International Journal of Ecology and Environmental Sciences 43 (2): 81-87, 2017
ISSN: 2320-5199 (Online)

Effects of Disturbance and Selective Logging on the Population Structure of Red Sanders (*Pterocarpus santalinus* L.f.) - An Endemic Tree of Kadapa Hill Ranges, Southern Eastern Ghats

CHENCHU ANKALAIAH[1] AND M. SRIDHAR REDDY*

Department of Environmental Science, Yogi Vemana University, Kadapa, Andhra Pradesh, India
[1] Email: chenchuankalaiah@gmail.com
* Corresponding author; Email: sridharmullangi@yahoo.com

ABSTRACT

The present study assessed the effects of logging and human disturbance on the population structure of Red sanders (*Pterocarpus santalinus*), an endemic and endangered dominant tree of dry deciduous forests of Kadapa hill ranges. A total of three study sites were selected on the level of two disturbance factors cattle grazing and fire wood collection as less, moderate and high disturbed sites. The objective is to compare the population structure and frequency of the life forms in reference to varied disturbance levels and selective logging across the three sites. Results showed variations in gbh class distribution, Population structure shape among the three study sites. Trees and seed lings formed the major life form. High variation was observed in the saplings distribution as major thinning occurred in the progression from seedling stage to established stages. Moderately disturbed site figured high density of individuals in all life forms and in basal area value. High percentage of cut stems and non- reverse 'J' shape population structure occurred astonishingly in less disturbed site. Highly disturbed site significantly lack the large girth size trees. These observations indicate that selective logging as the major factor that influenced the variation in population structure, stem density and basal area. The human disturbances factors especially selective logging of large size trees and rampant indiscriminate logging across all size may explain the variations in the population structure.

Key Words: Dry Deciduous Forests, Population Structure, Logging

INTRODUCTION

Tree community structure of Indian tropical dry deciduous forests is greatly influenced by human induced disturbances such as felling and lopping of trees, grazing and removal of plants or plant resources as non timber forest products (Sagar et al. 2003). In general both natural as well as human disturbances alter environmental conditions that may sometime increase or reduce species diversity in a forest community (Kennard, et al. 2002). Certain tree species have showed better regeneration in mildly disturbed forest sites, while few indigenous tree species were found to be sensitive to anthropogenic disturbances and are completely wiped out from the highly disturbed sites (Sagar and Singh 2004). It is opined that highly disturbed regimes involving selective logging of trees may lead to loss of late-successional species or reduction of unique species by favouring disturbance tolerant species thus mainly altering the forest structural attributes (Sapkota et al. 2009). While the fluctuating mild disturbances like grazing and fire wood collection may change the species richness and diversity of the forests (Sagar et al. 2003). 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 2003). The population structure can be known by enumerating the relative percentages of seedlings, saplings and adult trees and this size distribution can be used to predict the regeneration of a certain tree species (Gairola et al. 2014). This understanding of the population structure and regeneration behavior helps in

developing conservation strategies for endangered, endemic and threatened species (Bharali et al. 2013).

Eastern Ghats support diverse array of tropical forests in both protected areas and reserve forests which are of great economic and conservation significance (Rawat 1997). *Pterocarpus santalinus* (Red sanders) is one such endemic tree species with utmost economic and ecological importance that occurs only in Kadapa and Sheshachalam hill ranges (Raju and Nagaraju 1999). Its timber is of high value owing to its usage in making luxury furniture, carving toys and musical instruments, food processing and textile industry as colorant and medicinal purposes which has generated high demand in both domestic and international markets (Arunkumar and Joshi 2014). This situation created demand on supply side and illegal harvesting is being carried out by new modus operands even venturing into interior forests to meet the surplus demand. Any kind of such over-exploitation of a single species may alter its population structure and regeneration potential (Bharali et al. 2013). Although extensive studies are carried out on Red sanders micro-propagation (Balaraju et al. 2011) vegetative propagation (Reddy and Srivasuki 1990), phytochemical and pharmacological uses (Arunakumara et al. 2011). But study on population structure in reference to logging and human disturbances was not undertaken; hence the study is taken to evaluate the effects of disturbance on Red sanders population structure in its natural habitat.

