Land and Water Management Impacts on Biodiversity Conservation

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Introduction

The funding for conservation program from the U.S. Farm Bill increased from 500 million in 2002 to 3.5 billion dollars in 2022, which aims to facilitate the application of land management activities by providing an assessment of the essential biotic elements (Li and Zhang,2024). However, biodiversity conservation efforts often face challenges due to discrepancies between priority areas for species richness and land type patterns or economic valuation (Jenkins et al., 2015).

The South Florida Water Management District (SFWMD) implemented the Northern Everglades Payment for Ecosystem Services (NE-PES) as a pilot program, which incentive ranchers to enhance water and biodiversity conservation in agricultural landscapes. Payments are determined by total habitat assessment scores and range from $7 to $17 per enrolled acre (SFWMD,2024). However, there is currently no research comparing the effectiveness of the SFWMD program to similar initiatives in other water management districts. More importantly, the relationship between biodiversity outcomes and different land use types remains unclear.

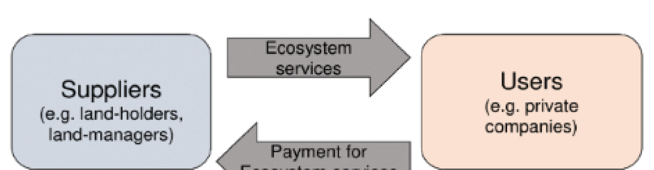

Figure 1. NE-PES Program

Importance

Atallah (2024) indicates the biodiversity targets are spatially heterogeneous across different land ownership. Jenkins et al., (2015) shows there are biodiversity priority mismatch in Florida panhandle (northwestern part in Florida) and keys region (southern islands) on trees, fish, and reptiles. Most of the region is privately owned, but with some federal and state lands (Figure 2). In the Figure 2a, the yellow point symbolize biodiversity score. The score equal to the proportion of the species' range that is unprotected (i.e., not in IUCN I to VI protected areas) divided by the area of the species' range. So if a large proportion of the species' range is within protected areas, the score accordingly decreases (Jenkins et al., 2015). Previous studies found that many biodiversity rich areas often on private lands that are subject to economic trade-offs. Aligning conservation priorities with land economics will require proactive policy and management interventions (Palmer et al., 2025).

