Designing digital systems for scale: Payments for Environmental Services

Payments for Environmental Services (PES), also known as Payments for Ecosystem Services, is a results-based financing mechanism to promote environmental conservation and restoration by the hands of local communities, farmers, and Indigenous communities, providing cash benefits for acting as custodians of nature. The publication explores the integration of digital technologies into Payments for Environmental Services (PES) schemes. The report underscores the potential of leveraging Digital Public Goods (DPG) and Digital Public Infrastructure (DPI) to enhance the scalability, efficiency, and effectiveness of PES programs. The research was conducted through interviews with UNDP practitioners, frontrunner countries with national PES schemes.

This guide is designed for PES practitioners, policymakers, financiers, and digital innovators. It begins with an introduction to PES, detailing its significance in promoting sustainable environmental services and providing financial incentives to local stakeholders. The document then delves into the opportunities and challenges associated with digitalizing PES schemes, highlighting lessons learned from previous implementations and the critical role of DPGs and DPIs in overcoming these challenges. The core of the report presents a practical framework for designing a digital PES system, including technical requirements, system architecture, and key software tools. It outlines a nine-step process for PES implementation, from application and legal assessment to field data collection, monitoring, and payment disbursement, and emphasizes the need for a modular, open-source approach that can be adapted to different national contexts and ecosystems. By showcasing the benefits of digital innovation in PES, UNDP aims to foster collaborative efforts among governments, NGOs, and the private sector to scale up nature and climate action globally. The report concludes with a call to action for increased investment in digital solutions that support sustainable development and climate resilience.

1. GENERAL STEPS TO ESTABLISH AND MANAGE A PES SCHEME

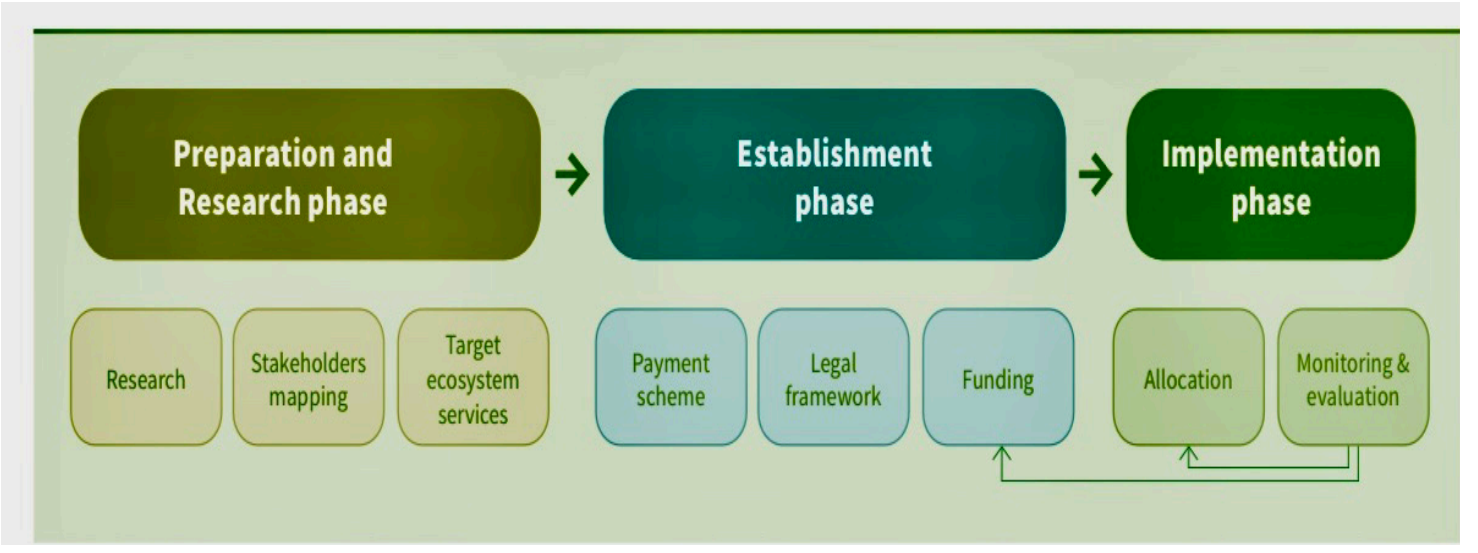
For countries that are developing an IT system for PES management, the report will inform the system architecture, readiness assessment, and technology roadmap. For countries and practitioners that are in the process of creating a new PES scheme, this report will show a future vision for digitally-enabled PES, which can help to design better processes and regulations. For donors and financers, the report will serve as an invitation for digital cooperation and investment opportunities toward open-source, open data, and local nature and climate action.

