Thakur AK *et al.* (2020)
Notulae Scientia Biologicae 12(2):341-355
DOI:10.15835/nsb12210620
Research Article

Abundance, frequency and distribution pattern of tree species in recorded forest area of Western Himalaya

Arun K. THAKUR[1]*, Rajesh KUMAR[1], Raj K. VERMA[2]

[1]*Forest Survey of India, Forest Inventory Lab, Kaulagarh, Dehradun 248001, India; arun_wii@yahoo.co.in (*corresponding author); rajsus1@rediffmail.com*
[2]*Himalayan Forest Research Institute, Shimla 171013, India; vermaraj@icfre.org*

Abstract

The forest in India have a long history of human induced modifications through intensive forest management that began in the colonial period but continued afterwards to meet the wood-based demand until the forestry goals shifted towards conservation efforts. All this greatly influenced the plant community structure. We attempt to describe the abundance and distribution pattern of trees in recorded forestland of Western Himalaya using the National Forest Inventory database. A total of 3549 sample plots laid across different forest types were analyzed to reveal the abundance, frequency and distribution pattern of 226 tree species/genus using various indices i.e. abundance by frequency ratio, Morisita index and variance mean ratio. Twelve tree species and *Eucalyptus* genus were found to be most abundantly found tree species in recorded forest area of Western Himalaya. Ten tree species were found to have regular distribution pattern, one hundred ninety-two were contagiously distributed while twenty-five were randomly distributed. Results derived from huge datasets helps in establishing firm statements with quoted significance value. *Myrica esculenta* and *Aegle marmelos* were found among the most abundantly occurring tree species whereas *Myrica esculenta, Syzygium cumini* and *Pyrus pashia,* were among the most relatively frequently occurring wild fruit yielding tree species. These species (apart from fodder tree species) can be considered in social forest and joint forest management programs in forest fringe villages/areas to enhance and sustain the provisional ecosystem services in Western Himalaya.

Keywords: abundance pattern; distribution pattern; frequency; National Forest Inventory

Introduction

Identifying and describing the distribution patterns that underlie the community structure has been an interesting aspect of community ecology. Explaining them is relatively easy with handful of species but is difficult in case when multiple species are involved. Detangling the processes involved in community assemblage is important for understanding how community functions and will behave under future environmental scenarios w.r.t climate change. Quite common species comprises the majority of the individuals while less common species makes a very small contribution. The quantitative pattern of rarity and commonness among species in a community is referred to as relative abundance. Such species abundance data (originated by

Received: 14 Dec 2019. Received in revised form: 28 May 2020. Accepted: 16 Jun 2020. Published online: 29 Jun 2020.

R. H. Whittaker) can be plotted in a rank abundance curve, where each species is represented by a vertical bar proportional to its rank abundance.

Species abundances data roughly gives idea about competition and predation, providing information on how a community function. They allow comparisons of how various communities differ from each other. Conservation biologists are often interested in relative abundance because rare species are more vulnerable to extinction. The spatial pattern originates by virtue of dynamic ecological processes operating at various scale and refers to the process or a combination of processes at given time (Fortin *et al.*, 2003). The literature reports plant-plant interaction, environmental heterogeneity, seed dispersal and disturbance (Bisigato *et al.*, 2005; Rayburn and Monaco, 2011) could be the reasons behind these.

Three basic spatial patterns discussed in literature are: 1) regular (uniform or even) patterns in which individuals are uniformly spaced; 2) random patterns - individuals have equal chance of living anywhere; 3) clumped (contagious) pattern - individuals have a higher probability of being found in some specified area (Mathur and Sunramoorthy, 2012). Odum (1971) described the clumped distribution as common most in nature, while random distribution exists only in uniform environments. The observed spatial patterns often have the potential to bring out the change in neighborhood. For e.g. regular patterns indicate intense competition between plants for limited resource (Stoll and Bergius, 2005), the aggregated patterns indicate neutral or positive plant interactions (Valiente-Banuet and Verdu, 2008).

The significance of spatial pattern has been explored by Salas *et al.* (2006), Law *et al.* (2009), Basiri *et al.* (2011) for tree/forest communities. The species distribution is very useful candidate essential biodiversity variable at regional or state scales (Turak *et al.*, 2016). A combination of vegetation type, slope, aspect, edaphic factors, and altitude (Sharma *et al.*, 2009, 2010; Gairola *et al.*, 2011) decides the composition and distribution pattern (Kessler, 2001; Schmidt *et al.*, 2006). The quantitative information of woody species determines the overall form and structure of a forest community and helps in planning and implementation of conservation strategies (Singh *et al.*, 2016). Although extensive literature (Rawat and Chandhok, 2009; Sharma *et al.*, 2009; Singh *et al.*, 2009; Rawat *et al.*, 2010; Raturi, 2012; Mehta *et al.*, 2015; Verma and Kapoor, 2016) is available on distribution pattern of dominant tree species in Western Himalaya (WH) but they are all in isolated segments representing local/ site level distribution pattern.

