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Impact of Alien Invasive Species (*Cassia spectabilis* DC.) on Soil Properties in Nagarahole Tiger Reserve

A. Akshayakumari, T.S. Hareesh, B.N. Sathish, B.G. Nayak, G.M. Devagiri, P.L. Rohan and H.R. Rashmitha

Department of Forest Biology and Tree Improvement, College of Forestry
Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Ponnampet-571 216, India
E-mail: akshaya141999@gmail.com

Abstract: The aggressive behavior of invasive alien plants has been reported to alter the plant species composition and is even observed to replace the native species. The current study was carried out to evaluate the impact of *Cassia spectabilis* on soil properties in D B Kuppe and Anechowkur Range of Nagarahole Tiger Reserve, located in Karnataka, India. The intensity of infestation was *categorized into three level viz.,* highly infested, moderately infested and non-infested areas. Four soil samples were collected at 0-20 cm and 20-40 cm depths randomly and composite sample was made and analyzed for soil physicochemical properties, which varied significantly between different levels of infestation across locations as well as across different depths. In both locations, the moderately infested areas recorded the highest percentage of organic matter. Soils within *C. spectabilis* had greater moisture content, electric conductivity, higher pH and highest percentage of organic matter than soils from other levels of infestation. But bulk density was highest in non-infested areas of *C. spectabilis*. Correlation analysis for tree regeneration with soil properties revealed that most of the variables were correlated with each other.

Keywords: *Cassia spectabilis* DC., Nagarahole Tiger Reserve, Alien invasive, Physicochemical properties, Soil properties

Alien invasive species are alien species in natural or semi-natural ecosystems or habitat, act as agent of change and threatens native biological diversity. These invasives are widely distributed in all kinds of ecosystems throughout the world and include all categories of living organisms. All introduced species do not become invasive; those will often become better competitors for native species. However, out of the many introduced species some become invasive and problematic. Factors such as rapid reproduction and growth, high dispersal ability, phenotypic plasticity and ability to survive on various food types and in a wide range of environmental conditions are likely to help these invasives to spread when compared to native species. The ecological interactions between exotic and native species are complex and still there is huge knowledge gap about this. The invasion of alien plants into natural habitats involves a number of significant changes to the habitat, often negatively affecting resident flora as well as fauna. Alien plants may directly modify the structure and complexity of the physical environment. The impact of alien invasive species results in direct displacement of native plant species, changes the structure of the soil by affecting the rate of decomposition, soil profile, nutrient content and moisture availability. Sharma and Raghubanshi (2006) reported that *L. camara* biology promotes the accumulation of litter under the shrub, resulting in a buildup of organic carbon and nitrogen and can also hold water for a longer time. Higher soil phosphorus often is correlated with invasion. Herr et al (2007), observed that *Solidago gigantea* (giant golden rod), an invasive to Europe showed lower soil pH and higher labile phosphorus fractions in invaded regions compared to non-invaded areas. The invasive- native interactions are prerequisite for formulating management strategies to safeguard the biodiversity (Zingthoi and Rai 2021a).

Cassia spectabilis DC*.* was introduced to botanical gardens in India as an ornamental plant. It escaped from the forest areas of Sikkim and widely became invasive in southern India. Ecological investigation is performed along disturbance gradient to emphasize the plant-plant and plant-soil interrelationship (Zingthoi and Rai 2021b). The Western Ghats in Southern India is one among the twelve mega biodiversity centers in the world and has rich biodiversity for its fauna and flora. *C. spectabilis* was introduced in the Western Ghats without proper knowledge about its potential to become an invasive species. After the introduction, started establishing itself extensively in the new areas and its management has become a challenging task. *C. spectabilis* is recognized as invasive plant in India Global Invasive Species Database of 2021 is now threatening several ecosystems including Nagarahole Tiger Reserve. The aggressive behavior of Invasive Alien Plants (IAP) reported to alter the plant species composition and is even observed to replace the native species and changes the soil properties. Hence the current study was carried out to evaluate the impact of *C. spectabilis* on soil properties in D B Kuppe and Anechowkur Range of Nagarahole Tiger Reserve, located in Karnataka, India.

