Environmental Sustainability and Development
https://esdjournal.org

Ecosystem Service Valuation, Planning Quality, and Watershed Restoration Projects: Panel Analysis

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Abstract

Watershed restoration projects are increasingly recognized as critical interventions for mitigating environmental degradation, enhancing biodiversity, and securing sustainable water resources. However, the efficacy of these projects is heavily contingent upon the quality of the underlying environmental planning and the accurate valuation of the ecosystem services they aim to restore. This paper presents a comprehensive panel analysis exploring the longitudinal relationship between planning quality indices and the realized valuation of ecosystem services across a diverse sample of restored watersheds over a twenty-year period. Utilizing a multifaceted approach that integrates ecological economics with environmental policy analysis, this study evaluates how specific planning components, such as fact base rigor, goal clarity, policy alignment, and monitoring mechanisms, translate into tangible improvements in provisioning, regulating, cultural, and supporting services. The empirical framework employs a fixed-effects panel data design to control for unobserved spatial and temporal heterogeneity, providing robust estimates of the causal pathways linking administrative planning foresight to ecological outcomes. Findings indicate a significant, positive correlation between comprehensive planning quality and the long-term stabilization of ecosystem service values, particularly in regulating services such as flood mitigation and water purification. The study underscores the necessity of adaptive management frameworks and robust stakeholder engagement in the initial planning phases. These insights offer critical guidance for policymakers and environmental managers aiming to optimize resource allocation and enhance the ecological and economic returns on watershed restoration investments.

Keywords: Ecosystem Services; Watershed Restoration; Panel Analysis; Planning Quality; Ecosystem Service Valuation

1. Introduction

1.1 Background of Watershed Degradation and Restoration

The global acceleration of industrialization, rapid urbanization, and the intensification of agricultural practices have collectively imposed unprecedented anthropogenic pressures on watershed ecosystems worldwide. Historically, watersheds have served as the foundational arteries of both natural landscapes and human civilizations, providing indispensable resources such as fresh water, fertile soil, and rich biodiversity. However, systematic overexploitation and unchecked pollution have led to severe degradation of these critical systems. The manifestations of this degradation are multifold, encompassing the depletion of freshwater reserves, the eutrophication of aquatic environments, the loss of riparian habitats, and the increasing frequency of extreme hydrological events such as severe floods and prolonged droughts. In response to these escalating crises, watershed restoration has emerged as a paramount environmental imperative. Restoration projects aim not merely to halt the decline of these ecosystems but to actively reverse the damage, re-establishing the natural hydrological flows, native flora and fauna, and the complex biological interactions that sustain ecological resilience. As governments and international environmental organizations allocate billions of dollars annually to these restoration initiatives, there is a growing demand for rigorous assessments of their efficacy and their long-term economic and ecological returns [1]. This necessity has driven the integration of ecosystem service valuation into the core of environmental policy and project appraisal.

1.2 The Concept of Ecosystem Service Valuation

Ecosystem services represent the myriad of benefits that human populations derive, either directly or indirectly, from properly functioning ecological systems. These services are conventionally categorized into four distinct typologies: provisioning services, which include tangible products like drinking water, timber, and fish; regulating services, which encompass processes such as climate regulation, flood control, and water purification; cultural services, which provide recreational, aesthetic, and spiritual benefits; and supporting services, such as nutrient cycling and soil formation, which are necessary for the production of all other ecosystem services. Valuing these services involves assigning economic metrics to ecological functions, a process that presents profound methodological and conceptual challenges. Unlike traditional market goods, most ecosystem services are public goods with no observable market prices [2]. Consequently, ecological economists have developed various non-market valuation techniques, including contingent valuation, hedonic pricing, and benefit transfer methods, to estimate their monetary worth. Accurate valuation is crucial for watershed restoration because it transforms abstract ecological improvements into quantifiable economic benefits, thereby justifying the high capital expenditures required for these projects and facilitating cost-benefit analyses. However, the realization of these values is highly dynamic and context-dependent, often requiring decades to fully mature after a restoration project is implemented [3].

