Journal of Coastal Research	14	1	37–46	Royal Palm Beach, Florida	Winter 1998

Trends of Beach Erosion and Shoreline Protection in Rural Fiji

Nobuo Mimura and Patrick D. Nunn

Center for Water Environment Studies
Ibaraki University
Hitachi, Ibaraki 316, Japan

Department of Geography
The University of the South Pacific
PO Box 1168
Suva, Fiji

ABSTRACT

MIMURA, N. and NUNN, P.D., 1998. Trends of Beach Erosion and Shoreline Protection in Rural Fiji. *Journal of Coastal Research*, 14(1), 37–46. Royal Palm Beach (Florida), ISSN 0749-0208.

A study of beach erosion and sea encroachment in the rural South Pacific was undertaken. Two islands of Fiji were chosen as study areas. On the basis of observation and interviews with elderly inhabitants of long-established coastal settlements, the coastal problems and countermeasures which they applied traditionally and recently were evaluated. Beach erosion in most of Fiji became significant only some 40 years ago. The causes of this change are considered to be a combination of human-induced development and global sea-level rise. Though people tried to respond to it mainly by building seawalls, there are many inappropriate elements in design and materials. Suggestions are made to improve coastal protection and to address the threats of predicted future accelerated sea-level rise and climate change.

ADDITIONAL INDEX WORDS: *Seawall, natural coastal protection, mangrove, coral reef, sea-level rise, climate change.*

INTRODUCTION

It has been pointed out that many islands in the South Pacific suffer from beach erosion. In addition, if sea level rises as predicted by the IPCC (HOUGHTON *et al.*, 1990; WATSON *et al.*, 1995), then many South Pacific island coastlines are going to be subjected to increased erosion, inundation and other problems as a consequence. It is unlikely that funds to protect the vast coastlines of these small-island nations adequately would be forthcoming — indeed it is unlikely to be regarded as the best possible use of such funds by island governments.

Most Pacific island communities are not fully part of the cash economy. Many depend for sustenance on crops they grow themselves, and for housing and other items on materials which are found freely within the areas which traditionally belong to them. If sea level rises as predicted and coastal problems worsen—as seems a reasonable assumption—then such communities will need to protect their shorelines in order to protect their livelihood. Present practices of coastal protection are not effective, and most such communities are unable to afford to build artificial structures of optimal design. It is therefore deemed essential to determine appropriate solutions within the constraints of funding, expertise and available materials.

The purposes of this study are (1) to analyze the present status of beach erosion, and (2) to evaluate the efficiency of both traditional and existing measures of coastal protection. A supplementary aim is to determine appropriate response options to predicted future sea-level rise and climate change.

97062 received and accepted in revision 7 May 1997.

STUDY AREA AND METHODS OF INVESTIGATION

Study area and geographic conditions

The islands Viti Levu and Taveuni in Fiji were chosen as the study area. Fiji is the largest island nation in the South Pacific and characterized by some of the highest coastal population densities. It is home to about 800,000 people, most of whom live on the largest two islands, Viti Levu and Vanua Levu. Most of these people—about 85%—live in coastal areas, particularly the flood plains and deltas of the major rivers and in the big coastal cities such as Suva and Lautoka (Figure 1; NUNN *et al.*, 1994).

Fiji lies astride the complex boundary between two major lithospheric plates—the Pacific Plate and the Indo-Australian Plate. There are also small plates in the Fiji region. The interaction of all these is complex and not clearly understood (HAMBURGER and EVERINGHAM, 1986; NUNN, 1991).

Most south and north coast areas of Viti Levu have experienced 1–2 m of emergence during the past few thousand years and many sites here are not experiencing the degree of erosion which affects sites elsewhere in the Fiji archipelago. On the other hand, the west coast of Viti Levu has not experienced the same degree of net emergence which has affected the above-mentioned coasts, and the east coast is believed to be stable.

Many parts of Viti Levu have also experienced late Holocene downwarping owing to sediment accumulation, since there are large rivers. Subsidence has characterized the river deltas of the Ba and Tavua (Nasivi) on the north coast, and the Rewa in the southeast. Since the Rewa Delta is low-lying and densely-populated, the need for artificial shoreline protection has long been recognized.

