Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Access, Obligation, and Resilience: Rule Bundles in Java's Forest-Edge Coffee Agroforestry

Medea Rahmadhani Utomo

medea@ub.ac.id

National Pingtung University of Science and Technology

Erekso Hadiwijoyo

Tokyo City University

Andrean Eka Hardana

Huazhong University of Science and Technology Hospital

Mofit Jamroni

Universitas Brawijaya

Ajik Siswantoro

Universitas Brawijaya

Anisa Aprilia

Universitas Brawijaya

Research Article

Keywords: access theory, climate adaptation, coffee agroforestry, collaborative forest management, Indonesia, social-ecological resilience

Posted Date: May 26th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9613443/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Forest-edge coffee agroforestry is increasingly exposed to heat stress, rainfall variability, pest and disease pressure, and price volatility. In state-forest landscapes, however, adaptation depends not only on shade, pruning, soil conservation and diversification, but also on the operational rules that allocate plots, regulate trees, assign labor obligations and structure market access. This qualitative case study examines coffee-based agroforestry in the Bambang Utara forest resort, Malang Regency, East Java, Indonesia, where Perhutani's Collaborative Forest Management scheme has mediated community access since 2004. Based on semi-structured interviews (N = 37), field observation and local document review, the article links access theory with social-ecological resilience. The findings show that membership-mediated rule bundles can stabilize benefit streams and support longer planning horizons, but these gains are conditional. Renewal uncertainty, protection duties, sanctions and compliance costs narrow the adaptation choices of labor- and capital-constrained households. Pine-resin tapping complements coffee by providing liquidity, yet its resilience value depends on assignment rules, transparent records, quality deductions and bargaining power. The article advances the concept of rule-bundle security: the perceived stability, fairness and enforceability of rules through which households convert forest access into adaptive capacity. Ecological evidence is treated as locally reported risk mechanisms rather than measured biophysical outcomes. The study shows that resilient coffee agroforestry requires rule designs that align investment horizons, equity safeguards, market transparency and ecological limits.

Introduction

Coffee smallholders in upland and forest-margin agroforestry systems face a tightening climate envelope. Rising temperatures, irregular rainfall, drought episodes, extreme rainfall and pest or disease dynamics can alter flowering, yield stability and household income (Bunn et al. 2015; IPCC 2022; Ovalle-Rivera et al. 2015). In Indonesia, where coffee is largely produced by smallholders and frequently embedded in agroforestry mosaics, adaptation is usually discussed through farm practices such as shade regulation, pruning, soil and water conservation, plant sanitation and livelihood diversification (Cuni-Sanchez et al. 2022; Duffy et al. 2021; Malau et al. 2023; Tran 2025; Verburg et al. 2019). These practices are essential, but they are not chosen in an institutional vacuum. In state-forest landscapes, farmers' ability to adapt depends on who can use land and trees, for how long, under which obligations and through which organizational and market channels.

This institutional dimension is particularly visible in Java's Perhutani landscapes. Perum Perhutani manages state production forests on Java and regulates community access through partnership arrangements, including Pengelolaan Sumber Daya Hutan Bersama Masyarakat (PHBM), a collaborative forest management scheme that distributes conditional use opportunities to forest-edge households while requiring stand protection, monitoring and compliance with permitted activities (Perum Perhutani 2001; Gunawan et al. 2023). These arrangements are not merely tenure labels. They operate as rule bundles: combinations of allocation criteria, renewal expectations, sanctions, collective labor

obligations, tree-management rules, tapping standards and marketing procedures. Such bundles influence whether households can invest in coffee, retain shade diversity, rehabilitate soils, respond to pests or diversify income through pine-resin tapping.

Agroforestry research has long shown that tree-crop systems can buffer climate risks through microclimate regulation, soil protection, water relations, diversification and ecosystem services (Lasco et al. 2014; Mbow et al. 2014; Quandt et al. 2023; van Noordwijk et al. 2021). Coffee agroforestry is especially relevant because shade management, labor availability and low-input production strategies directly affect farm performance and household resilience (Tilden et al. 2024). Yet a persistent gap remains between the biophysical and institutional strands of this literature. Coffee-adaptation studies tend to treat tenure or access as contextual background, while social-forestry studies often analyze participation, exclusion and bureaucratic contestation without tracing how everyday operational rules shape concrete adaptation choices (Erbaugh 2019; Maryudi et al. 2022; Rakatama and Pandit 2020; van Noordwijk 2020; Verheijen and Maryudi 2020; Wong et al. 2020). This article connects these strands by explaining how rule bundles translate governance into adaptation portfolios.

The case is the Bambang Utara forest resort (RPH) in Malang Regency, East Java, a Perhutani-managed pine production-forest landscape where coffee cultivation and resin tapping are central to forest-edge livelihoods. Participants narrated three phases: a remembered pre-reform baseline associated with restrictive access and conflict; the PHBM phase, implemented locally since 2004, which institutionalized membership-mediated allocation and monitoring; and a post-2016 social-forestry policy discourse that shaped expectations and administrative claims. A formal social-forestry permit was not reported at the site during fieldwork. The post-2016 phase is therefore treated as a policy-discursive and administrative environment, not as evidence of a formal permit-based regime.

The study asks three research questions: (1) how did rule bundles governing plots, trees, labor obligations, resin tapping, market access and sanctions differ across the remembered pre-reform baseline, the PHBM phase and the post-2016 policy-discursive environment? (2) Through what mechanisms do these rule bundles shape coffee adaptation choices and livelihood buffering? (3) Who benefits, who bears costs and what distributional and ecological trade-offs matter for social-ecological resilience? The contribution is the concept of rule-bundle security, defined as the perceived stability, fairness and enforceability of the operational rules through which households convert forest access into adaptive capacity.

