Beach ecosystem based adaptation trials,

North Tarawa, Kiribati

Report for the Environment and Conservation Division, Kiribati, as part of the Australian Aid/ SPREP Coastal Ecosystem Based Adaptation to Climate Change in Kiribati Project

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Summary

Beaches have many values to Pacific island communities, including the protection of land from marine processes, but in some locations are degraded and eroding. Ecosystem based adaptation of beaches using low cost techniques to reduce and repair erosion has been successfully trialled in Europe and Australia, and this project undertook similar adaptation trials in North Tarawa, Kiribati.

Beach ecosystem based adaptation trials were implemented at Tabon-te-bike, Buariki village, North Tawara, and reconnaissance was carried out of beach rehabilitation needs at other sites including the lagoon beach of the Nooto Ramsar site. Beach profile monitoring of erosion trends was commenced at Tabon-te-bike and Nooto lagoon beach. Spatial change analysis was carried out at both these sites, to show erosion rates at Buariki and some stability at Nooto.

Adaptation options trialled in collaboration with the Buariki village community were access control fencing and gateways, beach vegetation replanting and use of brush to protect a beach erosion scarp from direct wave action. At the Nooto Ramsar site the beach condition showed need for community education regarding improvement of beach values and low cost ways to reduce human impacts and increase beach resilience. Local community members showed enthusiasm and inventiveness regarding the beach rehabilitation trials, indicating potential for successful implementation of similar programs elsewhere in the Pacific islands Region.

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Contents

1 Purpose

Beach erosion is a widespread problem identified by communities in the Pacific islands region. This project has the objective of trialling ways of increasing the resilience of beaches to erosion, including the use of revegetation. A key objective is developing low cost methods that allow reduction of direct impacts that contribute to beach erosion, enabling natural processes of sand accretion and stabilisation to operate effectively.

2 Background

Beaches provide a range of ecosystem services (Defoe et al. 2009), including habitats for rare biodiversity, protection of the inland from marine processes and a buffer against relative sea-level rise inundation. Human stressors can impact upon habitats such as beach fringing vegetation, disturbing vertebrates and shorebirds that nest in the backshore (Santoro et al. 2012), and leading to erosion (Bird 2008, Defoe et al. 2009). Human trampling of upper beach vegetation has high impact on plants because of the loose abrasive nature of sand, causing vegetation dieback followed by sand disaggregation and erosion (Santoro et al. 2012). While beaches undergo morphological cyclic change of erosion and deposition within longer time scales (Bird, 2008), up to 70% of the world's beaches are experiencing erosion (Bird 1985; Zhang et al. 2004; Church et al. 2008), and this is expected to further increase with global sea level rise (Nicholls et al. 2007; Bird, 2008).

It is increasingly recognised that a relevant response to impacts including climate change is the application of ecosystem-based adaptation approaches (Hills et al. 2013), which integrates use of ecosystem services as an adaptation strategy. Use of beach vegetation rehabilitation to combat coastal erosion as an alternative to hard engineering has a relatively long history, with southern European beaches coming under severe pressure following tourist urbanisation from the 1960's (Gómez-Pina et al. 2002). Extensive beach and dune degradation in Spain was successfully restored in the 1990's with the initial objective of removing the cause by using fencing to reduce effects of human trampling, elevated dune walkovers to provide access from the road to the beach, and information posters to educate the public regarding how they may cause damage (Gómez-Pina et al. 2002). This was augmented by provision of new plants from a government funded nursery, and extensive dune replanting.

In western France, erosion of coastal dunes was restored following damage from heavy tourism foot traffic after 1988 by fencing and vegetation replanting (Rozé and Lemauviel 2004). Ten years later the restoration procedures were shown to be successful, with vegetation cover restored onto bare soil by combating visitor pressure, and accumulation and progradation of the dunes.

In Australia, following community concern about beach erosion and degradation of the coastline, restoration has been undertaken through collaboration between local councils, natural resource management agencies, and community voluntary groups such as Coastcare. In the island state Tasmania, experience through a number of such coastal works over nearly 20 years has resulted in an extensive "Coastal Works Manual: A best practice management guide for changing coastlines", including detailed technical guidelines (Page and Thorp 2010).

Although there have been reports and concerns about beach erosion in the Pacific islands region (Forbes and Hosoi 1995; Gillie 1997; Mimura and Nunn 1998; Duvat 2013; Duvat et al. 2013; Donner 2013) including vulnerability to erosion as a result of rising sea level (Nicholls et al. 2007), ecosystem based adaptation options on beaches in the region has not previously been explored. SPREP through facilitation from an Australian Aid grant has implemented this trial, in Kiribati in late 2013. Sites suitable for such ecosystem based adaptation were earlier identified for the project in North Tarawa by Otiawa (2013). The locations of sites described in this report are shown in Figure 1.