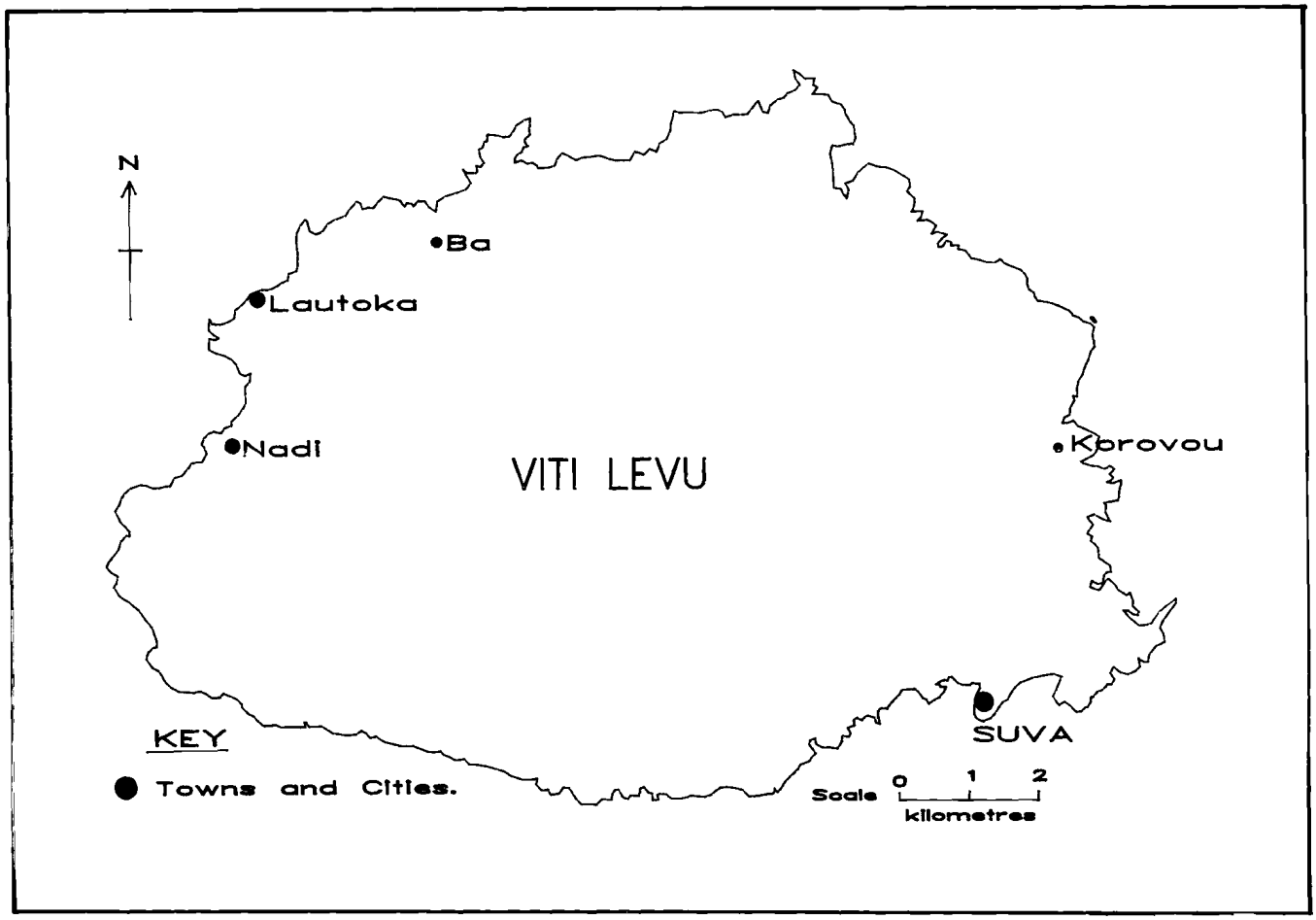

Figure 1. Island of Viti Levu, Fiji.

Regarding changes in mean sea level in the Pacific, the data from the Honolulu tide gauge on the stable (over the past 100 years or so) Hawaiian island of Oahu indicate that the mean sea level has been rising at about 1.5mm/yr. Though there are no comparable long-term tide-gauge records in Fiji, sea level is likely to have shown the same tendency (NUNN, 1993a).

Other external forces affecting Viti Levu include southeast trade winds, storm surges and high waves induced by cyclones and tsunami. The trade wind affects the coastline of the windward side, and wind-induced waves are the major cause of the beach erosion along these coasts. Cyclones mainly affect the east and northern coasts, while tsunami occur on the south coast of Viti Levu. The effects of tsunami resulting from earthquakes occurring in the Vatulele-Beqa seismic zone offshore the south coast are of great concern. Some villages fear the storm surges and tsunami, because they wash around the bases and stilts of the houses, resulting in scoring of the bases and tilting of the houses.

