COASTAL AND OCEAN JOURNAL

Article

Participatory Approaches to Land and Sea Use Patterns: A Case Study of Yavusa Navakavu, Fiji

Emeli Bernard [1], Fery Kurniawan [2,3], Luky Adrianto [2,3], and Joeli Varo [4]

[1] Study Program of Coastal and Marine Resource Management, IPB University, Bogor 16680, Indonesia; emelibernard@apps.ipb.ac.id
[2] Department of Aquatic Resource Management, Faculty of Fisheries and Marine Science, IPB University, Bogor 16680, Indonesia; ferykurniawan@apps.ipb.ac.id
[3] Center for Coastal and Marine Resources Studies, IPB University, Bogor 16680, Indonesia; lukyadrianto@apps.ipb.ac.id
[4] Discipline of Land Management and Development, School of Business and Management (BSM), University of the South Pacific, Suva, Fiji; joeli.varo@usp.ac.fj

Abstract: Sustainable land and sea use planning aims to balance environmental conservation with socio-economic development. This balance is particularly critical in coastal communities where traditional knowledge is plays a key role in resource management. This study examines land and sea use pattern in Yavusa Navakavu, Fiji, through participatory mapping, geospatial analysis, and landscape metrics. The results indicate that agriculture and forest cover dominate the land cover (53.85%), while the marine area is primarily used for fishing (79.91%). The forested area is characterized by a high level of landscape cohesion (99.07%) and a low level of fragmentation (Edge Density: 72.44 m/ha), indicating strong ecological connectivity and minimal urbanization pressure. The Locally Managed Marine Area (LMMA) system effectively supports conservation within the local community-based governance. However, the effects of climate change and development pressure are still significant. However, the impacts of climate change and development pressures from Suva City remain significant. Therefore, future research should incorporate high-resolution temporal data, socio-economic factors, and ecological monitoring to improve resource management and adaptive coastal planning.

Keywords: participatory spatial planning; land and sea use patterns; traditional knowledge

Citation: Bernard, E.; Kurniawan, F.; Adrianto, L.; Varo, J., 2025. Participatory Approaches to Land and Sea Use Patterns: A Case Study of Yavusa Navakavu, Fiji. *Coastal and Ocean Journal*, (9)1: 34-56. https://doi.org/10.29244/coj.v9i1.63157

Received: 11-03-2025
Accepted: 11-06-2025
Published: 26-06-2025

Publisher's Note: Coastal and Ocean Journal (COJ) stays neutral about jurisdictional claims in published maps and institutional affiliations.

1. Introduction

Sustainable land and sea management is urgent as there is increasing concern about escalating environmental pressure and expanding human activities (Korpinen *et al*., 2021). Traditional top-down governance models often fail to capture the complexity of socio-ecological systems, leading to inefficiencies, conflicts, and unsustainable resource management (Aggarwal et al., 2023). In this context, participatory approaches have gained prominence to integrate diverse stakeholder perspectives, enhance legitimacy, and improve decision-making processes (Dral, *et al*., 2023).

Participatory governance engages local communities, policymakers, researchers, and industry stakeholders in co-designing management approaches (Aggarwal *et al*., 2023). These approaches have been successfully applied in both terrestrial land use planning (Schugurensky *et al*., 2024) and marine spatial planning (MSP) (Douvere, 2008), highlighting the potential to balance conservation goals with economic and social needs. Participatory processes promote inclusive decision-making, enhance socio-ecological resilience, reduce conflict, and build adaptive capacity (Jager *et al*., 2019). Nevertheless, participatory models face severe challenges, such as power discrepancies, logistical issues, and integrating multiple knowledge systems (Reed *et al*., 2018). Closing the divide between local and scientific knowledge demands strict attention to be credible, legitimate, and suitably governed (Vierros *et al*., 2020).

This paper discusses the contribution of participatory approaches to influencing land and marine use patterns, with case studies determining best practices and ongoing challenges. Further, through critical analysis of the methodologies employed, the study aims to analyze land and sea use patterns in Yavusa Navakavu, Fiji, using spatial analysis, landscape metrics, and community-based participatory mapping to enhance the evolution of more adaptive, equitable, and ecologically sustainable spatial planning systems.

1.1. Case Study: Yavusa Navakavu

The study was conducted in Yavusa Navakavu, Fiji. This site is located on the southwestern coast of Viti Levu Island and adjacent to Suva, the capital of Fiji (Figure 1). It is a coastal region of significant ecological, cultural, and socio-economic importance. This area consists of seven Mataqalis (traditional land-owning units with tribal subdivisions: Laselase, Nabaramai, Nakaubeqa, Nasei, Natabuivalu, Natodre, and Waitabua) and comprises five villages—Muaivuso, Nabaka, Namakala, Ucuinamono, and Waiqanake—along with the Vunisinu settlement community. The region exemplifies the dynamic interaction between traditional resource management practices and contemporary development challenges, making it a critical case study for sustainable coastal management.

The geographical positioning of Navakavu, near Suva and Lami's industrial zones, highlights its strategic importance. It is an area of rich marine and terrestrial biodiversity, encompassing mangroves, coral reefs, and seagrass beds, which generate valuable ecosystem services for the surrounding communities. These resources are, however, coming under growing pressures of urbanization, pollution, climate change, overfishing, and unsustainable infrastructure development. Moreover, the illicit fishing of marine resources exposes these ecosystems to greater risk, thereby threatening the livelihood of the surrounding communities. A historical World War II site, the Bilo Gun Site, can also be found in the study area.

Traditional knowledge (TK) is central to Navakavu's resource management. The site is renowned for its Locally Managed Marine Area (LMMA), where the traditional "Tabu" system—

no-take zones marked out by community leaders—bears witness to the viability of community-based governance systems in regulating conservation with resource use (Lal *et al*., 2017). These traditional systems hold valuable lessons in how societies can govern their natural resources sustainably while maintaining the integrity of cultural heritage.

However, understanding the intricate relationship between traditional knowledge and modern conservation efforts in Navakavu is crucial for designing effective coastal resource management policies. By integrating indigenous practices with contemporary scientific approaches, this research aims to contribute to the broader discourse on sustainable resource management in small island developing states (SIDS). Despite the presence of the tabu (LMMA), Navakavu faced increasing pressure from urbanization derived from Suva and Lami towns, climate change, and resource conflicts. However, existing studies on MSP have not fully integrated local knowledge with GIS-based spatial analysis, despite clear opportunities for integrated land-sea management approaches (Jupiter *et al*., 2017). Therefore, this study seeks to bridge that gap by applying a participatory approach to mapping land and sea use patterns in the Navakavu coastal area. The findings will offer valuable lessons applicable to other coastal communities facing similar environmental and socio-economic challenges.