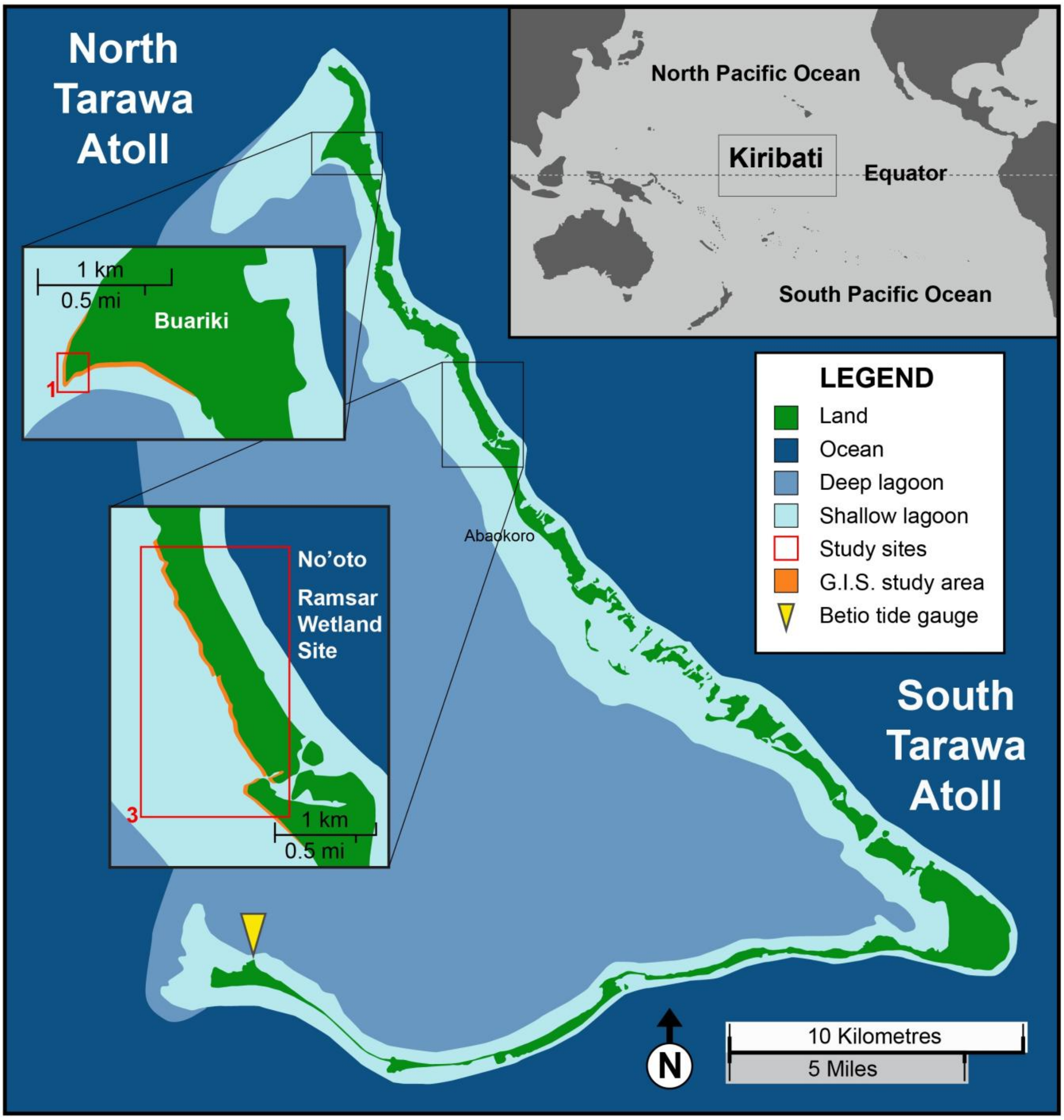

Figure 1. Map of Tarawa Atoll, Kiribati, showing locations of sites detailed in this beach ecosystem based adaptation report.

3 Tabon-te-bike at Buariki village

3.1 Introduction

Tabon-te-bike is located west of Buariki village and on Tarawa Atoll's lagoon shore at 01° 36.541' N, 172° 57.172' E, and is close to Buariki village (Figure 2). Community concern has been expressed about beach erosion over the last few decades (Tebano 2008; Otiawa 2013; Juillerat 2013), and being a 5 minute walk from the meeting house, this site was thought suitable as a trial site owing to its potential for use in community education. There is a straight road extending though the village to the coast that turns to the north at the location where the erosion site is. The location is to the north of a large intertidal sand spit (Figure 1, inset) where the shore has south to north orientation.

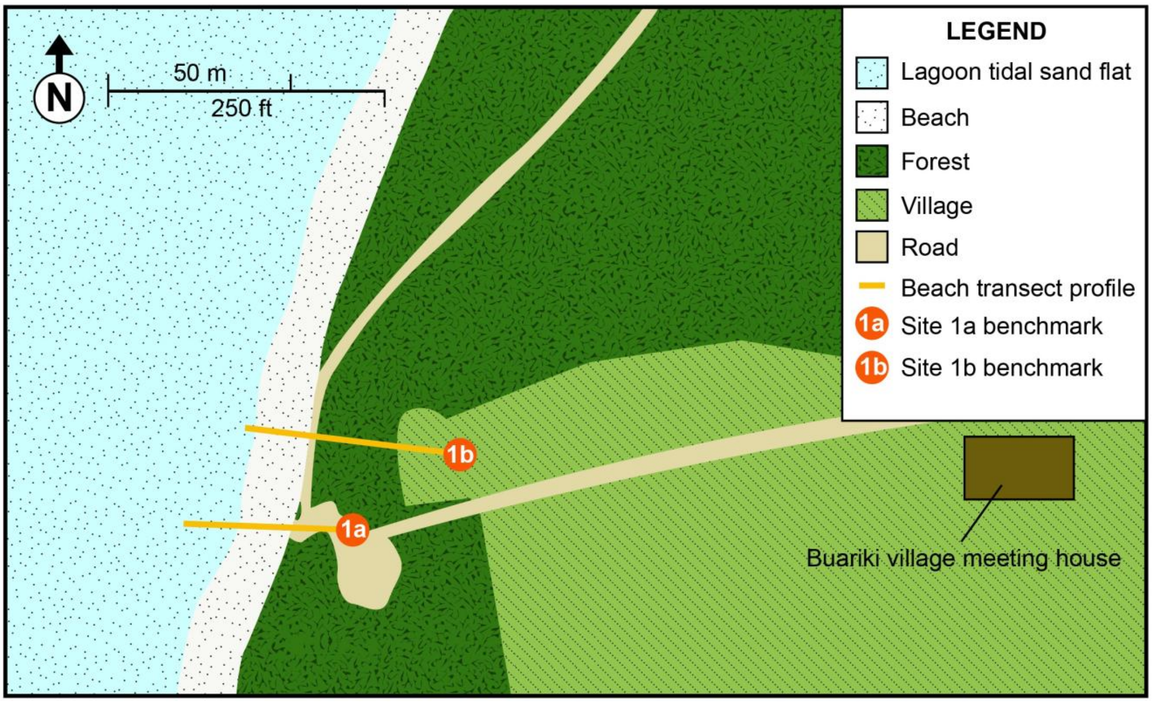

Figure 2. Map of Tabon-te-bike, Buariki, showing rehabilitation sites and beach survey transects.

3.2 Previous reports

The local community has reported concerns about erosion of the beach (Otiawa 2013), with a resident relating that 200 m of land has been eroded, and the road adjacent to the beach as having been three times reconstructed after eroding very fast. Of several sites assessed by Otiawa (2013), Tabon-te-bike is named site 1, and this is retained in this report for continuity.

Tebano (2008, page 42) from a visit in May 2008 shows an eroded beach described to be at the north western end of Buariki village in that report's Figure 4a, which could be the same site. This picture shows fallen trees across a beach scarp (scarp means a vertical cliff in sediment), where soil and tree roots are exposed as the upper beach is undercut.

Biribo and Woodroffe (2013) used aerial photography 1968-1998 to show shoreline change on Buariki, giving an endpoint rate calculated by dividing the maximum shoreline displacement by the time period to be greater than -0.2 m a^{-1} (Figure 3A), where the minus sign indicates erosion. Webb and Kench (2010) showed shoreline change 1969-2004 (Figure 3B), showing up to 200 m loss from the NW side of the spit where site 1 is located, at a rate of up to 5 m a^{-1}, and 200 m gain on the southern side of the spit. Despite the recent dates of these publications, the data used by each is fairly old and an updated analysis has been now undertaken.

