Invasion and Management of *Senna spectabilis* in Wayanad Wildlife Sanctuary, Kerala

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KERALA FORESTS AND WILDLIFE DEPARTMENT

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1. INTRODUCTION

Invasive alien species are plants or animals that are introduced by man, accidentally or intentionally, outside their native geographic range into an area where they are not naturally present and spread causing damage to native biodiversity that is being conserved (IUCN, 2013) Most of the invasive plants have similar growth strategies such as fast growth rates, short life-cycles, higher reproductive potential, high competitive capacity and allelopathic traits, which make them successful invaders of native habitats (Amith Kumar & Santhosh, 2014). Plant invasions have been recognized as one of the most serious global processes impacting the structure, composition and function of natural and semi-natural ecosystems (Mooney and Hobbs, 2000; Raizada et al., 2008; Vitousek et al., 1997). These species are invading large areas of land including Protected Areas. Inside forests, they are replacing the undergrowth and reducing the regeneration of native species. They decrease native species richness and abundance via competition and indirect effects (Gaertner et al., 2009). Also, they change community structure in ecosystems (Hejda et al., 2009). The problem continues to grow at great socioeconomic, medical and ecological cost around the world. A total of 173 species of invasive species in 117 genera under 44 families were documented as invasive alien plant species, representing 1% of the Indian flora (Reddy et al. 2008). Nearly 3% of these plants are trees (Reddy et al., 2008).

The Western Ghats are recognized as a global Biodiversity Hotspot (Mittermeier, et al., 1999; Myers et al., 2000). In the southern part of the Western Ghats, across three southern states of India, namely Tamil Nadu, Karnataka and Kerala, lies the Nilgiri Biosphere Reserve (NBR). NBR is the first Biosphere Reserve to be declared in India (in September 1986) under the UNESCO's Man and Biosphere program. The NBR is a globally important conservation area which supports in-situ conservation of many endangered, threatened and rare species including Asian elephant, Bengal Tiger, Gaur, Wild dog, White-rumped vulture, etc. The NBR has a significant number of endemic species (248 species), supports most of the large mammals found in peninsular India, and also hosts Red Data Book species: 55 Critically Endangered species, 148 Endangered species and 127 species listed as Vulnerable (CEPF, 2004). The NBR is home to over 6000 Asian elephants (Elephas maximus) and it is the single largest contiguous population of the species in Asia. Invasive plant species pose a serious threat to conservation and management of the Nilgiri Biosphere Reserve (NBR). The exotic invasive tree *Senna spectabilis* is rapidly spreading in various PAs in NBR. A large part of the Wayanad Wildlife sanctuary in NBR is covered by this invasive species. The spread of *S. spectabilis* is one of the major conservation and management challenges in Wayanad Wildlife Sanctuary. Given this context, this study: (1) maps the pattern of distribution of *S. spectabilis* in the Wayanad Wildlife Sanctuary (2) assesses the abundance of *S. spectabilis* in different density classes.

S. spectabilis H.S. Irwin & R.C. Barneby (Caesalpiniaceae) (syn. *Cassia spectabilis* DC) is a tree native to Central and South America (Irwin & Barneby, 1982).

Description: Tree. Ten or more metres high, the branchlets usually tomentose when young. Leaves moderately large, an average leaf about 20-foliolate; petiole short, pubescent, eglandular; rachis usually about 2 dm long, eglandular and otherwise like the petiole; leaflets several to many pairs, lanceolate, 3-8 cm long and usually about 2 cm wide, acute apically, obtuse basally, pubescent below, especially along the veins, puberulent to sub glabrous above and less dull than below, opposite on the rachis, with 10 or more pairs of prominent lateral veins; petioles 2-3 mm long, pubescent. Inflorescence of several terminal or subterminal several-flowered racemes; bracts lanceolate, a few mm long, caducous. Flowers yellow; sepals 5, obovate-orbicular, markedly unequal, up to 1 cm long and broad, glabrous to lightly puberulent; petals 5, mostly obovate, markedly unequal, up to 2.5 cm long and 1.5 cm broad, sub glabrous, venose, short-clawed; stamens 10, 3-morphic; the 3 lowermost the largest, their anthers oblong, about 7 mm long, short-rostrate apically and dehiscent by terminal pores, the loculi somewhat converging terminally; anthers of 4 median stamens 5-6 mm long, similar to the 3 lowermost except the rostrum reflexed and the loculi divergent terminally; 3 uppermost stamens markedly dissimilar, more or less rudimentary, the anthers distinctly bilobed, each lobe reniform and dehiscent the length of its outer margin; ovary linear, glabrous. Legume linear, turgid-quadrangular, up to 2 dm long and 1 cm wide, transversely multiseptate, tardily dehiscent along one margin (Missouri Botanical Garden, 2014).