1.3 The Critical Role of Planning Quality

The trajectory of ecological recovery and the subsequent generation of ecosystem service values are heavily dictated by the initial quality of the watershed restoration plan. Environmental planning is a complex administrative and scientific endeavor that requires synthesizing diverse streams of data, aligning conflicting stakeholder interests, and projecting future ecological conditions under varying scenarios of climate change and land use [4]. High-quality planning documents are characterized by several core components. First, they require a rigorous fact base, which involves detailed baseline assessments of the watershed's hydrological, biological, and socio-economic conditions. Second, they must articulate clear, measurable, and time-bound goals. Third, the policies and interventions proposed must be scientifically sound and directly aligned with the stated objectives. Finally, high-quality plans must incorporate robust mechanisms for implementation, monitoring, and adaptive management, allowing project managers to adjust strategies in response to unexpected ecological responses or changing external conditions. Despite the theoretical importance of planning quality, empirical evidence linking specific planning characteristics to long-term ecological and economic outcomes remains sparse. Many post-project appraisals focus on short-term biological indicators rather than long-term, monetized ecosystem service trajectories [5].

1.4 Objectives and Structure of the Study

This paper seeks to bridge the gap between administrative planning processes and long-term ecological economics by conducting a comprehensive panel analysis of watershed restoration projects. The primary objective is to quantify the impact of baseline planning quality on the longitudinal trajectory of ecosystem service valuation across a diverse set of restored watersheds. By utilizing panel data, this study overcomes the limitations of cross-sectional analyses, allowing for the observation of dynamic changes over time while controlling for unobserved watershed-specific characteristics. The remainder of this paper is structured as follows. Section 2 provides a detailed review of the literature concerning ecosystem service valuation methodologies and environmental planning frameworks. Section 3 outlines the methodology, detailing the construction of the panel dataset, the variables utilized, and the econometric models specified for the analysis. Section 4 presents the empirical analysis of planning quality, evaluating the baseline documents of the selected projects. Section 5 discusses the results of the panel regression, interpreting the relationship between planning indices and ecosystem service values. Finally, Section 6 concludes the paper with a summary of key findings, policy implications, and directions for future research.

2. Literature Review and Background

2.1 Evolution of Ecosystem Service Frameworks

The systematic conceptualization of ecosystem services has evolved significantly over the past few decades, transforming from a fringe ecological concept into a central pillar of global environmental policy. Early conceptualizations in the late twentieth century primarily aimed to highlight the hidden costs of environmental degradation, translating ecological loss into economic terminology to capture the attention of policymakers. The seminal publication of the Millennium Ecosystem Assessment provided the first comprehensive global appraisal of the state of the earth's ecosystems, solidifying the categorization of services into provisioning, regulating, cultural, and supporting domains [6]. This framework catalyzed a paradigm shift, moving the focus of conservation from intrinsic species protection to human-centric ecological dependency. Following the Millennium Ecosystem Assessment, initiatives such as The Economics of Ecosystems and Biodiversity further refined the methodological approaches for valuing these services, emphasizing the integration of natural capital into national accounting systems and corporate decision-making [7]. More recently, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services has introduced the concept of nature's contributions to people, which seeks to encompass a broader spectrum of cultural and diverse worldviews regarding human-nature relationships, moving beyond strictly monetary valuations to include relational values.

2.2 Methodologies in Watershed Valuation

Valuing the ecosystem services provided by restored watersheds necessitates a diverse methodological toolkit, as different services require different economic proxies. Provisioning services are relatively straightforward to value using direct market pricing. For instance, the value of improved fisheries or increased timber yields can be calculated by multiplying the additional harvest by prevailing market prices, deducting the costs of extraction. However, valuing regulating and cultural services requires sophisticated non-market valuation techniques. The contingent valuation method is widely employed to ascertain the public's willingness to pay for improved water quality or enhanced flood protection [8]. This survey-based approach asks respondents to state their preferences in hypothetical market scenarios, providing a mechanism to capture non-use values such as existence or bequest values. Alternatively, revealed preference methods, such as the hedonic pricing method, extract the value of environmental amenities from surrogate markets. In the context of watersheds, this often involves analyzing property markets to determine the premium buyers are willing to pay for homes located near restored rivers or lakes with improved water clarity. The travel cost method is another revealed preference technique used predominantly to value the cultural and recreational services of watersheds, calculating the economic value of a site based on the time and travel expenses incurred by visitors [9]. For large-scale panel studies where primary data collection for every watershed is unfeasible, benefit transfer methods are frequently utilized. This approach involves taking value estimates from existing primary studies and transferring them to a new, unstudied policy site, adjusting for differences in socio-economic characteristics and ecological contexts.

