Payment for Ecosystem Services in the Era of Sustainable Agriculture: Insights from The Northern Everglades Payment for Environmental Services Program

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Abstract

The transition to sustainable agriculture has underscored the critical role of Payment for Ecosystem Services (PES) programs in addressing environmental challenges while supporting agricultural productivity. This paper examines the Northern Everglades Payment for Environmental Services Program (NE-PES) as a case study to derive insights for designing cost-effective and collaborative PES programs. The NE-PES program implemented a hybrid payment scheme that integrates action-based and results-based contracts, enhancing economic efficiency and accountability. Advanced monitoring technologies, such as hydrological modeling and remote sensing, support accurate verification of service delivery, fostering trust among diverse stakeholders. Despite its achievements, challenges such as scalability, integration of diverse ecosystem services, and stakeholder heterogeneity highlight the need for innovative approaches in program design and implementation. The findings from this paper highlight cost efficiency of PES contract design. The paper also offered strategies to address scalability and integration for policymakers and practitioners as PES programs expand under climate-smart agricultural policies.

Keywords: Payment to Ecosystem Services; Contract Design; Sustainable Agriculture, Monitoring, Measuring, Reporting, and Verification

JEL Classifications: Q51, Q52, Q53, Q57

Introduction

The U.S. government has invested substantial funds in agri-environmental policies with a goal of limiting negative externalities from agriculture while bolstering farm income (Gómez-Limón et al., 2019). The Payment for Ecosystem Services (PES) framework is a cornerstone for addressing those conservation challenges in agricultural landscapes (Wunder, 2005). By compensating landowners or resource stewards for managing their land to provide ecosystem services, PES promotes conservation in a cost-effective and voluntary manner. Dee et al., (2023) highlight that by incorporating ecological considerations into economic planning, policymakers can mitigate adverse environmental impacts while promoting sustainable growth.

The establishment of robust and trustworthy Measurement, Monitoring, Report and Valuation (MMRV) processes is essential for ensuring the accountability, transparency, and effectiveness of PES programs. Ranchers and landowners play a critical role in agricultural ecosystem services through PES. To better measure and monitoring the PES effectiveness of these practices and improve ecosystem estimates, the Inflation Reduction Act (IRA) invests $300 million eight years to support USDA broader Measurement, Monitoring, Report and Valuation (MMRV) efforts (Smith & Swanson, 2024). These funds will support a comprehensive strategy to improve measurement and the monitoring effectiveness (Smith & Swanson, 2024). An additional $19.5 billion to support the USDA's conservation programs is expected to deliver reductions in greenhouse gas emissions or increases in carbon sequestration as well as significant other benefits to natural resources (e.g. soil health, water quality, pollinator and wildlife habitat).

Given that many of the current conservation initiatives are still in the implementation phase, this paper describes the existing and evolving design of the Northern Everglades Payment for Ecosystem Services (NE-PES) program, a historical program with 20 years of practice. Employing a case study approach, we analyze the historical design and outcomes of the NE-PES program in Florida to derive key lessons regarding economic efficiency and stakeholder engagement in PES. Our discussion specifically highlights how NE-PES's hybrid payment scheme and advanced monitoring framework contributed to its cost-effectiveness, and how its co-development framework fostered collaboration and trust among participating stakeholders. By examining these facets, this paper aims to provide actionable insights for the design and implementation of future PES programs.

The Introduction of NE-PES Program

The Northern Everglades (NE) is widely recognized as a crucial area for the restoration of ecosystem services (Figure 1), which area is defined by Northern Everglades and Estuaries Protection Program. Encompassing the largest mangrove ecosystem in the Western Hemisphere and the largest continuous stand of sawgrass prairie, the NE significantly contributes to water storage, nutrient reduction, and biodiversity conservation (National Research Council, 2012).

