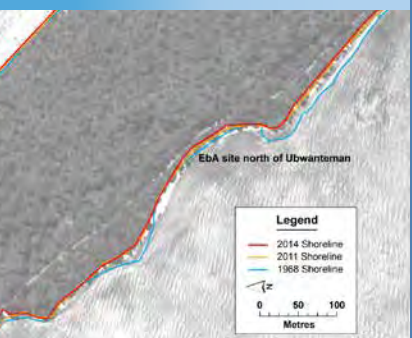
BEACH ECOSYSTEM-BASED ADAPTATION

Abaiang, Kiribati



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Secretariat of the Pacific Regional Environment Programme
P.O. Box 240, Apia, Samoa.
Telephone: + 685 21929, Fax: + 685 20231
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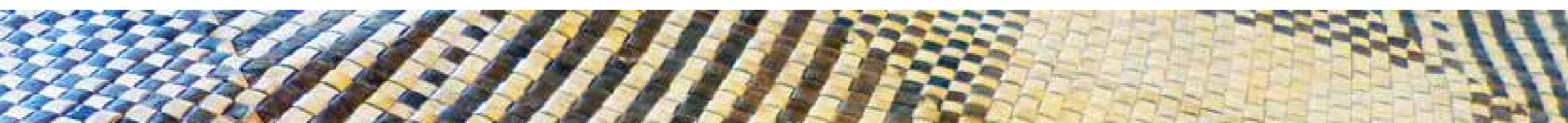


Summary

The erosion of beaches is prevalent on Pacific island coastlines, partly due to human causes. On Abaiang in Kiribati, many beaches have been reported as eroding, and coastal protection structures such as seawalls are expensive and can cause negative impacts.

Beach ecosystem based adaptation (EbA) can increase resilience of beaches to storms and sea level rise, using access control fencing and gateways, beach vegetation replanting and use of brush matting to protect beach erosion scarps from direct wave action. This project applied EbA methods at seven eroding beaches on Abaiang, all located on community land, in demonstrations involving all of the ten villages on the main island.

Author contact

Dr Joanna C. Ellison, School of Land and Food, University of Tasmania, Locked bag 1370, Launceston, Tasmania 7250, Australia Email: Joanna.Ellison@utas.edu.au

Contents

Introduction

Ecosystem-based adaptation (EbA) integrates biodiversity conservation and ecosystem services (Grantham et al. 2011), and engages natural ecosystem services to provide an adaptation strategy (Pramova et al. 2012; Hills et al. 2013). Vegetated coastal ecosystems such as seagrasses and mangroves are known to provide the coast with protection against flooding and erosion (Duarte et al. 2013), however the use of beach vegetation as an EbA strategy only recently been commenced to protect and rehabilitate eroding beaches. Beach EbA has been trialled on North Tarawa (Ellison 2014a) and Vava'u Tonga (Ellison 2014b). These trials led to development of a practical guide for communities to use as an adaptation to beach erosion problems (Ellison et al. 2015).

Objectives

Objectives of this project were give demonstrations of beach EbA at eroding beaches on Abaiang atoll, Kiribati, in cooperation with local communities, to extend their adaptive capacity to climate change and climate variability.

Abaiang

The main island of Abaiang atoll is 36.72 km long and maximum width 0.92 km (Office of Teberetitenti 2012). Abaiang has the fourth highest population of islands in Kiribati, with 5,502 people recorded in the 2010 census. Economic activities include fishing and agriculture, largely for subsistence. Extensive problems with coastal erosion on Abaiang have been documented, with 47 sites described (Ministry of Internal and Social Affairs [MISA] 2008). At one location south of Tebunginako village, this has resulted from ongoing adjustment of the shore to an earlier blocking of a channel (Webb 2006), but the whole of Abaiang suffers from events associated with coastal erosion (Office of Teberetitenti 2012).

Beaches rehabilitated are listed in Table 1 and located in Figure 1.

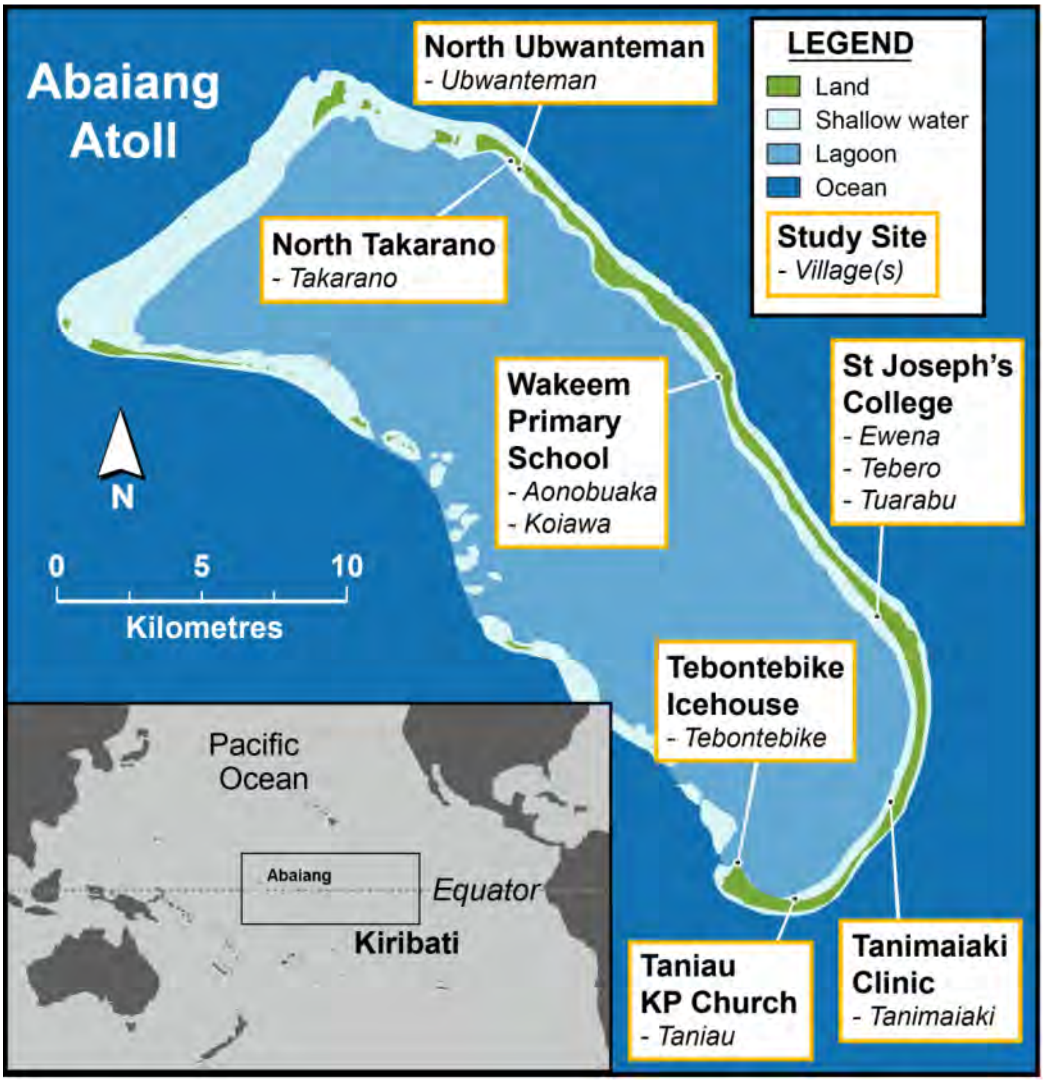


Figure 1. Map of Abaiang showing locations where EbA works were undertaken.

Site selection followed community information sharing, and community approval for the work to go ahead.

