

Decision Analysis on Choice of Conservation Baseline Data for Climate Change Resilient Project Design: Insights from Tumbatu Island in Zanzibar

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Abstract

Selecting robust conservation baselines is essential for designing climate-resilient development interventions, but it remains difficult in data-scarce Small Island Developing States (SIDS). This study provides an empirical spatial multi-criteria decision analysis framework that addresses baseline data selection challenges. Tumbatu Island in the Zanzibar Archipelago was used as a case study to prioritize five fundamental baseline-data thematic domains, namely, biophysical and environmental, climate and weather, institutional and governance, socio-economic and livelihood, and ecosystem services, which are considered significant for climate-resilient project design. The framework integrates literature synthesis, participatory focus group discussions (FGDs), key informant interviews (KIIs), and the Analytic Hierarchy Process (AHP). The study involved a total of eight (8) FGDs sessions and sixty-four (64) KIIs across the four shehias of Gomani, Jongowe, Mtakuja, and Uvivini. We synthesized AHP-derived priority weights with census population figures (total population 4935 across an inhabited land area of 8.98 km², representing an average density of ~549.5 people/km²). We spatially modelled this using Inverse Distance Weighting (IDW) interpolation in ArcGIS. AHP pairwise comparison yielded high structural consistency (Consistency Ratio, CR = 0.083 < 0.10). Biophysical and environmental data emerged as the most critical domain (eigenvector = 0.326), followed closely by climate and weather

data (eigenvector = 0.291), jointly capturing 61.7% of the cumulative decision weight and reflecting stakeholders' prioritized concern regarding live coral reef degradation, mangrove clearance, and monsoonal exposure. Institutional and governance data ranked third (eigenvector = 0.181), surpassing socio-economic indicators (0.119) and ecosystem services valuation metrics (0.084), revealing a pronounced local "ecosystem service valuation paradox." Exploratory spatial surface maps generated via IDW revealed localized gradients and intra-island non-stationarity in baseline data priorities, with peak biophysical-climatic data demand concentrated along vulnerable, densely populated coastal corridors. By clearly differentiating decision prioritization from empirical ecological magnitude, this research provides a transparent, replicable decision-support model for climate resilience and MEAL framework design across vulnerable island ecosystems.

Keywords

Conservation Baseline Data, Analytic Hierarchy Process (AHP), Inverse Distance Weighting (IDW), Climate Resilience Project, Spatial Non-Stationarity, Tumbatu Island, Zanzibar

1. Introduction

In the Anthropocene, the design and implementation of climate change-resilient conservation projects have increasingly depended on the accuracy, granularity, and architectural robustness of baseline data [1] [2]. Baseline data serve as the epistemic foundation against which ecological degradation is measured, adaptive management strategies are calibrated, and the additionality of conservation interventions is validated [3] [4]. However, conservation planners routinely confront a fundamental dilemma: the choice between divergent, often conflicting baselines derived from diverse methodological paradigms [5] [6].

In contemporary climate conservation discourse, baseline dilemmas typically encompass two distinct decision dimensions: first, methodological baseline typologies, *i.e.*, choosing between historical/static reference states, dynamic projected models, or counterfactual additionality baselines [7]-[11]. Secondly, thematic data domain prioritization, *i.e.*, identifying which thematic categories of socio-ecological, biophysical, climatic, and governance baseline information must be prioritized under tight resource and capacity constraints. Inappropriate weighting or misalignment in either dimension can induce path dependencies, leading to maladaptive project execution and misallocated capital, and thus heightened socio-ecological vulnerability [6] [10].

This baseline data selection dynamic is acutely pronounced in Small Island Developing States (SIDS) and autonomous sub-national island geographies, where structural vulnerabilities intersect with severe and chronic data scarcity [12]-[14]. Tumbatu Island, a coralline within the Zanzibar Archipelago, Tanzania, repre-

sents an archetype of this challenge [15]. Characterized by its highly specialized, climate-sensitive marine and terrestrial ecosystems, predominantly characterized by fragile coral reefs, intertidal mangrove stands, and dense coastal forests, Tumbatu supports indigenous communities whose livelihoods are fundamentally tied to artisanal fishing and subsistence farming activities [15] [16]. Accelerating climate hazards across the western Indian Ocean (WIO), such as monsoonal shifts, sea-surface warming, and tidal surges, heighten the urgency for resilient conservation planning [15] [17] [18]. However, the absolute scarcity of downscaled, long-term empirical meteorological and ecological monitoring records forces project designers to prioritize among competing thematic data needs [16] [19].

While theoretical conservation literature extensively explores temporal baseline typologies, *i.e.* historical, dynamic, and counterfactual, operational project design in data-scarce settings primarily requires determining which baseline-data domains provide the highest decision value for project scoping, risk mitigation, and impact tracking. Designing resilient interventions project for vulnerable insular geographies such as Tumbatu Island in the Zanzibar Archipelago is linked to various factors [20]-[22]. Various literatures epitomize main grouped such data as biophysical and environmental, climate and weather, socio-economic and livelihood, institutional and governance, as well as ecosystem services data [3] [23]-[25].