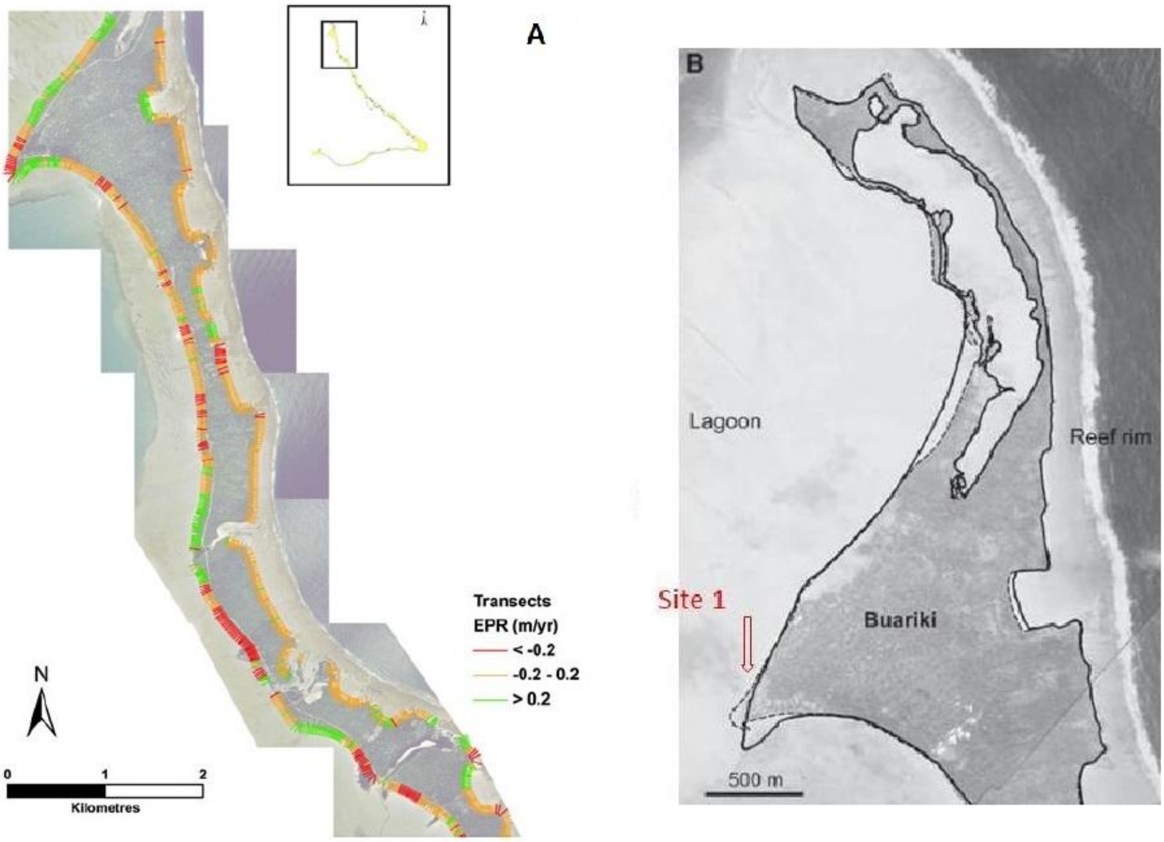

Figure 3. Shoreline changes at Buariki. A) From 1968-1998, adapted from Figure 5 of Biribo and Woodroffe (2013). B) From 1969-2004, adapted from Figure 6b of Webb and Kench (2010), with Site 1 of this report identified in red.

Juillerat (2013) visited in July 2013, and shows in his Figure 2 the scale of erosion at the site, with a 70 year old villager Mrs. Anuntetoka Maati standing offshore of the beach about 200-300 m, indicating where her home was located 58 years ago which would be 1955. Her family described to C. Juillerat a sandbag seawall constructed sometime in the 1980's by villagers, of which no evidence was apparent by 2013. Juillerat (2013) shows details of the erosion site in his report's Figures 9 and 10, noting the erosion scarp being just 75 cm from the road. This report recommends a number of soft options such as revegetation and boardwalks as suitable for a several erosion sites in North Tarawa.

3.3 Spatial change analysis

Existing spatial change analysis of the site (Figure 3) was out of date by at least 9 years, so a new analysis was undertaken using historical and most recent imagery. Satellite imagery from 2003 and 2013 was obtained as part of the project, and digital aerial imagery from 1998 was obtained from the Department of Lands, Government of Kiribati. Images were rectified using GPS points taken in the field, and the shoreline edge delineated using the vegetation edge. Results are shown in Figure 4.

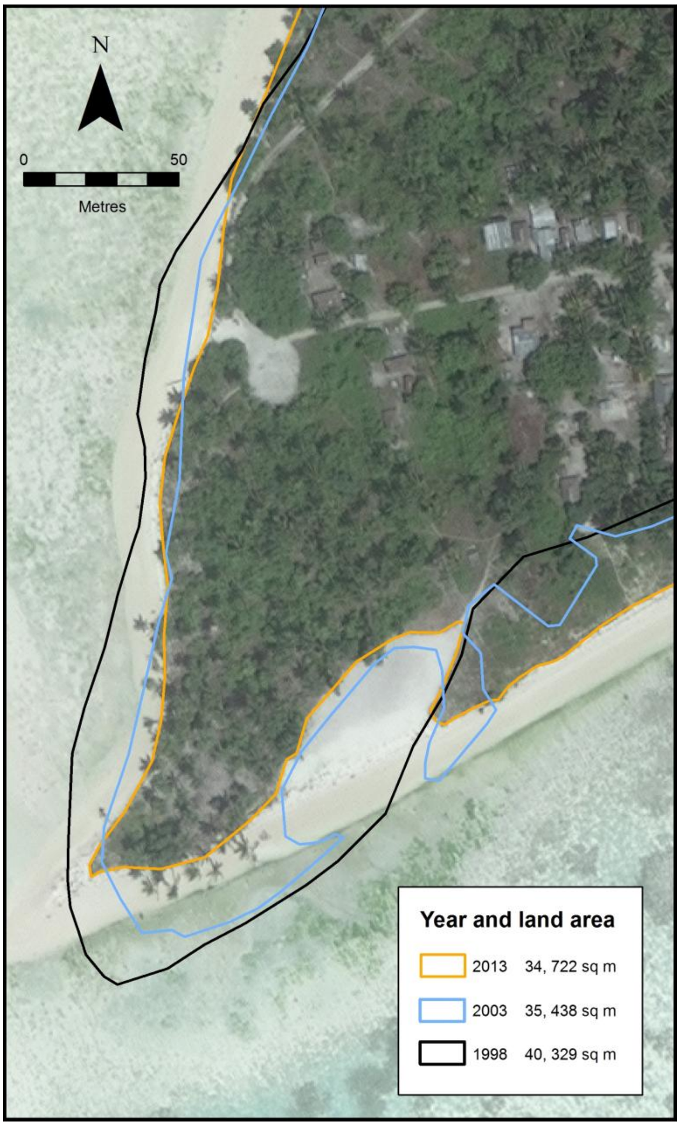

Figure 4. GIS analysis of shoreline change 1998-2013, Tabon-ke-bike, Buariki. The background image is 2013, and the land area calculations are based on the land area shown in the image.

Land area calculations (Figure 4) are of the land area included in the image, and show that the land area of this point of the island has reduced over time. The sand spit recurved towards the south 1998-2003, indicating a change in the prevalent winds such as from south-easterly to north-westerly, but since 2003 the erosion has occurred on both sides of the spit, and with some accretion further towards the southeast. The recent GIS analysis (Figure 4) showed the erosion has resulted in a vegetation retreat rate of 3 m a^{-1} 1998-2003, and 0.7 m a^{-1} 2003-2013. At site 1 (Figure 2), the rates of erosion are greater than the immediately adjacent sections to the north and south, which have both been fairly stable in the last 10 years (Figure 4). This indicates that there may be human impacts in the section where the road meets the coast that are exacerbating erosion.

3.4 Site observations

The intertidal beach at Tabon-te-bike showed an upper beach of sloped coarse unconsolidated sub-angular beach sand, marked by shell lines recording the higher tide levels and significant swash marks of the falling tide, and in which at very low tide groundwater outflow rills could be seen towards the base. At this point there was a break in slope to extensive sand flats offshore with an intertidal exposure that extended about 200 m offshore. This lower intertidal sand was finer and more consolidated, and with regular tidal pools, the near shore area having green algal cover.

