From Local Lessons to Global Scale

GENERALIZING EVIDENCE ON PAYMENTS FOR ECOSYSTEM SERVICES (PES)

Innovations for Poverty Action

BEST BETS EVIDENCE TO SCALE

DECEMBER 2025

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Executive Summary:

This report synthesizes evidence on Payments for Ecosystem Services (PES), a conservation approach that offers financial incentives to landholders who protect natural resources rather than converting land to other uses. PES programs have the potential to reduce deforestation and protect ecosystems while providing economic benefits to communities in low- and middle-income countries. However, their success depends on various local and implementation conditions that influence whether outcomes observed in one setting can be replicated elsewhere, especially at large scale and through government systems.

The analysis is organized around three key dimensions that affect PES effectiveness and scalability:

Local Conditions: The opportunity cost of land conservation — the benefits landholders forego by not developing land — and land tenure security are critical. PES works best on lands where conservation payments align with these opportunity costs and where land rights are clear enough to enforce contracts. National programs show that targeting forests at moderate to high risk of deforestation and using simple payment brackets improve both cost-effectiveness and fairness.

Behavioral Responses: PES effectiveness relies on behavioral incentives such as fairness perceptions, loss aversion, and monitoring visibility. Innovations like upfront payments and auctions help improve participation and outcomes by addressing specific behavioral barriers. Also ensuring program rules reduce opportunities for partial enrollment enhance impact.

Implementation Conditions: Four essential "plumbing" components—the practical systems and processes that keep a program running smoothly—enable large-scale delivery with fidelity. These include accurate land verification systems, reliable monitoring and enforcement of conditions, transparent and timely payment mechanisms, and low transaction costs for participants. Successful programs use satellite monitoring with targeted field checks, automate payments through digital systems, and make participant onboarding simple.

Long-term sustainability depends on stable funding. Earmarked taxes are the most reliable, public budgets scale fast but are more vulnerable to changing conditions (including changes in administration), private and user payments usually stay local, and combining public and private funds through blended finance can help attract investment and keep resources flowing over time.

This evidence-based synthesis offers practical guidance to policymakers and practitioners on where and how PES programs can be most effective and scalable and also with specific tips for designing effective PES.


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Introduction

This synthesis sits within IPA's Best Bets agenda on evidence-to-scale pathways. Payments for Ecosystem Services (PES) is one of IPA's 14 "emerging innovations"—approaches backed by solid evidence and early partner commitment, but that still need investment and policy work to scale. Best Bets are selected by IPA sector experts and scientific advisors after the review of hundreds of studies and weighing evidence strength, observed impacts, costs, partnership traction, and scalability factors; the portfolio explicitly maps innovations along a path from exploratory to emerging (where the Best Bets sit) then established, and calls for coalitions to move them to scale.

In the 2023 report, "Payment for ecosystem services to reduce deforestation and protect the environment" appears as one of the 14 featured innovations. PES has the potential to be a win–win: mitigating climate change while delivering economic benefits to households in low- and middle-income countries. While the theory is straightforward—compensating landholders for conserving rather than converting land—, the effectiveness and scalability of PES depend on a complex set of conditions that vary across contexts. Programs that succeed in one setting may fail in another, not because the mechanism is flawed, but because the enabling environment, behavioral responses, or delivery systems differ.

Despite growing interest in scaling PES, key gaps remain on *where, why, and under what delivery conditions* programs achieve true additionality[1], sustained ecological outcomes, and equitable benefit sharing. Our review therefore centers on the question: under which contextual, behavioral, and delivery conditions will results observed in one setting travel elsewhere—especially at scale and through government systems? To answer it, we combine two lenses. First, we use the Generalizability Framework (Bates and Glennerster 2017) to structure portability—what must hold in new settings for effects to persist. Second, we apply a scale-weighted synthesis, assigning greater weight to large and government-implemented programs, which better reflect real-world delivery constraints.

Specifically, the Generalizability Framework distinguishes three dimensions that jointly determine whether an intervention tested in one place can be expected to work elsewhere:

- **Local conditions**, which capture the structural and institutional features of a context—such as land tenure security or opportunity costs—that determine whether PES contracts are feasible and credible.
- **Generalized behaviors**, which reflect the predictable ways individuals respond to incentives, monitoring, and norms; in the case of PES, these levers include reciprocity, loss aversion, and social influence, with design innovations like front-loading or auctions extending their reach across contexts.
- **Implementation conditions**, which describe the administrative and financial environment required for programs to function at scale, including monitoring capacity, transaction costs, and the availability of sustainable funding.

By structuring the evidence base on PES along these three dimensions, we identify what lessons travel across contexts.

1 Additionality refers to the extent to which the environmental outcomes achieved by a program—such as avoided deforestation or carbon sequestration—would not have happened without the intervention. In other words, it measures the "extra" impact directly attributable to PES, beyond what would have occurred anyway.

Methodology

We synthesized findings from 40+ experimental and quasi-experimental studies of PES, prioritizing government-implemented programs at national or large subnational scale. Our main evidence base was the Conservation Effectiveness library and the body of studies synthesized in J-PAL's Policy Insight "Cash for Conservation: Climate Action on a Budget," which reviews the effectiveness and cost-effectiveness of PES and suggests how to improve both through better targeting, timing, and contract design. Here, we build on that evidence to examine where, why, and under what delivery and implementation conditions those results are likely to scale through government systems. Accordingly, we organize results under local conditions, generalized behaviors, implementation conditions and sustainability, drawing on program documents and evaluations to connect causal findings to real-world delivery.