Methods of Investigation

In order to find out about the status of beach erosion, and the nature and efficacy of shoreline-protection structures in the South Pacific, students of the University of the South Pacific were employed to carry out the work in their home areas during the long vacation 1994–95. Twenty-five villages were surveyed on Viti Levu and four on Taveuni.

Students were given a series of questions which they were required to use as the basis for starting a dialogue with selected elderly inhabitants of long-established coastal settlements. The questions cover such items as the history and situation of beach erosion, countermeasures, types and efficiency of coastal structures, materials used for structures, funds for construction, and ancestral practices.

Results of the interviews were passed on to the principal researchers at the culmination of the vacation in February 1995. One of the authors (PDN) was able to visit several settlements with student researchers and assure himself that the methods being used were uniform between researchers.

EXAMPLES OF THE PRESENT SITUATION

In order to demonstrate the concrete situations, two examples of the results of the interviews are summarized below.

Plate 1. The sea approach to Nukui village.

Nukui village, Viti Levu (Plate 1 to 3)

Nukui village is located at the mouth of the Rewa Delta on the southeast coast of Viti Levu. It is less than 0.5 m above sea level and the village is only about 250–300 m^2 in size. The population is about 300 and the number of houses about 35. This village has little farming land and is nearly surrounded by the sea and mangrove swamps. Its location is in the direct path of the southeast trade winds and experiences associated rough seas.

Sea encroachment is a very big problem in Nukui. The village headman, Timoci Baserawa (61 years old), who has held this position for 30 years, mentioned that there is no other place to go. The sea is encroaching on nearly all sides of the village. Coastal vegetation like *yevuyevu* (*Hernandia peltata*), *voronibebe* (*Tournefortia argentea*), *dilo* (*Callophyllum inophyllum*) and coconuts have been slowly washed away. Some houses have also had to relocated.

Mr Baserawa mentioned that they had been fighting this serious problem for a long time. They had brought in two foreign engineers to help them with the construction of seawalls. The first one came in the early 1960's. He used beachrock and rocks from the reef. Cement and iron rods were supplied by the government through the *tikina* (district) council; this construction was a vertical one about 1 m high and 50 cm wide. This seawall started to crack and then collapse in the wake of Hurricane Bebe in 1972. Sand now buries much of it.

After the collapse of this seawall in 1972, another engineer came. He also used cement and rocks from the reef but not iron rods. He instructed the villagers to use a different design where the basement was dug down into underlying beachrock. The basement is about 1 m wide and narrows towards the top which is about 1.75 meters above the beach now. According to Mr Baserawa, this seawall is much stronger and more effective than the first one. The seawall is constructed about 5 m seaward of the very recent shoreline so that the villagers could reclaim parts of their lost land.

The projects have been very costly. Although the rocks were locally available on offshore reefs and the cement was supplied by the government, the projects took a lot of the villagers' time. Also a lot of time and money was spent on providing catering services for the workers.

The cement and stone-wall is a better alternative to the ones used by their ancestors. Mr. Baserawa said that their ancestors used to poke sticks into the ground to make a fence along the shore, laying logs across the sand behind, and then piling up rubbish behind them. This was not very effective because, when storm waves came up the beach, the sticks were washed away.

Nabila village, Viti Levu

Nabila village is located on the west coast of Viti Levu. It is on a low-lying area less than 1 m above sea level. The village is about 100 m from the present shoreline which comprises a few patches of mangroves growing on the north and south sides of the village.

Although no real threat of sea encroachment or shoreline erosion felt by the villagers, Timoci Tuwai (48 years old) mentioned that the present shoreline is about 10–15 m inland from the shoreline where he remembers trees were once growing. Timoci stated that the foreshore was once covered with mangrove but, sometime in the 1930's and 1940's, the

Plate 2. Erosion and trees washed away near Nukui.

mangrove swamp was cleared on medical advice. This exercise allowed the coast to be eroded quickly (Plate 4). According to Timoci, sea encroachment and coastal erosion became even more of a problem when the land near the shore was cleared for sugar-cane farming. It is evident that the ploughing of the land makes the soil more vulnerable to erosion.

At present, the villagers do not see the impact of the sea upon their homes as a problem but at the same time they have been thinking about it. Tuwai mentioned that a part of the problem with constructing a seawall would be the difficulty the villagers would face in convincing the owner of the land between the village and the sea of the necessity for this.

