THE MAJOR CAUSE OF OBSERVED EROSION SURGE ON THE BEACHES NORTH OF DAR ES SALAAM CITY

N Nyandwi
Institute of Marine Sciences, P. O. Box 668, Zanzibar – Tanzania
e-mail: nyandwi@ims.udsm.ac.tz

ABSTRACT

Surges in coastal erosion north of Dar es Salaam city have been documented from 1977 to the early 1980s and around 1997/98. Analysis of the wind data shows that the documented increase in coastal erosion coincided with increased wind speeds. Extreme winds in excess of 10-11 m s^{-1} were experienced during 1976-78, 1984 and after 1996. Their coincidence with extreme high tides produced the high erosion rates. Using beach profile data for the years 1998-2000 the evolution of the beach profile with the changing monsoon winds and sediment input by rivers could be demonstrated. The beach erosion took place during the Southeast Monsoon when the alongshore sediment transport is northwards. During the Northeast Monsoon, the reversed transport is smaller to rebuild the beach. In this study incipient seaward shoreline shift was observed towards the end of the 1999 SE monsoon period and subsequent monitoring revealed a seaward shift by the end of the next NE monsoon. The shift of the shoreline was attributed to a redistribution of the large volumes of fluvial sand that was supplied during the El-Nino rains of April/May 1998. With the drop in annual wind strengths, coastal erosion has since stabilized.

INTRODUCTION

Coastal erosion is a serious environmental problem along the East African coast including Tanzania. The exact cause of the problem has for a long time remained uncertain. Studies on coastal erosion in Tanzania have concentrated mainly on the description of the situation at areas affected by the problem e.g. Dar es Salaam area (Alexander 1966, 1968, 1969, Mushala 1978, Schiller and Bryceson 1980, Rossi and Ange 1986, Beach Erosion Monitoring Committee 1987), Maziwi Island (Fay 1992) and Zanzibar Islands (Rossi and Ange 1986, Nyandwi 1990, Nyandwi and Muzuka 1991, Mohamed and Betlem 1996, Nyandwi 1996). Some publications give a general country overview of the erosion problems (Arthurton 1992, Shaghude *et al*. 1994). Several causes of coastal erosion have been proposed by some of these workers as follows; coastal tectonic uplift (Alexander 1966, 1968, 1969), sea level rise (Fay 1992), and changes in hydrodynamic conditions such as long-shore drift (Arthurton 1992). The Work by the Beach Erosion Monitoring Committee (1987) establishes the status of various factors thought to contribute to the erosion problems including sand mining from riverbeds, meteorological conditions, hydrodynamics as well as geomorphological response of the beaches. The relative importance of the various causes or any major cause of the observed erosion however, has not been determined. Starting April 1996 studies by researchers of the Institute of Marine Sciences and the Department of Mathematics of the University of Dar es Salaam have been carried out with the aim of understanding the cause of excessive beach erosion at Kunduchi and generating baseline data for the design of mitigation options. Dubi and Nyandwi (2000) conducted some preliminary studies for the mitigation of coastal erosion at Kunduchi beach and Nyandwi (2001a,b) evaluated the various causes of coastal erosion including anthropogenic causes but again the leading cause was not clearly identified. Implicitly, it appears that sealevel rise and coastal tectonic uplift are generally of regional to

global effect thereby leaving the changes in hydrodynamic conditions as the effective cause on the short term and at local scales. This work looks at the potential of the extreme winds as the major cause of the alarming erosion rates north of Dar es Salaam.