Criteria for site selection:

1. Strong local community support for the works, and willingness to participate and take responsibility for its maintenance
2. Erosion sites were reported in the Abaiang Island 2008 Socio-economic profile (MISA 2008), and 2012 Island report series reports (Office of Teberetitenti 2012)
3. Cause of the beach erosion is partly due to disturbance, rather than due to a cause that cannot be removed such as an adjacent seawall or groin
4. The beach is on public or community land, so accessible by all.

EbA demonstrations were undertaken at seven sites (Table 1), involving all ten villages on the main island of Abaiang, using procedures described in the Coastal Ecosystem based Rehabilitation Guide (Ellison et al. 2015), adapted by local community volunteers to the site characteristics.

Geographical Information Systems (GIS) analysis of shoreline change was conducted using 1964 aerial photographs, 2011 GeoEye satellite and 2014 Worldview-2 satellite mosaic imagery. These works are described in the following sections from North to South.

Table 1. EbA demonstrations on Abaiang January-July 2015. Beach condition categories follow Ellison et al. (2015).

Site	**Location**	**Offshore type**	**MISA (2008) site number**	**Beach condition**	**Villages involved**
S Takarano	N 01°56.687 E 172°55.281	Lagoon	10	5	Takarano
N Ubwanteman	N 01°56.531 E 172°55.447	Lagoon	12	5	Ubwanteman
Wakeem Primary school	N 01°52.746 E 172°59.028	Lagoon	21	4	Aonobuaka, Koinawa
St Joseph's College	N 01°48.198 E 173°02.060	Lagoon	30	4	Ewena, Tebero, Tuarabu
Tanimaiaki clinic	N 01°44.765 E 173°02.266	Lagoon	42	3-4	Tanimaiaki
Taniau KP church	N 01°42.943 E 173°00.438	Lagoon	40	4-5	Taniau
Tebontebike Icehouse	N 01°43.618 E 172°59.379	Reef	31	4	Tebontebike

South Takarano

Beach profile monitoring (Table 2) was commenced during this project at sites on the north-western coast of Abaiang, where Kiribati Government ECD staff had undertaken EbA work in

January 2015. GIS results showed coastal retreat of most of the northern lagoon shoreline, with significant loss in the last 3 years (Figure 2). South of Takarano (Table 1, Figure 2) the beach had eroded to undercut the main road, with a 50 cm scarp above a concave beach profile (Figure 3). A brush structure was built of 5.9 m in length and up to 1.85 m in width, by 6 volunteers from Takarano village.

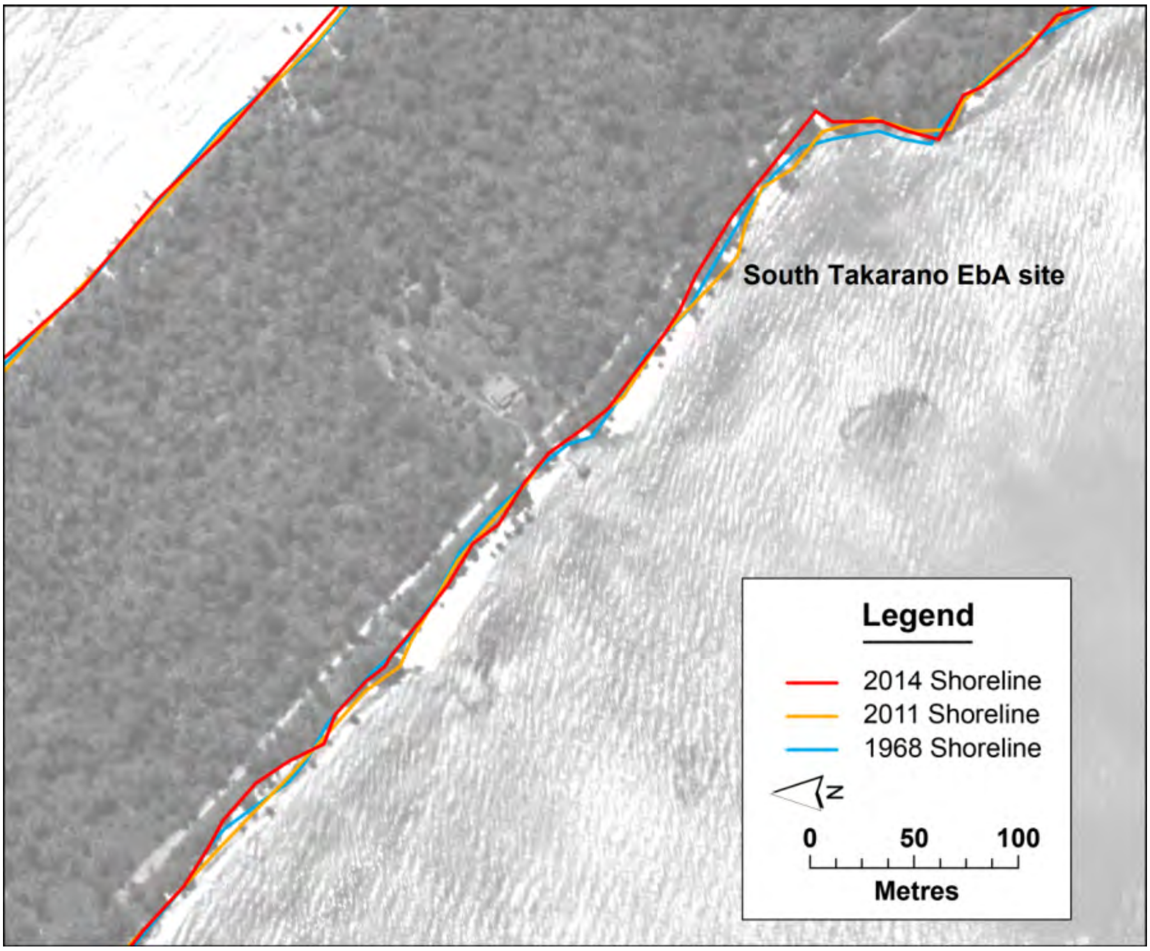


Figure 2. GIS analysis of coastal change at south Takarano.

Table 2. Beach profile data from EbA works south of Takarano.

Location: Takarano, alongside road south of village N 01°56.687 E 172°55.281

Dates: 3 February and 26 June, 2015 Staff: Arawaia, Ratita, George

Transect compass bearing (looking offshore): 227° magnetic

Backsight: To centre of top of black coral block landward of a fallen coconut tree, under a "Te Ango" tree, 13 m from the landward edge of the road.

Feb 3 2015		All measurements in meters	**June 26 2015**	
Distance	**Elevation**	**Notes**	**Distance**	**Elevation**
0	0	To benchmark as above	0	0
13	0	Landward edge of road	11.9	0.04
15.5	-0.009	Seaward edge of road	14.7	0.042
15.7	0.036	On road verge	15.68	0.051
16.8	-0.015	Top edge of scarp	15.76	0.008
16.86	-0.266	Below top edge of scarp	16.63	-0.035
18.2	-0.595	high tide mark on beach	17.61	-0.231
21.5	-0.985	Further down beach	21.08	-0.479
28.7	-1.663	Near large rock in beach	27.34	-1.117
41.6	-1.84	Seaward edge of beachrock	34.89	-1.749
56	-1.893	Gravel/ sandflats offshore	38.13	-1.795