PES is a resultsbased, conditional financing mechanism that compensates farmers and local communities for the environmental services provided, due to specific actions and efforts undertaken by these stakeholders in their land. Under PES schemes, payments are conditional upon performance that is to receive cash transfers, participants must achieve outcomes by doing (or refraining from doing) certain activities.

Across the world, various PES schemes, or PES-like schemes have emerged to incentivize farmers and local communities to maintain forests or watersheds on their land or avoid agricultural expansion into nearby forest areas. According to a recent study, there are more than 550 active programs around the globe and an estimated US$36–42 billion in annual transactions. This includes a variety of arrangements through which users of environmental services, from watershed protection and forest conservation to carbon sequestration, reward communities or individuals whose lands provide these services with payments or monetary compensation, including cash transfer.

PES has been critical especially in forest landscapes, given the forests' essential role for over 1.6 billion people's livelihood, as well as serving as the 'lungs' of the Planet. If deforestation is stopped and degraded forests were stored, forests can provide a third of the carbon emission reductions and removals needed to avoid the most severe impacts of climate change. Paying for the benefits of natural ecosystems is a way to recognize their value and ensure that these services continue to be provided well into the future. In the current economy, the strongest financial incentive given to farmers and local communities encourages them to convert nearby forests and forest patches on their land into agriculture fields to increase production, and hence increase household income. This is the trend that PES is trying to counter.

In addition to preserving natural resources, PES has the potential to improve livelihoods as it can transfer needed cash resources directly to impoverished groups. In addition to being widely used to cushion the economic damage from sudden shocks, conditional direct cash transfers have long been recognized as an effective tool for poverty reduction worldwide, yielding benefits to health, education, employment, and overall well-being. UNDP has been working with countries to establish new



▲ *Fig 1. PES life cycle* *Source: undp.org*

PES schemes, as well as to improve and enhance the implementation of existing PES schemes around the world. To further illustrate the benefits of PES, this section provides some examples of PES from countries.

PES schemes start from a preparation phase which includes an environment valuation study and feasibility study, stakeholder engagement and a process to define the target ecosystem services. Based on the research, a PES scheme is established. Specifically, this phase includes the designing of the programme and payment scheme, preparation of a legal framework and fund mobilization, which may be secured through international funding or national sources. Thereafter, implementation will start across years, which entails the conditional payments to individuals or communities, monitoring and evaluation of the programme, and funding replenishment. The diagram outlines the major steps required for establishing and implementing a PES scheme. Although not an exhaustive list, these steps serve as important benchmarks throughout the process and contribute to the overall success of the PES scheme. (Fig 1)

2. OPPORTUNITIES AND KEY CONCEPTS FOR DIGITALIZING PES SCHEMES

This section outlines how recent advancements in digital technologies and key concepts such as Digital Public Goods and Digital Public Infrastructure bring opportunities for PES and other similar innovative incentive mechanisms to be brought to scale.

Lessons learnt from earlier PES information management systems

Information management systems have been used for PES scheme implementation in earlier years. Interviews with managers of several front-runner national PES programmes surfaced three common challenges of earlier technology and approaches: Need for a holistic approach; Limited ability to update to new technology options; Lack of interoperability and open data policies.

Digital technology to support PES

Application Programming Interface (API) for interoperability: APIs are sets of protocols and tools that allow different software applications to communicate and share data and functionalities seamlessly. It is a direct way of solving the 'interoperability' issue. Most PES management systems pull data from different databases and overlay geospatial information.