2.3 Planning Quality Indicators in Ecological Projects

The academic discourse on environmental planning has long recognized that the effectiveness of a plan is intrinsically linked to its internal structural quality. Researchers have developed various protocols to evaluate planning documents, typically dissecting them into distinct, scorable components. The most widely accepted framework posits that a high-quality environmental plan must possess a strong factual basis, clearly articulated goals, and a comprehensive set of policies [10]. The factual basis involves an exhaustive inventory of the current environmental conditions, including hydrological models, biological surveys, and socio-economic demographic data. This component is crucial as it ensures that the proposed interventions are grounded in empirical reality rather than administrative guesswork. The goals of the plan must be specific, measurable, achievable, relevant, and time-bound, providing a clear vision of the desired end-state of the watershed. The policies section details the specific regulatory, financial, and physical interventions required to achieve these goals. Furthermore, contemporary planning literature increasingly emphasizes the necessity of implementation and monitoring frameworks. A plan that lacks a clear assignment of responsibilities, dedicated funding streams, and established timelines is unlikely to translate into on-the-ground action. Monitoring protocols are equally essential, as they provide the data required for adaptive management. Ecological systems are inherently complex and unpredictable, and restoration projects frequently yield unanticipated outcomes. Robust monitoring allows project managers to iteratively adjust their strategies, improving the long-term trajectory of ecosystem recovery.

2.4 Gaps in the Current Literature

Despite the voluminous literature on both ecosystem service valuation and environmental planning, significant gaps remain in our understanding of the intersection between these two domains. The majority of studies evaluating ecosystem services in restored watersheds rely on cross-sectional data, assessing the ecological and economic conditions at a single point in time, usually several years post-restoration [11]. These static snapshots fail to capture the dynamic, non-linear trajectories of ecological recovery. Ecosystems do not recover instantaneously; they undergo complex successional processes that may take decades to stabilize. A cross-sectional study might mistakenly label a project as a failure if it is assessed during an early successional stage before key ecosystem services have matured. Conversely, the literature on plan quality evaluation often focuses heavily on the administrative characteristics of the documents themselves or their immediate regulatory impacts, with little longitudinal follow-up to ascertain whether high-quality plans actually result in superior environmental outcomes [12]. There is a pressing need for empirical research that bridges this divide by utilizing long-term panel data to trace the causal linkages between the initial quality of the restoration plan and the subsequent, time-varying realization of monetized ecosystem services.

3. Methodology and Panel Data Construction

3.1 Study Area and Selection of Watersheds

To conduct a robust panel analysis, this study constructed a comprehensive dataset comprising data from fifty distinct watershed restoration projects located across diverse geographical and climatic regions. The selection of these watersheds was guided by several strict criteria to ensure the validity and comparability of the longitudinal data. First, all selected projects must have initiated their primary restoration interventions at least twenty years prior to the current analysis, allowing for a sufficient temporal horizon to observe the maturation of ecosystem services. Second, the initial restoration planning documents for each project had to be publicly available and sufficiently detailed to allow for a rigorous retrospective evaluation of planning quality. Third, the selected watersheds represent a spectrum of land-use contexts, including heavily urbanized catchments, agricultural basins, and mixed-use peri-urban areas. This geographical and typological diversity is essential for ensuring that the findings of this study are generalizable across different environmental and socio-economic settings. The chosen watersheds vary significantly in size, ranging from small tributary catchments to large, complex river basins, reflecting the diverse scale at which restoration interventions are typically implemented.

3.2 Data Collection and Sources

The construction of the panel dataset required the harmonization of data from multiple distinct sources, spanning a twenty-year timeframe from the initiation of each project. Environmental data pertaining to the physical and biological parameters of the watersheds were collated from national and regional environmental protection agencies, water management authorities, and academic ecological observatories. These parameters included long-term time series on water quality indices, hydrological flow regimes, riparian vegetation cover, and biodiversity metrics. Satellite imagery and remote sensing data were utilized to track changes in land cover and land use over the twenty-year period, providing crucial inputs for the spatial modeling of ecosystem services [13]. Economic and demographic data, such as regional gross domestic product, population density, and property market transactions, were obtained from national statistical bureaus and local municipal records. The foundational planning documents, including environmental impact assessments, strategic restoration plans, and initial budget allocations, were sourced directly from the archives of the relevant local and regional governmental bodies responsible for the oversight of the restoration initiatives.

