Environmental Sustainability and Development
https://esdjournal.org

Evaluating Land Stewardship with Ecological Compensation Schemes in Upstream Rural Households

Ye-Jin Moon*, Seung-Min Cha

Department of Bio-Environmental Chemistry, College of Agriculture and Life Sciences, Chungnam National University, Daejeon, Republic of Korea

Corresponding author: ye.j.moon@gmail.com

Abstract

The degradation of watershed ecosystems presents a profound challenge to global environmental sustainability, necessitating effective policy interventions to align the incentives of upstream land users with the provision of downstream ecological services. Ecological compensation schemes, widely implemented as a variant of payments for ecosystem services, aim to bridge this incentive gap by financially rewarding rural households for adopting sustainable land stewardship practices. This paper presents a comprehensive evaluation of such schemes by employing difference analysis to assess their impact on the agricultural and environmental behaviors of upstream rural households. By analyzing cross-sectional and retrospective panel data through a rigorous counterfactual framework, the study isolates the causal effects of compensation programs on indicators of land stewardship, including the reduction of agrochemical inputs, the adoption of organic fertilizers, and the implementation of soil and water conservation measures. The findings indicate that ecological compensation significantly enhances pro-environmental land management, although the magnitude of this effect exhibits substantial heterogeneity based on household socioeconomic characteristics, off-farm employment opportunities, and land tenure security. Furthermore, the analysis reveals that financial incentives must be complemented by technical extension services and robust community monitoring to sustain long-term behavioral changes. The results provide critical evidence for policymakers seeking to optimize the design, targeting, and conditionality of environmental compensation programs to achieve durable ecological outcomes while supporting rural livelihoods.

Keywords: Ecological Compensation; Land Stewardship; Difference Analysis; Upstream Households; Environmental Sustainability

1. Introduction

1.1 Background and Motivation

The provision of fundamental ecosystem services, particularly those related to hydrological regulation, water purification, and soil conservation, is heavily dependent on the land management decisions of upstream rural populations [1]. For decades, the continuous expansion of intensive agricultural practices and the conversion of fragile ecological zones for economic development have led to severe environmental degradation in critical watershed areas [2]. Downstream regions, which typically experience more rapid urbanization and industrialization, disproportionately reap the benefits of high-quality water resources while bearing little of the direct cost associated with their maintenance [3]. This spatial mismatch between the providers and beneficiaries of ecosystem services creates a classic environmental externality, leading to the systemic under-provision of conservation efforts [4]. To address this market failure, ecological compensation mechanisms, often conceptualized under the broader umbrella of payments for ecosystem services, have emerged as a dominant policy paradigm globally [5]. These schemes are fundamentally designed to internalize environmental externalities by transferring financial or in-kind resources from downstream beneficiaries to upstream land managers, thereby incentivizing the adoption of sustainable land stewardship practices [6]. Despite the proliferation of such programs, empirical evidence regarding their actual effectiveness in altering household-level land management behavior remains complex and occasionally contradictory, necessitating robust methodological approaches to disentangle program impacts from confounding socio-economic trends [7].

1.2 Research Objectives and Contributions

The primary objective of this research is to rigorously quantify the impact of ecological compensation schemes on the land stewardship behaviors of upstream rural households through the application of difference analysis. While numerous studies have documented the conceptual design and institutional frameworks of ecological compensation, there remains a critical gap in understanding the micro-level behavioral responses of the targeted populations, particularly in developing regions where rural livelihoods are intimately tied to natural resource extraction [8]. Evaluating these programs requires overcoming significant empirical challenges, most notably the issue of selection bias, as participation in compensation schemes is rarely entirely random, and program placement is often targeted at areas with specific ecological vulnerabilities or administrative characteristics [9].

This study contributes to the existing literature in three distinct ways. First, it employs a sophisticated difference analysis framework that meticulously constructs a valid counterfactual scenario, allowing for the precise estimation of causal treatment effects rather than mere correlations [10]. Second, the research conceptualizes land stewardship not as a binary indicator, but as a multidimensional construct encompassing a spectrum of agricultural practices, ranging from the reduction of chemical fertilizers and pesticides to the proactive adoption of vegetative buffer strips and contour farming [11]. Third, the analysis delves deeply into the heterogeneity of program impacts, investigating how variations in household demographic profiles, asset endowments, and local institutional contexts mediate the effectiveness of financial incentives [12]. By providing a granular analysis of these dynamics, the findings offer actionable insights for refining the targeting and conditionality of future environmental policies, ensuring that they achieve both ecological integrity and rural poverty alleviation.