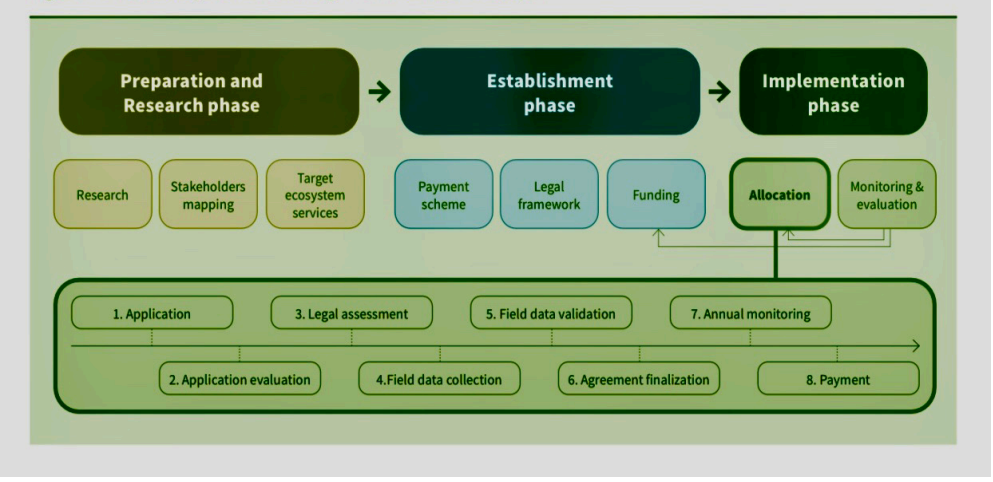
High-resolution satellite imagery and remote sensing: Satellite imagery and remote sensing allow better data collection, particularly in remote locations or large-scale implementation. Where field data collection is challenging, remote sensing can provide a first rapid assessment of land use, while field data acts as primarily a verification exercise, saving inperson trips. In addition to local ground proofing needs, ecosystem qualities, such as biodiversity, cannot be determined from satellite imagery and require a combination of different technology and/or human research.

Mobile phones: Simple technology can significantly improve and reduce the cost of field data collection, encourage user enrolment, ease cash payment and add possibilities for new ways of verification by the beneficiaries themselves. Enumerators are able to efficiently collect georeferenced information on farmers, communities, their land, and forests cover on their land. Various open-source data collection apps exist to assist depending on the type of environmental service.

Artificial intelligence (AI): AI can support the automation of farm boundary detection, differentiation between arable and forest land, eligibility criteria verification, monitoring of the forest, and decision-making on whether

critical elements of the PES agreement were fulfilled.

Distributed ledger technologies: Distributed ledgers are digital systems for recording the transaction of assets in which the transactions and their details are recorded in multiple places simultaneously. This technology is most famously exemplified by blockchain, which underpins cryptocurrencies like Bitcoin but can be applied to a wide range of other transactions and record-keeping systems, making them decentralized, immutable, and transparent. Countries with existing foundational Digital Public Infrastructure (DPI), such as a national digital ID system, are at an advantage when scaling the beneficiary enrolment. Especially when data such as bank information or land ownership are already integrated, with robust privacy and security measures.



▲ *Fig 2. The PES life cycle with the eight allocation sub-steps*

Source: undp.org

Digital payment systems: By enabling swift, secure, and transparent transactions, digital payment platforms significantly enhance the efficiency of PES initiatives. Existing DPI for Digital Payments makes it feasible to include a broader range of participants in PES schemes, as the ability to execute a payment transaction can often be a limiting factor in scaling the scheme. As PES is a growing climate action mechanism with commonalities across countries, regions, and types of ecosystems, it is well suited for a Digital Public Good (DPG) approach. DPG is open-source software, open data, open AI models, open standards and open content that adhere to privacy and other applicable best practices, do no harm and are of high relevance for attainment of the SDGs.