Where the road turns at the coast, the shoreline featured erosion as indicated by scarps in the sand and a concave-up profile, extending from the southern access point from the village road to the beach (called site 1a). High tide mark on the beach was very close to the vegetation edge, and the main access track showed trampled vegetation with damaged grass blades, with open sand with many footprints.

To the south of this 56 m erosion section at site 1a (Figure 2), there was a similar length of beach with the same orientation, but no evidence of erosion, with denser littoral vegetation inland. This indicated that human access is a contributor to the erosion issues adjacent. The littoral vegetation was dominated by *Premna serratifolia* (Te aroma) (Thaman 1987) and a 5 petal yellow flowered shrub, most likely *Turnera ulmifolia*, a naturalised shrub weed introduced to Tarawa (Space and Imada 2004).

3.5 Site 1a Transect survey

A cross sectional profile of the beach was surveyed at Site 1a using a tripod, level and calibrated staff, on 18th September 2013. The location of this site 1a transect is shown in Figure 2. The compass bearing of the transect surveyed was 265° magnetic from the temporary benchmark looking down the transect to offshore. The tripod was set up on the transect line, 14.3 m from the roadway oblong rock used as a temporary benchmark, which is shown in Figure 5. Results are shown in Table 1.

Figure 5. Profile of transect surveyed at Tabon-te-bike site 1a.

Table 1. Survey results from site 1a, 18th September 2013. *Change in height = back sight-fore sight

	Back sight (m)	Fore sight (m)	Distance (m)	Change in height* (m)	Notes
1	1.641		0		To oblong rock in centre of road
2		1.448	15.7	0.193	Top edge of grass, and top of break of slope from road level to down beach
3		1.573	17.2	0.068	Mid grass area
4		1.729	18.7	-0.088	Base of grassed erosion area
5		2.075	21.1	-0.434	Top of dry beach sand
6		2.555	25.6	-0.914	Down beach
7		2.987	30.8	-1.346	beach
8		3.291	34.6	-1.65	Change from beach to flat level sand offshore of beach
9		3.524	36.4	-1.883	To edge of smooth sand and hummocked sand offshore

The beach profile shown in Figure 5 has a flat to concave-up shape in the intertidal part of it towards the right, which is indicative of a beach that is eroding (Bird 2008). The GIS analysis (Figure 4) showed the erosion had resulted in a vegetation retreat rate of 3 m a^{-1} 1998-2003, and 0.7 m a^{-1} 2003-2013.

3.6 Remedial options trialled

The most effective adaptation to beach erosion is to try to remove the cause of the problem, or make the site more resilient to that cause of erosion. Beach vegetation disturbance was apparent particularly at the access points, with the beach to the south having similar conditions but not eroding, there having reduced human access. Fences are often necessary to control access and protect unstable or fragile coastal sediment and vegetation from damage by people or vehicles (Page and Thorp 2010). Restriction of human access across the eroded area upper beach along with vegetation replanting was trialled to make this site more resilient to erosion processes, and allow vegetation that fosters beach sediment accretion to recover.

On the main beach access at Tabon-ke-bike, members of the Buariki village community learned of the objective and asked about the dimensions of the area to be fenced, and obtained the necessary materials of poles and rope. The fencing was constructed at the end of the road from the village, across the upper beach slope (Figure 6).

Figure 6. A) Access control constructed by community members at Tabon-ke-bike site 1a. **B)** *Pandanus tectorius* and *Calophyllum inophyllum* wilding seedlings planted inside the enclosures.

Pandanus tectorius (Te kiana) and *Calophyllum inophyllum* (Te itai) (also known as *Alexandrian laurel*) wilding seedlings were collected from underneath parent trees where they would not have had enough light to thrive had they remained. These were planted inside the enclosures, using techniques suited for trees that will grow tall, including deep holes and organic matter layers. The *Calophyllum inophyllum* seedlings measured to the top of stem for future monitoring of growth.

It was decided that because such beach access control (Figure 6) is new in Kiribati, it would be good to introduce a name for it that included in the name the values of why it was done. This would circumvent resistance to change and allow instant understanding among the community regarding the objectives. This was explained to the Buariki community in the meeting house at Buariki, requesting something meaning "beach protection gateway" or the like, and it was decided to have a competition for nominations that evening. Nominations are shown in Table 2.

Table 2. Buariki community nominations of a new name for beach protection access control.

Order received	Kiribati name	Meaning	Votes
1	Bikeriki	Beach reclaim	3
2	Bikenboriki	Beach has eroded, faced challenges and storms; there is hope of getting it back	7
3	Buariki tabonario	This village, the paradise	5

3.7 Road margin to the north -Site 1b

The erosion extended from Tabon-ke-bike site 1a towards the north, as far as the road is close to the shore (Figures 2 and 4). A group of houses are located on the inland side of the road, and there was an access track opposite this with footprints and motorbike tracks onto the beach. This section (called site 1b) the grass on the seaward side of the road was only 20-60 cm wide before a 30-50 cm scarp from the road level down to the upper beach. This narrow section is fragile being composed of unconsolidated sand, though has a dense grass cover on about 50% of it.

3.7.1 Site 1b Transect survey

A cross sectional profile of the beach was surveyed at Tabon-te-bike Site 1b using a tripod, level and calibrated staff on 12th October 2013. The location of this survey transect is shown in Figure 2. The transect compass bearing was 262° magnetic from the benchmark to offshore, and the temporary benchmark recorded was on a concrete slab, a point on this aligned with back edge of a water tank base to the east (Figure 7). This was located landward of a home, and 6.60 m from water tank's nearest corner. The concrete slab had frayed edges so measurement to the edges was not made. Results are shown in Table 3.

Elevation benchmarks were not available, so MSL position was estimated by comparison of the water level as measured at 1329 that day with the water level recorded that minute on the Betio SEAFRAME tide gauge, using the technique explained in section 5.3 of the Plan- "Beach erosion: Ecosystem based adaptation monitoring plan" that is also an output from this project (Ellison 2014a). Figure 7 shows elevation relative to the Betio tide gauge data datum.

