Article

Distribution and population structure of *Pterocarpus santalinus* (Red sanders) in hill ranges of Kadapa region, Southern Eastern Ghats, India

C. Ankalaiah, **M. Sridhar Reddy**
Yogi Vemana University, Department of Environmental Science, Kadapa, Andhra Pradesh, 516005 India
E-mail: sridharmullangi@yahoo.com

Received 17 December 2021; Accepted 2 January 2022; Published 1 March 2022

Abstract
The present study involves the inventory of the four growth stages, seedling, sapling, juvenile trees and trees of Red sanders in tropical dry deciduous forests in hill ranges of Kadapa region. A total of 20 (1 ha) study sites were laid and in each of the study site, a total of ten (10×100 m) belt transacts were randomly laid to enumerate the growth stages. The objective is to derive quantitative information about the population of Red sanders in its natural occurrence area. Results indicated that seedlings are the dominant growth-form across the hill ranges and juvenile trees showed high variation in their distribution. The suffrutex stage, justified by the presence of multiple stems; among seedlings and saplings seems to play a major role in Red sanders regeneration success to overcome the prevailing drought, hot weather conditions and fire. The general population structure in reference to four growth stages of Red sanders was: seedlings > saplings > juvenile trees < Adult trees. Although inverse J shape population structure was recorded for the whole study area, variations in population structure profiles were noticed at one ha level. The occurrence of Red sanders abundance along the elevation revealed that lower elevation sites featured lower tree density and it reached maximum at 400-600 m and decreased later till 600-900 m. Overall Red sanders can be ranked as the dominant trees in these forests, but the progression of sapling stage to established stage like juvenile tree and trees is the bottleneck in the progression of population of Red sanders rather than the seedling germination and survival rates.

Keywords dry deciduous forests; population structure; red sanders; regeneration.

Proceedings of the International Academy of Ecology and Environmental Sciences
ISSN 2220-8860
URL: http://www.iaees.org/publications/journals/piaees/online-version.asp
RSS: http://www.iaees.org/publications/journals/piaees/rss.xml
E-mail: piaees@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

Pterocarpus santalinus commonly referred as Red sanders, is an endemic and threatened tree species that grows in Tropical Dry Deciduous Forests of southern Eastern Ghats with an altitude range of 160-1000 m

(Ankalaiah et al., 2017). Over 80% of Red sanders natural population distribution occurs mainly on hilly terrains of Kadapa region having soils derived from Quartzites and Sand stones rock types indicating a soil preference of shallow sandy loam soil (Raju and Nagaraju, 1999). Red Sanders is a valuable timber species with multiple uses. A natural dye 'santalin' is extracted from its heartwood which is used as a coloring agent in food items, leather, medicines and textile industries. Wood is durable and resistant to decay, wood rotting fungi, termite attack, also produces a rich resonant sound useful for making various musical instruments. A rare wavy grained variant wood heart wood is in high demand in Japan for making musical instrument 'shamsien' which they give as a present for the well wishers. Thus the timber is high in demand, especially in Japan and China for its exquisite color to prepare luxury furniture, carvings and for its superior acoustic qualities in preparing musical instruments (Arunkumar and Joshi, 2014). This situation created demand and illegal harvesting is being carried and well grown trees are logged for the heartwood. Any kind of such overexploitation of a single species may alter its population structure, seed output and regeneration potential (Bharali et al., 2013). The base line data of population structure gives an idea for understanding how population structure of the concerned tree species change over a period of time (Niklas et al., 2003) and how climate change impacts the distribution of plant species especially which are endemic and restricted in a particular geographic occurrence (Ramachandran et al., 2020). The quantitative data on the diameter/girth distributions of tree species and the ratio of the different size class groups in a population of a species provide inferences about the past changes and can even predict the future change of the target species in the forest composition (Sukumar et al., 1992; Sagar and Singh, 2004). Further, the inclusion of seedlings and saplings in tree population structure can provide better knowledge about the status of the species at early stage of regeneration (Bharali et al., 2013). This understanding of the population structure and regeneration behavior helps in developing conservation strategies for endemic and threatened species (Bharali et al., 2013; Choudhury et al., 2007). Although extensive studies are carried out, quantitative information on Red sanders population structure in reference to logging and forest disturbances was poorly available. Thus a study was carried at large scale in Red sanders natural occurrence range to analyze the population structure and regeneration of Red sanders in hill ranges of Kadapa region, southern Eastern Ghats

