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Impact of alien invasive species (*cassia spectabilis*) on floristic diversity and natural regeneration in southern tropical dry deciduous forest of Nagarahole Tiger Reserve

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ABSTRACT

The aggressive behavior of Invasive Alien Plants has been reported to alter plant species composition and even replace native species. Hence the current study was carried out to assess the forest structure and diversity in relation to C. spectabilis infestation and also evaluate the impact of C. spectabilis on natural regeneration in D B Kuppe and Anechowkur Range of Nagarahole Tiger Reserve, located in Karnataka, India. The intensity of infestation was categorized into three levels: highly infested, moderately infested, and non-infested areas. In each category, 20 quadrates of 20 × 20 m were laid randomly in ranges to study the floristic diversity, growing stock and regeneration pattern. It has been observed that the species richness, Shannon-Wiener index and Simpson's index of dominance was highest in non-infested areas, followed by moderately and highly infested areas. Similar pattern was also observed in regeneration pattern where regeneration diversity was found to be highest in the non-infested areas followed by moderately infested areas. Both basal area and density varied significantly among the different levels of C. spectabilis infestation. The values of density of regenerates were highest in the non-infested areas followed by moderately infested areas in both range of forests. From the study it was evident that the non-infested areas helping in improving the regeneration status of tree species.

Keywords: *Cassia spectabilis, Alien invasive, Diversity, Regeneration, Infestation, Density.*

INTRODUCTION

Alien Invasive Species are alien species that becomes established in natural or semi-natural ecosystems or habitat, an 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 (19). 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 the 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 (3).

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 several 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. An alien plant species that reaches a high abundance and dominates an ecosystem will potentially influence the performance of individual resident species and their population dynamics (25). 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 (15).

Cassia spectabilis DC. was reported as world's one of the "handsomest ornamental" by Irwin and Barneby (1982) which 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 (1). 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, it started establishing itself extensively in the new areas, and its management has become a challenging task (26). *C. spectabilis* is recognized as an invasive plant in India Global Invasive Species Database of 2021. It is now threatening several ecosystems, including the Nagarahole Tiger Reserve. The aggressive behavior of Invasive Alien Plants (IAP) has been reported to alter plant species composition and even replace native species. Hence, the current study was framed with the objective to assess the forest structure and diversity in relation to *C. spectabilis* infestation and also evaluate the impact

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of *C. spectabilis* on natural regeneration in D B Kuppe and Anechowkur Range of Nagarahole Tiger Reserve, located in Karnataka, India.

MATERIALS AND METHODS

Study site

The study was conducted to understand the impact of invasive alien species on floristic diversity and natural regeneration of other plant communities in D B Kuppe and Anechowkur Range of 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 range between 12°C and 32°C. The total geographical area of the reserve is 843.96 sq. km. located in the Kodagu and Mysore districts of Karnataka, India. The intensity of infestation was *categorized into three levels viz.,* highly infested, moderately infested, and non-infested areas.

A preliminary survey was carried out in order to select the different levels of infested areas. Based on the cover of *C. spectabilis*, infestation levels were grouped into three different categories, and a stratified random sampling technique was adopted by considering the level of infestation as different strata. The quadrates having 60-80 % *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. Geo coordinates of the quadrate area, species, height (m) and Girth at breast height (GBH) in cm) were recorded. In each main quadrate, five sub quadrates of 2 m ×2 m in four corners of the quadrate and one at the centre were laid to assess the regeneration status. All the regenerates within the sub quadrates were botanically identified and grouped under the following regeneration classes for further analysis (22) (Table 1).

Table 1: Regeneration classes

Sl. No.	Classes	Height (cm)
1	Class I	0-40
2	Class II	>40-100
3	Class III	>100 and ≤10 cm GBH
4	Class IV	>100 cm height and 10-30 cm GBH

The observation recorded during the field inventory was used to compute the density of regenerates, Importance value index, diversity parameters such as species richness, Shannon-Wiener index, Simpson's dominance index.

RESULTS

Floristic diversity, composition and structure of growing stock in relation to *C. spectabilis* infestation

The strong invaders will reduce the species diversity and density in the invaded areas (18). Moderately infested area recorded about 17 species followed by highly infested area with a least species richness of 9. Whereas, Anechowkur range reported the highest in moderately infested area followed by non-infested area with 18 species followed by highly infested area with a least species richness of 15 species (Table 2). From the present study, it is evident that the maximum number of species and higher diversity was obtained from non-infested area in D B Kuppe range and in moderately infested area in the Anechowkur range. Invasion of *Cassia spectabilis* has highly reduced the species diversity and composition in infested areas (4). Gooden *et al.* (2019) demonstrated that the invasion of forest communities by woody plant invaders draws out significant adverse effects on native vascular plant species diversity, both in terms of species richness and composition. A similar study by Dogra *et al.* (2009) reported that invasion of *Ageratum conyzoides, Lantana camara, Parthenium hysterophorus* have highly reduced the available habitats for the growth of other plant species and also lead to loss of productivity and diversity of species in the invaded areas.

In D B Kuppe range, highest Shannon's Diversity was observed in non-infested area, whereas in Anechowkuru highest diversity was observed at the moderately infested area. In both the ranges highly, infested areas reported less diversity because of infestation of alien invasive species had reduced the species number and its density in the area. Similar trend was observed in Simpson index in these ranges; the low Simpson index reported from non-infested areas could be due to presence of more diverse species. On the contrary, highly infected areas possess the highest Simpson's index among other area, which indicates that as the invasive species is dominating the community and taking the Simpsons index to higher value.

Importance Value Index (IVI), which shows a clear picture about the distribution of a particular species in an area. Studies from Hejda *et al.* (2009) showed that biological invasions will lead to homogenization of native communities. Key upper-story species of Nagarahole Tiger Reserve includes *Tectona grandis*, *Dalbergia latifolia*, *Pterocarpus marsupium, Lagerstroemia lanceolata*, *Terminalia paniculata*, *Cendrella toona* and *Bambusa arundinacea* and *Dendrocalamis strictus* (2).

