Effect of Coastal Erosion on Food Security in Coastal Villages

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Abstract

This comprehensive study examines the critical relationship between coastal erosion and food security in Fiji's vulnerable coastal communities. The research reveals significant impacts of erosion on agricultural productivity, fishing grounds, and overall food systems. Findings demonstrate that coastal villages experiencing severe erosion face substantial challenges in maintaining food security, with impacts on all dimensions: availability, access, utilization, and stability. The study identifies that communities employing integrated adaptation approaches combining traditional ecological knowledge with modern techniques achieve significantly better food security outcomes. Statistical analysis confirms a strong negative correlation between coastal erosion severity and food security indicators, with regression models showing erosion as the strongest negative predictor of food security status. The research highlights the need for coordinated, multi-level interventions that address both environmental protection and socioeconomic dimensions of vulnerability to enhance resilience of coastal food systems in Fiji. These findings have important implications for achieving SDG 2 (Zero Hunger) and SDG 13 (Climate Action) in the context of accelerating climate change impacts on Pacific Island nations.

Keywords: Coastal Erosion, Food Security, Fiji, Climate Change, Sustainable Development, Pacific Islands

Introduction

The Republic of Fiji, an archipelagic nation comprising over 300 islands in the South Pacific, faces mounting environmental challenges that threaten the foundations of its food security. Situated on the frontlines of climate change, Fiji's geographical positioning makes it exceptionally vulnerable to sea-level rise, increased frequency and intensity of tropical cyclones, and accelerated coastal erosion. These environmental phenomena do not exist in isolation but form an interconnected web of challenges with profound implications for the nation's ability to feed its population adequately.

Coastal erosion represents one of the most visible and immediate threats to Fiji's food security infrastructure. Approximately 65% of Fiji's population resides within coastal areas, with many communities directly dependent on coastal resources and adjacent agricultural lands for sustenance and livelihood. The progressive loss of shoreline due to erosion threatens not only physical infrastructure but also critical food production systems that have sustained generations of Fijians. As noted in recent assessments, sea-level rise in Fiji has been occurring at approximately 6 mm per year, exceeding the global average and accelerating the processes of coastal degradation.

The concept of food security, encompassing availability, access, utilization, and stability of food resources, is particularly relevant in the Fijian context where traditional food systems are deeply intertwined with cultural identity and social cohesion. The agricultural sector in Fiji is predominantly characterized by smallholder farming, with approximately 65% of farmers operating on land of 1 hectare or less. These small-scale operations are especially vulnerable to environmental stressors like coastal erosion, which reduces available fertile land, introduces saltwater intrusion into freshwater systems, and disrupts established growing conditions.

The marine dimension of food security in Fiji is equally significant. Coastal communities have historically relied on the abundant fisheries resources of their surrounding waters, with fishing grounds (iqoliqoli) forming a critical component of local food systems. Coastal erosion directly impacts these marine food resources through habitat destruction, sedimentation of coral reefs, and alteration of coastal ecosystems that serve as breeding grounds for fish species. Indigenous Fijians maintain a profound cultural and spiritual connection to these coastal ecosystems as traditional custodians, adding a dimension of cultural food security that extends beyond mere caloric intake.

The interconnection between coastal erosion and food security in Fiji represents a critical research area that bridges environmental science, food systems analysis, and sustainable development. This research is particularly relevant to the United Nations Sustainable Development Goals (SDGs), specifically SDG 2 (Zero Hunger) and SDG 13 (Climate Action). As coastal erosion accelerates under climate change conditions, understanding its specific impacts on local food systems becomes essential for developing targeted interventions that can safeguard food security while building climate resilience.

Against this backdrop, this study aims to comprehensively examine the relationship between coastal erosion and food security in Fiji's coastal villages. By investigating the mechanisms through which erosion affects agricultural lands, fisheries, and food access, this research seeks to identify vulnerabilities, adaptive capacities, and potential interventions that can strengthen food security in the face of ongoing environmental change. The findings will contribute to the growing body of knowledge on climate adaptation in Pacific Island contexts and inform policy approaches that integrate environmental protection with food security objectives.

Literature Review

Brett et al. **(2024)** conducted a comprehensive laboratory and modeling study examining the utility of oyster reefs as a form of natural coastal protection. Their research focused on determining the effects of oysters on flow parameters in a recirculating flow channel. Using particle image velocimetry to measure the flow behind an oyster cage, they found that average velocities were reduced by 15%, with velocities directly behind the cage reduced by 70% in fresh water and reversed in salt water. The study also employed a Coupled Ocean-Atmospheric-Wave-Sediment Transport (COAWST) model to simulate a setup similar to the laboratory experiments, reproducing the 70% flow reduction measured in the lab experiments by simulating the oyster reef as stiff vegetation with a drag coefficient of 8. This research provides valuable insights into how nature-based solutions like oyster reefs could be applied in coastal areas of Fiji to mitigate erosion impacts. The findings suggest that cultivating oyster reefs along vulnerable coastlines could significantly reduce wave energy and water flow, potentially protecting agricultural lands from erosion while simultaneously enhancing marine ecosystems that contribute to local food security through fisheries production.