Furthermore, because socio-ecological dynamics and human pressures vary spatially across the landscapes, baseline data need to exhibit spatial non-stationarity [26] [27]. In this context, Geographic Information System-based Multi-Criteria Decision Analysis (GIS-MCDA) offers a robust framework to evaluate such multi-attribute problems and capture spatial variation [28]-[30]. Accordingly, the primary objective of this study is not to model mathematical counterfactuals, but to systematically prioritize the five overarching baseline-data thematic domains using the Analytic Hierarchy Process (AHP) coupled with participatory stakeholder valuation, and to conduct exploratory spatial mapping via Inverse Distance Weighting (IDW) to examine spatial priority gradients across Tumbatu Island. The resulting framework provides a replicable decision pathway for conservation practitioners and MEAL specialists in data-poor insular environments.

2. Materials and Methods

2.1. Tumbatu Island in Zanzibar, the Study Area

Tumbatu Island (**Figure 1**) is located at latitude 5°49'7.00"S, longitude: 39°13'23.16"E within North "A" District of Unguja in Zanzibar Archipelago, Tanzania. The island lies within Tumbatu Marine Conservation Area (TUMCA), an IUCN Category VI marine protected area and Key Biodiversity Area covering approximately 162.9 km² extending from Nungwi southwards to Mangapwani and Fuoni. The island comprises an inhabited terrestrial landmass of approximately 8.98 square kilometres (km²) accommodating a total human population of 4,935 inhabitants (2022 Tanzania National Population and Housing Census projection),

yielding an average population density of ~ 549.5 persons/km². Tumbatu has historically maintained socio-cultural autonomy and isolation, which contributed to limited baseline ecological and socio-economic monitoring records [31]. To foster sustainable community development and ecological stewardship, Climate Action Network (CAN) Tanzania initiated the project “Strengthening Conservation and Climate Resilience on Tumbatu Island”, focusing on participatory biodiversity conservation applying a co-management approach, alternative livelihoods, and climate adaptation.

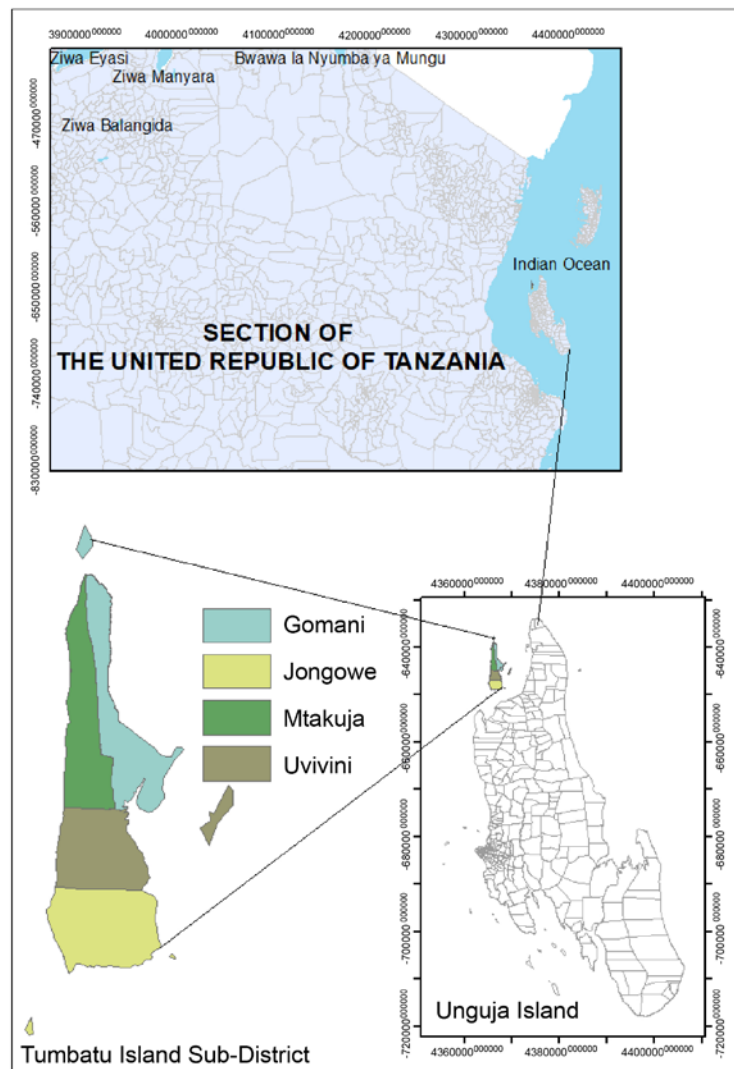


Figure 1. Map of Tumbatu Island Sub-District, the study area.