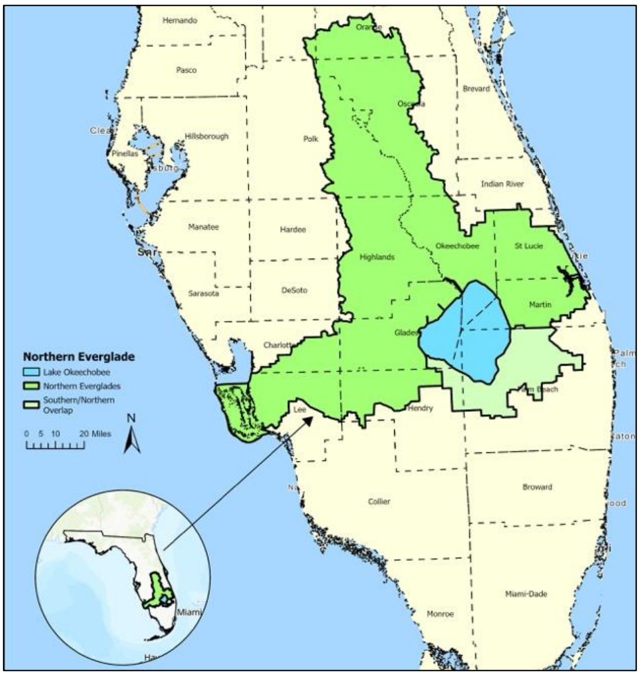

Figure 1: Northern Everglades Area

Given the vital role of the ecosystem services provided by the NE, a payment for ecosystem services program (hereinafter referred to as NE-PES) has been established. This program offers financial incentives to local ranchers who undertake efforts to maintain these essential ecosystem services (Villamagna et al. 2013). The NE-PES program was specifically designed to compensate ranchers for water storage, with additional payments for reductions in nutrient loads. This structure enables ranchers to sustain their income while simultaneously contributing to broader environmental objectives, including pollution reduction, wildlife support, and wetland restoration (Brander et al., 2024).

The NE-PES program represents a significant investment, with roughly $7 million already invested in its design and stakeholder collaboration. Additionally, an estimated $43 million in service payments are slated to be paid to ranchers based on contracts (FRESP, 2013; SFWMD, 2022). With its substantial funding, the NE-PES is characterized by extensive collaboration among various stakeholders, including:

- **Ranchers:** These are the providers of environmental services.
- **NGOs:** Organizations like World Wildlife Fund (WWF) and Resources for the Future (RFF), among many others, assist with the NE-PES program design.
- **Management agencies:** The South Florida Water Management District (SFWMD), Florida Department of Environmental Protection (FDEP), and the Florida Department of Agriculture and Consumer Services (FDACS) provide funding support and management.
- **Interdisciplinary technical support team**: This team comprises research scientists from the Institute of Food and Agricultural Sciences (IFAS) and the MacArthur Agro-Ecology Research Center (MAERC) at the University of Florida.

This collaborative framework underscores a collective commitment to both preserving the ecological integrity of the Northern Everglades and supporting the economic viability of ranching operations through the NE-PES program.

Design of the NE-PES Program

Monitoring, Measuring, Reporting, and Verification (MMRV) plays a pivotal role in assessing the effectiveness of Payment for Ecosystem Services (PES) projects in the era of sustainable agriculture (Wu, 2023).

A distinctive characteristic of the design of the NE-PES program is its watershed-specific MMRV process. The target reduction of the payment is derived from the Watershed Protection Plans (WPPs) developed by the South Florida Water Management District (SFWMD). These plans aim to manage nutrient sources at both local and regional levels (Northern Everglades Watershed Protection Plans (WPPs, 2024).

Payments to ranchers are based on the volume of water retained, with this parameter quantified through an established water flow monitoring system and baseline conditions. To support the MMRV process, the program significantly invested in automated water flow monitoring, water sampling, and subsequent analysis, commencing from the initial design phase at the pilot sites. Data collection at the designated monitoring sites (Figure 2) occurs basis monthly during the dry season (November – April) and biweekly during the wet season (May – October). The monitoring framework integrates on-site sensors, remote sensing techniques, and data protocols, to ensure the transmitting ability of the key payment metrics are delivered as expected.

