

## Innovation Subsidy Design and Payments for Ecosystem Services: A Mixed-Methods Approach to Multilateral Environmental Governance

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### ABSTRACT

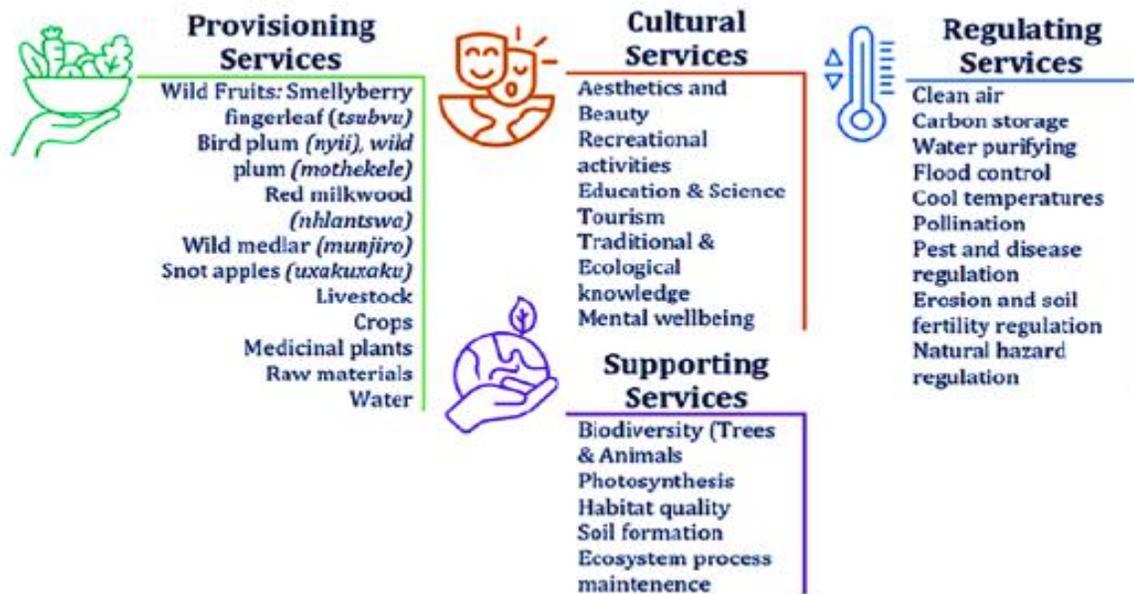
Unsustainable land use practices are a major contributor to climate change through increased greenhouse gas (GHG) emissions. Payments for Ecosystem Services (PES) offer a promising solution by providing financial incentives to individuals and communities that engage in sustainable natural resource management. In Pakistan, where environmental challenges such as desertification, deforestation, and water scarcity are escalating due to climate change and poor land governance, PES remains underutilized and insufficiently embedded in environmental and agricultural policy frameworks. This study examined the household-level socio-economic and land-use characteristics across four ecological zones of Punjab. The study investigates the potential for innovation subsidy designs under a payment for ecosystem services (PES) framework. Quantitative results show that the PES program significantly increased household income ( $\beta_3 = 0.550$ ,  $p < 0.1$ ) and adoption of sustainable practices ( $\beta_3 = 0.310$ ,  $p < 0.1$ ). While vegetation cover showed a positive trend ( $\beta_3 = 0.120$ ), ecological gains were moderate compared to socio-economic shifts. To ensure long-term success, Pakistan should formally integrate PES into the Climate Change Act through decentralized institutional coordination and timely payment disbursement. The results offer a practical roadmap for scaling up sustainable incentive mechanisms in line with the Pakistan Climate Change Act and Sustainable Development Goals (SDGs). Findings suggest that redesigned subsidies focusing on water-efficient crops and soil regeneration led to improved water use efficiency and increased farm-level incomes. PES initiatives showed moderate ecological improvements but high levels of community engagement and interest.