2.2. Baseline Data Criteria and Sub-Criteria Framework

Through systematic literature and policy review [3] [24] [25], five overarching baseline data domains and 22 constitutive sub-criteria were established (Table 1). In this study’s decision hierarchy, the five key domains served as the evaluated criteria in the formal AHP pairwise matrix, while the sub-criteria served as de-

tailed thematic guides during participatory focus group evaluations to ensure comprehensive coverage of baseline informational dimensions.

Table 1. Variables and sub-variables data for climate change resilient project.

SN	Criteria	Sub-criteria
A	Biophysical and Environmental Data	Land use/land cover (forest, agriculture, wetlands)
		Soil quality (organic carbon, erosion levels)
		Biodiversity indicators (species richness, key habitats)
		Water resources (river flow, groundwater levels)
		Ecosystem condition and degradation status
B	Climate and Weather Data	Historical rainfall patterns
		Temperature trends
		Extreme weather events (droughts, floods)
		Seasonal variability
C	Socio-economic and Livelihood Data	Household income sources
		Agricultural productivity
		Dependency on natural resources
		Food security status
		Access to climate services
D	Institutional and Governance Data	Existing policies and by-laws
		Land tenure systems
		Local governance capacity
		Presence of community-based organizations
E	Ecosystem Services Data	Carbon sequestration potential
		Water regulation capacity
		Pollination services
		Soil fertility support

2.3. Focus Group Discussion Protocol, Sampling, and Ethical Governance

To derive empirical weights that reflect ground-level decision priorities, participatory Focus Group Discussions (FGDs) were conducted in all four shehias of Tumbatu Island: Gomani, Jongowe, Mtakuja, and Uvivini. In total, eight FGD sessions were held, with two structured sessions in each shehia. The discussions involved 64 purposively selected key informants, comprising eight participants per session and 16 participants per shehia. Participant selection ensured balanced multi-stakeholder representation, including: (i) Shehia Advisory Council and local leadership representatives, (ii) women fishmongers' groups, (iii) artisanal fishers and seaweed farmers, (iv) community youth leaders, and (v) local environ-

mental committee members. Research authorization was obtained from local government authorities in North Unguja District and the respective Shehia Leadership Offices, in accordance with Revolutionary Government of Zanzibar research guidelines. At the beginning of each session, participants were briefed in Kiswahili on the study objectives, and informed verbal consent was documented. To ensure confidentiality and minimize dominance bias, data were anonymized and structured facilitation techniques were used. During the FGDs, participants collectively assessed the relative decision importance of baseline data domains using a structured facilitation matrix, producing consensus-based judgment scores for pairwise comparison.

2.4. Analytical Hierarchy Process (AHP) Model in Decision Analysis

The Analytic Hierarchy Process (AHP), developed by Saaty (1980), was deployed to evaluate the relative weights of the five overarching baseline criteria (A through E). The AHP method structures complex socio-ecological decisions into a multi-level hierarchy, deriving priority vectors through pairwise comparison matrices based on Saaty's 1 - 9 fundamental scale presented in **Table 2** [32] [33]. Consensus scores from FGD sessions across the shehias were synthesized using geometric mean aggregation to construct the group pairwise comparison matrix $A = (a_{ij})_{n \times n}$ where a_{ij} represents the relative importance of criterion i over criterion j , satisfying $a_{ij} > 0$ and $a_{ji} = 1/a_{ij}$.

Table 2. Saaty's 1-9 scale of pairwise comparisons.

Intensity of Importance	Definition	Explanation/Operational Meaning
1	Equal Importance	Two baseline criteria contribute equally to the conservation design objective
2	Weak or Slight	Intermediate value between equal and moderate importance
3	Moderate Importance	Experience and local judgment slightly favour one baseline criterion over another
4	Moderate Plus	Intermediate value between moderate and strong importance
5	Strong Importance	Experience and judgment strongly favour one baseline criterion over another
6	Strong Plus	Intermediate value between strong and very strong importance
7	Very Strong/ Demonstrated	A criterion is strongly favoured, and its dominance is demonstrated in practice
8	Very, Very Strong	Intermediate value between very strong and extreme importance
9	Extreme Importance	Evidence favouring one criterion over another is of the highest possible affirmation

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (1)$$

$$CR = \frac{CI}{RI} \quad (2)$$

where $\lambda_{\max}$ is the principal eigenvalue, n is the number of evaluated criteria ($n = 5$), and RI is the Random Consistency Index (**Table 3**; for $n = 5$, RI = 1.12) (Saaty, 1980). A CR value < 0.10 indicates acceptable judgment consistency.

Table 3. Average Lambda maximum/Saaty random consistency index (RI) value.

