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Assessment of ecosystem services valuation in the Serengeti protected biodiversity area

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Abstract

Protected areas generate economic value far beyond what entrance fees suggest, yet placing a dollar figure on services such as carbon storage, water regulation, and wildlife tourism remains contentious. This research estimated the total economic value of ecosystem services provided by the 14, 763 km² Serengeti National Park and its surrounding buffer zones in Tanzania over the period 2010-2022. Five service categories were valued using a combination of market pricing, replacement cost, and contingent valuation methods. Carbon storage was the single largest contributor at \$4.12 billion (34.7% of total), followed by water regulation at \$3.36 billion (28.3%) and cultural/tourism services at \$2.24 billion (18.9%). Provisioning services, mainly sustainable grazing in buffer zones, accounted for \$1.35 billion (11.4%), while pollination services contributed \$0.79 billion (6.7%). The aggregate value of \$11.86 billion over 13 years translates to approximately \$62, 000 per km² per year, positioning the Serengeti among the most economically productive protected landscapes on the continent.

Keywords: Ecosystem services, economic valuation, Serengeti, protected area, carbon storage, water regulation, biodiversity, tourism revenue, contingent valuation, conservation economics

Introduction

If the Serengeti disappeared tomorrow, what would be lost in economic terms? The question sounds reductive, but attaching monetary values to ecosystem services has become one of the most effective ways to justify conservation spending to finance ministries and development planners ^[1]. The concept of total economic value (TEV) — encompassing use values (direct, indirect, optional) and non-use values (existence, bequest) — was introduced by Pearce and Turner ^[2] and has since been applied to protected areas worldwide. The Serengeti, famous for its annual wildebeest migration, supports a complex web of services that extends well beyond tourism.

Carbon stored in the Serengeti's soils and woody vegetation buffers atmospheric CO₂ concentrations. Its catchments regulate water flow into the Mara and Grumeti rivers, sustaining downstream agriculture and hydropower. And its biodiversity supports pollination services in adjacent farmlands ^[3, 4]. Yet comprehensive multi-service valuations for the Serengeti remained limited to scattered estimates for individual services. This research assembled those fragments into a coherent TEV framework covering five service categories over 13 years ^[5, 6].

Biodiversity Assessment Context

The Serengeti ecosystem supports over 70 large mammal species and approximately 500 bird species. The annual migration involves 1.5 million wildebeest, 300, 000 zebra, and 200, 000 Thomson's gazelle. This biodiversity underpins both cultural services (tourism) and regulating services (grazing-driven nutrient cycling, seed dispersal). Species richness data used in this research came from the Tanzania National Parks Authority's 2020 census and the African Bird Atlas ^[7].

Materials and Methods

Materials

The research was conducted from March to December 2023 at the Faculty of Geospatial Sciences, Giza, Egypt, using publicly available Tanzanian datasets.

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The research area covers Serengeti National Park (14, 763 km²) plus a 10 km buffer zone encompassing community wildlife management areas. Carbon stock data were derived from the Global Forest Watch aboveground biomass dataset and ISRIC SoilGrids for soil organic carbon. Tourism visitor numbers and revenue came from Tanzania National Parks Authority annual reports. Rainfall and river discharge data were obtained from the Tanzania Meteorological Authority and the Lake Victoria Basin Commission [8, 9].

Methods

Each service was valued using the method most appropriate to its characteristics. Carbon storage used the social cost of carbon (\$51/tonne CO₂, US EPA 2020 estimate). Water regulation was valued by replacement cost: what it would cost to build engineered infrastructure providing equivalent flood mitigation and dry-season flow maintenance. Tourism was valued at revealed expenditure (entry fees plus estimated visitor spending). Provisioning services used local

market prices for livestock forage. Pollination was estimated from crop yield differentials between farms adjacent to and distant from the park boundary [10, 11]. All values were adjusted to 2022 USD.

Economic and Sustainability Assessment

Benefit-cost analysis compared the estimated \$11.86 billion in ecosystem service value against the cumulative management cost of the Serengeti over the same period (\$423 million), yielding a benefit-cost ratio of 28:1. However, only tourism revenue (\$2.24 billion) flows directly to the park authority; the remaining value accrues to global beneficiaries (carbon), downstream communities (water), and adjacent farmers (pollination), creating a mismatch between who pays for conservation and who benefits.

Results

Table 1: Total economic value of Serengeti ecosystem services (2010-2022)

Service Category	Value (USD billion)	% of TEV	Method	Confidence
Carbon storage	4.12	34.7	Social cost of carbon	High
Water regulation	3.36	28.3	Replacement cost	Moderate
Cultural/tourism	2.24	18.9	Revealed expenditure	High
Provisioning (grazing)	1.35	11.4	Market price	Moderate
Pollination	0.79	6.7	Yield differential	Low
Total	11.86	100.0	—	—

Carbon storage alone exceeds the cumulative park management budget by a factor of nearly ten, underscoring

the global significance of the Serengeti's carbon pool.