The schemes reviewed primarily aim to conserve existing forests to reduce deforestation, often generating multiple benefits, including capturing and storing carbon (carbon sequestration) and protecting biodiversity, in countries such as Costa Rica, Mexico, and Uganda. A portion of the evidence also addresses large-scale Payment for Watershed Services (PWS) schemes focused on water quality and flow regulation in locations such as Mexico and Brazil. We also draw on major national programs centered on agricultural land conservation and erosion control, such as China's Grain for Grain and the U.S. Conservation Reserve Program (CRP).

Local conditions

We focus on two local conditions that most strongly shape PES effectiveness: opportunity costs of conservation and land tenure security. For each, we explain how it links to outcomes using experimental and quasi-experimental studies, distill lessons from at-scale programs, and end with concise dos and don'ts for design. We also note two additional factors where evidence is not yet conclusive—trust in institutions and cultural perceptions of nature—which may matter for participation and social outcomes.

Local condition 1 – Opportunity cost of conservation

One of the key local conditions for the success of PES depends on how well payments align with the opportunity costs of conservation and their benefits—that is, the income or benefits landholders give up when they choose to conserve their land instead of using it for something else. Assuming the land being targeted is worth protecting; the issue is how to maximize conservation per dollar spent. At one end are high-opportunity-cost parcels—plots near roads or market infrastructure with profitable alternative uses—where the payments needed to offset forgone income are fiscally challenging. At the other end are low-opportunity-cost parcels—remote areas, steep slopes, or poor soils—where agricultural returns are minimal and enrolling them risks paying for conservation that would have happened anyway.

Experience from national programs highlights two ways to make cost offsetting affordable: aligning payment levels with the typical income landholders forgo from alternative land uses, while also compensating the costs of participation—such as time, administrative effort, or land management requirements—to ensure payments cover both the opportunity cost of not developing the land and the compliance cost of maintaining conservation; and using simple payment brackets instead of a flat rate to reflect differences across land types or locations without adding unnecessary complexity. Yet efficiency is only one part of the story—design must also weigh fairness, simplicity, and recognition of non-economic values.

1. Opportunity costs and effectiveness

Theory suggests that landholders with lower opportunity costs are more likely to participate, while high costs reduce enrollment (Wunder 2013) and there is some evidence that confirms it (Arriagada et al. 2009; Zanella et al. 2014). Moreover, Jack (2013) showed in Malawi that farmers with higher opportunity costs were also more likely to abandon contracts, underscoring that payments must be calibrated not only to attract enrollment but also to sustain compliance. This supports the intuition that PES is best suited for land under moderate deforestation pressure. At one extreme, enrolling low-threat lands leads to little additional conservation; at the other, compensating highly profitable uses is fiscally challenging. The policy challenge is to target the "sweet spot" where payments can realistically shift behavior.

One caveat is that in ecosystems with very high conservation value (e.g., exceptional biodiversity, rare or threatened species, critical ecological functions), PES can still be an appropriate instrument even if opportunity costs are high. This is because the social returns to conservation— the broader benefits to society— are also high. In these cases, PES should be assessed alongside other conservation tools—such as protected areas or livelihood diversification—and possibly combined with them. The key point is that all conservation strategies face the same underlying constraint: protecting high-opportunity-cost land is expensive and hard to enforce, whether the instrument is PES or regulation.