2 Study Area and Methodology

2.1 Study site

Southern Eastern Ghats of Andhra Pradesh constitute mainly tropical dry deciduous forest type and these forests which occur on the slopes of these Kadapa region hill ranges-Thurpu kondas, Veligindas, Guvvalacheruvu ghat, Palakondas and Lankamallas hill ranges forms the natural range area of Red sanders (Ankalaiah and Reddy, 2017). A total of 20 (1 ha) plots were laid the across hill ranges with natural distribution of Red sanders (14^0 36' 42.6" N 79^0 08' 24.5" to 130 48' 43" N and $79^0$11' 25.8" E). The study sites include Sri Lankamalleswara wildlife sanctuary, Reserve forests of Badvel, Siddavatam ranges, Guvvalacheruvu Ghat area,Vangimalla, Eddodikanam, YKota, Gadala, Kothakota, Dasarapalli, Sanipaya, Balapalle, Gopavaram, Ramapuram, Chitvel Reserve forest areas (Fig. 1). These sites mainly comprise of dry deciduous forests occurring in foothills, plateaus, valleys and hill ranges with an altitude range of 190 m to 843 m. The soil is red ferruginous loam, shallow and nutrient poor with a mixture of lose boulders of varying sizes in hill and deep in valleys and certain areas are covered with prominent quartzite out crops (Rawat, 1997). The mean temperature ranges between 13^0C-45^0C annual temperature with hot weather from mid February to June end with 30-40% relative humidity. Although the area receives rainfall from both south-west and north-east monsoons but does not lie in prominently in either of the monsoon periods and thus receives only 696 mm of mean annual rainfall.

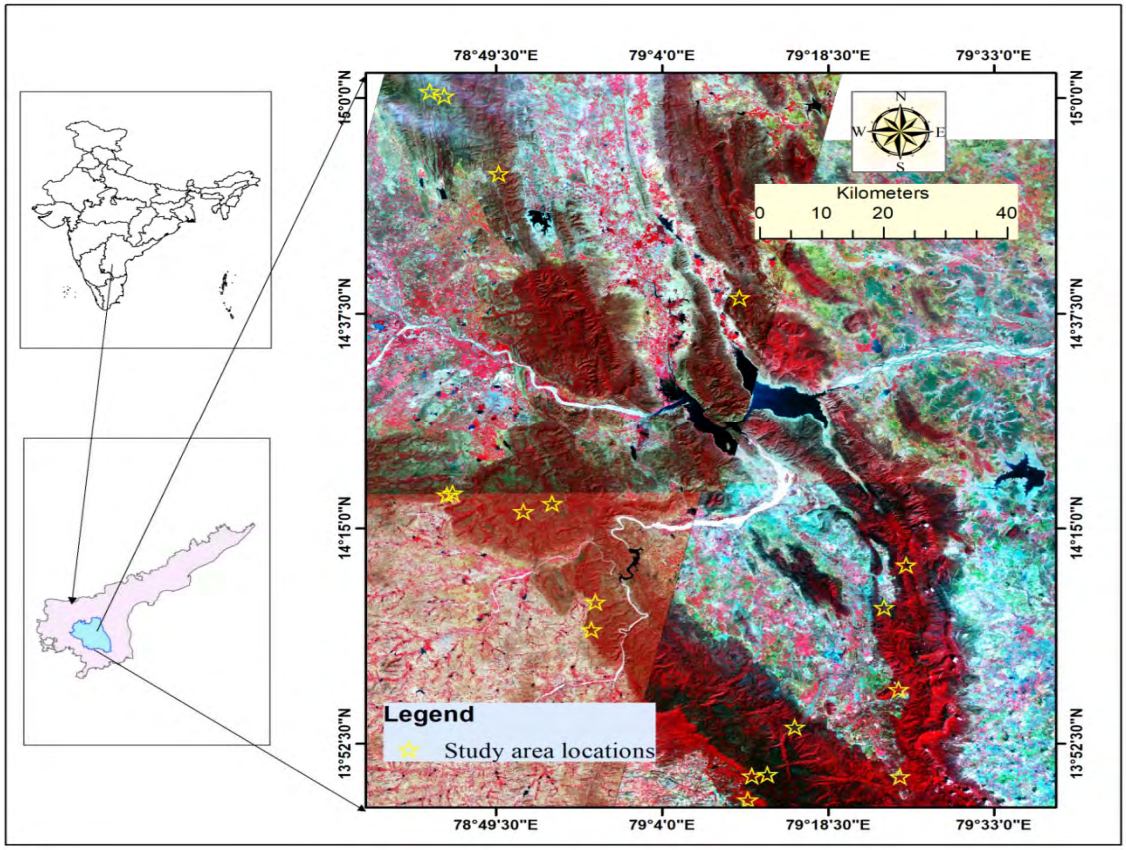

Fig. 1 Map showing the locations of 20 (1 ha) study sites in the kadapa hill ranges.