2. Literature Review and Theoretical Framework

2.1 Evolution of Ecological Compensation Programs

The conceptual foundation of ecological compensation is deeply rooted in welfare economics and environmental externality theory, specifically the Coase theorem, which posits that well-defined property rights and low transaction costs can lead to efficient negotiated solutions for environmental externalities [13]. Over time, this theoretical ideal has been translated into diverse policy instruments across the globe. In developed contexts, programs such as the Conservation Reserve Program in the United States and agri-environment schemes in the European Union have a long history of compensating farmers for retiring environmentally sensitive land or adopting specific ecological practices [14]. In developing nations, the approach has frequently taken the form of state-mediated payments for ecosystem services, where the government acts as the primary buyer on behalf of the public [15].

The transition from command-and-control environmental regulations to incentive-based compensation mechanisms represents a paradigm shift in natural resource management [16]. Command-and-control policies, which rely on strict prohibitions and punitive measures, have often proven difficult to enforce in remote upstream areas due to high monitoring costs and institutional capacity constraints [17]. Furthermore, such regulations can severely constrain the economic opportunities of impoverished rural communities, leading to resentment and clandestine non-compliance [18]. In contrast, ecological compensation schemes seek to align the economic interests of households with environmental objectives, theoretically transforming conservation from a regulatory burden into a viable livelihood strategy [19]. However, the success of these programs is highly contingent upon the adequacy of the compensation amounts, the transparency of the payment delivery mechanisms, and the perceived fairness of the institutional arrangements [20].

2.2 Land Stewardship and Rural Livelihoods

Land stewardship refers to the ethical and practical commitment to managing land resources in a manner that preserves their long-term ecological health and productivity while meeting current economic needs [21].

In the context of upstream watersheds, effective stewardship involves a complex transition away from conventional, high-input agriculture toward agroecological practices that minimize nutrient runoff, prevent soil erosion, and enhance biodiversity [22]. The decision-making process of rural households regarding land stewardship is inherently multifaceted, influenced not only by direct financial incentives but also by risk aversion, labor availability, technological knowledge, and deeply ingrained cultural norms [23].

Behavioral models of rural households suggest that farmers optimize their utility subject to a series of interlocking constraints. When an ecological compensation program is introduced, it alters the relative profitability of different land use options [24]. The direct income effect of the compensation payment can alleviate credit constraints, enabling households to invest in more sustainable but initially costly technologies, such as organic fertilizers or high-efficiency irrigation systems [25]. Conversely, if the compensation is tied to land retirement or strict land-use restrictions, it may trigger a substitution effect, forcing households to reallocate family labor from agricultural production to off-farm employment, which can indirectly reduce the intensity of environmental pressure on the land [26]. However, if the compensation is insufficient to offset the opportunity costs of forgone agricultural production, households may engage in strategic behavior, nominally complying with program requirements while shifting intensive practices to unenrolled parcels, a phenomenon known as leakage [27].

2.3 Theoretical Mechanisms of Difference Analysis

To establish a causal relationship between ecological compensation and changes in land stewardship, it is imperative to utilize a robust evaluation methodology. Difference analysis, particularly in the form of difference-in-differences, provides a powerful tool for observational data by comparing the changes in outcomes over time between a treatment group subjected to the policy and a control group that is not. The fundamental logic rests on the assumption that, in the absence of the intervention, the outcome variables in both groups would have evolved in a parallel manner.

The theoretical mechanism of this analytical approach involves netting out confounding factors that could bias the estimation of the policy effect. First, by taking the difference in outcomes before and after the intervention for the treatment group, the method eliminates the influence of time-invariant unobserved characteristics, such as innate soil quality or traditional cultural attitudes toward the environment. Second, by subtracting the contemporaneous change observed in the control group, the method accounts for time-varying external shocks that affect all households simultaneously, such as macroeconomic fluctuations, changes in regional agricultural commodity prices, or broad climatic variations. The resulting double difference isolates the specific behavioral shift attributable to the ecological compensation scheme itself, providing a highly credible measure of policy efficacy.

