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Coastal erosion in Trinidad in the Southern Caribbean : probable causes and solutions

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Abstract

This paper examines the rate of coastal erosion at several beaches on the island of Trinidad in the Southern Caribbean. Erosion rates are gauged from analyses of sequential beach profiles spanning the period 1990 to 2001, for most beaches. Based on data collected and differentiated according to season, average erosion rates are about 1 to 2 metres per year. However, for a single year extreme erosion rates approaching 10 to 12 metres have been noted, although these abnormal rates have been followed by accretion. Our data also show evidence of accelerated erosion, most likely linked to unduly high rates of relative sea level rise. Adaptation measures to cope with unduly high rates of coastal erosion include sea defences, limited by cost considerations, and retreat, which given limited land area, is not desirable.

1 Introduction

Coastal erosion is a natural occurrence, the rate of which would vary depending upon the kinetic energy of the waves, itself determined by weather and astronomical factors and upon the resistance of the coastline, as influenced by geology and morphology. However, abnormal and accelerated erosion rates are mainly due to extreme weather conditions, as for instance hurricanes, typical of the Caribbean region. It is also believed that sudden changes in sea level, whether euric or relative, can lead to accelerated rates of erosion (Leatherman et al., 2000; Singh, 1997; Aubrey et al.,1988).

One of the more likely consequences of sea level rise in small islands, as in the Caribbean, is coastal erosion and or inundation, especially where the geology is favorable (Komar, 1983). A very simple and convenient method of detecting and evaluating coastal erosion and inundation is through the analysis of beach profiles (Dean and Maurmeyer, 1983). Beach profiles are the physical and dimensional representation of the form of the beach and position of the back cliff at a given time. These profiles are normally constructed from data collected using an engineer's level and rod with reference to some known on-shore datum or benchmark. By comparing successive profiles, the volume and extent of beach material being removed (erosion) or deposited (accretion) can be deduced.

2 Methods

The vast majority of beaches that we surveyed consist mainly of loose sandy materials, that are least resistant to wave attack. Beginning in 1990, and up to 2001, beach profiles were surveyed at a number of beaches around the island of Trinidad (10-11^0 N and 60-61^0 W) in the Southern Caribbean. These beaches included Blanchisseuse and Toco-Salibia on the north coast, Salybay, Saline, North and South Cocos on the east coast, Guayaguare, Quinam and Los Iros on the south coast and Colombus and Icacos on the west coast. At Icacos, one profile was done where erosion (Corral Point) is taking place and the other where accretion (Punta del Arenal) is occurring. In some cases, as at Icacos (Corral Point) and Quinam, where the erosion rates are excessively high, different sets of profiles had to be taken due to loss of bench marks to the sea.In most cases, permanent benchmarks installed by the Institute of Marine Affairs (IMA), were already in place and were used for convenience and continuity.

Beach profile data for all beaches consisting of height - distance coordinates with respect to a fixed on-shore benchmark were collected at about 6-month intervals, since 1994, depending on funding to undertake fieldwork. Previous data on beach profiles for these same beaches, going back to 1990, were also obtained from the IMA.

The mean reference position of each profile, with respect to the established benchmark, is estimated within the intertidal zone, namely at points between the estimated high tide and low tide levels. The intertidal positions of the beach profiles are also differentiated according to season and year. Based on the beach profile data, we fixed a datum point in the intertidal zone relative to the benchmark, for each beach, whose change in position over time would represent erosion or accretion rates. This approach is similar to the high water line used by Pajak and Leatherman (2002).

We further differentiated the profiles according to seasons. In general, during the dry (winter) season (December to May), the seas of the Southern Caribbean are choppy and coastal erosion is dominant while during the rainy (summer) season (June to November), sedimentation, deriving from river discharges, including that of the Orinoco River in nearby Venezuela, is more common.