MATERIAL AND METHODS

The study was conducted to observe the impact of invasive alien species on soil properties in Nagarahole Tiger Reserve which lies between the latitudes 12° 15' 37.69" N and longitudes 76° 17' 34.4" E. The area receives 1000 to 1540 mm annual rainfall and favors the area to have high humidity with a temperature ranged between 12°C and 32°C. Elevation of the park ranges from 687 to 960 m. The total geographical area of the reserve is 843.96 sq. km. located in the Kodagu and Mysore districts of Karnataka, India. Based on the preliminary survey, *C. spectabilis* populations in the D B Kuppe and Anechowkur ranges were observed. The study was conducted in these two ranges of Nagarahole Tiger Reserve, *viz.,* D B Kuppe and Anechowkur. These parts were *categorized* into highly infested, moderately infested and non-infested areas based on cover/density of *C. spectabilis*.

Methodology: A preliminary survey was conducted to collect information about the infestation level. Based on the cover of *C. spectabilis*, infestation levels were grouped into different categories and a stratified random sampling technique was adopted with different levels of infestations as different strata (Fig 1). The quadrates having 60-80% of *C. spectabilis* cover was categorized as highly infested, 40-60% as moderately infested and areas with no *C. spectabilis* cover were considered as non-infested area. In each category, 20 quadrates of 20 m × 20 m were laid randomly in forests. In each of the main quadrates, four soil samples at 0- 20 cm depth and 20- 40 cm depth were collected randomly and the composite sample was prepared. The composite samples were air dried at room temperature. Soil samples were analyzed for pH, electric conductivity, percentage of organic matter and available organic carbon by adopting standard procedures.

Soil Analysis

Moisture content (%): Moisture content was measured by subtracting the weight of the dry soil from the weight of the moist soil, and then dividing by weight of the dry soil and it was expressed in percentage (Das and Keener 1997).

$$\text{Moisture (\%)} = \frac{\text{Weight of moist soil} - \text{Weight of oven dry soil}}{\text{Weight of oven dry soil}} \text{x } 100$$

Bulk density (g cc^{-1}): Bulk density was calculated by using the core sampling (5 cm diameter), the samples were then placed in an airtight container and oven drying at 10^{O}C until the constant weight was obtained in the laboratory. Then the bulk density was determined by dividing the weight by the sample volume and expressed as gram per cubic centimeter.

$$\text{Bulk density (g cc}^{-1}\text{)} = \frac{\text{Dry Weight}}{\text{Volume}}$$

pH (hydrogen ion concentration): The soil pH values were determined using a glass electrode digital pH meter with a soil and water ratio of 1:2.5. 10 g of sieved, air-dried soil (Fig 4), Sample was taken in a 50 ml beaker and 25 ml of water was added. It was stirred at a regular interval of half an hour and then allowed to settle for 30 minutes. The residue was taken for estimation of pH. The pH meter was standardized using pH 4 and 7 buffer solutions (Jackson 1967).

Electrical conductivity (dSm^{-1}): The soil electrical conductivity (EC) measures the number of various salts present in the soils (soil salinity) and directly related to its specific conductance. The EC of the soil samples were determined in 1:2.5 soil water suspension with an electric conductivity meter (Gliessman 2000).

Electric conductivity (dSm^{-1}): = Observed conductivity × Cell constant

Soil organic carbon (%): The soil organic carbon percentage was calculated as described by Walkley- Black method (Prabhat Kumar Rai 2021).

$$\text{OC (\%)} = \frac{\text{BTV} - \text{STV} \times \text{N of FAS} \times 0.003}{\text{Weight of soil sample}} \text{x100}$$

OC (%) = % Organic Carbon ×1.724

OC: Organic carbon, OM: Organic matter, BTV: Burette reading of blank (without soil)

STV: Burette reading with the soil, N of FAS: Normality of Ferrous Ammonium Sulphate

Data analysis: The data obtained was analysed using SPSS.