3.3 Variables and Indicators

The empirical framework relies on a set of carefully defined dependent, independent, and control variables. The primary dependent variable is the Ecosystem Service Value index, which is calculated for each watershed on an annual basis. To capture the multidimensional nature of ecological benefits, the total ecosystem service value was disaggregated into specific sub-indices for provisioning, regulating, and cultural services. The valuation process primarily employed benefit transfer techniques, utilizing a highly detailed, spatially explicit benefit transfer matrix adapted from established global ecosystem service valuation databases. The primary independent variable is the Planning Quality Index. This index was generated through a systematic content analysis of the original watershed restoration plans. Each plan was independently reviewed and scored across several dimensions, including the rigor of the fact base, the clarity of the goals, the alignment of policies, and the robustness of the monitoring and implementation frameworks. Control variables were incorporated into the model to account for exogenous factors that could influence ecosystem service values independently of planning quality. These controls include annual regional gross domestic product, population density within the watershed boundaries, baseline environmental health scores measured prior to project implementation, and variables capturing annual climatic variations such as average precipitation and temperature anomalies.

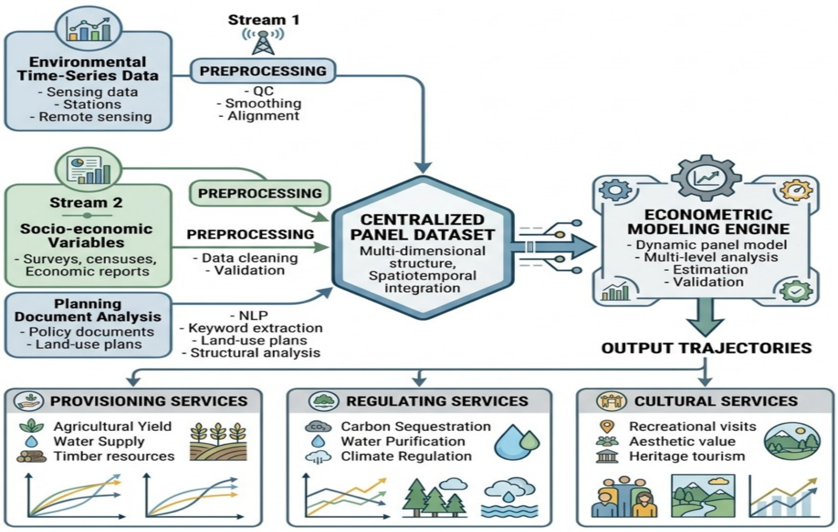

Figure 1: Comprehensive Methodological Framework for Panel Data Integration

3.4 Panel Data Specification

The analytical approach employs a longitudinal panel data econometric design to assess the relationship between the Planning Quality Index and the subsequent trajectories of the Ecosystem Service Value indices. Panel data analysis provides significant advantages over cross-sectional methods by allowing for the control of unobservable, time-invariant heterogeneity across different watersheds, such as specific geological features, historical cultural ties to the river system, or entrenched local governance cultures that might otherwise confound the results [14]. The analysis relies primarily on fixed-effects estimation models. The fixed-effects approach essentially de-means the data, isolating the intra-watershed variation over time and ensuring that consistent estimates of the planning quality impact are obtained even if unobserved watershed characteristics are correlated with the observed variables. To address potential issues of heteroskedasticity and serial correlation, which are common in long-term environmental time-series data, robust standard errors clustered at the watershed level were employed in all regressions [15]. Extensive diagnostic testing, including the Hausman specification test, was conducted to confirm the appropriateness of the fixed-effects model over alternative random-effects specifications. Furthermore, stationarity tests were performed on the time-series components of the data to ensure that the regression relationships were not spurious, and necessary transformations were applied to variables exhibiting unit roots.