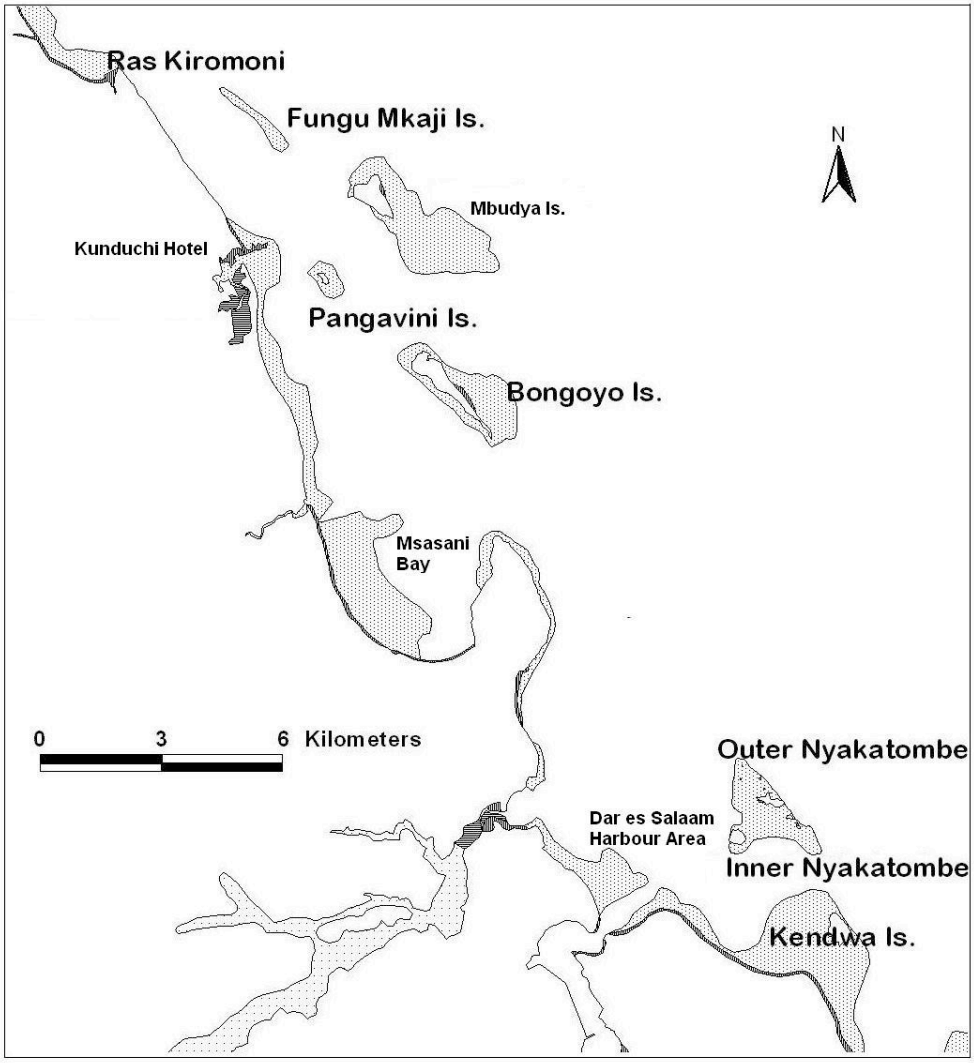


Figure 1: Kunduchi – Msasani beach where erosion surges are reported

LOCATION AND GEOMORPHOLOGY

Kunduchi Beach is located on the Tanzania mainland coast, approximately 24 km north of Dar es Salaam City (Fig. 1). The Dar es Salaam coastline is characterised by an invariably developed fringing reef (Temple 1970). The entire coastline of Tanzania is characterised by fringing reefs except in the vicinity of river mouths, where there is a

seasonal increase in suspended sediment, falls in salinity, radiant energy and light intensity. Inshore reefs are absent or poorly developed where the coastline is formed of sand barriers such as those found at Kunduchi. Most reef flats are not coral at all, but calcite-cemented calcareous sands or beach rock. In the vicinity of Kunduchi area, there are small rock outcrops, like those found at Bahari Beach and extensive rocky shores at Ras Kankadya. Off kunduchi Beach, there are three reef islands, Mbudya, Pangavini and Bongoyo (Fig. 1), with a core of raised coral reef. Temple (1970) found that the raised reef rock and the surrounding inter-tidal reef appear to have an interesting relationship in terms of location relative to each other. The raised reef is located on the northwestern sector of the inter-tidal flat. The asymmetrical disposition can be related to some physical control, which is probably the dominant south-east trade winds and the waves generated by them (Temple 1970). The coast of Tanzania is influenced by the northerly and southerly trade (monsoon) winds. From May to October, the southeast trade winds blow with great strength and constancy of direction. The northeast winds are weaker and blow from November to April. There are two short transition periods between the two seasons. Generally, winds blow from the east during the afternoon, centred around 15 hrs.