STUDY AREA

Tropical dry forests of Kadapa hill ranges are exposed to NTFP collection, fire, fodder and fuel wood collection and cattle grazing. A total of three study sites were selected from different areas of Kadapa hill ranges. These study sites were selected based on the vicinity of villages and road connectivity which influence the prevailing disturbance levels of cattle grazing and fuel wood collection. Disturbance factor selective logging was not considered for the primary selection of sites as it can be known after recording the number of cut stems. Site 1, namely Guvvalacheruvu (GVU) 14^0 19' N 78^0 46' E was near the state high way road and three villages are present with in 2 km range. Incidents of people venturing into forest area for fire wood collection and cattle grazing were commonly observed and this site is categorized as highly disturbed site. A contiguous site 2 (Vangimalla - VGM 14^0 16' N 78^0 51' E) that occurred very interior of the forest was selected. The incidents of people and cattle entering into the forest was not observed, hence the site was denoted as less disturbed site. Site 3 Gadala (GDL-13^0 57' N 79^0 13') from the contiguous hill range was selected as moderately disturbed site. The site was at least 5 km from the village road and activities of people entering into the forest are observed in limited as the forest is surrounded by scrub forests (Figure 1). The altitude range is between 258 to 604 m above mean sea level. The soil is red and shallow with prominent quartzite rock boulders. The annual temperature lies between 13^0C to 45^0C and the region receives about 696 cm annual rainfall. The natural vegetation of the dry deciduous forest type in the Kadapa Hill ranges include *Anogeissus latifolia* (Roxb. ex DC.) Gull. & Perr., *Pterocarpus santalinus, Chloroxylon swietenia* DC., *Bauhinia racemosa* Lam., *Dalbergia latifolia* Roxb. (Champion and Seth 1964).

METHODS

In each site, ten 10x100m belt transects were laid randomly to enumerate all the four life forms namely seedlings (<40 cm height), saplings (40cm–1.5m height), regenerating trees (10-30cm gbh; girth is measured at 1.37m height) and trees (>30 cm gbh) of Red sanders were recorded. Multiple stems of all trees >30cm gbh were noted in the field. The circumference and height of the cut stems was recorded in the field. Population structure was depicted using frequency of Red sander trees that occur in different gbh classes. Basal area was computed as $C^2/4\pi$; C= girth measured at 1.37 m height). Dispersion pattern (variance/mean) was computed and ratio of 1.0 indicates a random dispersion, <1.0 a uniform dispersion and >1.0 a clumped dispersion. Statistical analysis was done by using SPSS version 20.

RESULTS

The inventory of four important life forms of Red sanders such as seedlings, saplings, regenerating trees and trees (>30cm gbh) across three sites that varied along a disturbance levels yielded varied patterns. Trees formed the major life form with a mean (161 trees ha^{-1}) and range of 123-196 (Figure 2) followed by seedlings with mean of 156 and range of 109-186 individuals ha^{-1}. While regenerating trees were in the range of 65-132 with a mean of 116.5 individuals ha^{-1} and saplings were

