Distribution and population status of threatened medicinal tree *Saraca asoca* (Roxb.) De Wilde from Sahyadri–Konkan ecological corridor

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The study assesses distribution and population status of *Saraca asoca* from Sahyadri–Konkan ecological corridor. Eighteen localities at various protection levels ranging from wildlife sanctuary to private forests were selected and spatially mapped to arrive at a distribution map. Kolmogorov–Smirnov test indicated that the size class distribution of *S. asoca* from the sacred groves differed both from formally protected sites and private forest. *S. asoca* trees from sacred groves had the highest mean girth at breast height (GBH) values than the other two protection levels. GBH of *S. asoca* was in inverse proportion with the cumulative disturbance index.

Keywords: Cumulative disturbance index, Kolmogorov–Smirnov test, *Saraca asoca*, Sahyadri–Konkan ecological corridor, regeneration.

BIOLOGICAL resources are often referred to as the 'resource capital' of a nation[1]. Among the 34 global biodiversity hotspots, the Western Ghats of India occupies the fifth position in terms of 'economic potential' of its biological resources[2]. This region is home to over 4000 plant species of medicinal value, many of which are highly endemic to the region. Modern medicine depends on several high-value metabolite-yielding plant resources as major raw material. Of the 960 commercially traded medicinal plant species from India, 178 are consumed in volumes each exceeding 100 metric tonnes per year, which in turn makes up about 80% of the total industrial demand of all botanical products in the country[3]. Recent studies have indicated that majority of the demand of the pharmaceutical industry for medicinal and aromatic plants (MAPs) is fuelled from the harvesting of wild populations. This has led to unsustainable, unscientific harvesting, resulting in the rapid depletion of wild populations. In the Western Ghats, the population decline of endangered medicinal plants in the last decade alone has been greater than 50%.

Saraca asoca is one such species that has witnessed unsustainable harvesting and is in need of conservation attention. It is one of the 32 species of medicinal plants that has been prioritized by the Government of India's Planning Commission, as well as the National Medicinal Plant Board for 'research and development' purposes[4]. *S. asoca* is distributed throughout India, predominantly in southern India, Odisha and Assam, and up to an altitude of 750 m above sea level in the central and eastern Himalaya[5]. Although relatively widely distributed across the subcontinent, the population of *S. asoca* is highly fragmented[6]. With over half of the vegetation of the Northern Western Ghats (NWG) being cleared[7], highly fragmented, scattered natural populations of medicinally important species such as *S. asoca*, *Nothapodytes nimmoniana* (J. Grah.) D. J. Mabberley, *Symplocos racemosa* Roxb. and *Dysoxylum binectariferum* Hook. f. ex Bedd. exist in remnant forest patches or in informally protected forest landscapes known as 'sacred groves' (SG)[8].

In addition to habitat destruction as well as *S. asoca* occupying a narrow ecological niche, the decline in natural population of this species is also largely due to unsustainable methods of harvesting. Primarily, the harvesting of the bark causes irreversible damage to the plant. Recognizing the importance of this species and the imminent threat to its existence, *S. asoca* was assigned 'vulnerable' status by IUCN[9] and 'endangered' status by CAMP[10]. Due to its medicinal importance and its data deficient nature regarding its population structure and distribution, it has become essential to identify and spatially map the existing populations and assess the status of regeneration in the Sahyadri–Konkan ecological corridor. Using girth at breast height (GBH) as a measure, we evaluate if the formally protected areas indeed offer greater degree of protection to *S. asoca*. We also intend to find out if any statistically significant correlation exists between disturbance and GBH of *S. asoca* trees in areas under study.

The study area covers existing natural population of *S. asoca* in the Sahyadri–Konkan ecological corridor of Maharashtra (15°30′–20°30′N, 73°–74°E) from Pune, Raigad, Kolhapur, Ratnagiri and Sindhudurg district (Figure 1)[11]. The corridor covers an area of about 10,489 sq. km and further extends to Karnataka and Goa[12]. The major vegetation types in this corridor are moist deciduous and evergreen. The evergreen forests of

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this area are relatively poor in tree endemicity compared to the evergreen forests of the southern Western Ghats[12]. The average elevation of these ranges is 1000–1200 m above the mean sea level (m amsl).