The main morphological features of the area are the beach-ridge complexes, which form backshore terraces and the extensive tidal flats with irregular sand deposits or bars. The most distinctive feature is a sand-spit, which is located immediately north of the outlet of the Manyema tidal creek. The spit is highly dynamic, changing in shape and orientation over the years. Six streams, whose valleys are quite steep and rising from the heavily dissected higher ground of Tertiary clay-bound sands and gravel, drain the coastal plain surrounding Kunduchi Beach. The streams pass through the level plain of Holocene sediments. The underlying sediments are easily eroded because of poor consolidation. The rivers are expected to transport huge amounts of sand during the peak periods of flow. Peak period of river flow is between March-May, which is the peak of the rainy season. Short rains occur also in October and November (Newell 1957).

The economic activities of coastal community in Tanzania are mainly associated with ocean resources, largely fishing. It has been urged that some fishing methods such as dynamite fishing destroy the coral reefs and enhance erosion. Other uses of the ocean and nearshore resources in the area include salt pans for salt extraction and sand extraction from stream beds. Coastal erosion has in some cases been described as being excessive due to these activities.

Big investments in tourism industry and expensive homes are found along Kunduchi beach and neighbouring beaches. Many of the tourist hotels are already threatened by erosion. Hotel Africana (situated to the south of Kunduchi Beach Hotel) which was built on a sand plain had more than 50% of its residential huts lost by the late 1980's. The Kunduchi Beach Hotel, built in the 1970's on a sand plain, was already within less than 2 m of the fast encroaching sea before it was reclaimed in 1998. The hotel was built in the 1970's. Hemed (1987) found that beaches like the one in front of Silver sands hotel experienced bouts of erosion and accretion in successive periods of 33 to 35 days.

Kunduchi beach lies in an area where the continental shelf width increases rapidly seawards to include the Islands of Unguja and Mafia. At Ras Ndege, approximately 20 km south of Dar es Salaam, the 200 m contour, which indicates the approximate edge of the continental shelf, lies only 3 km offshore, while at Kunduchi the 200 m contour lies 16 km away and therefore, the intermediate area consists of relatively

shallow water. The Zanzibar channel, which separates Zanzibar from the Mainland, has depths hardly exceeding 60 m at the northern and southern entrances, while the mean depth of the channel is 20 m. From the Admiralty Chart of 1954, as one approaches Dar es Salaam, recognises submarine trenches in the inner shelf. The two most important submerged channels off the coast of Dar es Salaam that link to the Kunduchi area are 15 m deep each running almost parallel to the coastline and passing between the two small islands of Pangavini and Mbudya. They branch into a shallower channel, 10 m deep, that passes between the coastline and Pangavini. These channels may be important in directing offshore waves.

MATERIALS AND METHODS

The study involved evaluation of existing documents including maps, interviews with coastal inhabitants and hotel personnel, and complimenting with field beach profile data. Existing wind data reports were also assessed for any pattern in wind variability. Old people in the villages were asked on their experience as to when erosion was first experienced and where according to their recollection was the shoreline during the past decades. Hotel personnel were asked as to since when did they start to be concerned with the problem and what was the pattern. Reports of various studies that were commissioned by the government were consulted. Beach profiling was done using engineer's level and leveling rod (Hemed 1987) while shoreline change was measured from repeated shoreline fixing. A temporary benchmark was established near the shore which was used as reference point from which repeated profiles started. The profiles were measured down to the lowest water on low water springs. The collected information was analysed for any temporal pattern in the erosion process. The pattern of erosion of the beach in relation to the monsoon periods was documented using beach profiles.

RESULTS

Wind patterns

According to Lwiza (1987) wind speeds varied between 1.5 m s^{-1} and 8 m s^{-1} with an average of 5 m s^{-1} during the northeast monsoon period whereas the southeast monsoon winds had an average speed of 8 m s^{-1} and blew mainly from the south. Wind speeds in excess of 8 m s^{-1} were considered significant in causing excessive erosion. Analysis of the wind data for the Dar es Salaam area (Fig. 2) shows the yearly maximum wind speed to vary between 8 and 13 m s^{-1} with extreme winds in excess of 11 m s^{-1} occurring in 1976-78, 1984 and 1996. On a monthly basis, such extreme wind speeds occur during February, April and July (Fig. 3).