Their ancestors had deliberately left the mangrove swamp standing as a barrier. Coastal vegetation like *dilo* (*Calophyllum inophyllum*), *ivi* (*Inocarpus fagiferus*), *nawanawa* (*Cordia subcordata*) and coconut palms were not cleared to help protect the shore.

DISCUSSION OF RESULTS

Major Problems

The most significant finding of this study is that almost all the villages surveyed have problems of beach erosion and sea encroachment. Among the twenty-nine villages studied, twenty-seven villages were and are suffering from beach erosion as shown in Table 1. The only apparent exception was Vunibau village on the south coast of Viti Levu, where land reclamation using dredged sand from the Navua River has been used to protect the village from erosion. Elsewhere beach erosion and sea encroachment has brought about loss of land and coastal vegetation, and forced the relocation of buildings and infrastructure.

In many places, the major cause of such erosion is loss of the mangrove fringe and other natural protection. Mangroves are used to be common along many of Fiji's coastlines. Fringing and offshore reefs, and sandy beaches are other forms of natural protection. Indeed, some villagers call offshore reefs "natural seawalls". Yet, as coastal populations and developments have increased, people have cleared vast areas of shoreline vegetation to provide building materials, firewood, access for shipping, pest control and other reasons and have mined beach sand and other sediments (including beachrock) and coral for building and infrastructural development. Building resorts and coastal roads are other contributors to erosion. Ironically, the construction of seawalls sometimes worsens the erosion problems they are intended to solve (see below).

History of Coastal Protection

Another apparent trend found in the present survey is that many villages have been fighting beach erosion by constructing seawalls. Most seawalls constructed are rather crude, and many are not effective for the prevention of beach erosion. The purpose of the seawalls was not restricted to the prevention of beach erosion; some villages reclaimed land behind the seawalls to expand their land, a desire stimulated by the increase of the population and the loss of coastal land due to erosion.

Table 1 shows the distribution of the decades when the surveyed villages first constructed seawalls. It is apparent that most villages did not try to build seawalls before 1960, and that the number of the seawalls increased in the following decades. This means that, in all but a few cases, Pacific

Plate 3. Seawall in front of Nukui village.

Islanders did not need to protect their shorelines from erosion or inundation before 30 to 40 years ago. The reasons for this are as follows.

(1) prior to 1960, shorelines were largely in a natural condition—mangroves and other coastal vegetation fringed and/or covered shorelines and were not used by coastal people in an unsustainable manner;
(2) populations were less, so that people whose coastal settlement was under threat from the sea would have found it easier than they do today to move elsewhere.

Another possible reason is that, prior to 1960, the rate or magnitude of sea-level rise in Fiji was insufficient to cause many problems. In the last 40 years or so, the situation has changed. There is independent evidence that, at least since 1970, temperatures in the Pacific have increased at a faster rate than at any time since records began (WATSON *et al.*, 1995) and this may have produced a comparably rapid sea-level rise during this period. Although sea-level data do not show this clearly, the sea level has undoubtedly been rising at rates of 1.0–1.5 mm/year in this region during this period (WYRTKI, 1990, NUNN, 1993). If mean sea level rises, sandy beaches tend to respond by forming a new equilibrium profile; this transformation causes extensive beach erosion. This mechanism is known as the Bruun Rule (BRUUN, 1962). Though the amount of sea-level rise has not been great, this mechanism of shoreline erosion may have been operating around parts of the Viti Levu coast for several decades.

Artificial Structures

People in rural Fiji have tried to construct various types of structures ranging from simple lines of poles and piles of stones to concrete seawalls as shown in Plates 5 to 10.

In the distant past, people piled up sediment or stones in unconsolidated piles along the shoreline, or placed sticks along the beach to form a fence behind which debris could be piled. They can be seen even now as shown in Plates 5, 6 and 7. Such structures are likely to be severely eroded during storms, perhaps even under high-tide conditions but, as long as the labour was freely available to rebuild these structures as often as needed, people sought nothing more sophisticated. The change to seawalls and similar structures can thus be seen as a response, not only to the availability of new materials, but also to changing cultural conditions. Labour-intensive solutions of the kind employed in the past would be unlikely to find favour among many rural dwellers today.

Most seawalls have been built from reef rock or hard rocks available locally, often made available during nearby road construction. Most villages have or have planned to cement these rocks together to form an impermeable barrier. Bricks, although uncommon because they are comparatively expensive, are seemingly regarded as the ultimate material. In reality, while these materials are strong and generally resistant to wave action, improper or lack of design has often exacerbated coastal problems where they have been used.