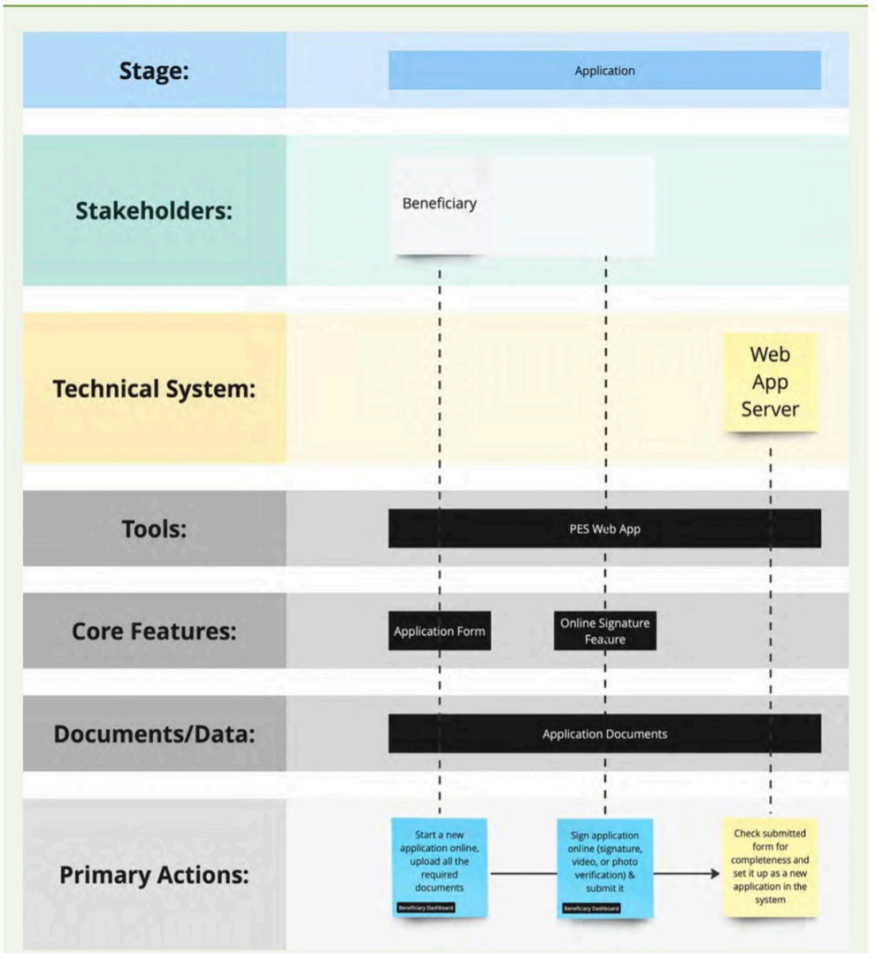
In recent times, Digital Public Infrastructure (DPI) has emerged as a critical enabler of digital transformation in multiple sectors in several countries. DPI is a set of shared digital systems that are secure and interoperable, built on open standards and specifications to deliver and provide equitable access to public and/or private services at a societal scale.

Designed and implemented well, DPI can boost the capacity of countries to achieve their national development priorities, accelerate the Sustainable Development Goals (SDGs) and also scale the green transition. DPIs are governed by rules and principles that drive and uphold sustainable development, inclusion, innovation, trust, human rights, and fundamental personal freedoms. There are three DPIs that are deemed 'foundational' to carrying out essential public functions and which should be accessible at a low cost to citizens or the end beneficiary. The following three foundational DPIs allow the technology stack to facilitate crosssectoral innovation and population-scale impact: Digital Identity; Digital Payments; and Consent-based Data Sharing.

3. DIGITALIZATION OF THE PES IMPLEMENTATION SYSTEM

This publication outlines how the PES implementation process works, and proposes a digital solution for each step of the process. The incentive allocation, which is the granting of funds, is one of the most important phases of the PES process as it comprises all the central PES allocation steps from the beneficiary application to the final compensation/payment. In total, this phase consists of eight sub-steps (Figure 2). A contract is made with each individual (or community). The land is monitored against ecosystem indicators (e.g., forest coverage, forest quality, biodiversity, water quality, etc.), results are validated, and payment is made. Some schemes have also included social safeguard requirements to complement environmental indicators.

Application: In the first stage of the fund-granting process, applicants send their application for their country's PES system via the PES web app. After filling in all the application data and attaching all the relevant documents (e.g., farm maps), the potential beneficiaries can directly sign their application online (either via written, photo, or video signature), from which it is automatically forwarded to the corresponding PES Team. From here, it will be analyzed in the next system stage. The application process can be streamlined if the country has a Digital ID system (Foundational DPI) which can be integrated with the PES application process.