In spite of comprehensive studies, hardly any literature is available to depict the most abundantly found tree species within the recorded forest area (RFA) of WH. We developed rank abundance diagram (RAD) to see the relative distribution of various tree species. The abundance and frequency are analyzed for encountered wild fruit tree species. We test our null hypothesis that there is no difference in the distribution pattern of tree species at a very large landscape i.e. WH. With the huge dataset of wide coverage in National Forest Inventory (NFI), this study will explore the physiographic zone level of distribution pattern of tree species. Such studies help in adding the significance value to the derived results and the results thus obtained can be further used in species level management of protected forest.

Materials and Methods

Study area

WH lies in north most part of the India and comprises of 20 studied districts belonging to three different states of India - Jammu and Kashmir, Himachal Pradesh and Uttarakhand (Figure 1). Since the data is used from NFI, every year 30 districts were selected randomly from whole country in such a way that all physiographic zones get covered. Only 20 districts were covered in NFI during the period 2002 to 2015.

While the WH exhibit semiarid and cold arid climates, the far eastern ranges represent some of the wettest places on earth with > 4000 mm annual precipitation. The effect of the monsoon becomes less pronounced in the WH. Unlike the central and eastern parts, the WH receives higher precipitation during winter in the form of snow. The Himalaya forests dominated by the temperate broad leaf forests largely by oak species (*Quercus* spp.) constituting an important natural resource base.

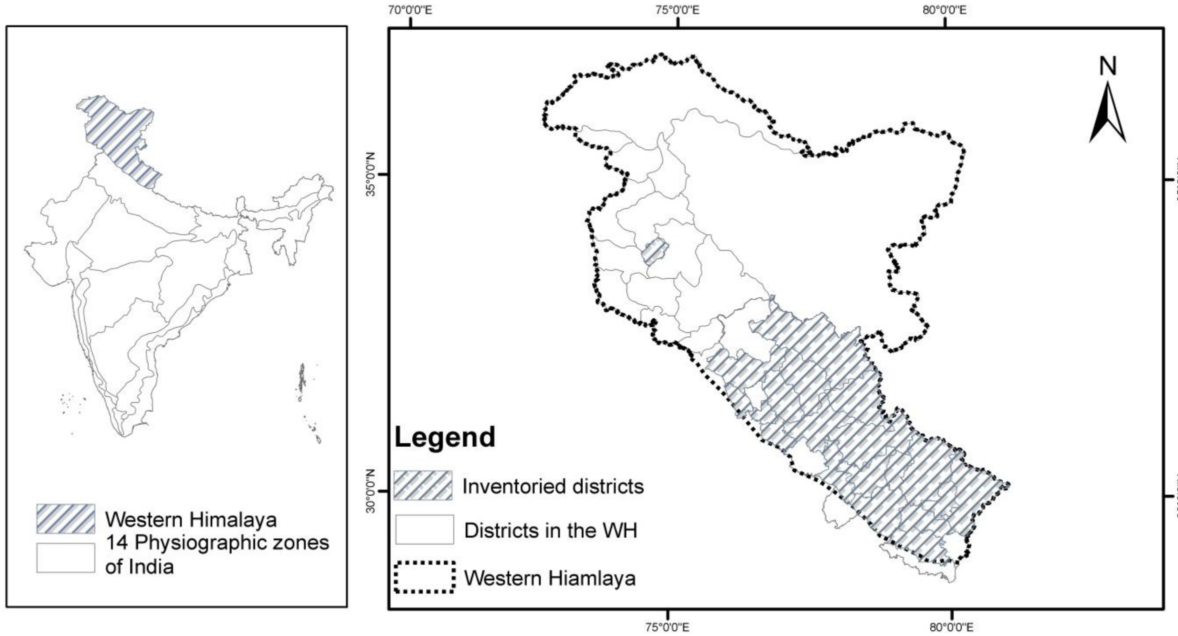

Figure 1. WH in India comprising inventoried districts in NFI

Survey and data collection

NFI of India follows two stage stratified sampling. The primary sampling units are the administrative units i.e. districts, in which the secondary units are selected by stratified systematic sampling (Figure 2a and 2b). Sampling is done in (1) forests, (2) urban trees outside Forest (TOF) and (3) rural TOF. Systematic square grids based on Survey of India topo-sheets are laid over the selected districts, to define the sample locations for the secondary sampling units. Till now, the organization has published 16 India State of Forest Report (ISFR), the latest being the ISFR 2019 that gives the assessment of forest cover within and outside RFA and Greenwash area, carbon stock in forest, etc. (FSI, 2019). Tewari and Kleinn (2015) has described the developmental history of NFI in India while and its biodiversity significance has been described by Thakur *et al.* (2018). Since the NFI data covers a significant part of WH and is an in systematic manner, it allows the assessment of the distribution pattern of tree species and reveals ecological information about the wild fruit yielding tree species. The NFI data collected during the period 2002-2015 was used for the study. The data afterwards was not used since the methodology got changed for the new NFI in the year 2016. The forest inventory plots are generated randomly within the declared RFA irrespective of the fact whether the forest inventory point is actually falling over the forest patch or not. Thus, the inventory plot falls under various categories as: 1) when sample plot laid and data collected; 2) plot visited is only described but not laid due to steep slope/obstruction; 3) plot not approached but vicinity is visited and plot is described; 4) inaccessible plots.