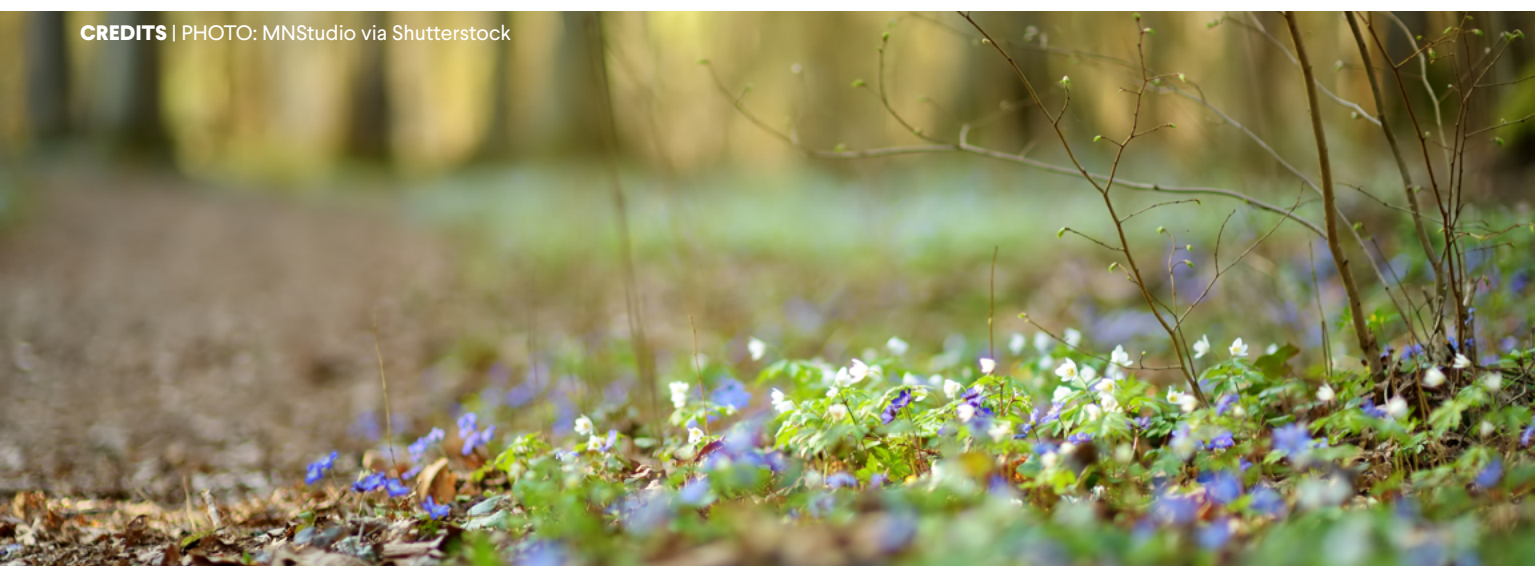
2. Lessons from at-scale programs

Large-scale schemes illustrate how governments have tried to operationalize this principle:

- **Prioritizing zones with high-risk of deforestation.** Mexico's national PES program gradually shifted its targeting strategy to focus on forests under greater threat of conversion. Over time, "renewed PES contracts increasingly went to areas facing high deforestation risks, as CONAFOR incorporated deforestation risk into its selection criteria" (Sánchez-Velásquez et al., 2024). This adjustment improved the program's additionality.
- **Anchoring to market returns.** Mexico's Program for Payments of Hydrological Environmental Services (PSA-H, by its Spanish acronym) tied rates to the income farmers would get from cultivating maize, and later indexed to the minimum wage to keep up with prices (Alix-Garcia et al 2014). Costa Rica pegged payments at US$40/ha, based on cattle pasture returns, and adjusted over time (Sánchez Chavesa and Chacón 2017). In contrast, Ecuador's Socio Bosque prioritized equity and scalability over precise alignment with opportunity costs, citing data gaps and political sensitivity (CDKN, 2014). This choice enabled rapid national coverage but led to mixed additionality outcomes (Cuenca et al. 2018; Gordillo et al. 2021).
- **Covering opportunity and compliance costs.** China's Grain for Green program compensated households for lost crop income through grain, cash transfers, tree seeds, and tax exceptions, while also probably easing compliance costs as the payments in many cases not only offset but also exceeded the opportunity costs (Uchida et al. 2005), . This dual design was successful in increasing total forest cover(Fu et al. 2019), though evidence shows mixed impacts on household welfare (Treacy et al. 2018).
- **Using a limited number of brackets is feasible**. Ecuador's Socio Bosque program shows that a tiered payment structure with only a few brackets is administratively viable at a national scale. The scheme pays a higher per-hectare rate for the first hectares, with declining payments for additional land and it also applies differentiated payment schedules across ecosystems—for example, distinct structures for páramo and forest communities, and a dedicated Socio Manglar incentive for mangrove conservation—recognizing their different ecological characteristics and values (MAATE, Socio Bosque II Operational Manual, 2022). Policymakers opted against a highly granular payment schedule, citing the high transaction costs and administrative complexity (Max Lascano, Socio Bosque Manager, cited in Solis and Malky, 2015).

3. Must-dos and don'ts when designing a PES program

- Do target land with high environmental value and moderate opportunity costs — not so low that there is no risk of conversion.
- Do link payment amount size to land returns (crop values, pasture costs, or proxies such as deforestation risk).
- Do use lightweight brackets to reduce misalignment in diverse landscapes and don't over rely on flat national rates or income ratios.
- Expect some over- and under-payment; recalibration and modest differentiation help minimize inefficiencies.



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Local condition 2 – Land tenure security

PES depends on clarity over who controls land, since contracts must identify a responsible party. De facto rights can be sufficient to generate compliance, but scaling requires safeguards against overlapping claims. Communal tenure provides a workable proxy at scale, while strict title requirements reduce inclusivity but can be offset through complementary titling campaigns. The design challenge is to strike a balance between credibility of contracts and broad participation. Tenure arrangements also shape who participates and who benefits. For example, women and indigenous peoples' land and trees rights are sometimes not recognized or secured, which limits access to forest management programs like PES (Habtezion, 2016; McLaren et al., 2025).

1. Land tenure security and effectiveness

PES contracts require enough tenure security that rights are uncontested and conditionality can be enforced. Small-scale experiments show this can be achieved with de facto recognition: in Uganda and Malawi, landowners without formal titles were still able to sign and comply with PES contracts because local communities recognized their claims (Jayachandran et al. 2017; Jack 2013). These examples highlight feasibility but rely on intensive local verification, which is harder to replicate at national scale. Title requirements reduce disputes and ease monitoring, but limit participation by poorer households and those in contested frontier areas. More flexible recognition (communal rights, use-right contracts) expands coverage but requires stronger local enforcement and monitoring institutions.