▲ *Fig 3. Application details*

Source: undp.org

Application evaluation: Once submitted, every application goes through an evaluation process. After a preliminary manual completeness review, the PES Team creates an initial geodata file (e.g., shapefile) of the beneficiary's farm area and uploads it to the PES web app. From there, it is converted into Structured Query Language (SQL) - readable Geographic Information System (GIS) data and uploaded to the backend SQL database.

Legal assessment: The legal assessment occurs after the initial application evaluation to verify the potential beneficiary's land ownership. If there are any impending legal issues, the PES Team marks those as having to be resolved by the beneficiary via the PES web application.

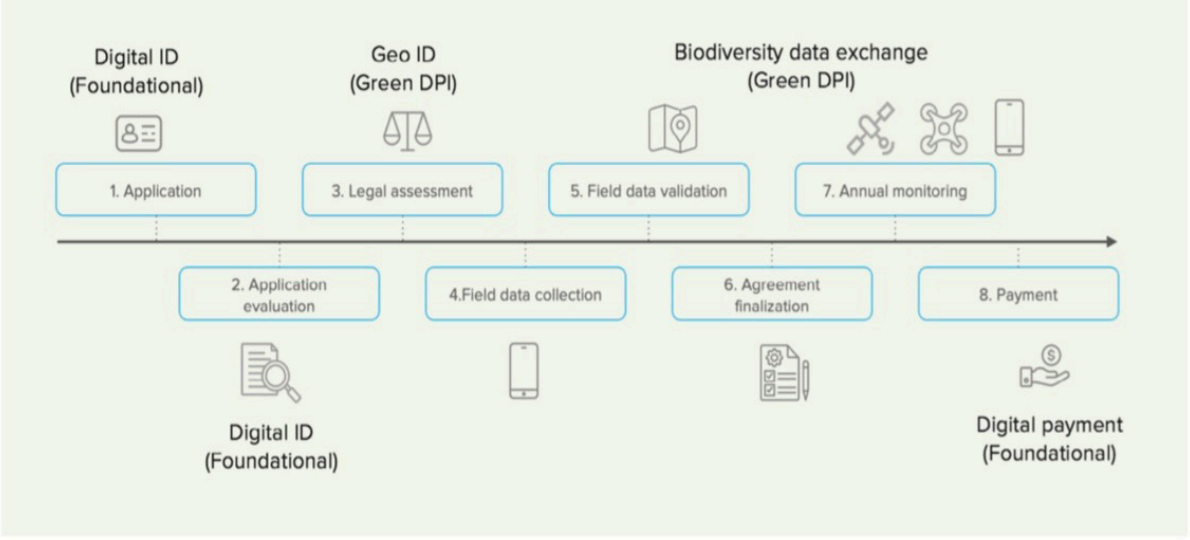
Field data collection: For the field data collection, an independent (or, in some countries, internal) PES expert is assigned (or, in some countries, personally contracted by the beneficiary) to visit and geolocate the farm. The PES Expert has to map out the ultimate and exact perimeters of the farm. The future PES area within (e.g., forest for protection, reforestation, agroforestry, etc.) as well as, in some cases, evaluate the condition and ecological value of the forest (there are other methods this value can be determined by, such as through GIS models that have been established for the PES scheme).

Field data validation: A fully automated validation process transforms the shapefiles from the previous step into SQL-readable geodata to verify that the field study documents comply with the approval requirements. On the SQL database, two separate checks are performed: first, to confirm the correctness of the uploaded geodata (e.g., identify topological errors), and second, to map out any overlaps with other areas (properties, government land, other PES areas, etc.).

Agreement finalization: An agreement is sent to the beneficiary via the PES web app to finalize the application process. Once signed, the agreement becomes official, and the SQL backend database takes the GIS location of the beneficiary's farm and merges the effective PES area with the geodata of all the other farm PES areas, thus creating a single file that complies in the entirety of the PES areas/sites. This geodata layer is crucial for monitoring and controlling the development of the PES program, as it documents all the forest/ecosystem areas that are part of the system.