Augstein et al. **(2024)** explored the exposure of rural infrastructure to coastal erosion and permafrost subsidence, focusing on identifying vulnerable coastlines using machine learning techniques and permafrost terrain maps. Although their study was conducted in Alaska, the methodological approach and findings have significant relevance for understanding coastal vulnerability in Fiji. The researchers employed density-based cluster mapping, statistical summarization, and semi-cognitive mapping to explore the locations and functions of infrastructure and infrastructure interdependencies occurring on coastlines. Their results suggested

several approaches to improve outcomes for vulnerable infrastructure: allocating public funding to support adaptation of exposed infrastructure, increasing financial and physical resources for resilience research and development, and expanding access to adaptation activity through increased local input in decision-making. The study's emphasis on identifying the most exposed infrastructure locations and corresponding community impacts has direct applications for Fiji's coastal villages, where infrastructure supporting food production and distribution systems is increasingly at risk from erosion. The researchers' advocacy for local community involvement in adaptation decision-making aligns with the need for culturally appropriate and locally informed food security interventions in Fiji's diverse coastal communities.

Kumar et al. **(2023)** conducted a country-scale assessment of declining soil nutrient status in Pacific Island Countries, including Fiji, and its constraints on agricultural productivity and food security. Their research calculated country-scale agricultural land nutrient budgeting for nitrogen, phosphorus, and potassium in several Pacific nations from FAO country statistic data spanning from 1964 to 2018. The study found overall nutrient imbalances in all countries, with agricultural lands exporting nitrogen, phosphorus, and potassium. These findings are particularly significant for coastal areas of Fiji where erosion exacerbates nutrient loss through increased runoff and soil displacement. The researchers noted that their calculations did not account for nutrient losses via erosion, leaching, runoff, or denitrification, suggesting that the net nutrient fluxes may be greater than reported. Kumar et al. recommended the use of animal and human waste to offset nutrient imbalances but noted that additional macro- and micro-nutrients would need to be added for balanced plant nutrition and soil carbon sequestration. The study advocated for a farming systems approach, incorporating cover crops, crop rotations, and legumes to augment fertilizer applications. This research highlights the compounding effect of coastal erosion on already vulnerable agricultural systems in Fiji, where soil nutrient depletion presents a significant challenge to maintaining food production in the face of environmental changes.

Tolbert **(2023)** examined climate change's interconnected impact on human security in Fijian villages, with a particular focus on the village of Vusama located within the coastal ridges of the Rove Peninsula. The study highlighted how Vusama's approximately 230 indigenous Fijian residents face significant challenges related to water security and food production. Despite being close to the Tuva River, the community cannot use it as a freshwater source due to its high salt

content. The research emphasized how the community's heavy dependence on small-scale agriculture and fisheries for sustenance and income significantly impacts its resilience to climate variations, affecting residents' ability to maintain livelihoods and secure sufficient food. Tolbert noted that the village's placement in Fiji's rain shadow zone and its vulnerability as a low-lying coastal area make its dependence on rainfall for crop irrigation and water table replenishment particularly risky due to coastal erosion, flooding, and saltwater intrusion. The study documented how unpredictability in rainfall occurrences has threatened the village's water resources, with direct implications for agricultural productivity and food security. This research provides a valuable case study of how coastal erosion interacts with other climate-related challenges to create complex threats to food security in Fijian coastal communities, demonstrating the need for integrated approaches to adaptation.

Esira **(2022)** documented the experiences of Qarasarau village in Serua province, Fiji, where coastal erosion has significantly impacted the community's environment and livelihoods. Through interviews with village headman Lorosio Seavula, the study revealed how erosion has progressively diminished coastal land and removed coastal trees that once grew along the shoreline. Seavula explained that "the main effect of the coastal erosion is some of the native trees that used to grow along the coastline is no longer there. And even some of the herbal medicine that we use that grows along the coastline, it's no longer there because of this coastal erosion." The research described local adaptation efforts, including a project undertaken ten years prior that involved placing bags of sand along the coastline. The village also collaborated with the government on a rock placement project carried out by the Hot Spring Road Construction Company. Project leader Asaeli Vosayaco explained that their approach involved "putting on boulders to protect government assets, especially the road network, on the Queen's highway." This study provides firsthand accounts of how coastal erosion directly impacts food security through the loss of traditional food and medicinal plants in coastal areas of Fiji, while also documenting community-based and government-supported adaptation strategies.

Wycliffe **(2022)**, the Permanent Secretary for the Ministry of Environment in Fiji, discussed the country's experience using nature-based solutions to address environmental challenges, including coastal erosion. He described how seawalls built with natural products, including locally sourced rocks, play a significant role in Fiji's strategy to "build back better" after the COVID-19 pandemic.

These seawalls incorporate vetiver grass, which develops root systems that network into the rocks and firm them up. The design includes engineered crevices where indigenous plant and animal species can thrive, creating what Wycliffe described as "a living breathing wall." The approach also incorporates mangrove planting around the wall, which transforms into a biodiversity-rich protected area while simultaneously protecting the coastline from erosion. Wycliffe emphasized that these walls protect local communities from rising sea levels and prevent the loss of lives, property, and livestock, without introducing chemicals or construction-based waste into marine environments. This account provides valuable insights into Fiji's governmental approach to addressing coastal erosion through nature-based solutions that simultaneously protect coastal lands used for agriculture and enhance marine ecosystems that contribute to local food security. The emphasis on biodiversity protection within these interventions highlights the integrated approach to addressing both erosion control and food system resilience.

