The world's only inland mangrove in sacred grove of Kachchh, India, is at risk

In India, Kachchh district of Gujarat represents ecologically one of the most fragile and peculiar desert arid ecosystems, where several unique species of terrestrial and aquatic plants and animals exist. Among these, vast saline mudflats of the Rann of Kachchh along with the two Gulfs are important wetlands that cover large area in Gujarat[1]. Kachchh is also a home of mangroves, which represent the phylogenetically unrelated groups of plant species that thrive along tropical and subtropical coastlines and are adapted to tolerate saline environments in the intertidal zone. The total mangrove area of the world has been assessed[2] at approximately 18.15 m ha, with estimates of Indian mangrove wetlands ranging from 681,000 ha (ref. 3) to 500,000 ha (ref. 4). The mangroves of Gujarat (22.55%) are the second largest after the Sunderbans (46.39%) in the mainland of India[5]. Among the inland mangrove communities, *Avicennia marina* represents the only sacred grove species of the world's inland mangroves. In general *A. marina* occurs in fringing to intermediate tidal zone, but the sacred grove of the mangrove in Shravan Kavadia is in a totally land-locked position having no surface connection to the sea. It is located near the famous temple of Shravan Kavadia, a Hindu pilgrimage site.

The inland mangrove in Shravan Kavadia is one of the most important sacred grooves of Gujarat for the local inhabitants and since long fire, harvesting, logging or collection of fire wood have been totally prohibited and considered religiously inauspicious by the local inhabitants for the sustainable development of the area. The sacred grove of the mangrove species is located 80 km inland from the nearest coastal belt of the Gulf of Kachchh and 150 km from the Arabian Sea and is situated in the eastern part of Banni grassland in Kachchh. It is located at 23°24′31.4″N and 69°58′19.5″E, at an altitude of 2–5 m. The entire area is more or less flat and without any gradient. In natural state the mangroves are dispersed for propagation (through seeds and propagules) by sea water. Hence the inland mangrove patches are of great geological interest[6]. The geology of this sacred inland mangrove is interesting. Over two millennia ago, the Rann of Kachchh was a shallow sea, which dried up with the uplifting of land due to tectonic shift[7]. The drying and uplifting of the land led to disconnection of the mangroves from the sea and created a land-locked condition for the mangroves. Therefore, the surviving mangrove patch in Shravan Kavadia belongs to one of the ancient bio-genetic pools. The location map of the site is given in Figure 1.

The climate of the desert/arid land site is dry with extreme weather conditions; the temperature ranges from 4°C to 49°C (being minimum in January and maximum in May–June), with low annual rainfall of 317 mm. Maximum rainfall occurs during the southwest monsoon between June and September. The rainfall is extremely erratic and variable in distribution; therefore, droughts are a recurring phenomenon. The soil consists of recent alluvium mixed at places with aeolian sandy deposit and the entire area has deep to very deep clayey and coarse-textured soil in discontinuous patches. The salinity is highly variable from 1 to 15 mmho/cm and pH may be as high as 8.5. The salinity changes with depth of the soil up to about 3 m. The water is highly saline, thus not suitable for irrigation or drinking purposes. Further, high silt and clay contents lessen the vertical and lateral movement of surface and subsurface water. About 70% of the area falls under very slow to slow permeability ranging from 0.00 to 0.13 cm/h, which subsequently leads to waterlogging in the low-lying areas during good rainfall years[8]. The soil moisture is extremely low (0.5%) during summer season.

The Banni grassland supports the growth of perennial and palatable grasses of high productivity, which grow in low to moderate saline areas comprising *Sporobous pallidus*, *Dichanthium annulatum*, *Sporobolus helvolus*, *Cenchrus ciliaris*, *Cenchrus setigerus*, *Desmostachya bipinata*, etc. High saline areas