2.2 Data collection

A total of 20 (1 ha), study sites, comprising of ten (10×100 m) belt transects with at least 50-100 m inter-distance between each transect were laid across the hill ranges. In each study site, all *Pterocarpus santalinus* seedlings (<40 cm height), saplings (40-150 m height and < 10 cm girth), juvenile trees (10-30 cm gbh) and adult tree individuals (≥30 cm girth at breast (1.37 m) height; gbh) were enumerated. Thus all growth-form plant individuals (life stages) of Red sanders were recorded at one ha scale.

The geographic location coordinates of each transect were recorded using Geographic Position System (Garmin GPS MAP 78S).

2.3 Analysis data

The computed graphs between the number of tree individuals with increasing gbh classes were carried out and the population structure of each site was assessed by the curve whether it follows the reverse 'J' shaped curve or not.

Regression analysis was carried out between the number of tree individuals and mid points of increasing gbh classes.

3 Results and Discussion

3.1 Spatial distribution

All the four growth stages of Red sanders such as seedlings, saplings, Juvenile trees and trees were inventoried across the 20 (1 ha) study sites (Fig. 1). Seedlings formed the dominant growth stage totaling to 3738 individuals with a mean of 186.9±78.17/ha and a range of 66 to 391 individuals/ha (Table 1). At 0.1 ha scale the range of seedlings occurrence was 0-95 individuals/0.1 ha. Eleven quadrats (10×100 m) did not featured any Red sanders seedling while six quadrats comprised of only 1-2 seedlings and two quadrats included more than 80 seedlings/0.1 ha (Fig. 4). Adult trees (>30 cm gbh) represented the second dominant growth stage featuring a total of 2801 tree individuals with a mean of 140 ± 49.7/ha and range of 64 to 241 tree density. At 0.1 ha scale the range of tree individuals was 1-40 individuals/0.1 ha. A quadrat (10×100 m) with only one Red sanders individual and seven quadrats with only 2-4 tree individuals were recorded. While a majority of 87 quadrats featured 8-16 individuals (Fig. 2). Saplings were in the range of 14-203 individuals/ha with a mean value of 79.75 ± 53.8. At 0.1 ha scale 27 quadrats did not featured any sapling, 28 quadrats had only 1-2 individuals and one 0.1 ha quadrat had constituted higher saplings (50 saplings/0.1 ha). The juvenile trees were found to be with mean value of 72.45±50.02 and range of 3–200 individuals/ha and 0-40 individuals/0.1 ha. A total of 22 quadrats (10×100 m) did not featured any juvenile tree and 27 quadrats figured only 1-2 individulas/0.1 ha and sixty quadrats featured 8-16 individuals. The Coefficient of Variation values (C.V.) among the four growth stages across the 20 sites indicate a lower C.V. value (35.49%) in the trees category (>30 cm gbh) followed by seedlings (41.8%) and higher C.V. values were recorded among saplings (67.5%) and juvenile trees (69.1%). At (10×100 m) scale, all the four growth forms did not tend towards normal distribution (Shapiro Wilk test, df (20) $P<0.05$). But when the density values at 1 ha scale were considered the growth forms such as seedlings (Shapiro Wilk test 0.958, df (20), $P=0.510$), juvenile (Shapiro Wilk test 0.935, df (20), $P=0.196$) and trees (Shapiro Wilk test 0.959, df (20), $P=0.522$) have tended towards normal distribution except saplings (Shapiro Wilk test 0.228, df (20), $P=0.05$). The overall progression of growth stages of Red sanders is Seedlings > Saplings > Juvenile trees < Adult trees, when abundance values of all 20 (1 ha) sites were considered. Whereas across the study sites;, in one site seedlings are lower than saplings and in four sites sapling density is lesser than juvenile tree density and the in only three study sites juvenile trees are in higher abundance than trees. The spearman rank correlation did not show significant relation ($r=0.18$) between altitude and Red sanders tree density. The trend revealed that lower elevation sites (100-300 m) featured lower tree density and it reached maximum at 400-600 m and decreased after wards till 600-900 m.