The values of the Important value index in D B Kuppe (Table 3) showed that *Tectona grandis* was found to be the most dominant species in highly infested area (142.83) and moderately infested area (79.02) followed by *Anogeissus latifolia* in highly infested area (41.37) and *Terminalia alata* (35.66) in moderately infested area. In the Non-infested area is dominated by *Terminalia alata* (44.21) followed by *Anogeissus latifolia* (41.65).

Table 4 shows the dominant species existed in Anechowkur range under different level of infestation. Among the various species, *Terminalia alata* ranked first position under different level of infestation followed by *Legestroemia microcarpa* in highly infested area (52.11) followed by *Anogeissus latifolia* in both the moderately and non-infested area.

Results from the present study indicates that, there was no much difference in species composition between different levels of infestation. Similar results were reported by Dyderski and Jagodzinski (2020) where they found lesser difference in species composition between similar types of invaded and non-invaded areas of *Prunus serotina*, *Quercus rubra*, and *Robinia pseudoacacia* of Wielkopolski National Park (West Poland) and reported that this might be due to vegetation continuity and the spread of invasive tree species.

Similar study by Reddy *et al.* (2008) in Mudumalai wildlife sanctuary reported that *Anogeissus latifolia, Tectona grandis, Terminalia alata, Phyllanthus emblica* and *Lagerstroemia microcarpa* were dominant in Dry deciduous forest and *Tectona grandis, Lagerstroemia microcarpa, Grewia tilifolia, Terminalia alata* and *Syzygium cumini* were dominant in moist deciduous forests of the sanctuary.

The species density in the invaded areas will decrease due to the powerful invaders. (Ortega and Pearson, 2005). Similarly, the present study reported that in D B Kuppe range, non-infested area had recorded comparatively higher tree density followed by the moderately infested area. Similarly, in Anechowkur range, non-infested area recorded higher tree density followed by moderately Infested area.

The invasion has significantly reduced the number of trees in these ranges by occupying the space of other trees, this is evident by getting significant different among different level of infestation. The invasion of alien species had drastically altered the structure, function and dynamics of invaded habitats (4). Kodandapani *et al.* (2004) reported that the reduction in the density of matured trees in moist deciduous forests could be probably due to the effects of disturbances such as fire. The frequency and intensity of forest fires in the tropical dry forests of the Western Ghats are increasing(Table 5).

Plant communities are generally more susceptible to invasion, when they are subjected to some disturbances. Seasonal deciduous forests in the tropics are thought to be more susceptible to invasion and domination by weed species (13). Similarly, in the present study both D B Kuppe and Anechowkur range showed highest basal area in non-infested area than the other level of infestation due to the presence more number of individuals and larger trees in the study area. Highly infested area recorded less basal area, it could be due to the fact that these areas are disturbed and make a space to colonize the new species which are very young, hence resulted in lesser basal area.

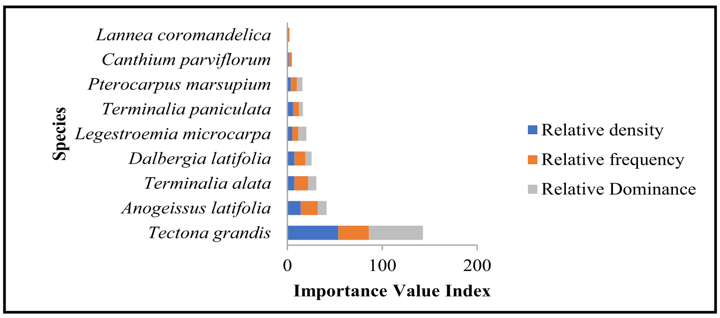
Table 2: Species richness and diversity of growing stock under different levels of infestation at D B Kuppe and Anechowkur ranges

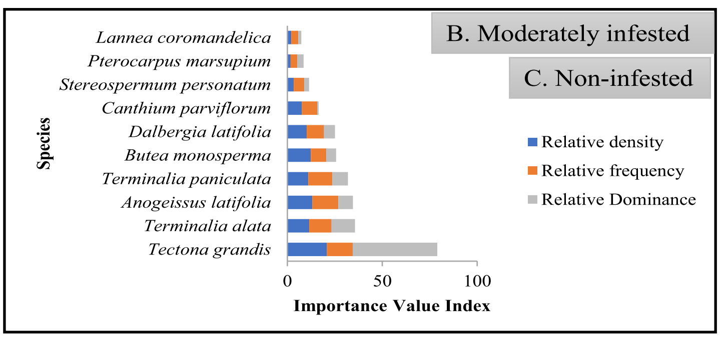
Level of Infestation	Species Richness		Shannon's diversity index		Simpson's index		Evenness index	
	DB Kuppe	Anechowkur	D B Kuppe	Anechowkur	D B Kuppe	Anechowkur	D B Kuppe	Anechowkur
Highly infested	9	15	1.54	1.83	0.33	0.26	0.70	0.63
Moderately infested	17	24	2.31	2.60	0.12	0.10	0.81	0.82
Non-infested	23	18	2.63	2.26	0.10	0.14	0.84	0.83

Table 3: Dominant species based on IVI values under different levels of infestation at D B Kuppe range

Species	Species IVI Rank		
	Highly infested	Moderately infested	Non- infested
Tectona grandis	1 (142.83)	1 (79.02)	3 (37.95)
Anogeissus latifolia	2 (41.37)	3 (34.55)	2 (41.65)
Terminalia alata	3 (30.49)	2 (35.66)	1 (44.21)
Dalbergia latifolia	4 (25.59)	6 (25.09)	7 (15.04)
Legestroemia microcarpa	5 (20.04)	-	6 (15.53)
Terminalia paniculata	6 (16.45)	4 (31.88)	8 (13.57)
Pterocarpus marsupium	7 (15.93)	9 (8.55)	-
Canthium parviflorum	8 (4.82)	7 (16.49)	-
Lannea coromandelica	9 (2.49)	10 (7.30)	-
Butea monosperma	-	5 (25.66)	5 (18.25)
Stereospermum personatum	-	8 (11.46)	9 (13.17)
Grewia tiliifolia	-	-	4 (26.06)
Adina cardifolia	-	-	10 (11.28)