Eighteen localities (ST1 to ST18) were studied for different ecological parameters (Table 1), of which age structure studies were performed in two protected areas (PAs) (one wildlife sanctuary and one reserved forest patch), six sacred groves and one private forest (PrF), adopting a transect-based methodology. Transects of dimension 100 m × 5 m were laid down in these localities. Within each transect, GBH of adult individuals (≥15 cm) and number of regenerating individuals of the species were recorded (Table 2).

Kolmogorov–Smirnov (KS) test[13] was performed for comparing populations from these sites. It is used to determine if the two datasets under consideration differ significantly or if they belong to the same population. This is dependent on the D value – the statistic under consideration. If the D value is significantly large (as indicated by smaller p value, p value < 0.05), then the populations differ significantly, thereby verifying if differing degrees of protection have any significant effect on tree population.

The percentage of overhead forest canopy cover was measured using spherical convex densiometer (forest densiometers, Model-C).

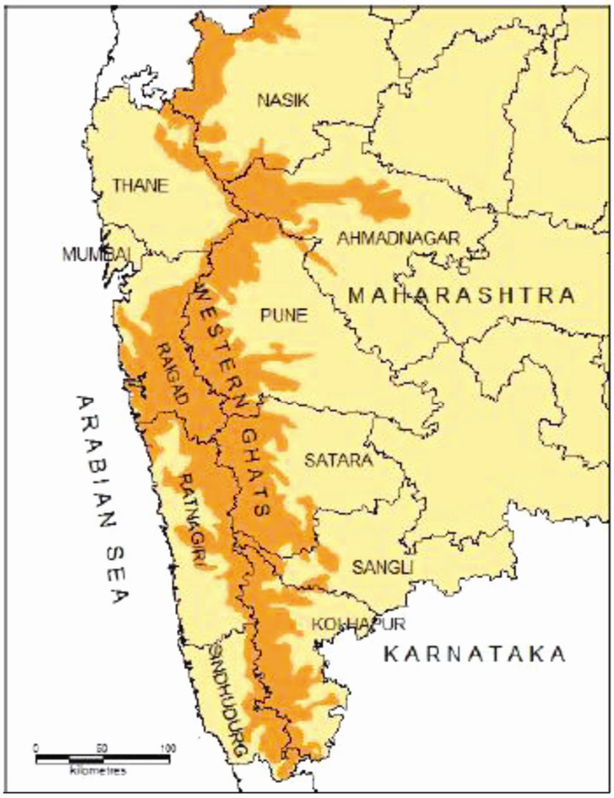


Figure 1. Geographical location of Sahyadri–Konkan ecological corridor.

Observations regarding level and type of disturbance were recorded following Tadwalkar *et al.*[14]. Each transect was assessed for the intensity of human disturbance which it had suffered. Evidence of this was based on observation of cut stumps, grazing, soil removal, presence of footpaths, fire and weeds. For each of these six features, the degree of disturbance seen was assessed at four levels: 0 = no significant impact, 1 = low impact, i.e. impact may not be clearly discernible to layman unless observed carefully, 2 = moderate impact, i.e. impact visible, but not threatening to the environmental element, 3 = high impact, i.e. threatening the very existence of a species; high level of habitat degradation. A cumulative disturbance index (CDI) was calculated for the studied localities by adding the six scores, giving a maximum CDI of 18. CDI was compared against modal and mean GBH values of *S. asoca* at different localities to find out correlation between them, if any.