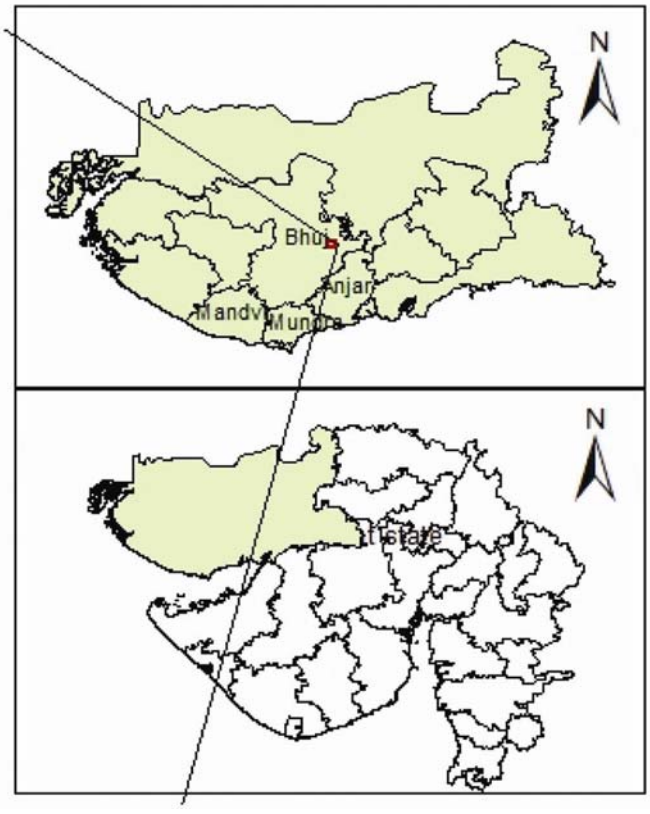

Figure 1. Location map of Shravan Kavadia.

are colonized by perennial grasses of low productivity and palatability such as *Aeluropus logopoides*, *Eurochondra* sp., etc. Among the tree species, *Acacia nilotica* once dominated the area. The shrub and tree strata were mainly composed of *Prosopis cineraria*, *A. nilotica*, *Acacia leucophloea*, *Acacia senegal*, *Salvadora persica*, *Salvadora oleodes*, *Capparis decdua*, *Tamarix* sp. and *Prosopis juliflora*. Presently, though palatable grasses and tree species like *Acacia* and *Salvadora* are present, their abundance has decreased significantly due to the massive invasion and dominance of *P. juliflora*[8].

The wild animals of the area comprise blue bull, chinkara, blackbuck, black-naped hare, wild boar, jackal, grey wolf, caracal, hyena, fox, jungle cat, etc. The area also supports avifauna, herpeto fauna and invertebrates. During good rainfall years, it also supports thousands of migratory cranes and over 150 species of migratory and resident birds.

The area has a very low population density of 3.6 person/km^2 (1991 Census). The residents of the area called Maldharis comprise of Muslims, Hindus and Vadhas communities. Livestock is the mainstay of the inhabitants, which constitutes the major bulk of their assets. Their interest mainly centres on livestock breeding and selling of milk products.

The Inland mangrove at Shravan Kavadia, covering an area less than a hectare near Bhuj in Kachchh district on the fringe of Banni in arid environment, is nature's wonder and its survival is a matter of scientific study. Even though the place is located more than 100 km away from the coastal area, it has a mangrove area of 0.7 ha near the Shravan Kavadia temple. This unique mangrove system is not found anywhere else in the world, as it has neither any connectivity with sea water nor is regular water supply available for the survival of trees. The inland mangrove was identified as a temple forest and nobody cuts or causes any damage to old trees of *Avicennia* in the groves[9].

Two decades ago, there were 80 adult trees in a dense patch. Unfortunately, half of the trees was destroyed during the 1998 cyclone. The Forest Department had reported the survival of 33 trees after the cyclone, which also included the partially damaged or top-broken trees. The Gujarat State Forest Department had partially fenced the area in 1998. Patel and Agoramoorthy[10] reported the existence of a total of 18 plants in this inland mangrove area.

Despite great threat to the survival of *Avicennia marina* in this inland mangrove patch, there is no care protection of this species. During our visits, we found several fallen logs of old trees and few standing trees infested with wood-boring insects on the stems and branches with deteriorating tree growth. Further, absence of young saplings and seedlings at the site strongly indicates the complete future elimination and extinction threat to this endemic inland mangrove species. We also observed a total of 16 trees, of which only 8 plants are the natural ones and the remaining are the coppiced branches from the original stand. The uprooted trees consisted of a strong trunk having a good height up to 18 m and diameter up to 14 m.

The soil samples were collected from 0 to 10 cm depth to study the soil physico-chemical characteristics of the patches with lying uprooted trees as well as standing live trees mixed with *Salvadora* sp. (Table 1). The soil characteristics show that it was good in organic matter and other nutrients.

Soil pH is an important factor for plant growth, but the actual mechanism by which soil pH in inland mangroves affects the growth of plant seedlings is still not well studied. pH values above 7.5 reduce the availability of iron, manganese, copper, zinc and boron ions to plants and extremes in pH can lead to conversion of certain essential nutrients into insoluble hydroxides through their precipitation[11].