3. Methodology and Data Collection

3.1 Study Area and Contextual Background

The empirical setting for this research is carefully selected to represent a typical upstream-downstream watershed dynamic where an ecological compensation program has been systematically implemented. The designated study area encompasses the mountainous upstream tributaries of a major river basin, characterized by steep topography, fragile soils, and a historically high reliance on smallholder agriculture. This region is critical for maintaining the hydrological balance and water quality for the densely populated, industrialized downstream municipalities. Recognizing the accelerating deterioration of the river's water quality, regional authorities initiated a comprehensive ecological compensation pilot program designed to induce upstream farmers to modify their agricultural practices.

The compensation program specifically targets the reduction of non-point source pollution by offering direct financial subsidies to households that commit to a suite of land stewardship protocols. These protocols require a verifiable reduction in the application of synthetic fertilizers and chemical pesticides, the proper management of livestock waste, and the maintenance of vegetative buffers along watercourses. The policy design relies on village-level administrative structures for the disbursement of funds and the primary monitoring of compliance, supported by occasional random audits from higher-level environmental protection bureaus. The strategic placement of this program, which was rolled out in specific priority sub-catchments before being expanded, provides a natural quasi-experimental setting ideal for the application of difference analysis.

3.2 Sampling Strategy and Survey Design

To construct a representative dataset capable of supporting rigorous econometric evaluation, a multi-stage stratified random sampling technique was employed. The stratification process was carefully designed to capture the spatial and socio-economic diversity of the watershed. In the primary stage, sub-catchments were stratified based on their participation status in the ecological compensation program, yielding a distinct set of treatment and control areas. Catchments were matched on observable pre-intervention characteristics, such as average elevation, distance to main waterways, and baseline agricultural intensity, to ensure a high degree of comparability.

In the subsequent stage, villages within the selected catchments were randomly sampled, followed by the random selection of individual households from village rosters. The survey instrument was a comprehensive, structured questionnaire administered through face-to-face interviews by thoroughly trained enumerators. The questionnaire was divided into several modules. The first module collected detailed demographic information, including household size, age, education levels, and off-farm employment status. The second module focused on agricultural production, capturing data on land holdings, crop choices, and precise quantities of various agricultural inputs utilized. The third module assessed specific land stewardship behaviors, environmental awareness, and the household's direct interaction with the ecological compensation program, including the timing of enrollment, the magnitude of payments received, and the perceived transaction costs of compliance.

3.3 Variable Measurement and Definition

The selection of variables is critical for accurately modeling the complex interactions between policy incentives and household behavior. The primary dependent variables represent distinct dimensions of land stewardship. To capture the mitigation of environmental harm, a continuous variable measuring the intensity of chemical fertilizer application per hectare is utilized. To represent proactive ecological enhancement, a binary variable indicating the adoption of organic fertilizers or integrated pest management techniques is defined. Additionally, an aggregate land stewardship index is constructed using principal component analysis to combine multiple conservation practices into a single, comprehensive metric of environmental performance.

The primary independent variable of interest is a binary indicator of program treatment status, which takes a specific value if a household resides in a treatment village during the post-intervention period. To control for heterogeneity across households that might confound the results, a robust set of covariates is included in the analytical models. Demographic controls encompass the age and educational attainment of the household head, serving as proxies for farming experience and the capacity to assimilate new information. Economic controls include the total area of arable land managed by the household, reflecting economies of scale, and the proportion of total household income derived from off-farm labor, which indicates the relative importance of agriculture to the family's livelihood strategy.

3.4 Analytical Framework and Estimation Strategy

The empirical strategy relies on the difference-in-differences methodology to evaluate the causal impact of the ecological compensation scheme. The core logic of the estimation involves comparing the trajectory of the land stewardship outcome variables in the treatment group against the trajectory of those same variables in the control group over the same time horizon. Because panel data following the exact same households over time was not entirely available, the study utilizes a repeated cross-sectional approach, supported by retrospective questioning to reconstruct pre-intervention baseline conditions.