Conceptual framing

The framework links access theory, adaptation and transformation, and social-ecological resilience. Following Ribot and Peluso (2003), access refers to the ability to derive benefits from things. It is produced not only by formal rights but also by authority, organization, social relations, knowledge, labor, capital, technology and market channels. In forest-edge coffee systems, cultivating a plot does not by

itself establish adaptive capacity. The practical question is whether a household can convert access into stable benefits and future-oriented investments.

We conceptualize operational governance as rule bundles. A rule bundle includes permissions, obligations, enforcement practices, renewal criteria, sanctions and procedures for recording, grading or distributing benefits. These bundles can stabilize access by making allocation and monitoring predictable. They can also create vulnerability when discretion, compliance burdens or market opacity concentrate costs on weaker households. Rule-bundle security therefore differs from conventional tenure security because it emphasizes everyday operational rules rather than legal title alone.

Resilience is understood as a property of the coupled livelihood-forest system: the capacity to absorb shocks, learn, adapt and avoid undesirable social or ecological states (Folke 2006; Holling 1973; Walker et al. 2004). Adaptation refers to adjustments in practices, livelihood portfolios and decision routines that reduce vulnerability under climatic and market stress. Transformation refers to changes in institutions, authority relations, aspirations and practices that redefine what adaptation becomes possible (Gosnell et al. 2019; O'Brien and Sygna 2013). In this framework, resilience is conditional and uneven rather than an automatic outcome of participation in collaborative forest management.

Materials and methods

Study design and site selection

This article reports an interpretive qualitative case study. The design is appropriate because the objective is mechanism-based explanation: to understand how actors interpret and operationalize rules, how rules shape feasible adaptation choices, and how costs and benefits are distributed. The study does not seek statistical generalization. Instead, it aims for analytical transferability to conditional state-forest or concessionary agroforestry settings where access is mediated by local organizations and forest agencies.

The Bambang Utara forest resort, Malang Regency, East Java, is a Perhutani-managed production-forest landscape characterized by pine stands and forest-edge agroforestry. The case was selected because it combines sustained negotiation over forest access, mature PHBM arrangements implemented locally since 2004, and livelihood portfolios in which coffee and pine resin jointly shape risk management. Provincial and national coffee statistics are used only to contextualize the importance of East Java coffee and Perhutani landscapes (BPS 2024; Ministry of Agriculture 2023). They are not used to infer unobserved changes at the study site after fieldwork.

Participants, sampling and data collection

Fieldwork in 2021 combined semi-structured interviews, observation of work and monitoring routines, and review of locally accessible documents such as partnership agreements, organizational rules,

meeting notes and resin-tapping procedures when shared. Thirty-seven semi-structured interviews were conducted with stakeholders involved in or affected by forest access arrangements and coffee-based agroforestry. The analytic focus is forest-edge households cultivating coffee under Perhutani-managed forestland (n = 22). Additional interviews with Perhutani personnel (n = 7), local forest-organization actors (n = 5) and village government representatives (n = 3) enabled triangulation of rules-in-use, enforcement practices and policy-period narratives.

Table 1
Interview participants and triangulation sources (fieldwork 2021)

Actor category	n	Recruitment route	Primary roles	Main evidence contributed
Coffee growers / forest cultivators	22	Purposive and snowball sampling from plot users	Agroforestry plot management; adaptation practices; livelihood choices	Experienced rules-in-use; constraints; perceived ecological and equity trade-offs
Perhutani staff	7	Key-informant purposive sampling	Plot oversight; stand management; enforcement; resin-tapping supervision	Implementation logics; monitoring and sanction routines; institutional constraints
Local forest-organisation actors	5	Purposive sampling across representation roles	Membership mediation; allocation; collective workdays; dispute handling	Organisational governance; contribution rules; boundary-making; legitimacy claims
Village officials	3	Purposive sampling based on administrative roles	Local administration; mediation support; conflict resolution	Periodisation narratives; local legitimacy; dispute pathways

Purposive sampling ensured coverage of plot allocation, renewal, stand-protection obligations, resin tapping, market channels and dispute handling. Snowball recruitment then identified additional plot users and organisational actors able to explain specific rule domains. Sampling continued until no substantively new access mechanisms or adaptation constraints emerged from additional interviews.

Positionality, translation and ethics

Interviews were conducted in Indonesian and, when preferred by participants, with local-language clarification. The interview guide covered five domains: access histories; coffee and shade-management decisions; labour obligations, patrols and collective workdays; resin tapping, quality assessment, deductions and record-keeping; and conflict, sanctions and perceived ecological change. Field notes were prepared for all interviews. Where participants granted permission, interviews were audio-recorded and later transcribed; where recording was inappropriate, expanded field memos were prepared from contemporaneous notes.

The research team approached the field as external academic researchers with institutional ties to agricultural and rural-development research rather than as representatives of Perhutani or local organizations. This position facilitated comparison across actor categories but also required caution because participants might frame claims strategically. Interview evidence was therefore triangulated across grower, organizational, Perhutani, village-government, observation and document sources. Quotation evidence is reported through paraphrased excerpts translated into English to preserve meaning while minimizing re-identification risk in a single-site governance study.