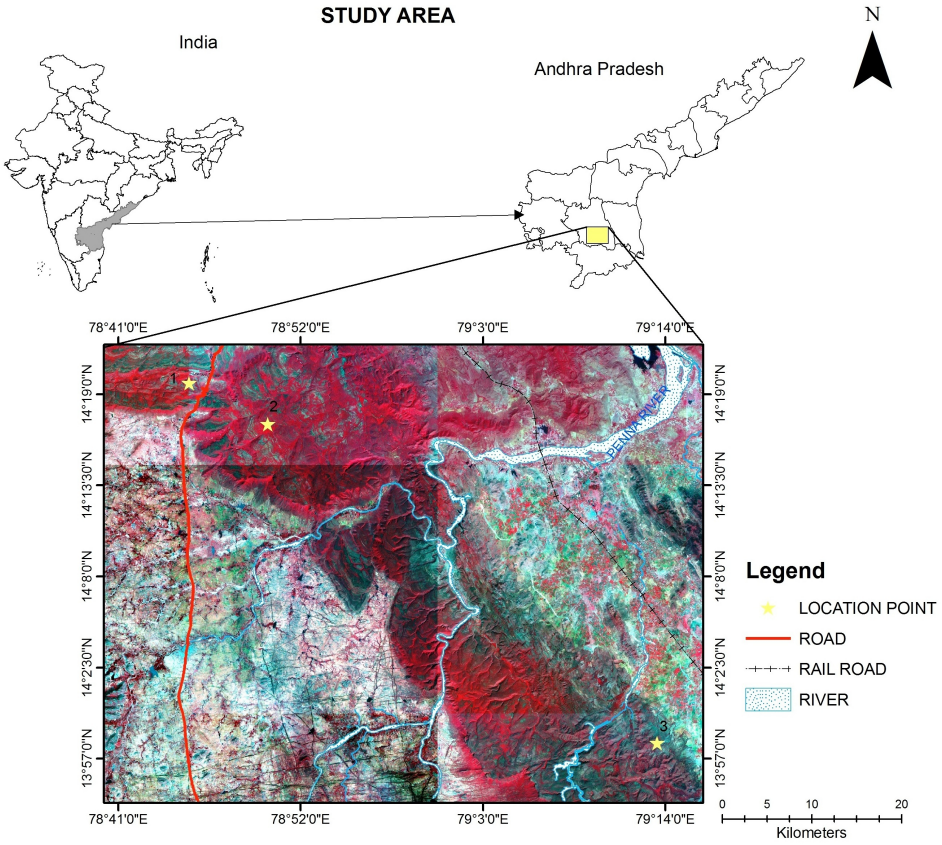

Figure 1. Map showing the study sites 1 (GVU- highly disturbed), 2 (VGM less disturbed) & 3 (GDL moderately disturbed) in the Kadapa hill ranges.

found to be with lower mean value of 73 individuals ha^{-1} and range of 44 –116 individuals ha^{-1}. When density was considered, across the three study sites, trees showed lesser value of Coefficient of Variation (C.V. = 23.8%) followed by seedlings (C.V. = 26.5%), regenerating trees (C.V. = 39.4%) and saplings represented a higher value of (C.V. = 52%). Among the three study sites, the moderately disturbed site registered higher number of individuals in all the life form categories (Figure 3). In the less disturbed site, except for the regenerating trees category which recorded less number of individuals, all the three life forms scored second place. In the highly disturbed site regenerating trees represented the second position and the other three life forms had lesser number of individuals.

A little margin of difference in the basal area values was observed between the moderate disturbed (5.07 m^2 ha^{-1}) and less disturbed sites (5.06 m^2 ha^{-1}) although the later site has higher number of stem density. While the highly disturbed site registered 2.66 m^2 ha^{-1} basal area which is at least 52% less than the other two sites. The abundance and basal area values of the sub-transects (10 x100m) represented by box plot revealed a high variation in tree density as well as in basal area in the moderately disturbed site and a sub-transect figured as an outlier as it comprised of 21.6% of total tree density in the site (Figure 4). In the less disturbed site, one sub-transect figured as an outlier as it comprised of 17.6% of total tree density and 17.2% of total basal area and in highly disturbed site no outlier among the sub-transects were observed. Mann-Whitney 't' tests showed significant variations ($P< 0.05$) in basal area and tree density values when less, moderately disturbed sites are tested with highly disturbed site. But significant variations ($P>0.05$) were not observed when moderately and less disturbed sites are considered.

