

## **Restoration of Sand Dunes along Human-altered Coasts: A Scheme for Miramar Beach, Goa**

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**I. Goal and Scope:** Miramar beach is located along the southern (left) bank of Mandovi River and about 3 km from the capital city of Panjim. A densely populated stretch is found east of Miramar up to Campal and beyond. Miramar beach extends about 4.5-km southwards up to Caranzalem and terminates against the wooded hill slopes of Cabo promontory. A prominent sand dune belt (leveled at several places) is found backing the beach from Miramar to Caranzalem. New dunes, presently low in height and capped by vegetation, are forming at many places along the upper reaches of this beach. This stretch consists of the most prominent dune belt within the estuaries of Goa (Mascarenhas, 1996; 1998).

During the last two decades, promotion of up market coastal tourism, competition between developed and promoters of real estate and coastal resorts to utilize coastal spaces, and rapid migration of population towards the coasts, extensive use of coasts for recreation has resulted in a dramatic proliferation of structures in the coastal zone. Most of this growth is unplanned and uncontrolled resulting in an over urbanization of coastal stretches (Sawkar et al., 1998). Of all coastal ecosystems, sand dunes show distinct evidences of severe damage and indelible impacts and, as such, have borne the maximum brunt of developmental activities. The degradation, destruction and elimination of coastal sand dunes of Goa are almost exclusively anthropogenic (Mascarenhas, 1990; 1996; 1998; 1999,a, b; 2000).

Miramar beach, one of the three most frequented beaches of Goa, is one such example. Irrespective of weather conditions, groups of tourists and also locals flock to this coastal spot for recreation. However, we note that this beach is being overused, and is hence under stress due to human actions. At Miramar in particular, large volumes of sand being blown inland thereby creating hazardous conditions to road and beach users evidence the impacts. This phenomenon of transport of beach sand by wind is in operation over the last two decades at least. If sand movement is not blocked at the beach itself, this recurring eolian process can prove detrimental to the stability and, eventually, the very existence of this famous beach.

Previous work in this area deals with grain size and mineralogy of beach sands (Kidwai, 1971), ecology of dune vegetation (Untawale and Nair, 1974), seasonal beach changes (Swamy, 1976; Murty et al., 1980), and effects of sand transport (Reddy and Sastry, 1988). Whereas this work is of academic interest, only a few papers dealing with societal or coastal management aspects are available (Mascarenhas, 1990; 1998; 1999,a, b; 2000; 2001). Therefore, this article describes human interference in the area, causes that lead to loss of beach sand, and the need of mitigation measures for which restoration of degraded sand dunes along Miramar beach is proposed.

**II. Methods:** This paper is based on extensive field observations and surveys along the entire coastal zone of Goa over the last five years. Existing toposheets, aerial photographs and recent satellite imageries were consulted to delineate sandy stretches including pocket beaches. More than 200 sites were inspected and surveyed. The photography of natural features of various coastal ecosystems depicts present coastal scenarios. Detailed ground truth data have been collected with which areas of concern are delineated (Mascarenhas, 1998; 1999A b; 2000).

Identification of causes that lead to eolian transport and consequent loss of beach sand is the first step in developing solutions to this problem. Data on wind direction wind speed, and seasonal changes in the pattern of winds are known. The predominant direction of wind and associated sand transport can thus be determined. The type, composition and grain size of beach sand is also available. However, suitable sand fences that can trap mobile sand need to be designed and fabricated. Appropriate species of local sand dune vegetation that show high survival rates are to be selected and adopted for plantation.

**III. Results and Conclusions:** Field investigations at Miramar indicate that a 300 m long and 50 m wide strip along the beach, adjacent to the roundabout, children's park and local school, has been opened up and is now bare (Figure 1). This large area earlier occupied by sand dunes is now flat and completely devoid of dune vegetation. Removal of vegetation is attributed to the continuous movement of tourists and other beach users for whom this entire strip serves as the entry point to the beach. Cultural events such as food festivals also end up damaging dune plants and flattening dune morphology. Our field observations have shown that, during windy days over the years, large quantities of fine sand are blown inland. This effect can be prominently felt up to the nearby school along the coast, and as far as Tonca (not shown in Figure 1) in the hinterland, and can be experienced by anyone as wind-borne sand grains often rise to knee level. Eolian transport of sand starts

in January and is found to be maximum during dry days in July. As a result, the Miramar roundabout and the road opposite the local school are covered by sand for most part of the year (arrows in Figure 1), creating dangerous road conditions for traffic.