Coding and trustworthiness

Analysis combined deductive and inductive coding and was informed by qualitative reporting principles for interview-based research (Tong et al. 2007). Deductive codes followed access mechanisms, rule-bundle components and resilience capacities. Inductive codes captured locally salient practices and tensions, including resin quality deductions, collective patrol norms, plot reassignment, compliance costs and perceived stand damage. The analysis proceeded through four steps: identifying rule domains and actor interpretations; mapping rule domains against access mechanisms; linking adaptation practices to investment horizons, labor availability, capital needs and market incentives; and testing the emerging explanation against negative and contrasting cases.

Table 2
Condensed analytical codebook and evidence matrix

Analytical domain	Deductive code	Inductive sub-code	Primary evidence source
Rule bundles	Allocation and renewal	Membership status; meeting-based review; plot reassignment risk	Growers; local forest organizations; Perhutani staff; local documents
Access mechanisms	Organization and authority	Mediation by local forest organizations; Perhutani approval; legitimacy claims	Local forest organizations; Perhutani staff; village officials
Labor and compliance	Protection obligations	Patrols; collective workdays; reporting disturbances; opportunity costs	Growers; monitoring actors; field observation
Market access	Resin and coffee standards	Quality deductions; record-keeping; buyer concentration; grievance variation	Growers; organizational actors; market-facing accounts
Adaptation portfolio	Coffee management	Shade/canopy regulation; pruning; sanitation; rejuvenation; soil cover	Growers; observation; Perhutani staff
Resilience and trade-offs	Equity and ecological risk	Labor-poor households; perceived soil-fertility decline; pine-stand damage risk	Cross-actor triangulation; observation; field memos

Trustworthiness was strengthened through cross-actor triangulation, method triangulation, negative-case checks and peer debriefing within the author team. The study uses cautious claim language when evidence is perception-based or observation-based rather than measured. Ecological findings are interpreted as locally reported risk mechanisms rather than quantified changes in soil fertility, forest cover or stand condition.

Results

Policy phases and changing access regimes

Participants narrated access dynamics through three phases: a remembered pre-reform baseline associated with restrictive authority and limited negotiation; a PHBM phase in which membership, contribution rules and monitoring routines mediated access; and a post-2016 policy-discursive environment in which national social-forestry reforms affected expectations and administrative claims without replacing PHBM as the observed local arrangement. Across phases, the central change was not simply more or less access. It was a reconfiguration of the mechanisms through which households could derive benefits from plots, trees, labor, knowledge and markets.

Table 3
Policy phases, dominant access mechanisms and strength of evidence

Phase	Access mechanisms emphasized	Observed resilience implications	Evidence strength and caution
Remembered pre-reform baseline	Authority and enforcement; limited negotiation channels; weak organizational mediation	Short planning horizons; reliance on short-return coping; conflict-prone access	Medium to low: based mainly on recalled narratives, triangulated across older participants and local actors
PHBM phase since 2004	Organization-mediated allocation; membership and contributions; monitoring; sanctions; resin tapping standards	More predictable benefit streams for compliant members; longer investment horizons for some; resin as liquidity buffer	High: supported by interviews, observation and available local documents
Post-2016 social-forestry policy discourse	Rising legitimacy claims, administrative requirements and expectations; PHBM remained the observed operational arrangement	Potential for stronger recognition, but also representation disputes, paperwork and unequal administrative capacity	Medium: treated as policy-discursive influence, not as evidence of a formal permit at the study site

Access is more than a plot

Coffee growers did not define access simply as the physical presence of land. Access meant the ability to keep using a plot, benefit from coffee and associated products, avoid sanctions, participate in

allocation processes, and remain recognized by both the local forest organization and Perhutani. PHBM expanded practical access through membership-mediated allocation, but this access was inseparable from obligations. Participation in meetings, collective activities and compliance routines became part of the mechanism through which households maintained access.

A long-term plot user explained that plot possession was insufficient if organizational recognition and compliance were weak; the relevant question was whether a household could continue working after fulfilling required contributions and protection duties. Local forest-organization actors similarly linked priority in allocation to active participation and compliance. Perhutani staff emphasized the reciprocal logic: benefits are permitted only where farmers contribute to maintenance and protection. These accounts show that PHBM transformed access from a largely conflict-prone condition into an organizationally mediated rule bundle.

Conditional rights and investment horizons

The time horizon of cultivation rights was a recurrent constraint. Participants described access as conditional, renewable and potentially revocable when obligations were not met. This condition did not eliminate coffee adaptation, but it changed its perceived risk. Long-return practices such as coffee rejuvenation, shade-tree diversification and substantial soil rehabilitation were less attractive when households were unsure whether they would retain the plot long enough to capture benefits.

A negative case is important. Some households with strong organizational standing interpreted conditionality as a source of predictability rather than insecurity. For them, rule compliance signalled legitimacy and helped secure the confidence needed for perennial investment. This variation indicates that rule-bundle security depends not only on the formal rule but also on household position within organizational and labor networks.

Protection obligations and labor burdens

PHBM embedded forest protection into everyday livelihood practice. Growers described obligations to report disturbances, follow permitted-use rules, participate in collective workdays and contribute to monitoring routines. Local forest-organization actors viewed these obligations as necessary to maintain legitimacy with Perhutani and to prevent the return of conflict and uncontrolled extraction. Village officials described disputes as typically handled first through discussion before formal sanctions or escalation.

These routines can strengthen resilience by reducing disturbance, building collective monitoring and creating a predictable sanction ladder. However, they also redistribute labor costs. Labor-poor households, elderly household heads, households with limited adult labor, or households dependent on off-farm work may experience participation requirements as opportunity costs. For such households, compliance may reduce time for pruning, mulching, weeding or off-farm income. The result is a

distributional mechanism: the same rules that create collective protection can narrow adaptation capacity for households least able to absorb labor demands.