RESULTS AND DISCUSSION

Soil moisture: The soil moisture content varied significantly among the different levels of infestation except D B Kuppe range at 0-20 cm depth. The highest moisture content was recorded in a moderately infested area followed by a highly infested area in D B Kuppe range. At Anechowkur range soil moisture was highest at highly infested area followed by a moderately infested area (In D B Kuppe range, at 20-40 cm soil depth, maximum moisture content was recorded in moderately infested areas followed by a highly infested area. Similarly, higher moisture content was observed in moderately infested area followed by highly infested areas of Anechowkur range (Table 1). The highest moisture content was recorded in a highly and moderately infested areas followed by a non-infested area in both locations. Similar results were obtained in Osunkoya and Perrett (2011) where, moisture content was significantly higher in *L. camara* infested patches areas. Contrasting the present study Debnath and Debnath (2018) showed moisture content is low in the invaded (*C. odorata*) sites than in the non-invaded natural sites.

Bulk density: The bulk density is expressed in terms of mass per unit volume of dry soil and it was calculated for all the soil samples and expressed in gram per cubic centimeter. The bulk density varied significantly in D B Kuppe range across all the infestation levels and in Anechowkur was non-significant among different level of infestation across different depth. In D B Kuppe Wildlife range, the non-infested areas recorded more bulk density at both soil depths followed by the highly infested areas. In Anechowkur range, maximum bulk density was recorded in non-infested areas in both depths, followed by moderately infested areas at 0-20 cm and 20-40 cm depth respectively. In both ranges highest bulk density was recorded in non-infested areas. Panwar et al (2016) reported that, Bulk density decreased and pore space increased as the invasion of Lantana increased. Similar results were obtained in the present study, where the soil bulk density showed a significant difference across all the infestation levels. The non-infested areas recorded more bulk density followed by the highly and moderately infested areas of both ranges. Contrasting to the present study Debnath and Debnath (2018) showed no significant differences among invaded and non-invaded sites of *Chromolaena odorata*. The bulk densities were higher in all the three strata of *Chromolaena odorata* invaded sites.

pH: Invaders contributing nitrogen-rich litter with higher decomposition rates increase soil nutrients and change pH. The hydrogen ion concentration (pH) was analysed for all the soil samples from different levels of infestation. There was significant difference in pH among different levels of infestation in both locations. In D B Kuppe range recorded neutral pH in all infestation levels. All the infestation levels of Anechowkur recorded acidic soil pH ranging from 5.87 - 6.22. Presence of high *C. spectabilis* will enhance the pH. Similar results reported for *L. camara*-infested soils in Australia where the higher soil pH was found in Lantana invaded sites compared to noninvaded sites (Osunkoya and Perrett 2011). In contrasting to the present study Comole et al (2021) reported that almost all soils collected from under the *Prosopis velutina* canopies had a significantly higher soil exchangeable Ca, K, Mg, and Na, organic matter (OM), total nitrogen (TN), available phosphorus (P), Electrical conductivity (EC), and cation exchange capacity (CEC) than the other sample positions, except for the pH which had the high value in inter-canopies.

Electric conductivity: The electric conductivity did not vary significantly between infestation levels in D B Kuppe range. Highly infested as well as moderately infested areas recorded the highest electric conductivity indicating high salinity in *C. spectabilis* infested areas. The electric conductivity did not show any significant difference between the infestation levels in D B Kuppe range. The electric conductivity varied significantly among different levels of infestation in Anechowkur range. Highly infested as well as moderately infested areas recorded the highest electric conductivity indicating high salinity in *C. spectabilis* infested areas. Osunkoya and Perrett (2011) observed was no significant difference in EC among Lantana invaded and non-invaded sites of Australia. Debnath and Debnath (2018) also reported that soil conductivity was higher in both the non-invaded sites of lower and middle strata respectively while it is higher in invaded site of top strata of *Chromolaena odorata* (Table 2).