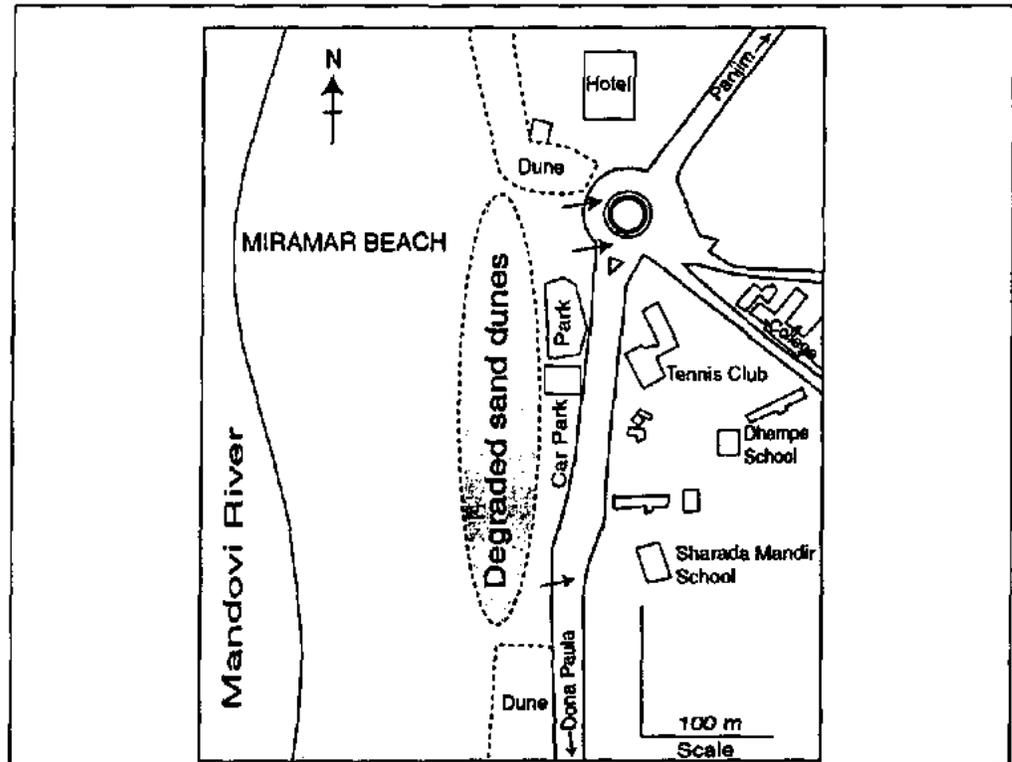


Figure 1: Map showing Miramar beach where sand dunes are flattened due to trampling. Arrows indicate wind direction as well as spots where eolian sand transport and deposition is most prominent

Coastal roads and beachfront buildings over the dune belts have led to damage of dune vegetation which acts as sand binders, obliteration of dune topography, removal of sand, leveling of dunes, all of which generate loose and free sand resulting in its excessive mobility. In all cases therefore, such roads are covered, sometimes in totality, by a layer of sand. This is a recurring regional phenomenon that is evident wherever pathways, roads or parking lots occupy (former) dune fields. Eolian sand movement is very conspicuous at such sites.

The process of sand mobility can be described as follows: Human interference on dunes invariably leads to damage to dune vegetation and uprooting of dune plants, a species that is crucial to the stability of sand dunes. Since the binding capacity of dune vegetation is lost, the dune sand is left exposed, and bare dunes are created. This results in the production of loose sand. Free sand is then liberated, rendered mobile due to wind action, and blown inland thus affecting populations and buildings located along its path. The process of shifting sand becomes prominent whenever wind speed exceeds 16 km/h. The average wind speed from January to May varies from 11 to 14 km/h. In comparison, wind speed increases to 23 km/h during the period of monsoons from June to August. For the rest of the year, wind blows at a speed of 10 km/h on an average. The predominant wind direction is southwesterly. Stronger the wind, greater is the volume of sand transported inland. This process is typically observed wherever large dune areas are razed and opened up. As such, this has become a large-scale eolian process at Miramar, as seen in the pictures taken on 2 July 1998 (Figure 2).



**Figure 2:** Accumulation of wind blown sand on the footpath and road on the roundabout at Miramar as observed on 2 July 1998. The backshore (also the major entry point to the beach) is completely open, flat and devoid of dune vegetation (Photo: Antonio Mascarenhas).

The portion of Miramar beach from where sand is blown inland is, in fact, a former dune complex that is now extinct. The present entry point to the beach is now located here. The access to the beach being very wide, pedestrian movement has completely leveled the dune over the years (Figure 2). These (former) sand dunes have been eliminated exclusively due to anthropogenic factors (Mascarenhas, 2001). As such, sand is rendered loose and is hence unstable and prone to continuous movement. The mobility of sand is a sign that it tries to find equilibrium by trying to occupy a place where it belongs: the roundabout, now located where sand dunes once stood.

The fact that sand is continuously blown inland also reveals that natural sand is in excess and hence easily susceptible to transport when sea winds get stronger than normal. This also indicates that Miramar beach is characterized by a positive sand budget. However, wind-blown sand on roads and parking lots is a nuisance to beach users and a hazard to road users. Moreover, a continuous loss of sand throughout the year can offset the limit of equilibrium and can eventually turn Miramar into a sand-deficient beach. This recurring eolian process can prove detrimental to the stability and, eventually, the very existence of this famous beach. Therefore, sand movement has to be blocked at the backshore itself and where original dunes are flattened or degraded (Figure 1).