1.1 *Senna spectabilis*

Senna spectabilis H.S. Irwin & R.C. Barneby (Caesalpiniaceae) (syn. Cassia spectabilis DC) is a tree native to Central and South America (Irwin &Barneby,1982).

Scientific Name: *Senna spectabilis*

Synonyms: Cassia excelsa, Cassia humboldtiana, Cassia spectabilis, Pseudocassia spectabilis

Common Name: White-bark Senna, Golden Senna, Calceolaria Shower, Spectacular Senna, Yellow Shower

Local name (Malayalam): Swarnakkonna, Manjakkonna, Rãkshasakkonna

Description: Tree. Ten or more metres high, the branchlets usually tomentose when young. Leaves moderately large, an average leaf about 20-foliolate; petiole short, pubescent, eglandular; rachis usually about 2 dm long, eglandular and otherwise like the petiole; leaflets several to many pairs, lanceolate, 3-8 cm long and usually about 2 cm wide, acute apically, obtuse basally, pubescent below, especially along the veins, puberulent to subglabrous above and less dull than below, opposite on the rachis, with 10 or more pairs of prominent lateral veins; petiolules 2-3 mm long, pubescent. Inflorescence of several terminal or subterminal several-flowered racemes; bracts lanceolate, a few mm long, caducous. Flowers yellow; sepals 5, obovate-orbicular, markedly unequal, up to 1 cm long and broad, glabrous to lightly puberulent; petals 5, mostly obovate, markedly unequal, up to 2.5 cm long and 1.5 cm broad, subglabrous, venose, short-clawed; stamens 10, 3-morphic; the 3 lowermost the largest, their anthers oblong, about 7 mm long, short-rostrate apically and dehiscent by terminal pores, the loculi somewhat converging terminally; anthers of 4 median stamens 5-6 mm long, similar to the 3 lowermost except the rostrum reflexed and the loculi divergent terminally; 3 uppermost stamens markedly dissimilar, more or less rudimentary, the anthers distinctly bilobed, each lobe reniform and dehiscent the length of its outer margin; ovary linear, glabrous. Legume linear, turgid-quadrangular, up to 2 dm long and 1 cm wide, transversely multiseptate, tardily dehiscent along one margin (Missouri Botanical Garden, 2014).

1.2 Invasiveness, history of introduction and spread of *S. spectabilis*

S. spectabilis is a medium to large tree from tropical America (Randall, 2012). This is a rapidly growing tree, which flowers and sets seed profusely, and re-sprouts readily when cut. It is spreading as an invasive plant in many parts of the world. In Uganda, the species is considered as an invasive alien species with high risk to the native flora (Mungatana and Ahimbisibwe, 2010). It was initially planted to create shade, but later farmers grew it as living fences to prevent crop depredation by wild animals in Tanzania (Wakabira, 2002). In Australia it is considered naturalised, has been recorded as a weed of the natural environment and an escapee from cultivation, and is labelled an invasive species, indicating its high negative impact on the environment due to its ability to spread rapidly and often create monocultures (Randall, 2007). In Singapore and Cuba, *S. spectabilis* has

been identified as an invasive species (Chong et al., 2009, Oviedo-Prieto et al., 2012). It is a cultivation escapee in Trinidad and Tobago (Irwin and Barneby, 1982).