Table 1 Inventory results of no of individuals of four growth forms of Red sanders at 1 ha scale and 0.1 ha scale.

S. no	Growth forms	Total no of individuals	10 (10×100 m (1 ha)		Coefficient of variation	10×100 m (0.1 ha)	
			Mean	Range		Mean	Range
1	Seedlings <40 cm height	3738	186.9	43 - 391	41.8%	18.6	0 - 95
2	Saplings 40-150 m ht < 10 cm girth	1595	79.75	14 - 203	67.5%	7.95	0 - 50
3	Juvenile trees 10-30 cm gbh	1449	72.45	3 - 200	69.1%	7.37	0 - 40
4	Trees (≥30 cm girth at (1.37 m) ht	2801	140.05	64 - 241	35.49%	14.0	1- 40

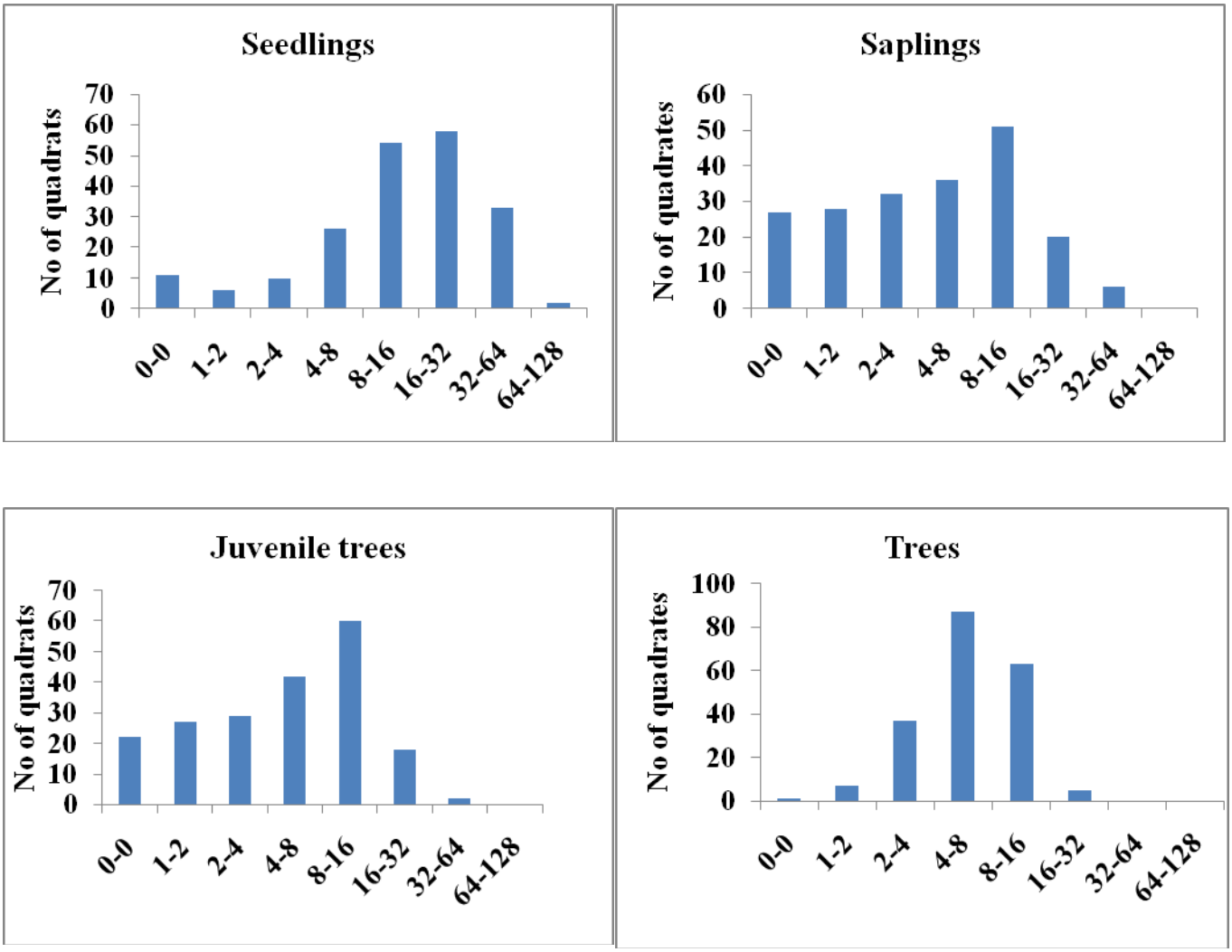

Fig. 2 Distribution of four growth forms- seedlings, saplings, juvenile trees and adult trees in 10 X 100m (0.1 ha) belt transects arranged on log2 scale.