The Kruskall Wallis test ($\chi^2_{0.05,4}$ $P<0.05$) revealed a significant difference in the frequency of tree individuals in different gbh classes across the three study sites. The gbh class-wise distribution in the highly disturbed site represented reverse 'J' shaped curve with maximum individuals (94%) occurring in the lower gbh classes (10-

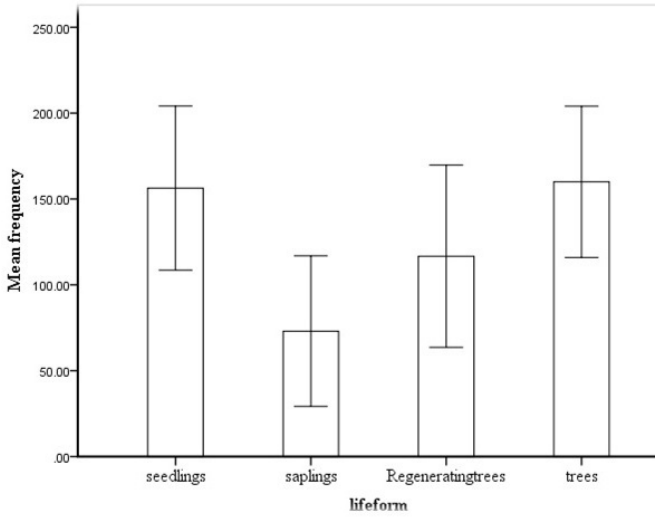

Figure 2. Cumulative frequency of different life forms of the Red sanders

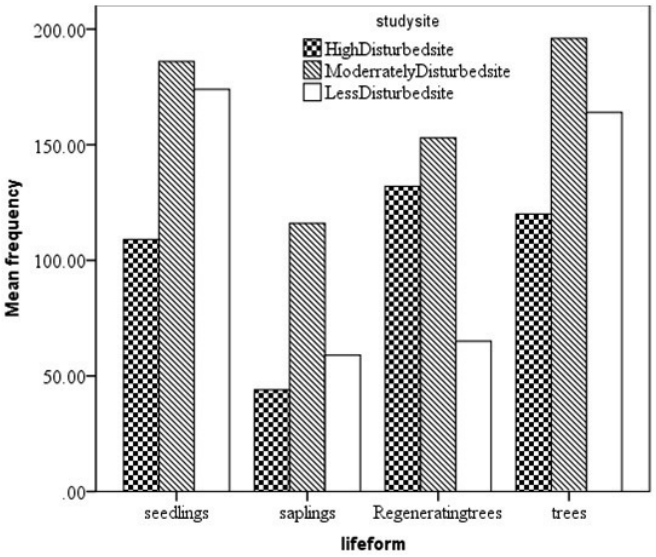

Figure 3. Life-forms across the three study sites

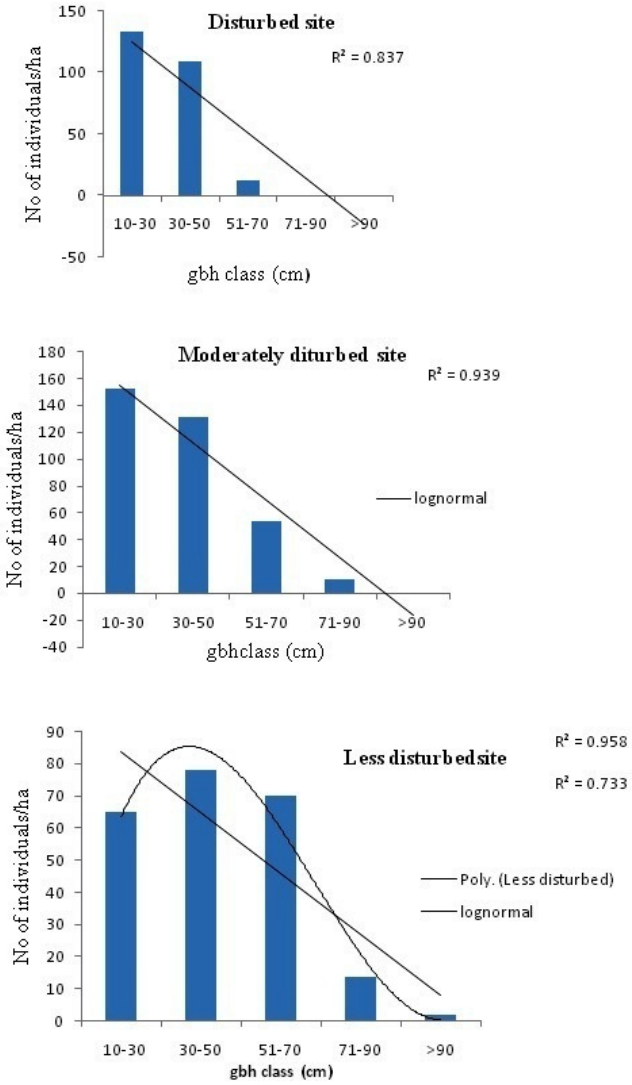

Figure 4. Frequency of individuals in different gbh classes among the three study sites

30 cm – 52%; 31-50 cm – 42%). The lognormal trend line showed a relatively high correlation value (r = 0.91; Figure 5). In the moderately disturbed site a typical reverse 'J' shape curve was obtained with the lower gbh classes registering 80% (10-30 cm – 43%; 31-50 cm – 37%) of tree individuals and a higher level of correlation (r = 0.97) between lognormal and gbh class wise distribution was observed. In the less disturbed site an uni-modal distribution rather than reverse 'J' shaped curve was obtained as 30-50 cm gbh class tree individuals represented (34%) higher than the lower gbh class (10-30 cm) with 28.4% of individuals and the higher gbh classes (>50 cm gbh) cumulatively registered higher value (37.5%) among all the three sites. The lognormal correlation was low with 0.85.

The gbh class distribution of all the logged stems across the three sites revealed astonishingly that 63% of cut stems (63) occurred in less disturbed sites and this site represented a high value in all categories except in low gbh (20-30cm) (Figure 6). Higher number of 18 cut stems occurred in 41-50cm gbh (28.5%) followed by 11 stems (17.4%) in 51-60 cm gbh and even in higher percentage (27%) in >70cm gbh classes. Interestingly moderately disturbed site registered low percentage of cut stems (17%) of which the majority (82%) occurred