Values within parentheses indicate IVI values





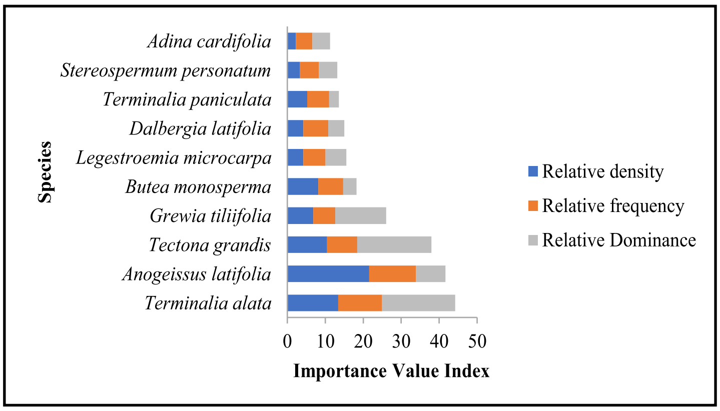


Figure 1: IVI of growing stock in different levels of infestation in D B Kuppe range

Table 4: Dominant species based on IVI values under different levels of infestation at Anechowkur range

Species	Species IVI Rank		
	Highly infested	Moderately infested	Non- infested
Terminalia alata	1 (65.30)	1 (51.31)	1 (106.78)
Legestroemia microcarpa	2 (52.11)	3 (30.48)	4 (21.92)
Syzygium cumini	3 (38.08)	-	6 (9.26)
Terminalia paniculata	4 (30.01)	4 (30.05)	9 (7.96)
Stereospermum personatum	5 (26.08)	5 (22.61)	3 (41.47)
Lannea coromandelica	6 (17.92)	-	-
Pterocarpus marsupium	7 (14.57)	-	-
Schleichera oleosa	8 (11.26)	10 (11.65)	-
Melia dubia	9 (11.18)	-	-
Annogeissus latifoila	10 (10.87)	2 (13.24)	2 (52.13)
Tectona grandis	-	6 (19.44)	7 (8.71)
Sapindus emarginatus	-	7 (16.91)	-
Dalbergia latifolia	-	8 (15.43)	5 (12.98)
Terminalia bellirica	-	9 (12.93)	10 (6.51)
Jacaranda mimosifolia	-	-	8 (8.27)

Values within parentheses indicate IVI values

Table 5: Density and basal area of growing stock at different levels of infestation at D B Kuppe and Anechowkur ranges

Infestation Level	D B Kuppe		Anechowkur	
	Density (Individuals ha^{-1})	Basal area (m^2 ha^{-1})	Density (Individuals ha^{-1})	Basal area (m^2 ha^{-1})
Highly infested	168	26.84	174	29.41
Moderately infested	294	38.68	255	28.01
Non-infested	383	49.05	405	49.65
S Em (±)	16.76	3.99	18.54	4.29
CD (0.05)	47.45	11.31	52.50	12.16

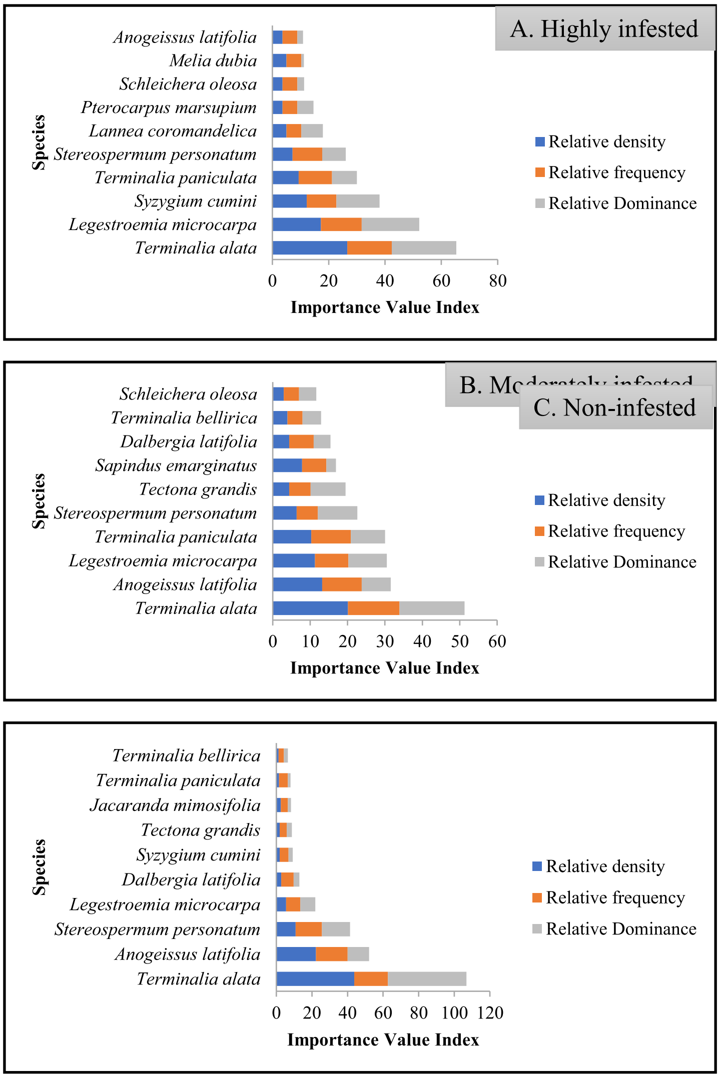


Figure 2: IVI of growing stock in different levels of infestation of Anechowkur range

Floristic diversity, composition and structure of regenerates in relation to *C. spectabilis* infestation

An increase in infestation of invasive tree species leads to decrease ecosystem resilience with negative impacts on natural regeneration (5).

From the present study it is evident that high species richness and diversity was found in non-infested areas and moderately infested areas followed by highly infested areas.

Supporting to the present study Ortega and Pearson, 2005 stated that, the strong invaders will reduce the species diversity and density in the invaded areas. Dogra *et al.* (2009) reported that loss of diversity of species in *Ageratum conyzoides, Lantana camara, Parthenium hysterophorus* infested areas of Himachal Pradesh.