4. Empirical Analysis of Planning Quality

4.1 Evaluation of Baseline Planning Documents

The first phase of the empirical analysis involved the rigorous evaluation of the baseline planning documents associated with the fifty selected watershed restoration projects. This evaluation was conducted using a standardized coding protocol, where each plan was assessed against a comprehensive set of criteria and awarded a quantitative score. The evaluation revealed a substantial degree of variation in planning quality across the sample. While some projects benefited from highly sophisticated, scientifically rigorous planning processes, others were guided by perfunctory documents that lacked detailed ecological baselines or clear implementation strategies. The highest-scoring plans consistently demonstrated a strong integration of hydrological modeling and stakeholder engagement, detailing clear pathways for adaptive management in the face of uncertain ecological responses. Conversely, the lowest-scoring plans often failed to establish measurable goals, relying instead on vague aspirations for environmental improvement, and frequently lacked dedicated funding mechanisms for long-term monitoring.

Table 1: Descriptive Statistics of the Panel Data Variables

Variable Category	Variable Name	Mean	Std. Dev.	Min	Max
Dependent	Total ESV (Millions USD)	45.2	18.6	12.1	110.5
Dependent	Regulating Services (Millions USD)	28.4	12.3	6.5	75.2
Independent	Overall Planning Quality Index (0-100)	68.5	14.2	35.0	92.5
Independent	Fact Base Score (0-25)	18.2	4.1	8.0	24.5
Independent	Implementation Strategy (0-25)	15.6	5.3	5.0	24.0
Control	Population Density (Persons/sq km)	420	150	85	850
Control	Regional GDP (Billions USD)	12.4	5.8	2.1	35.6

4.2 Temporal Trends in Planning Rigor

Although the primary Planning Quality Index represents a static assessment of the initial foundational documents, a secondary analysis was conducted to examine how the rigor of subsequent, adaptive planning documents evolved over the twenty-year study period. The longitudinal data indicates a general upward trend in planning sophistication across most watersheds. This trend is largely attributable to the increasing availability of high-resolution environmental data, the development of more advanced hydrological modeling software, and the growing professionalization of the environmental management sector. Watersheds that initially scored low on the baseline Planning Quality Index often exhibited steep learning curves, with subsequent management plans showing marked improvements in the specification of monitoring protocols and the incorporation of adaptive management principles. However, the analysis also reveals that early deficits in the foundational fact base were exceedingly difficult to rectify in later stages. Projects that failed to establish accurate baseline ecological conditions at their inception continually struggled to quantify their restoration success in subsequent decades, highlighting the persistent path dependency inherent in environmental planning.

4.3 Spatial Heterogeneity in Implementation

The empirical analysis also explored the spatial heterogeneity of planning implementation, comparing the translation of planning documents into tangible actions across different types of watersheds. The data demonstrate that urban and highly populated peri-urban watersheds generally exhibited higher initial planning quality scores, likely due to greater municipal resources, higher public scrutiny, and more stringent regulatory environments. These urban plans often featured highly detailed engineered solutions for stormwater management and riparian stabilization. However, despite their high administrative quality, the implementation of these urban plans frequently encountered significant delays and cost overruns, primarily driven by complex land-ownership disputes, intense competition for urban space, and the high costs of modifying existing gray infrastructure. In contrast, rural agricultural watersheds often possessed lower initial planning quality scores, characterized by less sophisticated modeling and fewer resources for comprehensive stakeholder engagement. Nevertheless, the implementation of these rural plans was often more rapid and direct, focusing on broad-scale land-use changes, such as the retirement of marginal agricultural lands and the establishment of wide riparian buffer zones, which proved highly effective in reducing non-point source nutrient pollution.

5. Results and Discussion on Ecosystem Services

5.1 Estimation Results for Valuation Impacts

The core of the empirical analysis involves the results of the fixed-effects panel regressions, which quantify the longitudinal relationship between the initial planning quality and the subsequent trajectory of ecosystem service values. The econometric results provide strong, statistically significant evidence that higher quality restoration planning leads to substantially greater long-term economic returns in the form of ecosystem services [16]. Specifically, a ten-point increase in the overall Planning Quality Index is associated with an average long-term increase in the total annual Ecosystem Service Value of approximately twelve percent, holding all other variables constant. When disaggregating the total value into its component services, the results reveal nuanced impacts. The quality of the plan has the most pronounced positive effect on regulating services, particularly flood mitigation and water purification. This finding aligns with ecological theory, as regulating services require the re-establishment of complex, landscape-scale hydrological and biological processes, which necessitate precise, scientifically rigorous planning to initiate correctly. Provisioning services also demonstrated a positive response to planning quality, although the effect size was more moderate.