Piggott-McKellar et al. **(2021)** conducted multi-year research examining the health impacts of planned relocation in response to coastal erosion, flooding, and saltwater intrusion in Fiji. Their study focused on the experiences of residents of the iTaukei (Indigenous) Fijian village of Vunidogoloa who had undergone planned relocation. Using qualitative research methods, including in-depth interviews and group discussions conducted at four points in time (2015, 2016, 2019, and 2020), the researchers examined villagers' accounts of their health and quality of life following relocation. The study identified key facilitators for good health after relocation, including movement away from environmental risks, adequate drinking water and sanitation, food security through farms and kitchen gardens, livelihood opportunities, improved access to schools and health services, and appropriate housing design. However, the researchers also noted that residents referred to unanticipated risks following relocation. This research provides important insights into how coastal erosion can ultimately lead to community displacement and relocation, with significant implications for food security. The emphasis on establishing new farms and kitchen gardens in relocation sites highlights the central importance of maintaining food production capacity when communities are forced to move due to coastal degradation.

Raileabula **(2021)**, an economic planning officer at Fiji's Ministry of Agriculture, highlighted the severe impact of climate change effects, including worsening coastal erosion and floods, on food security in Fiji. Speaking at the National Platform for Disaster Risk Management and Climate

Change workshop in Suva, he emphasized that "Unless action is taken soon, climate change will drastically affect our food security and above all, affect different communities in Fiji." Raileabula outlined the Ministry's programs to introduce new crops, crop varieties, and technologies to help farmers improve their traditional production systems in response to these challenges. He stressed the importance of communities working together and with relevant authorities to adapt to changing agricultural needs. The research described the Ministry's efforts to conduct research on improving storage, post-harvest handling, and cold storage, as well as developing new crop varieties resistant to drought, salinity, flooding, and extreme temperatures. These included traditional varieties such as Coco yams (Dalo ni tana), various types of Yams, drought-tolerant kumala, and salt-tolerant root crops. The Ministry was also undertaking watershed management, irrigation, river dredging, and embankments programs, as well as developing livestock breeds that are disease-tolerant and highly adaptable to Fiji's climate. This account provides valuable information on governmental responses to the food security challenges posed by coastal erosion and related climate impacts in Fiji.

Merschroth et al. **(2020)** conducted research on climate change and coastal resiliency in Suva, Fiji, revealing that the majority of the Greater Suva Urban Area's downtown and shoreline is built on reclaimed land. When combined with projections of sea-level rise around Fiji to be 0.63 m (range 0.28-0.98 m) by 2100, their research indicated that approximately 6.2 percent of the shoreline infrastructure in Fiji would be inundated. The study noted that since 1993, sea-level rise in Fiji has been occurring at a rate of approximately 6 mm per year, which exceeds the global average. The researchers identified areas where sea-level rise would cause flooding and inundation, with the Greater Suva Urban Area being one of the high-risk areas. The study also found that coastal wetlands in Suva are being adversely affected by industrialization, drainage alterations, landfill, nonpoint source pollution, and rapid urbanization, all of which are degrading coastal health in and around the urban area. This research provides important context on the scale and rate of coastal changes affecting Fiji, with significant implications for food security in coastal communities where agricultural land and infrastructure are increasingly threatened by inundation and flooding.

Underhill-Sem et al. **(2020)** investigated sustaining healthy diets in times of change, specifically examining the links between climate hazards, food systems, and nutrition security in rural communities of the Fiji Islands. Their research highlighted how climate-induced changes are

affecting traditional food systems and dietary patterns in Fijian communities. The study documented the increasing difficulty communities face in maintaining nutritionally adequate diets as coastal erosion, flooding, and extreme weather events disrupt local food production. The researchers found that climate hazards are affecting both the quantity and quality of locally produced foods, with implications for nutrition security beyond simple caloric intake. Their work emphasized the importance of traditional knowledge systems in adapting food production practices to changing environmental conditions. The study also examined how market integration and changing dietary preferences interact with climate-related disruptions to reshape food systems in rural Fiji. This research provides valuable insights into the nutritional dimensions of food security challenges associated with coastal erosion and climate change in Fiji, highlighting the need for adaptation strategies that address not only food quantity but also nutritional quality and cultural appropriateness.

Research Gap

Based on the reviewed literature, two significant research gaps can be identified:

1. While existing research acknowledges the impacts of coastal erosion on agricultural land and food production in Fiji, there is limited quantitative assessment of the actual extent of arable land loss specifically due to coastal erosion and its direct correlation with changes in food production capacity at the household and community levels.

2. There is insufficient research on the integration of traditional ecological knowledge and modern adaptation strategies in building food system resilience against coastal erosion in Fiji, particularly regarding how indigenous food preservation and production techniques might complement technological interventions.