The dominant species found in moist deciduous forest of D B Kuppe includes, *Holarrhena antidysenterica, Tectona grandis, Cassia fistula, Miliusa tomentosa, Dalbergia latifolia, Polyalthia longifolia, Bambusa bambos, Anogeissus latifolia, Pterocarpus marsupium, Callicarpa tomentosa, Adina cordifolia, Butea monosperma, Diospyros montana, Lannea coromandelica, Schleichera oleosa, Syzygium cumini* and *Ziziphus oenoplia* (Table 6).

The dominant species found in Anechowkur includes, *Bambusa bambos, Cipadessa baccifera, Cassia fistula, Murraya koenigii, Canthium parviflorum, Annona squamosa, Glycosmis pentaphylla, Dalbergia latifolia, Actinodaphne malabarica, Careya arborea, Acacia concinna, Bauhinia racemosa, Chukrassia tabularis, Holarrhena antidysenterica, Melia dubia, Pterocarpus marsupium, Syzygium cumini, Tectona grandis, Vitex altissima* and *Ziziphus oenoplia* (Table 7).

At the Anechowkur range also maximum species richness was found in moderately infested areas followed by non-infested areas. But the more diversity was found in non-infested areas followed by moderately infested areas. The species were found more evenly distributed in non-infested areas, followed by highly infested areas.

The Table 6 and 7 shows the dominant regenerating species in the D B Kuppe and Anechowkur ranges, respectively based on the Importance Value Index. Highly infested areas of D B Kuppe range was dominated by species such as *Holarrhena antidysenterica* followed by *Tectona grandis*. In moderately infested areas *Bambusa bamboo* (40.43) was the most dominant species followed by *Tectona grandis*. In non-infested areas also *Tectona grandis* was the most dominant species followed by *Cassia fistula* (Fig. 3).

In the Anechowkur range, *Bambusa bamboo* was found to be the most dominant regenerating species followed by *Cipadessa baccifera* in the highly infested (Fig.2). In moderately infested area *Cipadessa baccifera* found to be most dominating species among regenerates followed by *Annona squamosa*. *Tectona grandis* was the most dominating species among non-infested areas followed by *Dalbergia latifolia* (Fig. 4).

Table 6: Species richness and diversity of regenerates under different levels of C. spectabilis infestation at D B Kuppe and Anechowkur

Level of Infestation	Species Richness		Shannon's diversity index		Simpson's index		Evenness index	
	DB Kuppe	Anechowkur	D B Kuppe	Anechowkur	D B Kuppe	Anechowkur	D B Kuppe	Anechowkur
Highly infested	12	21	1.92	2.19	0.18	0.15	0.16	0.72
Moderately infested	17	24	1.99	2.21	0.17	0.15	0.12	0.70
Non-infested	14	23	2.09	2.39	0.15	0.13	0.15	0.76

Table 7: Regeneration of the Dominant species based on IVI values under different levels of infestation at D B Kuppe range

Species	Species IVI Rank		
	Highly infested	Moderately infested	Non-infested
Holarrhena antidysenterica	1(49.53)	4(19.79)	7(14.28)
Tectona grandis	2(34.20)	2(37.36)	1(47.24)
Cassia fistula	3(28.99)	6(18.21)	2(28.72)
Miliusa tomentosa	4(22.46)	-	-
Dalbergia latifolia	5(18.07)	3(36.57)	3(25.86)
Polyalthia longifolia	6(13.52)	-	-
Bambusa bambos	7(10.58)	1(40.43)	5(19.26)
Anogeissus latifolia	8(7.00)	-	-
Pterocarpus marsupium	9(6.51)	-	-
Callicarpa tomentosa	10(3.25)	-	-
Adina cordifolia	-	8(4.43)	9(3.86)
Butea monosperma	-	5(19.29)	4(22.78)
Diospyros montana	-	7(6.21)	8(9.07)
Lannea coromandelica	-	-	10(3.58)
Schleichera oleosa	-	-	6(15.34)
Syzygium cumini	-	10(3.07)	-
Ziziphus oenoplia	-	9(4.07)	-

Values within parentheses indicate IVI values

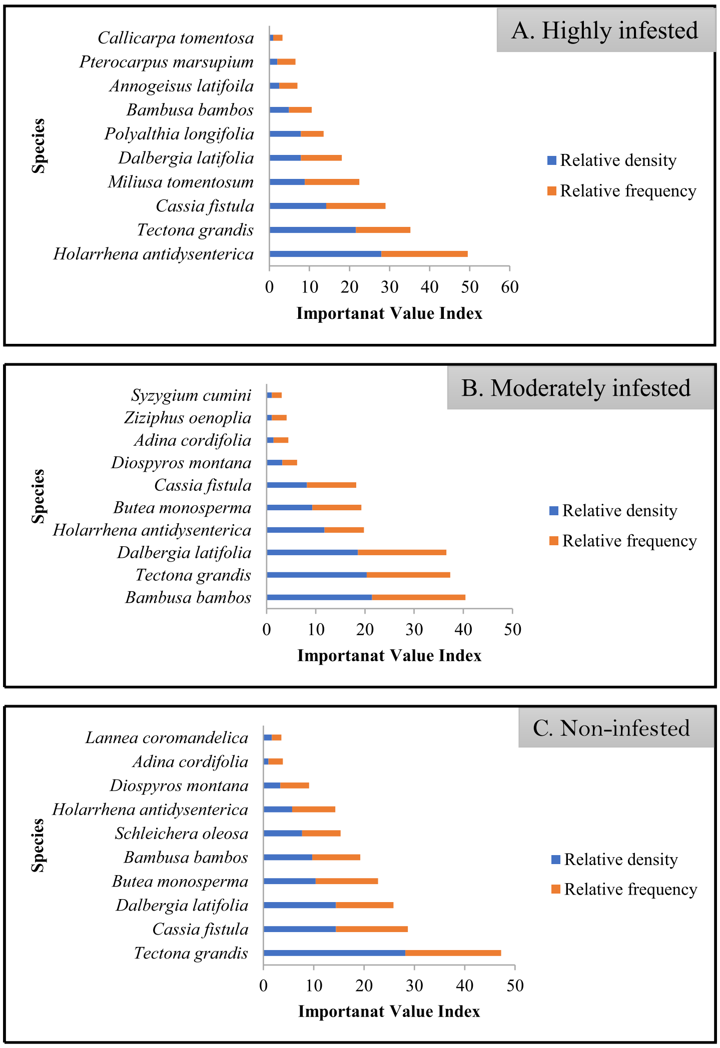


Figure 3: IVI of regenerates in different levels of infestation in D B Kuppe range