The analytical model specifies the outcome variable as a function of an intervention dummy variable, a time period dummy variable indicating whether the observation occurred before or after the policy implementation, and an interaction term between the intervention and time period dummies. The estimated coefficient on this interaction term represents the true causal effect of the policy, measuring the extent to which the change in the treatment group's behavior diverges from the background change experienced by the control group. To account for potential baseline imbalances between the groups, the model incorporates the comprehensive vector of household and parcel-level control variables. Furthermore, to address unobserved spatial heterogeneity, village-level fixed effects are integrated into the estimation, absorbing time-invariant local characteristics such as micro-climate, soil typology, and local cultural norms that could influence land management decisions. Standard errors are clustered at the village level to account for the potential correlation of regression residuals among households residing in the same community.

4. Empirical Results and Discussion

4.1 Descriptive Statistics

The descriptive statistics provide a foundational understanding of the sample characteristics and the baseline equivalency between the treatment and control cohorts. Table 1 presents the summary statistics for the key variables utilized in the empirical analysis, segmented by program participation status.

Table 1: Summary Statistics of Key Variables for Treatment and Control Groups

Variable Description	Treatment Mean	Treatment SD	Control Mean	Control SD
Chemical Fertilizer Intensity (kg/ha)	245.30	56.40	250.15	61.20
Organic Fertilizer Adoption (1=Yes, 0=No)	0.42	0.49	0.38	0.48
Age of Household Head (Years)	52.30	8.50	53.10	9.10
Education of Household Head (Years)	7.80	2.30	7.50	2.10
Total Arable Land Area (Hectares)	0.85	0.35	0.90	0.40
Off-farm Income Share (Percentage)	45.20	15.60	44.80	16.20

An examination of the baseline data reveals that prior to the implementation of the ecological compensation scheme, the treatment and control groups exhibited remarkably similar profiles regarding demographic attributes and agricultural endowments. The average age of the household head hovers in the early fifties, reflecting the broader demographic trend of rural aging and the out-migration of younger laborers. Educational attainment is generally modest, averaging around seven to eight years, corresponding to a junior secondary school level. Land holdings are highly fragmented, typical of mountainous smallholder agricultural systems, with average farm sizes falling below one hectare. Crucially, the pre-intervention levels of chemical fertilizer intensity and organic farming adoption are statistically indistinguishable between the two groups, providing strong preliminary support for the validity of the control group as a suitable counterfactual.

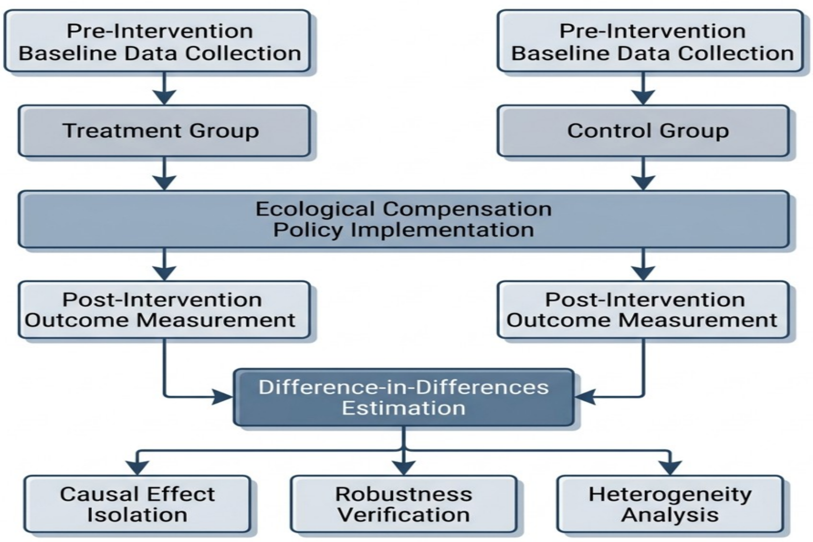

Figure 1: Comprehensive Analytical Flowchart of Difference Evaluation Methodology

4.2 Baseline Regression Results

The primary econometric analysis yields compelling evidence regarding the efficacy of the ecological compensation scheme in promoting sustainable land stewardship. The baseline difference analysis demonstrates that program participation induces a statistically significant reduction in the intensity of chemical fertilizer application. Specifically, households enrolled in the compensation program reduced their chemical inputs by a substantial margin compared to the control group, effectively reversing the historical trend of increasing agrochemical reliance in the watershed.