Almost all concrete seawall structures constructed in Fiji are vertical walls; examples are shown in Plates 8, 9 and 10. The prevailing idea is to build a barrier against the sea and wave action along the shoreline to protect the inland. However, vertical hard impermeable structures often generate unfavorable effects, such as strong reflection of waves, scouring of the foot of the seawall, and sucking out of the fill material. These often lead to seawall collapse. Release of sediment from nearshore areas can result in its being relocated on nearby reefs adding to the detrimental ecological impacts of seawall construction.

For the construction of modern seawalls, advice for the design appears to be informally given, if at all, in most rural settlements. Some villages copied seawalls from neighbouring villages, some had advisers from government or voluntary organizations. Design seems to have been a consideration of secondary importance to raw materials available in most cases. These problems are well known in modern coastal engineering, so it is necessary to apply appropriate technical knowledge to the construction of seawalls to avoid such undesirable effects.

Owing to their poor design and the lack of appropriate construction materials, many seawalls in Fiji (and elsewhere in the Pacific islands) require expensive maintenance, rebuilding or extension a year or more after they have been con-

Plate 4. Part of the shoreline at Nabila village which has been cleared of mangroves and other vegetation. The shoreline was once to the left of the photo.

structed. The reluctance of central or provincial governments to fund such requirements (particularly when villages without seawalls are demanding them) has led to the further deterioration of seawalls and similar structures in many places.

Protection by Vegetation

Traditionally many coastal peoples maintained a vegetation fringe along their shoreline, separating their village infrastructure from the sea. In those few cases, where this fringe has been maintained up until the present, the problems of shoreline erosion are much less than those where it has been disturbed and removed. Good examples in Fiji are the villages Daviqele and Nasau on Kadavu island, and the villages Korotolu and Nasau on the island Moce.

Mangroves have been one of the biggest casualties of twentieth-century development in the Pacific islands. In many coastal areas, they have been removed to make way for coastal developments or to supposedly reduce numbers of pests. Colonial governments seem to have naively equated mangrove swamps with disease and pestilence and encouraged rural communities to clear them wherever they could. Many rural coastal dwellers appreciate the irony of now being told by their governments to replant mangroves to protect their coasts from erosion.

The clearance of mangroves and associated inter-tidal zone vegetation does not only exacerbate the direct physical threat to the shoreline by allowing waves to reach parts which they did not reach before. The amount of unconsolidated sediment locked up in mangrove forests is phenomenal. Releasing this sediment has devastating effects on nearby reefs and other areas. It can block stream/river outlets and thereby exacerbate riverine flooding of low-lying areas. Loss of the mangrove ecosystem consistently reduces the numbers and varieties of marine life.

Table 1. *Distribution of villages with seawalls and period of seawall construction*

Study Areas		No. of Surveyed Villages	Existence of Seawalls		Period of Seawall Construction*			
			Seawalls	No Seawalls	Before 1960	1960's	1970's	1980's
Viti Levu	Subsiding area	2	2	0		2		
	South coast	9	7	2	1	1	2	3
	West coast	3	3	0				1
	North coast	1	1	0				
	East coast	10	8	2		1	4	2
	Subtotal	25	21	4	1	4	6	6
Taveuni		4	4	0		3		1
Total		29	25	4	1	7	6	7

* Villages in which the period of seawall construction was unclear are not included

Plate 5. Traditional coastal protection by wooden poles poked into the sand with sand and rubbish piled behind them.