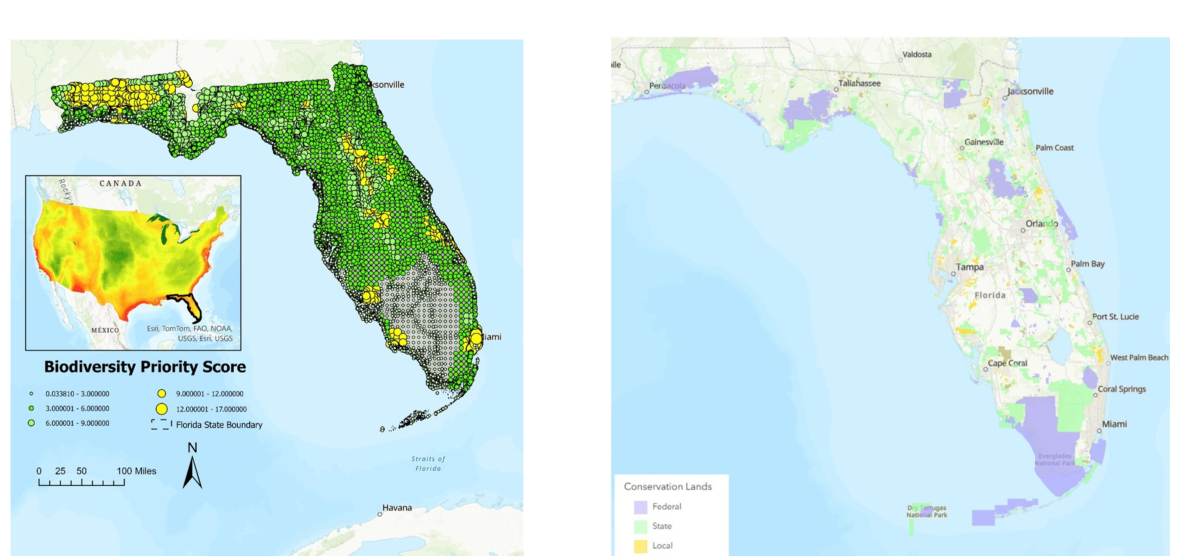

Figure 2. Visualize Mismatch of Florida Biodiversity Priority and Reservoir Lands' Ownership

Highlights

- **Research question 1** Which kind of land use have most significant impacts on biodiversity?
- **Research question 2** Which water management district has favorable effects on biodiversity conservation?
- **Research Goals** This study will give insight of land management strategy to enhance biodiversity conservative efforts in Florida.

Data and Methodology

1. **Data collection**. The land parcel data are obtained from the FDEP OTIS/GIS Section, and biodiversity priority data from biodiversitymapping.org. The parcel dataset includes polygon-level land information, where each parcel is identified by a unique Parcel ID, and each polygon within a parcel has its own unique Feature ID (FID). Using ArcGIS Pro, the parcel data are spatially intersected with the biodiversity dataset based on coordinates. This integration allowed for the identification of spatial patterns in biodiversity, land value and land use. The resulting data are exported as a CSV file for subsequent statistical analysis.
2. **Data process**. The percentage of agricultural and reservation lands was calculated by dividing the land area in square feet by the shape area. Land values were assessed at the parcel level. The study grouped biodiversity priority indices by parcel land value to examine the impact of biodiversity on land valuation. Due to limited data availability for 2023, the analysis used cross-sectional data. Duplicate entries were removed using Object ID, and outliers were excluded. The final validated dataset consists of 334,291 polygons across 10,009 parcels.
3. **Model**. Castro and Lechthaler (2022) described bio-economic models applied to land-use decisions as tools for evaluating ecosystem service provision. Advances in bio-economic modeling allow for the integration of multiple temporal and spatial scales. Building on this framework, the present study employs a spatial econometric approach to analyze biodiversity across Florida's landscape.

Analysis

The distribution of biodiversity priority scores was examined (Figure 3), followed by correlation analysis of key variables. Land value showed a significant negative correlation with biodiversity priority score (Pearson coefficient = -0.029). However, no significant correlation was found between land value and the percentage of agricultural land, reservation land, or water management. Based on these findings, the study proceeds to regress biodiversity priority scores on agricultural land percentage, reservation land percentage, and water management. The SFWMD (SF in Figure 4) is used as the reference group, and other districts are compared by excluding SF to evaluate the relative impact of water management on biodiversity.

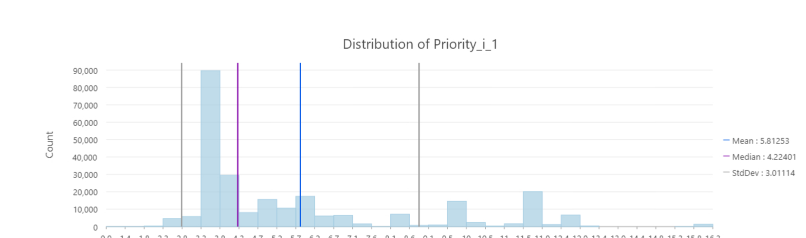

Figure 3. Biodiversity Priority Score Distribution

Regression Model: Independent variable Y is Biodiversity priority score; Dependent variables are land use of agricultural lands percentage and reservoir lands percentage; Spatial control variable include water management district fixed effects, which captures unobserved spatial heterogeneity, as shown in function (1).

Heteroskedasticity We also tested for spatial autocorrelation and detected nonlinear heteroskedasticity with an unknown structure. To address this, we applied a Heteroskedasticity-Consistent Covariance Matrix (HCCM) and used robust standard errors in the regression analysis.