The exact geo co-ordinates and elevations of all localities were recorded using a global positioning system (GPS) – Garmin Map 60 CSx GPS receiver. Using this, spatially explicit distribution maps were prepared using Geographic Information System software MapInfo 7.5 developed by Mapinfo Corporation. The recorded geo coordinates and elevation details were used for all localities. Monthly normalized differential value index (NDVI) images for 2014 were downloaded from moderate resolution imaging spectroradiometer (MODIS) product[15]. The spatial resolution of this NDVI images is 250 m. Average NDVI for the study area was calculated using 'raster' package in R[16,17]. Overlay analysis was performed with average NDVI and the sampled locations by extracting NDVI values at each location and depicted in Figure 2.

S. asoca was found to occur across a wide range of elevation. Of the eighteen sites studied, seven were present at an altitude of less than 200 m amsl, ten were between 200 and 400 m amsl and one was at an altitude of higher than 600 m amsl. Details of relevant ecological parameters of sampling sites are given in Table 1. The associated species observed at these sampling sites are listed in the appendix 1. Highest densities were found in semi-evergreen and moist deciduous forests with NDVI values ranging from 0.47 to 0.75. Overlay analysis suggested that most of the *S. asoca* locations were in the area with NDVI values of 0.5 to 0.7.

It was observed that *S. asoca* is confined to edges of gently flowing streams in its natural habitat in the low lying areas. Through age structure studies, we recorded a total of 298 adult and 441 regenerating individuals. The adult *S. asoca* tree density varied between 120 and 1140 adult trees per hectare in the studied localities.

Demographic profiles of *S. asoca* from PAs (ST2 and ST14) showed a good representation of recruitment (adults with GBH between 15 and 30 cm) (Figure 3); however, these sites were found to be lacking in large-sized adults. The population among the sampled SGs

Table 1. Ecological parameters assessed for sampled locations

Code	Protection level	Latitude (degree decimals)	Longitude (degree decimals)	Altitude (m)	Canopy cover (%)	Density (per ha)	Minimum GBH (cm)	Maximum GBH (cm)	CDI	Remarks
ST1	UF	18.60	73.21	381	25–50	360	12	130	–	Cattle grazing, fuel wood removal
ST2*	WLS	18.42	72.95	185	80–100	840	16	90	3	Cattle grazing, collection of seeds
ST3	UF	17.89	73.16	140	0–25	480	11	73	–	Cattle grazing, fuel wood removal
ST4*	SG	17.86	73.24	223	60–80	1140	15	60	6	Cattle grazing
ST5	UF	17.72	73.22	127	0–25	240	11	66	–	Cattle grazing, fuel wood removal
ST6*	SG	17.71	73.22	258	60–80	460	15	98	7	Cattle grazing
ST7	UF	17.66	73.27	200	0–25	120	9	54	–	Cattle grazing, fuel wood removal
ST8*	SG	16.93	73.85	374	40–60	340	15	74	7	Tourism, predation of seeds by Bonnet macaques
ST9*	SG	16.58	73.90	618	20–40	300	8	30	9	Tourism and fuel wood removal
ST10	UF	15.91	73.95	222	75–100	700	6	85	–	Cattle grazing, fuel wood removal
ST11*	UF	15.85	73.95	290	20–40	560	12	67	11	Cattle grazing, fuel wood removal
ST12	UF	15.84	73.97	241	25–50	640	6	30	–	Cattle grazing, fuel wood removal
ST13	UF	15.82	74.13	211	25–50	460	11	90	–	Cattle grazing, fuel wood removal
ST14*	RF	15.81	74.26	178	40–60	1000	15	40	6	Fuel wood removal
ST15*	SG	15.79	74.11	289	40–60	660	15	117	4	Cattle grazing, mining, pilgrimage and fuel wood removal
ST16	UF	17.69	73.22	281	25–50	120	9	54	–	Cattle grazing, fuel wood removal
ST17*	SG	15.58	73.95	200	60–80	660	15	149	3	Cattle grazing, mining, tourism, fuel wood removal and collection of seeds
ST18	UF	15.37	74.10	167	25–50	680	13	87	–	Cattle grazing, fuel wood removal

UF, Un-classed forest; WLS, Wildlife sanctuary; SG, sacred grove. *Localities sampled for population studies.