S. spectabilis was present in Colombia as of 1832 (recorded as *Cassia speciosa* by Kunth and Don, 1832). Introduction of the species to the West Indies is uncertain but it was likely to have spread from its native South America some time ago. Specimens from Trinidad and Tobago were collected in 1862 as *C. spectabilis* DC (Royal Botanic Gardens Kew, 2003) and the species was being cultivated in the Royal Botanic Gardens of Trinidad by 1869 as *C. spectabilis* (Prestoe, 1870). By 1879 the species was known to occur in South Mexico, Costa Rica, West Indies and the northern parts of South America as *C. spectabilis* DC (Godman et al., 1879). The species must be a relatively recent introduction to Puerto Rico, as it was not included in Bello's flora of Puerto Rico (Bello Espinosa, 1881). The species is considered by Irwin and Barneby (1982) as a cultivation escapee in Trinidad and Tobago and both native and adventive to northern parts of the Orinoco basin, Venezuela. The lack of collections of *S. spectabilis* from the West Indies in the US National Herbarium may be indicative of the foreign origin of this species for this region. In Puerto Rico, this species is known from US collections dating from 1954 (US National Herbarium). However, it is certainly much more widespread in Puerto Rico than what is currently reported in the literature or herbaria collections; recent fieldwork in Puerto Rico indicates that *S. spectabilis* is becoming widespread in the southern flanks of the Central mountain range in the area of Salinas and Villalba (Acevedo-Rodriguez, pers. comments).

The species is thought to have been introduced to Africa by Indian sawmill operators or Europeans for firewood and live boundary marking, as a way to reverse deforestation, desertification and fuelwood shortages; however, the species has since invaded most forest ecosystems, where it has outcompeted native tree species with its fast colonisation and thicket establishments (Mungatana and Ahimbisibwe, 2010). The species was present in Tanzania prior to 1967, when it was intentionally introduced to Mahale Mountains National Park in order to create shade and later cultivated by farmers as living fences to prevent crop damage by animals. It is now recognized as an invasive alien species in parts of Kenya, Malawi, Tanzania and Uganda (Wakibara and Mnaya, 2002; Witt and Luke, 2017). This species was introduced in India as an avenue tree in the middle of 1980s. It was identified as an invasive alien species in 2012 in Wayanad Wildlife Sanctuary (Sajeev et al., 2012).

1.3 History of introduction and spread of Senna in Wayanad Wildlife Sanctuary

According to Sajeev et al. (2012) there are about 38 alien invasive species (AIS) found in the forests of Kerala. In the Invasive Ranking (I-Ranking) conducted by Kerala Forest Research Institute in 2012, *S. spectabilis* was categorised as a medium risk species. In Wayanad WLS, *S. spectabilis* was first introduced in 1986. The seedlings of the plant were raised at Ponkuzhy (11.69595, 76.39365) by the social forestry wing of Kerala Forest Department. The trees were first planted in the forest office compound at Muthanga as shade trees. Less than ten trees were planted in 1986 at Muthanga (Raghavan, Pers. Comm.). For several years this species was not identified as an invasive species. The species was noticed regenerating profusely inside Wayanad Wildlife

Sanctuary after 25 years of its introduction. In 2013, after realising the impact of this species to native flora and fauna, the forest department started its management to control its further spread. The department tried to control its spread through various means such as: (1) girdling (cut through the bark all the way around a tree or branch); (2) applying kerosene in the debarked area. Initially 19500 trees were treated with this method. This control measure was assessed by a team of experts from Wildlife Trust of India (WTI). This study reported that a very small percentage of trees completely died after 8 months of the management measure. The study also reported a high number of coppice shoots sprouting from the trees that were debarked (WTI, 2014). The girdling method continued in the following years in different locations. The management effort was not successful in stopping or limiting the spread of Senna. Instead, huge amounts of seeds in the soil started regenerating, and multiple coppice shoots also started growing from each tree. Thus, the management effort only helped in increasing the spread of the invasive species.

Kerala Forest Research Institute conducted a study in 2016-2017 to manage the species through physical and chemical methods. Six physical methods and six chemical methods were tried out in the field. A detailed report on *S. spectabilis*, with management prescriptions, was submitted to Kerala Forest Department.