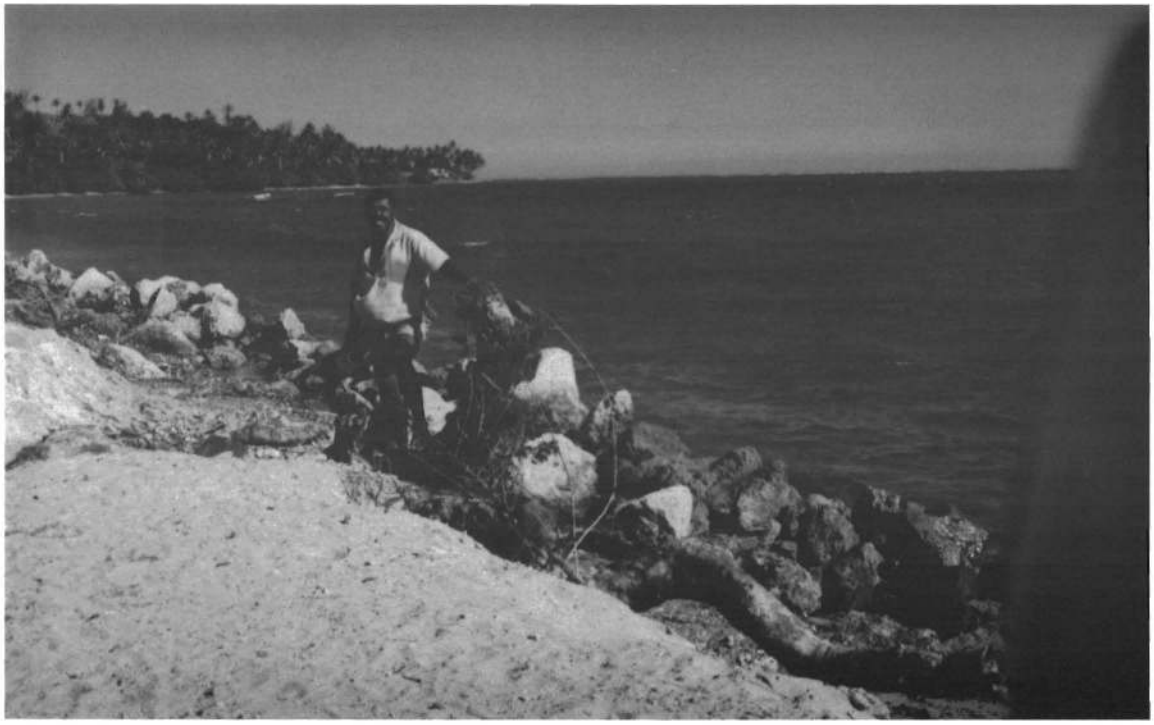

Plate 6. Piled stones along the shoreline.

Plate 7. Protection using old tires.

Plate 8. Vertical seawall of drums with concrete inside.

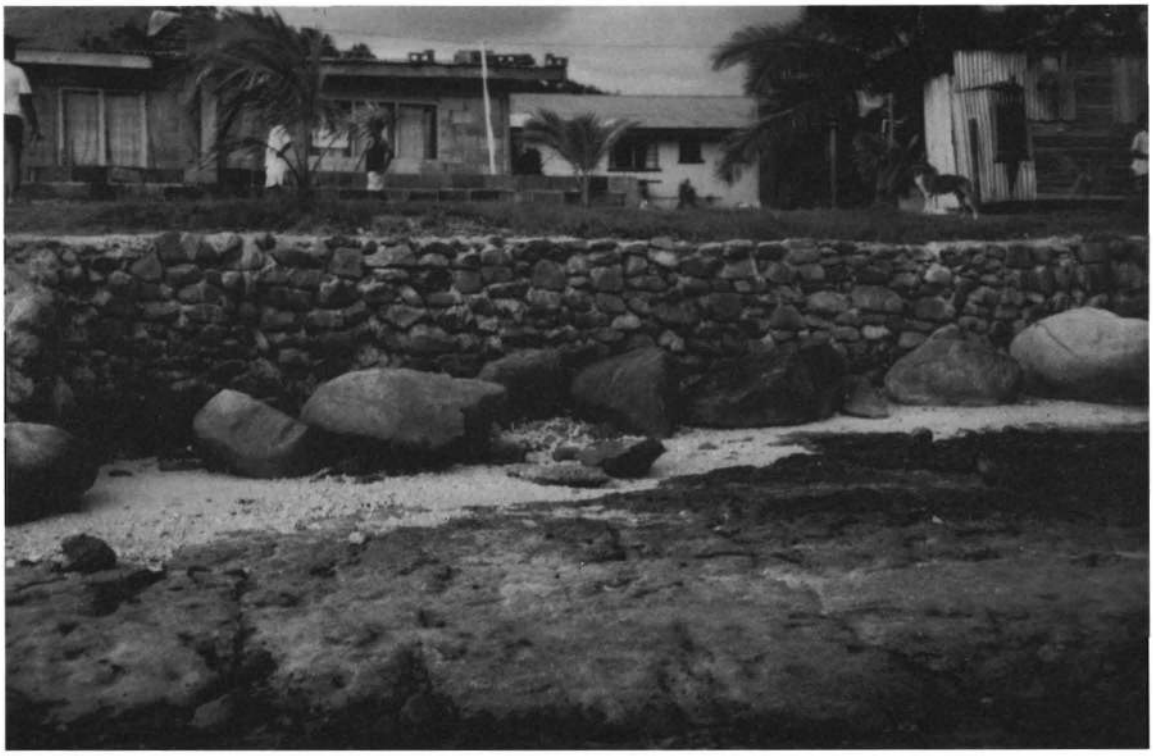

Plate 9. Vertical seawall with toe protection by large stones.