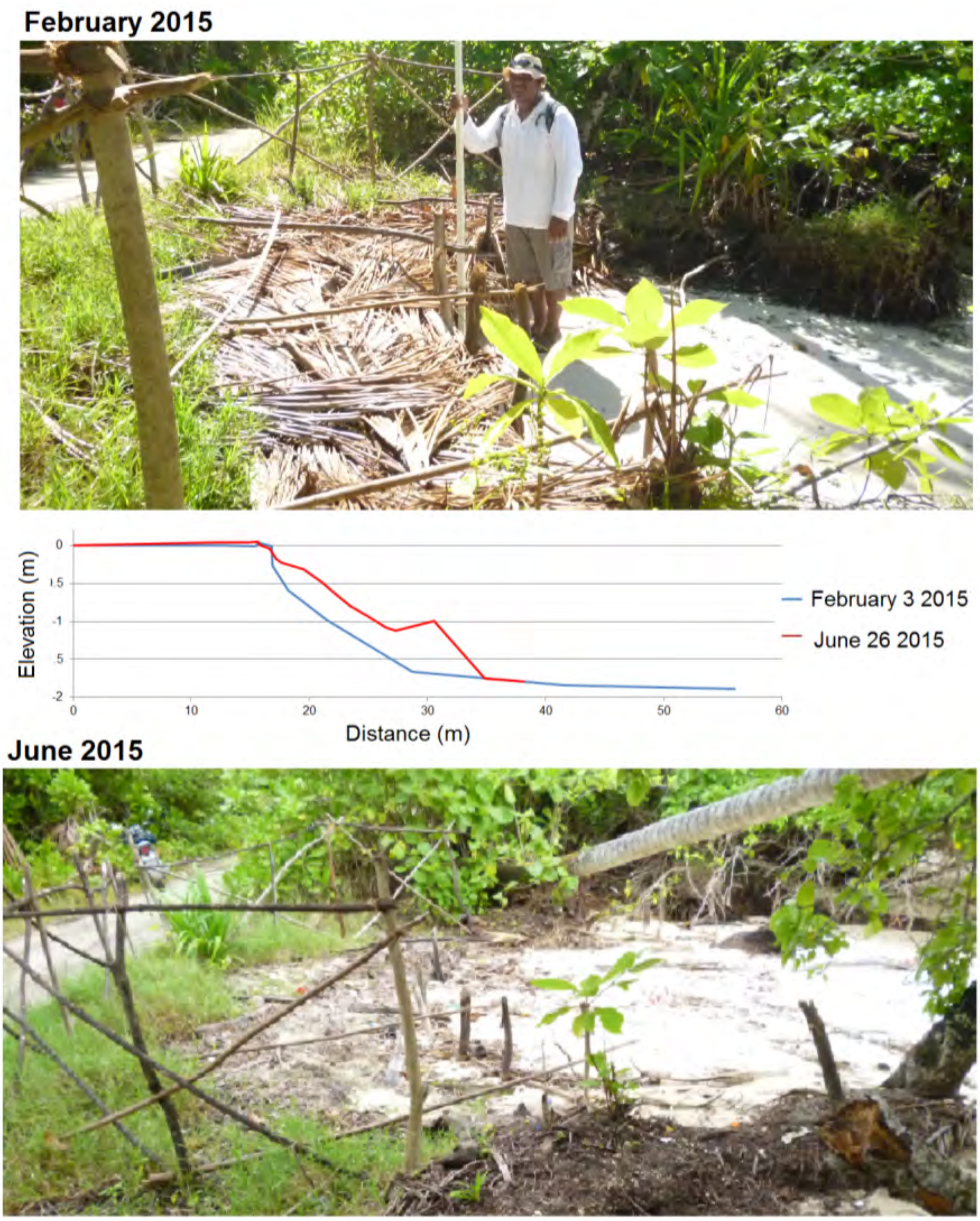


Figure 3. Profile diagram of EbA works south of Takarano.

In June 2015 the beach had accreted to cover the brush structure, and the profile of the beach had become convex, and using the guidelines in Ellison et al. (2015) the beach had recovered to a level 3/2. The beach sand offshore of the brush structure had accreted about 50 cm (Figure 3). Other erosion sites on this section of road identified in MISA (2008) all showed the road to remain to be undercut, with no beach infill. This site could recover further if revegetated, with beach vines, grasses and tree seedlings, to give it resilience against storm swell events.

Between Ubwanteman and Takarano

North of Ubwanteman (Table 1, Figure 1) the beach had eroded to undercut the main road, with a 0.5 m scarp above a concave beach profile (Table 3). GIS analysis showed significant retreat along this whole section of lagoon shoreline (Figure 4).

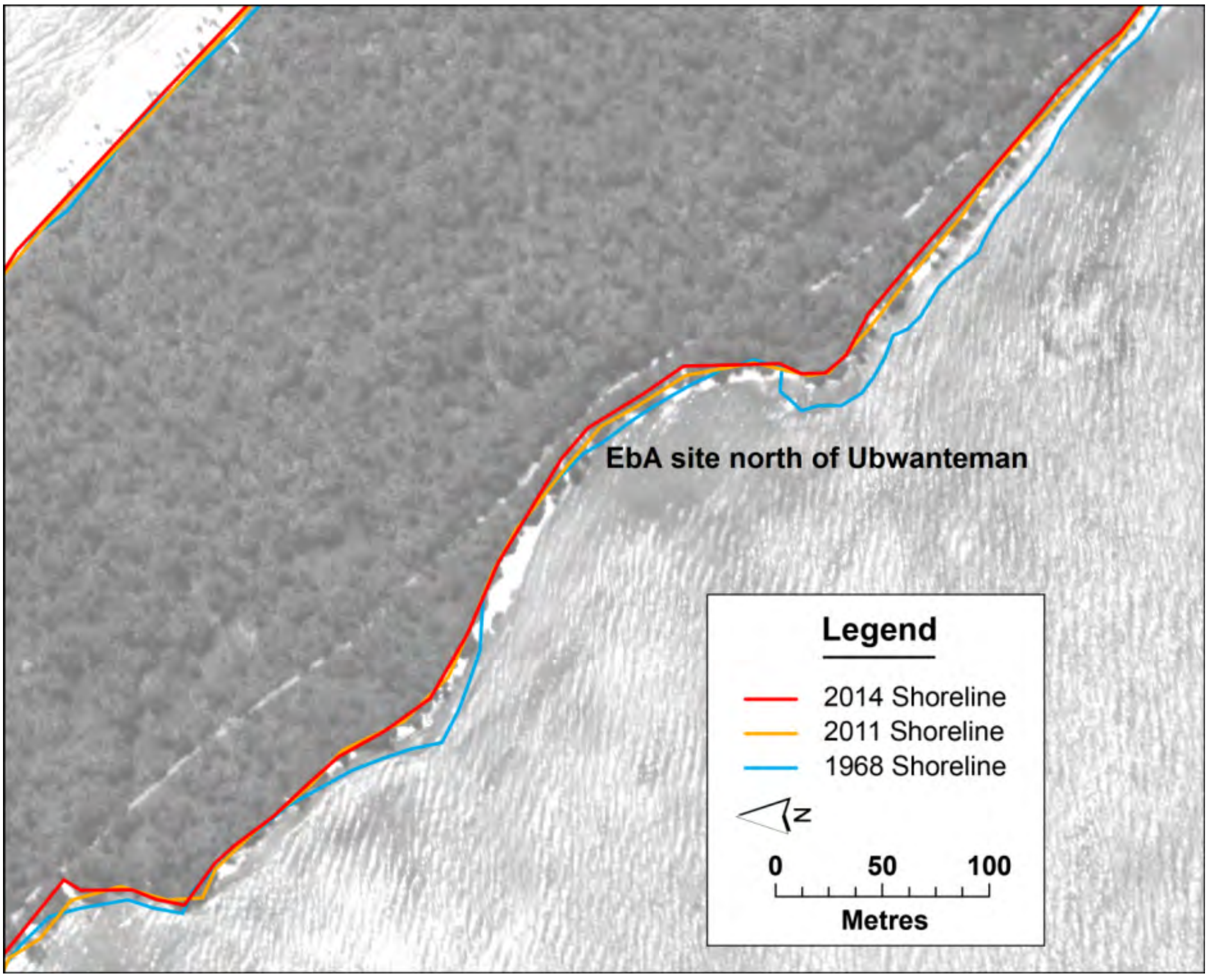


Figure 4. GIS analysis of coastal change at north Ubwanteman.