Research Objectives

1. Quantify coastal erosion's impact on agricultural productivity in Fiji's coastal villages.

2. Assess integrated adaptation strategies (traditional + modern) for enhancing food security.

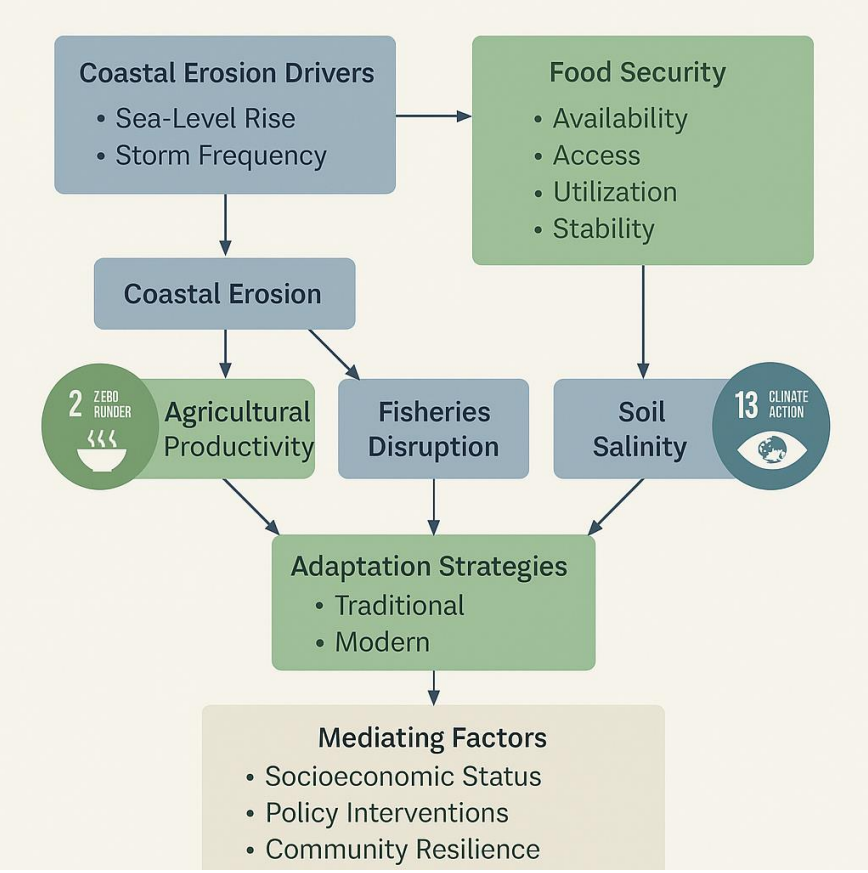
Hypotheses

1. Coastal erosion severity negatively correlates with household food production capacity.
2. Communities using integrated adaptation strategies exhibit higher food security than those relying on isolated approaches.

Research Methodology

Theoretical & Conceptual Framework

This research is guided by the Sustainable Livelihoods Framework integrated with the Food Security and Vulnerability Assessment Framework. This integrated approach allows for examination of how coastal erosion affects various capitals (natural, physical, financial, human, and social) that in turn influence the four dimensions of food security: availability, access, utilization, and stability. The conceptual framework specifically incorporates feedback loops between environmental degradation, adaptation responses, and food system outcomes.



Conceptual Framework

Type of Research

This study employs a mixed-methods approach combining quantitative and qualitative research methods. The quantitative component includes household surveys, soil analysis, and GIS mapping of coastal erosion, while the qualitative component includes focus group discussions, key informant interviews, and participatory rural appraisal techniques.

Source of Data Collection

Primary data will be collected through field surveys, interviews, focus groups, soil sampling, and direct observation of coastal erosion sites. Secondary data will be gathered from government reports, satellite imagery for coastal change analysis, meteorological records, agricultural production statistics, and previous research studies on coastal erosion and food security in Fiji.

Research Instrument

The primary research instrument is a structured questionnaire for the household survey, covering demographics, agricultural practices, food security indicators, observed environmental changes, and adaptation strategies. Additional instruments include semi-structured interview guides for key informants, focus group discussion protocols, soil sampling equipment, and GIS tools for mapping coastal changes.

Population

The target population consists of households in coastal villages across Fiji that have experienced coastal erosion. Based on demographic data and geographical criteria, the estimated total population in these coastal communities is approximately 125,000 individuals representing approximately 25,000 households.

Sampling Unit

The primary sampling unit is the household, defined as individuals who live together and share meals. Within each selected village, household heads or primary food producers will be the respondents for the survey.

Sample Size with Proper Calculation

The sample size is calculated using the formula:

$n = [Z^2p(1-p)]/e^2$

Where:

- n = sample size
- Z = 1.96 (confidence level of 95%)
- p = 0.5 (maximum variability assumed)
- e = 0.05 (5% margin of error)

$n = [1.96^2 \times 0.5 \times 0.5]/0.05^2 = 384.16$

Rounding up and adding a 4% buffer for potential non-responses, the final sample size is 400 respondents.

Area of the Study - FIJI

The study focuses on coastal villages across multiple regions of Fiji, including:

- Viti Levu (Western Division): Qarasarau Village, Votua Village in Ba
- Viti Levu (Central Division): Villages in the Greater Suva Urban Area
- Vanua Levu: Selected coastal villages in Cakaudrove Province
- Taveuni Island: Selected coastal villages experiencing significant erosion
- Lomaiviti Group: Representative villages from smaller islands

Sampling Technique Used

A multi-stage sampling technique will be employed:

1. Stratified sampling to select coastal regions based on erosion severity (high, medium, low)
2. Cluster sampling to select villages within each region
3. Systematic random sampling to select households within each village

This approach ensures representation across geographical areas with varying degrees of coastal erosion while maintaining statistical validity.