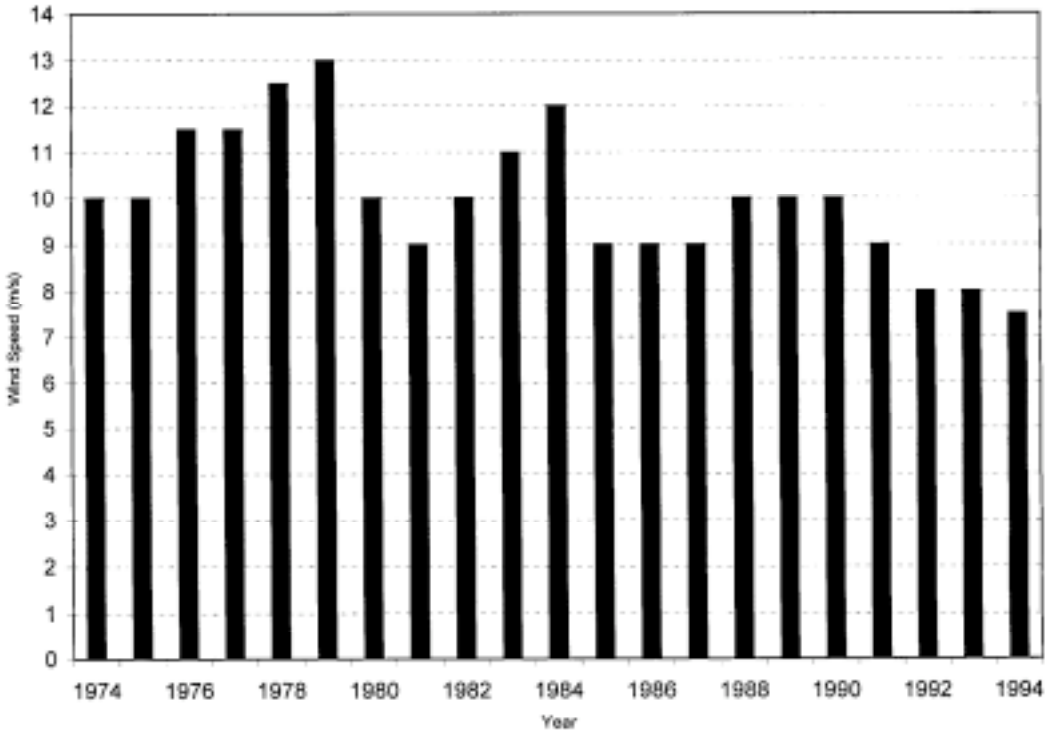


Figure 2: Annual maximum wind speed over 1974 –1994

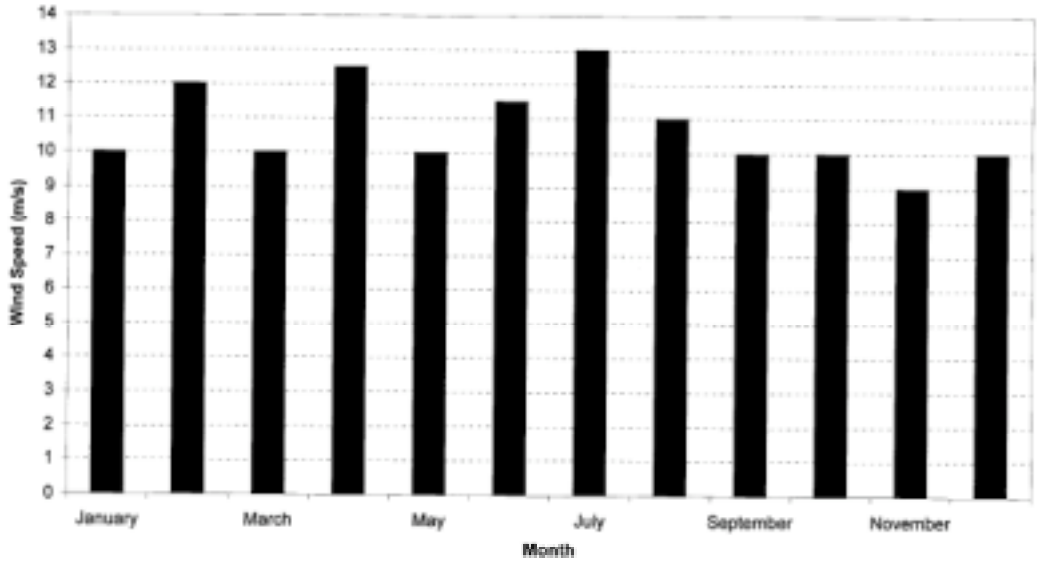


Figure 3: Monthly maximum wind speed between 1974 and 1994

Erosion pattern

Documentary evidence from various reports and interviews with coastal community show that concern on erosion started in 1977 following wave attack at Silversands Hotel. By 1980 concern was raised at other beach hotels including Kunduchi Hotel and Hotel Africana. The reports of the studies commissioned by the owners of the tourist hotels and other infrastructures seem to coincide with erosion events as shown in Table 1. An overlay of map series for the years 1962, 1982 and 1992 shows the shoreline migration over the 30 years period revealing serious erosion in the vicinity of the Kunduchi Hotel and the Manyema creek while accretion is shown towards the entrance of Tegeta river (Fig. 4). On yearly basis, the shoreline monitoring between 1999 and 2000 shows erosion at both Kunduchi Hotel and the entrance to River Tegeta (Fig. 5). In the central part of the shoreline stretch there was a seaward shift of about 5m. From the beach profiles it was noticed that erosion predominated on the upper beach while deposition took place on the lower part and on the tidal flat especially during the SE monsoon period (Fig. 6). Closer observation of the NE monsoon beach profiles (Fig. 7) reveals some deposition in the lower portion of the beach slope.

Table 1: Periods of increased coastal erosion as reflected by commissioned study reports.

Year	Report	Study Area	Client
1977-80	Bryceson, I. & Stoemer, K.P. (1980). Recommendation for Beach Erosion control at Silversands Hotel.	Silversands Hotel	University of Dar es Salaam
1985	Norman, J. O. (1985). Project proposal on control of coastal erosion in the recreational area north of Dar es Salaam.	Area north of Dar es Salaam	Department of Minerals, Lands, Housing and Urban Development, Dar es Salaam
1986	Rossi, G. and St. Ange, K. (1986). Report on coastal erosion in Zanzibar and north of Dar Es Salaam.	Kunduchi Beach Hotel, Hotel Africana	Ministry of Lands, Housing and Urban Development
1987	Beach Erosion Monitoring Committee, (1987). Beach erosion along Kunduchi beach, north of Dar Es Salaam.	Msasani Bay to Bahari Beach Hotel	National Environment Management Council
1997-99	Dubi, A. M. & Nyandwi, N. (2000). "Preliminary Studies for the Mitigation and Control of Coastal Erosion at Kunduchi Beach, Dar es salaam".	Kunduchi	University of Dar es Salaam.