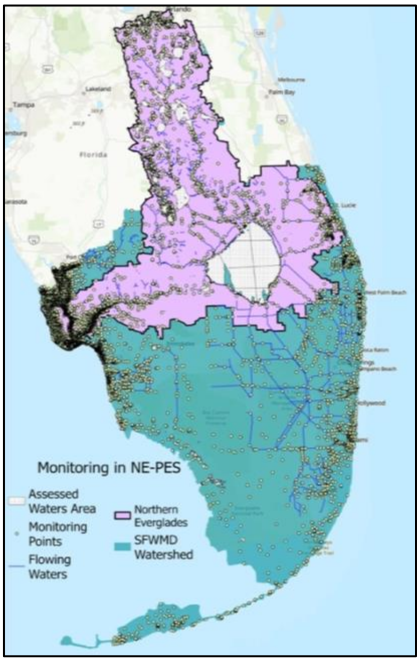

Figure 2: NE-PES Moniorting Sites Update to May 2024

Note: The yellow points are water quality monitoring sites. The polyline feature class representing the watershed monitoring program's flowing waters (Rivers, Streams, and Canals) resource coverages across the State of Florida. The assessed waters area features in the State of Florida that are monitored by the U.S. Environmental Protection Agency (US EPA).

Ranchers are eligible to receive payments for both verified water retention (based on the confirmed volume of water stored) and water quality (based on the reductions in nutrient loads) improvements (Shabman & Lynch, 2013). As a premise for enrollment, the ranchers need to enroll or started the ranchlands containing in the FDACS best management practice (BMP) program by the date of the solicitation release, and comply with SFWMD rules and regulations, and federal wetlands regulations regarding of the lands in his/her ownership. So, eligible ranchers may develop management strategies that provide either both water retention and nutrient reduction services, or solely water retention, in a cost-effective manner to get payment.

The compensation for water storage ranges from $98 to $158 per acre-foot and the compensation for nutrient loads (e.g., total phosphorus [TP] and nitrogen [N]) are compensated at a rate of $15 to $42 per kilogram of total nitrogen treated (Brander et al., 2024). To receive payments, ranchers are required to submit certain records include monthly riser board elevation levels at outfall structures, changes to the board elevations, rainfall data, water levels, and site conditions (Shabman & Lynch, 2013). Given the seasonality of the annual water retention and nutrient removal levels, the contract is designed based a 10-year rainfall periods average level, and hydrological models are used to predict how proposed management practices will alter water retention and nutrient reduction levels compared to baseline conditions (Shabman & Lynch, 2013).

The monitoring agency agreed that contracts would be based on model predictions of average annual water retention or nutrient removal service expected during a 10-year rainfall record period. Finally, utilize hydrological models to predict how proposed management plans will alter water retention and nutrient reduction compared to baseline conditions (Shabman & Lynch, 2013). The ranchers might fall short of or exceed the service level commitment over the period of contract, but the average service level should be provided. To address the agency (buyer) concern that services being paid for would be "above and beyond" existing requirements, the district developed an operational tool for calculating baseline environmental services (Shabman & Lynch, 2013). Using the tool, only above-baseline water retention services were to be credited for payment (SFWMD, 2022).

Water Farming Payment (WFP) for Environmental Services Pilot Projects (ESPP) is a performance-based payment. Participants receive compensation both for implementing prescribed land and water management practices (e.g., modifying berms, pump operations) and for volume of water retained and nutrient reduction achieved through hydrological monitoring. Each monitoring site is monthly inspected monthly by the SFWMD contractor to document compliance with contract requirements. The contractor completes a monthly monitoring report, and service providers are required to submit an annual certification stating that the project is operating as designed (Shabman & Lynch., 2013).