2. MATERIALS AND METHODS

2.1 Study area

Wayanad Wildlife Sanctuary: The Wayanad Wildlife Sanctuary (WWS) is part of a contiguous stretch of forest with Bandipur, Nagarahole and Mudumalai Tiger Reserve of NBR. The total area of the sanctuary is 344.44 Km2. Wayanad has some of the richest forests in terms of biodiversity in the Western Ghats, containing several species of endemic, threatened and endangered flora and fauna. Almost all large mammals of peninsular India occur in Wayanad. The larger herbivores include the Asian elephant (Elephas maximus), Gaur (Bos gaurus), and Sambar deer (Rusa unicolor). Wayanad is also a key landscape for large predators like Tiger *(Panthera tigiris)*, Leopard (*Panthera pardus*), and Wild dog (*Cuon alpinus*) (Narasimen, R. K et al. 2014). A large tribal population directly depends on the forests of Wayanad for daily livelihood requirements. The study area has monsoon-dependent forests showing strong seasonality with mainly two seasons. The southwest monsoon provides major rainfall to the region, and the rainfall during the northeast monsoon is meagre.

2.2 Methodology

2.2.1Mapping the distribution and abundance of *S. spectabilis*

The abundance of Senna in the grids was categorised into different classes ranging from high to absent. The abundance data was collected in 2019-2020. This categorization was done based on the visual classification of density and percentage cover within the range of vision of the observer by walking in the grids. The areas inside the grids with no Senna were classified as 'absent', very sparse distribution as 'low' (1-10% of the canopy covered

by *S. spectabilis*), the range of abundance between low and high as 'medium' (10-40% of the canopy covered by *S. spectabilis*), and grids with high abundance of Senna were categorised as 'high' (≥40% of the canopy covered by *S. spectabilis*).

2.2.2 Assessing the density of S. Spectabilis

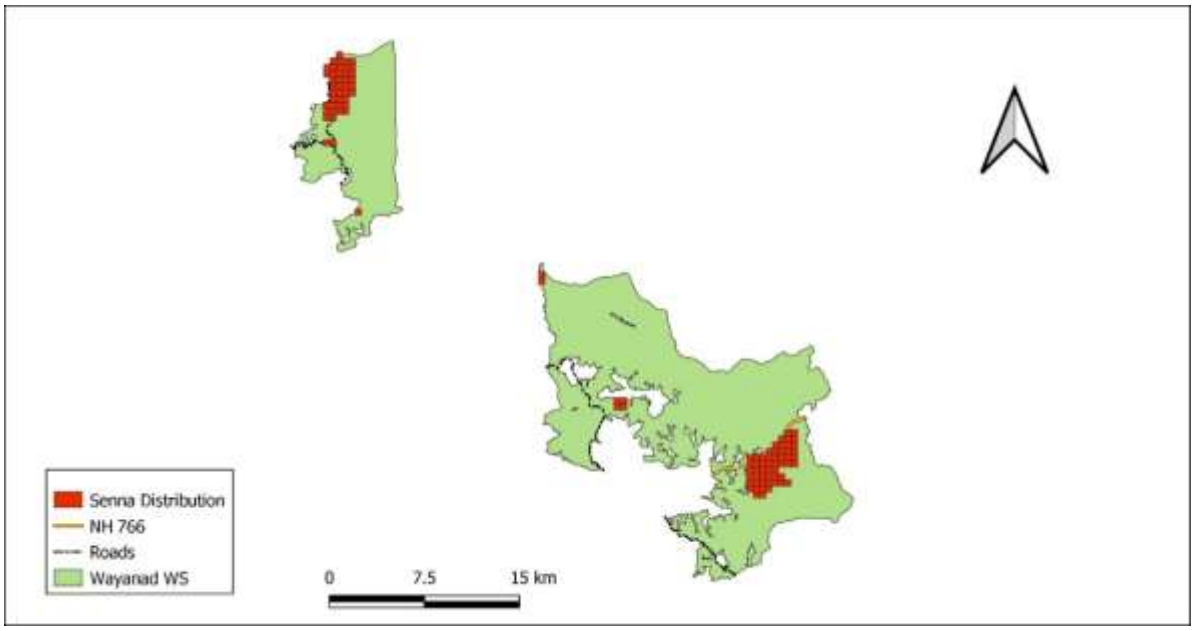
A total of 80 vegetation plots of 20 × 20 meters of four abundance classes were laid as high (n=40), medium (n=20), low (n=20). Sampling was carried out by considering the vegetation types as stratum variables. Four observers walked along the transects in different abundance classes of Senna and plots were laid at every 50-meter interval on either side of the trail. Care was taken to avoid laying the plot on the roads or areas cleared for visibility (vista clearing). Sampling was carried out in the areas where S. spectabilis was managed in previous years as well as in the unmanaged areas. At each sample plot, S. spectabilis plants with stem ≥ 10 cm GBH were enumerated. Information such as, GBH, height, tree condition (multiple branches or single trunk) were recorded.