Table 2. Regeneration classes

Class	Category
1	<40 cm height
2	40–100 cm height
3	>100 cm height, <10 cm girth at breast height
4	>130 cm height, <15 cm girth at breast height

(ST4, ST6, ST8, ST9, ST15 and ST17) showed large variation. ST4 and ST8 showed the highest number of individuals in low GBH measurement categories. Illicit felling of adult trees was also observed here. ST6 showed reverse J-shaped curve with good representation of recruitment (adults of different GBH classes from 15 cm and above) and large-sized adults. It showed a healthy and only moderately disturbed population structure. Population of ST9 was found to be undergoing high pressure from lopping; thus, the site was deficient in medium and large sized adult trees. The private forest site (ST11) also showed a similar demographic profile. High proportion of medium-aged trees was found in ST15 and ST17.

KS test found that size class distribution of the adult populations from the sacred groves differs from formally protected sites with $D = 0.45$ (p value < 0.0005), as well as from private forest, with $D = 0.36$ (p value < 0.0005) (Figure 4). However, there was no significant difference between size class distribution of adult populations from the protected areas and private forest ($D = 0.15$, p value $= 0.328 > 0.05$) (Figure 5). The same was reflected in single factor ANOVA between GBH values of *S. asoca* adult trees and three protection classes – formally protected sites, informally protected sacred groves and private forest (p value < 0.005), with mean GBH values being 30.5, 40.3 and 27.4 cm respectively.

The graph of cumulative disturbance index (CDI) versus modal value of GBH in different localities showed a significantly negative correlation between these two parameters, i.e. modal GBH value decreases with increase in CDI values ($r = -0.7272$, p value < 0.005) (Figure 6). Single factor analysis of variance (ANOVA) indicated significant difference between CDI value and corresponding GBH values of *S. asoca* adult trees (P value < 0.005).

The highest percentage of regenerating individuals in Class 1 (Table 2) was found in protected forest patches such as ST2 (WLS) and ST14 (RF) (Figure 7), while SGs (ST4, ST6, ST8, ST9, ST11, ST14, ST15 and ST17) had the highest percentage of regenerating individuals in classes 3 and 4 (Table 2). No recruiting individuals (adults with GBH between 15 and 30 cm) were observed in private forest (ST11). Graph of regeneration versus canopy cover percentage (Figure 8) demonstrates better germination of species ($r = -0.887$, p value $= 0.23$) when openings in the canopy were 40–60%. Preliminary results of this work have been reported by Patwardhan *et al.*[18].

Recruitment of viable seeds, germination, establishment and growth of seedlings are indicators of the regeneration potential of a plant community, which in turn affects the population's age structure[19]. Plotting the size class distribution of this population showed a 'reverse J'