Lessons Learned from the NE-PES Program

The NE-PES program offers insights into improving the economic efficiency of PES initiatives, primarily through three successful practices:

Hybrid Payment Scheme: The NE-PES program adopted a hybrid payment scheme that combines action-based practices for implementing specific water management practices with results-based payments for verified water retention and nutrient removal. Participants receive compensation both for implementing prescribed land and water management practices (e.g., modifying berms, pump operations) and for volume of water retained and nutrient reduction achieved through hydrological monitoring. This hybrid payment scheme, particularly when outcome-based payments are averaged over multiple years, offers both practical and direct incentives for providers to achieve desired environmental outcomes.

Recent research indicates that retrofitting on-farm water detention areas under NE-PES removed nitrogen at roughly $12 per kilogram, compared to $180–$214 per kilogram for equivalent nutrient removal in traditional approaches of subsidy program (e.g. wetlands or tailwater systems) (Shukla & Shukla, 2024).

Reduction of Transaction Costs: A critical consideration in the PES program is the reduction of transaction costs. The NE-PES program incorporated multiple initiatives to address this challenge: First, by basing payments on a combination of prescribed practices and verified results averaged over multiple years, this program establishes a low-cost approach to documentation and verification; Second, the employment of the hydrology model allowed for the accurate consideration of site-specific conditions, including soil type, vegetation, topography, and existing infrastructure. Third, the integration of remote sensing techniques, such as LiDAR, offers a scalable solution for monitoring effort, which allows for explanation under future programs (Wollenberg et al., 2022).

Co-development and Stakeholder Engagement: An essential component of the NE-PES program is its strategy for co-development and stakeholder engagement, which has been instrumental in building trust throughout the program's design and implementation phases. The program's multi-stakeholder governance structure, actively engaging ranchers, government agencies, NGOs, and scientists, fostered transparency in the process and helped to considered stakeholders' preferences.

Moving Forward with NE-PES: Emerging Challenges

NE-PES started with 8 volunteer ranchers implementing pilot dispersed water management projects on their land from 2005. After the first solicitation,14 proposals were received from ranchers in the Northern Everglades, of which 8 were approved for NE-PES contracts

(Shabman & Lynch., 2013). NE-PES becomes a recognized model for ecosystem service delivery, with over 100,000 acre-feet of water storage contracted and a shift toward broader participation including smaller landowners and ecologically sensitive sub-watersheds from 2021 (SFWMD, 2022). NE-PES comprises 67 storage sites across 13 ranches, monitored through the Dispersed Water Management program in the present (SFWMD, 2024).

Quantifying multiple ES: sustainable agriculture involves multiple ecosystem services (e.g. water related services, GHG emission, and biodiversity conservation). Each service requires different technologies, which can lead to varied understandings and trust levels among stakeholders. Ranchers may understand visual indicators of water retention but may distrust remote sensing data due to lack of technical familiarity. For GHG measurement, high-tech instruments (Eddy covariance towers or soil chambers measure CO_2 and methane fluxes) required specialized knowledge, which limit accessibility for landowners and raise concerns about data credibility and payment justification (Frey et al., 2021). In this context, extension services could play a crucial role in explaining these technologies and contracts to broader audiences, thereby enhancing understanding and trust. For example, simplified contracts that bundle several ecosystem services or develop integrated proxy indicators could streamline multi-service agreements (Frey et al., 2021). The program also needs to consider interactions with other ecosystem services and regulatory requirements. Without further efforts to counteract habitat loss and degradation, Leclère et al., (2020) projected that global biodiversity will continue to decline. The NE-PES needs to maintain endangered species habitats to comply with the Endangered Species Act. Besides, policymakers should remain vigilant about potential leakage or spillover effects, coordinating PES efforts with broader land-use planning to prevent environmental gains in one region from causing losses in another.