Organic matter and organic carbon: The organic matter content of the soils differed significantly across locations and different infestation levels. Among different infestation levels, moderately infested areas recorded the highest organic matter. The values illustrated in Table 3 depict the organic matter percentage In D B Kuppe range, highest percentage of organic matter was in the moderately infested areas (4.13

Table 1. Moisture content (%) and Bulk density (g/cc) under different infestation level at D B Kuppe and Anechowkur range in different depths

Level of infestation	D B Kuppe				Anechowkur			
	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
	Moisture content (%)		Bulk density (g/cc)		Moisture content (%)		Bulk density (g/cc)	
Highly infested	6.96	7.51	0.89	0.88	3.92	3.51	0.95	0.94
Moderately infested	8.16	9.08	0.85	0.88	3.58	3.71	0.95	1.00
Non-infested	6.68	6.18	0.94	0.96	1.91	2.24	0.98	0.98
CD (p=0.05)	NS	1.94	0.05	0.05	1.16	0.71	NS	NS

NS - Non-significant

%) followed by highly infested areas at 0-20 cm depth, whereas in 20-40 cm depth also observed the maximum percentage of organic matter in moderately infested areas followed by highly infested areas (Table 3). Highest percentage of organic matter was recorded in the moderately infested areas at 0-20 cm depth, followed by non- infested area. At 20-40 cm depth, the maximum percentage of the organic matter was in moderately infested areas followed by the non-infested areas in moist deciduous forest of Anechowkur. Sharma and Raghubanshi (2006) reported that *L. camara* biology promotes the accumulation of litter under the shrub, resulting in a buildup of organic carbon and nitrogen and can also hold water for a longer time. Similar results were obtained from the present study, that in among different infestation levels, infested areas recorded highest organic matter and organic carbon, followed by non-infested areas. Debnath and Debnath (2018) also showed that total carbon and organic matters are higher in the non-invaded sites of *Chromolaena odorata* than the invaded sites at Tripura, but Zingthoi Khuppi Sakachep and Prabhat Kumar Rai (2021) reported that alteration in native vegetation composition cause depletion in soil organic carbon and soil organic matter.

Association of tree regenerates with soil properties in different levels of infestation: Spearman rank correlation analysis for tree regeneration with soil properties revealed that most of the variables were correlated with each other in D B Kuppe range and Anechowkur (Table 4). Tree regeneration

Table 2. pH and electric conductivity (dS/m) under different infestation level at D B Kuppe and Anechowkur range in different depths

Level of infestation	D B Kuppe				Anechowkur			
	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
	pH		Electric conductivity (dS/m)		pH		Electric conductivity (dS/m)	
Highly infested	7.08	7.23	0.11	0.10	6.22	6.18	0.09	0.10
Moderately infested	7.15	7.05	0.10	0.09	6.17	6.15	0.09	0.08
Non-infested	6.82	6.91	0.11	0.08	5.87	5.87	0.06	0.06
CD (p=0.05)	0.20	0.16	NS	NS	0.15	0.17	0.02	0.02

Table 3. Organic matter (%) and organic carbon (%) under different infestation level at D B Kuppe and Anechowkur range in different depths

Level of infestation	D B Kuppe				Anechowkur			
	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
	Organic matter (%)		Organic carbon (%)		Organic matter (%)		Organic carbon (%)	
Highly infested	3.82	3.54	6.59	6.10	2.56	2.60	4.41	4.48
Moderately infested	4.13	3.92	7.11	6.76	3.09	3.18	5.33	5.49
Non-infested	3.60	3.29	6.20	5.66	3.07	2.81	5.30	4.85
CD (p=0.05)	0.40	0.34	0.69	0.59	0.30	0.32	0.53	0.55

Table 4. Association of tree regenerates with soil properties

Infestation level	Moisture content (%)	Bulk density (g/cc)	pH	Electric conductivity (ds/m)	Organic matter (%)	Organic carbon (%)
D B Kuppe range						
Highly infested	-0.042	-0.103	0.404**	0.343*	0.235	0.235
Moderately infested	0.003	0.039	0.132	-0.131	-0.124	-0.124
Non-infested	-0.147	0.342	-0.098	0.081	-0.426**	-0.426**
Anechowkur range						
Highly infested	0.285	0.271	-0.571**	-0.447**	-0.423**	-0.423**
Moderately infested	0.315*	0.326*	-0.167*	0.248	-0.006	-0.006
Non-infested	-0.391*	0.133	-0.262	-0.268	-0.305	-0.305

**Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level which was collected from same plots of soil samples taken.Correlation analysis for tree regeneration with soil properties revealed that most of the variables were correlated with each other. In D B Kuppe range tree regeneration in highly infested area negatively correlated with moisture content and bulk density, significantly positively correlated with electric conductivity and pH. Positively correlated with organic matter and organic carbon. Regeneration of moderately infested area were positively correlated with moisture content, bulk density and pH and negatively correlated with electric conductivity, organic matter and organic carbon. In non-infested area moisture content and pH negative correlation, bulk density and electric conductivity shows positively correlation and regeneration were significantly negatively correlated with organic matter and organic carbon. The correlation for tree regeneration with soil properties in Anechowkur range tree regeneration in highly infested area showed positively correlation with moisture content and bulk density and all other parameters like EC, OC and organic matter were significantly negative correlation. In moderately infested area regeneration significantly positively correlated with moisture content and bulk density (significantly negative correlated with pH) but positively correlated with EC and negatively correlated with organic matter and organic carbon. Significantly negative correlation was observed between regeneration and moisture content in non-infested area of Anechowkur, but regeneration was positive correlation with bulk density. Other parameters include EC, OC and organic matters were negatively correlated with regeneration. Dassonville et al (2008) observed strong positive impacts in sites with initially low nutrient concentrations in the topsoil of invaded plots compared to uninvaded ones, while negative impacts were generally under the uninvaded plots. Ahmad et al (2019) reported that invasion by *Leucanthemum vulgare* had a significant impact on key soil properties in the invaded plots. The soil pH, water content, organic carbon and total nitrogen were significantly higher in the invaded plots as compared with the uninvaded plots. In contrast, the electrical conductivity, phosphorous and micronutrients*, viz.* iron,