3 Results

For purposes of brevity, we present the results of the beach profile analyses for four of the beaches surveyed, where erosion and accretion rates are most pronounced, namely South Cocos, Los Iros , Quinam and Icacos – Punta del

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Arenal. We first examine the South Cocos beach on the eastern (Atlantic) shores of Trinidad (Fig.1) where coastal erosion is most evident (Figs. 2a and 2b). As can be seen in Figure 2a, because of excessive erosion rates (Fig. 2b), the form of the beach profiles changed somewhat after 1998, when we had to choose another benchmark, that we tied to the previous, that was about to be engulfed by the sea. Figure 2a shows the ever-shifting beach profiles for the South Cocos beach over the past seven years. It is evident (Fig. 2a) that the position and form of the profiles shift back and forth from season to season and year to year, sometimes eroding, sometimes accreting. For instance, since the first profile was taken on 26/07/90, the near-shore part of the beach receded to its most landward position in 1996 (04/01/96). This was followed by a period of accretion during 1997 and 1998. Since 1998, to 2001, a stabilization of the beach was observed. It is very likely that the relative sea level perturbation that existed between 1990 and 1996, and that caused severe erosion rates, averaging 2 metres per year stabilized since 1998 (Fig 2b). The form of the profile in 2001 was gently sloping and uniform meaning that it has reached a new equilibrium level, following the previous perturbation, likely caused by accelerated relative sea level rise. In general then, it would appear that net erosion between 1990 and 1996 at the near-shore position was accompanied by deposition at the far-shore side, thereby causing the beach profiles to become less concave, generally, over time (Bruun and Schwartz 1985).

Los Iros bay on the south coast of Trinidad (Fig. 1) also shows evidence of erosion between 1990 and 1996 (Fig. 3a), except for the wet season of 1995, when substantial accretion in the intertidal zone occured (Fig. 3b). Between 1990 and 1993, in both dry and wet seasons, erosion proceeded at a rate of about 3 m/yr (Fig. 3b). Also the accretion rate in the intertidal zone at Los Iros, in 1994 and 1995 (Fig. 3b) was very similar to that observed at other beaches on the south coast, as Guayaguare, thereby lending evidence to the abnormal deposition of Orinoco sediments in the wet season on the south coast of Trinidad. Since, 1996, there has been a steady accretion taking place. As in the case of South Cocos, this would imply that there might have been a trigger, most likely relative sea level rise, that lead to accelerated erosion between 1990 and 1994, followed by slow accretion and stabilisation of the beach profile.

Two separate beach profiles were done for the Icacos beach on the south western tip of the island (Fig. 1), one at Corral Point, where severe erosion is seemingly taking place, and one at Punta del Arenal (Figs. 4a and 4b) where accretion is supposedly occurring. We are unable to provide recent beach profiles for Corral Point, because of the incessant loss of benchmarks, being reclaimed by the sea. At Corral Point, significant erosion occurred between 1990 and 1991, when the retreat of the intertidal zone was about 10 (wet season) to 12 (dry season) metres. Thereafter in 1992, accretion approaching 5 metres per year took place, following which a new episode of erosion, at a rate of about 2 metres per year, occurred, between 1992 and 1996. Other visible signs of severe erosion and inundation are evident at this beach. A former lighthouse, which was near the shore about 50 years ago, is now at least 200 metres out to sea. Also, the local authorities built a seawall in 1995 to arrest the rate of erosion. However, this

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wall and an adjacent house were reclaimed by the sea, by 1999. During our last site visit in October, 2002, severe erosion was still evident.

As for the Punta del Arenal profile, which is located a few hundred metres downcurrent from Corral Point (Fig. 1), accretion seems to be dominant (Figs. 4a and 4b). Between 1990 and 2001, the average rate of accretion in the intertidal zone was about 1.5 metres per year (Fig. 4b). However some amount of erosion, approaching 6 metres, occurred between 1995 and 1996 (Fig. 4b). However, since 1998, accretion of the beach resumed and continued to 2001(Fig. 4b). Based on field measurements, involving visual analysis of the position and orientation of the older and more mature coconut palms, observations and analyses of the accreted material and verbal accounts from elders, total accretion on this beach would seem to be close to 180 meters over the last 70 or so years.