A brush structure was built of 23.4 m in length, and up to 2.9 m in width, with a small *Messerschmidia* tree in the centre (Figure 5). In February 2015, the high tide mark was inside the brush structure, indicating the high tide waters were washing at the sand in the scarp below the road edge.

Table 3. Beach profile data from EbA site north of Ubwanteman.

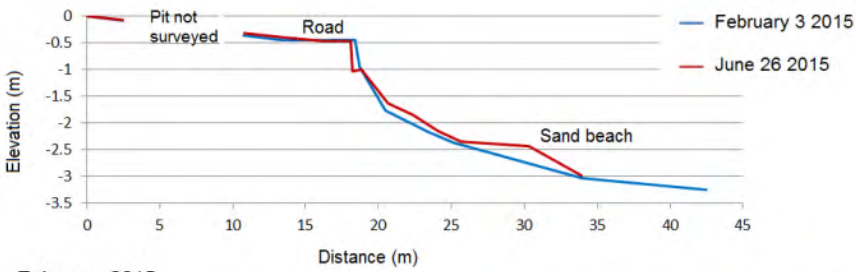
Location: Between Ubwanteman and Takarano. N 01º56.531 E 172º55.447

Dates: 3 February and 26 June, 2015 Staff: Arawaia, Ratita, George

Transect compass bearing (looking offshore): 233º magnetic

Backsight: To rock embedded in soil south of "Te Uri" tree, 13.6 m inland of road

Feb 3 2015		All measurements in meters	**June 26 2015**	
Distance	**Elevation**	**Notes**	**Distance**	**Elevation**
0	0	To backsight as above	0	0
13.36	-0.465	Landward edge of road	13.5	-0.407
16.7	-0.465	Seaward edge of road	16.2	-0.467
16.8	-0.465	Top edge of scarp	18.1	-0.471
18.41	-0.465	Below top edge of scarp	18.23	-1.032
18.7	-0.965	On scarp face	18.83	-1.01
20.46	-1.768	Top of beach	20.68	-1.638
23.4	-2.166	Mid beach	22.39	-1.849
25.15	-2.376	Base of beach, top of beachrock	24.11	-2.158
34	-3.031	Base of beachrock	25.69	-2.351
42.5	-3.259	Offshore sandflats	33.9	-2.985



February 2015

June 2015

Figure 5. Profile diagram of EbA works north of Ubwanteman.

In June 2015, the brush had compacted and sunk, and needed maintenance and infill, which police have volunteered to undertake. Resurvey of the beach showed that while the road base has eroded a little, the majority of the beach has accreted by at least 0.2 m (Figure 5). The upper beach remains concave in profile, while the lower beach has developed a convex bar. This site could be further stabilised with maintenance and repair of the brush structure, along with the planting of beach vines around the top of the beach.

Wakeem Primary School

Wakeem Primary School (Table 1, Figure 1) has a combined campus with the Junior Secondary School between Koinawa and Aonobuaka villages. The long lagoon frontage was all degraded (level 4), with disturbed vegetation and a sand cliff at the top of the beach of up to 80 cm. Teachers said that the school was established in 1999, and soon after lost a number of classrooms and a maneaba on the seaward side of the road, with loss of about 30 m of land bit by bit. GIS analysis showed this coastal retreat (Figure 6).

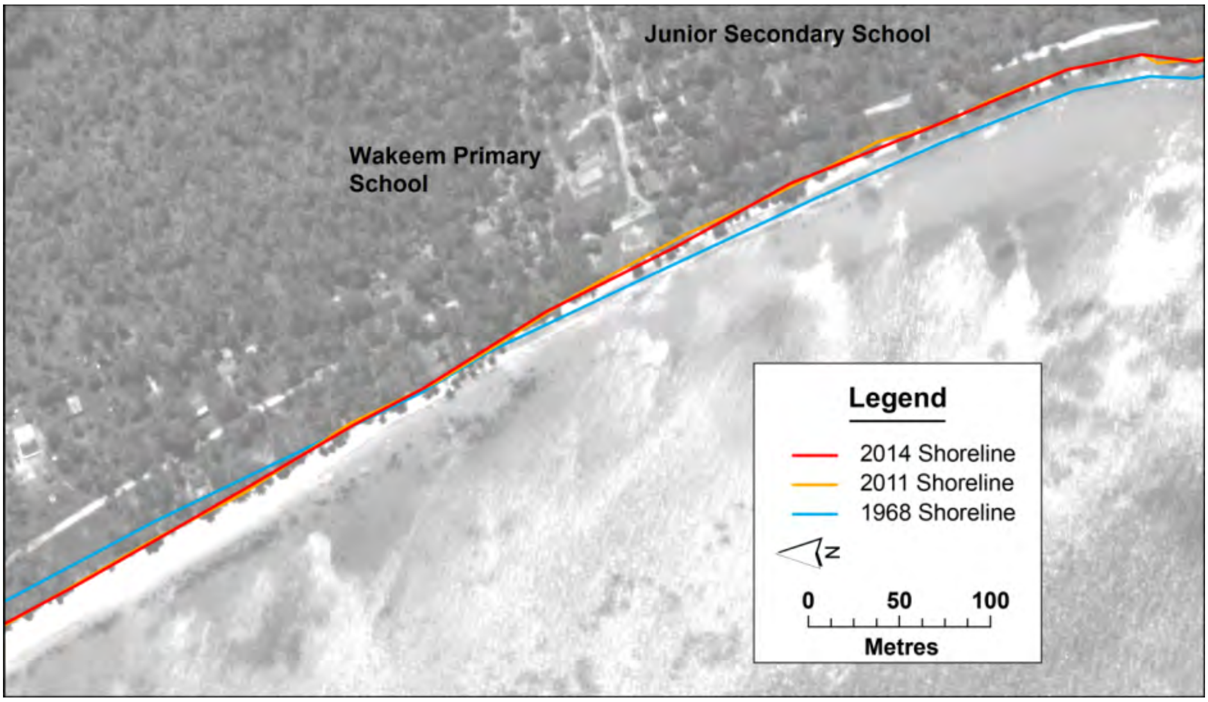


Figure 6. GIS analysis of coastal change at Wakeem Primary School.

Pigs were tied to coconut trees at the northern edge of the beach, and had been digging and uprooting vegetation so no ground vegetation remained, loosening sand for erosion at high tide. The surveyed profile (Table 4, Figure 7) showed a 0.4 m scarp at the top of the beach, below which the beach profile was flat or straight in shape.

Table 4. Beach profile data from EbA works at Wakeem Primary School.

Location: Wakeem Primary School		N 01º52.746 E 172º59.028		
Date: 23 June, 2015		Staff: Arawaia, Ratita, George		
Transect compass bearing (looking offshore): 236º magnetic				
Backsight: To northern edge of concrete slab, 3.5 m from its seaward edge, on landward side of road at Wakeem Primary school, 17.2 cm above ground to north.				
Back sight	Fore sight	Distance (m)	Change in	Notes

(m)	(m)		height (m)	
1.342		0	0	To backsight as above
	1.386	18	-0.044	Landward edge of road
	1.386	26.35	-0.044	Seaward edge of road
	1.352	32	-0.01	1 m from scarp top
	1.472	48.0	-0.13	Top edge of scarp
	1.719	51.0	-0.377	Below top edge of scarp
	2.127	52.0	-0.785	Middle of scarp
	2.344	54.0	-1.002	Top of beach
	2.726	57.0	-1.384	Mid beach
	2.859	58.4	-1.517	just above beachrock
	3.283	62.7	-1.941	Base of beachrock
	3.555	65.3	-2.213	Base of beach
	3.937	70.4	-2.595	Offshore sandflats

A large brush structure was built of 36 m in length, with the northern half built by 20 volunteers from Aonbouaka village, and southern half by Koinawa village (Figure 7, base). The width was up to 2.8 m, and infilled by dense coconut fronds and woody brush. Two access pathways were created within the brush structure, and *Pandanus* seedlings and cuttings planted behind this by school children.