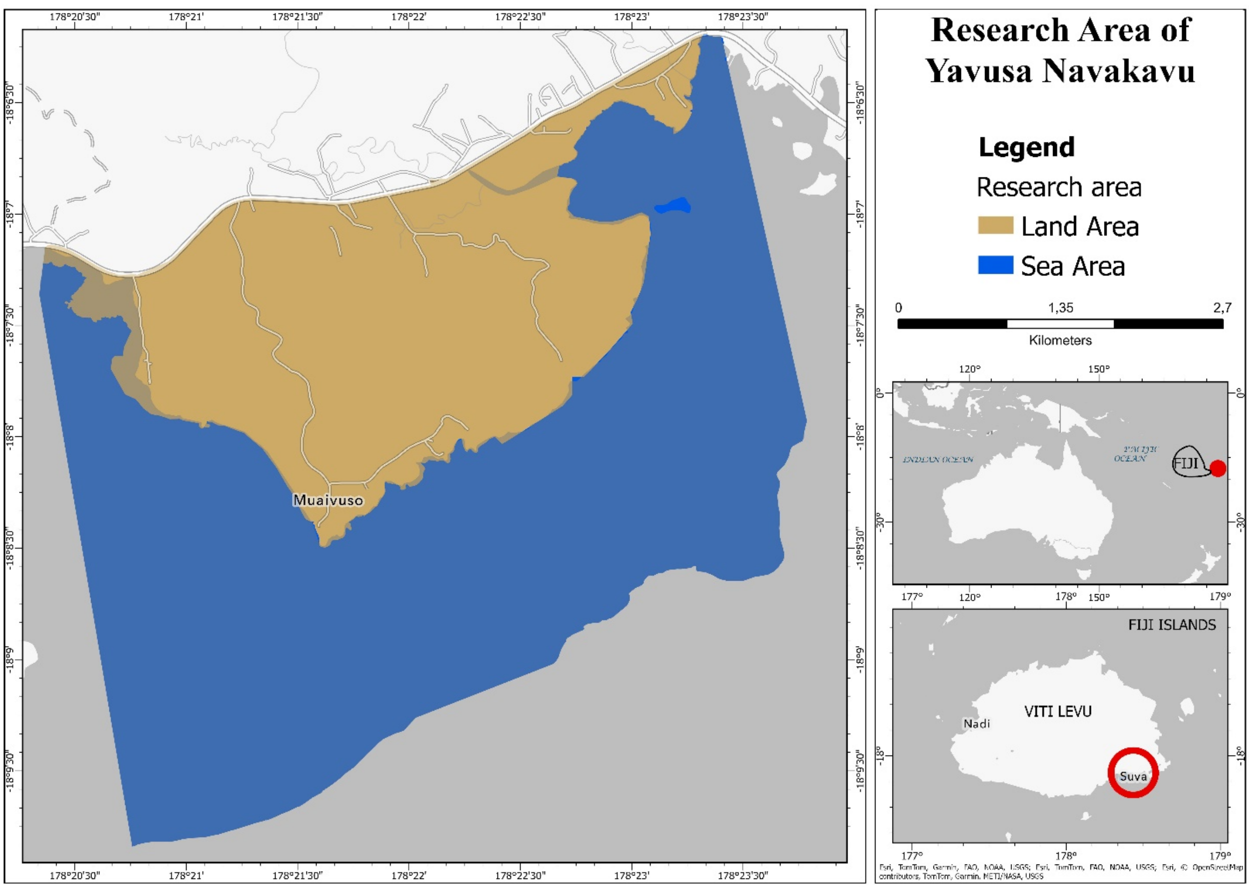

Figure 1. Yavusa Navakavu research area

2. Materials and Methods

2.1. Data Sources and Collection

Data collection involved a combination of secondary and primary data sources. Current land use data was obtained from various sources: Yavusa Navakavu communities, past research papers, the Ministry of Fisheries, and Government/ Stakeholder Reports. Remote sensing data was also used to ensure current conditions by digitizing in combination with field data, including current sea utilization and land cover (Pelawi *et al*., 2024). Sea utilization and cover data are primarily obtained through direct observation and GPS (Global Positioning System) field surveys. GPS was used to locate exact points to enhance accuracy, and photographs were taken to document mapped locations visually. This iterative mapping approach using participatory resources mapping ensured that traditional knowledge and field-based evidence were integrated into the final analysis (Febrianti *et al*., 2024).

Before conducting community consultations, a pre-field observation was carried out, which included snorkeling around the tabu (LMMA) to assess ocean health. This preliminary assessment provided baseline information on the ecological conditions of the marine environment. Most collected data were obtained from local community inputs (see Figure 2) and field observations. During fieldwork, A0-sized maps of the study area were printed and presented to community members, who were invited to map out their existing sea use zones and current land-use patterns. Additionally, semi-structured interviews and questionnaires were conducted to gain deeper insights into the community's relationship with their marine and coastal ecosystem, resource management practices, and observed environmental changes. After the community had identified and mapped the existing land and sea activities, the annotated maps were revalidated in the field (Al Amin *et al*., 2020).

Figure 2. Fieldwork and participatory process in Yavusa Navakavu

2.2. Data Analysis

The spatial analysis of land and sea use patterns was conducted using a combination of ArcGIS Pro and Fragstats to assess land cover distribution and spatial patterns using configuration and landscape metrics. ArcGIS Pro was employed for geospatial data processing, visualization, and analysis. Land and sea use data were classified, i.e., land uses are built areas, forests and agriculture, mangroves, Bilo sites, villages, and roads. Sea uses include fishing, diving, Ba ni kalou, and tabu (LMMA). Preprocessing steps included georeferencing, projection standardization, and supervised classification.

Fragstats software was utilized to quantify landscape metrics that characterize spatial patterns and the structural composition of land and sea use. The metrics computed included class-level metrics: These included the percentage of landscape (PLAND), largest patch index (LPI), edge density (ED), connectivity (CONNECT), and cohesion (COHESION), which provided insights into the dominance and fragmentation of specific land and sea use classes (McGarigal *et al*., 2012). Landscape-level metrics: Including LPI, ED, CONNECT, COHESION, Shannon's Diversity Index (SHDI), Simpson's Diversity Index (SIDI), Shannon's Evenness Index (SHEI), and Simpson's Evenness Index (SIEI), which helped assess overall landscape heterogeneity and aggregation trends (Gustafson, 2018). These analyses provided quantitative evidence on the spatial structure of land and sea use, supporting participatory decision-making processes in sustainable resource management.

A spatial distribution analysis was performed using kernel density estimation and spatial autocorrelation techniques (Moran's I) to determine clustering and dispersion patterns (Getis, 2017). Additionally, proximity analysis assessed the relationships between land and sea use areas and critical ecological features, such as mangroves, coral reefs, and fisheries. In detail, the Getis-Ord General G statistic was applied to measure the degree of clustering for either high or low values. Integrating geospatial and statistical analyses enabled a comprehensive understanding of land and sea use patterns, providing empirical evidence for the effectiveness of participatory approaches in sustainable management.

3. Result

3.1. Participatory Spatial Mapping

3.1.1. Land cover of Yavusa Navakavu

Yavusa Navakavu's land cover demonstrated characteristics of small creeks, mangroves, and general land cover distribution (Figure 3). The brown-shaded regions dominated the landscape, representing terrestrial land cover. In contrast, the green areas signified mangrove ecosystems essential to coastal protection and biodiversity. The network of small creeks, marked in light blue, reflects high hydrological connectivity, and this was anticipated to affect sediment transport and nutrient exchange within the coastal ecosystem. For example, land cover change studies in Yavusa Navakavu by Cameron *et al*. (2021) and Jupiter *et al*. (2017) acknowledged the rising pressures of coastal development, resource exploitation, and climate change on such ecosystems. Historical analysis shows that mangrove destruction and land cover changes have affected local fisheries and traditional resource management systems. As represented on the map, the spatial distribution of the current land cover benefited the region's current marine spatial planning and conservation efforts. In this research, we engaged the community members from Muaivuso, Waiqanake, and Nabaka villages in participatory mapping, interviews, and attempting questionnaires. All participants represented diverse livelihood backgrounds and social statuses, ensuring a comprehensive understanding of land and sea use patterns (Gajardo *et al*., 2023).

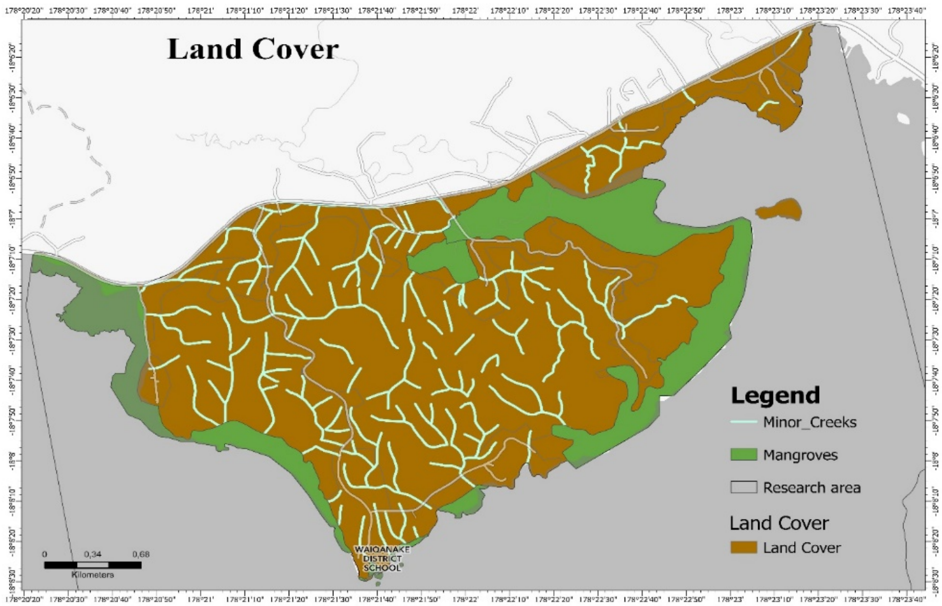

Figure 3. Land cover map of Navakavu

3.1.2. Land use of Yavusa Navakavu

The Land Use Map of Navakavu illustrated the spatial distribution of key land use categories, emphasizing the dominance of forest and agricultural land, followed by built-up areas, mangroves, and open spaces (Figure 4). The built-up areas, marked in brown, were primarily concentrated along the coastal zone and are predominantly used for residential, industrial, and school's purposes.