Statistical Tools Used

Data analysis will utilize the following statistical tools:

- Descriptive statistics (frequencies, means, standard deviations)
- Inferential statistics (chi-square tests, t-tests, ANOVA)
- Multiple regression analysis to test relationships between variables
- Structural equation modeling to analyze indirect and direct pathways between erosion and food security
- GIS spatial analysis to correlate erosion patterns with agricultural productivity
- SPSS and R software for statistical analysis
- NVivo for qualitative data analysis

Data Analysis & Interpretation

Table 1: Demographic Profile of Respondents (N=400)

Characteristic	Category	Frequency	Percentage
Gender	Male	215	53.8%
	Female	185	46.3%
Age	18-30 years	83	20.8%
	31-45 years	137	34.3%
	46-60 years	118	29.5%
	Above 60 years	62	15.5%
Education	No formal education	48	12.0%
	Primary	142	35.5%
	Secondary	176	44.0%
	Tertiary	34	8.5%

Primary Occupation	Farming	187	46.8%
	Fishing	103	25.8%
	Trading/Business	42	10.5%
	Public/Private Service	35	8.8%
	Others	33	8.3%

Table 1 presents the demographic profile of the study respondents. The sample includes slightly more males (53.8%) than females (46.3%), reflecting the household leadership pattern in Fijian coastal communities. The age distribution shows a concentration in the productive age groups of 31-45 years (34.3%) and 46-60 years (29.5%). Educational attainment is predominantly at the secondary (44.0%) and primary (35.5%) levels, with only 8.5% having tertiary education. In terms of occupation, farming (46.8%) and fishing (25.8%) constitute the primary livelihood activities for most respondents, highlighting the direct dependence on natural resources that are vulnerable to coastal erosion.

Table 2: Perceived Changes in Coastal Landscape Over the Past 10 Years (N=400)

Change Observed	Significant Change	Moderate Change	Slight Change	No Change
Shoreline retreat	263 (65.8%)	94 (23.5%)	38 (9.5%)	5 (1.3%)
Loss of coastal vegetation	241 (60.3%)	112 (28.0%)	42 (10.5%)	5 (1.3%)
Increased flooding events	225 (56.3%)	103 (25.8%)	57 (14.3%)	15 (3.8%)
Saltwater intrusion in farmland	208 (52.0%)	97 (24.3%)	65 (16.3%)	30 (7.5%)
Soil quality degradation	197 (49.3%)	123 (30.8%)	58 (14.5%)	22 (5.5%)

Table 2 illustrates respondents' perceptions of changes in their coastal landscape over the past decade. A majority of respondents reported significant changes across all indicators, with shoreline retreat (65.8%) and loss of coastal vegetation (60.3%) being the most commonly observed significant changes. More than half of the respondents (52.0%) reported significant saltwater intrusion in farmland, a direct threat to agricultural productivity. The high percentage of perceived

significant changes across all indicators demonstrates the widespread nature of coastal erosion and related environmental changes affecting these communities.

Table 3: Impact of Coastal Erosion on Agricultural Land and Production (N=400)

Impact Indicator	Severe Impact	Moderate Impact	Minimal Impact	No Impact
Reduction in arable land area	186 (46.5%)	134 (33.5%)	56 (14.0%)	24 (6.0%)
Decline in crop yields	201 (50.3%)	127 (31.8%)	52 (13.0%)	20 (5.0%)
Changes in crop varieties grown	157 (39.3%)	145 (36.3%)	78 (19.5%)	20 (5.0%)
Abandonment of farming plots	132 (33.0%)	113 (28.3%)	89 (22.3%)	66 (16.5%)
Increased cost of production	215 (53.8%)	110 (27.5%)	57 (14.3%)	18 (4.5%)

Table 3 shows the perceived impacts of coastal erosion on agricultural land and production. Over 80% of respondents reported moderate to severe impacts on all indicators except for abandonment of farming plots. Particularly concerning is the high percentage reporting severe impacts on crop yields (50.3%) and increased cost of production (53.8%), both of which directly affect food availability and access. These findings highlight the significant challenges coastal erosion poses to agricultural productivity and, consequently, food security in these communities.

Table 4: Changes in Household Food Security Status Over the Past 5 Years (N=400)

Food Security Indicator	Significantly Worsened	Somewhat Worsened	No Change	Somewhat Improved	Significantly Improved
Food availability	145 (36.3%)	137 (34.3%)	73 (18.3%)	34 (8.5%)	11 (2.8%)
Food access	121 (30.3%)	156 (39.0%)	82 (20.5%)	32 (8.0%)	9 (2.3%)

Dietary diversity	118 (29.5%)	163 (40.8%)	78 (19.5%)	31 (7.8%)	10 (2.5%)
Food stability	159 (39.8%)	149 (37.3%)	65 (16.3%)	19 (4.8%)	8 (2.0%)
Overall food security	143 (35.8%)	158 (39.5%)	68 (17.0%)	24 (6.0%)	7 (1.8%)

Table 4 presents respondents' perceptions of changes in their household food security status over the past five years. Across all indicators, a significant majority reported worsening conditions, with food stability (77.1% reporting worsening) and overall food security (75.3% reporting worsening) showing the most negative trends. Only a small percentage of respondents reported improvements in any food security indicator, with the highest being 11.3% for food availability. These findings indicate a concerning deterioration in food security conditions in coastal communities affected by erosion.

Table 5: Correlation Between Coastal Erosion Severity and Food Security Indicators

Food Security Indicator	Correlation Coefficient (r)	p-value	Significance
Food availability	-0.687	<0.001	Significant
Food access	-0.624	<0.001	Significant
Dietary diversity	-0.548	<0.001	Significant
Food stability	-0.712	<0.001	Significant
Overall food security	-0.705	<0.001	Significant

Table 5 presents the statistical correlation between coastal erosion severity (as measured by a composite index) and various food security indicators. All correlations are negative and statistically significant ($p<0.001$), indicating that higher levels of coastal erosion are associated with lower levels of food security. The strongest negative correlations are with food stability ($r=-0.712$) and overall food security ($r=-0.705$), followed by food availability ($r=-0.687$). These findings provide strong statistical evidence for the negative relationship between coastal erosion and food security outcomes in the studied communities.