2.2.3 Seed/Seedpod count

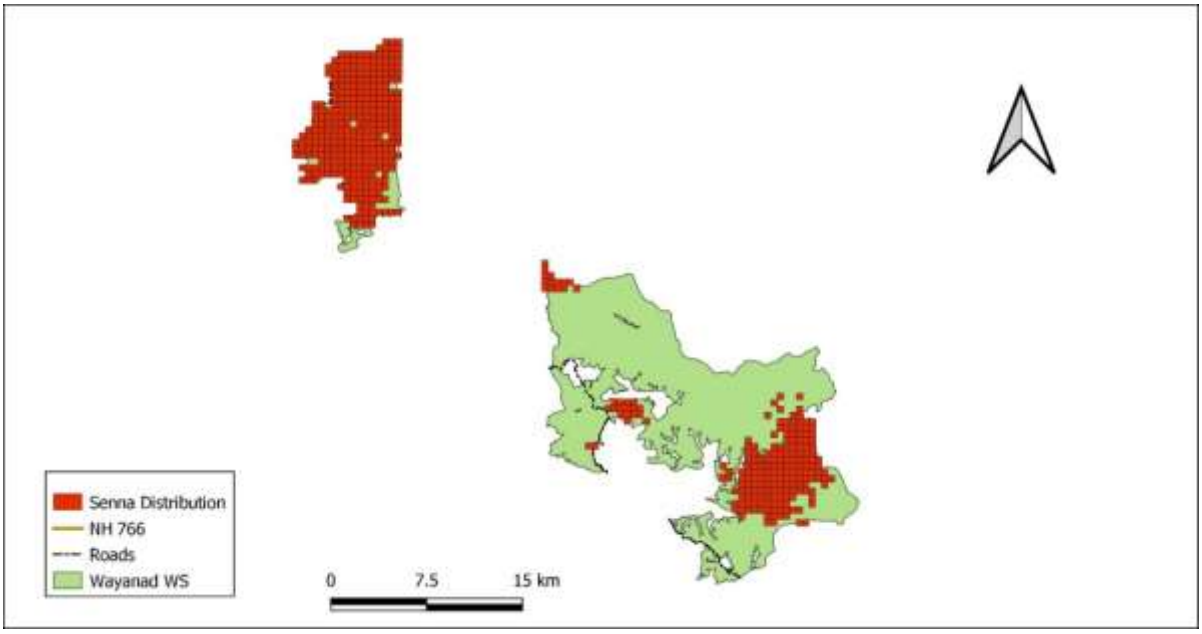
Seedpods were counted from a total of 50 S. spectabilis trees in different size (≥ 10 cm GBH) and from different vegetation type in Wayanad Wildlife Sanctuary. A total of 75 seedpods were collected from 15 trees (5 pods from each tree). The seedpods were cut along the midrib and the seeds were counted in each seedpod.

3. RESULTS

Figure 1. Change in distribution of *S. spectabilis* over a 10-year period in Wayanad Wildlife Sanctuary



Distribution of S. spectabilis in Wayanad wildlife sanctuary in 2013-2014



Distribution of S. spectabilis in Wayanad wildlife sanctuary in 2022-2023

3.1 Distribution and Abundance

Our results show that an area of 123.86 square kilometres (more than 35 % of the sanctuary) is occupied by *S. spectabilis* in 2022-2023, out of which an area of 90.46 square kilometre area has very low where the species is distributed very scattered, 7.15 square kilometres has low, 7.64 square kilometres has medium and 18.61 square kilometres has high abundance of the species (Figure 3). The degree of invasion is very high in Tholpetty and Muthanga ranges of the sanctuary.