Resin tapping as livelihood buffer and bargaining arena

Pine-resin tapping emerged as a crucial complement to coffee. Coffee income is seasonal and vulnerable to climate and market variability, while resin can provide more regular liquidity. Participants described resin as a buffer that helps smooth consumption and finance coffee management. However, this buffering function depends on access to tapping assignments, adherence to technical standards, quality assessment, deductions and record-keeping.

Resin tapping rules were justified by stand-protection concerns. Participants described standards regarding tapping depth, frequency, tools and tree condition. These standards can reduce pine damage when consistently applied. Yet quality deductions and record control also became arenas of bargaining. For growers and tappers, the issue was not merely whether deductions existed, but whether standards were transparent, consistently applied and contestable. The coffee-resin portfolio therefore functions as institutionally mediated adaptation: it buffers income risk, but only under rule conditions that prevent unequal block allocation, opaque deductions and weak grievance channels.

Coffee adaptation practices and governance constraints

Growers described several coffee adaptation practices: adjusting canopy cover to buffer heat and moisture stress; pruning and sanitation to maintain plant health; mulching and ground cover to conserve soil moisture and reduce erosion; and diversification with other crops, perennials, resin tapping or off-farm work. Constraints clustered in three domains. First, tree and canopy rules can limit species selection and shading intensity. Second, capital and labor shortages constrain maintenance, especially when combined with protection obligations. Third, market dependence and opaque deductions reduce incentives to invest in quality improvement.

Table 4
Reported adaptation practices and governance-related constraints

Adaptation practice	Intended resilience function	Governance or market constraints reported
Shade and canopy regulation	Buffers microclimate; reduces heat and moisture stress; supports soil protection	Limits on species or canopy intervention; fear of sanctions; uncertain renewal discourages long-lived shade investment
Soil and water conservation	Improves moisture retention; reduces erosion and nutrient loss; stabilizes yield conditions	Labor constraints from collective obligations; limited capital for inputs; short horizons discourage rehabilitation
Coffee management: pruning, sanitation, rejuvenation	Maintains plant health; reduces disease and yield volatility; supports longer-term productivity	Time-bound rights discourage rejuvenation; uneven technical guidance; opportunity costs of compliance duties
Diversification: annuals, perennials, resin, off-farm work	Spreads risk and smooths income across seasons and shocks	Unequal resin-block access; buyer concentration; quality deductions; representation disputes within organizations

Institutional triggers and pathway effects

The mechanisms above can be summarized as institutional triggers that altered rule bundles and, through them, access pathways and adaptation choices. Disturbance, policy and organizational triggers do not affect adaptation directly. They first alter rule bundles; rule bundles then reshape access pathways, investment horizons, labor availability and bargaining conditions; these finally shape adaptation portfolios and resilience outcomes.

Table 5
Institutional triggers, rule changes and adaptation pathway effects

Institutional trigger	Rule-bundle change	Access mechanism affected	Adaptation consequence
Post-1998 conflict and disturbance memories	Need for negotiated control and clearer community mediation	Authority; legitimacy; organization	Created demand for PHBM-style mediation and reduced reliance on opportunistic access
PHBM implementation locally since 2004	Membership-based allocation, contribution rules, monitoring and sanctions	Plot access; organizational standing; labor obligations	Lengthened investment horizons for compliant households but made access conditional on participation capacity
Stand-protection requirements	Patrols, reporting duties, permitted-use rules and sanction ladder	Labor; authority; ecological legitimacy	Reduced perceived disturbance but redistributed labor burdens across households
Resin tapping standard-setting	Technical tapping standards, quality checks, deductions and records	Market access; bargaining; liquidity	Created income buffering but introduced exposure to opaque deductions and unequal block allocation
Post-2016 social-forestry discourse	Legitimacy claims, paperwork, expectations of recognition; no reported formal permit at site	Political access; administrative capacity	Potentially expanded voice while increasing risks of representation disputes and administrative exclusion

Distributional and ecological trade-offs

Two trade-off clusters were repeatedly reported. The first is distributional. Membership-based access can widen participation, but allocation, renewal, representation and resin-block assignment are not neutral processes. Households with stronger organizational participation, labor availability and social standing are better positioned to convert rules into benefits. Households with weaker labor and capital endowments face higher compliance costs and may avoid longer-horizon investments.

The second cluster concerns ecological-risk mechanisms. Participants reported localized concerns about soil-fertility decline, erosion risk and pine-stand damage linked to livelihood intensification, improper tapping or poorly managed canopy intervention. Because this study did not measure soil properties, stand condition or forest-cover change, these findings should be interpreted as locally reported ecological risks rather than quantified ecological impacts. The accounts nevertheless identify pathways through which resilience gains could become fragile: if short-term benefit streams are stabilized without monitoring slow variables such as soil cover, organic matter, erosion hotspots and tree health, the system may accumulate ecological vulnerability.

Discussion

From tenure security to rule-bundle security

The central theoretical contribution is to shift attention from access as a binary condition to rule-bundle security. In many agrarian and forest-governance debates, access is treated as a matter of whether farmers have land or do not have land. The findings show that this is insufficient. Forest-edge coffee growers may have plot access but still face uncertainty over renewal, sanctions, permitted tree management, labor obligations and market deductions. Conversely, conditional access can support adaptation when rules are predictable, fairly enforced and aligned with coffee investment cycles.