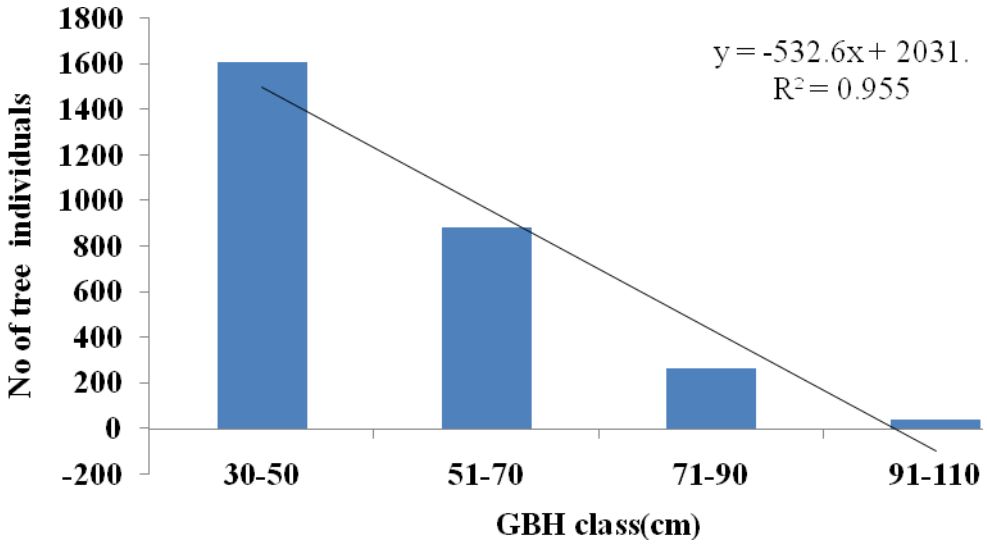

Fig. 3 The graph showing the inverse "J" shape curve drawn with increasing gbh classes and number of total tree individuals in each gbh class in the 20 (1 ha) study sites.

3.2 Population structure

The population structure of Red sanders revealed an inverse 'J' shaped curve with gradual decrement of tree individuals with increasing gbh classes (Fig. 3). Among the 20 study sites, 16 sites featured reverse J shape curve and four sites featured bell shaped population curves. This is possible as the majority of tree individuals occurred in 30-50 cm gbh class (57.5%; range of 39.5% to 88.5%) and a substantial proportion of trees were also recorded in 51-70 cm gbh class (34% to 39%). In the 71-90 cm gbh class, four sites did not featured any tree, six sites had trees in the range of 1-10 individuals and in six sites 12-41 range of trees were recorded. In the >90 cm gbh class, ten sites did not comprised of any individual, while nine sites featured 1-5 tree individuals and one site had higher number of 12 individuals per hectare. A linear regression carried out on the natural logarithm (ln) of the density of Red sanders individuals in the respective gbh classes against the gbh class midpoint for twenty (1-ha sites) has featured a significant correlation (r^2 = 0.953; P<0.05) and the linear regression equation is Y = -0.054 X +9.275, P<0.05. Across the 20 sites, higher share of mean basal area (1.68 m^2/ha; 29.5%) was provided by 51-70 cm gbh class although the corresponding tree density is low (45 tree individuals/ha) (Fig. 4). While the lower gbh class (30-50 cm) has contributed a basal area of 1.25 m^2/ha (22%) owing to higher tree density (80 tree individuals/ha). The trees in the 71-90 cm gbh category have accounted for 13.35% of basal area and the trees in higher gbh classes (91-110 cm and >110 cm) have contributed each of just 1.75% of total basal area.