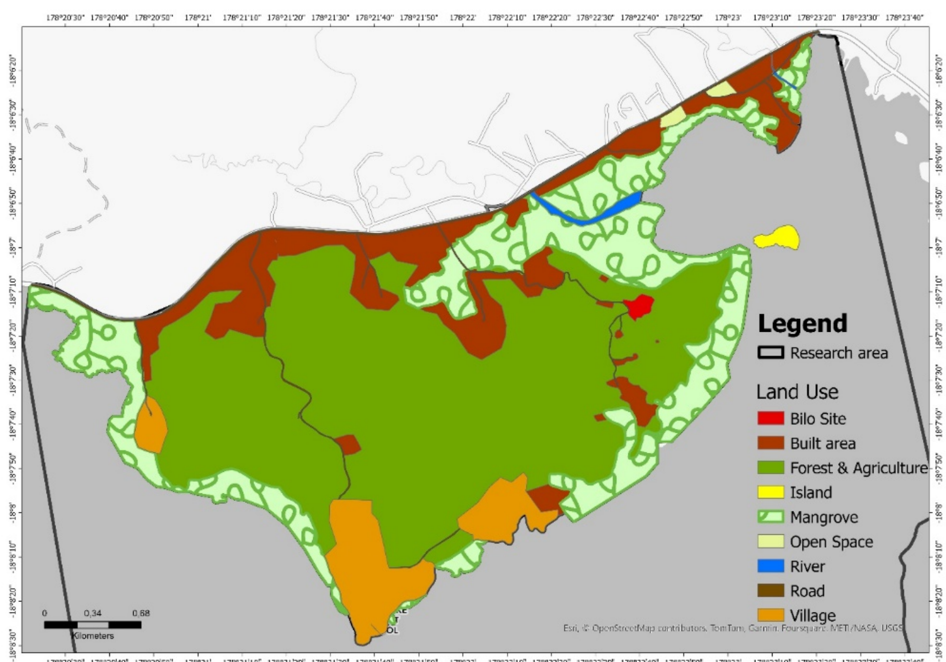

Figure 4. Land use map of Navakavu

This pattern aligned with past studies, such as those by Nunn *et al*. (2006), highlighted the expansion of coastal settlements in Pacific Island communities due to population growth and limited inland development opportunities. The prevalence of forest and agricultural land suggested that traditional subsistence farming remains a crucial livelihood activity, as supported by Veitayaki (2002), who emphasized the role of agroforestry in sustaining Fijian coastal communities. These land covers aso contribute significantly to carbon sequestration, particularly in Viti Levu Island, as highlighted by Avtar *et al*. (2013)

The presence of mangroves, mapped distinctly, reflected their ecological and socio-economic significance, reinforcing findings on their role in coastal resilience and fisheries (Sunkur *et al*., 2024) and additionally, identifying a "Bilo Site," a culturally significant area, aligned with research on integrating local heritage in land use planning. This shows that cultural heritage is about preserving the physical artifacts and respecting and sustaining the social and spiritual relationships communities have with their environment. Given the increasing demand for housing, the dominance of residential development in built areas raises concerns about sustainable infrastructure planning, as discussed by Storey & Hunter (2010), who warned of potential environmental and resource management challenges in expanding Pacific settlements. This land use distribution was a critical baseline for future urban planning and marine spatial management efforts in Navakavu.

3.1.3. Sea cover of Yavusa Navakavu

The Sea Cover Maps of Navakavu depicted the benthic composition, highlighting coral/algae dominance alongside seagrass, rubble, and sand, as well as the underwater geomorphic features, including reef slopes, lagoons, and reef flats, which were vital for marine biodiversity, ecosystem stability, and coastal protection (Figure 5). The Sea Cover Benthic and Geomorphic Maps of Navakavu provided a detailed spatial representation of the marine ecosystem, highlighting both the biological composition and underwater structural features that defined the coastal environment. The Benthic Map identified dominant seabed types, including coral/algae, seagrass, and sand, essential for marine biodiversity and ecosystem stability. The presence of coral and algae suggested productive reef habitats that support fish populations and other aquatic organisms, aligning with findings from previous studies on coral reef resilience in Pacific Island communities (Couch *et al*., 2022). Similarly, the distribution of seagrass beds underscored their ecological importance in carbon sequestration and as critical nursery grounds for various marine species (Shayka *et al*., 2023; Duarte *et al*., 2013). The mapping of benthic substrates aided in assessing habitat health and informed conservation strategies for sustainable resource management.

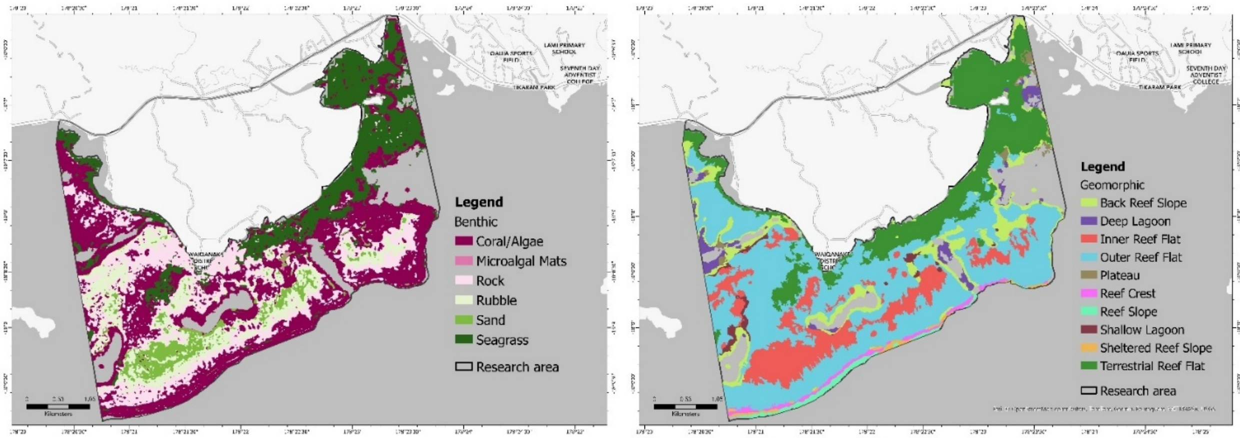

Figure 5. Sea cover maps (Benthic & Geomorphic) of the Navakavu coastal area (Source: Allen Coral Atlas, which was downloaded on 16th January 2025, https://allencoralatlas.org/atlas/#11.69/-18.1237/178.3208)

On the other hand, the Geomorphic Map categorized the physical underwater features such as reef slopes, lagoons, and reef flats, which played a crucial role in coastal protection and marine resource sustainability. The presence of outer reef flats and reef crests indicated natural wave barriers, reducing coastal erosion and enhancing shoreline stability, a phenomenon well-documented in coastal geomorphology research (Madin *et al*., 2022). Additionally, shallow and deep lagoon systems contributed to marine biodiversity by providing habitats for juvenile fish and invertebrates, reinforcing findings from past research on lagoon ecology in tropical marine environments (Unsworth *et al*., 2020). Understanding these geomorphic structures was vital for marine spatial planning and the development of ecosystem-based management approaches for Navakavu's coastal resources.

3.1.4. Sea use of Yavusa Navakavu

The Sea Use Map of Navakavu illustrated the spatial distribution of marine activities, highlighting areas designated for fishing, diving, cultural practices, and conservation (Figure 6). A tabu (LMMA) area signified community-driven marine resource management, aligning with studies on traditional ecological knowledge in Pacific fisheries (Jupiter *et al*., 2014). The Ba ni Kalou area reflected the cultural and spiritual significance of the sea, reinforcing past research on integrating local marine governance into sustainable coastal management (Muehlig-Hofmann *et al*., 2017). Additionally, identifying shipw reck and jetty locations suggested their potential role in tourism and habitat formation, as noted in studies on artificial reefs and marine biodiversity. This map underscored the interconnectedness of ecological, cultural, and economic values in marine spatial planning for Navakavu.