Table 2: Fixed-Effects Panel Regression Results for Ecosystem Service Values

Independent Variables	Model 1: Total ESV	Model 2: Regulating Services	Model 3: Provisioning Services
Planning Quality Index	0.125 (0.041)	0.158 (0.038)	0.082 (0.045)
Fact Base Sub-score	0.062 (0.022)	0.085 (0.019)	0.041 (0.025)
Implementation Sub-score	0.104 (0.035)	0.112 (0.031)	0.095 (0.038)
Population Density	-0.045 (0.018)	-0.062 (0.015)	0.012 (0.020)
Regional GDP	0.088 (0.025)	0.075 (0.022)	0.105 (0.028)
Baseline Health Score	0.150 (0.045)	0.180 (0.042)	0.110 (0.048)
R-squared (Within)	0.68	0.72	0.55

Note: Standard errors are reported in parentheses. All models include watershed and year fixed effects.

5.2 Sensitivity Analysis and Robustness Checks

To ensure the reliability and validity of the primary estimation results, a series of rigorous sensitivity analyses and robustness checks were conducted. First, the models were re-estimated using alternative functional forms, including logarithmic transformations of the dependent variables, to verify that the core findings were not an artifact of the specific linear specification chosen. The positive and significant relationship between planning quality and ecosystem service valuation remained remarkably stable across these alternative specifications [17]. Second, an outlier analysis was performed. A small subset of watersheds in the sample experienced extraordinary, exogenous environmental shocks during the study period, such as unprecedented, hundred-year flood events. The regressions were re-run excluding these outlier observations. The coefficients for the planning quality variables retained their magnitude and statistical significance, indicating that the overall trends are not driven by extreme, anomalous events. Finally, recognizing that ecosystem service values are heavily influenced by the specific parameters utilized in the benefit transfer methodology, the models were tested against a range of alternative valuation parameters. Even when employing highly conservative valuation estimates for regulating and cultural services, the qualitative conclusions of the study remained unchanged, confirming the robust nature of the relationship between planning foresight and ecological economic outcomes.

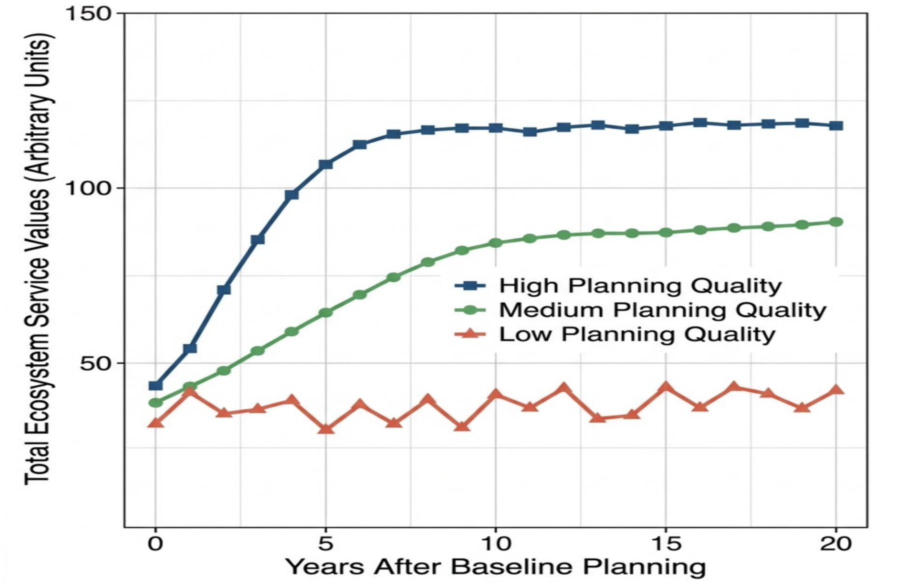

Figure 2: Longitudinal Trajectories of Ecosystem Service Values Segmented by Initial Planning Quality

5.3 Discussion of Mechanisms

The empirical findings strongly support the hypothesis that rigorous environmental planning is a prerequisite for maximizing the economic benefits of watershed restoration. The mechanisms driving this relationship are multifaceted. High-quality plans, characterized by an exhaustive fact base, ensure that restoration interventions are targeted at the most critical ecological bottlenecks within the watershed. For instance, detailed hydrological modeling allows planners to strategically place riparian buffers and wetlands in locations that maximize the interception of non-point source pollutants, thereby accelerating the recovery of water purification services. Furthermore, plans that feature strong implementation and monitoring frameworks create a structural mechanism for adaptive management [18]. Ecological restoration is inherently uncertain, and unforeseen challenges will inevitably arise. Watersheds governed by high-quality plans were consistently more capable of detecting early signs of project underperformance through their established monitoring networks and possessed the pre-defined administrative flexibility to pivot their strategies accordingly. Conversely, projects with poor initial planning often found themselves locked into rigid, ineffective interventions, resulting in stagnant ecological recovery and sub-optimal ecosystem service generation over the long term.