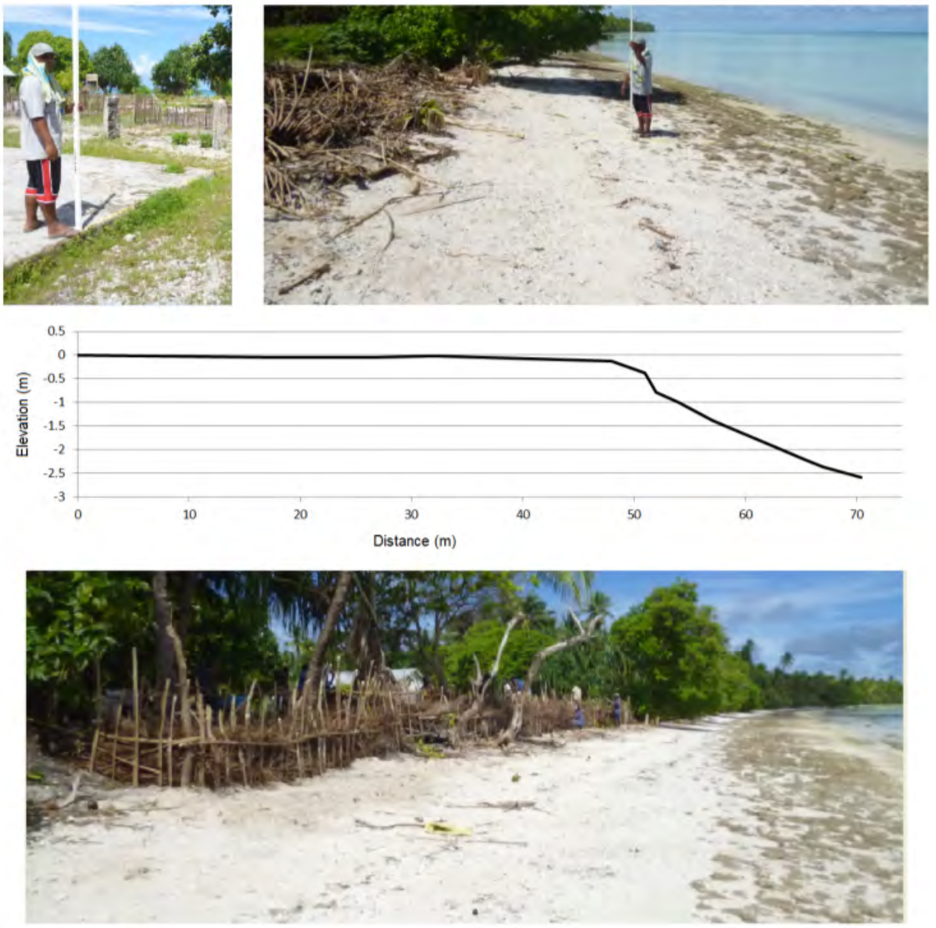


Figure 7. Beach profile diagram and EbA works at Wakeem Primary School.

St Joseph's College lagoon shore

This was the largest length of beach where EbA works were undertaken this project, with a total length of 148 m. GIS results were not able to incorporate the 1966 data, owing to poor quality of the imagery, and a few meters of erosion were shown 2011-2014. High tide mark was undercutting a scarp at the top of the beach, and Geography students from the High School had been monitoring erosion and cut back. Facilities at a Pre-School on the shore just south of the junction were being undercut. The roots of many large trees along the top of the beach were badly undercut, with the root bole exposed. The ground cover landward of these trees, however, was good with over 90% coverage, and a diverse assemblage of vines, grass and tree seedlings. Owing to the length of the works, two profiles were surveyed, to the north and south of the road junction (Tables 5 and 6; Figures 8 and 9).

Table 5. Beach profile data from north of the school/ main road junction.

Location: North St Joseph's College N 01°48.183 E 173°02.073 Date: 24 June, 2015 Staff: Arawaia, Ratita, George Transect compass bearing (looking offshore): 222° magnetic Backsight: NW upper corner of concrete base of "SJC-Tabwiroa" sign.				
Back sight (m)	Fore sight (m)	Distance (m)	Change in height (m)	Notes
1.045		0	0	To backsight as above
	1.226	0	-0.181	Ground level beside block
	1.277	5.8	-0.249	Landward edge of road
	1.294	11.6	-0.249	Seaward edge of road
	1.703	45	-0.658	
	1.722	46.5	-0.677	Ground level above beach
1.663	1.937	46.9	-0.892	
	2.279	55.7	-1.129	Mid beach
	3.714	66.8	-2.051	Base of beach
	3.906	73.2	-2.243	Offshore sandflats

To the north of the access road from the junction, where a stone crucifix stands above the beach, a brush structure of 90 m in length was built (Figure 8), of 1.3-2.2 m in width increasing up to 3.9 m where brush surrounded the seaward roots of large trees. Heights of the structure matched decreasing height of the eroding scarp from up to 0.8 m high at the southern section reducing to 0.5 m at the northern end. An access path was created though this about half way along this 90 m length. The northern half of this 90 m structure was built by 20 volunteers from Ewena village, and the southern half built by 27 volunteers from Taburo village (the closest village to the site).

An access path of 7.3 m width was created at the end of the road down to the Pre-School.