The Quinam beach on the south coast is another beach where excessive erosion has been occurring, since we started our measurements in 1995. Here too, we have lost our benchmarks on two occasions, since 1998. However, with the beach profile data at our disposition (Fig 5a), it is evident that erosion is pronounced at this location, averaging close to 7 meters per year between 1995 and 1998 (Fig. 5b). A further peculiarity of this beach is that the backshore consists of cliffs of heavy clays that slump and are then washed away.

4 Discussion

Our results of the preceding sections show evidence of significant coastal erosion at certain locations in Trinidad, being at a rate of about 1 to 2 metres per year, on average, and even approaching 10 (Los Iros) to 12 (Icacos-Corral Point) metres in a single year (Table 1) and the removal of significant volumes of beach material, except for Punta del Arenal (Table 2), at several beaches in Trinidad, including South Cocos, Guayaguare, Los Iros, Icacos, and Quinam. This accelerated rate of coastal erosion may be due to relative sea level rise, as it influences exposure of new and less resistant materials to wave attack, and saturation and slumping of loosely compacted soils (Bruun and Schwartz, 1985). The backshore zone of the great majority of the beaches studied in Trinidad mainly consist of loosely compacted sands, except for the Los Iros and Quinam beaches on the south coast, that have a high clay content, it is known that even clays loose their plasticity at moisture levels exceeding 21 percent. Also, if this recent accelerated erosion rate is due to sea level rise, how does one separate this from natural or background coastal erosion.

In the particular case of Trinidad, it is suspected that because of extensive underground extraction and petroleum and asphalt mining, land subsidence may be taking place, especially in the oil belt in the southern part of the island (Aubrey et al., 1988). The deposition of sediments on the ocean floor from the neighbouring Orinoco River could also lead to subsidence. Remember that land subsidence may produce the same effect as sea level rise insofar as coastal inundation and erosion are concerned.

5 Conclusion

It transpires from the preceding then that, in general, severe erosion is taking place at several locations around Trinidad, especially at Icacos-Corral Point, Quinam and Cocos South. In some locations such as at Icacos-Punta del Arenal, accretion is occurring, although this is rare.
How might the local government cope with these unduly high rates of erosion in an island of roughly 5,000 square kilometres, where land space is already limited. The options available are to let nature take its course, since remediation costs for such engineering solutions as seawalls and revetments and beach nourishing, are excessively high. On the other hand, retreat may not be possible. This is the case along the east coast near the Manzanilla-Cocos beaches, behind which is the heritage site Nariva Swamp. It is believed that once a thin strip, a spit formation, along which the main road connecting the north and south of the island, is breached, the brackish to freshwater wetland and its rich biodiversity risk being damaged (Ellison, 1989). A coastal zone management plan for Trinidad would therefore seem to be highly desirable.

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Table 1: Approximate erosion rates at the back-shore location of several beaches in Trinidad, 1990-2001.

Beach	average erosion rate (m/yr)	maximum annual erosion rate (approximate) (m/yr)	Remarks
South Cocos	1.7 (1990-96)	9 (1991-92)	Accretion (1997) and Stabilisation (1996-2001)
Guayaguare	2.5 (1990-93)	7 (1991-92)	Accretion (1994; 1999; 2001)
Los Iros	1.6	10 (1991-92)	Accretion 1994-95 Sudden erosion 1996 Accretion 1996-2001
Icacos (Coral Point)	2	12 (1990-91)	Loss of bench mark 1999; 2001 Disappearance of retention wall 1998
Blanchicheuse	1	5 (1990-91)	Accretion 1993-94
Saline	1	4 (1991-92)	accretion 1990-91
Quinam	10	9 (1995-98)	Excessive erosion and slumping

Table 2: Annual erosion rates/sediment volumes (m^3/m^2) of several beaches in Trinidad, 1990-2001.