4 Discussion

The present inventory data on the four growth forms of the Red sanders indicate that seedlings are the dominant growth-form across the hill ranges in Kadapa region. While the higher C.V. values indicate a high spatial variation in their distribution revealing the importance of the microenvironment conditions for regeneration (Teketay, 2005). The frequency distribution of saplings also showed considerable variation as they revert back to seedlings height and to sapling stage multiple times owing to the occurrence of fires. This situation leads to high gestation period in the sapling stage itself and this was authenticated by the presence of saplings with multiple shoots in higher proportion (41%-53%) (Ankalaiah et al., 2017). This feature of

possessing multiple stems among the persistent seedlings and saplings is referred as 'suffrutex stage in the regeneration literature of dry forests trees as also recorded in the dominant trees such as *Pterocarpus angolensis* (Shackleton, 2002) and *Burkea africana* (Wilson and Witkowski, 2003) of Miobo wood lands of Africa. It was suggested that the suffrutex stage is simulated from factors such as protection from fire or cattle browsing and escape from competition to grow with rapid aboveground growth to enter into next established stage (Banda et al., 2006).

According to Umashankar (2001) fair regeneration represents seedlings>saplings>juvenile trees>adult trees. But among the 20 (1-ha) study sites the prevailing progression is seedlings > saplings > juvenile trees < Adult trees., in 17 sites juveniles were in lower density than trees, seedlings are greater than saplings in 19 study sites and in 13 study sites, saplings are greater than juvenile trees. This situation suggests many stochastic features influence the regeneration and recruitment of Red sanders and hence such diverse condition prevails among the 20 (1 ha) study sites. A higher degree of reduction from sapling phase to established stage like juvenile trees was observed in the study sites as it reflects the importance of its survival from seedling to sapling and into juvenile tree of 10-30 cm gbh for the self maintenance of the population. Thus, juvenile trees formed the most variable growth stage with high coefficient of variation value, in the demographic profile of Red sanders. This is in conformity with observations made in tropical dry forests where the sapling survival is greatly influenced by the abiotic factors and human disturbances and majority of plant populations show greater reduction during the sapling phase (Teketey, 2005).

The overall regeneration profile revealed that the contribution of seedlings was higher than the saplings, juveniles and adults to the total population. Such a similar population structure was also recorded for prominent Miobo wood land tree namely *Pterocarpus angolensis* (Shackleton, 2002) and as well in Rhododendron species of Temperate broad leaved forests of Arunachal Pradesh (Bharali et al., 2013). Regeneration profiles showed negative slope values in 13 study sites indicating fair regeneration progression. These conditions suggest that there is reduced and slower rate of progression in the individuals from juvenile stage to the next adult tree stage as it undergoes high gestation period as also observed among tree species in African dry forests (Pare et al., 2009). The density data on seedlings, saplings and juvenile trees indicate that overall in hill ranges of Kadapa region, seed germination is not the limiting stage in regeneration as they form seedling/sapling bank over the years, but the movement from saplings into juvenile trees and then towards trees is the bottleneck in the population structure of Red sanders.

The enumeration results of trees ≥30 cm gbh with a mean value 140 trees/ha indicate that the Red sanders tree can be ranked as the dominant tree in the dry hill forests of Kadapa region. Similarly the population study of Red sanders in its natural range yielded nine individuals/0.1 ha (Hegde et al., 2012) and 110 Red sanders tree individuals per ha in Sri Lankamalleswara wildlife sanctuary revealed (Mastan, 2020) along with co-dominants like *Anogeissus latifolia, Chloroxylon swietenia, Terminalia alata*. Similar kind of dominance by few trees as dominant and co-dominants was also reported from dry forests of Vindhyan hills in Sariska Tiger project (Yadav and Gupta, 2006) and Vindhyan hills (Sagar et al., 2003). Further a mean tree density of 92 Red sanders tree individuals/ha and a significant negative relationship between total tree density and disturbance levels was noted in the Kadapa region forests (Ramana and Reddy 2020). These dry deciduous forests of southern Eastern Ghats hill ranges which include kadapa hill ranges occur in regions endowed with topography of hills and valleys, nutrient poor soils, both natural and biotic disturbances, harsh dry conditions that create microhabitat conditions in which only few dominant trees can endure (Ratnam et al., 2019).