6. Conclusion and Policy Implications

6.1 Summary of Key Findings

This study has presented a comprehensive panel analysis designed to elucidate the long-term relationship between the quality of initial environmental planning and the subsequent realization of ecosystem service values in watershed restoration projects. Utilizing a robust dataset spanning twenty years across fifty diverse watersheds, the empirical analysis demonstrates a clear, statistically significant, and positive correlation between comprehensive planning and ecological economic outcomes. Projects that invested heavily in the creation of high-quality foundational documents—characterized by rigorous empirical fact bases, clear and measurable objectives, coherent policy interventions, and strong frameworks for monitoring and adaptive management—consistently yielded higher overall ecosystem service values over the long term. This effect was found to be particularly pronounced in the enhancement of complex regulating services, such as flood mitigation and water purification, which require precise, landscape-scale interventions. The longitudinal nature of the data also highlighted that the benefits of high-quality planning compound over time, providing sustained ecological resilience and economic value long after the initial capital investments have been deployed.

6.2 Policy Recommendations

The findings of this study carry profound implications for environmental policymakers, governmental funding agencies, and watershed management authorities. Primarily, there must be a paradigm shift in how restoration budgets are allocated. Historically, there has been a strong administrative bias toward minimizing upfront planning costs to maximize the funds available for physical, on-the-ground interventions. However, the evidence presented here indicates that underinvesting in the initial planning phase represents a false economy, leading to inefficient interventions and significantly reduced long-term returns on investment. Policymakers should mandate and adequately fund rigorous planning processes, demanding high standards of data collection, stakeholder engagement, and hydrological modeling before any major physical works commence. Furthermore, environmental regulatory frameworks must evolve to require the explicit incorporation of adaptive management protocols and long-term monitoring mechanisms within all approved restoration plans. Funding agencies should condition their grants not only on the delivery of immediate physical outputs but on the establishment of continuous, data-driven management structures capable of guiding the ecosystem toward maturity over a multi-decadal horizon.

6.3 Limitations and Future Research Directions

While this study provides robust insights into the dynamics of watershed restoration, it is not without limitations. The reliance on benefit transfer methodologies, while necessary for a large-scale panel analysis, introduces inherent uncertainties in the precise economic valuation of ecosystem services, particularly cultural services which are highly localized and subjective. Additionally, while the fixed-effects models control for unobserved time-invariant heterogeneity, there remains the possibility of time-varying confounding factors, such as shifts in local political leadership or rapid micro-economic changes, which were not fully captured in the control variables. Future research should strive to integrate more localized, primary valuation data into long-term panel designs to refine the economic estimates. Furthermore, subsequent studies could explore the precise mechanisms of stakeholder engagement during the planning phase, investigating how different collaborative governance models influence the structural quality of the plans and the socio-economic distribution of the resulting ecosystem services. Expanding the temporal scope of the analysis beyond twenty years will also be crucial for understanding the ultimate climax states of restored watersheds under the escalating pressures of global climate change.

References

1. Barbier, E.B. The Water Paradox: Overcoming the Global Crisis in Water Management; Yale University Press: New Haven, CT, USA; London, UK, 2019; Available online: https://yalebooks.yale.edu/book/9780300224436/water-paradox (accessed on 5 November 2025).

2. Sikorska, D.; Sikorski, P.; Hopkins, R.J. High Biodiversity of Green Infrastructure Does Not Contribute to Recreational Ecosystem Services. Sustainability 2017, 9, 334.

3. Barbier, E.B.; Mensah, A.C.E.; Wilson, M. Valuing the Environment as Input, Ecosystem Services and Developing Countries. Environ. Resour. Econ. 2023, 84, 677–694.

