Coastal sand dunes – A neglected ecosystem

Coastal sand dunes are common in different parts of the world. These are natural structures which protect the coastal environment by absorbing energy from wind, tide and wave action[1]. Despite geographical differences, sand dunes have been considered as a specific ecosystem due to several common environmental features. Coastal sand dunes constitute a variety of microenvironments due to substrate mobility and physical processes[2]. Plants establishing on coastal sand dunes are subjected to several environmental fluctuations which affect their growth, survival and community structure. The most important factors include temperature, desiccation, low moisture retention, soil erosion, sand accretion, soil salinity, salt spray, changes in organic matter and pH (ref. 3). The purpose of this note is to emphasize in general the characteristic features, importance and the status of coastal sand dune ecosystem of Karnataka particularly concerning legumes as they supplement the nitrogen to these nitrogen-deficient ecosystem.

Karnataka has a coastline of about 300 km (Mangalore to Karwar) (12°52′N, 70°49′E to 14°51′N, 74°7′E). It is evident that as much as 70 km is vulnerable to severe sea-erosion particularly during the south-west monsoon. Approximately 50 m parallel to the low-tide line, in many locations *Casuarina* green mantle has been established. The coastal sand dune stabilizing plants in temperate regions are predominantly the members of Poaceae[4], while in tropical sand dunes the members of Asteraceae, Convolvulaceae, Poaceae and Leguminosae are dominant[5,6]. A survey of legumes was conducted on the sand dunes across 12 locations along the Karnataka coast during post-monsoon season (1998–99). Twelve km transact (one km on each location) along the barrier dunes with 72 quadrats (3 x 3 m; six quadrats on each location) revealed the existence of 13 legume species (Table 1). Among these, *Canavalia rosea* was most frequent followed by *Canavalia cathartica* and *Crotalaria verrucosa*. *Canavalia rosea* and *C. verrucosa* were most abundant followed by *C. cathartica*. The dune survey also revealed the existence of one more legume, *Tephrosia purpurea* which was not found in the quadrats scanned. All the legumes possess profuse and active nodules on the dunes surveyed. *Derris triflorum*, an inhabitant of mangroves, was also found on the sand dunes at four locations, of which at Hangarakatta they grew profusely. The established seedlings of indigenous trees, *viz. Tamarindus indica*, *Pongamia pinnata* and *Erythrina indica* were also seen at many locations suggesting their ability to grow on the sand dunes. The animal component associated with dune vegetation includes: rabbits, birds, small reptiles, insects (adults and larvae) and nematodes. Among the dune legumes *C. verrucosa* was found to be severely damaged by the insect attack on most of the dunes.

The extent of coastal sand dune disturbance particularly in Karnataka coast can be classified into three types: (i) severe sand dune erosion; (ii) severe accretion of sand, and (iii) moderate disturbance. The severe dune erosion results in the removal of sand dunes and vegetation which leads to exposure of roots and death of plants (e.g. location Kaup). Heavy sand accretions bury the dune plants, seedlings and seeds beyond their capability to establish (e.g. Bengre, Bhatkal and Honnavar). However, moderate disturbance allows the seeds to get buried at new sites with better nutrients, microbes and moisture regimes. It is known that burial of seedlings of temperate plants (*Agropyron psammophilum* and *Panicum virgatum*) up to 75% of their height helps to build up maximum shoot biomass[3]. In tropical sand dunes of Gulf of Mexico, shrubby species (*Chamaecrista chamaecristoides* and *Palafoxia lindenii*) were most tolerant to burial, followed by creepers (*Canavalia rosea* and *Ipomoea pes-caprae*) and grasses (*Schizachyrium scoparium* and *Trachypogan gouini*)[7]. In Karnataka, moderate burial of the stolons of *Ipomoea pes-caprae*, *Canavalia rosea* and *C. cathartica* prevented them from drying.

To reduce wind erosion, beach grasses like *Uniola paniculata* and *Panicum* sp. are widely employed in coastal USA[8,9]. *Ammophila breviligulata* has been planted to prevent dune erosion at Massachusetts since 1985 (ref. 10). Although there are no serious attempts to prevent dune erosion by revegetation in India, surveys have been conducted to understand the status and diversity of sand dune vegetation[11,12].