Tables 2 and 3 provide information about the uprooted and standing (live) trees of *A. marina*. The morphometric details of the trees show that the uprooted trees (45 number) of *A. marina* have a girth circumference at ground level (CGL) ranging from 140 to 330 cm, and the living trees (8 in number) have CGL of 9–107 cm, indicating quite young trees compared to the previously uprooted ones.

The increasing rate of mortality of *A. marina* observed from 1998 to 2013 may be ascribed to the cyclone in 1998 which uprooted several trees[10], leaving only, 40 plants. Further, an erratic precipitation from 1932 to 2001 in Bhuj taluk along with the adjacent areas of Shravan Kavadia showed a high coefficient of

Table 1. Physico-chemical characteristics of upper 10 cm of soil from different patches

Parameter	Live patch	Dead patch	*Prosopis–Salvadora* mixed patch
pH	7.0	7.5	7.2
EC (μS)	28500	13400	10640
Salinity (ppt)	29	12	13
Temperature (°C)	39	41	38
Moisture (%)	22.11	11.89	31.91
Organic carbon (%)	1.4	0.83	1.6

Table 2. Description of uprooted trees

	Uprooted tree	
Parameter	Maximum	Minimum
Girth at ground level (cm)	330	140
Diameter at ground level (cm)	140	107
Diameter at first branching level (cm)	180	50
Length from ground level to first branch level (cm)	360	294

Table 3. Description of live trees of *Avicennia*

	No. of trees							
Parameter	I	II	III	IV	V	VI	VII	VIII
Girth at ground level (cm)	9	29	35	39	52	84	94	107
Height (cm)	40	192	348	191	350	727.4	602.4	797.4

variation from 68% to 79% (1982–91). It indicated the high year-to-year variability, with annual evapo-transpiration rate of 1887 mm (ref. 12). Gilman *et al.*[13] and Field[14] reported that a strong link exists between mangrove habitat condition and rainfall trend. It is further observed that decreased rainfall, increased temperature and evaporation lead to increased salinity, decreased seedling survival, growth and net primary productivity and reduced mangrove area because of conversion of land into a hypersaline flat. Furthermore, a decrease in precipitation results in increased salinity because of smaller water input to groundwater and less fresh surface water input to mangroves. Field[14] ascribed the reduced productivity of mangroves under increased salinity conditions to increased tissue salt levels and concomitant decrease in water availability. These factors could also be responsible for reducing the population of inland mangrove species. Patel *et al.*[15] reported the inhibited growth of *A. marina* in higher salinity, as evident by the results, which show the species to be highly salt-tolerant during germination, but the growth of seedlings is promoted by low salinity.

The serious survival risk of the sacred grove species is further aggravated and triggered by the invading alien species, *P. juliflora*. The latter requires 3–4 times more water to produce a unit of dry matter as do native perennial grasses[16]. Hence it might have worsened the soil moisture condition, affecting the inland mangrove patch. According to Patel and Agoramoorthy[10], wood borers are also a great threat to the inland mangrove.

The survival of *A. marina* in the inland mangrove of the sacred groves of Shravan Kavadia, being the only inland mangrove in sacred grove in the world, deserves immediate conservation and management attention. Despite their extreme habitat, a few trees (eight) are still live. In several coastal areas of India, mangrove forests have been successfully restored either through *in situ* or *ex situ* conservation. Biotechnological approach would also help to keep the genetic pool of the species. So this small patch of *Avicennia* mangrove can be protected and restored through serious and scientific intervention of local Forest Department, government and non-government organizations. Immediate action is required by the local inhabitants, the government and the media for the protection of the rare sacred grove species of *A. marina* in this inland mangrove patch.

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NIMISHA TRIPATHI[1,5,*]
RAJ S. SINGH[2]
BHOOMI BAKHORI[1]
CHANDANA DALAL[3]
DAYESH PARMAR[1]
BIKASH MISHRA[4]

[1]*Gujarat Institute of Desert Ecology, Bhuj 370 001, India*
[2]*CSIR-Central Institute of Mining and Fuel Research, Barwa Road, Dhanbad 826 001, India*
[3]*Institute of Research in Ecology and Environmental Technology, Bhuj, India*
[4]*School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110 067, India*
[5]*Present address: Green Earth Citizen, Väpnaregatan 45, 586 47 Linköping, Östergötlands län, Sweden*
**For correspondence.*
e-mail: nymphaea7@gmail.com