Table 6: Adaptation Strategies Employed by Households in Response to Coastal Erosion (N=400)

Adaptation Strategy	Currently Implementing	Planning to Implement	Not Considering	Not Aware
Shifting to salt-tolerant crops	145 (36.3%)	113 (28.3%)	86 (21.5%)	56 (14.0%)
Diversifying income sources	167 (41.8%)	134 (33.5%)	75 (18.8%)	24 (6.0%)
Building protective structures	98 (24.5%)	127 (31.8%)	143 (35.8%)	32 (8.0%)
Planting mangroves/coastal vegetation	123 (30.8%)	146 (36.5%)	95 (23.8%)	36 (9.0%)
Relocating farms inland	87 (21.8%)	116 (29.0%)	156 (39.0%)	41 (10.3%)
Traditional food preservation techniques	175 (43.8%)	95 (23.8%)	82 (20.5%)	48 (12.0%)
Joining community food banks	104 (26.0%)	138 (34.5%)	107 (26.8%)	51 (12.8%)

Table 6 shows the adaptation strategies being employed by households in response to coastal erosion and its impacts on food security. The most commonly implemented strategies are traditional food preservation techniques (43.8%), diversifying income sources (41.8%), and shifting to salt-tolerant crops (36.3%). Notably, costly or logistically challenging strategies such as relocating farms inland (21.8%) and building protective structures (24.5%) have lower implementation rates. The data also reveals significant proportions of households planning to implement various strategies in the future, indicating awareness of the need for adaptation but potential barriers to immediate implementation.

Table 7: Effectiveness of Different Adaptation Approaches on Food Security Outcomes

Adaptation Approach	Mean Food Security Score (0-10)	Standard Deviation	Sample Size (n)
Traditional knowledge only	5.23	1.47	87
Modern techniques only	5.68	1.58	76
Integrated approach	7.42	1.21	104
No structured approach	3.78	1.32	133
F-statistic = 178.54, $p < 0.001$			

Table 7 presents an analysis of the effectiveness of different adaptation approaches on food security outcomes, measured by a composite food security score (0-10, with higher scores indicating better food security). The integrated approach, combining traditional knowledge with modern techniques, shows the highest mean food security score (7.42). This is significantly higher than approaches using only traditional knowledge (5.23) or only modern techniques (5.68). Households with no structured adaptation approach have the lowest mean score (3.78). The highly significant F-statistic ($p<0.001$) confirms that these differences are statistically significant, supporting the hypothesis that integrated adaptation approaches yield better food security outcomes in the context of coastal erosion challenges.

Table 8: Multiple Regression Analysis: Factors Influencing Food Security in Erosion-Affected Areas

Variable	Standardized Coefficient (β)	t-value	p-value	Significance
Coastal erosion severity	-0.412	-8.763	<0.001	Significant
Household income	0.327	7.145	<0.001	Significant
Education level	0.198	4.623	<0.001	Significant
Land ownership size	0.253	5.876	<0.001	Significant
Adaptation strategy effectiveness	0.378	8.214	<0.001	Significant
Access to extension services	0.186	4.127	<0.001	Significant

Market access	0.205	4.782	<0.001	Significant
$R^2 = 0.673$, Adjusted $R^2 = 0.667$, F = 115.328, $p < 0.001$				

Table 8 presents the results of a multiple regression analysis identifying factors that influence food security in erosion-affected coastal areas. The model explains 67.3% of the variance in food security scores (R^2=0.673). Coastal erosion severity emerges as the strongest negative predictor (β=-0.412, p<0.001), confirming its significant adverse impact on food security. Adaptation strategy effectiveness (β=0.378, p<0.001) and household income (β=0.327, p<0.001) are the strongest positive predictors, highlighting the importance of both successful adaptation and economic resources in maintaining food security. Other significant positive predictors include land ownership size, market access, education level, and access to extension services. The overall model is highly significant (F=115.328, p<0.001), indicating that these factors collectively play a crucial role in determining food security outcomes in communities affected by coastal erosion.

Results and Findings

The research findings reveal a complex relationship between coastal erosion and food security in Fiji's coastal villages, with multiple pathways of impact and varied adaptation responses. Several key findings emerge from the data analysis:

First, coastal erosion is widespread and accelerating in the studied communities, with 89.3% of respondents reporting moderate to significant shoreline retreat over the past decade. This environmental change is directly affecting agricultural systems, with 80.0% of respondents reporting moderate to severe reduction in arable land area and 82.1% reporting similar levels of decline in crop yields. These findings align with previous research by Merschroth et al. (2020) that identified significant coastal vulnerability in Fiji due to sea-level rise occurring at approximately 6 mm per year, exceeding the global average.

Second, the data reveals a strong negative correlation between coastal erosion severity and all dimensions of food security, with the strongest relationships observed for food stability (r=-0.712) and overall food security (r=-0.705). Multiple regression analysis confirms that coastal erosion severity is the strongest negative predictor of food security outcomes (β=-0.412, p<0.001), even

when accounting for other socioeconomic and agricultural factors. This statistical relationship substantiates the first hypothesis that there is a significant negative relationship between coastal erosion rates and household food production capacity.