Simultaneously, the program exhibits a pronounced positive effect on the adoption of proactive conservation practices. The likelihood of a household substituting synthetic inputs with organic fertilizers or implementing physical soil conservation measures increases significantly in response to the policy intervention. These dual findings—the mitigation of harmful practices and the encouragement of beneficial ones—confirm that the financial incentives provided by the ecological compensation scheme successfully alter the calculus of rural decision-making. The magnitude of these effects remains robust and stable even after the sequential introduction of household demographic controls and village-level fixed effects, indicating that the observed behavioral shifts are genuinely attributable to the policy itself rather than spurious correlations with unobserved local characteristics.

4.3 Robustness Checks and Validity Verification

To ensure the reliability of the baseline findings, a series of stringent robustness checks were conducted. The most critical assumption of the difference analysis framework is the parallel trends assumption, which dictates that in the absence of the treatment, the outcomes of the treated and control groups would have followed the same trajectory. To validate this, a pseudo-treatment time placebo test was executed. The analysis artificially shifted the supposed implementation date of the policy to several years prior to the actual rollout. The results of this placebo regression showed no statistically significant divergence between the groups during the pre-treatment period, strongly supporting the validity of the parallel trends assumption.

Furthermore, alternative specifications of the dependent variables were tested. Instead of continuous measures of fertilizer intensity, categorical variables representing different thresholds of chemical usage were employed. The results remained consistent across these alternative definitions. Additionally, to address any residual concerns regarding sample selection bias where unobservable factors might influence both program placement and agricultural outcomes, a propensity score matching technique was integrated with the difference analysis. By restricting the estimation strictly to households in the treatment and control groups that shared highly similar pre-treatment likelihoods of being selected for the program, the subsequent double-difference estimates mirrored the baseline results, confirming the robustness and stability of the program's positive impact on land stewardship.

4.4 Heterogeneity of Program Impacts

While the aggregate effect of the ecological compensation scheme is distinctly positive, a deeper investigation reveals significant heterogeneity in how different types of households respond to the identical policy intervention. Disaggregating the sample by household income structure uncovers divergent behavioral pathways. Households with a higher proportion of their income derived from off-farm employment demonstrate a much stronger response to the compensation scheme, rapidly reducing agricultural inputs and occasionally abandoning marginal, high-slope parcels entirely. For these households, the compensation payments serve to lower the opportunity cost of transitioning labor away from agriculture, accelerating their integration into the non-agricultural economy.

Conversely, households heavily reliant on agriculture for their primary subsistence exhibit a more cautious response. While they comply with the basic requirements of the compensation scheme, their reduction in chemical intensity is less pronounced, and they face steeper barriers to adopting labor-intensive organic practices. Furthermore, the analysis reveals that land tenure security plays a pivotal role in mediating program effectiveness. Households possessing clearly documented and stable land rights are significantly more likely to invest in long-term stewardship practices, such as planting vegetative buffer strips or undertaking deep soil amelioration, compared to households operating on informally leased or insecurely held plots. This indicates that the time horizon over which households expect to reap the benefits of their conservation investments fundamentally dictates the depth of their commitment to sustainable stewardship.

5. Conclusion and Policy Implications

5.1 Summary of Core Findings

This study has provided a rigorous empirical evaluation of the impact of ecological compensation schemes on the land stewardship behaviors of upstream rural households. Utilizing a sophisticated difference analysis framework applied to comprehensive survey data, the research successfully isolated the causal effects of the policy intervention from confounding socio-economic and environmental trends. The empirical results definitively demonstrate that financial compensation mechanisms can be highly effective in mitigating environmentally detrimental agricultural practices. Specifically, the program induced a significant reduction in the intensity of chemical fertilizer application and concurrently stimulated a marked increase in the adoption of organic farming techniques and soil conservation measures. However, the study also uncovered critical nuances in the policy's effectiveness, revealing that the behavioral response to environmental incentives is deeply heterogeneous, heavily moderated by off-farm labor market participation, the scale of agricultural operations, and the security of land tenure.