Table 1. Abundance and extent (in hectare) of *S. spectabilis* invaded area in different ranges of the Wayanad Wildlife Sanctuary

Range	Scattered	Low	Medium	High	Grand Total
Kurichiat	405.5	56.6	80.9	65.4	608.4
Muthanga	1721.3	281.2	314.0	928.3	3244.9
Sulthan Bathery	777.0	18.4	5.3	0.0	800.7
Tholpetty	6124.4	358.8	363.3	867.6	7732.1
Total	**9028.2**	**715.0**	**763.6**	**1861.3**	**12386.0**

3.2 Density of S. spectabilis

Table 2: Density of Senna spectabilis in different class of abundance

Abundance	# Senna Trees/Ha.	# Senna Trunks/Ha.
High	1305	3113.75
Low	140	198.75
Medium	428.75	656.25

Resource requirement for eradication and management of Senna varies according to the size, density and number of tree trunks. Debarking a tree with multiple trunks (coppicing) requires more manpower than for a tree with single trunk. The data shows that the majority of trees in Wayanad are small in size, 81% of them have a GBH of less than 25 cm and 18% have GBH between 25 and 50 cm.

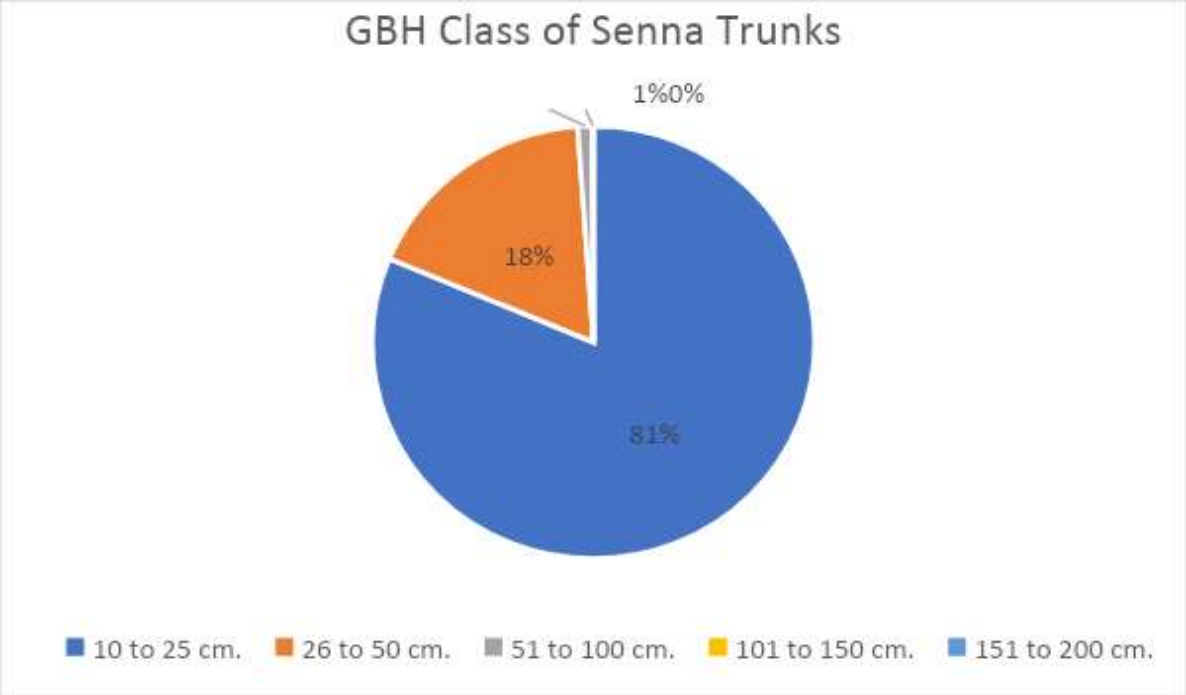


Figure 2: Percentage of different GBH class of *Senna spectabilis* tree trunks