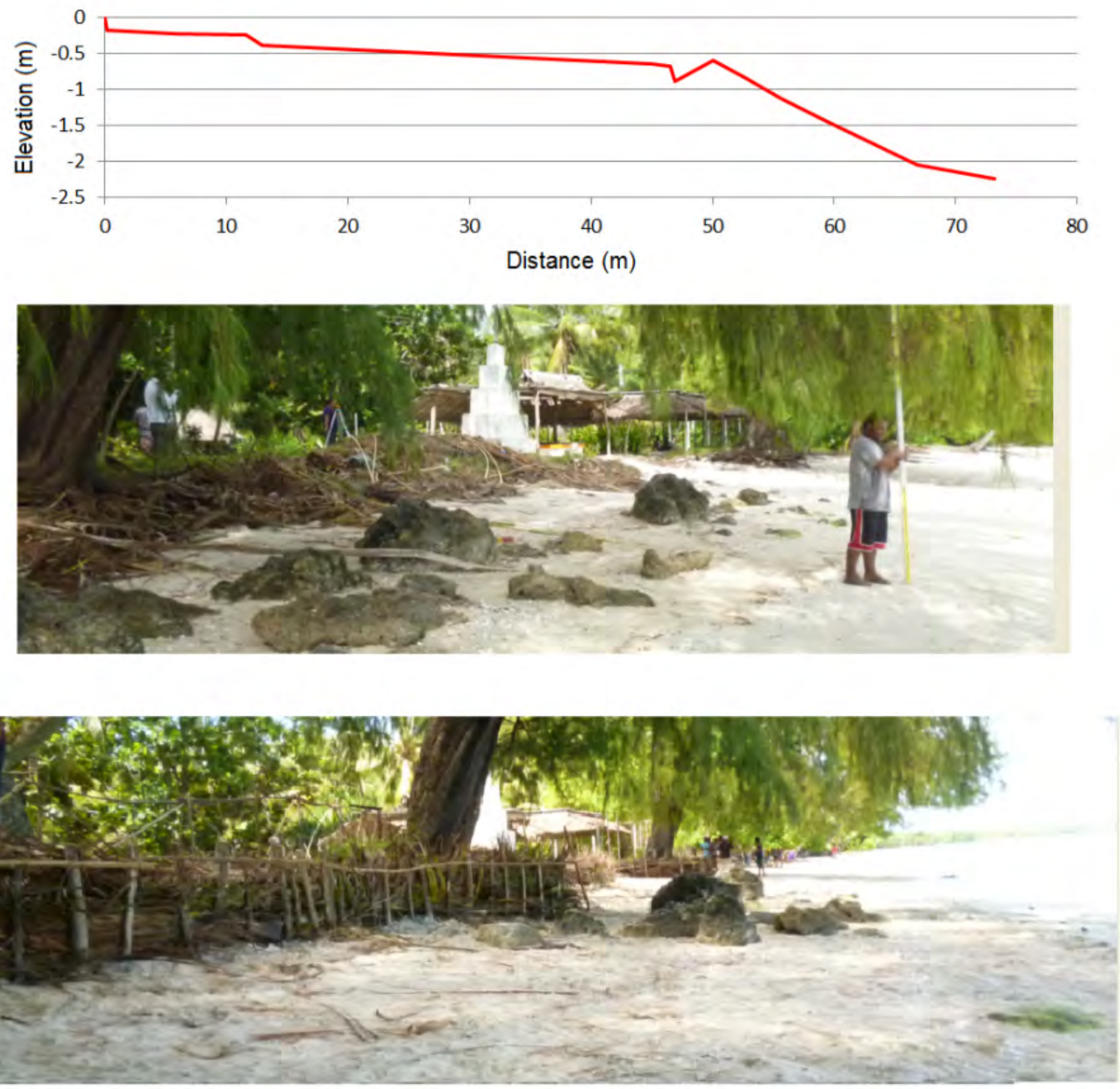


Figure 8. Beach profile diagram and EbA works at St Joseph's College (north).

Table 6. Beach profile data from south of the school/ main road junction.

Location: South St Joseph's College N 01º48.198 E 173º02.060 Date: 24 June, 2015 Staff: Arawaia, Ratita, George Transect compass bearing (looking offshore): 224º magnetic Backsight: SW base corner of house on the SE side of the road junction.				
Backsight (m)	Foresight (m)	Distance (m)	Change in height (m)	Notes
0.918		0	0	To backsight as above

	1.132	0.1	-0.214	Ground level beside block
	1.404	16	-0.486	Landward edge of road
	1.415	21.8	-0.497	Seaward edge of road
	1.645	23.4	-0.727	Ground level above beach
1.483	1.922	50	-1.004	Top edge of scarp
	1.637	56	-0.154	Below top edge of scarp
	1.842	56.6	-0.359	Lower on scarp
	2.554	61.7	-1.071	Top of beach, HTM
	3.046	66.2	-1.563	Mid beach,
	3.612	73.8	-2.129	Base of beach
	3.916	80.5	-2.433	Offshore sandflats

To the south of the access road from the junction, a brush structure of 50.3 m in length was built by 21 volunteers from Tuarabu village (Figure 9), and included protection to the seaward side of the pre-school playground that had been undercut. Widths were 1.7-3.0 m with the wider sections surrounding the seaward roots of large trees, and heights from 0.5-0.8 m. Staff of St Joseph's College agreed to maintain and monitor the brush structure.

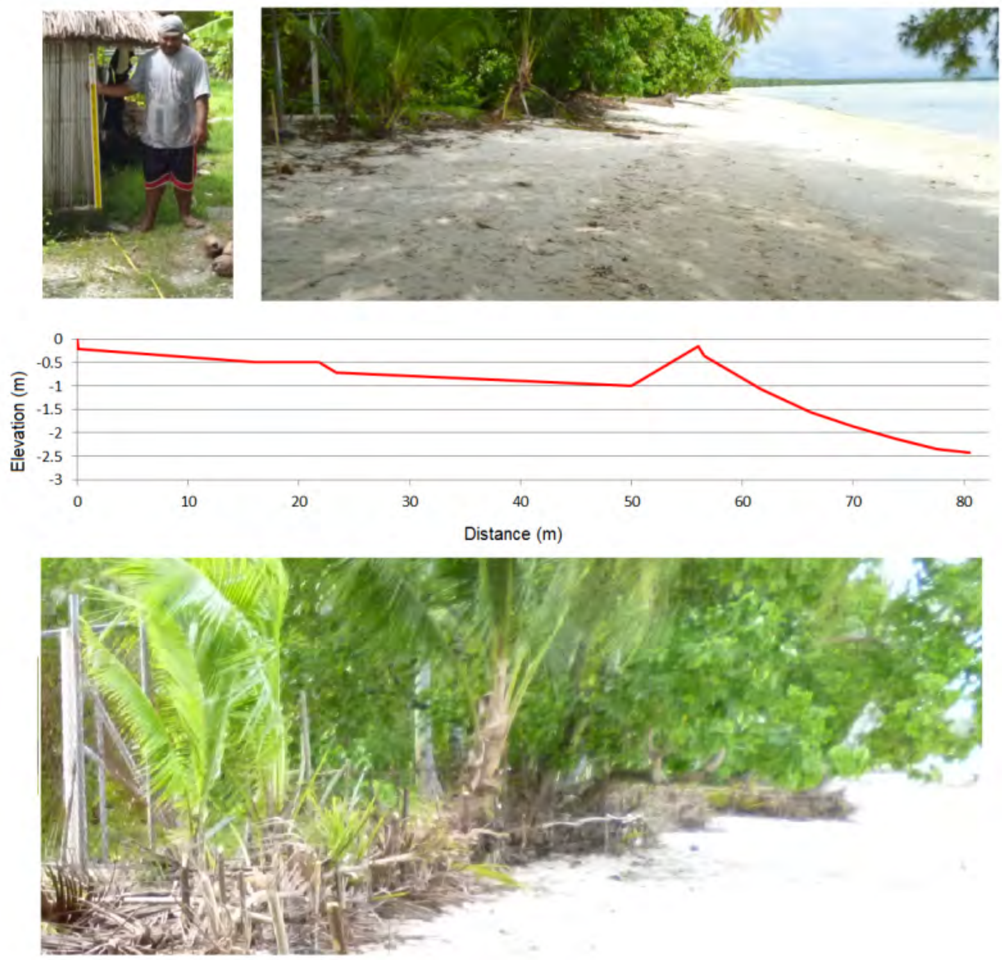


Figure 9. Beach profile diagram and EbA works at St Joseph's College (south).

Tanimaiaki

Opposite a new medical clinic built with European funding, this beach was in a moderately degraded condition, with the high tide mark extending into upper beach vegetation, and some of this had been cut and damaged. GIS results showed <10 m of accretion 1966-2011, and stability with a little erosion 2011-2014. A beach monitoring profile was surveyed, and benchmarked to the floor of the entrance to the medical clinic (Table 7), showing a flat beach profile (Figure 10). A brush barrier was constructed of about 5 m in length, and a further 6 m of access control fencing installed to alleviate pressure on an eroding section with an access path through. This involved the work of 15 volunteers from Tanimaiaki village.

Table 7. Results from beach profile transect at Tanimaiaki Clinic

Location: Tanimaiaki Clinic N 01°44.765 E 173°02.266

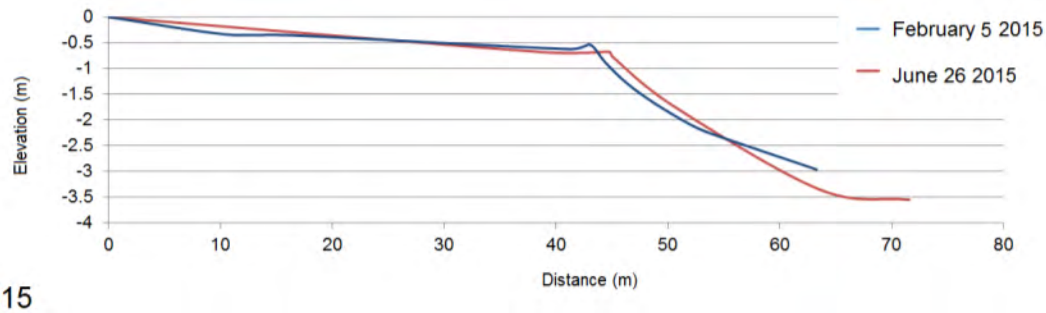
Dates: 5 February and 26 June, 2015 Staff: Arawaia, Ratita, George

Transect compass bearing (looking offshore): 285° magnetic

Backsight benchmark: Entrance to clinic, base of southern metal post at the outer entrance, ground is 13.5 cm lower than this point

Feb 5 2015		All measurements in meters	**June 26 2015**	
Distance	**Elevation**	**Notes**	**Distance**	**Elevation**
0	0	To benchmark as above	0	0
39	-0.684	To road edge (lagoon side)	16.8	-0.358
44.7	-0.674	End of level ground, grass	41.3	-0.624
45.1	-0.779	Lower edge of grass, top of beach	43.0	-0.531
50.6	-1.742	Mid sand beach	51.8	-2.063
63.6	-3.353	Base of sand beach	53.7	-2.251
71.6	-3.551	Sandflats offshore	63.3	-2.962

February 2015



June 2015

Figure 10. Beach profile diagram and EbA works at Tanimaiaki Clinic.