2. Lessons from at-scale programs

- **Strict title requirements.** Costa Rica's PSA started requiring formal cadastral titles (officially registered proof of land ownership) soon after the program was launched (Arriagada et al. 2009, 2012). Ecuador's Socio Bosque also required legal, uncontested titles. In cases where the government organized titling campaigns—such as around Cuyabeno Reserve, it increased the likelihood of households and indigenous communities with de facto rights to join (Jones et al. 2017; Gordillo et al. 2021).
- **Communal or use-right tenure as alternatives.** Other large programs show that PES can scale without parcel-level titling. Mexico's PSA relied on ejidos (communal landholdings managed by groups of farmers) and indigenous communities, contracting with collective institutions whose rights were legally recognized (Alix-García et al. 2012; Costedoat et al. 2015; Le Velly et al. 2017). Brazil's Bolsa Floresta enrolls families in sustainable-use reserves. Eligibility depends on residence and compliance with reserve rules rather than private titles. The state remains the de jure landowner but issues concessões de direito real de uso (CDRUs) — real-use rights agreements— to households or associations, allowing contracts to be enforced while safeguarding community livelihoods (Carvalheiro et al. 2010).

3. Must-dos and don'ts when designing a PES program

- Do accept de facto rights when they are locally recognized and uncontested, especially when communal institutions can serve as the contracting unit.
- Do align rules with inheritance/marital property so women can be rightsholders and direct payees (e.g., co-titling/co-beneficiaries and accept women's use-rights).
- Do rely on existing tenure proxies (ejidos, household use-right contracts) to enable scale without requiring a title from each participant.
- Do adapt design to low-trust contexts: offer shorter contracts or work through respected local intermediaries to increase credibility and participation.
- Don't assume strict titling is necessary—but if required, pair PES with titling campaigns or cadastral support (e.g., Costa Rica's georeferencing service) to avoid excluding the poor.
- Expect trade-offs: strict title rules improve enforceability but reduce inclusivity; flexible recognition expands coverage but shifts responsibility to local governance.

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Other conditions considered but that need more research

Cultural perceptions of nature

From an ecological perspective, it may make little sense to implement PES in communities that already display strong pro-environmental norms and collective conservation behavior: if conservation is happening anyway, payments risk being non-additive. Moreover, several authors have warned that introducing monetary incentives in such contexts can crowd out intrinsic or moral motivations, weakening rather than reinforcing existing prosocial norms (Frey & Jegen 2001; Bowles 2008; Kosoy & Corbera 2010). Conversely, in settings where collective action has eroded or conservation norms are weak, PES may have the potential to crowd in new prosocial dynamics by institutionalizing collaboration and trust (Wunder 2013).

Empirically, a global review of 74 PES schemes finds that program designs that empowered participants, offered in-kind benefits, and fostered autonomy tend to strengthen intrinsic motivation (crowding-in) and improve social cohesion and perceived fairness, while schemes perceived as controlling are more prone to crowding-out effects. However, these motivational shifts do not consistently translate into stronger ecological outcomes, such as higher forest cover or improved water quality (Akers & Yasué 2019). This suggests that while motivation-sensitive design enhances social performance, ecological effectiveness depends also on other factors.

Trust in institutions

Trust in implementing agencies is likely relevant, but rarely measured directly. Some evidence suggests it interacts with tenure security. In Ecuador's Socio Bosque, for example, households hesitated to enroll due to fears of dispossession once land was under contract (Jones et al. 2017; Gordillo et al. 2021). By contrast, in Costa Rica, participation in the PSA program was often perceived as strengthening land rights and trust in government institutions (Arriagada et al. 2015). These contrasting experiences suggest that credibility of institutions and perceived fairness of implementers can either undermine or reinforce participation. In low-trust contexts, design adaptations—such as shorter contracts or relying on respected local intermediaries (Schomers et al. 2015)—may help, but evidence is still anecdotal rather than systematic.

Generalized Lessons on Behavior

At its core, PES is an incentive mechanism: by compensating landholders for what they forgo, it shifts the cost–benefit balance toward conservation. Across programs, a set of core behavioral levers is always at play; more recent design innovations activate additional behavioral levers and further improve outcomes.

The core behavioral levers are:

- **Reciprocity.** Participants view the payment as a fair exchange for their effort to conserve resources, which reinforces the legitimacy of conservation.
- **Endowment effect and loss aversion** .Once participants expect a payment, failing to meet the conditions feels like losing something they already own, which increases their motivation to comply. This effect is reinforced by commitment mechanisms: when payments are conditional and made only after conservation actions are verified, participants are more likely to follow through.
- **Salience of monitoring and deterrence.** When participants know that their land will be checked through spot visits or satellite imagery, the perceived probability of detection increases, which raises compliance even when actual enforcement resources are limited.