Table 8: Regeneration of the Dominant species based on IVI values under different levels of infestation at Anechowkur range

Species	Species IVI Rank		
	Highly infested	Moderately infested	Non-infested
Bambusa bambos	1(52.73)	9(4.10)	-
Cipadessa baccifera	2(33.43)	1(40.14)	4(16.81)
Cassia fistula	3(26.83)	4(23.61)	3(23.67)
Murraya koenigii	4(17.04)	-	-
Canthium parviflorum	5(16.01)	5(19.05)	5(12.81)
Annona squamosa	6(11.09)	2(35.58)	-
Glycosmis pentaphylla	7(10.44)	-	-
Dalbergia latifolia	8(5.76)	3(27.39)	2(34.64)
Actinodaphne malabarica	9(4.68)	-	-
Careya arborea	10(3.84)	-	-
Acacia concinna	-	8(6.50)	-
Bauhinia variegata	-	-	6(11.70)
Chukrassia tabularis	-	-	9(8.17)
Holarrhena antidysenterica	-	-	8(9.29)
Melia dubia	-	10(3.70)	-
Pterocarpus marsupium	-	-	10(7.33)
Syzygium cumini	-	7(8.85)	-
Tectona grandis	-	-	1(39.00)
Vitex altissima	-	6(13.39)	-
Ziziphus oenoplia	-	-	7(9.93)

Values within parentheses indicate IVI values

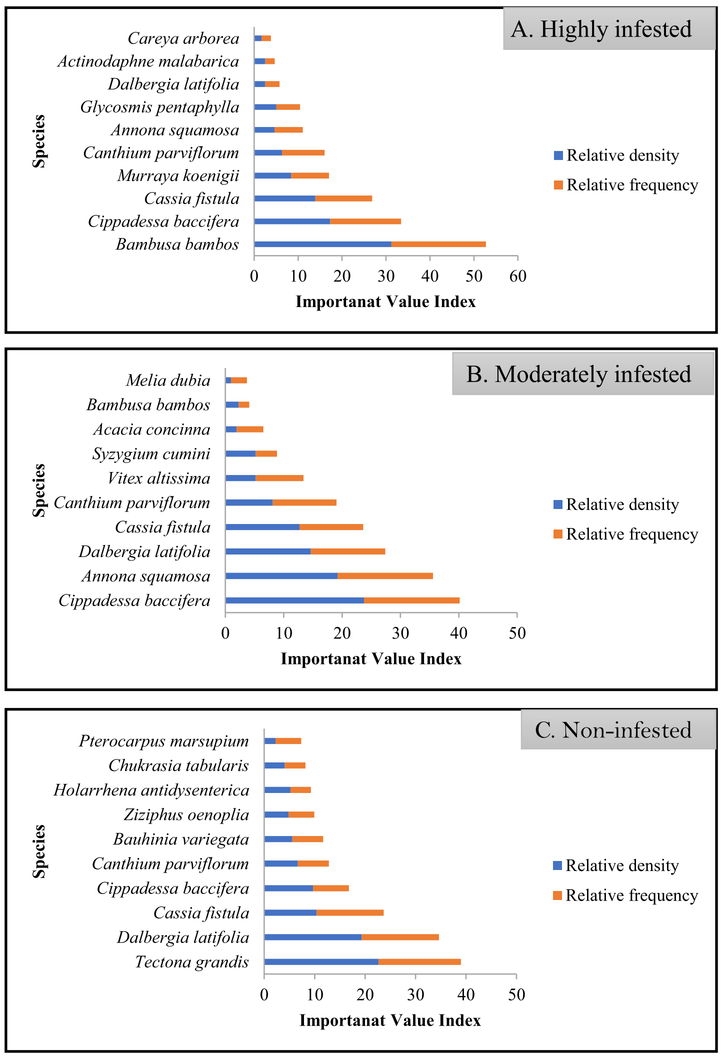


Figure 4: IVI of regenerates in different levels of infestation of Anechowkur range

C. spectabilis grows extremely fast (6) and flourishes on acidic and infertile soils (16). It flowers and sets seed precociously, (17), and the seed remains viable for up to 3 years (28). It resprouts quickly, prousely, and persistently when cut (27).
From the present study it is evident that the non-infested area had recorded comparatively higher regenerates (554 individuals ha^{-1}) followed by moderately infested area (540 individuals ha^{-1}) and a relatively low regenerates density of 521 individuals ha^{-1} was recorded in highly infested area in D B Kuppe range. In Anechowkur range also, non-infested area had higher density (656 individuals ha^{-1}) followed by moderately (384 individuals ha^{-1}), and relatively low density was recorded in highly infested area (296 individuals ha^{-1}).
Wakibara and Mnaya (2002) reported that *C. spectabilis* suppressed the regeneration and growth of native tree species at Mahale Mountains National Park, Tanzania and that its removal allowed the natural regeneration in National Park. Gilbert *et al.*, (2007) reported that *C. spectabilis* take over gaps in natural forests, thus interfering with the regeneration of indigenous trees.
The distribution of different regeneration classes in different level of infestation at D B Kuppe and Anechowkur were depicted in Fig. 5 and Fig. 6 respectively. In both ranges, regeneration status followed a normal trend of an inverse 'J' shaped curve among different levels of infestation. At D B Kuppe, non-infested area recorded maximum total number of regenerates followed by moderately and highly infested area. Whereas at Anechowkur highest number of regenerates was found in moderately infested area followed by non-infested area and highly infested area.