Beach Profile	Erosion (m^3/m^2)	Remarks
Guayaguyare	- 0.01	Steady-gradual
Blanchisseuse	- 0.03	Steady-gradual
South Cocos	- 0.01	Severe-certain years
Los Iros	- 0.04	Severe-certain years
Punta Arenal	+ 0.04	Accretion

Source : A. El Fouladi. ‘ La hausse relative du niveau moyen de la mer à Trinidad : causes probables et impacts’. Ph D Dissertation in preparation, Université de Montréal

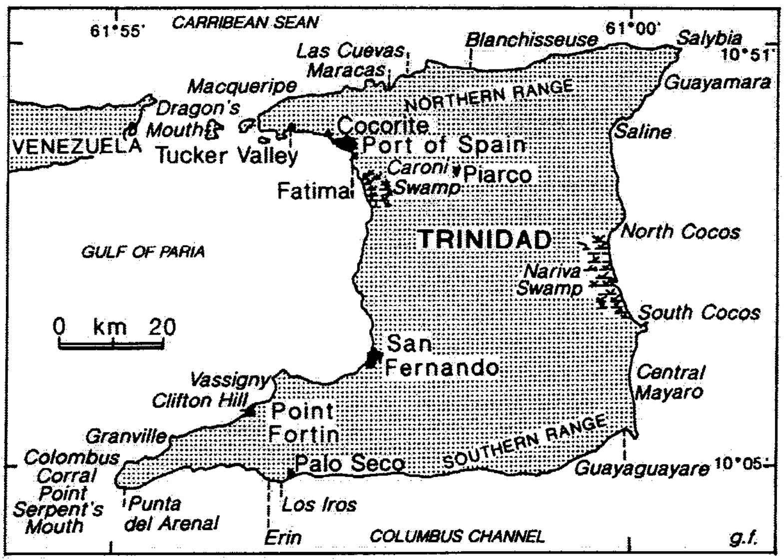

Fig. 1. (a) Map of Greater Caribbean. (b) Map of Trinidad showing different sites.

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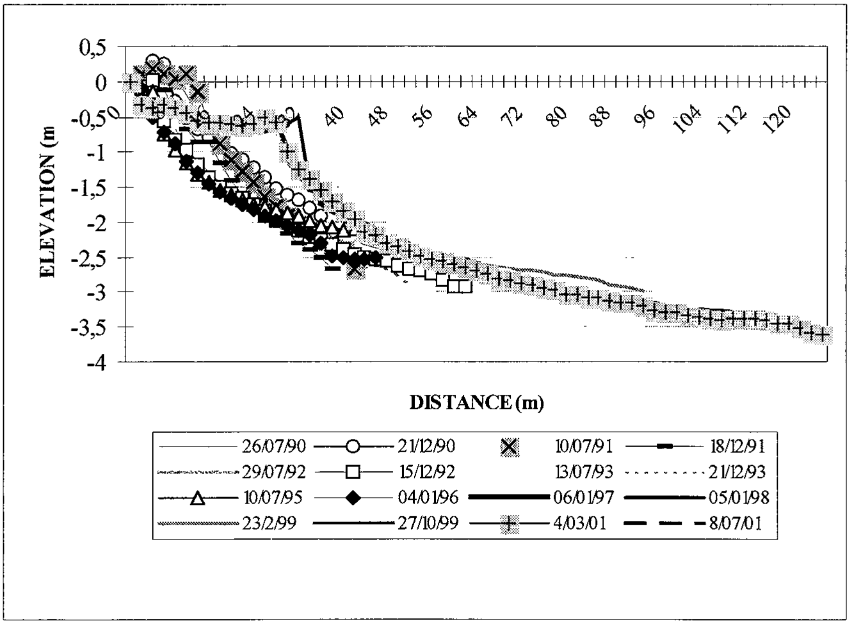

Figure 2a. Beach profiles for South Cocos beach (profile direction 265 ^{0}), 1990-2001.