In June, the access fence was no longer there, but the brush structure had largely remained and become infiltrated by sand deposits. This site lacks maintenance as is outside one of the villages. The beach profile results showed accretion of the upper beach by 0.2 m.

Taniau

At the Taniau Kiribati United Church community, the high tide mark extending underneath buildings, and the beach in a degraded condition (level 4-5). At least 40 cm of sand loss was evident from exposed roots of trees. GIS results were inconclusive. Previous coastal protection works had been washed away, and the beach eroded back further.

A beach monitoring profile was surveyed (Table 8), and benchmarked to a stone in the floor of the meeting house. This topographic survey related to high tide mark demonstrated that the floor level of the meeting house is just 2.68 m above tidal datum, and late that month a 2.94 m tide was predicted, and village leaders were informed of the date and time of this prediction. Information shared about maintenance and repair of the brush barrier.

Table 8. Beach profile data from Taniau Kiribati United Church.

Location: Taniau Kiribati United Church N 01°42.943 E 173°00.438 Dates: 6 February, 2015 Staff: Arawaia, Ratita, George Transect compass bearing (looking offshore): 6° magnetic Backsight benchmark: largest rock in the seaward maneaba edge rocks, inside edge, 2.5 cm higher than the floor of the maneaba, and 13.5 cm higher than outside ground level				
Feb 3 2015		All measurements in meters	**June 26 2015**	
Distance	**Elevation**	**Notes**	**Distance**	**Elevation**
0	0	BS to benchmark	0	0
10	-0.961	Ground between two buildings		
15.1	-0.984	By seaward post of seaward house	-0.351	15
18.2	-0.874	Upper beach	-0.815	17.1
19.6	-1.065	Further down beach	-1.155	20.7
26	-1.654	Further down sand beach	-1.39	23.7

37.7	-2.393	Lower edge of beach	-1.747	27.7
47.7	-2.606	Reef flats offshore	-1.907	30.9

A brush barrier was constructed of about 10 m in length, with an access path through, and a further 5 m of access control fencing to alleviate pressure on an eroding section (Figure 11). This involved the work of 11 volunteers from Taniau village.

When revisited in June, residents reported that during two high tides in late February had coincided with high waves from Cyclone Pam. Sand under the village houses had eroded, and waves damaged the brush structure, with cross bracing broken by waves such that the brush washed out. Following this, poles in the brush structure were replaced, these made shorter to reduce drag on waves, matting added, and the structure was extended to the south. The February work proved to be a demonstration, and the design was modified following experience. Sand was also mined from the lower beach and brought up to raise the ground level under village houses, as shown on the left of the profile diagram (Figure 11). The beach part of the profile showed no change.

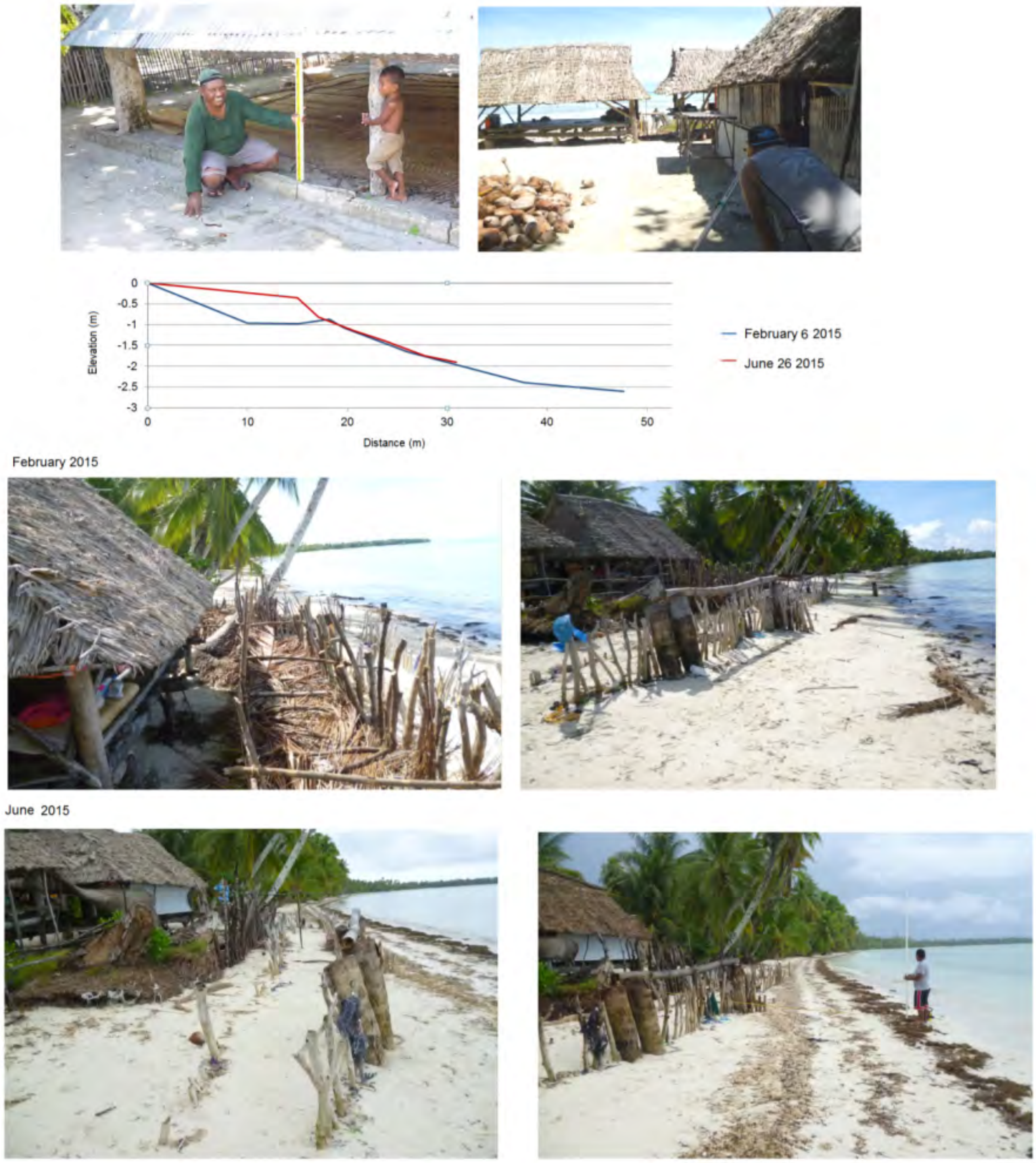


Figure 11. Beach profile transect and EbA works at Taniau.

Tabontebike village

At the south end of the village, the beach was in a badly degraded condition, with a 1.10 m cliff eroded in the sand beach, which had eroded back to within 10 m of the icehouse (CPPL building). Community members described this as occurring in the last few years, when king tides combine with winds. While EbA is not the best technique for a windward shore, a demonstration was undertaken. A beach monitoring profile was surveyed (Table 9), and benchmarked to the concrete base of the icehouse building.