### 1. Introduction

The 21<sup>st</sup> century is defined by a series of interconnected environmental crises, including climate change, unprecedented biodiversity loss, and the degradation of critical natural resources such as land and water (Kalkuta, 2025). A central manifestation of this crisis is unsustainable land use, a problem affecting an estimated 1.6 billion hectares of land worldwide and affected 3.2 billion people (Geneva Environment Network, 2025). These challenges are often a consequence of economic activities that treat natural capital. This classic case of market failure, where the social costs of environmental degradation are not reflected in private economic decisions, has led to a global shift in conservation policy (Ahmed, 2023).

In response, there has been a growing interest in innovative, market-based conservation finance mechanisms that aim to internalize these environmental externalities. Payments for Ecosystem Services (PES) have emerged as a policy solution

(Santamaria, 2025; Song et al., 2023; Bredemeier et al., 2022; Yu et al., 2021; Jack et al., 2008). The concept is elegantly simple: those who benefit from a healthy ecosystem downstream water user, global carbon markets pay those who provide these services upland farmers, forest communities to maintain or restore the ecosystems that produce them (Jodas, 2025; Piolett et al., 2024). Ecosystem services are generally divided into four categories: provisioning, regulating, cultural, and supporting services. Provisioning services refer to the material outputs provided by ecosystems, included food, water, and other resources. Regulation services encompass benefit divided from regulation of ecological process, such as disease control, flood protection, and climate regulation. Cultural services represent non-material benefits. Finally, supporting services consist of the fundamental ecological processes that sustain life on earth and enable the provision of all other ecosystem services (Ali & Kamraju, 2023; Millennium Ecosystem Assessment, 2005).



Source: Millennium Ecosystem Assessment, 2005

**Figure 1: Ecosystem Services Categories**

This approach, which operates on the principles of voluntariness, conditionality, and well-defined services, represents a departure from traditional grant-based conservation, offering a potentially more sustainable and scalable model for environmental stewardship as presented in figure 1.

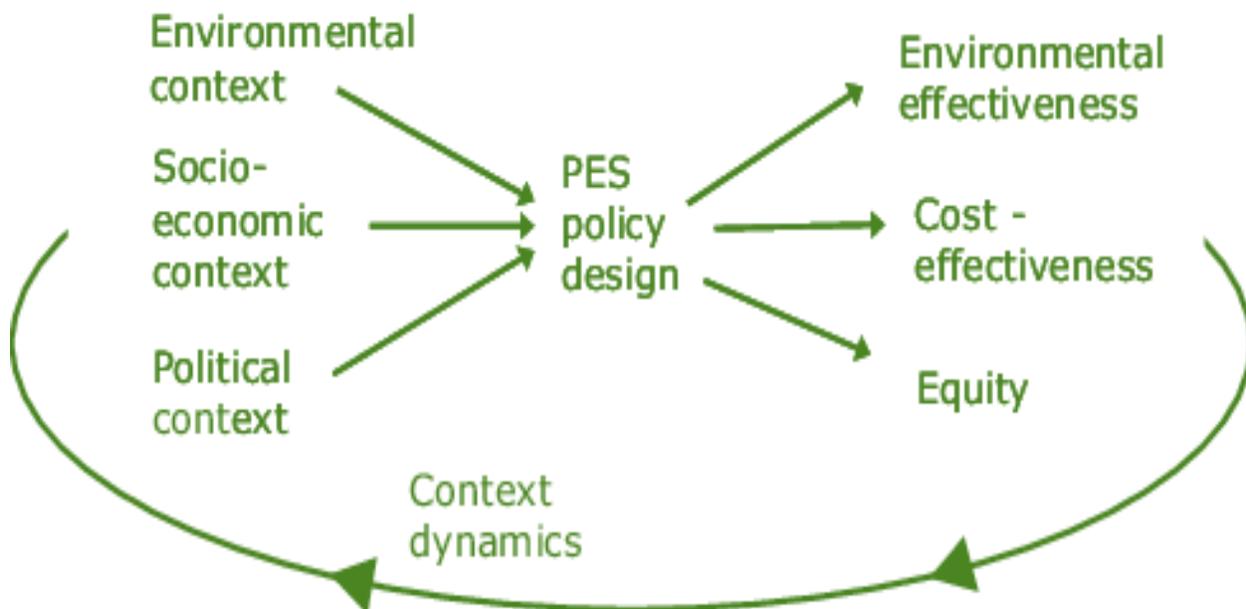
### The Context of Payments for Ecosystem Services in Developed and Developing Countries