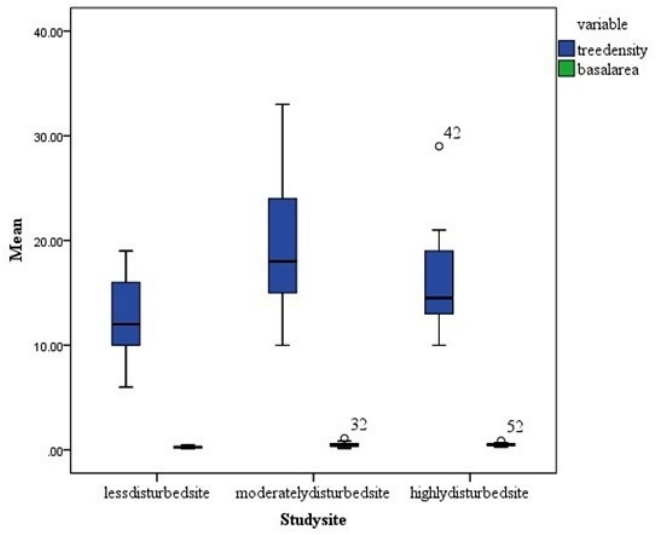

Figure 5. Stem density and basal area using the subtransect density

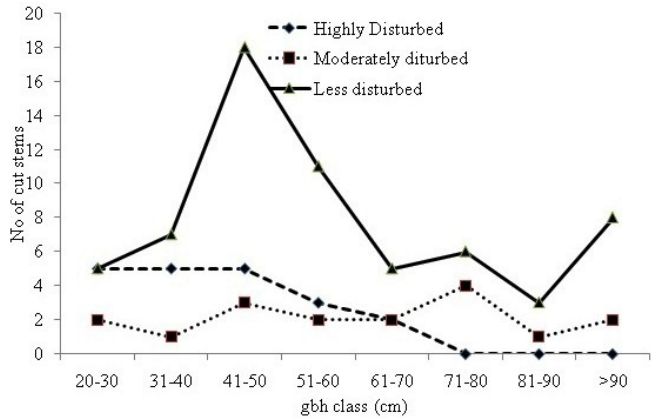

Figure 6. Frequency of cut stems in different gbh classes among the three study sites.

in high gbh classes >41cm. In the highly disturbed site 20cut stems (20%) were recorded and among them 75% were in lower gbh (<50 cm) classes.

The dispersion pattern (Variance/Mean) for all the life forms at 3 ha scale showed clumped dispersion (>1.0). At one ha scale; except for trees in less disturbed site which showed near random dispersion (≈1.01) all the three life forms across the sites featured clumped dispersion. Red sanders has the strategy of production of multiple stems (clonal) from a damaged stem base. The enumeration of multiple stem trees revealed that more than half of the trees in moderately disturbed site (53%) and highly disturbed site (55.3%) comprised of multiple stems and the less disturbed site had 39% of trees with multiple stems.

DISCUSSION

The inventory revealed that the Red sanders featured high stem density and high basal area value in the moderately disturbed site. The values indicate that Red sanders possess tolerance to moderate abiotic disturbance and high ecological amplitude as also observed among few trees such as *Anogeissus latifolia*, *Diospyros melanoxylon* Toxb. and *Lannea coromadelica* (Houtl.) Merr. in dry tropical forests of Vindhyan hill ranges (Sagar et al. 2003). While the high tree species richness was recorded in less disturbed site than the moderately and highly disturbed site (Un published data), it infers that certain tree species may tolerate the disturbance and others may disappear due to disturbance as tree species richness in a particular forest area is the cumulative outcome of the differential response of tree species towards disturbance (Sagar and Singh 2004).

Trees and seedlings of Red sanders formed the dominant and less varied life form across the three sites. This feature can be explained by the ability of the Red sanders to produce re-sprouters from root crown and multiple stems as coppice from a damaged stem base. Similar kind of dominance by *Burkea africana* Hook. tree species in miobo woodlands (Pate et al. 1990) and by certain root crown resprouter trees in Bori wildlife sanctuary of central India (Saha 2001) was observed. But when the disturbance and fire frequency increases the dominance may shift from root crown sprouters to root sprouters as it happened in Mudumalai wildlife sanctuary, where trees like *Santalum album* L. and *Pterocarpus marsupium* Roxb. are replaced by *Anogeissus latifolia, kydia calycina* Roxb., *Wrightia tinctoria* (Roxb.) R.Br. (Saha and Howe 2003)

A higher degree of thinning from seedling phase to established stages was observed in the study sites and this is in conformity with observations made in tropical dry forests where the seedling survival is greatly influenced by the abiotic factors and human disturbances and usually majority of plant populations show greater reduction during the seedling phase (Khurana and Singh 2001). Similar observation of reduction in seedling survival due to human disturbances was observed for an endemic tree, *Rhododendron mechukae* A.A. Mao & A.Paul in Eastern Himalaya (Bharali et al. 2013). While

the relatively high survival and presence of saplings in the moderately disturbed site suggests that Red sanders can with stand suitable moderate biotic disturbance like fire and similar marked abundance of saplings of five trees in relatively less disturbed stand was recorded in sub tropical forests of Northeast India (Khan et al. 1987). The study on *Pterocarpus angolensis* DC. also revealed that regeneration is better in the sites affected by fire rather in sites laid in the protected National park meant to conserve ungulates (Schwartz et al. 2001).