5.2 Policy Recommendations

The insights derived from this analysis offer several vital recommendations for the optimization of current and future ecological compensation programs. First, policymakers must move away from uniform, flat-rate payment structures and transition toward spatially and demographically targeted compensation models. Designing differentiated payment tiers that account for the varying opportunity costs of different household typologies—particularly distinguishing between subsistence-reliant farmers and those transitioning to off-farm employment—would enhance both the ecological efficiency and the equity of the program.

Second, the provision of financial incentives must be tightly coupled with the delivery of targeted agricultural extension services. The findings suggest that while compensation can alter financial calculations, the transition to sustainable stewardship is often constrained by a lack of technical knowledge regarding organic farming or integrated pest management. Establishing robust, localized technical support systems is essential to ensure that households can successfully implement the required conservation practices without suffering catastrophic yield declines. Finally, strengthening land tenure security through formalized titling programs in upstream watersheds is a prerequisite for maximizing the long-term efficacy of ecological compensation. Secure property rights lengthen the planning horizons of rural households, making them far more receptive to investing in durable ecological infrastructure.

5.3 Limitations and Directions for Future Research

While this research offers robust evidence regarding the efficacy of ecological compensation, it is subject to certain limitations that provide avenues for future scholarly inquiry. The reliance on retrospective data collection to construct the pre-intervention baseline, while methodologically sound and validated by robustness checks, inherently carries the risk of recall bias. Future research should prioritize the establishment of long-term, prospective panel datasets that track identical households over multiple years before, during, and after policy implementation. Additionally, this study focuses primarily on the micro-behavioral responses of individual households. Future studies should broaden the analytical lens to investigate the aggregate macro-ecological outcomes of these behavioral shifts, integrating advanced hydrological and spatial modeling to quantify the actual downstream improvements in water quality and ecosystem service delivery that result from upstream land stewardship improvements.

References

1. Nyanghura, Q.M.; Biber-Freudenberger, L.; Börner, J. Incentives for biodiversity conservation under asymmetric land ownership. Ecol. Econ. 2024, 219, 108152.

2. WaterCard. Real Water Conservation Starts Here; Watercard: San Francisco, CA, USA, 2025; Available online: https://www.watercard.org/# (accessed on 5 November 2025).

3. Deutz, A.; Heal, G.M.; Niu, R.; Swanson, E.; Townshend, T.; Zhu, L.; Delmar, A.; Meghji, A.; Sethi, S.A.; Tobinde la Puente, J.

Financing Nature: Closing the Global Biodiversity Financing Gap. The Paulson Institute, The Nature Conservancy, and the Cornell Atkinson Center for Sustainability. 2020. Available online: https://www.paulsoninstitute.org/conservation/financing-nature-report/ (accessed on 5 November 2025).

4. Rosegrant, M.W.; Sulser, T.B.; Wiebe, K. Global investment gap in agricultural research and innovation to meet Sustainable Development Goals for hunger and Paris Agreement climate change mitigation. Front. Sustain. Food Syst. 2022, 6, 965767.

5. Bramwell, B.; Lane, B. Critical research on the governance of tourism and sustainability. J. Sustain. Tour. 2011, 19, 411–421.

6. Koppelaar, R.H.; Pamidi, S.; Hajósi, E.; Herreras, L.; Leroy, P.; Jung, H.Y.; Concheso, A.; Daniel, R.; Francisco, F.B.; Parrado, C.; et al. A digital product passport for critical raw materials reuse and recycling. Sustainability 2023, 15, 1405.

7. Börner, J.; Wunder, S.; Wertz-Kanounnikoff, S.; Tito, M.R.; Pereira, L.; Nascimento, N. Direct conservation payments in the Brazilian Amazon: Scope and equity implications. Ecol. Econ. 2010, 69, 1272–1282.

8. Neuhofer, B. Experience design. In Encyclopedia of Tourism Management and Marketing; Edward Elgar: Cheltenham, UK, 2022; pp. 179–182.