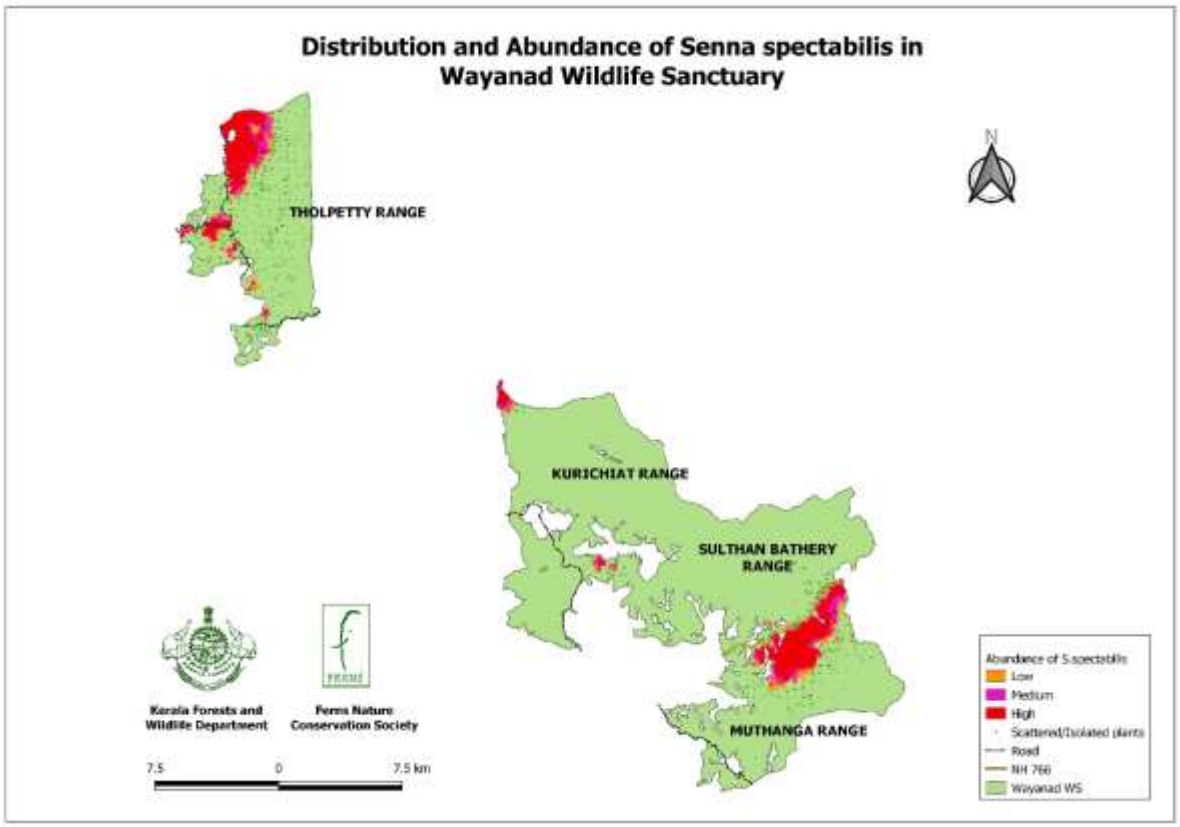
Density of Senna trees and regeneration of seedlings vary in different vegetation types. Highest density of trees and seedlings in Wayanad Wildlife Sanctuary is found in open areas with no large trees. Here, the estimated density of Senna is 1883 trees (>10 cm GBH) and 2633 seedlings (>10 cm GBH) per hectare. A large portion of

heavily infested areas are open areas in Muthanga range in the sanctuary. These areas were previously clear-felled monoculture plantations of eucalyptus.

Table 3: Density of Senna trees and seedlings in different vegetation types

Vegetation Type	# Senna Trees/Ha.	# Senna Seedlings/Ha.
Moist Deciduous	492	1665
Dry Deciduous	413	447
Eucalyptus Plantation	766	856
Teak Plantation	793	1268
Open areas	1883	2633

Figure 3. The abundance of *S. spectabilis* in Wayanad Wildlife Sanctuary in 2022-2023



3.3 Count of Seeds

The average count of seedpods on a *S. spectabilis* tree was recorded 238.9 and the average number of seeds recorded in a seedpod was 103.3. The estimated number of seeds on a tree in Wayanad Wildlife Sanctuary is 24678.4.