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

2.5. Demographic Weighting and Spatial IDW Interpolation Settings

To model spatial baseline data demand across the Tumbatu Island landscape, the global AHP criteria weights (w_i) were integrated with shehia-level demographic exposure data. Population statistics for each shehia (Gomani: pop = 1114; Jongowe: pop = 3821; Mtakuja: pop = 2741; Uvivini: pop = 4279; total $N = 11,956$) were normalized by relative population proportion ($p_s = \text{Pop}_s / \text{Pop}_{\text{total}}$). The shehia-specific baseline decision index (S_{is}) for criterion i at shehia location s was calculated as: $S_{is} = w_i \times p_s$. The resulting indices served as input values at the four shehia administrative centroids in ArcGIS v10.4. Spatial surfaces were generated using Inverse Distance Weighting (IDW) interpolation based on Tobler's First Law of Geography. The IDW interpolation parameters were explicitly configured as follows: (i) power parameter $p = 2$ (standard inverse distance squared), (ii) variable search neighborhood utilizing all 4 shehia observation points, (iii) output raster cell size of 30 m $\times$ 30 m, and (iv) spatial interpolation extent clipped strictly to the Tumbatu Island sub-district land boundary. Given that the interpolation is parameterized across four shehia centroid inputs, the resulting surfaces are interpreted as exploratory spatial visualizations of community baseline priorities rather than definitive, continuous empirical physical fields.

3. Results

3.1. Choice of Key Conservation Baseline Data

The key variables (criteria) presented in **Table 2** were obtained as a result of a participatory data collection method (Focus Group Discussion (FGD)). The five categories of key variables were obtained after grouping similar themes into the sub-criteria (**Table 2**). It was revealed that each sub-criteria have some degree of influence on the key variables regarding the design of climate resilient conservation project. Note: analysis of sub-criteria was beyond the scope of this study.

3.2. Spatial Modelling of Baseline Decision Priorities

The findings revealed biophysical and environmental data as the most prioritized baseline data, followed by climate and weather data, and ecosystem services data as the second and third most prioritized baseline data for climate-resilient conservation development project.

4. Discussion

This study reveals that empirical, contextual and methodologically sound data are profoundly pivotal baseline data for designing climate-resilient development projects, notably for extremely vulnerable ecosystems such as that of Tumbatu Island. The results of AHP (Table 4 and Table 5) integration with GIS-based IDW operationalises MCDA as a robust framework that resolves foundational obstacles in conservation development project planning. The study findings exemplify that baseline selection is inherently non-uniform across spatial scales and thematic dimensions. Such findings call for a shift from aggregated, static models toward spatially explicit, hybrid decision architectures.

Table 4. Pairwise comparison matrix of the relative weights of key variables from Table 1.

	A	B	C	D	E
A	1	2	2	2	3
B	1/2	1	3	3	3
C	1/2	1/3	1	1/3	2
D	1/2	1/3	3	1	2
E	1/3	1/3	1/2	1/2	1
TOTAL	2.83	4.00	9.50	6.83	11.00
Note:	A:	Biophysical and Environmental Data			
	B:	Climate and Weather Data			
	C:	Socio-economic and Livelihood Data			
	D:	Institutional and Governance Data			
	E:	Ecosystem Services Data			

Table 5. Normalization matrix on relative weight of key variables.

	A	B	C	D	E	Eigenvectors
A	0.353	0.500	0.211	0.293	0.273	0.326
B	0.176	0.250	0.316	0.439	0.273	0.291
C	0.176	0.083	0.105	0.049	0.182	0.119
D	0.176	0.083	0.316	0.146	0.182	0.181
E	0.118	0.083	0.053	0.073	0.091	0.084
TOTAL	1.000	1.000	1.000	1.000	1.000	1.000

Maximum eigenvalue ($\gamma_{\max}$) = 5.372; Number of criteria (n) = 5; Consistency Index (CI) = $(\gamma_{\max} - n)/(n - 1)$ is 0.093; Random Index (RI) = 1.12; Consistency Ration (CR) = 0.083.

4.1. Primacy of Biophysical and Climatological Baseline Priorities

In this study, AHP priority weighting analysis revealed biophysical and environmental data (eigenvector = 0.326) and climate and weather data (eigenvector = 0.291) as the dominant baseline requirements for climate-resilient project design.

Importantly, within the context of multi-criteria decision analysis, these weights reflect stakeholders' perceived decision importance and operational urgency during project scoping rather than in situ measured ecological rates of change. This high valuation directly corresponds to the acute vulnerability of Tumbatu's socio-ecological system. In coralline island settings across the Western Indian Ocean (WIO), coral reef flats, intertidal mangrove stands, and thin topsoils form the first line of natural defense against ocean warming, storm surges, and monsoonal shocks [17] [18] [24]. Stakeholders strongly prioritized local meteorological trends because without accurate biophysical-climatic benchmarks, project teams cannot establish reliable impact tracking indicators or evaluate project additionality over time [2] [4]. Furthermore, given the absence of downscaled weather stations on Tumbatu Island, establishing community-validated weather and climate baselines is recognized as essential to prevent maladaptive investments [19] [22].

4.2. Institutional Governance, Livelihoods, and the Ecosystem Services Paradox

Institutional and Governance Data occupied (eigenvector = 0.181) at the third position of importance, outranked Socio-economic and Livelihood Data (0.119); and Ecosystem Services Data (0.084). Critical findings in this study reflect an acute operational awareness among local stakeholders that technical and ecological conservation interventions frequently fail when institutional arrangements, customary property rights, and community co-management structures are weak or poorly understood [34] [35]. On Tumbatu Island, where natural resource use is governed through traditional village leadership and Shehia structures, establishing an institutional baseline is critical for legitimate, durable conservation contracts henceforth long—term sustainability of the development programme [15].