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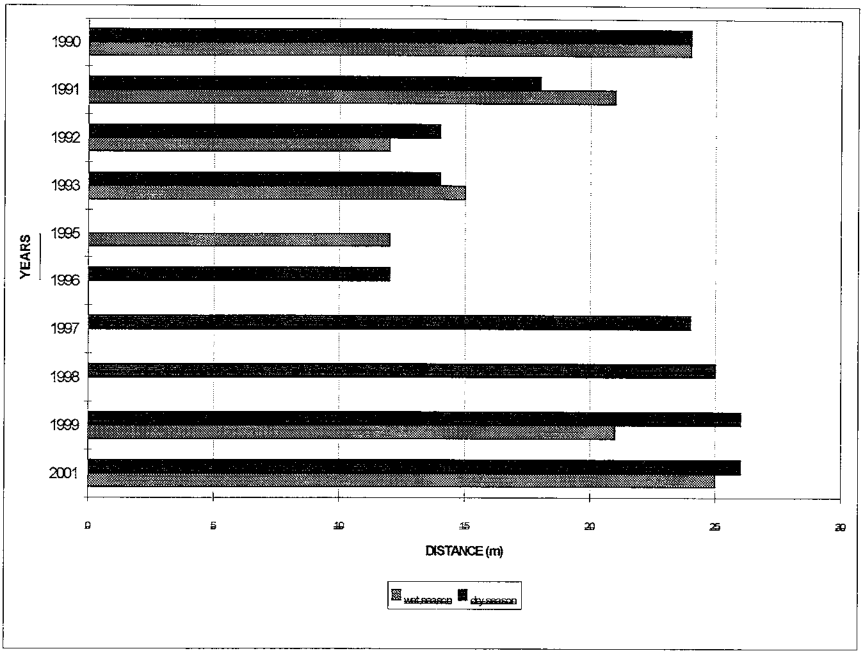

Figure 2b. Erosion rates for South Cocos beach (profile direction 265 ^{0}), 1990-2001.

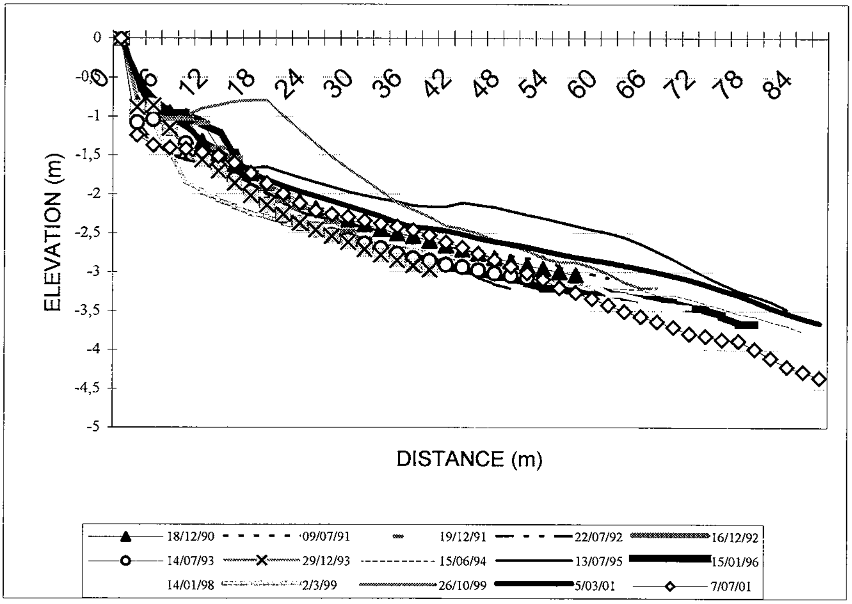

Figure 3a. Beach profiles for Los Iros beach (profile direction 07 ^{0}), 1990-2001.