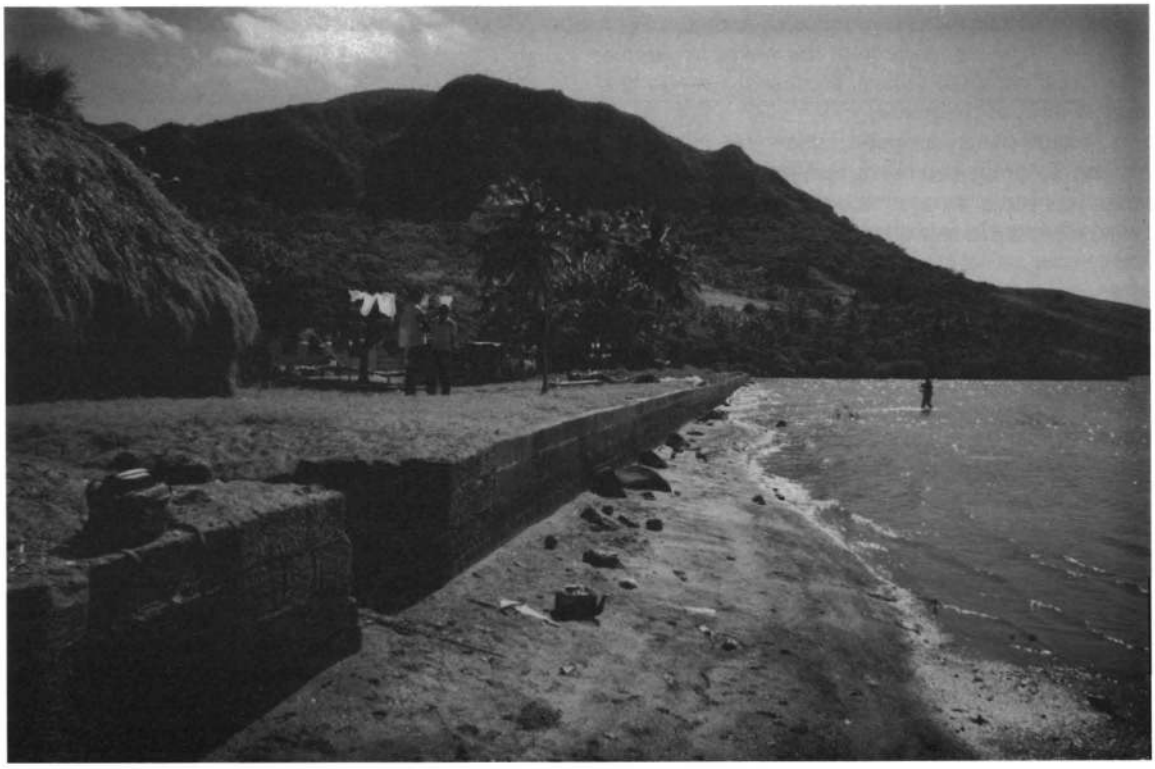

Plate 10. Vertical seawall of concrete blocks and land reclamation behind it.

It is difficult to know what rural Pacific coastlines look like in an undisturbed state since most have probably been significantly altered in the past 50 years if not earlier. Many villages have, particularly in the past rather than recently, deliberately planted vegetation along their shorelines to prevent them being eroded and to reduce the effects of inundation on the village and surrounding low lands.

IMPROVEMENT OF COASTAL PROTECTION

Based on the results of the present survey, it is possible to make suggestions for coastal protection.

(1) It is everywhere apparent that coastal erosion was exacerbated when mangroves and other coastal vegetation were cleared. This means that the natural protection, not only vegetation but also coral reefs and sandy beaches, have been playing essential role in protecting the coast. Therefore, it is first suggested that such natural protection should be enhanced and/or restored as appropriate.