Table 9. Results from beach profile transect at Tabontebike Ice House (CPPL building)

Location: Tabontebike Ice House			N 01º43.618 E 172º59.379	
Dates: 4 February 2015; 26 June 2015			Staff: Arawaia, Ratita, George	
Transect compass bearing (looking offshore): 328° magnetic				
Backsight benchmark: To SW corner of concrete building, top of outer prominent brick, 0.168 m lower than top of lowest large brick in the wall.				
Feb 4 2015		All measurements in meters	**June 26 2015**	
Distance	**Elevation**	**Notes**	**Distance**	**Elevation**
0	0	To benchmark as above	3.3	0.063
1.35	-0.035	Sand surface in front of building	5.3	-0.069
10.4	0.038	Top of scarp (Feb); Upper beach (June)	18.5	-0.425
10.8	-0.383	Base of scarp (Feb); Upper beach (June)	22.8	-0.729
18	-1.341	Middle of sand beach	27	-1.112
26.5	-2.368	Base of sand beach	30.3	-1.113
39	-2.641	Sandflats offshore	36.1	-1.943

GIS analysis was unable to incorporate 1968 data owing to poor quality of the image. Shoreline change 2011-2014 was variable around the point (Figure 12) with erosion found to the north of the Icehouse building where the profile (Figure 13) was surveyed.

Figure 12. GIS analysis of coastal change at Tabontebike north western coast.

Volunteers from the community, 16 in number, gathered materials from inland, and also provided coconut string. They built a brush barrier of 8 m in length, and 1.7 m wide, using *te ri* poles and coconut branches. Towards the end of this work a storm occurred at high tide, during which waves were even washing though the ice house from front to back, and further beach erosion was evident. The brush barrier mostly held up even though not completed at the time, and sand was washed through it to deposit and become more solid. In June, the brush structure was still in position, even though storms and people had removed all of the poles. The brush was firm with sand washed through it, and the shoreline has accreted sediment.

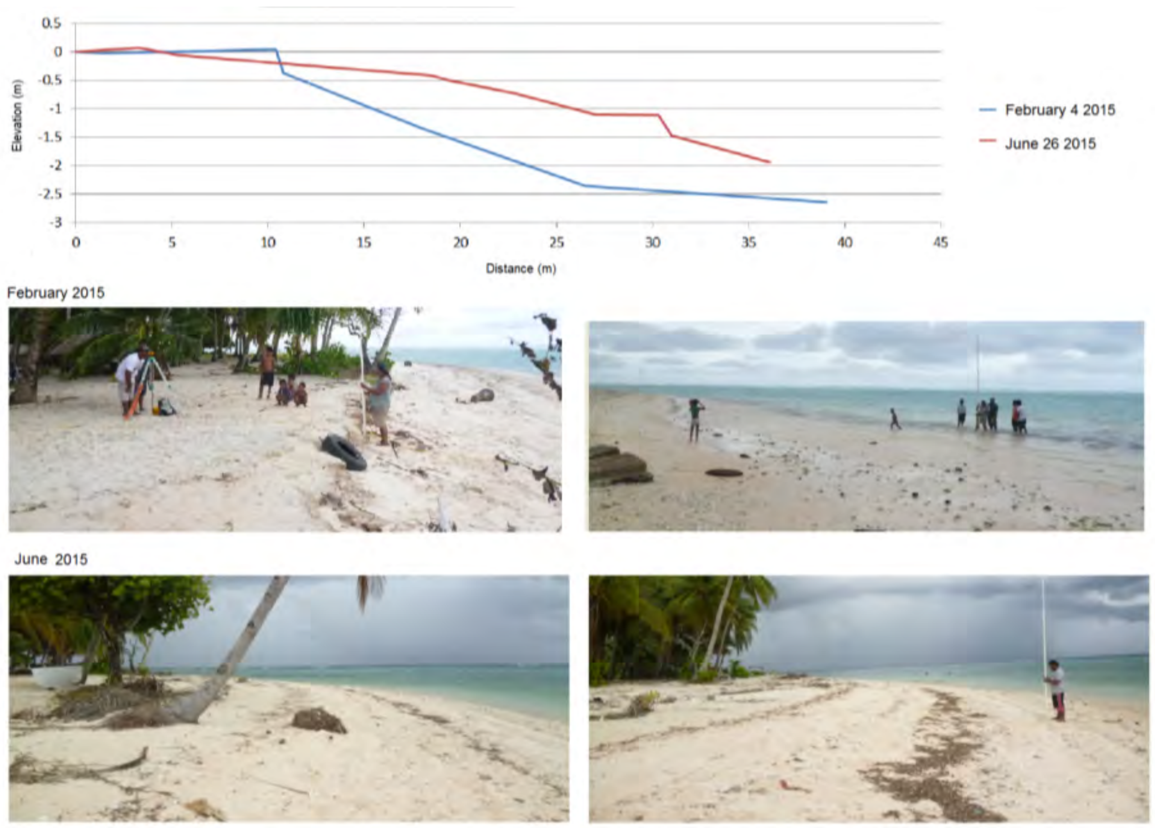


Figure 13. Beach profile transect at Tabontebike.

Discussion

Beach EbA advanced through this project with trial of larger brush structures built by volunteers from several villages simultaneously. An innovation introduced this stage in beach EbA included use of *Guettarda speciosa* (L.) *te uri* in construction of brush barriers, because feedback from village participants contributed that it is more resilient than other wood types to breakdown in seawater. Larger diameter posts built closer together also proved to be a better option. These practices are recommended for future works.

With most beaches surveyed in a degraded condition (Table 1). The brush structure proved to be the most useful EbA works. These are infilled with dead coconut fronds, pinned down by horizontal poles so high water does not lift or move it. It prevents wave action from directly contacting the erosion scarp, but allows the water to penetrate and sand to be carried into the brush from the beach, where friction causes it to settle. This creates a more solid structure, on which vines and creeping grasses can be planted, further stabilising the shore with roots and creating a pioneer psammosere (beach vegetation succession). The brush structure has been used to provide protection from wave action around exposed tree roots of large shoreline stabilising trees, also providing protection from direct human impacts. They are each built in a day by volunteers from a village, and costing about $100 each for use of a truck to get materials from inland, and purchase of coconut string.

Early data shows that these eroded beaches have subsequent to EbA works accreted sediment (Figures 3, 5, 10). Further research on the longer term outcomes would allow evaluation and further improvement of beach EbA procedures.

Community information and feedback

Consultations with the Mayor of Abaiang and Town Officer were undertaken during the project, particularly to allow initial contact with village communities. In villages, information sessions were undertaken with community members and volunteers, using the EbA guide and A3 laminated copies of the posters translated into Kiribati language. Information sessions were held with staff and students at a number of schools (Figure 14), providing laminated posters.

Figure 14. EbA information sessions at Abaiang schools.

Conclusions and Recommendations

The following actions are recommended for further improvements in beach rehabilitation:

- Further community education using the signs in the Rehabilitation Guide
- Watering of beach seedlings and planting more, including vines
- Maintenance of EbA fencing and brush matting when required
- Transect re-measurement at about 12 month intervals to show erosion or accretion
- Extension of EbA approaches to further atolls, using the Guide (Ellison et al. 2015).

Monitoring and measures of success

Rehabilitation works using EbA intends to improve the condition of the beach, and re-assessment of beach condition over time can be carried out using the criteria in the Beach Rehabilitation Guide (Ellison et al. 2015). Monitoring the beach profile transects over time will show measures of success of such as upwards accretion of the beach and increase in convexity of shape. Techniques are provided in the Plan (Ellison 2014b). Measures of success also include increase in ground cover and canopy cover of beach vegetation, and this will give positive feedback to increase sand accretion.

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