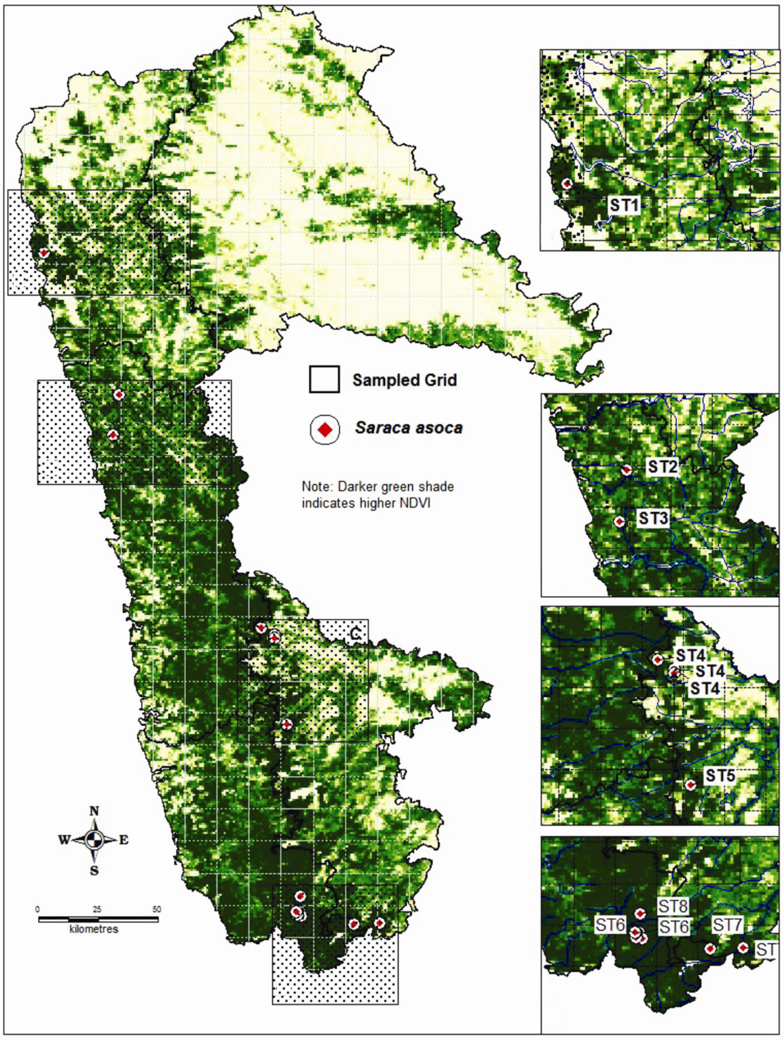


Figure 2. Distribution of *Saraca asoca* overlaid on NDVI.

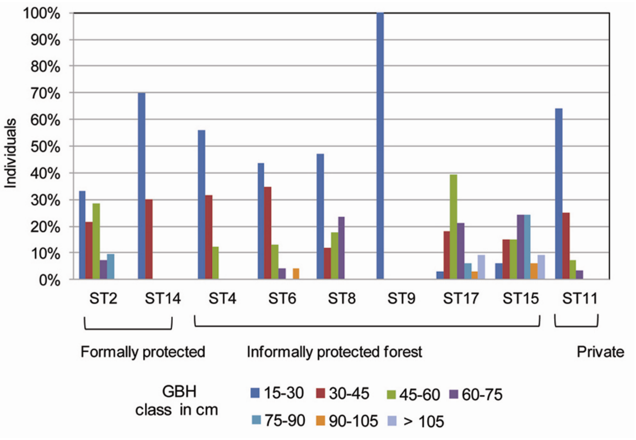


Figure 3. Demographic profile of adult individuals of *S. asoca*.

shaped pattern, i.e. a large number of individuals in small size classes and a few individuals in large size classes, indicating that these populations are expanding through active recruitment. KS test provided an additional measure of distinctness in nature of size class distribution. The dependence of several tropical tree species on canopy openings for germination and seedling growth is well documented[20,21]. This study demonstrates a similar trend by finding higher levels of regeneration of *S. asoca* in the proximity of canopy openings (Figure 8).

Sites in close proximity to human settlements (such as ST11, also a private forest) were found to witness high degrees of disturbance and no recruitment (likely due to cutting of *S. asoca* for fuel wood). As a result, few stunted individuals of *S. asoca* were seen left behind after selective harvesting of higher girth classes, a practice that adversely affects natural regeneration and threatens population spread, as also observed by Lyaruu *et al.*[22] in a dry Afromontane forest in Tanzania.

'Sacred groves' or informally protected sites were also found to exist under similar ecological constraints. Shortage of mature reproductive individuals as well as individuals in smaller size classes were observed in ST8 and ST4; this regeneration failure is similarly speculated to be related to their over-exploitation for poles, fuel wood and