Conversely, the low-priority weight assigned to Ecosystem Services Data ($w = 0.084$) highlights what may be termed the “paradox of ecosystem services valuation” in data-scarce island environments [36]–[38]. While international climate finance and carbon offset mechanisms place high emphasis on quantifying abstract ecosystem functions such as carbon sequestration potential and nutrient flux [6] [7], local practitioners and community members perceive these metrics as abstract, difficult to measure, and secondary to immediate tangible threats to livelihoods and habitat security. This gap underscores the necessity for MEAL frameworks to bridge theoretical ecological service metrics with tangible socio-economic co-benefits during project baseline formulation.

4.3. Spatial Priority Gradients and IDW Modeling

The integration of AHP decision weights with demographic data and IDW interpolation demonstrates distinct geographic variations across the four shehias of Tumbatu Island, namely Gomani, Jongowe, Mtakuja, and Uvivini. As shown in **Figure 2**, biophysical and climatic baseline demand is most intense along the densely populated northern and western coastal reaches of Gomani and Jongowe,

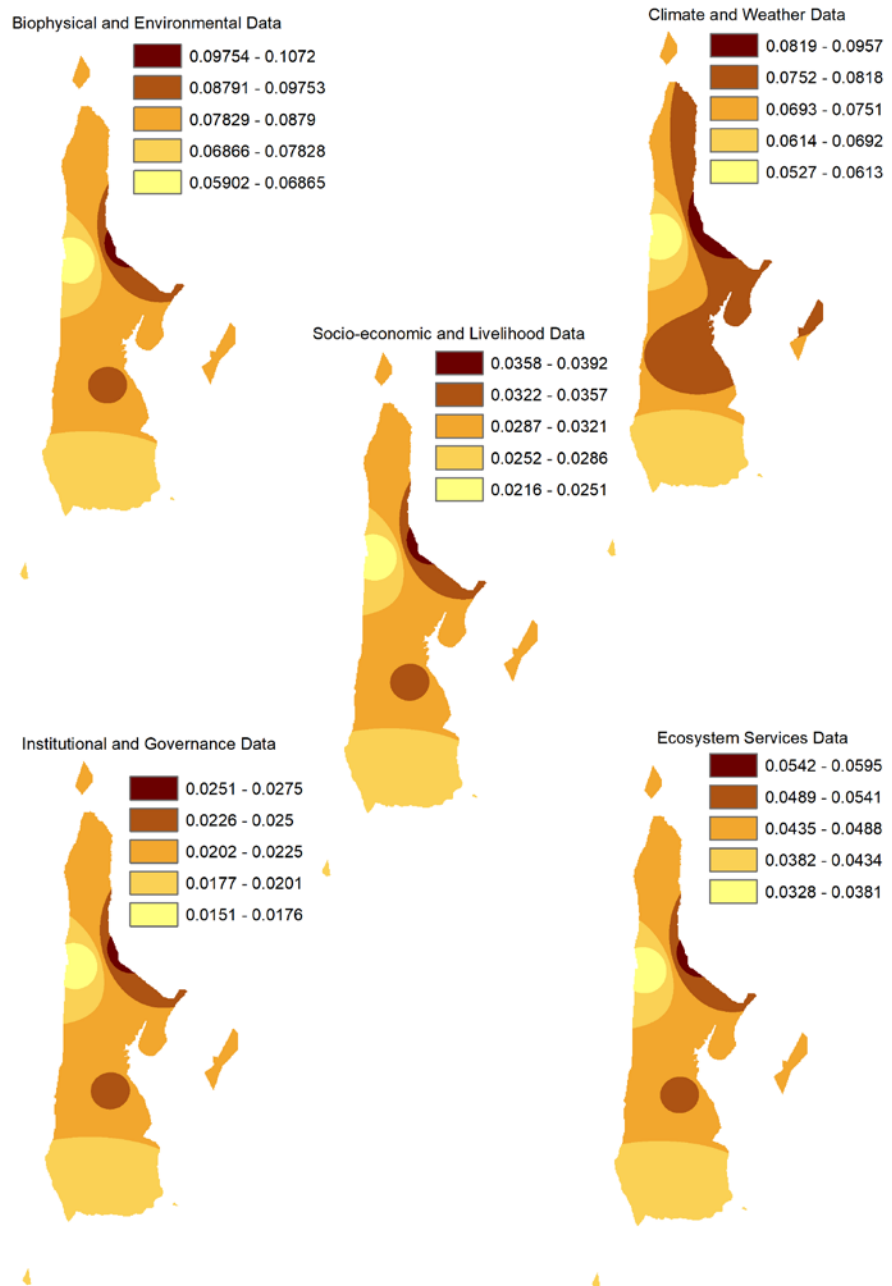


Figure 2. Spatial dynamics of baseline data at Tumbatu Island.