This contribution extends access theory by specifying how mechanisms of access become operational in climate adaptation. Authority, organization, labor, knowledge, capital, markets and legitimacy do not merely determine who benefits from resources; they structure which adaptation options appear feasible. Coffee rejuvenation, shade diversification and soil rehabilitation require a time horizon. Resin tapping requires assignment and quality standards. Compliance requires labor. Market upgrading requires transparent grading and records. Rule-bundle security therefore links governance design directly to household adaptation capacity.

Conditional resilience and the politics of obligation

The study also complicates optimistic narratives of collaborative forest management. PHBM can stabilize access, create organizational mediation and reduce conflict, but resilience is not evenly produced. Obligations are politically and materially consequential. When forest protection, monitoring and participation duties are shifted onto local households, the costs are not distributed equally. Labor-poor households may become formally included but practically constrained. This finding resonates with social-forestry debates on responsibility, equity and exclusion (Erbaugh 2019; Verheijen and Maryudi 2020; Wong et al. 2020).

The implication is not that obligations should be removed. Forest-edge agroforestry requires rules to protect stands, manage conflicts and prevent maladaptive intensification. The problem is rule design. Obligations need clear proportionality, transparent exemption or substitution mechanisms, and credible appeal processes. Without such safeguards, collaborative governance can unintentionally convert participation into a compliance burden that narrows adaptation for weaker households.

Coffee-resin portfolios as institutionally mediated adaptation

A distinctive empirical contribution is the coffee-resin portfolio. Pine-resin tapping provides liquidity that can buffer coffee's seasonal and climate-sensitive income. This supports classic livelihood-diversification arguments that rural households combine activities to spread risk (Barrett et al. 2001; Ellis 1998). However, the case shows that diversification is not automatically resilient. Resin contributes to

adaptation only when assignment rules are fair, tapping standards are ecologically credible, records are transparent and deductions are contestable.

This matters for agroforestry adaptation research because it expands the unit of analysis. Adaptation is not only a set of practices within the coffee plot. It is also a portfolio of institutionally governed activities that finance, delay, enable or discourage those practices. A household that receives predictable resin income may be better able to maintain coffee or invest in soil cover. A household excluded from tapping assignments or subject to opaque deductions may remain vulnerable even when nominally included in forest management.

Ecological risk mechanisms and slow variables

The ecological findings are intentionally framed as risk mechanisms rather than measured outcomes. Participants' accounts of soil-fertility decline, erosion concerns and pine-stand damage do not establish quantified ecological change. They do, however, identify the governance pathways through which ecological vulnerability may accumulate. Rule bundles that reward short-term benefit extraction without monitoring soil cover, stand health and tapping damage can weaken the slow variables on which long-term resilience depends.

Consequently, this article is positioned as a governance and institutional adaptation study within agroforestry systems rather than as a biophysical assessment. Its ecological contribution is to identify how actors perceive, govern and potentially mitigate ecological risk pathways within rule-bound tree-crop systems. This framing matches Agroforestry Systems' interest in studies that connect biophysical and socioeconomic dimensions and avoids claiming to quantify the magnitude of ecological change without plot-level measurements.

Design principles for equitable resilience

The findings suggest five rule-design principles. First, plot and resin-block allocation should use written, transparent criteria and a credible appeal process. Second, renewal horizons should better match coffee investment cycles so that farmers are not pushed toward short-return extraction. Third, labor and protection obligations should include proportional contributions, exemptions or alternative forms of participation for labor-poor households. Fourth, resin and coffee quality standards should be simple, recorded and contestable so that deductions do not undermine trust or investment incentives. Fifth, routine monitoring should include ecological indicators such as soil cover, erosion hotspots, canopy condition and pine-stand health, alongside social indicators such as participation burden and representation.

Limitations and future research

This study has four limitations. First, it is a single-site qualitative case study designed for mechanism-based explanation rather than statistical generalization. The mechanisms are most transferable to settings where land use is conditional and time-bound, access is mediated by local organizations, and

households rely on multi-activity forest-economy portfolios. Second, the remembered pre-reform baseline is subject to recall bias, although cross-actor triangulation reduced the risk of relying on a single narrative. Third, fieldwork was conducted in 2021, while later policy and statistical references are used only to contextualize the case. Follow-up interviews would strengthen claims about post-fieldwork changes. Fourth, ecological and production outcomes were not measured directly. The study does not quantify forest-cover change, canopy structure, soil fertility, erosion, coffee yield or quality.

Future research should combine qualitative access analysis with plot-level biophysical measures, production records and remote-sensing evidence within forest-resort boundaries. Comparative studies across Perhutani and non-Perhutani landscapes could test whether rule-bundle security operates similarly under different agencies, commodities and organizational histories. Longitudinal research would also clarify whether transparent renewal and market rules lead to greater investment in coffee rejuvenation, shade diversification, soil stewardship and quality upgrading over time.

Conclusions

Forest-edge coffee resilience is shaped by the interaction between farm-level adaptation and governance-defined access to land, trees, labor, knowledge and markets. In Bambang Utara, PHBM-mediated access has stabilized benefit streams for some households, reduced conflict-prone access and enabled coffee-resin livelihood portfolios. Yet resilience gains remain conditional. Time-bound rights, compliance duties, labor burdens, sanctions, uneven representation and opaque market deductions can narrow adaptation choices and distribute costs unevenly.

The study's core argument is that resilient coffee agroforestry requires rule-bundle security. Access reforms are most likely to support climate adaptation when they provide predictable renewal, transparent allocation, proportionate obligations, contestable deductions, organizational accountability and monitoring of ecological slow variables. Policy should therefore move beyond the question of whether communities have access and ask how operational rules convert access into adaptive capacity, for whom and at what social and ecological cost.