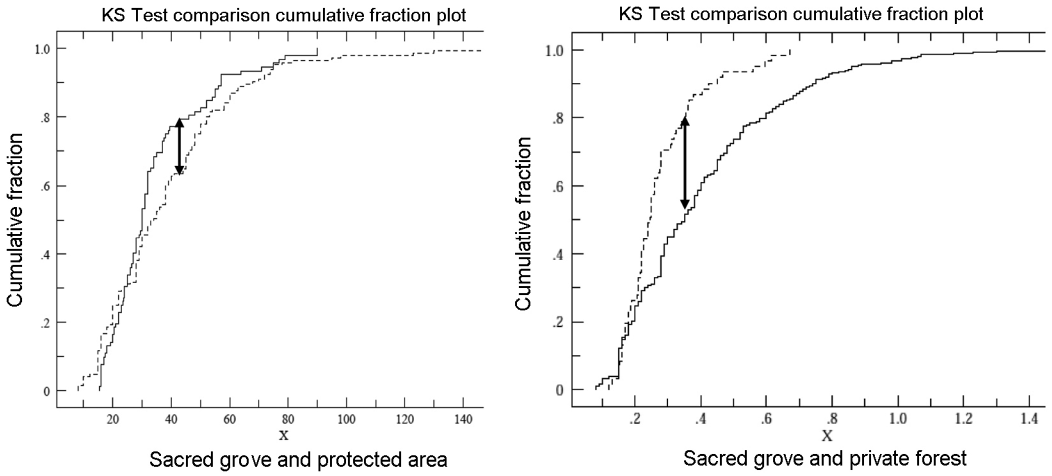


Figure 4. Kolmogorov–Smirnov (KS test comparison cumulative fraction plot for adult individuals of *S. asoca*.

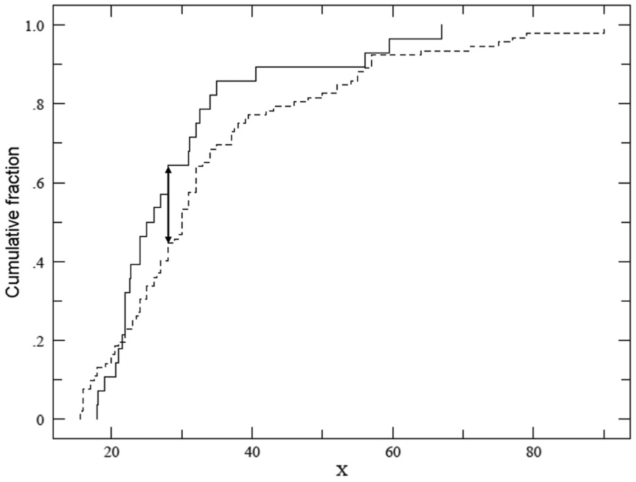


Figure 5. KS test comparison cumulative fraction plot for adult individuals of *S. asoca* from private forest versus protected area.

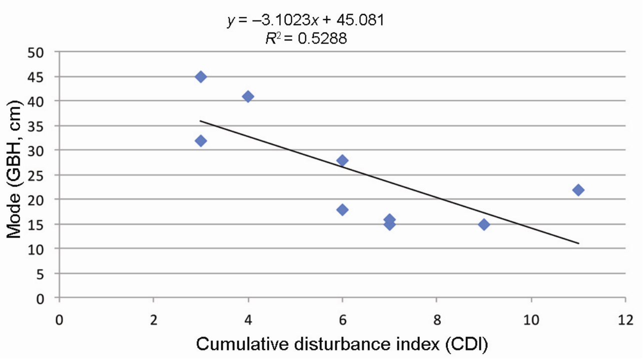


Figure 6. Cumulative disturbance index versus girth at breast height (mode) (cm) of adult *S. asoca* trees.

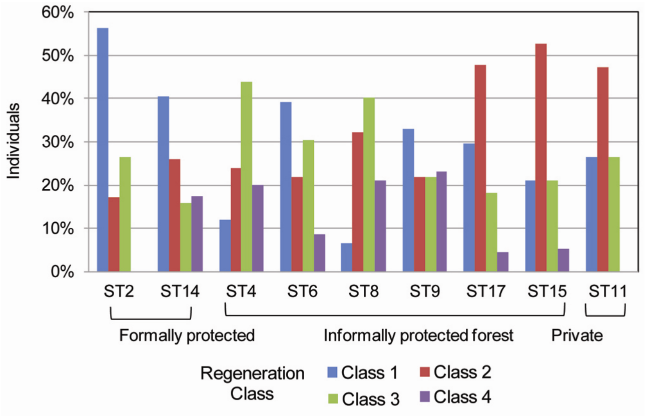


Figure 7. Regeneration status of *S. asoca* at various protection levels.