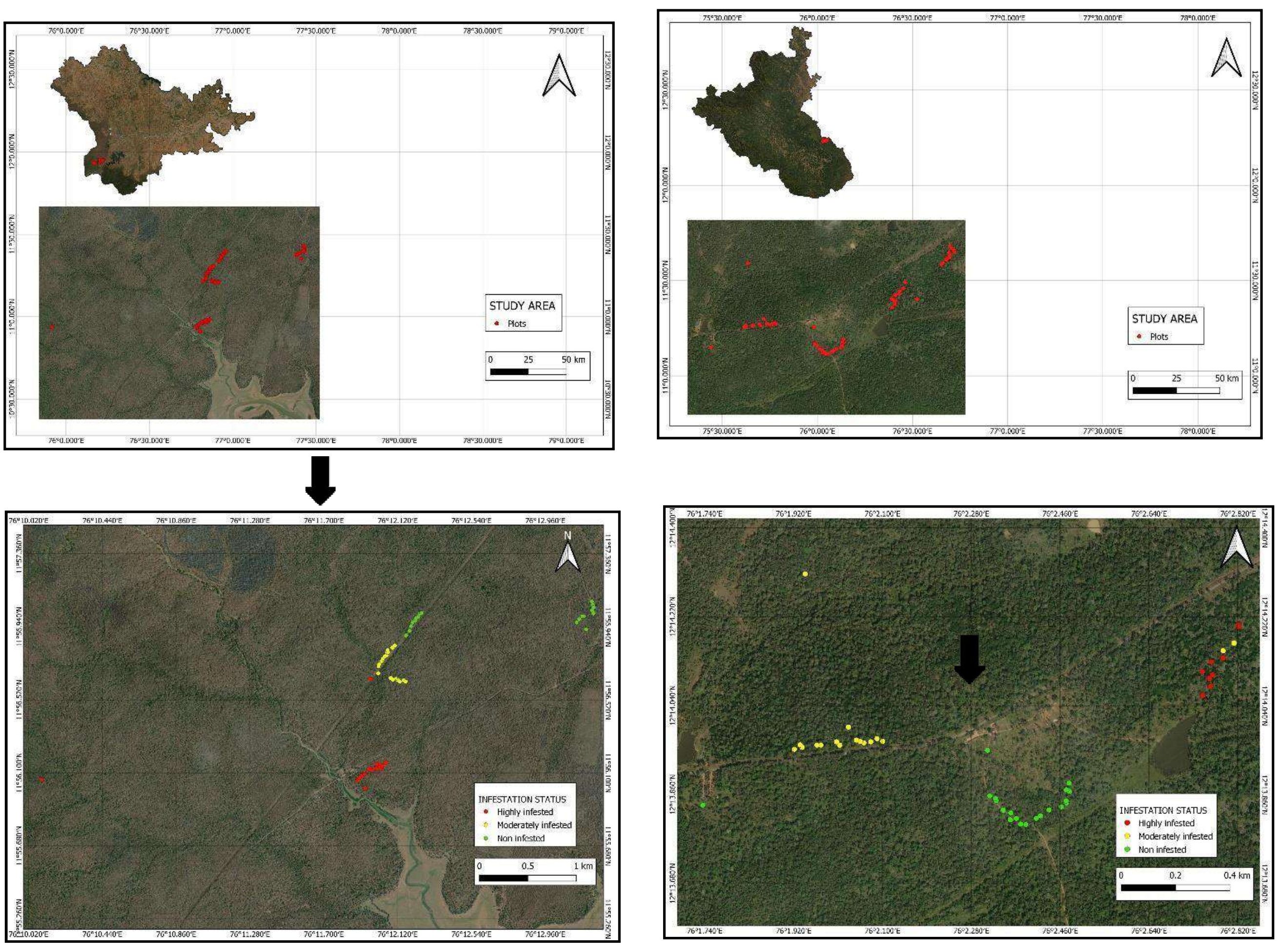
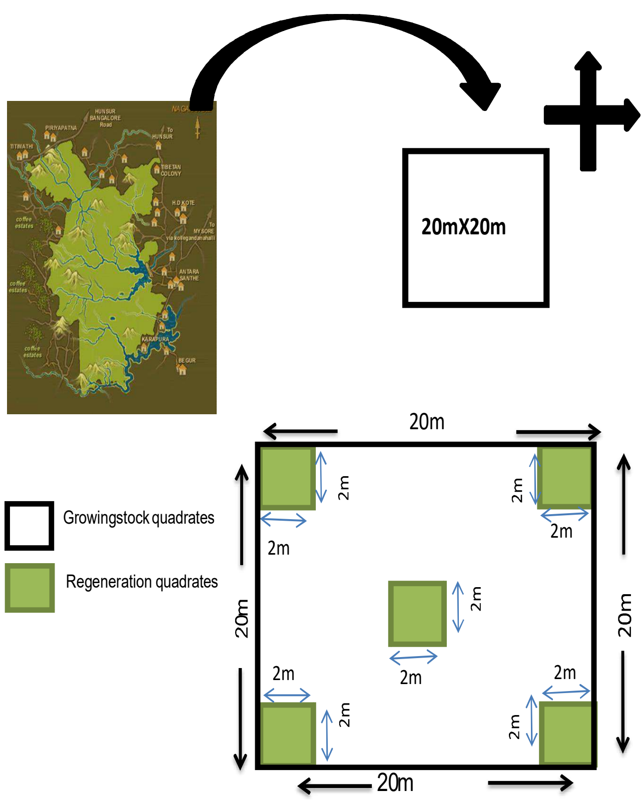


Fig. 1. Location map of the study area

A. Highly infested area B. Moderately infested area (D B Kuppe Wildlife Range) C. Non-infested area

A. Highly infested area B. Moderately infested area (Anechowkur Wildlife Range) C. Non-infested area

Fig. 2. Different levels of infestation



copper, manganese and zinc, were significantly lower in the invaded plots as compared with the uninvaded plots.

CONCLUSION

Soil physicochemical properties varied significantly between different levels of infestation across locations as well as across different depths. In both location of moist deciduous forests, the moderately infested areas recorded the highest percentage of organic matter. Soils within *C. spectabilis* had greater moisture content, higher electric conductivity, higher pH and highest percentage of organic matter than soils from other levels of infestation. But bulk density was highest in non-infested areas of *C. spectabilis*. Correlation analysis for tree regeneration with soil properties revealed that most of the variables were correlated with each other. Based on the present study, management plan can be made for removal of *C. spectabilis* through different ways in the future. Allelopathic effect of *C. spectabilis* need to studied and value addition of *C. spectabilis* can be taken up to improve the livelihood of local tribal communities. A long-term study can also be taken up to see the impacts of *C. spectabilis* and its removal on floristic diversity and regeneration over a time scale by establishing permanent plots.

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