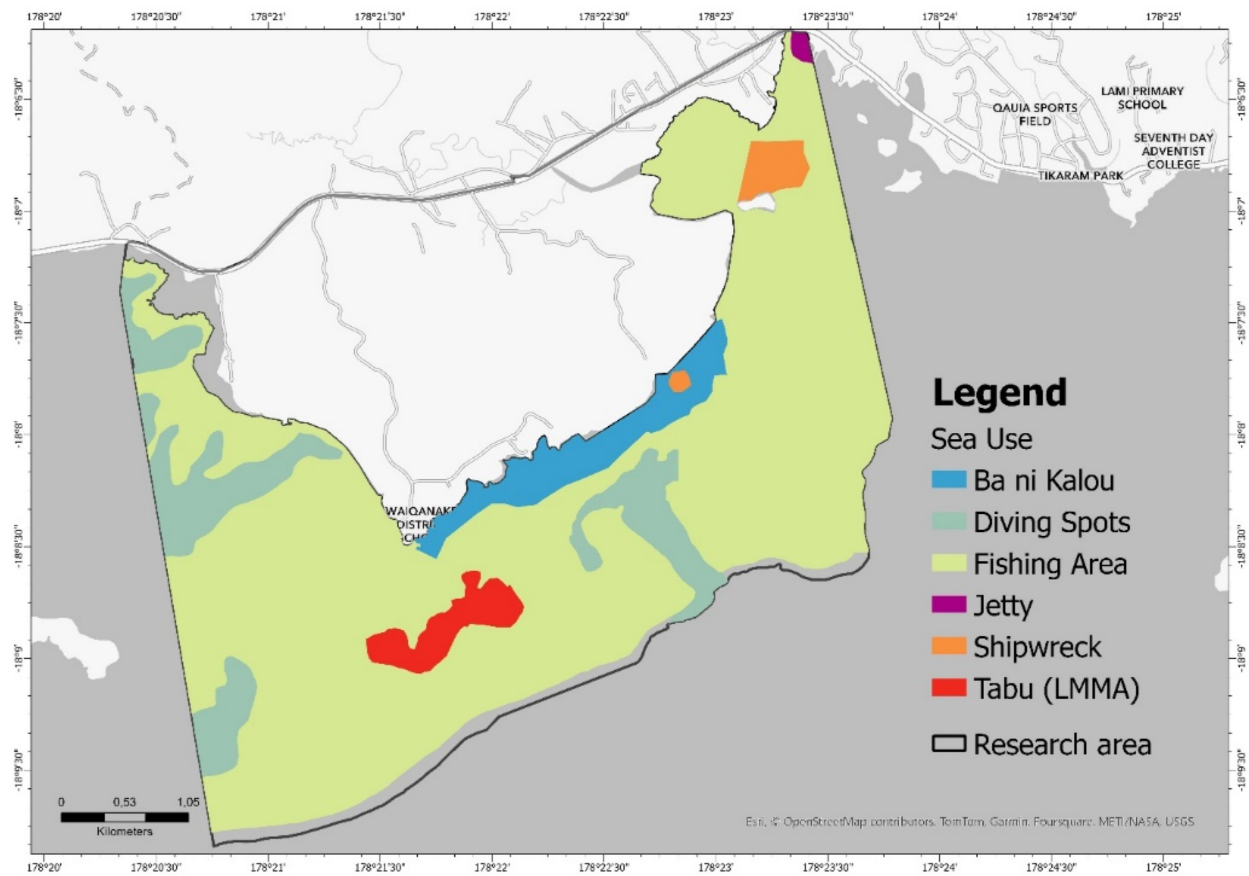

Figure 6. Sea use map of the Navakavu coastal area

3.2. Land and Sea Use and Cover Distributions

3.2.1. Land use and cover (LULC) metrics

Table 1 presents the land use and land cover (LULC) analysis of Navakavu, demonstrating the prevalence of forest and agriculture, accounting for 53.85% of land cover. This finding confirms previous studies that emphasized the significance of these landscapes for ecological resilience and local livelihoods (Thaman, 2008). Mangroves represented 22.34% of the landscape, playing a crucial role in shoreline protection and facilitating carbon sequestration, a conclusion consistent with research that highlighted the environmental importance of the Pacific's mangrove forest ecosystem (Quashigah *et al*., 2025). Urban areas covered 14.38%, indicating the expansion of human development and infrastructure, a trend common among many urbanizing coastal communities (Pasquali & Marucci, 2021). Despite their limited area, the Bilo Site and Veisari River sites hold considerable cultural and hydrological importance. The high levels of cohesion in most land cover classes reflected landscape connectivity, which was vital for ecosystem resilience (Smith & Ramirez, 2022). Conversely, the low connectivity of road networks suggested fragmentation, potentially affecting accessibility and planning. This assessment underscored the need for integrated land use planning to balance development and conservation in Navakavu.

Table 1. Spatial distribution and landscape metrics of land use types in Yavusa Navakavu coastal area

Type	PLAND (%)	LPI (%)	ED (m/ha)	CONNECT	COHESION
Built area	14.3805	7.2603	38.0155	25.6410	98.4773
Bilo Site	0.2493	0.2493	0.9571	0.0000	93.6308
Forest & Agriculture	53.8505	53.5768	35.3558	66.6667	99.8555
Island	0.3728	0.3728	0.0000	0.0000	94.8528
Mangrove	22.3352	12.1826	25.5069	32.1429	99.0466
Open Space	0.3283	0.1736	1.4245	100.0000	92.0773
River	0.0134	0.0100	0.3339	100.000	61.4053
Road	1.4579	0.2504	30.1031	10.8504	85.2754
Veisari River	0.4029	0.4029	2.5485	0.0000	95.0612
Village	6.6093	4.0965	10.6279	33.3333	98.2856

Table 2 presents key landscape metrics relevant to the study area's Land Use and Land Cover (LULC). The metrics include the LPI, ED, CONNECT, Cohesion, and diversity indices such as SHDI, SIDI, SHEI, and SIEI. These metrics provide valuable insights into land cover classes' spatial patterns, fragmentation, and diversity, essential for understanding landscape dynamics and promoting ecological sustainability.

Table 2. Landscape-level metrics for LULC in the Yavusa Navakavu coastal area

LPI	ED	CONNECT	COHESION	SHDI	SIDI	SHEI	SIEI
53.5768	72.4365	11.0148	99.0654	1.2662	0.6348	0.5499	0.7054

The LULC landscape analysis of Navakavu highlighted a dominant land cover type (LPI 53.58%) and relatively high connectivity (CONNECT 11.01), indicating a structured but somewhat isolated landscape. However, the high edge density (ED = 72.44 m/ha) indicated an increasing urban fragmentation, aligning with previous findings on the impacts of coastal urbanization in Fiji (Nunn *et al*., 2017). This trend underscores the need for improved zoning regulations in Navakavu to manage rapid land use changes effectively. Moreover, expanding built areas into traditionally managed coastal zones could contribute to habitat degradation, increased sedimentation in marine ecosystems, and conflicts over resource use. Despite these concerns, a high cohesion (99.07%) suggested strong ecological integrity, which benefited ecosystem services like erosion control and carbon sequestration. Moderate land use diversity (SHDI 1.27, SIDI 0.63) supported resilience, but uneven distribution (SHEI 0.55, SIEI 0.71) showed signs of potential land use conflicts (Prasetyo & Arifin, 2019). Strategies like Marine Spatial

Planning (MSP) and tabu (LMMA) were prioritized to balance development with ecological conservation to ensure sustainable coastal management.

3.2.2. Sea Use Sea Cover (SUSC) Metrics

The table below shows the spatial distribution and configuration of the study site's Sea Use and Sea Cover (SUSC) areas. These areas encompassed key marine and coastal features such as fishing zones, tabu –(LMMA), shipwrecks, diving spots, and other essential ecological and cultural sites. Table 3 presented seascape metrics, including PLAND, LPI, ED, CONNECT, and Cohesion, to evaluate these areas' spatial structure and interconnectivity.

Table 3. Spatial distribution and metrics of SUSC types in Yavusa Navakavu coastal area

Type	PLAND (%)	LPI (%)	ED (m/ha)	CONNECT	COHESION
Ba ni Kalou	5.0028	5.0028	3.5263	0.0000	99.4748
Diving Spots	10.9316	3.9278	12.1615	30.0000	99.2372
Fishing area	79.9082	79.9082	19.7999	0.0000	99.9820
Jetty	0.2050	0.2050	0.2663	0.0000	96.8092
Tabu (LMMA)	2.5250	2.5250	3.1269	0.0000	99.1991
Shipwreck	1.4274	1.2752	1.6091	0.0000	98.5544

Table 3 illustrated that the fishing area dominated the marine landscape, covering 79.91% of the total area and boasting the highest LPI (79.91%), indicating that it was the largest continuous spatial unit. The high cohesion value (99.98%) suggested that fishing areas are well-connected and not significantly fragmented. This pattern aligned with previous studies highlighting the importance of extensive, continuous fishing grounds for maintaining local livelihoods and food security (Prasetyo & Arifin, 2019; Wulandari *et al*., 2022).

Diving spots covered 10.93% of the total landscape, but their LPI was only 3.93%, indicating that they were relatively scattered and did not form a dominant patch. However, the edge density (12.16 m/ha) and connectivity index (30.00) suggested that these areas had a moderate level of interconnectivity. This spatial structure supported marine ecotourism, as highly connected diving sites attracted more divers and generated conservation interest (Sala *et al*., 2018).

The tabu (LMMA) area accounted for 2.52% of the total area, with a high cohesion index (99.19%), indicating strong physical connectivity. Tabu areas were essential for traditional resource management, promoting sustainable fishing practices and biodiversity conservation (Jupiter *et al*., 2014). Their spatial configuration aligned with the community-based marine management framework widely practiced in the Pacific (Cohen *et al*., 2012).

The Ba ni Kalou (sacred sites) occupied 5% of the landscape and had a high cohesion index (99.47%), indicating they were well-defined and protected from fragmentation. These sites held significant cultural and spiritual value, reinforcing the need for marine spatial planning approaches that integrate traditional knowledge and conservation efforts (Aswani *et al*., 2017).

The shipwreck and jetty areas had the smallest coverage, 1.43%, and 0.21%, respectively, with low connectivity (0.00) and relatively low cohesion (98.55% and 96.81%). While they were not major players in marine resource extraction, shipwrecks could serve as artificial reefs, supporting marine biodiversity (Edwards *et al*., 2010). On the other hand, jetties served as critical infrastructure for transportation and economic activities, highlighting their functional importance despite their limited spatial extent (Fletcher *et al*., 2011).

Furthermore, Table 4 presented key landscape metrics for the sea use and sea cover (SUSC) of Navakavu, reflecting the spatial composition and configuration of marine resources. These metrics provided insights into the seascape's connectivity, fragmentation, and diversity, which are crucial for sustainable marine resource management.