Abbreviations

CFM, Collaborative Forest Management; KPH, Kesatuan Pemangkuan Hutan; LMDH, Lembaga Masyarakat Desa Hutan; LKDPH, Lembaga Kerja Sama Pengelolaan Hutan; PHBM, Pengelolaan Sumber Daya Hutan Bersama Masyarakat; RPH, Resort Pemangkuan Hutan.

Declarations

Funding declaration statement

Not applicable, there is not funding for this research.

Author Contribution

Medea led the conceptualization, methodology, analysis, and manuscript preparation. Mofit, Ajik, and Andrean contributed to field coordination, data collection, and contextual interpretation. Anisa and Erekso contributed to the literature review, data organization, and manuscript revision. All authors reviewed and approved the final manuscript.

Acknowledgement

We thank Universitas Brawijaya, local partners, and all participants for facilitating field access and sharing their experiences.

Data Availability

This study uses original data obtained from the interview process or discussions with several farmers, policymakers, and people who influence the resilience patterns and farmers' access to natural resources for the utilization of coffee farming.

References

1. Barrett CB, Reardon T, Webb P (2001) Nonfarm income diversification and household livelihood strategies in rural Africa: concepts, dynamics, and policy implications. Food Policy 26:315–331. https://doi.org/10.1016/S0306-9192(01)00014-8
2. BPS (2024) Statistik Kopi Indonesia 2023. Badan Pusat Statistik, Jakarta
3. Bunn C, Läderach P, Ovalle Rivera O, Kirschke D (2015) A bitter cup: climate change profile of global production of Arabica and Robusta coffee. Clim Change 129:89–101. https://doi.org/10.1007/s10584-014-1306-x
4. Cuni-Sanchez A, Twinomuhangi I, Aneseyee AB, Mwangi B, Olaka L, Bitariho R, Soromessa T, Zafra-Calvo N (2022) Everyday adaptation practices by coffee farmers in three mountain regions in Africa. Ecol Soc 27:32. https://doi.org/10.5751/ES-13622-270432
5. Duffy C, Toth GG, Hagan RPO, McKeown PC, Rahman SA, Widyaningsih Y, Sunderland TCH, Spillane C (2021) Agroforestry contributions to smallholder farmer food security in Indonesia. Agrofor Syst 95:1109–1124. https://doi.org/10.1007/s10457-021-00632-8
6. Ellis F (1998) Household strategies and rural livelihood diversification. J Dev Stud 35:1–38. https://doi.org/10.1080/00220389808422553
7. Erbaugh JT (2019) Responsibilization and social forestry in Indonesia. For Policy Econ 109:102019. https://doi.org/10.1016/j.forpol.2019.102019

8. Folke C (2006) Resilience: the emergence of a perspective for social-ecological systems analyses. Glob Environ Change 16:253–267. https://doi.org/10.1016/j.gloenvcha.2006.04.002
9. Gosnell H, Gill N, Voyer M (2019) Transformational adaptation on the farm: processes of change and persistence in transitions to climate-smart regenerative agriculture. Glob Environ Change 59:101965. https://doi.org/10.1016/j.gloenvcha.2019.101965
10. Gunawan B, Abdoellah OS, Hadi F, Alifi GJ, Suhendi RN, Aisharya IY, Gunawan W (2023) From laborers to coffee farmers: collaborative forest management in West Java, Indonesia. Sustainability 15:7722. https://doi.org/10.3390/su15097722
11. Holling CS (1973) Resilience and stability of ecological systems. Annu Rev Ecol Syst 4:1–23. https://doi.org/10.1146/annurev.es.04.110173.000245
12. IPCC (2022) Climate Change 2022: impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge. https://doi.org/10.1017/9781009325844
13. Lasco RD, Delfino RJP, Espaldon MLO (2014) Agroforestry systems: helping smallholders adapt to climate risks while mitigating climate change. Wiley Interdiscip Rev Clim Change 5:825–833. https://doi.org/10.1002/wcc.301
14. Malau LRE, Mudhofir MRT, Astana S (2023) Coffee agroforestry as an alternative to the implementation of green economy practices in Indonesia: a systematic review. AIMS Agric Food 8:762–788. https://doi.org/10.3934/agrfood.2023041
15. Maryudi A, Sahide MAK, Daulay MH, Yuniati D, Syafitri W, Sadiyo S, Fisher MR (2022) Holding social forestry hostage in Indonesia: contested bureaucracy mandates and potential escape pathways. Environ Sci Policy 128:142–153. https://doi.org/10.1016/j.envsci.2021.11.013
16. Mbow C, Smith P, Skole D, Duguma L, Bustamante M (2014) Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. Curr Opin Environ Sustain 6:8–14. https://doi.org/10.1016/j.cosust.2013.09.002
17. Ministry of Agriculture (2023) Buku Outlook Komoditas Perkebunan: Kopi 2023. Kementerian Pertanian Republik Indonesia, Jakarta. https://satudata.pertanian.go.id/assets/docs/publikasi/Buku_Outlook_Kopi_2023_lengkap.pdf
18. O'Brien K, Sygna L (2013) Responding to climate change: the three spheres of transformation. In: Proceedings of Transformation in a Changing Climate. University of Oslo, Oslo, pp 16–23
19. Ovalle-Rivera O, Läderach P, Bunn C, Obersteiner M, Schroth G (2015) Projected shifts in Coffea arabica suitability among major global producing regions due to climate change. PLoS ONE 10:e0124155. https://doi.org/10.1371/journal.pone.0124155
20. Perum Perhutani (2001) Keputusan Dewan Pengawas Perum Perhutani Nomor 136/KPTS/DIR/2001 tentang Pengelolaan Sumberdaya Hutan Bersama Masyarakat (PHBM). Perum Perhutani, Jakarta
21. Quandt A, Neufeldt H, Gorman K (2023) Climate change adaptation through agroforestry: opportunities and gaps. Curr Opin Environ Sustain 60:101244. https://doi.org/10.1016/j.cosust.2022.101244