where artisanal fishing pressure, intertidal resource harvesting, and coastal erosion exposure are heavily concentrated. In contrast, institutional and socio-economic baseline priorities display localized southern gradients, reflecting variations in community organization and alternative livelihood activities. From an analytical perspective, this intra-island variation illustrates the non-uniformity of conservation baseline needs across space, demonstrating the limitation of uniform island-wide baseline assumptions [25] [30] [39]. Methodologically, because the IDW model interpolates across four shehia centroid observation points, the resulting raster surfaces are presented as exploratory spatial priority patterns rather

than formal statistical proofs of non-stationary physical processes. Nonetheless, this spatial MCDA approach provides practical spatial targeting guidance, ensuring that scarce monitoring resources are allocated to the most critical baseline dimensions in high-priority zones.

5. Conclusion

Designing climate-resilient conservation and development projects within vulnerable, data-scarce island environments requires clear, structured decision pathways for establishing baseline data. Rather than resolving temporal baseline typologies (historical vs. counterfactual), this study successfully operationalized an integrated AHP-IDW multi-criteria decision framework to prioritize five overarching baseline data domains on Tumbatu Island, Zanzibar. The AHP analysis revealed high structural consistency ($CR = 0.083 < 0.10$) and established that Biophysical and Environmental Data ($w = 0.326$) and Climate and Weather Data ($w = 0.291$) represent the foremost baseline priorities, accounting for over 61.7% of the cumulative decision weight. Institutional and Governance Data ($w = 0.181$) proved more influential than Socio-economic Data ($w = 0.119$) and Ecosystem Services Data ($w = 0.084$), emphasizing the foundational role of local governance in project sustainability. The exploratory spatial IDW analysis demonstrated clear localized gradients across the four shehias, confirming that baseline data acquisition should be spatially tailored to local socio-ecological pressures. By distinguishing stakeholder decision priorities from physical ecological measurements and providing reproducible participatory protocols, this framework serves as a practical blueprint for conservation planners, MEAL specialists, and climate finance architects across Small Island Developing States globally.

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Author Contributions

Conceptualization, M.T.M.; methodology, M.T.M., S.S.M., B.J.M., and J.B.; formal analysis, M.T.M., J.B. and I.Y.H.; investigation and data collection, M.M.M., B.H.M., E.S. and V.G.K.; writing—original draft preparation, M.T.M. and B.J.M.; writing—review and editing, M.T.M., M.M.M., and S.S.M.; geospatial modeling, J.B. and M.T.M. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Ahmad, I., Ping, W., Ullah, S., Faqeih, K.Y., Alamri, S.M., Alamery, E.R., *et al.* (2025) Spatiotemporal Mapping of Urban Flood Susceptibility: A Multi-Criteria GIS-Based Assessment in Nangarhar, Afghanistan. *Land*, **14**, Article No. 2376. <https://doi.org/10.3390/land14122376>
- [2] Ajaleen, Y., Al-qaise, Y., Rozar, N. and Btoush, Q. (2022) The Impact of Stakeholder Behavior on Decision Making and Sustainability. *Special Education*, **1**, 1-12.
- [3] Ali, M., Nakamo, S. and Maguta, M. (2025) Three Decades of Land Use and Land Cover Changes in Mjini Magharibi, Zanzibar, Tanzania: Implications on the Coastal Mangrove Forest Ecosystems and Urban Development. *Rural Planning Journal*, No. 1, 15-29. <https://doi.org/10.59557/rpj.1.1.2025.174>
- [4] Apolinário, A.E., Silva, W.D.O., dos Santos, M. and Morais, D.C. (2026) A Spatio-temporal Gis-Based Multicriteria Assessment of Intra-Urban Water Security under a Large-Scale Urban Mining Disaster in Maceió, Alagoas State (AL), Brazil. *Environment Systems and Decisions*, **46**, Article No. 55. <https://doi.org/10.1007/s10669-026-10118-6>
- [5] Awazi, N.P. (2025) East Africa's Coast: Bridging People and Nature for Community Resilience through Sustainable Management of Mangrove Ecosystems. In: Awazi, N.P., Ed., *Building Climate Resilient Communities along Africa's Coasts: The Role of Mangroves*, Springer, 79-99. https://doi.org/10.1007/978-3-031-90843-9_4
- [6] Blanco, M.B., Rudman, A.N., Greene, L.K., Razafindrainibe, F., Andrianandrasana, L. and Welch, C. (2020) Back to Basics: Gaps in Baseline Data Call for Revisiting an Environmental Education Program in the SAVA Region, Madagascar. *PLOS ONE*, **15**, e0231822. <https://doi.org/10.1371/journal.pone.0231822>
- [7] Boivin, N. and Crowther, A. (2021) Mobilizing the Past to Shape a Better Anthropocene. *Nature Ecology & Evolution*, **5**, 273-284. <https://doi.org/10.1038/s41559-020-01361-4>
- [8] Burak, M.K. (2023) The Lion's Share: Spatiotemporal Patterns of Lion Landscape Use in a Shared Human-Wildlife System. Ph.D. Dissertation, Yale University. https://elischolar.library.yale.edu/gsas_dissertations/1429
- [9] Chaube, S., Pant, S., Kumar, A., Uniyal, S., Singh, M.K., Kotecha, K., *et al.* (2024) An Overview of Multi-Criteria Decision Analysis and the Applications of AHP and TOPSIS Methods. *International Journal of Mathematical, Engineering and Management Sciences*, **9**, 581-615. <https://doi.org/10.33889/ijmems.2024.9.3.030>
- [10] Coffield, S.R., Vo, C.D., Wang, J.A., Badgley, G., Goulden, M.L., Cullenward, D., *et al.* (2022) Using Remote Sensing to Quantify the Additional Climate Benefits of California Forest Carbon Offset Projects. *Global Change Biology*, **28**, 6789-6806. <https://doi.org/10.1111/gcb.16380>
- [11] Desbureaux, S., Girard, J., Dalongeville, A., Devillers, R., Mouillot, D., Jiddawi, N., *et al.* (2024) The Long-Term Impacts of Marine Protected Areas on Fish Catch and Socioeconomic Development in Tanzania. *Conservation Letters*, **17**, e13048. <https://doi.org/10.1111/conl.13048>
- [12] Donaldson, L., Wilson, R.J. and Maclean, I.M.D. (2017) Old Concepts, New Challenges: Adapting Landscape-Scale Conservation to the Twenty-First Century. *Biodiversity and Conservation*, **26**, 527-552. <https://doi.org/10.1007/s10531-016-1257-9>