Table 4. Seascape-level metrics for SUSC in Yavusa Navakavu coastal area

LPI	ED	CONNECT	COHESION	SHDI	SIDI	SHEI	SIEI
79.9082	20.2450	27.2727	99.8942	0.7373	0.3462	0.4115	0.4154

Table 4 analysis showed that a single dominant marine feature occupied most of the seascape (LPI: 79.91%), indicating low fragmentation but potential resource concentration. The moderate Edge Density (ED: 20.25 m/ha) suggested some degree of fragmentation, while good connectivity (CONNECT: 27.27) and high cohesion (99.89%) ensured ecological stability and habitat integration. However, low habitat diversity (SHDI: 0.74, SIDI: 0.35) and uneven distribution of marine resources (SHEI: 0.41, SIEI: 0.42) indicated improved marine resource management. Enhancing habitat diversity and implementing Marine Spatial Planning (MSP) strategies could promote the sustainable use and conservation of marine ecosystems.

3.3. Spatial Autocorrelation

3.3.1. Spatial Autocorrelation for LULC (*Moran's Index)*

Moran's I was a statistical measure used to assess spatial autocorrelation. It revealed whether spatial patterns are clustered, dispersed, or random. The outcomes of this analysis assisted in determining whether specific spatial distributions were statistically significant or occurred by chance.

Figure 7 bellow illustrated the computed Moran's Index (-0.319329), and the z-score (-0.743798) indicated that the spatial pattern did not exhibit significant clustering or dispersion. The p-value (0.456998) was relatively high, signifying that the observed spatial pattern was not statistically different from a random distribution. The z-score fell within the -1.65 to 1.65 range, corresponding to the yellow-shaded area in the normal distribution curve, reinforcing the conclusion that the spatial arrangement was random (Zhang *et al*., 2021).

Since Moran's I value was negative but not significantly so, it suggested weak tendencies toward dispersion without statistical support for a meaningful spatial pattern (Wulandari *et al*., 2023). In applied spatial analysis, such results implied that external factors influencing spatial patterns were either weak or nonexistent. This had implications for spatial planning, resource distribution, and land-use policies, where randomness may indicate the absence of dominant clustering forces (Anselin, 1995).

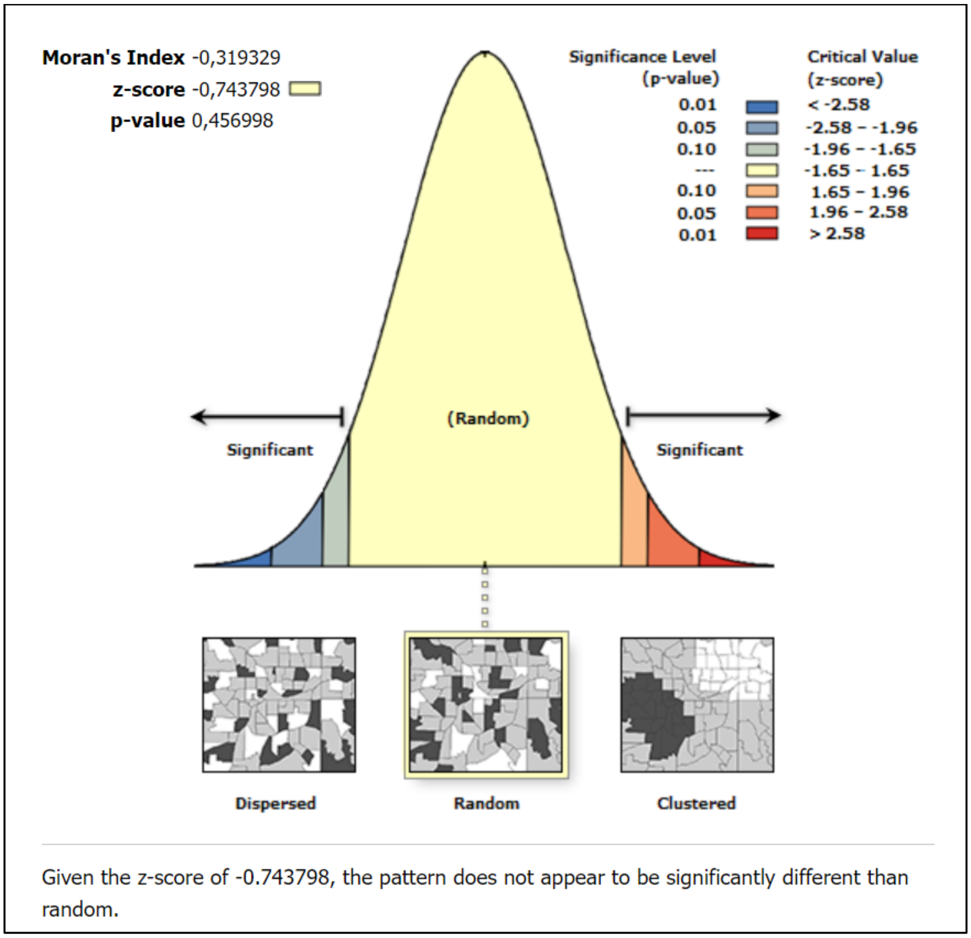

Figure 7. Spatial autocorrelation of LULC of Yavusa Navakavu coastal area

3.3.1. Spatial Autocorrelation for SUSC (*Moran's Index)*

Moreover, Figure 8 presents the spatial autocorrelation results for the SUSC seascape, highlighting the statistical significance and distribution pattern of spatial features. The results of analysis indicated that the spatial pattern of the SUSC landscape did not exhibit significant clustering or dispersion. The computed Moran's Index (- 0.180598) and z-score (0.039307) indicated that the p-value (0.968646) was considerably high, suggesting that the observed spatial distribution was not statistically different from a random pattern. The z-score fell within the range of -1.65 to 1.65, aligning with the yellow-shaded region in the normal distribution curve, reinforcing the conclusion of randomness (Mitchell, 2005). A near-zero Moran's I value suggested that spatial features were neither strongly associated nor spatially dependent. This outcome implied that external factors influencing spatial clustering or dispersion were weak or absent. In practical applications, such results indicated that the spatial processes shaping the distribution of features were either random or not strong enough to create a significant spatial structure (Getis & Ord, 1992). These findings were particularly relevant in marine spatial planning, land-use assessments, and ecosystem management, where understanding spatial patterns could inform policy decisions (Anselin, 1995).

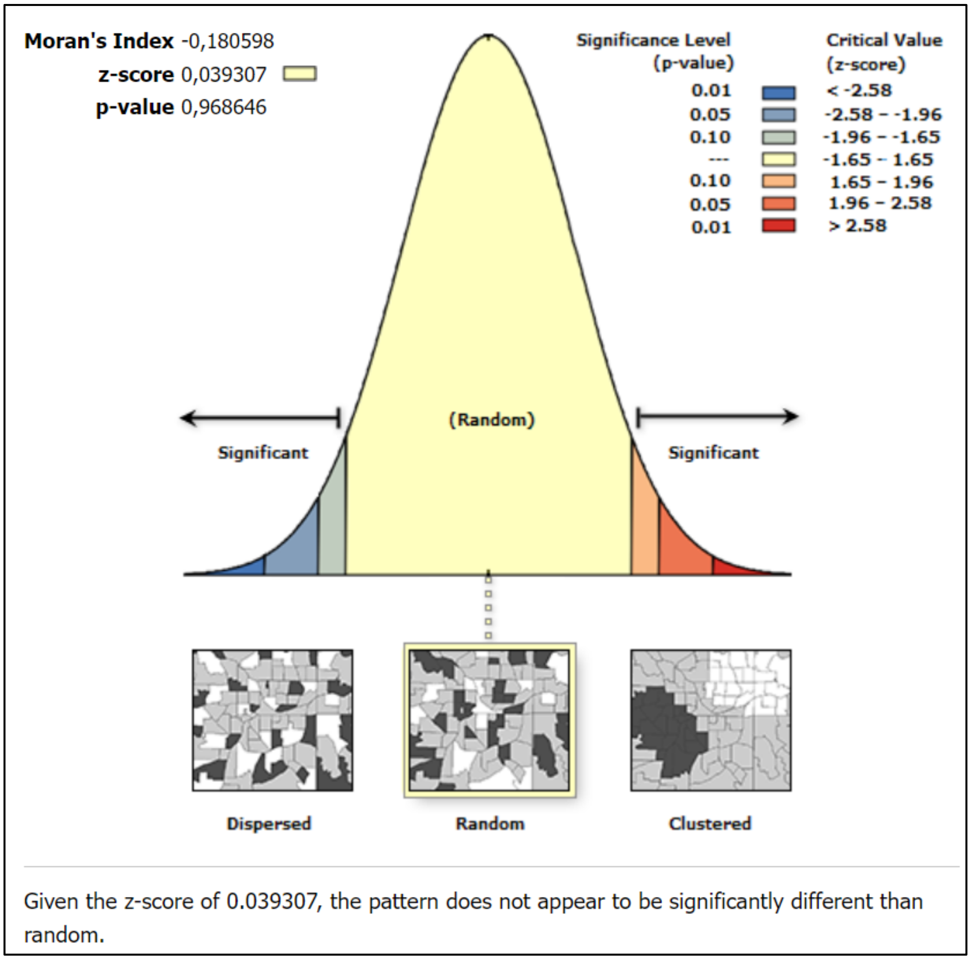

Figure 8. Spatial autocorrelation of SUSC of Yavusa Navakavu coastal area

3.4. Level Clustering Values

3.4.1. High-Low-Level Clustering for LULC

The spatial clustering analysis aimed to determine whether high or low values of the studied variable displayed significant clustering patterns across geographic space. Therefore, in Figure 9, the High-Low Clustering reports the results of the spatial clustering analysis using the General G statistic. The observed General G value of 0.089724, with a z-score of -1.7178 and a p-value of 0.085836, indicated that the spatial distribution of values does not significantly deviate from randomness. The significance level interpretation, shown in the figure, revealed that the low-clustered pattern observed has less than a 10% probability of occurring by random chance. This implied a weak tendency toward clustering low values, but the result was not statistically significant at conventional thresholds (e.g., $p < 0.05$). The visualization further reinforced this interpretation by demonstrating a predominantly random distribution with only slight clustering tendencies. This suggested that external factors influencing the distribution may not be strong enough to create distinct spatial clusters or that additional data refinement was needed to uncover more pronounced spatial patterns.