22. Rakatama A, Pandit R (2020) Reviewing social forestry schemes in Indonesia: opportunities and challenges. For Policy Econ 114:102052. https://doi.org/10.1016/j.forpol.2019.102052
23. Ribot JC, Peluso NL (2003) A theory of access. Rural Sociol 68:153–181. https://doi.org/10.1111/j.1549-0831.2003.tb00133.x
24. Tilden GM, Aranka JN, Curry GN (2024) Ecosystem services in coffee agroforestry: their potential to improve labour efficiency amongst smallholder coffee producers. Agrofor Syst 98:383–400. https://doi.org/10.1007/s10457-023-00917-0
25. Tong A, Sainsbury P, Craig J (2007) Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. Int J Qual Health Care 19:349–357. https://doi.org/10.1093/intqhc/mzm042
26. Tran M (2025) Enabling ecosystem-based adaptation for climate-resilient coffee farming in Flores, Indonesia: lessons from monitoring and evaluation. Stockholm Environment Institute, Stockholm. https://doi.org/10.51414/sei2025.006
27. van Noordwijk M (2020) Prophets, profits, prove it: social forestry without evidence will fail. One Earth 2:394–397. https://doi.org/10.1016/j.oneear.2020.05.008
28. van Noordwijk M, Coe R, Sinclair FL, Luedeling E, Bayala J, Muthuri CW, Cooper P, Kindt R, Duguma L, Lamanna C, Minang PA (2021) Climate change adaptation in and through agroforestry: four decades of research initiated by Peter Huxley. Mitig Adapt Strateg Glob Change 26:18. https://doi.org/10.1007/s11027-021-09954-5
29. Verburg R, Rahn E, Verweij P, van Kuijk M, Ghazoul J (2019) An innovation perspective to climate change adaptation in coffee systems. Environ Sci Policy 97:16–24. https://doi.org/10.1016/j.envsci.2019.03.017
30. Verheijen B, Maryudi A (2020) The boom of social forestry policy and the bust of social forests in Indonesia: developing and applying an access-exclusion framework to assess policy outcomes. For Policy Econ 120:102290. https://doi.org/10.1016/j.forpol.2020.102290
31. Walker B, Holling CS, Carpenter SR, Kinzig A (2004) Resilience, adaptability and transformability in social-ecological systems. Ecol Soc 9:5. https://doi.org/10.5751/ES-00650-090205
32. Wong GY, Moeliono M, Bong IW, Pham TT, Sahide MA, Naito D, Brockhaus M (2020) Social forestry in Southeast Asia: evolving interests, discourses and the many notions of equity. Geoforum 117:246–258. https://doi.org/10.1016/j.geoforum.2020.10.010