Beyond the core levers, empirical evidence highlights several design innovations that exploit other behavioral levers and improve outcomes:

- **Liquidity and present bias**. In India, advancing part of the payment up front while keeping the rest conditional increased compliance by about ten percentage points, though cost-effectiveness remains uncertain because front-loading may attract participants unlikely to comply (Jack et al. 2025).
- **Choice architecture** to prevent participants from enrolling only parcels they already planned to conserve. Requiring full enrollment of all of participants' eligible forest in Mexico reduced deforestation by 41 percent and quadrupled cost-effectiveness.
- **Self-selection.** Auctions or scoring rules can help identify landholders who are more likely to comply at a lower cost. In Malawi, auction winners kept more trees alive than lottery winners (Jack, 2013), while in the U.S. CRP, many marginal contracts were non-additional, highlighting the value of scoring rules (Aspelund & Russo, 2023)[2]. Finally, ensuring follow-through between take-up (e.g., planting) and the end outcome (e.g., tree survival) is critical: in Zambia, initial adoption of subsidized tree planting was high, but survival collapsed when maintenance costs, droughts, and pests struck—misaligned incentives rewarded planting rather than survival (Olivia et al., 2020).

Together, these cases show that while PES is fundamentally an incentive program, its effectiveness depends not only on payment size but on how incentives are structured to align with barriers and facilitators on the ground.

Must does and don'ts when designing a PES program

From this evidence, we can draw practical lessons. In short, PES works best when it tackles behavioral frictions—the psychological or practical barriers that prevent people from acting on their intentions to conserve. These frictions can include lack of information, limited trust in institutions and uncertainty about future payments. Addressing these factors—through clear communication, timely payments, or simple program rules—makes financial incentives more effective than relying on payments alone.

- Do pair conditionality with credible monitoring—spot checks, satellite imagery, or community verification—to make participants more likely to follow through and discourage rule-breaking.
- Do design enrollment rules that reduce the risk of only enrolling land that landowners already expect to conserve.
- Do consider the use of timing innovations (front-loading or milestone payments) to ease liquidity constraints and sustain conservation effort beyond initial adoption.
- Do use screening tools (auctions or scoring rules) to improve targeting and additionality—but only if they explicitly factor in deforestation risk and if the country has strong administrative capabilities.
- Expect trade-offs: stricter rules (e.g., full enrollment, auctions) improve additionality and efficiency but may reduce participation among smaller or liquidity-constrained landholders; flexible rules expand access but risk inefficiency or leakage.

2 In Malawi, farmers bid their minimum required payment in a sealed-bid, uniform-price auction for tree planting; in the U.S., bids were ranked by environmental value and cost using the Environmental Benefits Index (EBI).

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Implementation conditions

We examine four implementation conditions that determine whether PES can function at scale with fidelity: land verification, conditionality & enforcement verification, payment systems, and low transaction costs. For each, we briefly explain why it matters for reliable delivery, distill lessons from at-scale programs and initiatives, and close with a concise set of do's and don'ts for practical design. Together, these conditions align who signs, what is monitored, how and when payments flow, and how easy it is to participate—the core plumbing that turns contracts into credible, scalable programs.

Implementation Condition 1 - Land Verification

1. Land verification and fidelity in implementation

To enroll participants and later verify compliance, programs must know whose land it is and which polygon (i.e., the mapped parcel or area of land delineated in GIS data) is under PES. Where programs require legal title, a reliable cadastre is needed—this is how large schemes such as Costa Rica, Ecuador, and Mexico have operated. But title is not strictly necessary for operations: a georeferenced contract polygon (linked to a recognized rights holder) can be enough to run payments and monitoring (see the Land tenure security section). Even when title is required, at-scale programs still georeference the contracted area for monitoring and enforcement.

2. Lessons from at-scale programs

- **Two-layer architecture** is standard in at-scale programs. Large programs distinguish a rights layer (e.g., the entire area under title, communal right, assembly act, or other ownership) from an operational layer (polygon) that defines the enrolled area. Costa Rica linked contract polygons to the National Registry; Mexico's PES uses contract polygons for payment and verification alongside ejido/assembly records; Ecuador's Socio Bosque enrolls titled parcels (or sub-parcels) as polygons used for monitoring (Arriagada et al., 2012//2015; Alix-García, 2012; Costedoat et al., 2015; Jones & Lewis, 2015; Jones et al., 2017; Ramírez-Reyes et al., 2018; Le Velly, Sauquet & Cortina-Villar, 2017; Scullion et al., 2011).
- **Who bears verification costs.** Program designs shift the burden—and thus costs—between applicants, intermediaries, and the state. In Costa Rica, intermediaries/NGOs (e.g., FUNDECOR) typically capture polygons while the government validates (FONAFIFO/SINAC), lowering participant burden (Arriagada et al., 2012). In Mexico, private technical service providers digitize polygons and CONAFOR approves and stores them—costs are shared (fees plus applicant time) (Costedoat et al., 2015; Scullion et al., 2011). In Ecuador, landholders/communities must physically mark boundaries as a contract requirement, while the ministry (MAE/MAATE) administers and verifies—placing more of the burden on participants (Jones et al., 2017).
- **Low-cost assistance can reduce the burden of the participants.** School-based mapping brigades (e.g., ag-school programs in Argentina) can digitize parcels and provide basic field checks with phones/GPS and open access tools, reducing applicant time and expense and complementing official layers where cadastre or titles are incomplete.

3.Must-dos and don'ts when implementing a PES program

- Do explore low-cost options for polygon capture (intermediaries, NGOs, student extension brigades using mobile or GPS tools).