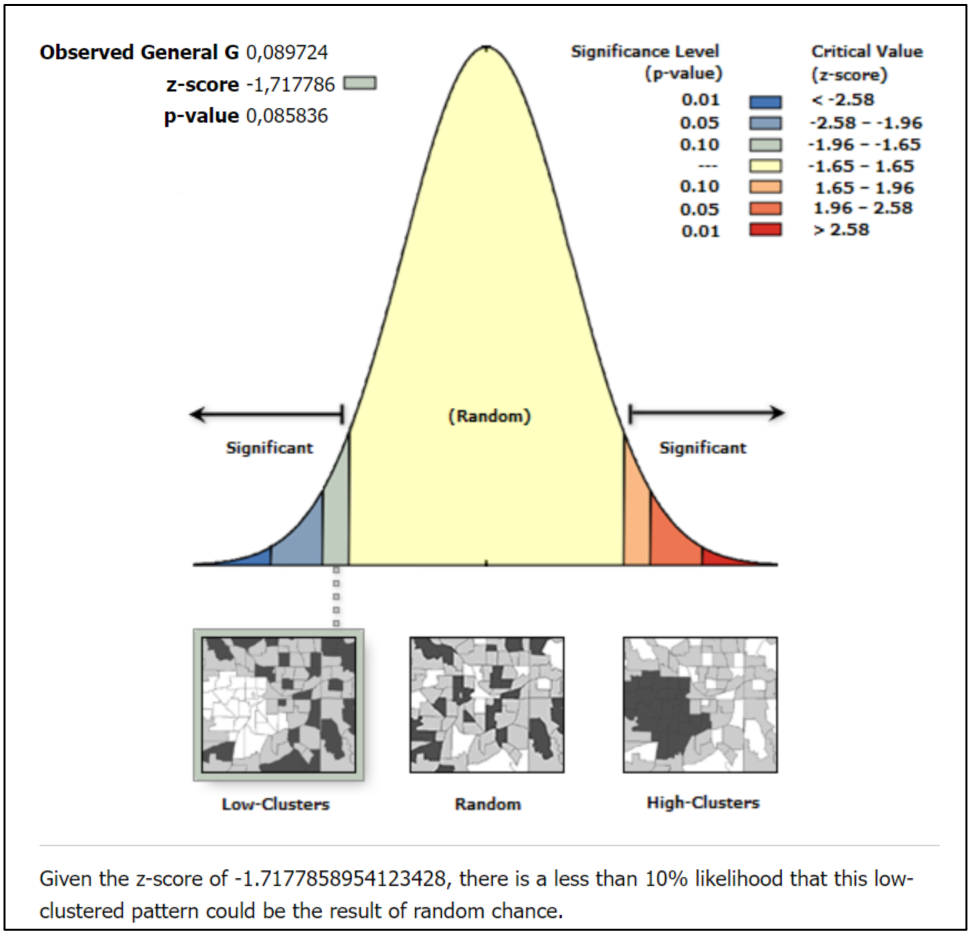

Figure 9. High-low clustering for LULC of Yavusa Navakavu coastal area

3.4.2. Level Clustering for SUSC

The spatial analysis of SUSC in Navakavu was conducted to assess whether specific marine areas exhibited significant clustering patterns of high or low values. Therefore, Figure 10 illustrated the High-Low Clustering Report for Navakavu's sea use and cover and revealed an observed General G value of 0.224329, with a z-score of 0.820121 and a p-value of 0.412147. These results indicated that the spatial distribution of sea use and cover did not significantly deviate from randomness. The z-score fell within the range of -1.65 to 1.65, suggesting no strong clustering of high or low values was present. The figure shows that the data revealed a predominantly random pattern rather than distinct clustering. This implied that the factors influencing sea use and sea cover in Navakavu might have been evenly distributed or affected by diverse, localized conditions rather than overarching spatial trends. The absence of significant clustering suggested that marine resource management efforts may need to consider other spatial or environmental variables to discern meaningful patterns in sea use and cover distribution.

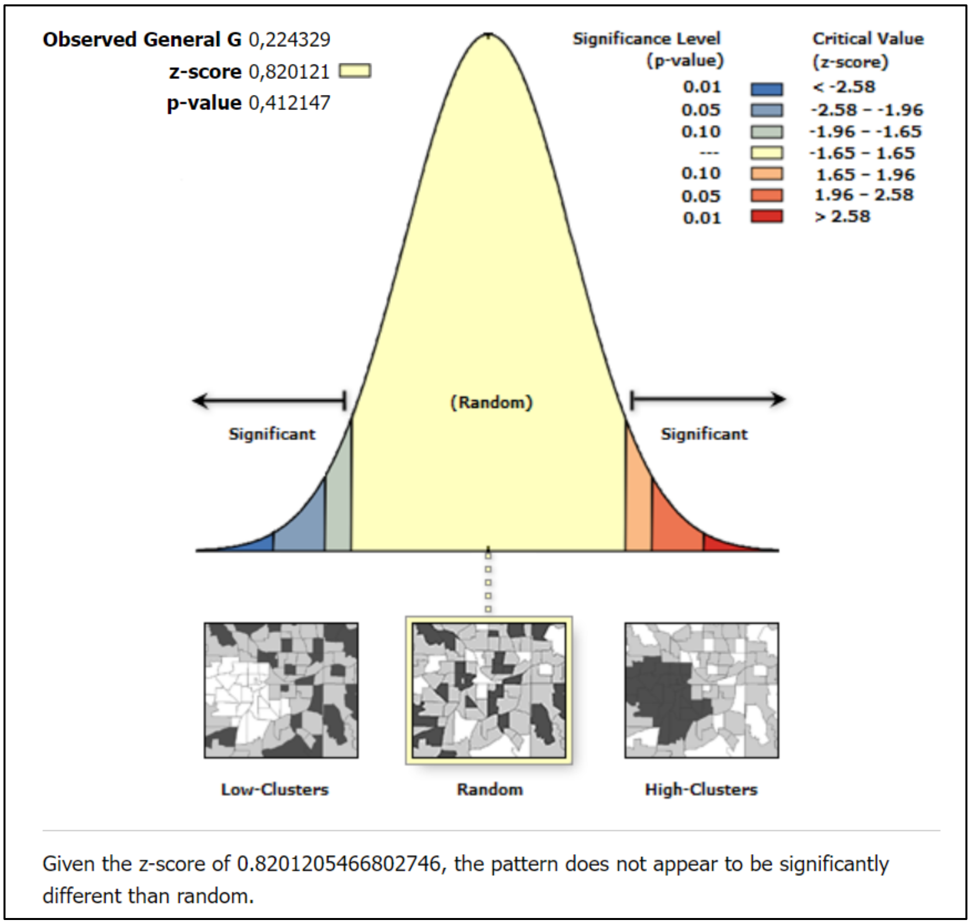

Figure 10. High-low clustering for SUSC of Yavusa Navakavu coastal area

4. Discussion

This research analyzed the spatial patterns and characteristics of land use and sea use in Navakavu by applying GIS analysis, spatial statistics, and participatory mapping techniques. The results indicated that agricultural land and forest cover dominate the land cover, occupying 53.85% of the total landscape, while marine cover was mainly used for fishery activities. In contrast, marine cover was used primarily for fishery activities, accounting for 79.91% of the sea landscape. The findings were consistent with other studies, which emphasize the reliance of coastal communities on natural resources for food and livelihood security (Thaman, 2008; Johannes, 2002). The spatial analysis detected a high landscape cohesion (99.07%), indicating strong integrity in terrestrial and marine ecosystems. Moderate fragmentation in urban lands (ED: 72.44 m^2/ha) was noted, indicating high pressures from urban development. Similar trends have also been expansion, observed in Pacific Island settlements where coastal areas were limited by the availability of inland space (Nunn *et al*., 2017). The comparatively high connectivity index (CONNECT: 11.01 on land, 27.27 at sea) suggests that while some ecological corridors are maintained, some sites may be subject to isolation, with consequences for biodiversity and ecosystem resilience (McGarigal *et al*., 2012).