4. DISCUSSION

Biodiversity conservation is not on the top agenda for most countries in Asia, probably because the links between biodiversity protection and the broader socioeconomic welfare of human societies remain poorly understood. As such, research should possibly focus more on the socioeconomic impacts of invasive alien species (IAS) to demonstrate the impacts of IAS on livelihoods. Research should also focus on the costs and benefits of IAS management. There are very few studies which have clearly demonstrated the environmental benefits of IAS control, especially for those invasive plant species which have a negative impact on biodiversity. The forests in Wayanad Wildlife Sanctuary is one of the most important tiger and elephant habitats in India. No study on the impact of *S. spectabilis* on wildlife habitats has been carried out till date in India. Such studies need to be done very urgently in Wayanad Wildlife Sanctuary.

The Wayanad Wildlife Sanctuary covers an area of 344.44 Km^2. Presently, around 23% of the area of the Sanctuary is infested/occupied by *S. spectabilis*. Regeneration of native plant species is almost absent in the areas where the abundance of *S. spectabilis* is high. Highest density of *S. spectabilis* in the study area was found in open areas. Such open areas were previously clear-felled monoculture forest plantations of eucalyptus.

S. spectabilis tree density is very high in areas where the trees were girdled between 2013 and 2015. More Senna seedlings started growing in the open spaces created when the mature tree trunks dried after girdling and gradually the tree density has increased. By contrast, in Mahale NP of Tanzania it was observed that there was suppressed regeneration of *S. spectabilis*, while regeneration of the native species increased in managed areas. Along with girdling, the seeds from ground were also gathered in Mahale NP (Wakabira, 2002). Studies from Kibale National Park in Western Uganda show that ring barking is an effective control measure. There is a need to re-enforce the method by uprooting seedlings from the ring barked sites, for a period of four years after ring barking (Mutonyi, 2007). In Bandipur Tiger Reserve, 64.29% of the trees girdled in 2012 completely dried after two years. Coppice shoots died there also because the Karnataka Forest Department had been regularly weeding them out after girdling (WTI, 2014).

The results of management of the species from other parts of the world shows that follow-up management is required for the complete eradication of the species from an area. Density of mature trees is relatively less in moist deciduous and dry deciduous forests of Wayanad Wildlife Sanctuary. However, the present study observed a large number of seedlings in moist deciduous forests: this hints that the fertile soil and openness of moist

deciduous forest could be advantageous for the survival and growth of the seedlings. The increase of invasion in the last ten-year period recorded in the studies from Wayanad Wildlife Sanctuary indicates that the species has the potential to affect the tropical forest ecosystem very rapidly.

An adult Senna tree recorded to produce an average of 238 pods and each pod produce more than 100 seeds. A few large trees have been recorded to have more than 1000 pods. Hence it is expected to have a huge seed bank in the soil.

As the native mammals disperse the seeds of *S. spectabilis* in the Western Ghats (Anoop et al. 2022) the spread of the species will increase significantly in coming years.

FUTURE MANAGEMENT OF *S. SPECTABILIS* IN THE WESTERN GHATS

The complete eradication of *S. spectabilis* requires a unique set of considerations. We would recommend the following strategies for the eradication of the species in the Western Ghats: (1) Removal of soil seed reserve requires continuous removal of seedlings through hand pulling. We suggest removing the saplings during the monsoon season when the soil is damp and the entire root system can be removed. (2) Debarking of adult trees during summer needs to be continued. Constant removal of adult trees and pruning of branches will lower flowering and fruiting that reduce the dispersal of seeds to new areas by the dispersers. The removal of *S. spectabilis* creates open spaces that might get infested by other invasive species such as *Lantana camara* and *Chromolaena odorata*. To avoid this, we suggest carrying out eco-restoration in the managed areas by planting native species which are ecologically suited to the site conditions. (3) The density of *S. spectabilis* is high in the areas where the plants had established in the early stages of invasion. The low-density areas have been invaded recently and the plants in such areas are younger. Hence, priority for eradication should be given to low-density areas to prevent further spread. (4) It is important to understand the interactions of *S. spectabilis* and native dispersers for its better management. (5) The ecology of *S. spectabilis* and its impact on native vegetation and wildlife needs to be investigated in detail. (6) We suggest a survey in the Western Ghats to map areas where the species is present and to monitor changes of the existing populations. This information is crucial for the management of the species in the landscape.

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