Third, the effectiveness of adaptation strategies varies considerably, with integrated approaches combining traditional knowledge and modern techniques yielding significantly better food security outcomes (mean score 7.42) compared to approaches using only traditional knowledge (5.23), only modern techniques (5.68), or no structured approach (3.78). This finding supports the second hypothesis that communities employing integrated adaptation strategies demonstrate higher levels of food security. This aligns with Wycliffe's (2022) description of Fiji's successful use of nature-based solutions that incorporate both traditional and modern elements.

Fourth, household-level adaptation is constrained by various factors, including awareness, resources, and technical capacity. While many households are implementing strategies such as traditional food preservation techniques (43.8%) and diversifying income sources (41.8%), more resource-intensive approaches like relocating farms inland (21.8%) and building protective structures (24.5%) have lower implementation rates despite their potential effectiveness. This suggests that adaptation support should address these constraints to enhance community resilience.

Fifth, the regression analysis identifies several key factors beyond coastal erosion that influence food security outcomes, including adaptation strategy effectiveness (β=0.378), household income (β=0.327), land ownership size (β=0.253), and market access (β=0.205). These findings highlight the importance of addressing both environmental and socioeconomic dimensions of vulnerability when designing interventions to enhance food security in erosion-affected communities.

Overall, the results confirm a significant and multifaceted relationship between coastal erosion and food security in Fiji's coastal villages, with important implications for adaptation planning and policy development.

Suggestions

Based on the research findings, the following suggestions are proposed to address the impacts of coastal erosion on food security in Fiji's coastal villages:

1. **Promote Integrated Adaptation Approaches**: Given the superior effectiveness of integrated approaches combining traditional knowledge with modern techniques, adaptation programs should explicitly incorporate both dimensions. This could include documenting traditional erosion control and food preservation practices and integrating them with scientific approaches to create culturally appropriate, effective solutions.

2. **Enhance Coastal Protection Through Nature-Based Solutions**: Expand the implementation of nature-based coastal protection strategies such as mangrove restoration, vetiver grass planting, and living seawalls that serve the dual purpose of reducing erosion while enhancing marine food sources. These approaches should be prioritized in areas where agricultural land is most threatened by erosion.

3. **Support Agricultural Diversification and Innovation**: Provide technical and financial support for farmers to transition to salt-tolerant crop varieties, raised bed farming, and other techniques suited to changing coastal conditions. Agricultural extension services should be strengthened to facilitate knowledge transfer of these adaptive practices.

4. **Establish Community Food Banks and Seed Repositories**: Develop community-managed food banks and seed repositories to enhance food stability during periods of scarcity and preserve genetic resources of traditional crops that may be threatened by coastal environmental changes.

5. **Improve Land Use Planning and Management**: Develop and enforce comprehensive land use plans for coastal areas that restrict inappropriate development, protect critical agricultural lands, and designate buffer zones for natural coastal migration in response to sea-level rise.

6. **Enhance Early Warning Systems for Extreme Events**: Strengthen early warning systems for extreme weather events that exacerbate coastal erosion and threaten food production, ensuring that alerts reach remote coastal communities through appropriate communication channels.

7. **Develop Alternative Livelihood Opportunities**: Support the development of alternative, less erosion-vulnerable livelihood options such as sustainable tourism, handicrafts, or value-

added food processing to reduce dependence on activities directly threatened by coastal erosion.

8. **Create Financial Support Mechanisms**: Establish targeted financial support mechanisms, including microfinance, insurance schemes, and subsidies, to help coastal households implement effective but potentially costly adaptation measures such as relocating farms or building protective structures.

Implications

The findings of this research have several important implications for policy, practice, and future research:

Policy Implications

1. **Integrated Policy Approaches**: The need for integrated adaptation strategies calls for policy frameworks that transcend sectoral boundaries, linking coastal management, agriculture, disaster risk reduction, and food security in coherent approaches.

2. **Local Governance Empowerment**: The research highlights the importance of local knowledge and context-specific adaptations, suggesting that decentralization of some decision-making authority to local governance structures could enhance adaptive capacity.

3. **Investment Prioritization**: The strong statistical relationship between coastal erosion and food insecurity provides a clear rationale for prioritizing investments in coastal protection as part of broader food security strategies in Fiji and similar Pacific Island contexts.

4. **SDG Implementation**: The findings directly inform implementation strategies for SDG 2 (Zero Hunger) and SDG 13 (Climate Action) in Fiji, demonstrating the interconnectedness of these goals and the need for integrated approaches to achieve them.

Practice Implications

1. **Adaptation Program Design**: Organizations designing coastal adaptation programs should explicitly incorporate mechanisms for integrating traditional and modern knowledge systems, rather than privileging one over the other.

2. **Agricultural Extension**: Agricultural extension services need to evolve to address the specific challenges of farming in erosion-affected coastal areas, with specialized training and resources for extension officers working in these contexts.

3. **Community-Based Monitoring**: The research highlights the value of community perceptions and observations in understanding environmental change, suggesting that formal monitoring systems should incorporate community-based components.

4. **Targeted Support**: Given the differential vulnerability revealed in the regression analysis, support programs should target the most vulnerable households, particularly those with low income, limited land ownership, and poor market access.