Those population curves of trees in the tropical dry forests which resemble reverse J shaped curve and drop exponentially with increase in gbh classes indicate a continuous regeneration (Khamyong et al., 2004). The population structure of Red sander trees for the whole 20 (1 ha) study site revealed a typical reverse 'J' shape

curve. The curve suggests that mature tree individuals will be replaced well with younger tree individuals. The size class structure in six study sites showed skewed nature towards left side with the presence of majority of trees in the smaller girth classes and lack of strikingly large sized trees can be explained by the past indiscriminate logging of trees across all the size classes. The typical reverse 'J' shape curve and high correlation values (slope values) in eleven study sites indicates that the tree harvesting occurred in the past and it has got reduced to certain extent at present. This feature can be strengthened by the high basal area value. Such kind of reverse 'J" shape population structure indicating future ideal regeneration was also observed in *Elaeodendron transvaalense* species under the bark harvesting pressure (Tshisikhawe and Van Rooyen, 2013). The lack of reverse J shape curve in the three sites with lower trees individuals in 30-50 cm gbh class and >70 cm gbh class than 51-70 cm gbh in the tree demographic profile indicated a lack of expanding recruitment and wood smugglers are actively involved in tree logging. A comparable population structure was observed for *Pterocarpus angolensis* which is also being harvested unsustainably for timber in Tanzanian dry forests (Schwartz et al., 2002). This kind of exploitation of relatively younger trees and whole range of large sized trees may affect the seed production as only few trees are found to produce fruits in a season and even fruit set is low for this species (Rao and Raju, 2002).

5 Conclusions

Seedlings represented the most dominant growth stage followed by trees and saplings and less frequent growth stage was juvenile trees and the coefficient of variation values indicated that trees are the less varied growth form and juvenile trees are highly varied in their occurrence. Red sanders is characterized by the occurrence of seedlings and saplings in high abundance than juveniles across the study sites. The presence of multiple stems; among seedlings and saplings suggest the presence of suffrutex stage and this mechanism of producing above ground shoots seasonally after a drought period or after a disturbance like fire and browsing play a major role in Red sanders regeneration success. The population structure in reference to four growth stages of Red sanders revealed a progression of: seedlings > saplings > juvenile trees < Adult trees. The size class distribution of Red sanders trees (≥30 cm gbh) revealed an inverse 'J' shaped curve with higher proportion of individuals in lower gbh class (30-50 cm gbh) followed by the trees in higher gbh classes. A highly skewed nature of reverse 'J' shaped curve with nearly 90% of trees featuring in lower gbh class was noticed in six sites suggesting an indiscriminate logging of trees across all the size classes. The typical reverse 'J' shape population structure indicating expanding population where young individuals can replace older trees in future and high basal area was noticed in eleven sites. The population structure in three sites did not featured a reverse 'J' shape curve due to lower representation of lower gbh class 30-50 cm gbh class and higher gbh class (>70 cm) in comparison to 51-70 cm gbh class. The study indicates that Red sanders is economically extinct in few sites and varied degree of logging is prevalent in other sites. In these conditions also, Red sanders occur as the predominant tree of hill ranges of kadapa region as it can persist by the presence of suffruscent seedling/sapling bank, but the point of concern is the illegal harvesting of mature trees and habitat degradation. Over all it was observed Red sanders can with stand seasonal drought and fire conditions but not the severe logging conditions.

Acknowledgement

The authors profusely thank MOEF & CC for providing the financial support and Andhra Pradesh Forest Department for granting the permission and providing logistic support.

References

Ankalaiah C, Mastan T, Reddy MS. 2017. A study on the density, population structure and regeneration of Red sanders (*Pterocarpus santainus* Fabales: Fabaceae) in a protected natural habitat – Sri Lankamalleswara wildlife sanctuary, Andhra Pradesh, India. Journal of Threatened Taxa, 9: 10669-10674

Arunkumar AN, and Joshi G. 2014. *Pterocarpus santalinus* (Red sanders) an endemic, endangered tree of India: current status, improvement and the future. Journal of Tropical Forestry and Environment, 4: 1-10

Banda T, Schwartz, MW, Caro T. 2006. Effects of fire on germination of *Pterocarpus angolensis*. Forest Ecology and Management, 223: 116-120

Bharali S, Paul A, Khan ML. 2013. Population studies of *Rhododendron mechukae* – A newly recorded endemic species from Eastern Himalaya, India. Journal of Biodiversity Management and Forestry, 2: 1-5

Choudhury BI, Khan ML, Arunachalam A, Das AK. 2007. Ecology and Conservation of the Critically Endangered Tree Species *Gymnocladus assamicus* in Arunachal Pradesh, India. Research Letters in Ecology, 2007: 1-5

Hedge M, Singh BG, Krishnakumar N. 2012. Non-Detriment Findings (NDFs) Study for *Pterocarpus santalinus* L. f. (RED SANDERS) in India. Institute of Forest Genetics and Tree Breeding. Indian Council of Forestry Research and Education, Coimbatore, India