The research hypothesis, in this case, demonstrated that the current land and sea use patterns in Yavusa Navakavu were strongly influenced by cultural practices and traditional knowledge, which, over time, have facilitated the sustainable management of resources. The evidence overwhelmingly supports this hypothesis, as the occurrence of the Tabu (LMMA) area, managed by the local communities, reflects their active involvement in the conservation of their resources (Lal *et al*., 2017). The combination of modern spatial planning and Indigenous practices presented a distinctive strategy toward sustainability, hence the relevance of Indigenous ecological knowledge (Veitayaki, 2000). Nevertheless, the research identified emerging weaknesses, particularly in developed areas, where urbanization forces lead to fragmentation. The observation concurs with existing literature that portrayed the tension between urban growth and traditional land-use strategies on Pacific coastlines (Storey & Hunter, 2010).

However, a significant limitation of the present study is the use of spatial analysis and community-based mapping approaches, which, although valuable, may be limited in their ability to represent ecological processes across temporal scales. The validity of remote sensing data may affect the accuracy of classifications and trends. Studies could incorporate long-term temporal data to better understand changes over time. Furthermore, although community contributions were insightful, there is a need to recognize the potential for acknowledging potential biases in land-use reporting. Future research must incorporate high-resolution temporal data sets and ecological monitoring techniques to confirm spatial patterns and examine changes in biodiversity at temporal scales. Furthermore, this study's research gap refers to the limited availability of longitudinal data regarding land and sea use changes in Navakavu. While previous studies have examined similar trends in Pacific coastal settlements, a multi-temporal framework is necessary to understand the impact of socioeconomic and environmental change on resource use over time (Cinner *et al*., 2012). Additionally. In contrast, this study integrates spatial analysis with local knowledge, future studies should incorporate ecological monitoring to assess biodiversity and habitat quality about trends in land and marine use.

Moreover, one gap is in evaluating the effects of climate change on customary resource management. Available literature suggests that sea level rise, coastal erosion, and changes in fish populations may compromise the viability of customary practices; however, empirical studies from Navakavu are still lacking (Nunn *et al*., 2017). Future research needs to examine climate adaptation strategies within community-based conservation initiatives. A more in-depth examination of the socio-economic drivers of land and marine use is also required. This study highlighted the importance of indigenous knowledge; however, external factors, such as urbanization, tourism, and commercial fishing, are expected to increasingly affect resource distribution. The integration of economic assessments with spatial analysis could provide a more comprehensive understanding of the sustainability of resources in Navakavu.

The participatory process employed in this study involved local communities in mapping land and sea use patterns, conducting semi-structured interviews, and validating spatial data through community feedback. This approach has several advantages, including the integration of traditional knowledge, enhanced accuracy of information, community ownership and empowerment, and improved decision-making capacity. Through the participation of local communities, the research incorporated conventional ecological knowledge (TEK) in spatial planning. This aspect is of considerable importance in Navakavu, where traditional practices, such as tabu (LMMA) areas, played a significant role in resource management. Community mapping provided detailed, ground-level data that complemented remote sensing and GIS data, ensuring that the spatial maps accurately reflected local realities. The exercise also instilled a sense of ownership in the people, making them more proactive in resource management and conservation efforts. By engaging stakeholders, realistic suggestions were generated that have a better chance of being accepted and adopted by the community.

However, the participatory method also has its share of disadvantages. Engaging communities in participatory mapping and workshops is time-consuming and requires a significant number of resources, which can be particularly challenging in resource-poor settings. Community inputs can be motivated by social interaction, power imbalances, or individual motivations, which can introduce biases into data collection and reporting processes. Moreover, findings from participatory research are likely to be context-specific and cannot necessarily be extrapolated to other areas or populations. Integrating qualitative community data with quantitative spatial analysis is challenging, especially where local knowledge conflicts with empirical scientific data. To address these limitations and enhance future studies, we present a Spatial Participatory Framework to support sustainable land and marine resource use planning. The framework integrates indigenous knowledge with modern spatial approaches, emphasizing the enhancement of community participation throughout the planning process. The method begins with community outreach and stakeholder identification, during which major stakeholders, including local individuals, traditional leaders, government officials, non-governmental organizations, and researchers, are identified. Preliminary meetings and workshops are then conducted. The second phase involves participatory data gathering, which utilizes sketch maps, GPS, semi-structured interviews, and field surveys to collect both qualitative and quantitative data on land and marine use patterns, customary practices, and environmental changes. The collected information is subsequently integrated with GIS and remote sensing data in the spatial analysis and integration phase, where spatial maps are generated and landscape metrics are extracted to quantify landscape structure and fragmentation. The data validation and community verification phase ensured that spatial maps accurately reflected local knowledge and practices by presenting preliminary findings to the community for comment and modifying the maps based on their feedback. In scenario planning and decision-making, various land and marine habitat use scenarios are developed collaboratively with the community, taking into account both conservation goals and socio-economic needs. Policy recommendations and actionable plans for implementing conservation measures, such as strengthening tabu (LMMA) or establishing new tabu areas, have also been developed.

Lastly, the monitoring and adaptive management phase establishes a mechanism based on the community for monitoring changes in land and sea use patterns over time, with adaptive management measures modified according to monitoring outcomes and evolving environmental conditions.

The proposed framework offers numerous advantages, including empowering local communities, enhancing data accuracy, promoting sustainability, and improving resource management skills. By incorporating community perceptions and recognizing their expertise, the model creates ownership and responsibility among stakeholders. The combination of local knowledge with empirical information enhances the validity of a geographical representation, and the prioritization of environmental protection and socio-economic development balances resource management sustainability. The model also enhances local resource management capabilities, promoting community-driven conservation initiatives. Conclusively, the results of this research highlight the significance of incorporating local knowledge and contemporary spatial planning tools in strengthening sustainable management strategies for Navakavu resources. The proposed Spatial Participatory Framework provides a scientific foundation for future research endeavors and policy recommendations that prioritize community engagement, information integration, and adaptive management strategies. By acknowledging the limitations of this research and incorporating high-resolution temporal data, ecological monitoring, and climate resilience measures, subsequent research can improve the sustainability and resilience of Navakavu and other coastal communities. By doing so, this approach confirms the value of local knowledge and provides a template for reconciling conservation actions with developmental processes amid growing environmental and socio-economic pressures.

5. Conclusions

Agriculture, forestry, and fishing were the prevailing land uses, with ecological connectivity maintained through traditional conservation practices such as the Ba ni Kalou and Tabu system (LMMA). However, increased urban drift to Suva city and climate change pose significant threats to resource sustainability. Moreover, this research contributes to spatial planning by utilizing GIS analysis and highlighting the importance of community-based conservation and the preservation of traditional knowledge. While the study provides valuable information, data resolution, temporal constraints, and errors in remote sensing classification must be considered. Future research should focus on long-term ecological monitoring, socio-economic drivers, and climate resilience actions to enhance adaptive coastal management. Strengthening participatory governance and integrating Marine Spatial Planning (MSP) to balance conservation and sustainable development in Navakavu and other coastal communities around Fiji and the Pacific.

6. Acknowledgments

First and foremost, we express our deepest gratitude to the Lord for providing His strength, wisdom, and guidance throughout this research. We sincerely thank the Archipelagic and Island States (AIS) Forum, the United Nations Development Program, and the Government of Indonesia for awarding us the Innovator Scholarship in collaboration with the IPB University International Master Program in Small Island Studies (Study Program of Coastal and Marine Resources Management), Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences. We extend our heartfelt appreciation to Mr. and Mrs. Naisilisili for their invaluable support and active participation during fieldwork and to the people of Yavusa Navakavu. Additionally, we are grateful to our colleagues, families, and friends for their unwavering encouragement and support throughout this study. Your collective efforts have played a crucial role in the success of this research.

References

Aggarwal, R., Gupta, A., & Tiwari, M., 2023. Participatory governance in socio-ecological systems: Integrating local perspectives for adaptive planning. Environmental Management Journal, 58(2), 223–237.

Anselin, L., 1995. Local Indicators of Spatial Association – LISA. *Geographical Analysis, 27 (2), 93 – 115.*

Al Amin, M.A., Adrianto, L., Kusumastanto, T., Imran, Z., & Kurniawan, F., 2020. Participatory mapping: Assessing problems and defined marine conservation planning and zoning in Joy Bay, Indonesia. *IOP Conference Series: Earth and Environmental Science, 414 (1), 012001.*

Aswani, S., Christie, P., Muthiga, N., Mahon, R., Primavera, J., Cramer, L.A., & Barbier, E., 2017. The way forward with ecosystem-based management in tropical contexts: Reconciling with existing management systems. Marine Policy, 74, 145-154.

Avtar, R., Sawada, H., & Kumar, P., 2013. Role of remote sensing and community forestry to manage forests for the effective implementation of REDD+ mechanism: a case study on Cambodia. *Environment, Development and Sustainability, 15 (6), 1593-1603.*

Cameron, C., Maharaj, A., Kennedy, B., Tuiwawa, S., Goldwater, N., Soapi, K., & Lovelock, C. E., 2021. Landcover Change in Mangroves of Fiji: Implications for Climate Change Mitigtaion and Adaptation in the Pacific. *Environmental Challenges, 2, 100018.*

Cinner, J.E., McClanahan, T.R., Graham, N.A., Pratchett, M.S., Wilson, S.K., & Raina, J.B., 2012. Gear-based fisheries management as a potential adaptive response to climate change and coral mortality. *Journal of Applied Ecology*, 49(1), 163-173.