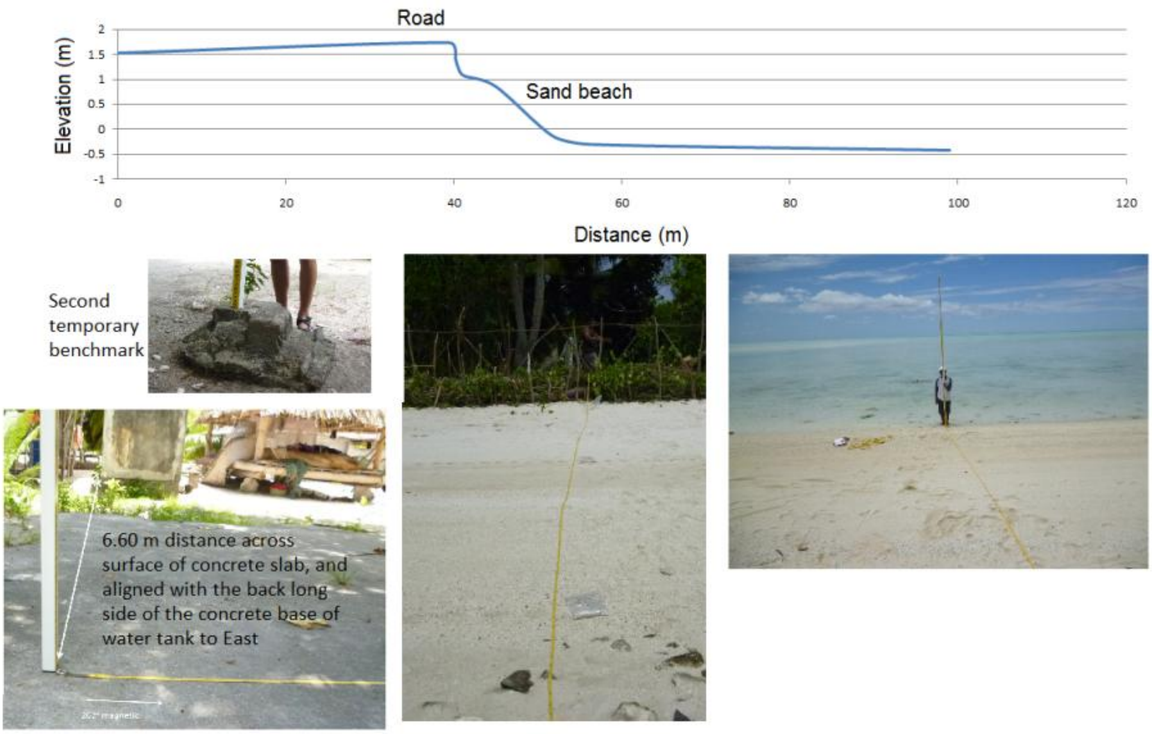

Figure 7. Profile of transect surveyed across the road margin at Tabon-ke-bike (Site 1b).

Figure 7 shows a concave-up shape to the beach profile in the intertidal part of it towards the right, which is indicative of a beach that is eroding (Bird 2008). The GIS analysis (Figure 4) showed the erosion had resulted in a vegetation retreat rate of 3 m a^{-1} 1998-2003, and 0.7 m a^{-1} 2003-2013.

Table 3. Survey results from site 1b, 12th October 2013. *Change in height = back sight-fore sight

	Back sight (m)	Fore sight (m)	Distance (m)	Change in height* (m)	Notes
1	1.573				To concrete slab centre.
2	1.457		18.1		Offsight to concrete block
3		1.367	39.5	0.206	To outer edge of road
4		1.682	40.2	-0.109	To top of grass above cliff
5		1.854	40.5	-0.281	To base of cliff
6		2.028	41.2	-0.455	To top of beach
7		2.246	45.0	-0.673	To mid beach
8		3.246	51.85	-1.673	Base of sloping dry coarse beach
9		3.408	56.34	-1.835	Water level 0.164 m at 1324 (waves pushing water level up and down. To base of flatter sand but sloped beach
10		3.525	99.0	-1.952	Water level 0.282 m 1329 (calmer) To outer edge of algae and hummocky offshore

3.7.2 Remedial options trialled

At Site 1b, ecosystem rehabilitation options have been recognised to be the best option (Juillerat 2013), including revegetation and access control. It must be recognised however that this site has previously experienced some 200 m of erosion, and there is now less than 1 m left as a buffer between the road and the beach, it would have been better to have at least 5 m for these trials. The section adjacent to the road was too narrow to risk tree planting, as a hole may cause the seaward side to drop off and so leave not much left. Truck tracks indicated that vehicles were also driving close to and even over the grass of the vulnerable edge. It was decided to prune the bushes on the landward side of the road that the trucks were swerving seaward to avoid (Figure 8).

In September 2013, brush cut from the landward side of the road was laid alongside the base of the eroding cliff, and held in place with stakes (Figure 8). This was a temporary trial that one month later proved to be successful, with accretion of sand in the upper beach having occurred in the previous month. This adaptation is a modification of the “Revegetation in coastal areas Guidelines G-7.3” of Page and Thorp (2010), who described use of seed laden brush laid on the sand, to trap sand, and also prevent human access to fragile or rehabilitated areas. At site 1b, brush placed below the eroding cliff is intended to also reduce wave action as well as trap sand.

Figure 8. Site 1b at Tabon-ke-bike looking south in September 2013. **A)** Before, vegetation on the left of the picture is pushing traffic onto the narrow grass edge of the beach. **B)** After, vegetation was cut back along where the children are standing, and a temporary barrier placed along the grass edge of the beach to prevent human access.

In October 2013, the temporary brush barrier was rebuilt to be a more secure structure, also the road edge fenced to prevent human or traffic access over the fragile grass edge (Figure 9). Traditional coconut string was used to lash poles, thought to have a usage timeframe of about 2 years. The green leaves that can be seen in the barrier at the beach cliff edge (Figure 9) is just because the brush is fresh cut, it later browned off (Figure 10). Care was taken not to cover or disturb the live grass.

Figure 9. Site 1b at Tabon-ke-bike in October 2013, after the brush wave barrier was made more substantial, and the read edge was fenced to control disturbance.

Figure 10. Site 1 about a month after the EbA trials were commenced, these photos were taken by Arawaia Moiwa.

Seedlings of beach vines such as *Ipomoea pes-caprae* (Te ruku) are to be planted when ready on the grass edge at the road side site 1b, and encouraged to grow out over the brush, so further trapping sand.

3.8 Further work and maintenance

At both sites

- Removal of any logs/ debris that may wash over an damage rehabilitation/ replanting works at high tide.

At Site 1a

- Watering of beach seedlings by local community.
- Monitoring of seedling growth or mortality, replacement if mortality occurs.
- Transect re-measurement at about 12 month intervals to show erosion or accretion.
- A more secure benchmark needs to be installed or selected, and the road rock (Figure 5) related to this new benchmark by survey.

At Site 1b

- Seedling planting, of vines using a smaller planting hole than that needed for trees so reducing risk to the <1 m of ground remaining. Preparation for example of Te ruku takes 3 months, so undertake planting these along the grass edge when possible, watering them and encouragement to grow out over the brush.
- Watering of beach seedlings by local community.
- Monitoring of seedling growth or mortality, replacement if mortality occurs.

- Transect re-measurement at about 12 month intervals to show erosion or accretion.

Details of these techniques are given in the Beach erosion: Ecosystem based adaptation monitoring plan (Ellison 2014a).

4 Central lagoon coast of Nooto

4.1 Introduction

Kiribati became a signatory to the Ramsar Convention earlier in 2013, with its first gazetted site at Nooto in North Tarawa (Figure 11). This 1,033 hectare Ramsar site includes windward and leeward coasts of the atoll, and mangrove margins and internal lagoons, and is habitat to a number of rare and threatened wetland species (Teariki-Ruatu 2013). These species include the endangered Green Turtle *Chelonia mydas* and the vulnerable Giant Clam *Chelonia mydas*, and the near threatened bonefish *Albula vulpes*. Other faunal species that inhabit the different habitats at the Ramsar site include Coconut crabs (*Birgus latro*), mangrove crabs (*Scylla serrata*), trochus (*Trochus niloticus*) - a marine snail, sea cucumbers (*Holothuria atra*), and a variety of reef fish, sharks, and four species of giant clams (*Tridacna spp*.), including the vulnerable *Tridacna gigas* (Teariki-Ruatu 2013).

There has been little assessment to date of the biophysical conditions of this new Ramsar site, and with the Kiribati Government's Environment and Conservation Division a reconnaissance was made of the condition and management needs of the lagoon shore of the Ramsar site (Figure 12), which was prioritised because human habitation was denser on this coast.