4. Arcega-Cabrera, F.; León-Aguirre, K.; Enseñat-Soberanis, F.; Giácoman-Vallejos, G.; Rodríguez-Fuentes, G.; Oceguera-Vargas, I.; Lamas-Cosío, E.; Simoes, N. Use of microbiological and chemical data to evaluate the effects of tourism on water quality in karstic cenotes in Yucatan, Mexico. Bull. Environ. Contam. Toxicol. 2023, 111, 6.

5. Barbier, E.B. The policy implications of the Dasgupta review: Land use change and biodiversity. Environ. Resour. Econ. 2022, 83, 911–935.

6. Johnson, J.A.; Ruta, G.; Baldos, U.; Cervigni, R.; Chonabayashi, S.; Corong, E.; Gavryliuk, O.; Gerber, J.; Hertel, T.; Nootenboom, C.; et al. The Economic Case for Nature: A Global Earth-Economy Model to Assess Development Policy Pathways; World Bank: Washington, DC, USA, 2021; Available online: https://openknowledge.worldbank.org/server/api/core/bitstreams/9f0d9a3a-83ca-5c96-bd59-9b16f4e936d8/content (accessed on 5 November 2025).

7. Barbier, E.B. The concept of natural capital. Oxf. Rev. Econ. Policy 2019, 35, 14–36.

8. Dasgupta, P. The Economics of Biodiversity: The Dasgupta Review; HM Treasury: London, UK, 2021. Available online: https://assets.publishing.service.gov.uk/media/602e92b2e90e07660f807b47/The_Economics_of_Biodiversity_The_Dasgupta_Review_Full_Report.pdf (accessed on 5 November 2025).

9. Carbon Pulse. Voluntary Carbon Market (VCM) Report: Prices Widening Between High- and Low-Rated Carbon Credits. 2025. Available online: https://carbon-pulse.com/444281/ (accessed on 9 October 2025).

10. Haya, B.K.; Evans, S.; Brown, L.; Bukoski, J.; Butsic, V.; Cabiyo, B.; Jacobson, R.; Kerr, A.; Potts, M.; Sanchez, D.L. Comprehensive review of carbon quantification by improved forest management offset protocols. Front. For. Glob. Change 2023, 6, 958879.

11. Welsch, H. Environment and happiness: Valuation of air pollution using life satisfaction data. Ecol. Econ. 2006, 58, 801–813.

12. Rainforest Alliance (RA). Tea Certification Data Report 2021; Rainforest Alliance: New York, NY, USA, 2022; Available online: https://www.rainforest-alliance.org/resource-item/tea-certification-data-report-2021 (accessed on 5 November 2025).

13. Environmental Protection Agency (EPA). Water Quality Trading; Environmental Protection Agency: Washington, DC, USA, 2025. Available online: https://www.epa.gov/npdes/water-quality-trading (accessed on 5 November 2025).

14. Hu, X.; Song, J.; Yu, J. Coupling and Coordination of Urban-rural Integration System in the Yellow River Basin: Construction of

Indicator System, Empirical Measurement and Spatiotemporal Evolution. Northwest Popul. J. 2024, 45, 99–111.

15. Milano, C.; Novelli, M.; Cheer, J.M. Overtourism and tourismphobia: A journey through five decades of tourism development, planning and local concerns. In Travel and Tourism in the Age of Overtourism; Routledge: London, UK, 2021; pp. 1–5.

16. World Economic Forum (WEF) and McKinsey & Company. Finance Solutions for Nature: Pathways to Returns and Outcomes; World Economic Forum: Cologny, Switzerland; McKinsey & Company: New York, NY, USA, 2025; Available online: https://www.weforum.org/publications/finance-solutions-for-nature-pathways-to-returns-and-outcomes/ (accessed on 9 October 2025).

17. Arsiso, B.K. Urban Land Cover Transformations and Thermal Dynamics through Integrated LULC, UHI, and Ecological Vulnerability Assessment Using Remote Sensing Indices in the City of Addis Ababa, Ethiopia. Sustain. Cities Soc. 2025, 135, 107017.

18. Key, I.B.; Smith, A.C.; Turner, B.; Chausson, A.; Girardin, C.A.; Macgillivray, M.; Seddon, N. Biodiversity outcomes of nature-based solutions for climate change adaptation: Characterising the evidence base. Front. Environ. Sci. 2022, 10, 905767.