Survival of plants under harsh conditions depends on symbiosis with mycorrhizal fungi, rhizobia and other endophytes. Arbuscular mycorrhizal (AM) fungi are common in sand dune systems throughout the world and they are known to significantly contribute to the development of plant community structure

Table 1. Occurrence of legumes on coastal sand dunes of Karnataka

Legume	Frequency of occurrence (%)*	Relative abundance (%)**	Location***
Canavalia rosea (Swartz) DC.	44.4	19.2	1–9
Canavalia cathartica Thours	22.2	6.1	1–4, 6, 7, 9, 10, 12
Crotalaria verrucosa L.	18.1	19.2	1, 2, 4–6, 12
Derris triflorum DC.	16.7	3.9	2, 7, 8, 12
Erythrina indica Lam.	15.3	3.2	1, 2, 4, 6–8, 12
Crotalaria retusa L.	12.5	15.7	2, 7, 9
Crotalaria striata DC.	9.7	5.3	2, 4, 7, 9, 11, 12
Mimosa pudica L.	5.6	14.6	11
Pongamia pinnata (L.) Pierre	5.6	1.8	12
Vigna sp.	4.2	2.1	1, 8
Alysicarpus vaginalis (L.) DC.	2.8	7.1	11
Alysicarpus rugosus (Willd.) DC.	2.8	1.4	2, 3
Tamarindus indica L.	1.4	0.4	6

*Number of quadrats possessing a particular legume species divided by total number of quadrats analysed (72) x 100.
**Number of a particular legume species recorded divided by total number of all legume species (281) x 100.
***See Table 2 for details.

Table 2. Status of selected locations of coastal sand dunes of Karnataka

Location	Vegetation	Human interference	Erosion
Thalapady (1)	Profuse	Fishing, road	Less
Someshwara (2)	Moderate	Recreation	Moderate
Surathkal (3)	Less	Sand and shell removal, seawall	Severe
Padubidri (4)	Profuse	Boat lodge, road	Less
Kaup (5)	Less	Recreation, sand removal	Severe
Katpadi (6)	Moderate	Fishing, boat lodge, sand removal, road	Less
Thottam (7)	Moderate	Recreation, road	Less
Hangarakatta (8)	Moderate	Fishing, sand and shell removal, seawall, road	Moderate
Maravanthe (9)	Scanty	Fishing, recreation, sand and shell removal, seawall, road	Severe
Byndoor (10)	Moderate	Seawall	Severe
Kumta (11)	Less	Boat lodge, seawall, road	Severe
Karwar (12)	Profuse	Recreation	Less

and sand dune stabilization[13–16]. AM fungal interaction in rhizosphere facilitates adequate nourishment of dune vegetation and their establishment[14]. Moderate colonization of sea oats by AM fungi in the nursery was found to be sufficient for the successful establishment on the Florida beaches[15]. The spores of AM fungi were recovered at a depth of 130 cm from the rhizosphere of the perennial grass, *Elmus mollis* in Japanese coast[17]. It has been demonstrated that sand dune AM fungal spores withstand immersion in seawater and get dispersed to new sites through seawater medium[18].

Mycorrhizae are also known to improve soil structure and stability by forming aggregates[19]. It is evident that hyphae of AM fungi bind sand grains forming sand aggregates, which remain intact even after the death of the root and hyphae[14]. Sand aggregates of different sizes resist strong winds and storms[14,20]. Most studies on AM fungi of coastal dunes are confined to temperate regions, only a few are available from the Indian coast. A survey of 53 sand dune species along the Chennai coast showed colonization of most of them[21]. Another survey of 10 dune plants at four locations in south-east Tamil Nadu revealed high AM spore density during summer season[22], whereas 12 plants of Someshwara dunes on the west coast showed the presence of 16 AM fungi[23]. A recent survey confirmed the occurrence of a very rich AM population at Someshwara. However, with increased disturbance at locations like Kaup the AM fungal population has been observed to decrease drastically[24].