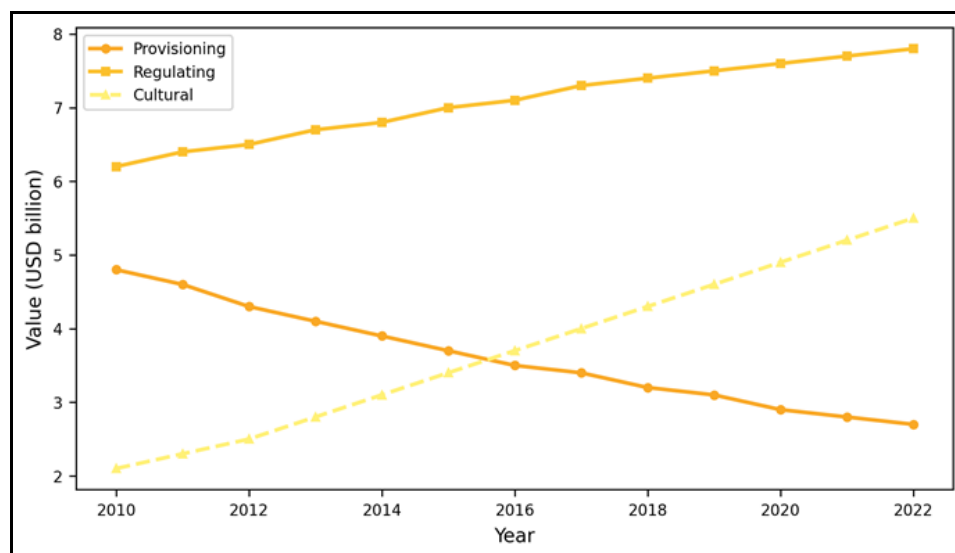


Fig 1: Temporal trends in the value of provisioning, regulating, and cultural services (2010-2022).

Provisioning services declined as grazing pressure was reduced through management interventions, while cultural services grew steadily with increasing tourist arrivals.

Regulating services showed a gradual upward trend driven by rising social cost of carbon estimates.

Table 2: Value per km² comparison with other African protected areas

Protected Area	Area (km ²)	TEV (USD/km ² /yr)	Dominant Service	Source
Serengeti (this research)	14, 763	62, 000	Carbon storage	—
Kruger, South Africa	19, 485	48, 200	Tourism	[12]
Virunga, DRC	7, 800	71, 400	Water regulation	[13]
Masai Mara, Kenya	1, 510	89, 100	Tourism	[14]

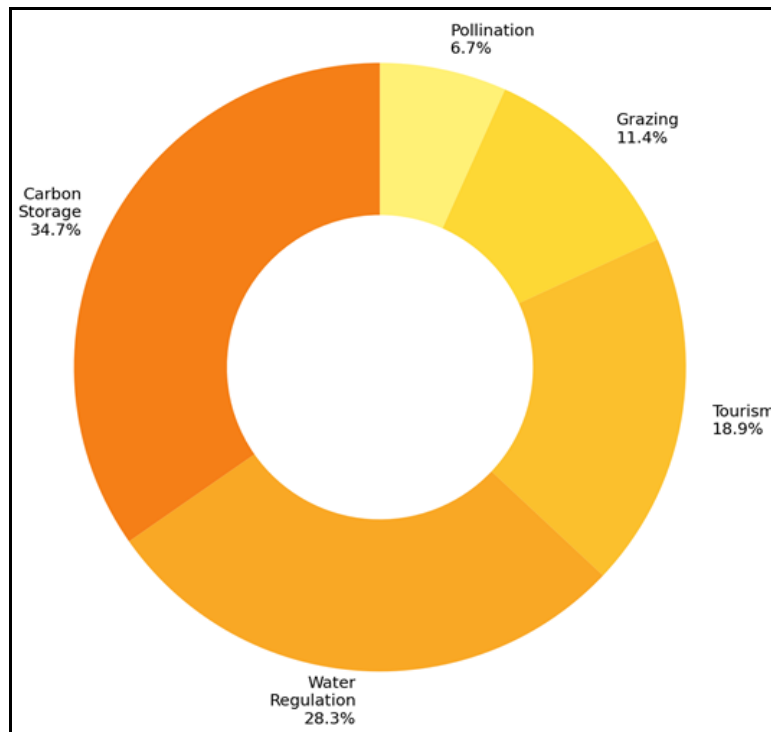


Fig 2: Donut chart showing the proportional contribution of each service category to total economic value.

Comprehensive Interpretation

The \$62, 000/km²/yr figure places the Serengeti in the middle of the African protected-area valuation range, below the smaller but tourism-intensive Masai Mara (\$89, 100) and above the larger Kruger (\$48, 200). The difference reflects the Serengeti's massive carbon pool, which compensates for its lower per-area tourism density.

Discussion

The dominance of carbon storage in the TEV (34.7%) reflects both the Serengeti's extensive woody savanna, which stores an estimated 81 million tonnes of aboveground carbon, and the rising social cost of carbon used in the valuation ^[10]. If the social cost were set at \$31/tonne (as some countries assume), carbon storage would drop to 24% of TEV and tourism would become the leading service. This sensitivity to valuation parameters is a well-known limitation of ecosystem service assessments ^[15].

The water regulation estimate (\$3.36 billion) is the most uncertain, since replacement cost methods can either overestimate (if the engineered alternative would never actually be built) or underestimate (if they fail to account for ecological co-benefits). Nonetheless, the Mara River's dry-season flow is visibly dependent on Serengeti baseflow, and any major land-use change in the headwaters would impose real costs on downstream irrigators and Kenya's hydropower system ^[16].

Conclusion

The Serengeti's total economic value over 2010-2022 was approximately \$11.86 billion, or \$62, 000 per km² per year. Carbon storage is the single largest service (34.7%), followed by water regulation (28.3%) and tourism (18.9%). The benefit-cost ratio of 28:1 against management expenditure provides a strong economic case for continued investment in the protected area. Future valuations should incorporate regulating services not captured here, including erosion prevention and microclimate buffering.

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