The observed clumping dispersion of Red sanders across the three sites for all the life forms can be explained by its ability to produce re-sprouts and coppice stems due to disturbance (Mastan et al. 2016) and effective utilization of microhabitats on the dry slopy areas of the hills (Raju and Nagaraju 1999). Similar kind of clumped distribution was also observed for trees such as *Holorrhaena antidysentrica* Wall. ex DC. and *Lagerstroemia parviflora* Roxb. in sites with moderate disturbance and *Anogeissus latifolia* and *Butea monosperma* (Lam.) Taub. in sites with high degree of disturbance in dry Vindhyan hills. Further, in these forests the authors found that majority of tree species altered their dispersion nature along the disturbance gradient (Sagar et al. 2003). Similarly in the present study, Red sanders featured near random dispersion in the moderately disturbed site and can be explained by the occurrence of tree logging in the past but got reduced at present in this site. Such kind of variation in clumping due to logging was also observed in the distribution of *Olea capensis* (Knob.) Gilg & Schelleneb. canopy tree in Kakanega forest of Kenya (Tsingalia 2010).

The size class structure in the highly disturbed site 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 with lognormal distribution in the moderately disturbed site indicates that the tree harvesting occurred in the past and it has got substantially reduced at present. This feature can be strengthened by the high basal area value, low percentage of cut stems and presence of multiple stems in the higher girth classes. Such kind of reverse 'J" shape population structure indicating future ideal regeneration was also observed in *Elaeodendron transvaalense* Jacq. species under the bark harvesting pressure (Tshisikhawe and Van Rooyen 2013). The presence of high percentage of cut stems and uni-modal mound shaped curve in the less disturbed site suggests that the wood smugglers are at present entering clandestinely into the interior forests and are actively involved in tree logging of both high and smaller girth class trees also. The targeted girth class is 41-50cm gbh as the specific size may be easy to carry on their shoulders even from the interior forests. Such kind of overharvesting of stems has resulted in reduction of drum making tree species in central Uganda (Omeja et al. 2004).

CONCLUSION

The present study reveals that in the dry deciduous forests of Kadapa hill ranges Red sanders was predominant in the moderately disturbed dry deciduous forests among forests under varied disturbance regime. But the size class structures showed marked differences among less, moderate and highly disturbed sites. Highly disturbed site featured skewed type population structure with the lack of reproductively fit mature trees. Less disturbed site under the selective logging pressure had hump shaped structure with less regenerating and large girth trees. The typical reverse 'J' shape population structure in the moderately disturbed site indicate that Red sanders has the ability to regenerate and can able to resist the stress of fire and grazing but not the selective logging. It can be concluded that past intense tree harvesting and current and past selective logging conditions will influence the population structures. Thus the selective felling can be major factor for the abnormal size class distribution and total lack of larger girth mature trees is due to intensive rampant tree felling of the Red sanders species. Major part of kadapa hill ranges is out of Protected Area network and reserve forests outside them also sustain rich biodiversity. Especially Red sanders can form the dominant tree in such reserve forests and on the other side, the lack of Red sanders trees in the surrounding highly disturbed unreserved forests calls for strengthening the conservation efforts in the reserved forests of the kadapa hill ranges.

ACKNOWLEDGEMENTS

We thank the Ministry of Environment, Forests and Climate Change, New Delhi for providing the financial support (14-63-2013RE). The on-field logistic support given by Andhra Pradesh Forest Department (APFD) is deeply appreciated and we thank the Narional Remote

Sensing Centre, Hyderabad for providing the imagery of the study area.

REFERENCES

Arunakumara, K.K.I.U.; Walpola, B.C.; Subasinghe, S. and Yoon, M.H. 2011. *Pterocarpus santalinus* Linn. f. (Rath handun): A review of its botany, uses, phytochemistry and pharmacology. Journal of the Korean Society for Applied Biological Chemistry 54: 495-500.

Arunkumar, A.N. 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(2): 1-10.