Figures

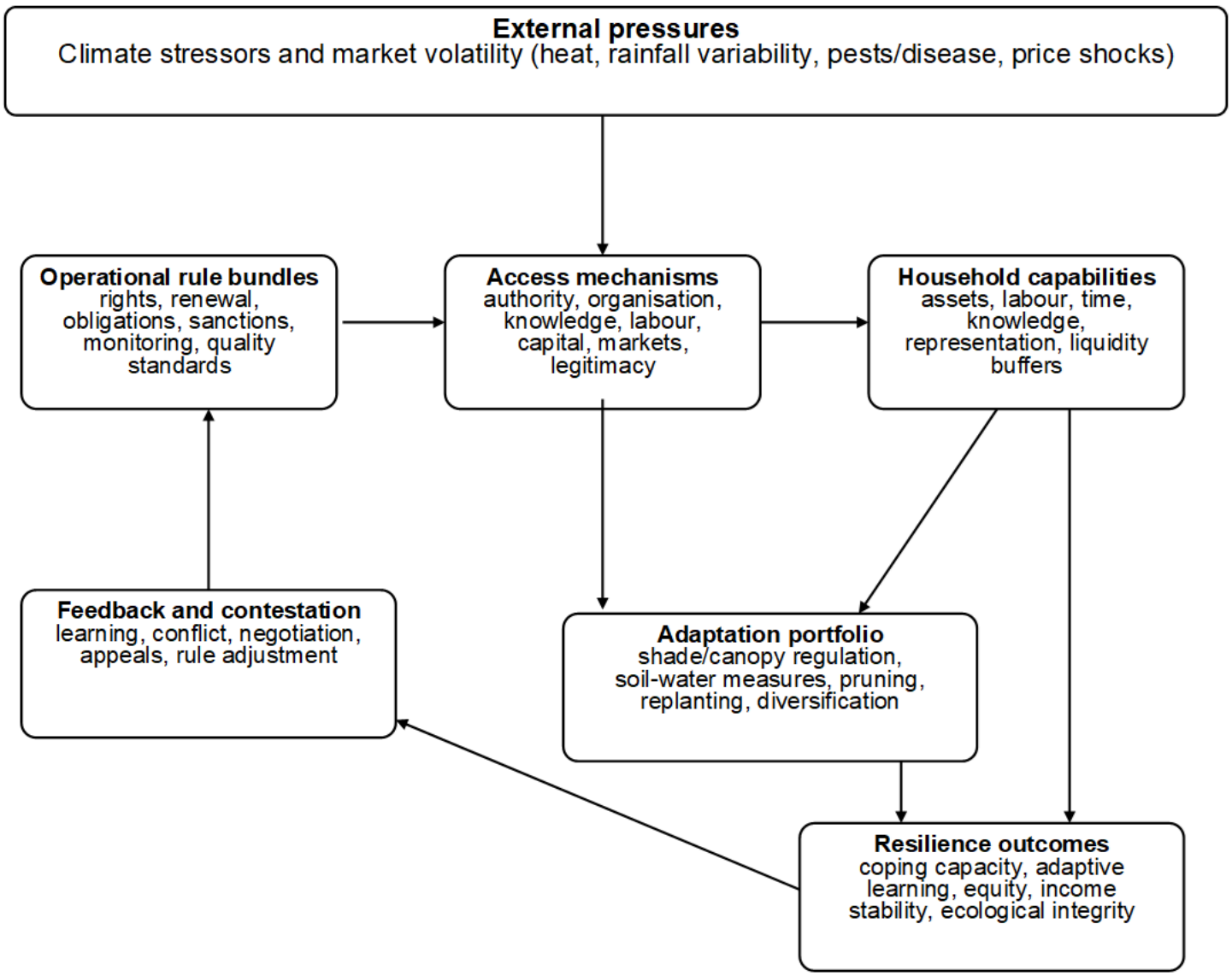


Figure 1

Analytical framework: rule bundles translate external pressures into differentiated access, adaptation portfolios and resilience outcomes

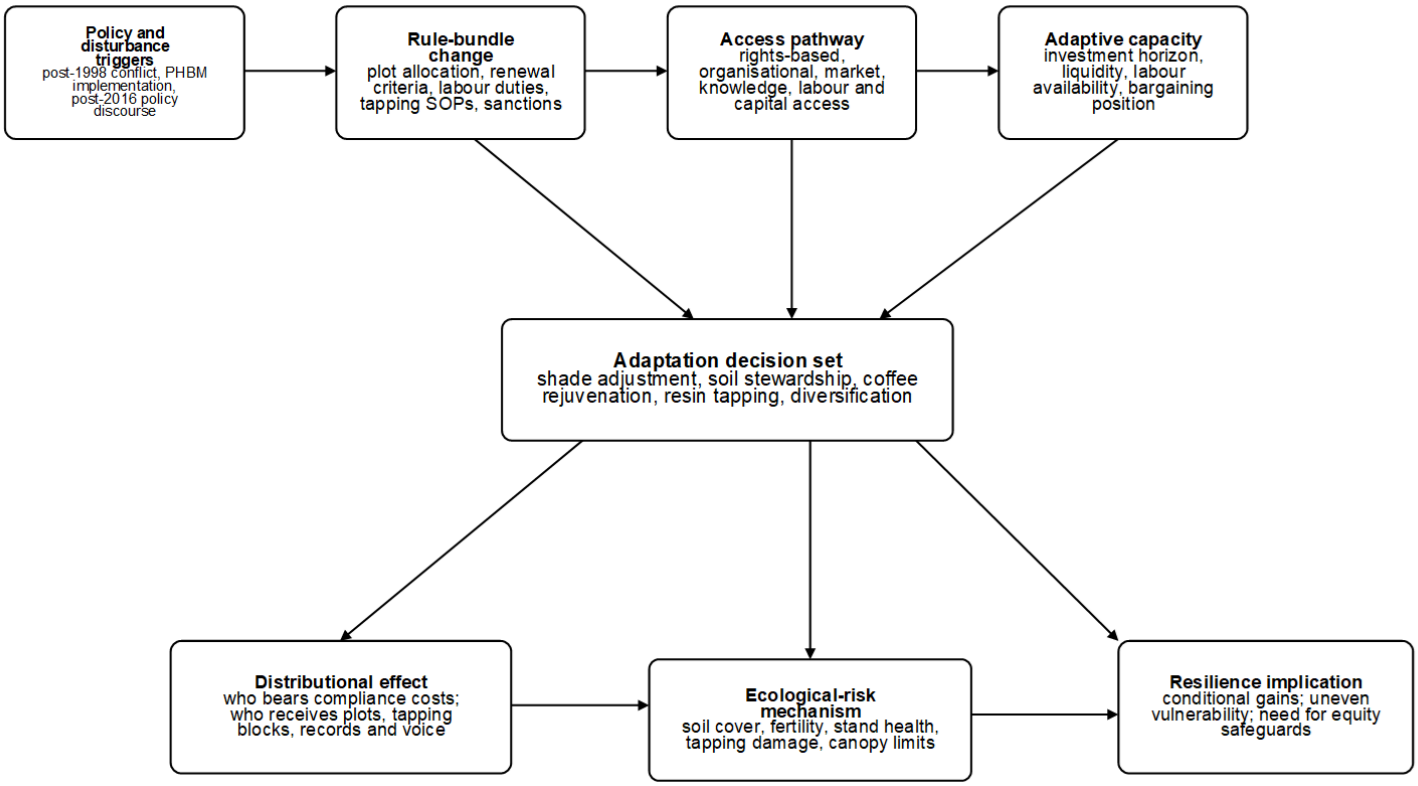


Figure 2

Mechanism pathway: rule bundles reconfigure adaptation choices through investment horizons, compliance burdens and bargaining conditions