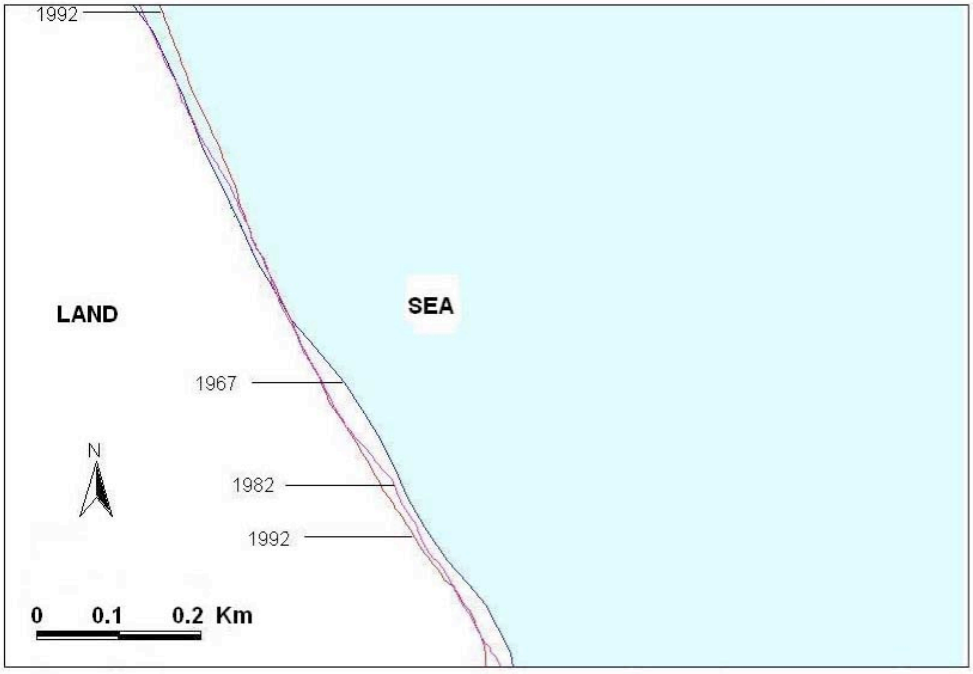


Figure4: Shoreline shift over 30 years (1962-1992)