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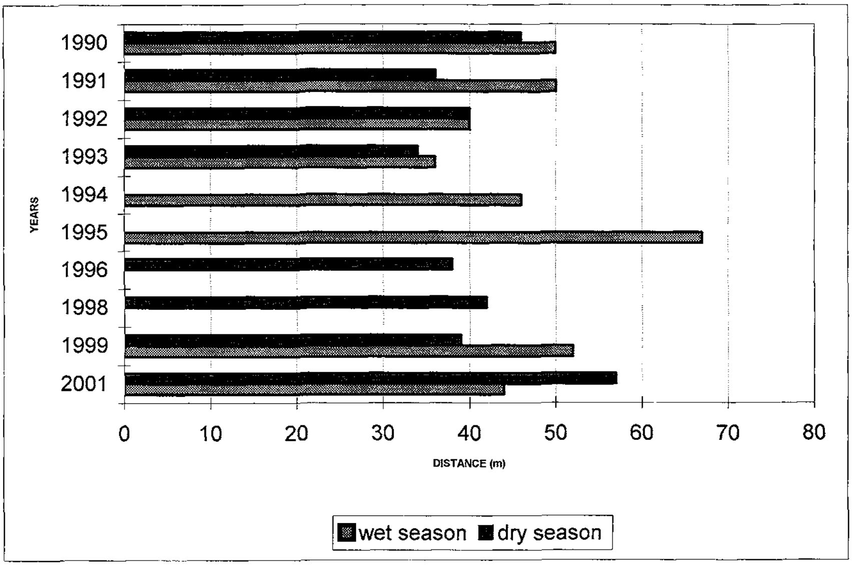

Figure 3b. Erosion rates for Los Iros beach (profile direction 07 ^{0}), 1990-2001.

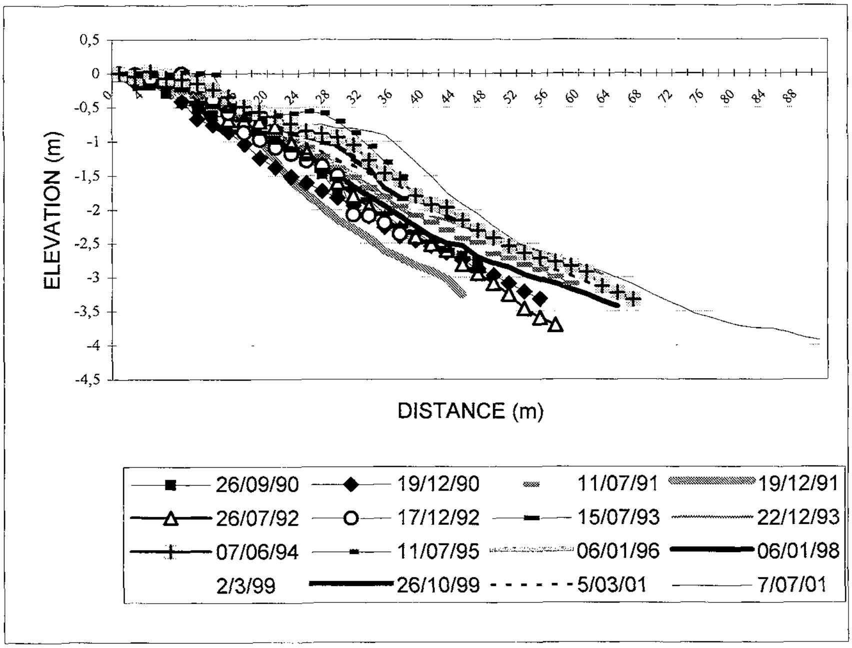

Figure 4a. Beach profiles for Icacos – Punta del Arenal beach (profile direction 105 ^{0}), 1990 -2001.