The valuation of ecosystem services is a new approach that gained attention of researchers in both developed and developing countries (Zandebasiri & jahanbazi, 2023). Payments for ecosystem services programs began emerging in the early 1990s at various spatial scales, with Costa Rica pioneering the world's first national-level program in 1997 (Garrido Mateos, 2025; Sainz-Santamaria, 2025; Zemke, 2026). Payment for ecosystem services (PES) related to water quality and quantity are more commonly implemented outside of Europe, even though such instruments are also acknowledged within the EU. Globally, they are particularly prevalent in Asia, central, and south America, where downstream hydropower companies often provide direct payment to upper stream handloaders in exchange sediment loads (Balikova et al., 2024; Wang et al., 2020; Vuletic et al., 2020; Bennett & Ruef, 2016). The application of PES is particularly relevant in developing countries, where a

significant portion of the population relies directly on natural resources for their livelihoods. In these regions, land use decisions, such as deforestation for agriculture, are often driven by poverty and a lack of viable economic alternatives (Mayr et al., 2025).

According to the Global Climate Risk Index, Pakistan 5<sup>th</sup> most vulnerable country in the world and faces environmental problems that affect its people and economy (Igini, 2024). Pakistan's dependence on natural resources provides an opportunity to adopt PES schemes that managing this resource sustainably. The framework for PES policy design, show in figure 2, consider that Pakistan faces acute environmental pressures, including desertification, water scarcity, and forest loss.

The concept of innovation subsidies can be effectively integrated with PES. Innovation subsidies, which are financial incentives to encourage the adoption of new technologies or practices, can complement a PES scheme by reducing the upfront costs for providers to adopt environmentally friendly practices (Le et al., 2024; Balikova et al., 2024). In Pakistan, most existing research have focus on ecosystem valuation with selected ecosystem services (Hassan et al., 2022; Muhammad et al., 2021; Balasubramanian, 2020; Hussain et al., 2018; Lekshmi et al., 2015; Kc et al., 2013).



Source: Designing Payments for Ecosystem Services: Lessons from Previous Experience with Incentive-Based Mechanisms, 2008

**Figure 2: PES Policy Design**

Many previous studies emphasize payment for ecosystem services (PES), forest management, land use, public attitudes, and dryland hotspot (Siddique et al., 2025; Shekhar et al., 2025; Ali et al., 2023; Akhtar et al., 202; Aziz, 2021; Din et al., 2020; Ali et al., 2020; Khan et al., 2019a; Khan et al., 2019b; Alam, 2013). Environmental governance in Pakistan is a complex and often fragmented landscape. Despite having a comprehensive legal framework, including the Pakistan Environmental Protection Act (PEPA) 1997, the implementation and enforcement of environmental laws remain weak (Ali & Shah, 2019). There is a general lack of environmental literacy and limited public participation in policymaking, making community-based conservation initiatives difficult to sustain (Zaheer et al., 2019). Ambiguous or insecure land tenure and property rights can be a major barrier to PES, as providers may lack the legal standing to enter long-term contracts for ecosystem services.

The existing body of literature highlights the need for context-specific research that can inform policy design. However, there is lack of comprehensive studies that access PES adoption across multiple zones, integrating both ecological and socio-economic outcomes. To address this gap, the present study investigates innovation in subsidy design and implementation of payment for ecosystem services (PES) in Punjab, Pakistan across four distinct ecological zones.

**2. Materials and Methods**

This study conducts primary data to design an innovation subsidy framework for payment for ecosystem services (PES) across ecological zones Punjab, Pakistan.