Cohen, P.J., Evans, L.S., & Mills, M., 2012. Social networks supporting the governance of coastal ecosystems in the Solomon Islands. *Conservation Letters*, 5(5), 376-386.

Couch, C. S., Huntington, B., Charendoff, J. A., Amir, C., Asbury, M., Basden, I., Lamirand, M., Torres-Pulliza, D., Brown, V., & Shantz, A. A. (2024). Coral reef community recovery trajectories vary by depth following a moderate heat stress event at Swains Island, American Samoa. *Marine Biology*, 171(11), Article 218.

Douvere, F. 2008. The importance of marine spatial planning in advancing ecosystem-based sea use management. *Marine Policy, 32*(5), 762-771.

Dral, D., Mahon, R., & Clements, R., 2023. Decentralized decision-making in coastal governance: Innovations and constraints. Coastal Management, 51(1), 45–61.

Duarte, C. M., Losada, I. J., Hendriks, I. E., Mazarrasa, I., & Marbà, N., 2013. The role of coastal plant communities for climate change mitigation and adaptation. Nature Climate Change, 3, 961-968.

Edwards, H.J., Elliott, I.A., Pressey, R.L., & Mumby, P.J., 2010. Incorporating climate change and connectivity into marine protected area design. *Marine Ecology Progress Series*, 414, 147-161.

Febrianti, R. A., & Handayani, E. T., 2024. Participatory mapping for sustainable mangrove conersvation in Tinjul Village, Indonesia. *Jurnal Geografi, 12 (2), 113-125.*

Fletcher, C.H., Romine, B.M., Genz, A.S., Barbee, M.M., Dyer, M., Anderson, T.R., ... & Rooney, J.J., 2011. National assessment of shoreline change: Historical shoreline change in the Hawaiian Islands. *U.S. Geological Survey Open-File Report* 2011–1051.

Getis, A., & Ord, J.K., 1992. The analysis of spatial association is done using distance statistics. *Geographical Analysis*, 24(3), 189-206.

Gajardo, L. J., Sumeldan, J. D. C., Sajorne, R., & Requieron, J. R., 2023. Culytral values of ecosystem services from coastal marine areas: Case of Taytay Bay, Palawan, Philipines. Ocean & Coastal Management, 235, 106482.

Getis, A. 2017. *Spatial autocorrelation and spatial filtering techniques in geography*. Geographical Analysis, 49(3), 185-204.

Gustafson, E. J. 2018. *Quantifying landscape spatial pattern: What is the state of the art?* Ecosystems, 21(4), 731-742.

Jager, N. W., Newig, J., Challies, E., & Kochskämper, E., 2019. Pathways to implementation: Evidence on how participatory governance enhances policy delivery. Policy Studies Journal, 47(3), 605–636.

Johannes, R.E., 2002. The renaissance of community-based marine resource management in Oceania. *Annual Review of Ecology and Systematics*, 33(1), 317-340.

Jupiter, S.D., Cohen, P.J., Weeks, R., Tawake, A., & Govan, H., 2014. Locally-managed marine areas: Multiple objectives and diverse strategies. *Pacific Conservation Biology*, 20(2), 165-179.

Jupiter, S., Wenger, A., Klein, C., Albert, S., & Mangubhai, S., 2017. Opportunities and constraints for implementing integrated land-serina management on islands. *Environmental Conservation*, 44(3), 254-266.

Korpinen, S., Meißner, K., Laamanen, M., & Stelzenmüller, V., 2021. Cumulative impacts on marine ecosystems: Scientific concepts and practical approaches. ICES Journal of Marine Science, 78(4), 1234–1245.

Lal, P. N., Holland, P., & Ralogaivau, S., 2017. Integrating conservation with development: Community engagement in Fiji's LMMA. Pacific Studies, 40(2), 33–50.

Madin, J. S., Madin, E. M. P., & Booth, D. J., 2022. Coral reefs support coastal fishery sustainability by buffering wave energy and enhancing habitat complexity. Global Change Biology, 28(1), 141–153.

McGarigal, K., Cushman, S.A., & Ene, E., 2012. *FRAGSTATS v4: Spatial pattern analysis program for categorical maps.* University of Massachusetts, Amherst.

Mitchell, A., 2005. The ESRI guide to GIS analysis, Volume 2: Spatial measurements and statistics. *Redlands, CA: ESRI Press.*

Muehlig-Hofmann, A., Veitayaki, J., Polunin, N. V. C., Stead, S., & Graham, N. A. J., 2017. Community-based marine resource management in Fiji – from yesterday to tomorrow. *Marine Policy*, 82, 104–114

Nunn, P. D., & Kumar, R., 2006. Human responses to coastal change in the Pacific Islands: Implications for climate change adaptation. In Global Environmental Change (Vol.16, Issue 2, pp. 121-131)

Nunn, P. D., Runman, J., Falanruw, M., & Kumar, R., 2017. Culturally grounded responses to coastal change on islands in the Federated States of Micronesia, northwest Pacific Ocean. *Regional Environmental Change, 17(4), 959-971.*

Pasquali, M., & Marucci, A., 2021. Coastal urban expansion and its effects on Pacific Island ecosystems. *Urban Planning International*, 36(5), 55–65.

Pelawi, R.B., Panuju, D. R., & Rusdiana, O., 2024. Land cover change and carbon potential in mangrove ecosystems at the social forestry area (Study case: Indramayu Rengency, Indonesia). *Jurnal Pengelolaan Sumberdaya Alam dan Linkungan (Journal of Natural Resources and Environmental Management).*

Prasetyo, L. B., & Arifin, H. S., 2019. Landscape ecological approach for sustainable coastal management. *Jurnal Ilmu dan Teknologi Kelautan Tropis*, 11(2), 427–440.

Reed, M. S., Vella, S., Challies, E., De Vente, J., Frewer, L., Hohenwallner-Ries, D.,& van Delden, H., 2018. A theory of participation: What makes stakeholder and public engagement in environmental management work? *Restoration Ecology, 26*(S1), S7-S17.

Quashigah, B., Chand, R., & Nand, Y., 2025. The ecosystem services of Pacific mangroves: Climate adaptation and coastal resilience. *Environmental Conservation and Development*, 15(1), 23–37.

Sala, E., Mayorga, J., Bradley, D., & Worm, B., 2018. The economics of marine protected areas. *Science Advances*, 4(5), eaat2732.

Schugurensky, D., Zapata, M., & Torres, E., 2024. Participatory land use planning: Lessons from Latin America. *Planning Theory & Practice*, 25(1), 12–30.

Shayka, B. F., Hesselbarth, M. H. K., Schill, S. R., Currie, W. S., & Allgeier, J. E., 2023. The natural capital of seagrass beds in the Caribbean: Evaluating their ecosystem services and blue carbon trade potential. *Biology Letters, 19*(6), 20230075.

Smith, J. A., & Ramirez, M., 2022. Integrating cultural heritage and hydrological function in landscape management: A case study approach. *Landscape and Urban Planning*, 217, 104271.

Storey, D., & Hunter, S., 2010. Kiribati: An environmental perfect storm. *Australian Geograpgher*, 41(2), 167-181.

Thaman, R. R., 2008. Pacific Island agrobiodiversity and ethnobiodiversity: A foundation for sustainable Pacific Island life. *Biodiversity*, 9 (1-2), 102-110.

Unsworth, R. K. F., Collier, C. J., Henderson, G. M., & McKenzie, L. J., 2020. Tropical seagrass meadows and their role in coastal ecosystems. Estuarine, *Coastal and Shelf Science*, 243, 106919.

Veitayaki, J., 2000. Fisheries resource-use culture in Fiji and its implications. In A. Hooper (Ed.), *Culture and sustainable development in the Pacific* (pp. 116-130). Canberra: ANU E Press.

Veitayaki, J., 2002. Taking advantage of indigenous knowledge: The Fiji case. *International Social Science Journal*, 54 (173), 395-402.

Vierros, M. K., Harrison, A. L., Sloat, M. R., Ortuño Crespo, G., Moore, J. W., Dunn, D. C., Ota, Y., Cisneros-Montemayor, A. M., Shillinger, G. L., Watson, T. K., & Govan, H., 2020. Considering Indigenous Peoples and local communities in governance of the global ocean commons. *Marine Policy, 119, 104039.*

Wulandari, D., Santoso, A., & Nugroho, S., 2022. Spatial analysis of fishing grounds and their role in supporting coastal community livelihoods*. Jurnal Ilmu dan Teknologi Kelautan Tropis, 14(1), 55–67.*

Wulandari, D., Santoso, A., & Nugroho, S., 2023. Assessing spatial randomness in coastal land-use patterns: Implications for sustainable management. *Jurnal Ilmu dan Teknologi Kelautan Tropis*, 15(1), 89–102.

Zhang, Y., Li, X., & Wang, J., 2021. Spatial autocorrelation analysis of land use changes and its driving forces in coastal areas. *Environmental Monitoring and Assessment*, 193(4), 215.