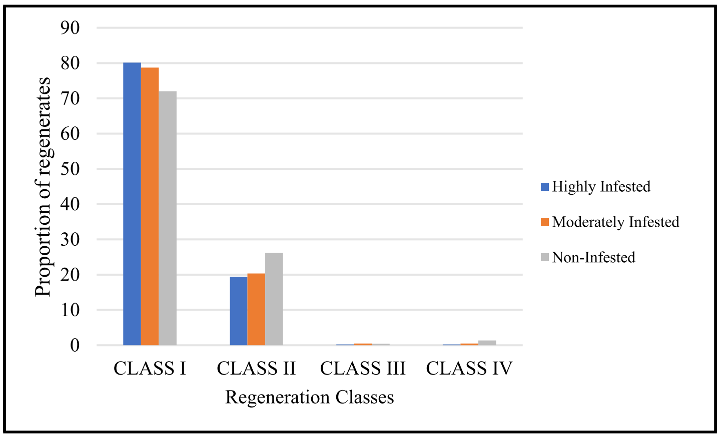


Figure 5: Status of regeneration in different levels of infestation in D B Kuppe range

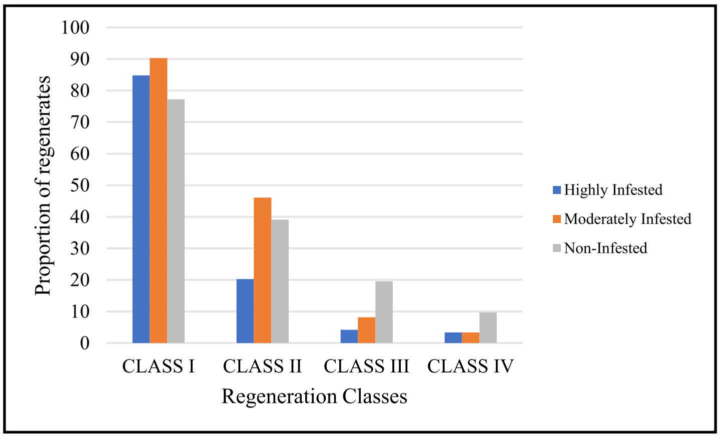


Figure 6: Status of regeneration in different levels of infestation in Anechowkur range

The health of the forest is often indicated by the size class distribution of the community of plants. A reverse J-shaped curve for the size class distribution reflects a growing population, with a large proportion of seedlings and saplings (21). From the present study it is evident that the status of regeneration followed a normal trend of inverse 'J' shaped curve among different levels of infestation at both locations. The number of regenerates decreased with higher regeneration class. A higher proportion of regenerates was found in class I and less in class IV.

Similarity of regenerating species

The similarity with respect to the composition of regenerating species between different levels of infestation in D B Kuppe and Anechowkur is presented in table 10 and 11 respectively. In D B Kuppe Wildlife Range, the highest similarity (71.87 %) was observed between moderately infested areas and non-infested areas whereas, in Anechowkur Wildlife Range, the highest similarity (45.83 %) was observed between moderately infested areas and non-infested areas. Most of the species were common between highly and non-infested areas. The similarity of regenerating species between different levels of infestation is presented in a dendrogram (Fig 18). The similarity index decreased among infested and non-infested areas in both locations. Highest similarity of tree species occurred between moderately and non-infested areas of both ranges even similar environmental conditions.
Supporting results were observed in Dogra *et al.* (2009), where they reported that similarity index of species was decreased drastically among the uninvaded and areas invaded areas of *Ageratum conyzoides, Lantana camara, Parthenium hysterophorus* at Shivalik hills of Himachal Pradesh.

Table 9: Similarity matrix of regenerates between different levels of infestation in D B Kuppe range

Level of Infestation	Highly infested	Moderately infested	Non- infested
Highly infested	*	53.83	47.50
Moderately infested	*	*	71.87
Non- infested	*	*	*

Table 10: Similarity matrix of regenerates between different levels of infestation in Anechowkur range

Level of Infestation	Highly infested	Moderately infested	Non- infested
Highly infested	*	40.07	26.48
Moderately infested	*	*	45.83
Non-infested	*	*	*

Association between relative density of growing stock and regeneration

The trend line represents the linear relationship between the growing stock and regenerating individuals of the present study. Each point represents a tree species. Points which are present on the line and away from the origin represent a very good regeneration concerning its stock. The point below the line represents a poor regeneration, and the point below and away from that line represents a very poor regeneration, and that species may become extinct if the causal factors continued on it (10).
From the present study, it is evident that *Tectona grandis, Dalbergia latifolia, Pterocarpus marsupium, Butea monosperma* and *Canthium parviflorum*, regeneration was relatively good for the existing density of growing stock but the regeneration of *Anogeissus latifolia* and *Terminalia alata* was poor though the considerable stock of trees was there in both highly and moderately infested areas whereas, in non-infested areas, *Anogeissus latifolia* and *Terminalia alata* were found to be

performing better. This indicates that, *C. spectabilis* is may causing dispersal barrier for these species. Regeneration of *Terminalia alata, Grewia tiliifolia* and *Anogeissus latifolia* were poor, even though these are bird dispersal species, regeneration was poor though the considerable stock of trees was there in both the locations.