- [13] Farr, C.M., Reed, S.E. and Pejchar, L. (2018) Social Network Analysis Identifies Key Participants in Conservation Development. *Environmental Management*, **61**, 732-740. <https://doi.org/10.1007/s00267-018-1017-6>
- [14] Farwig, N., Sprenger, P.P., Baur, B., Böhning-Gaese, K., Brandt, A., Eisenhauer, N., *et al.* (2025) Identifying Major Factors for Success and Failure of Conservation Programs in Europe. *Environmental Management*, **75**, 425-443. <https://doi.org/10.1007/s00267-024-02086-x>
- [15] Faulkner, P., Sarathi, A., Crowther, A., Smith, T., Harris, M., Ali, A.K., *et al.* (2022) Human-Ecodynamics and the Intertidal Zones of the Zanzibar Archipelago. *Frontiers in Earth Science*, **10**, Article ID: 982694. <https://doi.org/10.3389/feart.2022.982694>
- [16] Hamad, A.U. and Sawe, J.R. (2025) Coastal Community Responses to the Impact of Climate Change in Tanzania—A Case of North “A” District, Zanzibar. *American Journal of Climate Change*, **14**, 483-507. <https://doi.org/10.4236/ajcc.2025.143024>
- [17] Hamad, I.Y., Staehr, P.A.U., Rasmussen, M.B. and Sheikh, M. (2022) Drone-Based Characterization of Seagrass Habitats in the Tropical Waters of Zanzibar. *Remote Sensing*, **14**, Article No. 680. <https://doi.org/10.3390/rs14030680>
- [18] Hemming, V., *et al.* (2022) An Introduction to Decision Science for Conservation. *Conservation Biology*, **36**, e13868.
- [19] Ijaz, N., Ijaz, Z., Zhou, N., ur Rehman, Z., Abbas Jaffar, S.T., Ijaz, H., *et al.* (2025) Geotechnical Data-Driven Mapping for Resilient Infrastructure: An Augmented Spatial Interpolation Framework. *Buildings*, **15**, Article No. 3211. <https://doi.org/10.3390/buildings15173211>
- [20] Kebede, E.A., Abou Ali, H., Clavelle, T., Froehlich, H.E., Gephart, J.A., Hartman, S., *et al.* (2024) Assessing and Addressing the Global State of Food Production Data Scarcity. *Nature Reviews Earth & Environment*, **5**, 295-311. <https://doi.org/10.1038/s43017-024-00516-2>
- [21] Kitali, L.J. (2026) Local Community Engagement, Governance, and Sustainability in Marine Resource Management: Evidence from Tanzania. *African Journal of Empirical Research*, **7**, 59-70. <https://doi.org/10.51867/ajernet.7.1.6>
- [22] Klaoudatos, D. and Theocharis, A. (2025) Methodologies for Data-Poor Fisheries Assessment in the Mediterranean Basin: Status, Challenges, and Future Directions. *Fishes*, **11**, Article No. 22. <https://doi.org/10.3390/fishes11010022>
- [23] Kubiszewski, I., Costanza, R., Anderson, S. and Sutton, P. (2020) The Future Value of Ecosystem Services: Global Scenarios and National Implications. In: Ninan, K.N., Ed., *Environmental Assessments*, Edward Elgar Publishing, 81-108. <https://doi.org/10.4337/9781788976879.00016>
- [24] Liu, M., Lin, M., Dong, L., Caruso, F. and Li, S. (2022) An Integrated Strategy for Monitoring Cetaceans in Data-Poor Regions. *Biological Conservation*, **272**, Article ID: 109648. <https://doi.org/10.1016/j.biocon.2022.109648>
- [25] Amorim Maia, A.T., Calcagni, F., Connolly, J.J.T., Anguelovski, I. and Langemeyer, J. (2020) Hidden Drivers of Social Injustice: Uncovering Unequal Cultural Ecosystem Services behind Green Gentrification. *Environmental Science & Policy*, **112**, 254-263. <https://doi.org/10.1016/j.envsci.2020.05.021>
- [26] Makame, M.O. and Said, S.S. (2024) The Role of Sport Tourism in Diversifying Tourism Activities in Zanzibar: The Need for Institutional Support for Sustainability. In: Van Rheeën, D., Naria, O., Melo, R. and Sobry, C., Eds., *Sport Tourism, Island Territories and Sustainable Development: A Comparative Perspective*, Springer, 453-466.