Our knowledge of ethnobotanical aspects of coastal sand dune vegetation is inadequate. Tender pods of *Canavalia rosea* and *C. cathartica* serve as vegetable for the coastal dwellers. Their pods and seeds attract rabbits. Latex of *Launaea sarmentosa* is commonly used by fishermen to heal skin injury caused by fish spines while fishing. The following species planted on dunes as fence by farmers help withstand soil erosion: *Clerodendrum inerme*, *Cyperus orenius*, *Opuntia* sp., *Pandanus odoratissimus*, *Spinifex littoreus* and *Vitex trifolia*. Sand dune legumes as cover crops in coconut basins serve as nitrogen fixers, green manure and mulch. They also serve as nutritious fodder for the livestock.

Besides marine pollution, human interference with this dune ecosystem is increasing. Accumulation of tar balls and plastics on the high-tide line or beaches is common. The other major factors which affect dune vegetation are road construction along the dunes and dumping of granite boulders as a measure of erosion prevention. Accumulation of organic debris on the dunes due to waves and tides appears to be extremely important for the establishment of vegetation. The granite wall totally prevents the deposition of organic matter which in turn affects the vegetation. In certain locations removal of leaves, twigs, roots and seeds for fuel is evident. The sand and shell removal is also a threat to dune vegetation, so also fishery activities particularly sheltering of small boats on the dunes (Table 2).

Certain viable strategies to conserve vegetation would include: (i) demarcation of space for human activities above the low-tide zone; (ii) establishment of *Casuarina* and *Acacia* green belts without disturbing dune vegetation; (iii) protection of coastal vegetation by fencing at selected locations; (iv) establishment of dune plants particularly legumes in coconut groves as cover crops, green manure, mulch and fodder; and (v) germplasm collection of dune species in national herbaria.

There is an urgent need to study the bioresources of coastal ecosystem to promote conservation, rehabilitation and optimum utilization. Based on these studies, the concept 'ecosystem people'[25] can be applied for sustainable use of coastal bioresources. For future needs, understanding the nature of stress-tolerance and application of stress-tolerant genes in agriculture, horticulture, forestry and environmental conservation is of utmost importance. The microbes particularly diazotrophs, rhizobia and mycorrhizae adapted to such extreme habitats deserve special attention.

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29 March 1999 Chamoli earthquake: A preliminary report on earthquake-induced landslides using IRS-1C/1D data

In the early hours of 29 March 1999, an earthquake of magnitude of 6.8 hit the north-western part of India (Table 1). The maximum impact of this earthquake was felt in the hill districts of Chamoli, Rudraprayag and Tehri in the Garhwal region of Uttar Pradesh, where it claimed about 100 lives, left several hundred people injured and about 6000 houses damaged, apart from causing damage to property worth crores of rupees. Electricity, water supply and communication facilities also suffered extensive damage, especially in the Chamoli town, Gopeshwar (the district HQ of Chamoli) and Okhimath region of Rudraprayag district (Figure 1). Landslips mobilized by the earthquake have cut off portions of Mandakini valley and Mandal valley and several major roads. Ground cracks and openings were reported to have developed at several places. Aftershocks of less magnitude still continue to threaten people in the region. While the rescue and rehabilitation efforts have been initiated by the administration, defence forces and NGOs, scientific studies on the mechanism and effects of the earthquake have been taken up by several scientific organizations.

The Himalayan province on the whole is geodynamically very active and is prone to violent crustal movements generally along the existing thrusts and faults, causing earthquakes. The magnitude of these seismic events has varied from moderate to high. During the past century, the Himalayan region has experienced four major earthquakes of magnitudes above 8 in the Richter Scale and several others of lesser magnitudes. The epicenters generally follow lines parallel to the major thrust lines like the Main Boundary Thrust, Main Central Thrust or other parallel thrusts and are

Table 1. Chamoli earthquake parameters

Organization	USGS	IMD
Originating (IST) h:min:s	00:35:14	00:35:00
Epicentral location	Lat: 30.49°N Long: 79.28°E	Lat: 30.2°N Long: 79.5°E
Focal depth (km)	15	15
Magnitude	6.3 (mb)	6.8 (ml)
Surface wave magnitude (ms)	6.6	–