**IV. Recommendations and Outlook:** Coastal eolian dunes are often mobile and show a dynamic behavior that should be understood, respected but not contradicted by anthropogenic influences (Guilcher and Hallegouet, 1991). Dunes cannot simply follow a pattern that is not naturally theirs (Daley et al., 2000). Hence they should be allowed and be able to evolve freely and naturally in form and space. Since sand dunes are dynamic, geomorphologically fragile and ecologically sensitive, these geomorphic edifices have been classified as CRZ I under the CRZ Notification of 1991 (MEF, 1991). Sand dune belts therefore cannot be disturbed by any activity whatsoever.

Eolian transport of sand at Miramar was first reported in 1977 (see Reddy and Sastry, 1988) indicating that this process is continuing for the last 24 years, or may be even earlier. Although visible to everyone, the implications of such sand transport, a recurring annual process, have not been examined. The Miramar roundabout which was built more than 100 years ago was, in fact, a wrong choice as the present circle was located on former sand dunes, and too close to the beach. Similarly, a concrete wall along Caranzalem beach is almost completely buried in sand, as seen in front of the local school. Considering a continuous loss of sand, the issue of eolian sand transport needs to be addressed, and as such, degraded sand dunes of Miramar beach (Figure 1) need to be restored as they have ceased to perform their functions.

There are various ways of restoring dunes that are destroyed. Artificial nourishment of beaches is one such method that has been classified as a modern scientific strategy to counter sand depletion along coasts. It comprises a simple, easy and cheap solution that substitutes costly measures such as sea walls and stone embankments. Therefore, beach nourishment is now the preferred alternative (Mendelssohn et al., 1991; Daley et al., 2000).

Beach nourishment is a method that involves filling a threatened portion of the beach with sand brought from an area that has surplus sand. Excess sand which is blown inland at Miramar has to be collected and dumped back on the beach so that the latter can recuperate, or on the dunes in the vicinity so that these edifices can be nourished. Degraded areas or fractured dunes can thus be revived. Therefore, sand that is routinely collected from Miramar circle and adjacent roads needs to be reused to create new dunes, and not be discarded as is often done.

Eolian transport of sand needs to be stopped at the upper beach itself, the site of presently degraded sand dunes as shown in Figure 1. A simple method of inducing accretion of sand is to impede wind velocity. Deposition of sand can be easily achieved by erecting 1 m high wire mesh, wooden or geotextile fences perpendicular to the direction of prevailing winds. In general, sand gets deposited 6 to 8 m downwind behind these barriers as observed behind artificial objects lying on the beach.

Fences have saved sand dunes the world over. Made of artificial objects such as wooden planks or nylon nets, such meter high fences can be erected all over the backshore, the area that is presently flat and devoid of vegetation. A series of linear fences, oriented north - south, have to be fixed parallel to each other, but oriented perpendicular to the direction of prevailing wind that blows from west - southwest (arrows in Figure 1). Such artificial obstacles provoke winds to deposit their sand content; new sand dunes can thus be created gradually. A series of fences can therefore intercept and trap wind-blown sand over a considerable area along the upper beach. These fences will also guard dunes, once they are formed, from being overrun by humans. Sand will therefore fix itself on the backshore instead of spilling onto the road as observed at present.

Once these mounds of sand grow in size and fences are buried, planting of appropriate vegetation can stabilize these artificially created sequences of sand dunes (Mendelssohn et al., 1991). Planting of appropriate dune plants is the best and the cheapest method available as these species act as excellent sand binders. To ensure its stability, the dune can be covered by (planting) specific dune vegetation that does not require much care. Therefore, fencing of dune strips as seen along the Miramar - Dona Paula stretch is a welcome step. Other existing dunes which are bare, devoid of, or with sparse vegetation can likewise be stabilized from further deterioration by erecting fences and fixing dune plants wherever upper portions of beaches have no vegetation that serve as sand traps. This exercise will not only preserve dune vegetation but will also fix sand that is in a state of mobility on Miramar beach; sand dunes thus remain stable.

If this approach is to be successful, a crucial prerequisite is that movement of pleasure seekers onto the beach has to be controlled and restricted along one or two fixed narrow passages only. This requirement has to be guaranteed by the local government, as the present barren and leveled backshore will have to be reserved only for the creation, formation and growth of new dunes, in our case fashioned artificially.

The concepts of sand dune restoration are virtually unknown to our coastal managers. Restoration of coastal ecosystems (Guilcher and Hallegouet, 1991; Spurgeon, 1999; Daley et al., 2000) can also be adopted wherever coastal dunes are degraded due to human interference, particularly along high-value tourist coasts of India. Our proposal assumes significance because a beach management plan has been recently proposed for Miramar, and also because restoration (or creation of artificial) sand dunes has rarely been attempted before.

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