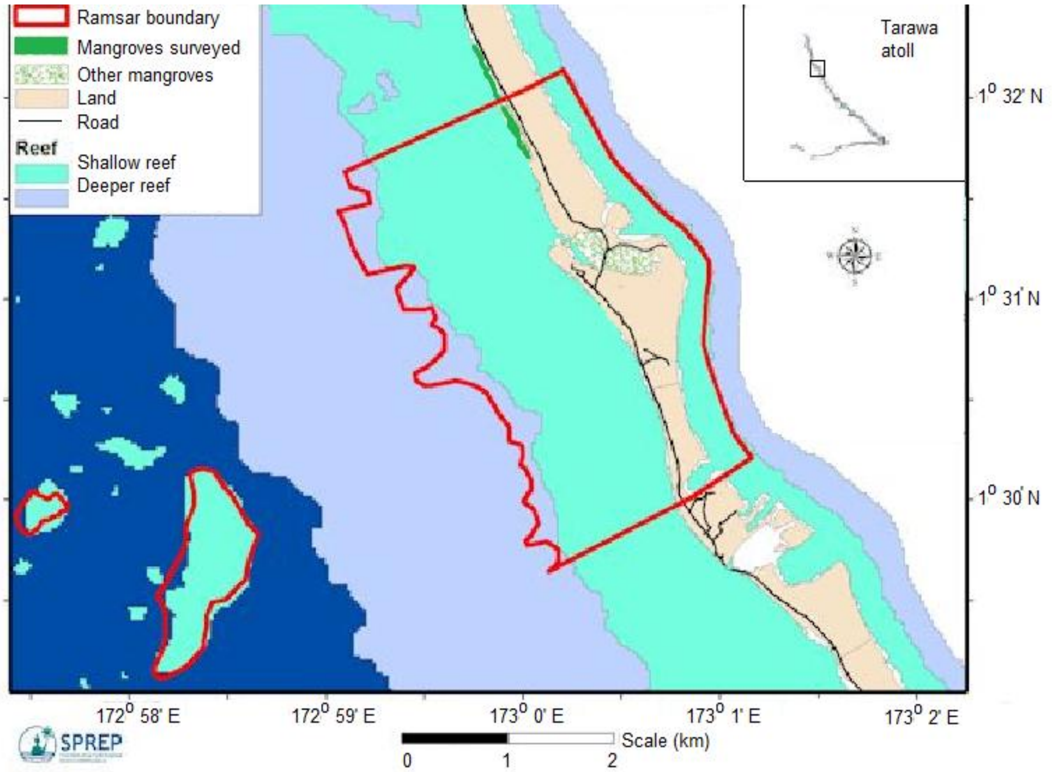

Figure 11. Map of the Nooto Ramsar site. Adapted from the SPREP map on the Ramsar website- Kiribati's first Ramsar site http://www.ramsar.org/cda/en/ramsar-news-archives-2013-kiribati-nooto/main/ramsar/1-26-45-590%5E26198_4000_0_

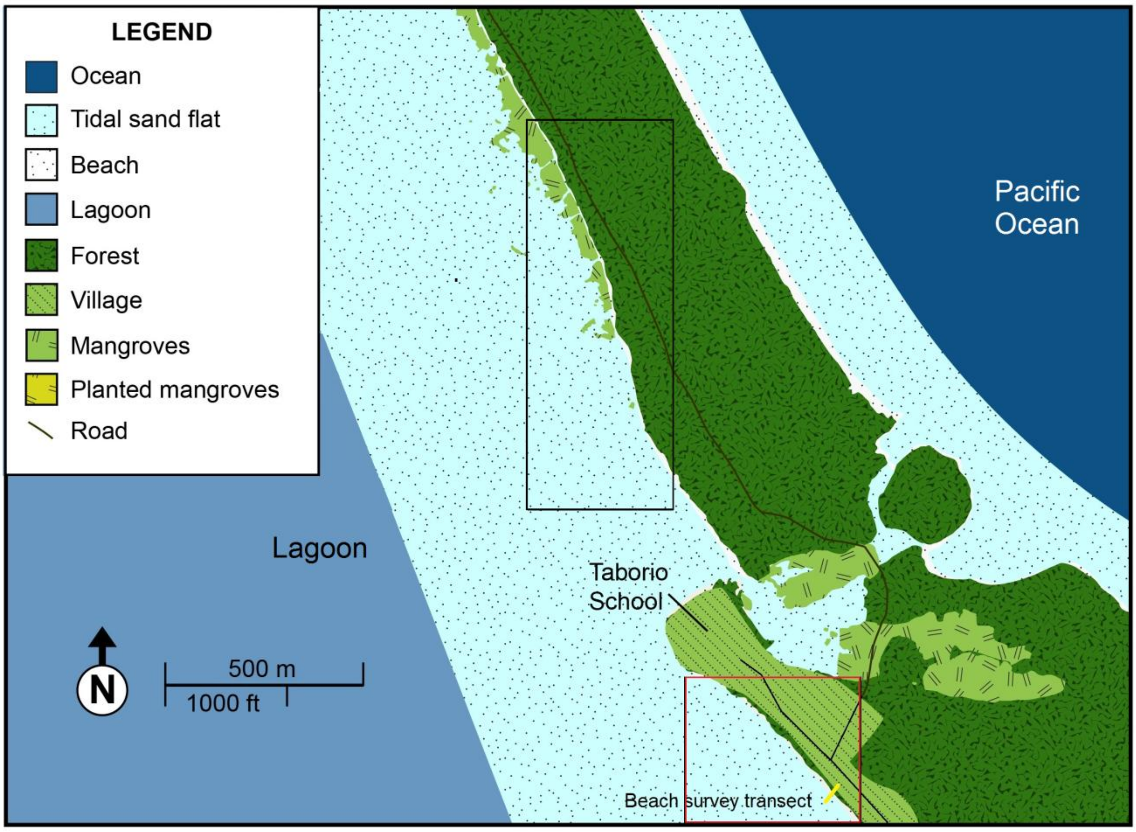

Figure 12. Map of vegetation and landuse of Nooto, showing GIS and beach survey locations.

4.2 Spatial change analysis

Existing spatial change analysis of the site (Biribo and Woodroffe 2013) was out of date by 15 years, so a new analysis was undertaken using historical and most recent imagery. Satellite imagery from 2003 and 2013 was obtained as part of the project, and digital aerial imagery from 1998 was obtained from the Department of Lands, Government of Kiribati. Images were rectified using GPS points taken in the field, and the shoreline edge delineated using the vegetation edge. Results from the red box area in Figure 12 are shown in Figure 13.