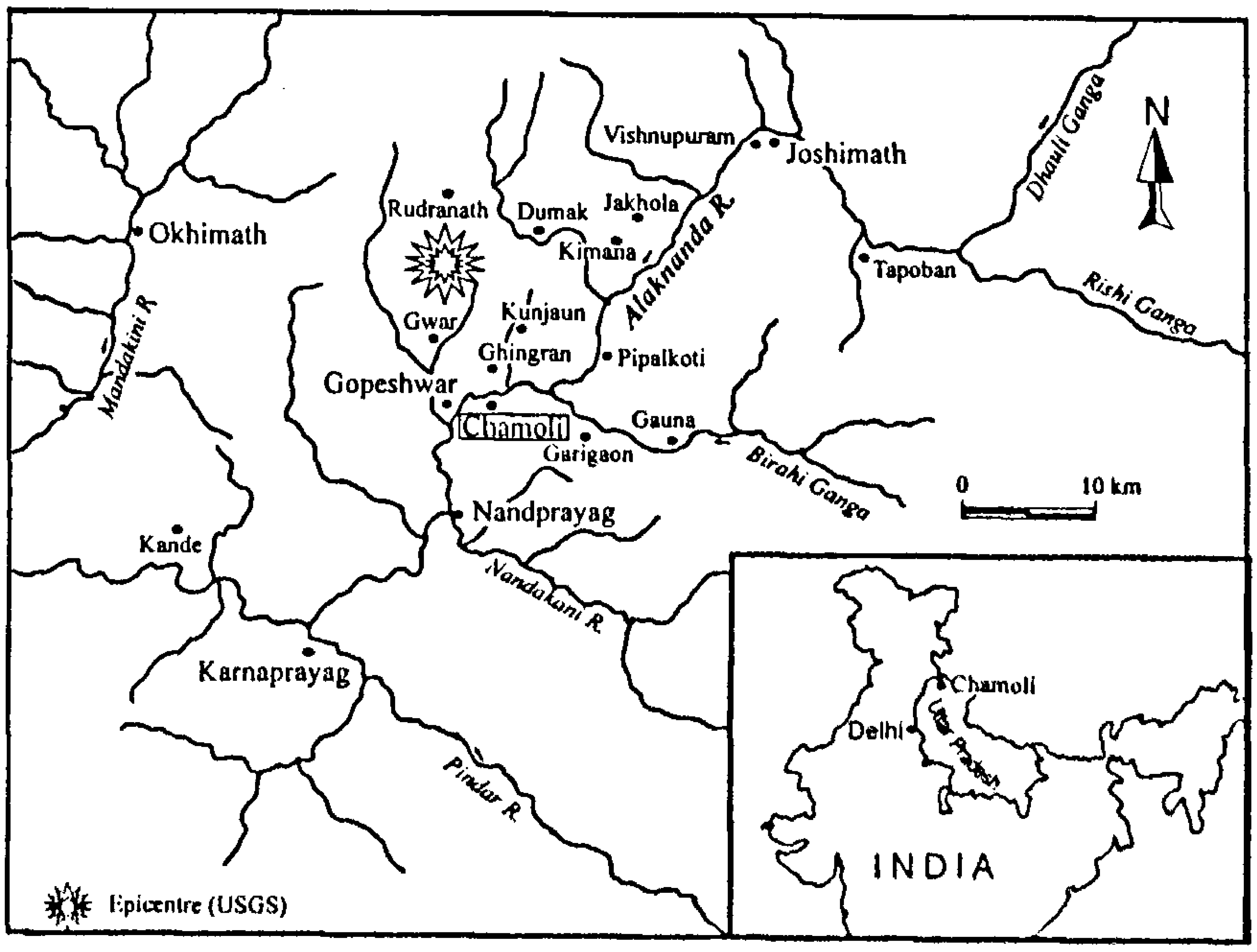

Figure 1. Location map of the earthquake-affected area.