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Implementation Condition 2 - Conditionality Verification

1. Conditionality & Enforcement verification and fidelity in implementation

While monitoring technologies have improved, actual sanctioning for non-compliance is infrequent and politically sensitive. In a global sample, approximately 63 percent of the programs monitor comprehensively, yet only approximately 26 percent sanction consistently; nearly half reportedly never sanction (Wunder et al., 2018). Because enforcement is hard in practice and may increase complexity for implementers and participants, a natural question is whether relaxing conditionality—up to unconditional cash—could still deliver conservation. Emerging efforts advocate testing unconditional transfers for conservation (for example, Cash for Conservation Working Group). But causal evidence is still emerging and mixed. A randomized trial of unconditional community payments in Sierra Leone led to more land clearing in the short run (Wilebore et al., 2019). A hybrid in India—advancing part of the payment unconditionally while keeping the rest conditional—raised measured compliance by approximately 10 percentage points , but also drew in more eventual non-compliers, so cost-effectiveness did not clearly improve (Jack et al., 2025). New pilots are being developed to continue to build this evidence and to potentially test more clearly the differentiated impacts of conditionality versus unconditionality.

Given this still inconclusive evidence on unconditional transfers, and the strong evidence on PES models using conditionality, we focus next on lessons from at-scale programs to strengthen monitoring and enforcement in practice. We found that to increase effectiveness, programs can combine satellite-first monitoring with targeted ground-truthing, transparent rules for exceptions (e.g., involuntary non-compliance), and a sanction schedule that is actually used—not merely written.

2. Lessons from at-scale programs and initiatives

- **Satellite-first, field-verified systems are now standard practice.** Mexico and Costa Rica evolved from heavy field verification (e.g., early PSA cohorts verified approximately 50 percent of parcels) toward satellite-led detection with targeted site visits (Arriagada et al., 2012; Alix-García, 2012; Ramírez-Reyes et al., 2018; Izquierdo-Tort et al., 2024). Countries designing new PES programs can follow this model through two paths: either build an in-house monitoring pipeline using free technical assistance (e.g., NASA's ARSET) and open tools (R/Python/Google Earth Engine) connected to open imagery, or use ready-to-use platforms that already integrate imagery and alerts, such as MapBiomas (for annual land-use maps and deforestation polygons) or Global Forest Watch[3] (for near-real-time

3 Near-real-time means a delay of 2 to 8 days. This lag depends on variables like the satellite's revisit schedule and data processing time. For optical satellites, the delay can sometimes extend to 15 days or more due to persistent cloud cover, but radar-based alerts help overcome this issue.

forest-change alerts and parcel-level tracking).[4] These platforms vary in coverage and accuracy—stronger in heavily forested countries and thinner elsewhere—so governments should assess local coverage and complement or adapt their national forest monitoring systems to support PES. In any of these cases, satellite data comes first, but field verification remains essential to calibrate detection algorithms and resolve flagged parcels, ensuring accuracy and affordability at scale.

- **Build national capacity with free technical assistance.** NASA trainings (e.g., Evaluating ecosystem services) and open geospatial toolkits allow governments to set up monitoring protocols without bespoke vendors.
- **Monitoring ≠ enforcement—the political economy is the bottleneck.** Looking at the at-scale programs we found that the main reasons for the lack of enforcement were: collective governance constraints (ejidos/commons), shocks or involuntary infractions, and reluctance to punish entire communities for a subset of violators (Scullion et al., 2011; Honey-Rosés et al., 2011; Costedoat et al., 2015).
- **Graduated, partial sanctions are common in collective settings.** Where some members defect, implementers often reduce payments rather than terminate contracts to avoid penalizing compliant households (Izquierdo-Tort et al., 2024). Making this logic explicit—warning → partial withholding → termination—improves fairness and credibility.

3. Must-dos and don'ts when implementing a PES program

- Do make monitoring salient: publish clear protocols, run random checks, and notify participants of satellite flags and challenge windows.
- Do use a satellite-first + stratified ground-truthing protocol with pre-set accuracy targets and documented exception rules (e.g., shocks, involuntary infractions).
- Do leverage free technical assistance (e.g., NASA trainings) to build an updatable, in-house monitoring system; when quality, frequency, and resolution suffices, rely on free/subsidized imagery (e.g., Global Forest Watch), reserving paid data/services for edge cases.
- Expect political pushback and edge cases; plan for dispute resolution, community-level governance constraints, and partial sanctions to avoid punishing compliant participants.

Implementation Condition 3 - Payment system

1. Payment system and fidelity in implementation

Payments are the "plumbing" that keeps PES running. When transfers are predictable, fast, and transparent, participants trust the contract and stay compliant; when they are late or uncertain, participation and effort might drop. Modern payment infrastructure—built on digital ID, digital payments platforms and consent-based data sharing—can widen access and lower costs, but only if onboarding is inclusive (customer support, offline options). Yet, as the UNDP (2024) report notes, PES has not fully benefited from recent digital advances, leaving many management processes manual and outdated.