Scalability of MMRV Systems: Implementing rigorous MMRV techniques and processes across larger and more diverse landscapes introduces complex trade-offs between accuracy, cost, and practicality. Shukla & Shukla, (2024b) found that payoff to the farmers for Stormwater Detention Area (SDA) retrofits in the Everglades basin through a PES program can achieve higher N treatment economically and facilitate large-scale adoption. The cost of additional N treatment from retrofits was $12/kg, an order of magnitude less than the published costs for other detention systems including newly constructed wetlands ($180/kg) and tailwater recovery systems ($214/kg). While site-specific monitoring was successful, expanding these systems to larger geographical areas and diverse agricultural operations requires innovative solutions. Emerging technologies such as remote sensing, blockchain for verification, and machine learning for data analysis could offer cost-effective ways to scale monitoring systems while maintaining accuracy and credibility (Fuss et al., 2021). As climate-smart agricultural policies (backed by initiatives like the IRA conservation funding) expand PES programs, contract design and PES scale up programs will require innovations to keep MMRV cost-effective and scalable, such as leveraging remote sensing and automation, without sacrificing accuracy (Frey et al., 2021). Integrating multiple ecosystem services (e.g. water retention, nutrient reduction, biodiversity) into single programs need streamlined metrics and bundled incentives, so that synergies are captured efficiently.

Landowner Participation and Funding Uncertainties: Uncertainty about long-term funding commitments can make landowners worry about the program will not last long enough to justify their efforts or investments. Moreover, potential regulatory consequences of participation (for example, stricter future oversight or obligations resulting from enrollment in a PES program) may deter involvement. In addition, significant knowledge gaps in ecological dynamics, hydrological modeling accuracy, and nutrient cycling processes could limit the data collection if these practices are seen as infringing on privacy or management autonomy (Wunder et al., 2018). It can erode the confidence of both sellers and buyers of services—dampening buyers' willingness to pay (WTP) for outcomes that are difficult to verify. Besides, expected benefits to farmers include increased productivity and profits while reducing risk exposure. A broad of ecosystem monitoring tools—such as assemblage time series—indicate a negative correlation between economic production and biodiversity (Sorice et al., 2011). Thus, strategies that mitigate the trade-offs between ecosystem service provision and economic returns may enhance landowner participation in conservation programs. Addressing these participation and funding uncertainties is essential for creating inclusive programs that attract a wide range of landowners and maintain their commitment over time.

Uncertain Long-Run Biophysical Conditions: The success of PES projects often hinges on environmental factors—such as precipitation temperature, and other ecological conditions—that are outside human control and subject to change over decades. Changes in precipitation patterns and water availability can dramatically impact the supply and effectiveness of ecosystem services like water retention or carbon sequestration. Jordan et al., (2025) project that over the next century many dryland regions will experience significantly less annual precipitation, more frequent drought stress, and shifts in the seasonality and form of rainfall. This uncertainty complicated the design of PES contracts and MMRV systems, since it is difficult to predict and measure ecosystem service outcomes reliably over long-time horizons.

Long-term precipitation pressures will have prolonged and substantial impacts on the supply and demand of ecosystem services. Therefore, PES payment schemes should be adaptive, effectively accommodating shifting baselines and consider climate variability to maintain efficacy under evolving biophysical conditions.

Conclusion

In summary, the Northern Everglades case illustrates that proactively addressing transaction costs is central to successful PES program design and scalability. By reducing transaction costs and aligning agricultural producers' objectives with conservation goals, such PES programs become more inclusive. Besides, if total phosphorus (TP) levels exceed or below targets, tradable credits could serve as an effective mechanism to meet SFWMD mandates or facilitate BMAP purchases for offset and sale. As climate-smart agriculture initiatives seek to replicate and scale up such programs, embedding these cost-reducing mechanisms will be crucial. The hybrid incentive structures, rigorous yet feasible monitoring, stakeholder engagement, and adaptive planning could offer a practical template for enhancing the efficacy of PES initiatives.

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