**Study Area and Sampling**

The research was conducted in four distinct ecological zones in the Punjab, Pakistan.

**Table 1: Distribution of Selected Districts Across Ecological Zones of Punjab, Pakistan**

Ecological Zone	Area
North (Fertile zone)	Attock, Chakwal, Rawalpindi, and Jhelum
Barani Zone (Rainfed)	Potohar region, Khushab
Sandy Land Zone	Rahim Yar Khan and Bahawalnagar
South Zone (Fertile)	Multan and Bahawalpur

Each zone is characterized by distinct agro-ecological conditions and farming practices. These zones were selected because they represented the diverse ecological, climatic, and agricultural settings of Punjab.

A stratified purposive sampling method was used to select 300 households that were proportionally divided across the four ecological zones to capture their diverse agro-ecological diversity. Each zone contributed approximately 75 households, further divided into two groups:

**1. Treatment Group (n=150):** Households participating in a pilot PES program, which provides financial incentives for the adoption of sustainable agricultural practices, such as agroforestry and efficient water management.

**2. Control Group (n=150):** Households in demographically and economically similar areas that were not participating in the program.

**Quantitative Component**

The quantitative component of the study was based on a comprehensive household survey carried out at two points in time:

Pre-treatment (baseline): Before the program's implementation

Post-treatment (follow-up): one year after program's implementation

The survey collected data on a wide range of variables, including: 1: Socio-economic data: Household income, farm size, education level, and alternative livelihood sources. 2: Land-use practices: Crop diversity, use of fertilizers and pesticides, water management techniques, and presence of tree cover. 3: Environmental outcomes: Self-reported and remotely sensed data on vegetation cover, soil erosion, and water quality.

**The Difference-in-Differences (DiD) Model**

The primary analytical tool for quantitative data was the Difference-in-Differences (DiD) model. The DiD model

**3. Results and Discussion**

This study examined the household-level socio-economic and land-use characteristics across four ecological zones of Punjab to access the potential for innovation subsidy designs under a payment for ecosystem services (PES) framework.

**Descriptive Statistic**

The descriptive statistic table 1, results reveal that heterogeneity across zones of Punjab, reflecting diverse agro-ecological conditions and farming practices. Average household size was relatively similar, similar, ranging

estimates the causal effect of an intervention by comparing the change in outcomes over time for a treatment group to the change in outcomes for a control group.

Functional form of the model:

$$Y_{it} = f(X_1, X_2, \dots, X_3) + \varepsilon_{it} \tag{1}$$

Econometric Equation:

$$Y_{it} = \beta_0 + \beta_1(Treatment_i) + \beta_2(Post_t) + \beta_3 (Treatment_i \times Post_t) + X_{it} + \varepsilon_{it} \tag{2}$$

Where:

$Y_{it}$  is the outcome variable (e.g., household income, vegetation cover) for household  $i$  at time  $t$ .  $Treatment_i$  is a binary variable equal to 1 if the household is in the treatment group and 0.  $Post_t$  is a binary variable equal to 1 for the post-treatment period and 0 for the pre-treatment period.  $(Treatment_i \times Post_t)$  is the interaction term, and its coefficient  $\beta_3$  represents the average treatment effect of the PES program.  $X_{it}$  shows the control variables, and  $\varepsilon_{it}$  is the error term.

The validity of the DiD model rests on the parallel trend's assumption, which posits that in the absence of the treatment, the average outcome of the treatment and control groups would have followed parallel trends over time. We tested this assumption by examining pre-treatment trends in key outcome variables and found no significant differences, bolstering the credibility of our causal estimates.

between 5.9 and 6.5 members. Income difference was also apparent, with the households in the North reporting the highest average annual income (PKR 240,000) and those in the Barani zone the lowest (PKR 190,000). The use of fertilizer was also highest in Sandy land, reflecting input-intensive farming, while the Barani zone had the lowest (85.7 kg/acre). Overall, the results indicate clear variations across ecological zones in terms of landholding, income, irrigation, and input use.