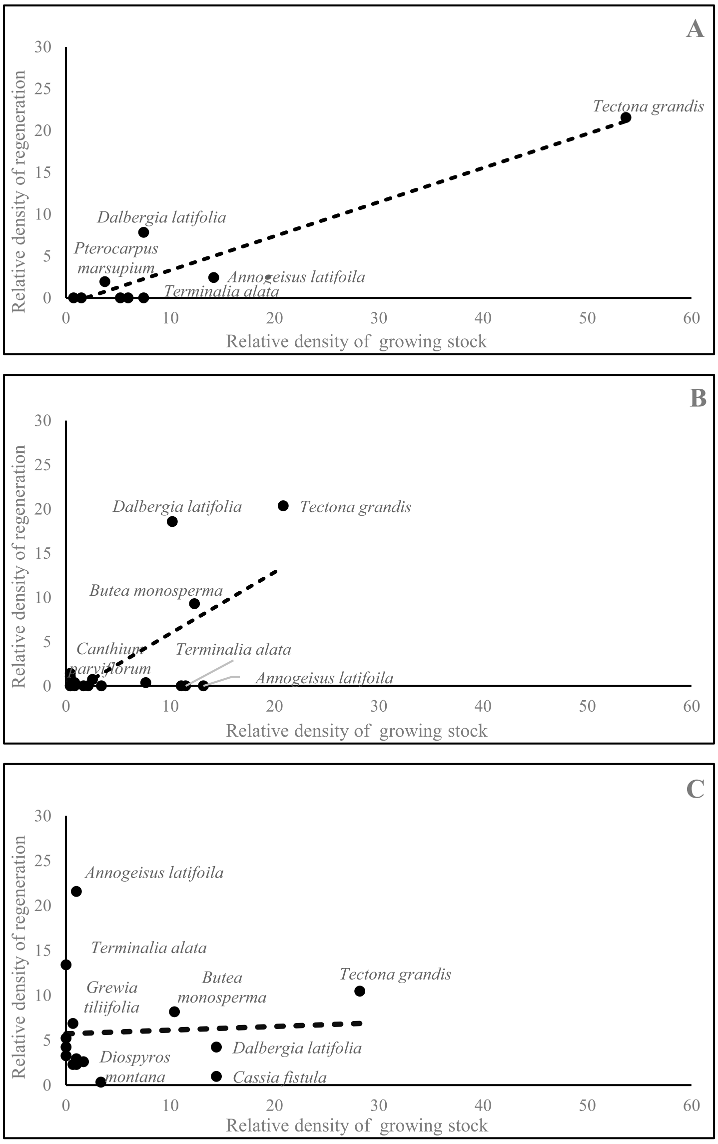
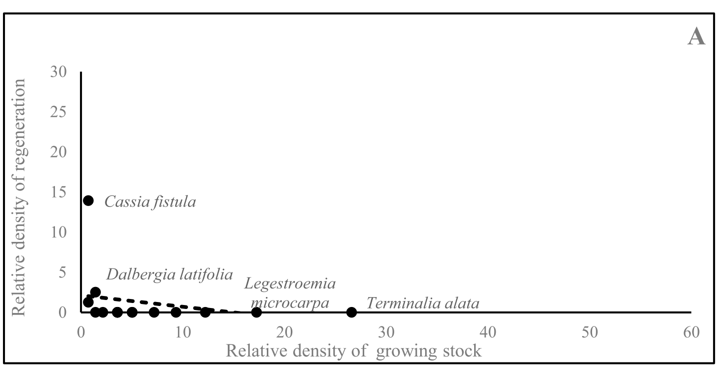


Figure 7: Relative density of growing stock and regeneration at different levels of infestation in D B Kuppe range (A: Highly infested, B: Moderately infested, C: Non-infested)



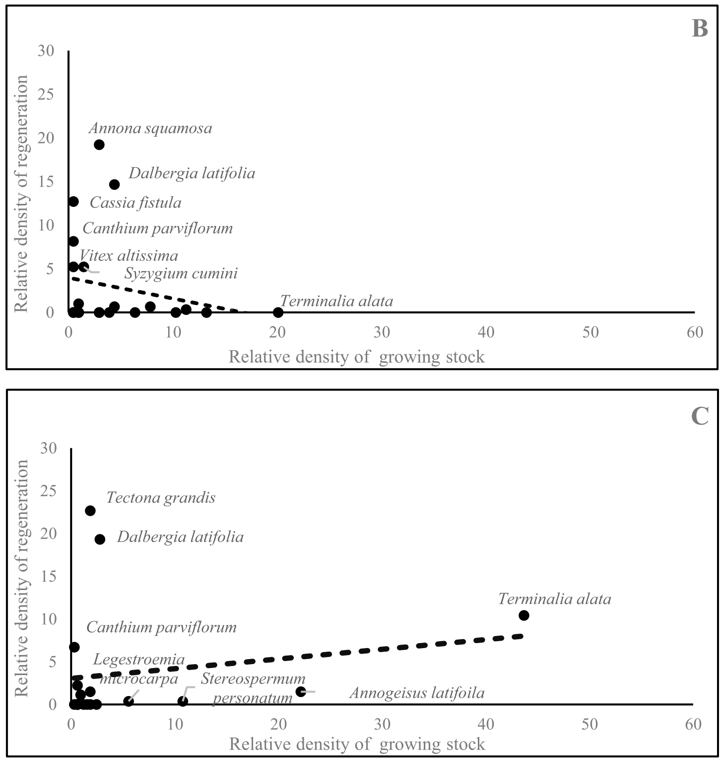


Figure 8: Relative density of growing stock and regeneration at different levels of infestation in Anechowkur range (A: Highly infested, B: Moderately infested, C: Non-infested)

Status of regeneration in different life forms

Population structure refers to the numerical distribution of individuals of different sizes or within a population at a given moment. Similar to the results of the present study Sundaram (2011) reported that the size class structure of trees and shrubs in Biligiri Rangan Hills has changed over time with an increase in Lantana abundance between 1997 to 2008. Lantana invasion resulted in recruitment limitations of trees.

The non-infested areas, contributed highest tree species percentage in D B Kuppe range where, 86 % were tree species. Highly infested area recorded highest percentage of shrub species (17%) and in non- infested area 7 % were climbers. In Anechowkur range, highly infested area recorded highest percentage of tree species (81%), non -infested area recorded maximum percentage shrubs (25%) as well as climbers (13%).

Gentle and Duggin (1997) reported that invasive species such as Lantana removal encouraged regeneration of tree as well as shrubs compared to other different levels of infestation. *L. camara* inhibits native plant species recruitment by allelopathic interference of seed germination, seedling growth and survivorship. Sharma and Raghubanshi (2015) reported that in the wet sclerophyll forests of south-eastern Australia, non-invaded and managed sites showed significantly more fern, herb, tree and vine species than Lantana invaded sites. Managed sites had significantly more herb and shrub species than either non-invaded or invaded sites.