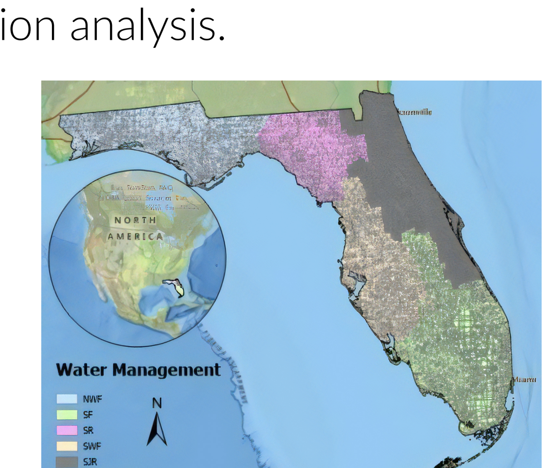

Figure 4. Water Management Districts in Florida

Result

Outputs

$$y_{ij} = \beta_0 + \beta_1 a_{ij} + \beta_2 r_{ij} + \theta_j + \varepsilon_{ij} \tag{1}$$

(i)Polygon ID; (j)Parcel group ID; (Y)Biodiversity priority score; (a)Agricultural land percentage, (r) Reservation land percentage; (θ) Water management (dummy) .

Coefficients	Estimate	Std error	z value	P value
Intercept	5.415	0.193	28.7	<2e-16
Agriland$_p$	-0.0827	0.021	-3.91	0.001
Reservior$_p$	-0.4232	0.147	-2.92	0.003
NWF	0.0823	0.0214	3.841	0.001
SJR	0.0536	0.0244	2.207	0.03
SR	0.0403	0.0247	1.627	0.08
SWF	-0.0584	0.0247	-2.360	0.02

Table 1. Robust Heteroskedasticity Regression Output

Explanation

Regression results show that both agricultural and reservoir land percentages have negative coefficients, indicating that higher proportions of these land types are associated with lower priority score. This suggests that landscapes with greater agricultural or reservoir coverage tend to have higher biodiversity. Among the two, reservoir land appears to have a relatively more positive effect on biodiversity conservation, consistent with empirical observations. Additionally, Figure 2 shows that state reservoirs are associated with lower biodiversity priority scores than federal reservoirs, suggesting that state reservoirs may support local biodiversity more effectively.

Regarding water management district, SF shows more favorable biodiversity outcomes compared to NWF, SJR, and SR, but less effective than SWF. Besides, the Bayesian Information Criterion (BIC) for the HCCM regression model was 11,848, compared to 12,005 for the OLS model, indicating that the HCCM model better accounts for heteroskedasticity and provides a better fit.

Conclusion

Florida's case exemplifies the broader challenges of reconciling biodiversity conservation with land use and water management. Correlation analysis using downscale data shows a positive relationship between priority scores and land value, which consistent with prior findings that enhanced biodiversity can increase land value.

Changes in agricultural and reservoir land use have stronger positive impacts on biodiversity conservation compared to other land types. This highlights the need for policymakers to prioritize agricultural land in the design of PES, given the trade-off between economic and ecosystem benefits. A key challenge is ensuring that payments lead to additional ecosystem service gains, rather than compensating landowners for actions they would have undertaken regardless.

Heterogeneity among inactive water management districts may contribute to weaker biodiversity outcomes, as ranchers act as weaker links in addressing spatial-dynamic externalities (Atallah, 2024). In contrast, the SFWMD demonstrates stronger performance in biodiversity conservation with positive external effects. There may be spillover effects from SFWMD into neighboring districts such as SWF and SJR, which show better biodiversity outcomes than NWF.

However, estimating spillover effects requires more data and sophisticated modeling approaches. The observation that SWF outperforms even SFWMD may be due to factors not captured in this study—a key limitation. A major strength of this approach lies in its use of rich geographic data, which supports causal inference and helps identify underlying mechanisms.