**Table 2: Descriptive Statistic**

Variable	North Zone	Barani Zone	Sandy Land	South Zone
Household size	5.9 (1.9)	6.1(2.2)	6.5 (2.3)	6.3 (2.0)
Age of Household	44.8 (11.5)	46.3 (12.9)	45.5 (12.1)	46.2 (12.6)
Education	9.1 (3.9)	7.8 (4.2)	7.5 (4.1)	9.0 (3.8)
Landholding Size (acres)	5.1 (2.7)	3.8 (2.5)	6.2 (3.2)	4.0 (2.6)
Annual Household Income (PKR)	240,000 (88,000)	190,000 (78,500)	200,000 (80,000)	230,000 (82,300)
Main income source = (farming %)	78.5	70.2	76.8	70.7
Irrigation Access (%)	55.0	40.0	80.0	69.0
Fertilizer use (kg/acre)	90.0 (21.4)	85.7 (20.8)	110.2 (25.5)	95.0 (22.1)

Mean (SD)

**Difference-in-Differences Estimates of PES Program**

The DiD table 3, results show a significant positive impact of the PES program across four ecological zones in Punjab,

Pakistan. The interaction term (Treatment × Post) captures the causal effect of intervention. The household income (0.550\*), Standard Error 0.180\*\* significantly increased,

suggesting that subsidies provided direct financial relief and incentivized sustainable practices. This is consistent with finding from Wunder et al., (2000); Engel et al., (2008). The Grain-to-green program in China (Giefer, 2020) showed that income subsidies helped to improve rural livelihoods. The positive effect on vegetation cover indicates that PES subsidies encourage land restoration and agroforestry. PES interventions promote forest growth and reduce soil erosion. This aligns with Kemigisha et al., 2023; Nath et al., 2023; Pagiola, 2008. The PES subsidies can improve ecological outcomes through input support and land diversification. The adoption of PES practices (0.310\*, SE (0.100 \*\*)

significantly increased among treatment households, showing well-designed subsidies are effective to overcoming barriers to behavioral change. The results further show that in Barani (rainfed) zone, subsidies mainly supported water conservation and soil management practices. In the Sandy land zone households adopted measures to improve soil fertilizer and reduce excessive fertilizer use; while North and South fertile zones, focused on agroforestry and crop diversification. The R-squared value indicates that household and zone factors were important, though other influences also mattered.

**Table 3: DiD Result**

Variables	Income	Vegetation Cover	Adoption of PES
Treatment (Household in PES)	0.210 (0.150)	0.045 (0.030)	0.120 (0.080)
Post (After Program)	0.320 (0.140)**	0.065 (0.025)**	0.090 (0.050)*
Treatment × Post	0.550 (0.180)*	0.120 (0.040)*	0.310 (0.100)*
Household controls	Yes	Yes	Yes
Zone fixed effects	Yes	Yes	Yes
R-squared	0.42	0.35	0.39

Notes: Robust standard errors in parentheses. \*\*\*p<0.01, \*\*p<0.05, \*p<0.1.

#### 4. Conclusion

This study examines the innovation subsidy designs payment for ecosystem services (PES) across four ecological zones in Punjab, Pakistan. Statistical analyses included Difference-in-Differences (DiD) regression models. Overall, finding underscore that PES subsidies are most effective when they are context-specific, addressing both ecological and socio-economic realities of farming households. The study suggests strong institutional coordination is needed to minimize bureaucratic delays and ensure timely disbursement, while farmer awareness and training program can enhance adoption. Integrating monitoring through surveys, remote sensing, and community feedback will strengthen accountability. Financial sustainability requires innovative funding mechanisms, including green taxes, climate fund, and private public partnership. This study is limited by its one-year follow-up period, which may not fully capture long-term ecological impacts like forest maturation. Future research should utilize longer longitudinal data and perform cost-benefit comparisons with traditional subsidy schemes to provide deeper insights.

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