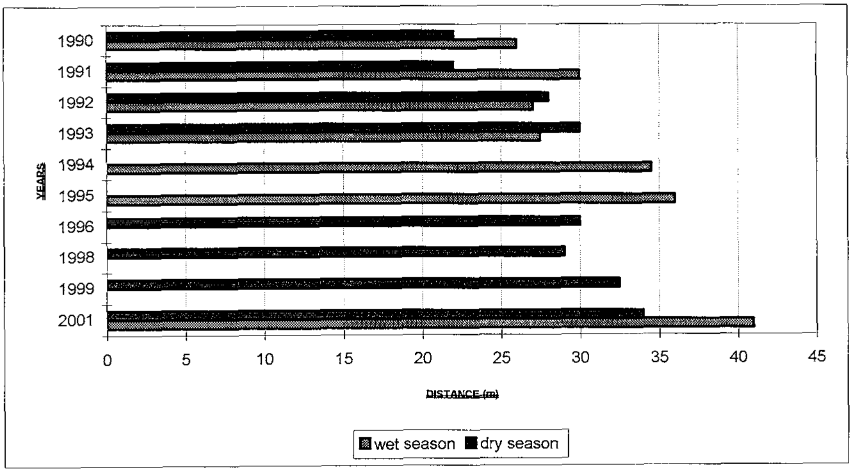

Figure 4b. Beach profiles for Icacos – Punta del Arenal beach (profile direction 105 ^{0}), 1990 -2001.

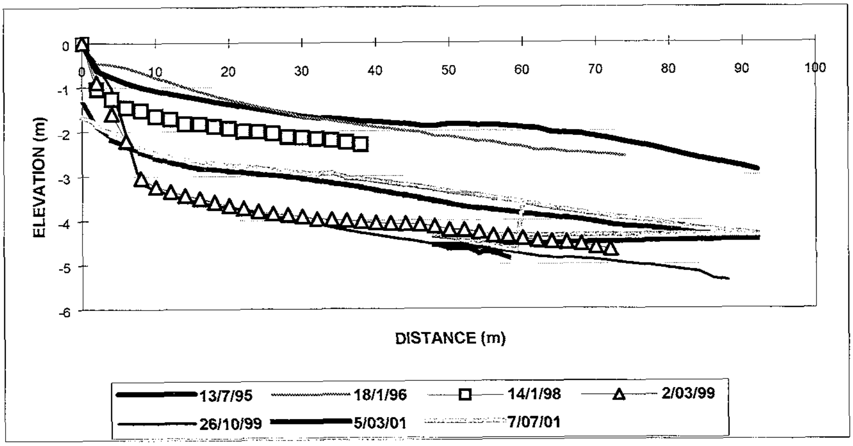

Figure 5a. Beach profiles for Quinam beach (profile direction 180 ^{0}), 1995 -2001.

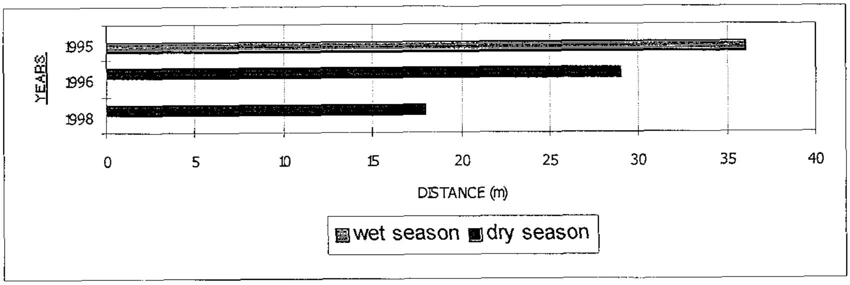

Figure 5b. Erosion rates for Quinam beach (profile direction 180 ^{0}), 1995 -1998.