- [27] Makombore, L., Farley, J., Danielsen, J. and Marchessault, A.C. (2026) Building Ethical Foundations for Economic Models: Ecological Restoration and Conservation in the Ecozoic. *Conservation*, **6**, Article No. 37. <https://doi.org/10.3390/conservation6010037>
- [28] Manyama, M.T., Hepelwa, A.S. and Nahonyo, C.L. (2019) Analysis of Socio-Ecological Impacts of Built Environment at Dar Es Salaam Metropolitan Coastline, Tanzania. *Open Journal of Social Sciences*, **7**, 161-182. <https://doi.org/10.4236/jss.2019.710014>
- [29] Martínez-Abraín, A., Llaneza, L. and Oro, D. (2026) The Past as a Wrong Baseline for Future Conservation: Alternatives to the Use of Historical Distributions for Cataloguing the Threat Status of Large Carnivores. *Journal for Nature Conservation*, **93**, Article ID: 127338. <https://doi.org/10.1016/j.jnc.2026.127338>
- [30] McLean, B., Hikmany, A.H., Mangora, M. and Shalli, M. (2012) Legal and Institutional Framework for Effective Management of Marine Managed Areas in Tanzania, Zanzibar Report. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.2687649>
- [31] Mitchell, P. (2022) African Islands: A Comparative Archaeology. Routledge. <https://doi.org/10.4324/9781003245360>
- [32] Mohamed, M.K. (2025) Economic Valuation of Mangrove Ecosystem Services: Insights from Willingness to Pay Analysis for Chwaka Bay Mangrove Forest, Zanzibar. *Wild*, **2**, Article No. 21. <https://doi.org/10.3390/wild2020021>
- [33] Mwanga, S.S., Mbekenga, M.J., Mahoo, H.F. and Yonah, I.B. (2025) Utilization of Indigenous Knowledge (IK) Indicators in Weather Forecasting and Livelihood Planning in Coastal Regions of Tanzania. *American Journal of Climate Change*, **14**, 393-412. <https://doi.org/10.4236/ajcc.2025.142020>
- [34] Navarro, L.M., Armstrong, C.G., Changeux, T., Frisch, D., Gil-Romera, G., Kaim, D., *et al.* (2025) Integrating Historical Sources for Long-Term Ecological Knowledge and Biodiversity Conservation. *Nature Reviews Biodiversity*, **1**, 657-670. <https://doi.org/10.1038/s44358-025-00084-3>
- [35] Ndesanjo, R.B. (2025) Implications for Coastal Livelihoods of the Blue Economy Agenda in Tanzania. *Tanzania Journal of Development Studies*, **23**, 15-37. <https://doi.org/10.56279/njiy8787/tjds.v23i1.2>
- [36] Ndomba, P.M. and Killingtveit, Å. (2026) An Operational Streamflow Forecasting System for a Data-Scarce Catchment in Tanzania. *Water*, **18**, Article No. 285. <https://doi.org/10.3390/w18020285>
- [37] Nobles, M., Lall, R., Mathes, R.W. and Neill, D.B. (2022) Presyndromic Surveillance for Improved Detection of Emerging Public Health Threats. *Science Advances*, **8**, eabm4920. <https://doi.org/10.1126/sciadv.abm4920>
- [38] Noe, C., Mwamfupe, A., Kweka, O., John, R.W., Silvano, P., Namkesa, F.D., *et al.* (2022) Conservation and Development in Tanzania: Background, History, and Recent Developments. In: Noe, C., Brockington, D. and Ponte, S., Eds., *Contested Sustainability: The Political Ecology of Conservation and Development in Tanzania*, Boydell & Brewer, 33-70. <https://doi.org/10.2307/j.ctv2x4kp1m.8>
- [39] Panigrahi, N. (2023) Inverse Distance Weight. In: Daya Sagar, B.S., *et al.*, Eds., *Encyclopedia of Mathematical Geosciences*, Springer International Publishing, 666-672. https://doi.org/10.1007/978-3-030-85040-1_166