Annual monitoring: Every year, all the agreed-upon PES farm/community areas need to be monitored to verify their compliance with the initially drafted beneficiary agreements. This can be done either entirely remotely or with the help of a PES Expert who conducts a field visit to verify the beneficiary's farm area directly on the ground. Any potential changes to the agreed-upon PES area are tracked and uploaded to the PES web app.

Payment: After the annual monitoring results are finalized, the last step of the fund-granting process is the payment stage. Here, the backend PES system automatically relays the compensation payment to each beneficiary to reimburse them for their efforts. This can be done as a bank transfer, via check, or with the help of local NGOs, which might pay out any payment directly to the corresponding beneficiaries in cash (depending on the paymentrelated locally available). This is an apparent case where a foundational DPI Digital Payment system can be useful. After the payment,

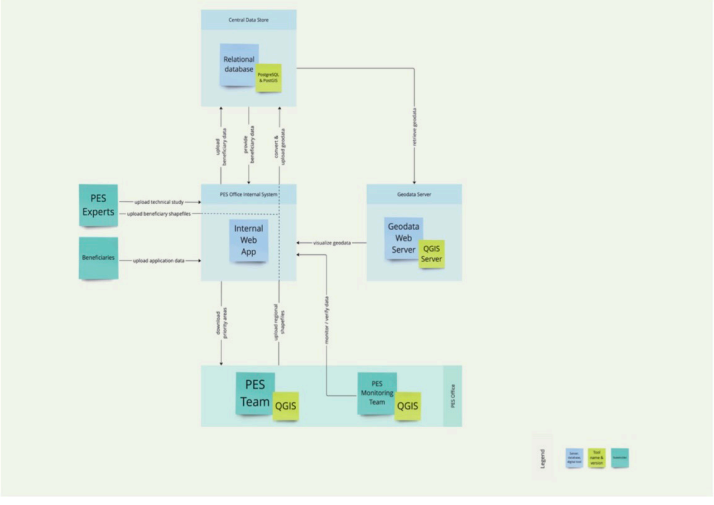


▲ *Fig 4: DPI opportunities for each step of PES implementation*

Source: undp.org

the PES fundgranting process repeats itself the following year, either at the annual monitoring step or at the application stage (if the agreement expires and needs to be renewed). Fig 4

DPI opportunities: As identified in each process section, a digital PES system will greatly benefit from leveraging on foundational DPIs if they already exist in a country. In addition, a 'geospatial ID' or land registry is a potential 'Green DPI' to help streamline the contracting and monitoring processes, along with a data exchange protocol for biodiversity and ecosystem data to incentivize data sharing from beneficiaries, private sector and citizens to revolutionize results verification.



▲ *Fig 5. PES system data flow*

Source: undp.org

4. TECHNICAL REQUIREMENTS AND ARCHITECTURE

The final section outlines the technical requirements, system architecture, information architecture, and core feature lists for a digital solution to support PES schemes implementation.

Technical requirements - data flow: The underlying structure of the universal PES process follows a heavily streamlined system approach with a high degree of automatization. The data flow on the right indicates how information is sent from one tool to another, thus creating an intricate system in which all data exchange paths are greatly optimized.

Technical requirements - Tools & software: RDBMS Server (PostgreSQL & PostGIS); QGIS Server; Web Backend Server; Internal PES Web App; GIS Software (QGIS.

System architecture: PES process. As part of its overarching system framework, the universal PES process features a variety of tools and software elements that all work together in the streamlined processing of geospatial data and beneficiary application documents. Hereby, all the tools that are part of the system fall into one of two overarching categories: frontend or backend. While the frontend tools are responsible for all the manual activities that must be executed as part of the PES process, the backend handles all the automated geodata analysis procedures and storing relevant beneficiary application data.

Information architecture - PES web application: A crucial component of the universal PES Process is the so-called PES web application (web app for short), which acts as the central interaction point between the front- and back-end of the system. The PES web app is the online portal through which all local geographic data generated by PES Experts and Teams is converted into SQL GIS data and then uploaded to the corresponding SQL database ▪

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Source: undp.org