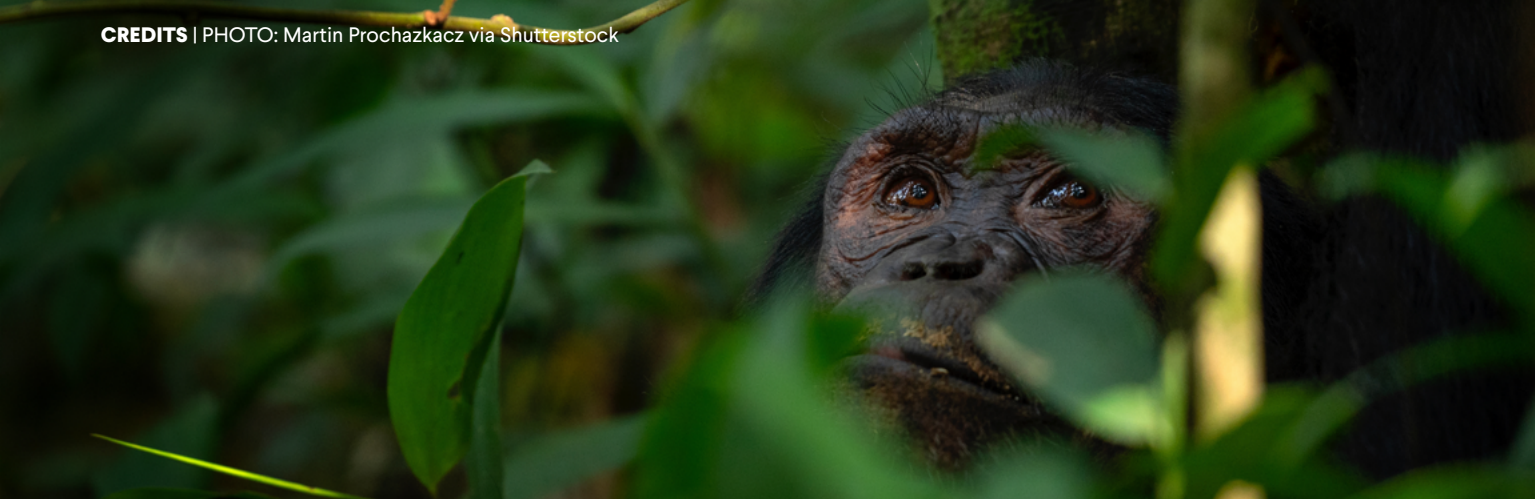
2. Lessons from at-scale programs

- **Sector-managed payment systems are the norm.** In Mexico, Ecuador, and Costa Rica, environmental agencies administer payments directly to beneficiary or organizational accounts; programs rarely "ride" social-assistance payment systems, though Mexico has examples of co-financed municipal trusts that sit alongside the federal program.
- **Bank transfers dominate, with organizational payees in collective tenure.** Ejidos/associations often receive funds centrally and allocate internally against the contract polygon and local rules; this requires local transparency.
- **Modernize PES payments.** To modernize payments, programs should automate disbursements once compliance is verified, use digital channels (such as bank transfers, and mobile wallets) to reduce risk, and leverage digital public infrastructure—such as digital ID, interoperable payment platforms, and consent-based data sharing—to make transfers faster, cheaper, and more transparent (UNDP, 2024).

3. Must-dos and don'ts when implementing a PES program

- Do publish a simple payment calendar and service levels (when verification closes, when funds land), treat on-time payment as a key performance indicator.
- Do pay direct-to-account or mobile wallet whenever possible.
- Do consider piggybacking on existing public rails (social-protection or DPI payments) where banking access is low.

4 Effective parcel resolution is set by the data.10 m imagery ≈ 100 m² per pixel and 30 m imagery ≈ 900 m²; in practice you want approximately 3×3 pixels to detect change confidently—about 0.09 ha at 10 m and 0.81 ha at 30 m (rule of thumb: parcels ≥ 1 ha work well; smaller plots need higher-resolution imagery or field checks).



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Implementation Condition 4 - Low transaction costs

Transaction and participation costs are the administrative, informational, and time-related burdens that landholders face when enrolling in and complying with PES programs. They include the costs of preparing applications, traveling to administrative offices, learning about requirements, and working with intermediaries. These costs strongly influence who participates and whether a program can scale without excluding poorer households.

1. Transaction costs and fidelity in implementation

Lowering transaction and participation costs is essential to preserve fidelity at scale. Every extra step—maps, technical plans—filters out the very landholders many PES programs aim to reach, biases enrollment toward better-off or better-connected applicants, and diverts implementer bandwidth from monitoring and learning to gatekeeping. High transaction costs also depress take-up even when payments are attractive, and they erode compliance when ongoing "maintenance" burdens (e.g., patrols, reporting) are not accounted for. By contrast, simple, credible procedures and funded facilitation (e.g., marketing, technical assistance, trusted intermediaries) expand the relevant applicant pool, improve representativeness, and stabilize compliance.