Balaraju, K.; Agastian, P.; Ignacimuthu, S. and Park, K. 2011. A rapid in vitro propagation of Red Sanders (*Pterocarpus santalinus* L.) using shoot tip explants. Acta Physiologiae Plantarum 33: 2501-2510.

Bharali, S.; Paul, A. and Khan, M.L. 2013. Population studies of *Rhododendron mechukae* – A newly recorded endemic species from Eastern Himalaya, India. Journal of Biodiversity Management and Forestry 2 (3): 1-5.

Champion, H.G. and Seth, S.K. 1968. A Revised Survey of Forest Types of India. Government of India, Delhi, India. 404 pages.

Gairola, S.; Rawal, R.S.; Todaria, N.P. and Bhatta, A. 2014. Population structure and regeneration patterns of tree species in a climate-sensitive subalpine forests of Indian western Himalaya. Journal of Forestry Research 25 (2): 343-349.

Kennard, D.K.; Gould, K.; Putz, F.E.; Fredericksen, T.S. and Morales, F. 2002. Effect of disturbance intensity in regeneration mechanisms in a tropical dry forest. Forest Ecology and Management 162: 197-208.

Khan, M.L.; Rai, J.P.N. and Tripathi, R.S. 1987. Population structure of some tree species in disturbed and protected subtropical forests of north-east India. Acta Oecologica 8 (3): 247-255.

Khurana, E. and Singh, J.S. 2001. Ecology of seed and seedling growth for conservation and restoration tropical dry forests: A review. Environmental Conservation 28: 39-52.

Mastan T.; Sadasivaiah, B. and Reddy, M.S. 2016. Tree diversity and structure of a tropical dry deciduous forest in sri Lankamalla wildlife sanctuary, southern Eastern Ghats, India. Indian Forester 142(9): 813-819.

Niklas, K.J.; Midgley, J.J. and Rand, R.H. 2003. Tree size frequency distributions, plant density, age and community disturbance. Ecology Letters 6: 405-411.

Omeja, P.; Obua, J. and Cunningham, A.B. 2004. Regeneration, density and size class distribution of tree species used for drum making in central Uganda. African Journal of Ecology 42: 129-136.

Pate J.S.; Froend, R.H.; Bowen B.J.; Hansen A. and Kuo, J. 1990. Seedling growth and storage characteristics of seeder and resprouter species of Mediterranean-type ecosystems of S.W. Australia. Annals of Botany 65: 585–601.

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

Rawat, G.S. 1997. Conservation status of forests and wildlife in the Eastern Ghats, India. Environmental Conservation 24 (4): 307-315.

Reddy, K.K. and Srivasuki, K.P. 1990. Vegetative propagation of Red Sanders (*Pterocarpus santalinus* Linn.). Indian Forester 116: 536-40.

Sagar, R. and Singh, J.S. 2004. Local plant species depletion in a tropical dry deciduous forest of northern India. Environmental Conservation 31 (1): 55-62.

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

Saha, S. 2001. Comparison of vegetation structure and composition between secondary deciduous forests and *Tectona grandis* (family Verbanaceae) plantations in Bori Wildlife Sanctuary of central India. Forest Ecology and Management 148: 159-167.

Saha, S. and Howe, H.F. 2003. Species composition and fire in a dry deciduous forest. Ecology 84 (12): 3118-3123.

Sapkota, I.P.; Tigabu, M. and Oden, P.C. 2009. Species diversity and regeneration of old-growth seasonally dry *Shorea robusta* forests following gap formation. Journal of Forestry Research 20: 7-14.

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

Tshisikhawe, M.P. and Van Rooyen, M.W. 2013. Population biology of *Elaeodendron transvaalense* Jacq. In the presence of harvesting. Tylon 82:303-311.

Tsingalia, M. 2010. Impacts of selective logging on population structure and dynamics of a canopy tree (*Olea capensis*) in Kakamega forest. African Journal of Ecology 48: 569-575.

Received 3 January 2017
Accepted 12 June 2017