bafarasat et al 2025). Economic mechanisms (cooperative and sociopreneurship) may provide incentives and legitimacy, but early financial indicators require careful interpretation and transparent accounting before being used as evidence of sustainable conservation finance (Angelsen 2009; Ntibona et al 2022).

Because this study relies on program-produced documents and covers a 12-month window, it cannot support causal claims of conservation effectiveness or counterfactual comparisons. The evaluation matrix and timeline therefore function as the core contribution: they specify what is required for future outcome-based inference (wet–dry season repetition, replication, uncertainty reporting, QA, and independent triangulation).

Conclusions. This study presents early-stage evidence mapping of spring-water and catchment conservation in Prigen Subdistrict, Pasuruan (East Java, Indonesia) using a four-pillar synergy framework (spring-water, ecology, social institutions, economy, and education). Based on first-year program documentation (May 2024–April 2025), the available evidence mainly reflects baseline and process indicators. These include discharge snapshots for eight springs, restoration outputs such as tree planting, indicative biodiversity indices that suggest possible monoculture risk, screening-level carbon and greenness estimates, institutional arrangements (FVCI/FFG/fVFMI), and early cooperative and employment indicators. However, this first-year documentation does not yet support outcome-based or causal evaluation. Key elements remain insufficiently reported, including seasonal replication, uncertainty quantification, quality assurance, independent verification, and counterfactual or historical comparison. Therefore, the main contribution of this manuscript is not to claim impact, but to propose a structured pathway for evidence-based assessment. Discharge may serve as a core performance indicator, ecological metrics may function as risk screens, governance and education may strengthen monitoring and maintenance, and economic mechanisms may be assessed for their ability to cover stewardship costs. Future research should apply the proposed evaluation matrix and timeline through repeated wet- and dry-season measurements, standardized plot-based ecological monitoring, transparent carbon and greenness protocols, and triangulation with independent data sources. This approach would allow the four-pillar synergy framework to be evaluated as an evidence-based conservation case over a multi-year period.

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