2. Lessons from at-scale programs

- **Information costs dominate early on.** In Costa Rica's PES, early cohorts faced awareness and paperwork barriers; FUNDECOR's hands-on enrollment support improved follow-through (Arriagada et al., 2012). In Uganda, two-thirds of non-enrollers reported not knowing about the program or its content (Jayachandran et al., 2017, Appx. Fig. A1).
- **Streamline documentation and proofs.** Costa Rica's early PES rules (pre-2000) demanded cadastral and cartographic maps, proof of ownership, and a plan, processed first-come, first-served—raising costs and advantaging those with time and transport (Arriagada et al., 2015). Later relaxations and local intake support reduced burdens.
- **If you require management plans, subsidize them.** Stricter rules (e.g., forest management plans, mapping) raised private burdens; Mexico's PSA-H paired requirements with funds for technical advisors, while Costa Rica leveraged intermediaries to prepare plans for a transparent, capped fee (Sims et al., 2014; Costedoat et al., 2015; Arriagada et al., 2012).
- **Different compliance costs.** Socio Bosque's flat per-hectare payments did not reflect higher surveillance/monitoring costs for extensive, sparsely populated territories, weakening appeal and effectiveness for those contexts (Perafán and Pabón 2019).

3. Must-dos and don'ts when implementing a PES program

- Do budget for outreach and simple messaging to cut information and search costs, especially at the beginning.
- Do calibrate trade-off: lower application costs can increase inclusion-error risk (e.g. duplicate claims) and reduce the probability of compliance (if technical assistance is not requested, participants may not have a feasible management plan in place and fail to comply), but higher costs increase exclusion risk (especially poorer households). Measure both and set a proper threshold.
- Do leverage intermediaries or service providers to assist with applications if needing more complex requirements.
- Don't assume transaction costs are negligible—small administrative fees or paperwork burdens can systematically exclude participants.

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Sustainability

Across countries, three financing streams have been used at scale to underpin PES programs, and a fourth, blended finance, is an emerging innovation that can complement and connect the others.

1. **Tax-backed public models.** Costa Rica's PSA, for example, was originally financed through a fuel tax and water fees, providing a stable national revenue base, and has since diversified by adding resources from the Green Climate Fund, the World Bank's Forest Carbon Partnership Facility, and voluntary carbon markets to reduce dependence on fossil-fuel revenues and sustain long-term commitments (UNDP 2024). This example also shows that when a tax base (e.g., fuel) is designed to shrink, there is a need to blend in other resources.
2. **Budget-funded models**—as in Ecuador's Socio Bosque or Mexico's PES programs—depend mainly on annual public appropriations and external cooperation, which makes them vulnerable to fiscal shocks and shifting political priorities; payment suspensions and budget cuts have repeatedly undermined trust and continuity (McLaren et al., 2025).
3. **Private buyer and user-financed models** operate mostly at local and subnational levels, led by water utilities, tourism operators, or companies purchasing carbon or biodiversity credits. While these arrangements can effectively link beneficiaries and service providers, the main PES buyers are usually government agencies (WRI 2025).

Emerging innovation: Blended finance models. These combine public, private, and development funds to diversify the capital sources, use public/donor resources to de-risk and crowd in private capital, and build long-term financing architecture. For example, the Herencia Colombia fund blends national budget allocations with donor endowments and impact investment to finance protected areas; within this structure, PES can be one of the financed instruments. While not yet used at national scale for PES in most countries, blended finance can connect and amplify the three established streams and reduce single-source risk.

In summary, for at-scale PES, earmarked tax finance has been the most predictable; public budget-only models can scale quickly but are pro-cyclical; private buyer and user-financed models remain concentrated locally; and blended finance is a promising, cross-cutting innovation to stabilize flows, crowd in private capital, and sustain commitments—though its use at scale in PES is still nascent. Another aspect of sustainability concerns what happens after payments end; rigorous evidence on post-payment durability remains limited.

Conclusions

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Key lessons from the evidence base include:

- **Local conditions.** PES performs best where opportunity costs are moderate and tenure is clear enough to sign and enforce contracts. Targeting the "sweet spot" (not low-threat land, not highly profitable conversion) and using simple payment brackets improves value-for-money. On tenure, strict title reduces disputes but shrinks inclusion; recognized communal/use-rights scale more easily but require stronger local governance. Two plausible contributors—trust in institutions and cultural perceptions of nature—matter for participation and social outcomes, but causal evidence linking them to ecological impact remains mixed.
- **Generalized behaviors.** PES works by shaping behavior through a few reliable levers: reciprocity/fairness (payments seen as a fair exchange sustain buy-in); loss aversion/commitment (conditional, ex-post payments make non-compliance feel costly); and salient monitoring (satellite/spot checks raise perceived detection, boosting compliance). Design tweaks tap on additional levers—timing innovations (front-loaded payments), full-plot enrollment to curb strategic selection, and auctions/scoring rules to screen for higher additionality.
- **Implementation conditions.** Scale with fidelity hinges on four pieces of "plumbing": (1) land verification that separates who signs (rights layer) from what's paid/monitored (contract polygon); (2) conditionality & enforcement verification that is satellite-first with targeted ground truthing and a sanction ladder actually used; (3) transparent payment systems that deliver on time; and (4) low transaction costs via streamlined rules and assisted applications (through intermediaries, technical providers or student extension brigades).
- **Sustainability.** Durable PES pairs stable finance with institutionalized delivery. National programs are most predictable when backed by earmarked tax revenues; public budget-only models scale fast but are pro-cyclical; private/user funds are frequently used at the local and subnational level. Long-run success also depends on on-time payments, credible monitoring and sanctions and periodic rate, and bracket recalibration (including for heterogeneous compliance costs).

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5 These documents were consulted during the course of the literature review, but were not utilised directly in the final text.

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