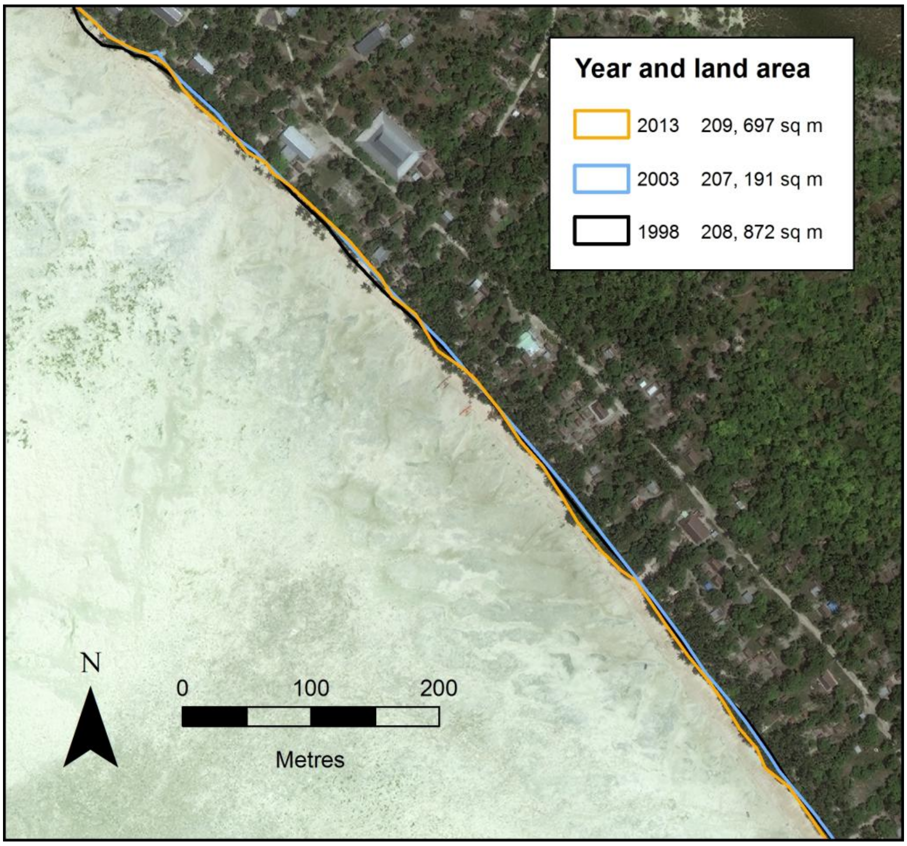

Figure 13. GIS analysis of shoreline change 1998-2013 at Nooto Ramsar site southern lagoon shore beach, of the southern red box area shown in Figure 12. The background image is 2013, and the land area calculations are based on the land area shown in the image.

Spatial change analysis results and land area calculations (Figure 13) show that this section of the coast has been been largely stable in the last 10 years, whereas results from 1968-1998 showed it to be accreting (Biribo and Woodroffe 2013). The beach shoreline of the northern lagoon shore of the northern box area shown in Figure 12 was also analysed by GIS for comparison with the southern village section, and results are shown in Figure 14. This analysis focussed on the beach of the northern section, and change in the mangrove cover is discussed in a separate report from this project (Ellison 2014b)

Figure 14. GIS analysis of beach shoreline change 1998-2013 at Nooto Ramsar site northern lagoon shore beach, of the northern black box area shown in Figure 12. The background image is 2013, and the land area calculations are based on the land area shown in the image.

Results of spatial change analysis 1998-2013 (Figure 14) showed that the beach shoreline to the north of the inner lagoon entrance (Figure 12) has prograded over the last 15 years in the central section of the area analysed, and has been largely stable to the north and south of the area analysed. The progradation in the centre of Figure 14 has been fairly rapid, at a rate of about 3 m a^{-1}.

4.3 Field observations

A reconnaissance of beach condition of the southern lagoon beach (Figures 12 and 13) commenced at the meeting house at 01^{o} 30.898’ N; 173^{o} 00.438’ E located to the south of the road junction, and extended towards the north to the rock point north of the Taborio Catholic secondary school at 01 31.243^{o} N; 173 00.120^{o} E (Figure 12).

The entire section of beach showed human impact (Figure 15), including:

- human trampling of beach edge vegetation
- low biodiversity of beach edge vegetation
- access pathways causing vegetation-free gaps along the beach vegetation edge
- poor vegetation density and diversity along the upper beach
- concave and narrow sections of beach
- pigs tied to beach edge trees digging up sand and causing disaggregation and erosion
- sand mining hollows on the upper beach at about the level of the absent vegetation line
- some informal seawalls disrupting beach natural conditions
- a large coral/ beachrock constructed seawall alongside the Catholic secondary school
- cans and other rubbish all along the beach particularly offshore of the school’s seawall
- human faeces on both the open beach and on rocks offshore of the secondary school.

Figure 15. Central open beach section of the lagoon shore of the Nooto Ramsar site.

The beach shape showed poor accretion with flat to concave-up profiles in some sections. The beach was narrow, and the high tide mark was close to the top of the beach slope.

Offshore was evidence of previous mangrove planting efforts, with 3000 planted south of the meeting house in 2007, extending offshore of the beach to some 30 m, and a further 1000 were planted about a year later in several sections towards the Catholic school (Arawaia Moiwa, pers. communication). All of these planted seedlings did not develop into trees, and suffered mortality with just a few remaining as seedlings and showing no growth.

4.4 Beach profile

In order to evaluate the beach shape, and to provide a baseline for future monitoring, a profile was surveyed on the beach behind the village meeting house, at 01° 30.898’ N; 173° 00.438’ E. This section was heavily trampled by people, and loose pigs were also around, such that ground vegetation was minimal.

A concrete block at village level behind the beach slope was selected as an elevation benchmark, to allow the profile to be re-surveyed in future. The point chosen was the exact centre of its diagonals (Figure 16). Survey results are shown in Table 4. The transect commenced between the two *Cocos* trees in from of this, with a magnetic bearing of 225° from the slab to offshore.