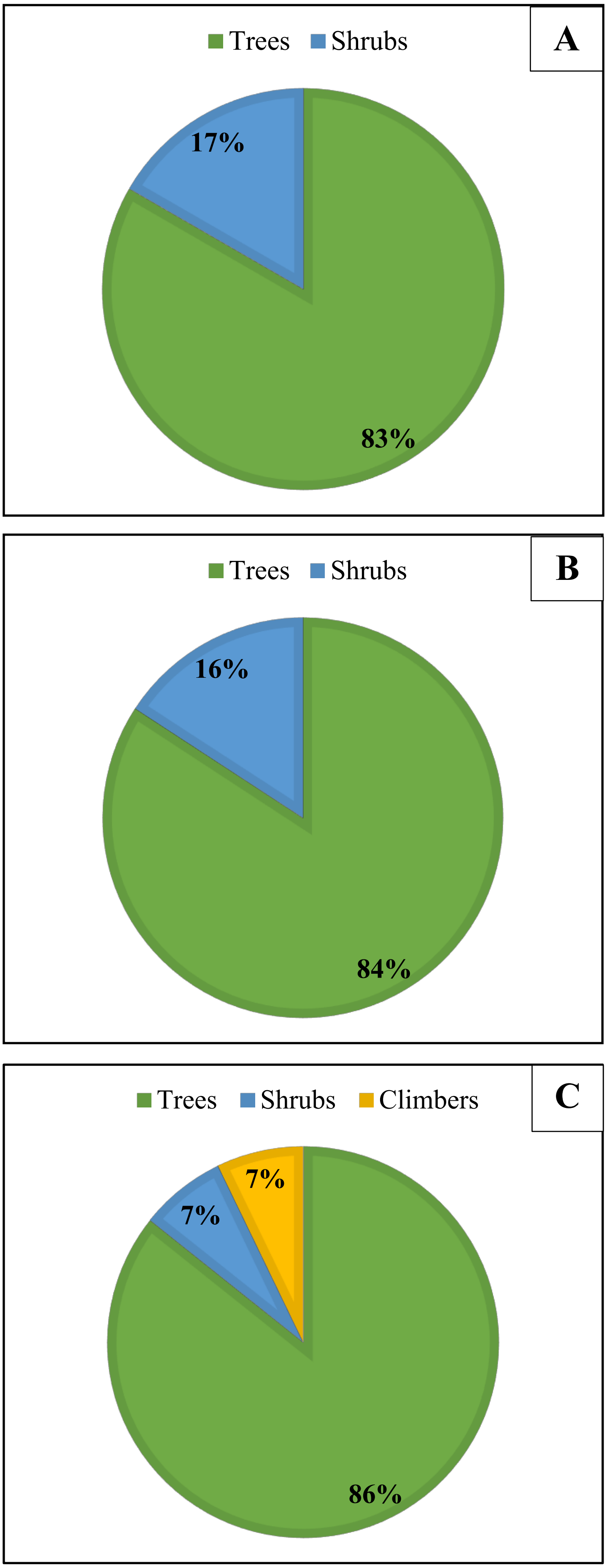


Figure 9: Life forms of regenerates under different levels of infestation at D B Kuppe range (A: Highly infested, B: Moderately infested, C: Non-infested)

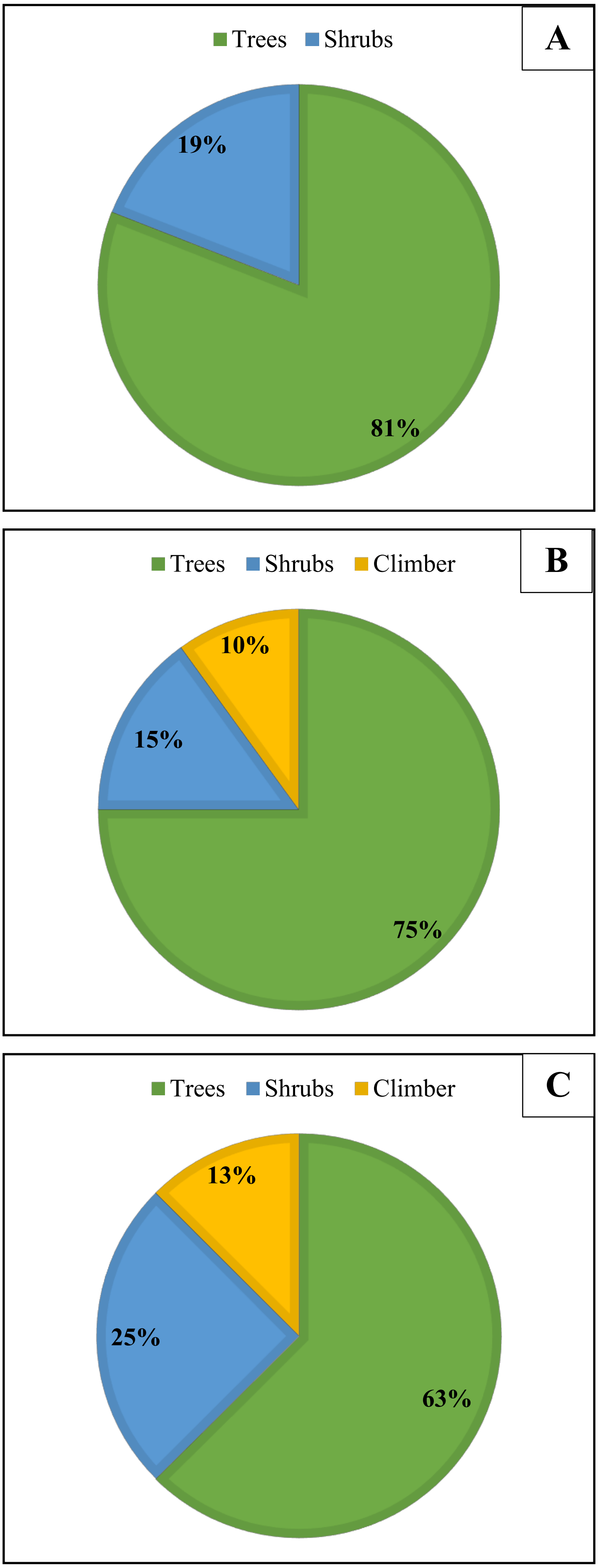


Figure 10: Life forms of regenerates under different levels of infestation at Anechowkur range (A: Highly infested, B: Moderately infested, C: Non-infested)

CONCLUSIONS

The outcome of the present investigation can be used as baseline data for future management of *C. spectabilis* with essential details about infestation of the species. Based on the present study management plan can be drawn 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. 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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