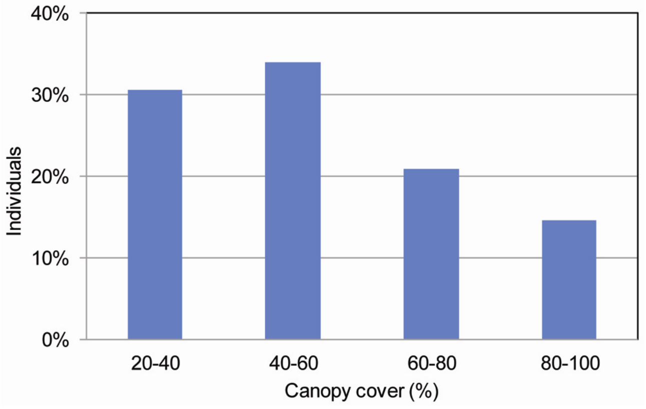
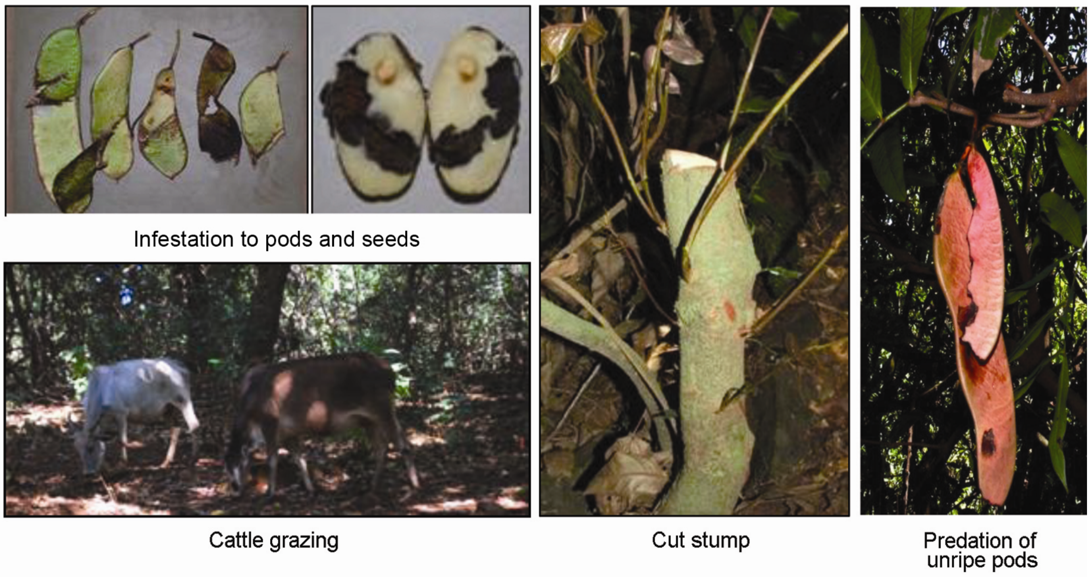


Figure 8. Regeneration status of *S. asoca* at various canopy cover (%) levels.

timber. In ST8, in addition to man-made causes of disturbance, bonnet macaques were observed to be damaging the inflorescence and eating young leaves, presenting a major hindrance to plant development due to their predation of unripe pods (Figure 9). In addition, ST8 also being a site of pilgrimage, is the site of extensive amounts of garbage dumping (including polythene bags). This hinders regeneration by trapping seeds in



Infestation to pods and seeds

Cattle grazing

Cut stump

Predation of unripe pods

Figure 9. Factors that limit population build-up of *S. asoca*.