Khamyong S, Lykke AM, Seramethakun D, Barfod AS. 2004. Species composition and vegetation structure of an upper montane forest at summit of Mt. DoiInthanon, Thailand. Nordic Journal Botany, 23: 83-97

Mastan T, Ankalaiah C, Ramana CV, Reddy MS. 2020. Assessment of Tree Diversity in Nithyapoojakona Dry Deciduous Forest of Sri Lankamalleswara Wildlife Sanctuary, Southern Eastern Ghats, India. Indian Journal of Ecology, 47(2): 390-396

Mastan T, Ankalaiah C, Ramana CV, Reddy MS. 2020. Assessment of tree diversity in Nithyapoojakona forest of Sri Lankamalleswara wildlife sanctuary, southern Eastern Ghats, India, Indian Journal of Ecology 47(2): 390-396

Niklas KJ, Midgley JJ, Rand RH. 2003. Tree size frequency distributions, plant density, age and community disturbance. Ecology Letters, 6: 405-411

Pare S, Savadogo P, Tigabu M, Oden PC, Ouadba JM. 2009. Regeneration and spatial distribution of seedling populations in Sudanian dry forests in relation to conservation status and human pressure. Tropical Ecology, 50: 339–353

Raju KK, Nagaraju A. 1999. Geobotany of Red Sanders (*Pterocarpus santalinus*): a case study from the southeastern portion of Andhra Pradesh. Environmental Geology, 37: 340–344

Ramachandran RM, Roy PS, Chakravarthi V. 2020. Land use and climate change impacts on distribution of plant species of conservation value in Eastern Ghats, India: Simulation study. Environmental Monitoring Assessment, 192 (2): 1-21

Ramana CV, Reddy MS. 2020. Assessment of tree population structure and diversity along disturbance gradient in Tropical dry deciduous forests, southern Eastern Ghats, India. Environment and Ecology, 38 (4): 882-893

Rao SP, Raju AJS. 2002. Pollination ecology of the Red Sanders *Pterocarpus santalinus* (Fabaceae), an endemic and endangered tree species. Current Science, 83: 1144-1148

Ratnam J, Chengappa SK, Machado SJ, Nataraj N, Osuri AM, Sankaran M. 2019. Functional traits of trees from dry deciduous forests of Southern India suggest seasonal drought and fire are important drivers. Frontiers in Ecology and Evolution, 7: Article 8

Rawat GS. 1997. Conservation status of forests and wildlife in the Eastern Ghats, India. Environmental Conservation, 24: 307-315

Sagar R, Singh JS. 2004. Local plant species depletion in a tropical dry deciduous forest of northern India. Environmental Conservation, 31: 55-62

Sagar R, Raghubanshi AS, Singh JS. 2003. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. Forest Ecology and Management, 186: 61-71

Schwartz MW, Caro TM, Banda-Sakala T. 2002. Assessing the sustainability of harvest of *Pterocarpus angolensis* in Rukwa Region, Tanzania. Forest Ecology and Management, 170: 259-269

Shackleton CM. 2002. Growth patterns of *Pterocarpus angolensis* in savannas of the South African lowveld. Forest Ecology and Management, 166: 85-97

Sukumar R,. Dattaraja HS, Suresh HS, Radhakrishnan R, Vasudeva R, Nirmala S, Joshi NV. 1992. Long term monitoring of vegetation in a Tropical deciduous forest in Mudumalai Southern India. Current Science, 62: 608-616

Teketay D. 2005. Seed and regeneration ecology in dry Afro montanne forests of Ethiopia: I. Seed production population structures. Tropical Ecology, 46: 29-44

Tshisikhawe MP, VanRooyen MW. 2013. Population biology of *Elaeodendron transvaalense* Jacq. In the presence of harvesting. Tylon, 82: 303-311

Uma Shankar. 2001. A case study of high tree diversity in a sal (*Shorea robusta*) - dominated lowland forest of Eastern Himalaya: Floristic composition, regeneration and conservation. Current Science, 81: 776-786

Wilson BG, Witkowski ETF. 2003. Seed banks, bark thickness and change in age and size structure (1978-1999) of the African savanna tree, *Burkea africana*. Plant Ecology, 167: 151-162

Yadav AS, Gupta SK. 2006. Effect of micro-environment and human disturbance on the diversity of woody species in the Sariska Tiger Project in India. Forest Ecology and Management, 225: 178-89