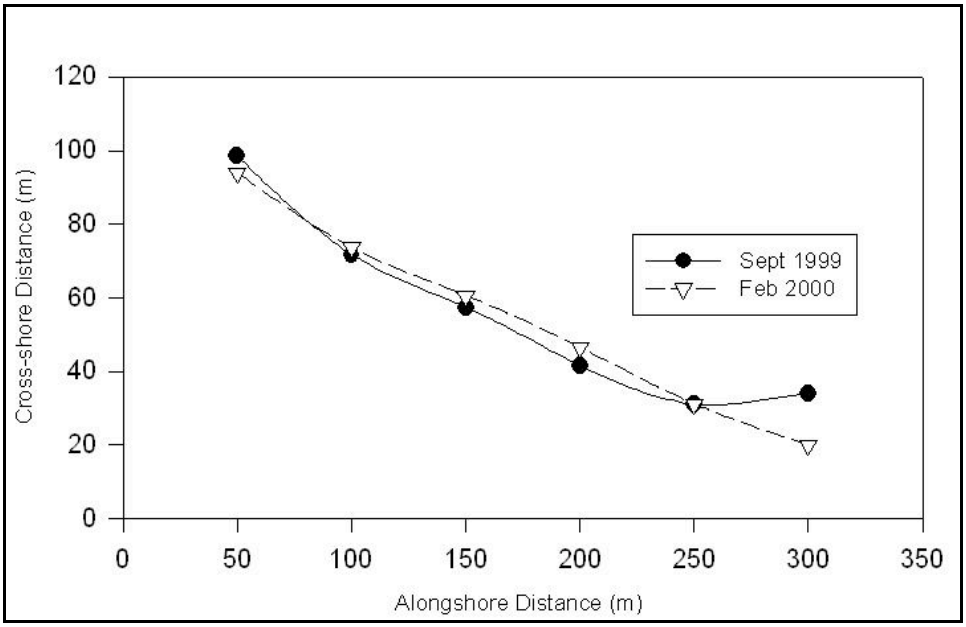


Figure 5: Shoreline shift between the monsoons 1999/2000

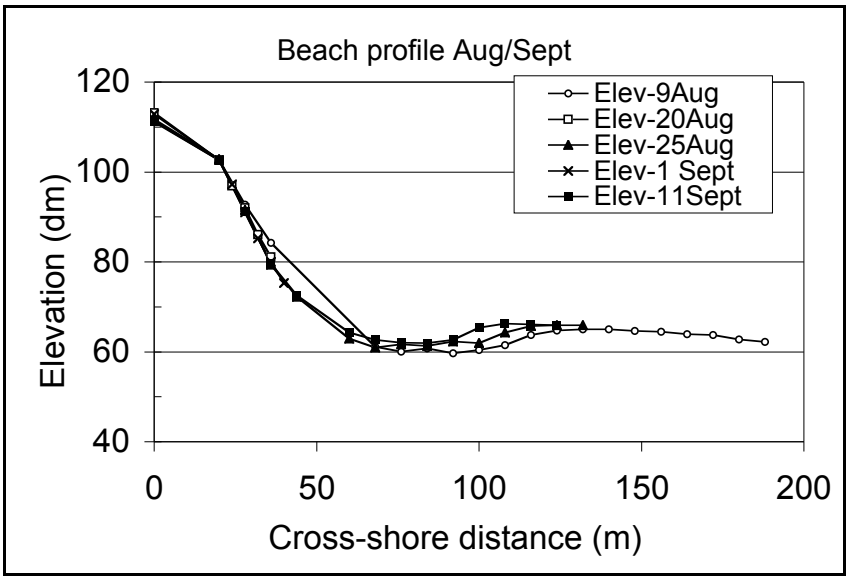


Figure 6: Beach profile during SE monsoon of 1999

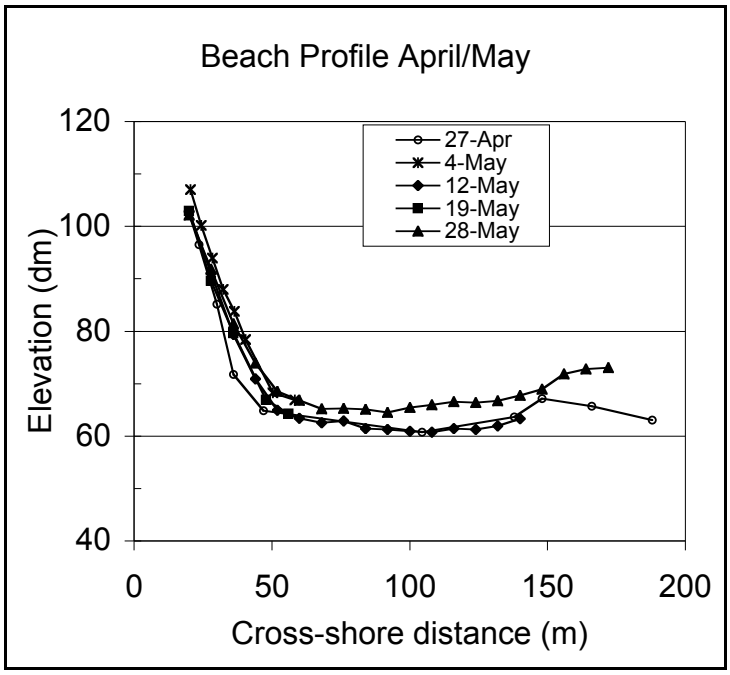


Figure 7: Beach profile during NE monsoon of 2000

DISCUSSION

The coincidence of alarming erosion with periods of extreme winds points to causal relationship between extreme winds and coastal erosion. Increased wave activity due to extreme winds has been the leading cause of surging erosion in the area. Conducive erosion conditions are more created when the strong wave activity coincides with extreme spring tides allowing for erosion of the highest parts of the beach and even overtopping the shoreline. Examination of tide tables for Dar es Salaam shows that extreme spring tides occur during March/April and October/November and during these events the times of high water are generally between 16 and 18 hrs and between 04 and 06 hrs (Hartnoll, 1974). During these times, the winds also have an easterly direction, thereby adding to the erosive conditions (Lwiza 1987). Other factors may be considered to enhance the process as noted by the Beach Erosion Monitoring Committee (1987). The committee provided the first inventory of combined effects of sand mining from river beds, meteorological conditions, hydrodynamics as well as geomorphological response of the beaches although did not point out the leading cause. Much as episodic sediment input from River Tegeta during the El Nino rains of 1998 (Nyandwi and Dubi 2001) led to spontaneous beach buildup, reduction in the supply would lead to increased erosion. As such heavy rains that fall over shorter periods resulting in excessive river discharges may produce large sand supplies that in may end up in reducing or even reversing the erosion rates, a situation depicted at the Kunduchi beach after the El-Nino rains of 1998 and subsequent rains. Although the beach profiles indicated that the beach eroded mainly during the SE monsoon, coastal erosion or shoreline retreat may eventually occur during both monsoons because the conducive erosive conditions are dictated by extreme winds that occur during February, April, and July in conjunction with extreme tides (Dubi 2001). This implies that beach erosion and accretion are cyclic whereas special conditions are necessary to eventually lead to actual coastal erosion.

CONCLUSION

In conclusion it can be stated that the erosion bouts that have been observed over certain periods in the coastal area north of dare s Salaam are a result of coincidence of extreme high tides with increased wind speeds.

ACKNOWLEDGEMENTS

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