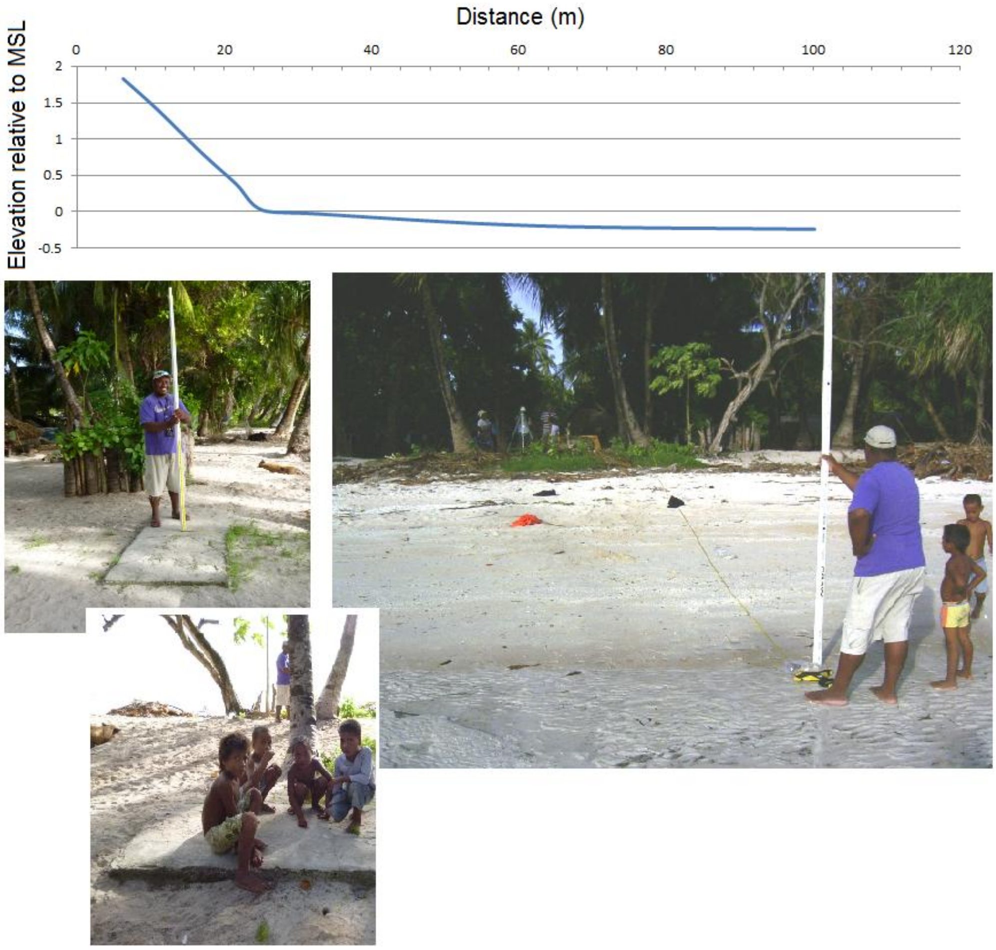

Figure 16. Surveyed beach profile on the lagoon shore at the Nooto meeting house.

Table 4. Transect survey data from Nooto, 13th October 2013. Transect compass magnetic bearing: 225° from beach to offshore.

Site No.	Back sight (m)	Fore sight (m)	Distance (m)	Change in height (m) (back sight-fore sight)	Notes
1	1.414		0	1.414	To centre of concrete block at seaward edge of houses
2		1.510	6.3	-1.51	To top of beach, recording village height
3		1.939	11.0	-1.939	Beach slope commences, finer sand
4		2.544	17.1	-2.544	Shell line at high tide mark, coarser sand
5		2.956	21.62	-2.956	Lower beach, tidal flat upper edge
6		3.319	25.22	-3.319	Consolidated tidal flats, fine sand
7		3.372	32.8	-3.372	
8		3.535	62.3	-3.535	
9		3.582	100.2	-3.582	Water level 1702

Elevation benchmarks were not available, so MSL position was estimated by comparison of the water level as measured at 1702 that day with the water level recorded that minute on the Betio SEAFRAME tide gauge. This technique is explained in section 5.3 of Ellison (2014a), and section 5.2 of that Plan uses results from Nooto (Table 4) to demonstrate how to do beach profile data analysis. Figure 16 shows elevation determined in this manner relative to the Betio tide gauge data datum.

4.5 Recommendations

The spatial change analysis found that while the south Nooto lagoon beach was advancing seawards with accretion 1968-1998 (Biribo and Woodroffe 2013), after 1998 the beach position showed no further beach progradation (Figure 13). Reconnaissance carried out in October 2013 found that the beach has evidence of decline in beach values (Figure 15) and indications of erosion with a concave-up beach profile (Figure 16). This reconnaissance can identify some priorities for management of the southern lagoon beach at Nooto:

1. The beach condition would be improved by a community education program that informs residents about beach values, how these are sustained, and what actions that can be undertaken to increase beach values such as biodiversity and sediment accretion. This needs to be targeted at both the adult and school community, with the objective of reducing the human impacts on the beach identified in section 4.3. Conceptual diagrams on beach values, beach damage and beach management have been developed as part of this project.
2. The beach could be rehabilitated using access control and vegetation planting, to reduce erosion and enhance accretion and biodiversity.
3. The beach profile (Figure 16) should be re-surveyed at about 12 monthly intervals to monitor erosion or accretion, and other beach profiles added to the monitoring program,

spaced at regular intervals towards the north and south. A feasible spacing would be one about 300 m to the north half way between the meeting house and the Catholic school, and at similar spacing towards the south. Technical guidance for how to survey a beach profile is provided in the Beach erosion ecosystem based adaptation monitoring plan (Ellison 2014a).

5 North of Abaokoro Bridge

This site (Figure 1) was mentioned in the reconnaissance report (Otiawa 2013) because of issues with the bridge channel silting up, and the Buariki village community wanting to have it made more usable for boats at all tides. No erosion issues of concern were reported, however an erosion site is present north of the bridge, 01^{o} 29.710' N, 173^{o} 00.938' E, with a 40-60 cm erosion vertical scarp extending along a c. 100 m length of beach (Figure 17), located on the lagoon side of North Tarawa. There are houses and boats moored at the western end of a 100 m stretch. This erosion scarp is cut into an older level surface that extends inland to the road and is vegetated by open *Cocos nucifera*, *Scaevola taccada*, and a tufted grass possibly *Eleusine indica*, with *Terminalia catappa* and *Pandanus* at the closer to the causeway end.

Figure 17. Eroding beach describe with the lagoon passage of Abaokoro Bridge in the background.

Below the scarp is loose calcareous beach sand with intact bivalves and whorl shells, and along most of the stretch the high tide wave mark is reaching just below the scarp. There is evidence of higher water washout from the scarp, leaving roots exposed with the finer organic sand of the platform material eroded out. This shoreline erosion has resulted in resilient trees of *Cocos* and *Calophyllum inophyllum* being undercut and near islanded. The intertidal beach profile however is convex-up, and there is a large accumulation of sand at the mouth of the passage over which the bridge is constructed. Longshore drift at this site appears to be East to West, and it is possible that the strong currents through the bridge causeway may be causing eddy deposition to the west, that is partly blocked from free movement by a beach rock outcrop the west of the sand buildup and the causeway.

5.1 Further work and maintenance

If this site is a priority, then the following could be undertaken:

- Community consultation
- Spatial change analysis of trends of erosion, to identify rates of erosion and causes
- Beach profile survey and later re- measurement to monitor erosion or accretion
- Beach vegetation replanting and reduction of human disturbance factors.

6 Conclusions

Spatial change analysis at Tabon-te-bike confirmed that beach erosion west of Buariki village has been ongoing over the last 15 years, with re-curvature of the sand spit showing that this was partly related to changes in prevalent winds and currents. However, erosion was shown to be greater at access points, indicating the ecosystem based adaptation has potential to reduce erosion rates. At Nooto lagoon beach, some deterioration of beach condition was found, combined with a loss over the last decade of the beach progradation trend that had previously occurred up to 15 years ago.

Use of low cost beach ecosystem adaptation options of community education, access control, beach vegetation replanting and brush protection wave barriers give potential to reduce beach erosion and increase beach values in the Pacific islands region. Conceptual diagrams on beach values, beach damage and beach management have been developed as part of this project, and the design of these has been intended for use in helping community education. The village communities involved in these trials showed enthusiasm, inventiveness and engagement, showing that there is potential for the application of Pacific islanders' traditional skills in construction and plant nurturing to increase the resilience of beaches to erosion pressures.

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9 List of Acronyms

EbA	Ecosystem based Adaptation
ECD	Environment and Conservation Division, Kiribati Government
GIS	Geographic Information Systems
GPS	Global positioning system, refers to handheld device that records position
ICCAI	International Climate Change Adaptation Initiative
$m\ a^{-1}$	Meters per year
MSL	Mean Sea Level
Ramsar	Convention on Wetlands of International Importance
SEAFRAME	Sea Level Fine Resolution Acoustic Measuring Equipment
SPREP	Secretariat of the Pacific Regional Environment Program