(2) Many places need artificial structures today, because of the increase in the use of coastal areas. The largest problem associated with the design of seawalls is that they fight the sea only along a single line (the shoreline). If waves and storm surges can reach this line without dissipating their energy, they can easily affect these structures leading to scouring their foot and collapse. It is necessary to change the concept of the design from line to area protection. In the latter case, utilizing natural protection is again important. If there are offshore reefs, mangroves, and sandy beaches from offshore to the front of the village, it is easy to protect the waves by simple structures in front of the village, because the waves has already lost most of their energy.

(3) From the engineering viewpoint, there are additional suggestions. In order to absorb the energy of incident waves, gently-sloping structures are much more effective than vertical ones. In addition, the structures face the most dangerous situation when their bases are scored. Therefore, toe protection by stones or concrete blocks with necessary weight is essential for the safety of the protection of the seawall itself.

(4) In preparation for future sea-level rise and climate change, it is important to increase the height of the ground on which many coastal villagers live. For this purpose, it can be recommended that, wherever possible, they should move to higher ground. In addition, this is also necessary to ensure people's safety from storm surges and tsunamis, since seawalls are often not high enough to prevent these flooding the land.

The above suggestions would be effective solutions to the present problems of coastal erosion and inundation in Fiji and other Pacific islands, and broadly match those of a major work on Pacific coasts (SHERWOOD and HOWORTH, 1996). In addition, these approaches seem the most effective for future threats from accelerated sea-level rise and climate change.

CONCLUSIONS

In the present study, the status of coastal erosion and measures being taken to combat it was analyzed for two islands of Fiji on the basis of observations and interviews with elderly people. Most villages are found to have been suffering from beach erosion and sea encroachment. Moreover, they continue to struggle against such problems mainly by building seawalls and reclaiming land.

It was found that such problems were apparently not significant in most parts of Fiji 40 years ago. Seawall construction increased only after 1960. It is considered that the intensification of the beach erosion was brought about mainly by human-induced causes, such as increased use of beaches, clearance and exploitation of mangroves, coral rocks, sands, and other natural resources. An acceleration of sea-level rise at the time is also a likely cause.

The solutions to shoreline erosion developed in the past 30–40 years in Fiji have been largely inappropriate, often exacerbating the problems they were designed to solve. From an engineering viewpoint, suggestions were made to improve the situation. There is an urgent need to impart good clear advice to coastal communities contemplating building shoreline protection structures, which can help to develop better preparation for the future threats of sea-level rise and climate change.

ACKNOWLEDGEMENTS

The authors thank Joeli Koroikata, Matavuso Kotobalavu and Grace Tui for their assistance with the fieldwork, together with the numerous Fiji people without whose interest and hospitality, this study would have been far more difficult.

LITERATURE CITED

BRUUN, P., 1962. Sea-level rise as a cause of shore erosion. *Journal of Waterways and Harbors Division* (American Society of Civil Engineers) 88, 117–130.

HAMBURGER, M.W. and EVERINGHAM, I.B., 1986. Seismic and aseismic zones in the Fiji region. *Royal Society of New Zealand, Bulletin,* 24, 439–453.

HOUGHTON, J.T., JENKINS, G.J., and EPHRAUMS, J.J., (eds), 1990. *Climate Change: The IPCC Scientific Assessment (Report Prepared for IPCC by Working Group I).* Cambridge University Press, 365p.

NUNN, P.D., 1991. Tectonic environments of Fiji. *United Nations ESCAP, CCOP/SOPAC Technical Bulletin* 7, 67–76.

NUNN, P.D., 1993. Recent sea-level changes in the Pacific with emphasis on the evidence for recent sea-level rise in Fiji. *In:* AALBERSBERG, W., NUNN, P.D., and RAVUVU, A.D. (editors). *Climate and Agriculture in the Pacific Islands: Future Perspectives.* Suva: Institute of Pacific Studies, University of the South Pacific, 53–57.

NUNN, P.D., RAVUVU, A.D., AALBERSBERG, W., MIMURA, N., and YAMADA, K. 1994. *Assessment of Coastal Vulnerability and Resilience to Sea-Level Rise and Climate Change. Case Study: Yasawa Islands, Fiji. Phase 2: Development of Methodology.* Apia, Western Samoa: South Pacific Regional Environment Programme, 118p.

SHERWOOD, A. and HOWORTH, R., 1996. Coasts of Pacific Islands. *SOPAC Miscellaneous Report* 222, 40p.

WATSON, R.T., ZINYOWERA, M.C., and MOSS, R.H., (eds), 1995. *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analysis.* Cambridge University Press, 878p.

WYRTKI, K., 1990. Sea level rise: the facts and the future. *Pacific Science,* 44, 1–16.