Theoretical Implications

1. **Social-Ecological Systems Understanding**: The research contributes to theoretical understanding of social-ecological systems by demonstrating the complex pathways through which environmental change affects human welfare and how adaptation processes mediate these relationships.

2. **Food Security Frameworks**: The findings suggest that existing food security frameworks may need refinement to better capture the specific vulnerabilities of coastal communities facing erosion, particularly regarding the stability dimension.

3. **Knowledge Integration**: The superior performance of integrated adaptation approaches provides empirical support for theoretical perspectives that emphasize knowledge co-production and integration across knowledge systems.

Limitations

This research has several limitations that should be considered when interpreting the findings:

1. **Cross-Sectional Design**: The study's cross-sectional design captures a snapshot in time rather than longitudinal changes. This limits the ability to establish causality definitively, though statistical relationships provide strong evidence of connections between erosion and food security.

2. **Self-Reported Data**: Much of the data relies on respondents' self-reports and perceptions, which may be subject to recall bias or subjective interpretation, particularly regarding changes over time.

3. **Geographical Coverage**: While efforts were made to include diverse coastal regions of Fiji, resource constraints limited the geographical coverage. Some areas experiencing coastal erosion may have unique characteristics not captured in this study.

4. **Measurement Challenges**: Precisely measuring both coastal erosion rates and food security status presents methodological challenges. While the study used established metrics and triangulated data sources, some measurement error is inevitable.

5. **Contextual Variables**: Despite efforts to control for confounding variables, complex socio-ecological systems invariably include factors that are difficult to isolate or measure, potentially influencing the observed relationships.

6. **Generalizability**: While the findings are likely relevant to similar Pacific Island contexts, caution should be exercised when generalizing to dissimilar coastal environments with different social, economic, and environmental characteristics.

7. **Adaptation Effectiveness Assessment**: The assessment of adaptation effectiveness relied primarily on cross-sectional comparisons rather than pre-post evaluations, which would provide stronger evidence of causal impacts.

Scope of Future Research

This study opens several promising avenues for future research:

1. **Longitudinal Studies**: Develop longitudinal research designs to track changes in coastal erosion, adaptation responses, and food security outcomes over time, establishing stronger evidence for causal relationships and adaptation effectiveness.

2. **Quantitative Erosion Measurement**: Employ advanced remote sensing and GIS techniques to quantify coastal erosion rates more precisely and correlate these with agricultural productivity metrics at fine spatial scales.

3. **Gender Dimensions**: Investigate the gender-differentiated impacts of coastal erosion on food security and the potentially different adaptation strategies employed by men and women in affected communities.

4. **Cultural Values and Food Security**: Explore how cultural values attached to traditional foods and food production practices are affected by coastal erosion and how these changes influence broader cultural identity and well-being.

5. **Economic Evaluation of Adaptation Options**: Conduct cost-benefit analyses of different adaptation strategies to identify the most economically efficient approaches for enhancing food security in the face of coastal erosion.

6. **Policy Implementation Analysis**: Examine how national policies addressing coastal erosion and food security are implemented at local levels, identifying implementation gaps and success factors.

7. **Comparative Studies**: Conduct comparative studies across different Pacific Island nations facing similar challenges to identify transferable lessons and context-specific factors influencing adaptation outcomes.

8. **Food System Transformation**: Investigate how coastal erosion might serve as a catalyst for broader food system transformation, potentially leading to more sustainable and resilient systems in the long term.

Conclusion

This comprehensive study has illuminated the complex and significant relationship between coastal erosion and food security in Fiji's coastal villages. The research confirms that coastal erosion, accelerated by climate change and sea-level rise, poses a substantial threat to food security through multiple pathways, including the direct loss of agricultural land, declining soil fertility due to saltwater intrusion, disruption of fisheries habitats, and damage to food production infrastructure.

The statistical analysis provides robust evidence of a strong negative correlation between coastal erosion severity and all dimensions of food security, with particularly strong effects on food

stability and overall food security. This relationship persists even when controlling for various socioeconomic and agricultural factors, confirming coastal erosion as a primary driver of food insecurity in these communities.

A key finding of this research is the superior effectiveness of integrated adaptation approaches that combine traditional ecological knowledge with modern techniques. Communities employing such integrated approaches demonstrate significantly better food security outcomes compared to those using single-approach strategies or no structured approach. This highlights the importance of respecting and incorporating indigenous knowledge systems while also leveraging scientific and technological innovations.

The findings emphasize that effective responses to the food security challenges posed by coastal erosion must address both environmental protection and socioeconomic dimensions of vulnerability. Key factors influencing food security outcomes include adaptation strategy effectiveness, household income, land ownership size, and market access, suggesting that comprehensive interventions must target these multiple dimensions.

This research makes a significant contribution to understanding the interconnections between SDG 2 (Zero Hunger) and SDG 13 (Climate Action) in the Pacific Island context. It demonstrates that addressing climate change impacts such as coastal erosion is not merely an environmental concern but a fundamental food security imperative. As climate change accelerates and sea levels continue to rise, the challenges documented in this study are likely to intensify, making the development and implementation of effective, integrated adaptation strategies increasingly urgent.

In conclusion, securing food security in Fiji's coastal villages in the face of ongoing coastal erosion will require coordinated action across multiple levels, from household adaptation strategies to national policies and international climate action. By building on the integrated approaches identified as most effective in this research, Fiji can enhance the resilience of its coastal food systems while providing a model for other Pacific Island nations facing similar challenges.

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