9. Wang, P.; Guo, B.; Sun, Z. Sustainable Urban-Rural Symbiosis in China: A Study from the Symbiosis Theory Perspective on Level Measurement and Spatial Difference Analysis. Sustainability 2025, 17, 2790.

10. White, K.; Habib, R.; Hardisty, D.J. How to SHIFT consumer behaviors to be more sustainable: A literature review and guiding framework. J. Mark. 2019, 83, 22–49.

11. Tao, J.; Xie, X.; Peng, R.; Bei, N. Digital Economy and Environmental Pollution in the Manufacturing Sector: Emission Reduction Effects and Mechanisms. Int. Rev. Econ. Financ. 2024, 96, 103737.

12. Forest Stewardship Council (FSC). The Share of Sustainable Wood: Data on FSC's Presence in Global Wood Production. Forest Stewardship Council, 2018. Available online: https://fsc.org/sites/default/files/2019-08/Global%20Volume%20of%20FSC-certified%20Wood%20-July%202018.pdf (accessed on 5 November 2025).

13. Barbier, E.B. Water and Economic Growth in Developed and Developing Countries. Water Econ. Policy 2024, 10, 243002.

14. Sravan, C.; Mishra, P.P. Bridging the gap between finance and conservation biology: How derivatives can help in conservation. J. Nat. Conserv. 2024, 78, 126550.

15. Barbier, E.B.; Burgess, J.C. Economics of Water Scarcity and Efficiency. Sustainability 2024, 16, 8550.

16. Nureen, N.; Nuţă, A.C. Envisioning the Invisible: Unleashing the Interplay Between Green Supply Chain Management and Green Human Resource Management: An Ability-Motivation-Opportunity Theory Perspective Towards Environmental Sustainability. J. Compr. Bus. Adm. Res. 2024, 1, 55–64.

17. Barbier, E.B. Capitalizing on Nature: Ecosystems as Natural Assets; Cambridge University Press: Cambridge, UK, 2011.

18. Barbier, E.B. Greening Agriculture for Rural Development. World Dev. 2025, 191, 106974.

19. United Nations (UN). The Future of Sustainable Trade—Due Diligence Initiatives, Voluntary Sustainability Standards and Developing Countries; United Nations: Geneva, Switzerland, 2025.

20. Fares, N.; Islam, M.S.; Jauhar, S.K.; Kucukaltan, B. Towards an International Digital Product Passport: The New Paradigm of a Worldwide Circular Economy. Circ. Econ. Sustain. 2025, 5, 5475–5495.

21. Forest Stewardship Council (FSC). 44 Sustainability Certifications for Businesses and Sustainability Professionals; Forest Stewardship Council: Bonn, Germany, 2024; Available online: https://fsc.org/en/blog/sustainability-certifications# (accessed on 5 November 2025).

22. Barbier, E.B. Reform economics of managing global water supplies. Nature 2023, 617, 252.

23. Marine Stewardship Council (MSC). The Marine Stewardship Council Annual Report 2020–2021; Marine Stewardship Council: London, UK, 2022; Available online: https://www.msc.org/about-the-msc/reports-and-brochures (accessed on 5 November 2025).

24. Willer, H.; Trávníček, J.; Schlatter, B. (Eds.) The World of Organic Agriculture: Statistics and Emerging Trends 2025. Research Institute of Organic Agriculture FiBL and IFOAM—Organics International, Frick and Bonn. 2025. Available online: https://www.organic-world.net/yearbook/yearbook-2025.html (accessed on 9 October 2025).

25. Delacote, P.; L'horty, T.; Kontoleon, A.; West, T.A.; Creti, A.; Filewod, B.; LeVelly, G.; Guizar-Coutiño, A.; Groom, B.; Elias, M. Strong transparency required for carbon credit mechanisms. Nat. Sustain. 2024, 7, 706–713.

26. Food and Agricultural Organization (FAO) of the United Nations. The State of Food and Agriculture 2023—Revealing the True Cost of Food to Transform Agrifood Systems; FAO: Rome, Italy, 2023.

27. Lapworth, D.J.; Baran, N.; Stuart, M.E.; Ward, R.S. Emerging organic contaminants in groundwater: A review of sources, fate and occurrence. Environ. Pollut. 2012, 163, 287–303.