Appendix 1. List of associated species

Antiaris toxicaria Lesch.
Bridelia retusa Spreng
Caryota urens L.
Chukrasia tabularis A. Juss.
Dimocarpus longan Lour.
Drypetes roxburghii (Wall.) Hurusawa,
Erinocarpus nimmonii J. Graham
Flacourtia montana Graham
Grewia microcos L.
Hydnocarpus pentandra (Buch.-Ham.) Oken
Lagerstroemia parviflora Roxb.
Mallotus philippensis (Lam.) Muell.-Arg.
Mangifera indica L.
Meyna laxiflora Robyns.
Nothapodytes nimmoniana (J. Graham*)* Mabb.
Nothopegia castaneifolia (Roth) Ding Hou
Pandanus odoratus Thunb.
Sterculia guttata Roxb.
Stereospermum chelonoides (Lf.) DC.
Syzygium cumini (L.) Skeels
Terminalia tomentosa Roxb. (ex DC) Wight & Arn

Artocarpus heterophyllus Lam.
Butea superba Roxb
Chionanthus mala-elengi (Dennst.) P.S. Green
Dillenia pentagyna Roxb.
Diospyros candolleana Wt.
Dysoxylum binectariferum Hook.f. ex Bedd.
Erythrina variegata L.
Garcinia talbotii Raiz. & Sant
Holigarna grahamii (Wt.) Kurz.

Macaranga peltata (*Roxb*.) Mueller
Mammea suriga (Buch.-Ham. ex Roxb.) Kosterm.
Memecylon umbellatum Burm.f.
Neolamarckia cadamba (Roxb.) Bosser

Sageraea laurifolia (Graham) Blatt.
Sterculia urens Roxb.
Symplocos racemosa Roxb.
Terminalia bellirica Roxb.

polythene as well as by attracting more macaques to the site.

Another site, ST17 is in the proximity of a road, under construction at the time of study, leading to a bauxite mine. Chopping of *S. asoca* individuals along the periphery of the grove was observed. A gently flowing stream runs through ST14 and ST17. Regeneration through seeds was less in these sites as compared to the re-sprouting from rootstocks, as seeds were dispersed because of the water. Survival of plants after being cut was a phenomenon especially evident at site ST17.

Though populations of the species were observed throughout the study area, regenerating populations were seen to be uncommon. Recruitment of the regenerated individuals was seen to be affected in both WLS and PrF. A significant number of *S. asoca* individuals (61 in a 5 × 100 m transect) was found on privately owned lands, where farming and fuel wood extraction are primary land use activities. In such cases, the trees are lopped and regenerating saplings uprooted. However, under such conditions, small populations of the species still thrive in these areas.

KS test indicated that the size class distribution of the adult populations from the sacred groves differed both from formally protected sites and private forests. Mean GBH values of *S. asoca* trees were highest in sacred groves than those from protected sites and private forest. GBH of the adults was found to be in inverse proportion with the CDI. Effective conservation of *S. asoca* in natural population can be achieved by high levels of protection (involving the local community and government), creation of forest gene banks and more extensive, scientific studies of the species. Reducing harvest pressure on wild populations and promoting viable commercial cultivation with the community and government participation are feasible strategies, but must be developed with an understanding of the implementation challenges. First steps for future course of action include developing package of practices for cultivation as well as experimental pilot plots for growth studies. Experiments on bark harvests with the goal of informing the optimal strip size, when and how much to harvest, time and process of bark healing, etc. will provide several valuable and much-needed insights for the sustainable utilization of this important bio-resource. Community buy-in and sustained engagement is essential for this endeavour to succeed, including development of awareness among community members and the local population on the importance of this species. Re-introduction of the species, if carried out, should be done keeping in mind the suitability of the site and ecological niche (for instance, it was seen in this study that areas with riparian ecology with 40–60% openings in canopy served as suitable regions for growth). Finally, in the light of the prevalence of mammal frugivory on these plants, conservation measures should take this into account and control it.

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