3549 plots were laid in WH during the period 2002-2015. However, there were 2230 plots with the presence of tree species shown over 9 major forest types of India (Figure 3). A total of 456 plots falls under tropical zone (below 700 m), 995 plots in sub-tropical zone (700-2000 m), 770 plots in temperate zone (> 2000-3500) and 9 sample plots in subalpine and alpine zone (>3500 m) if we distribute WH along altitude (Negi, 2000). The plot is square shaped, 0.1 ha in size (Figure 2c) and involves the collection data of trees like diameter at breast height > = 10 cm, height of trees, canopy diameter etc. (explained in "Manual of instructions for field inventory-2002", specifically designed for field inventory). 226 tree species were found and identified taxonomically excluding one species code used for the species identified but not given code in NFI manual and one species for unidentified species/miscellaneous species. Since we assume the unidentified/non-coded species represents some different species, we include them in our analysis but do not discuss them in the result.

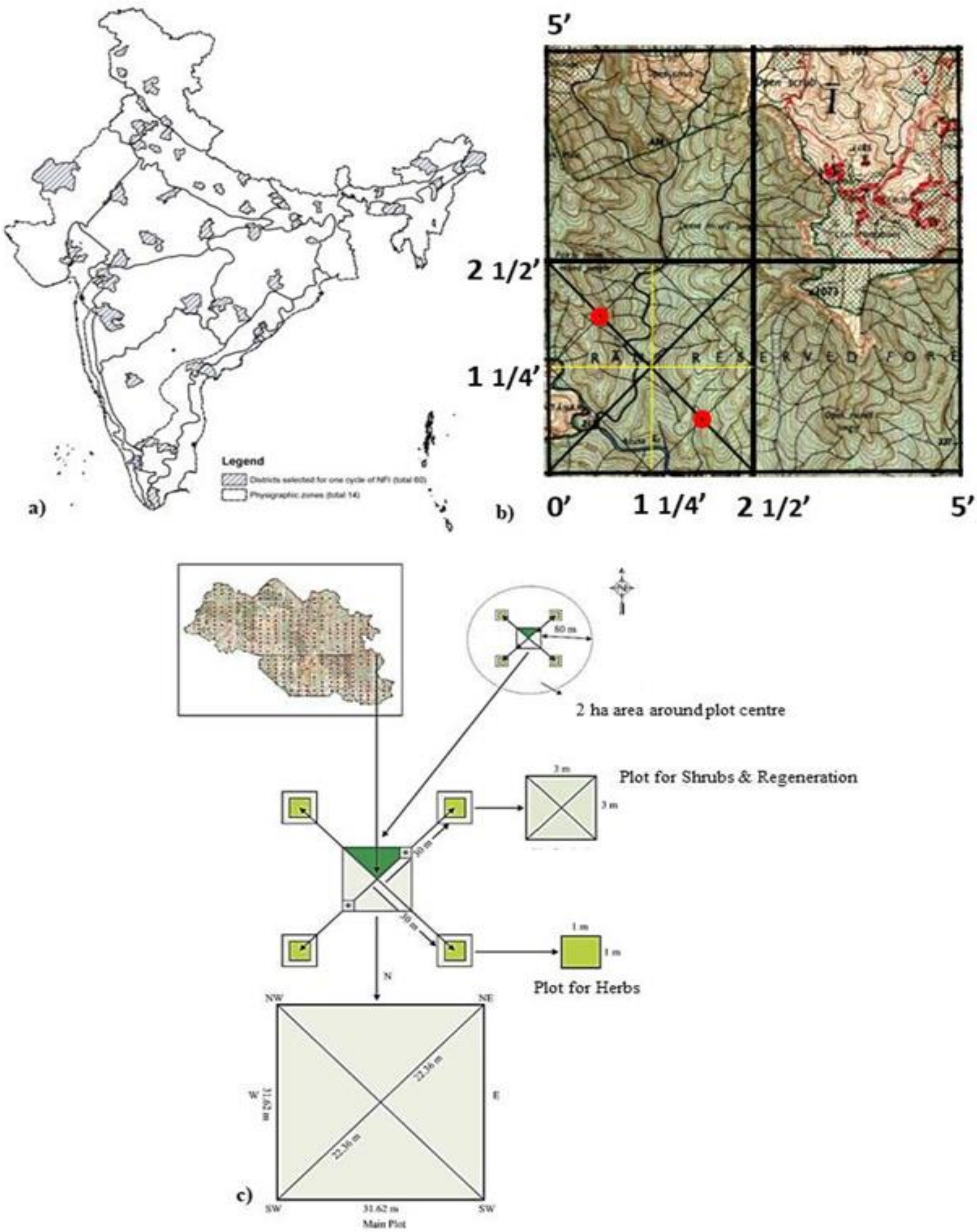

Figure 2. Sampling strategy in NFI: a) Random selection of 60 districts from all physiographic zones; b) Systematic grid over scanned toposheets; c) Description of sampling unit

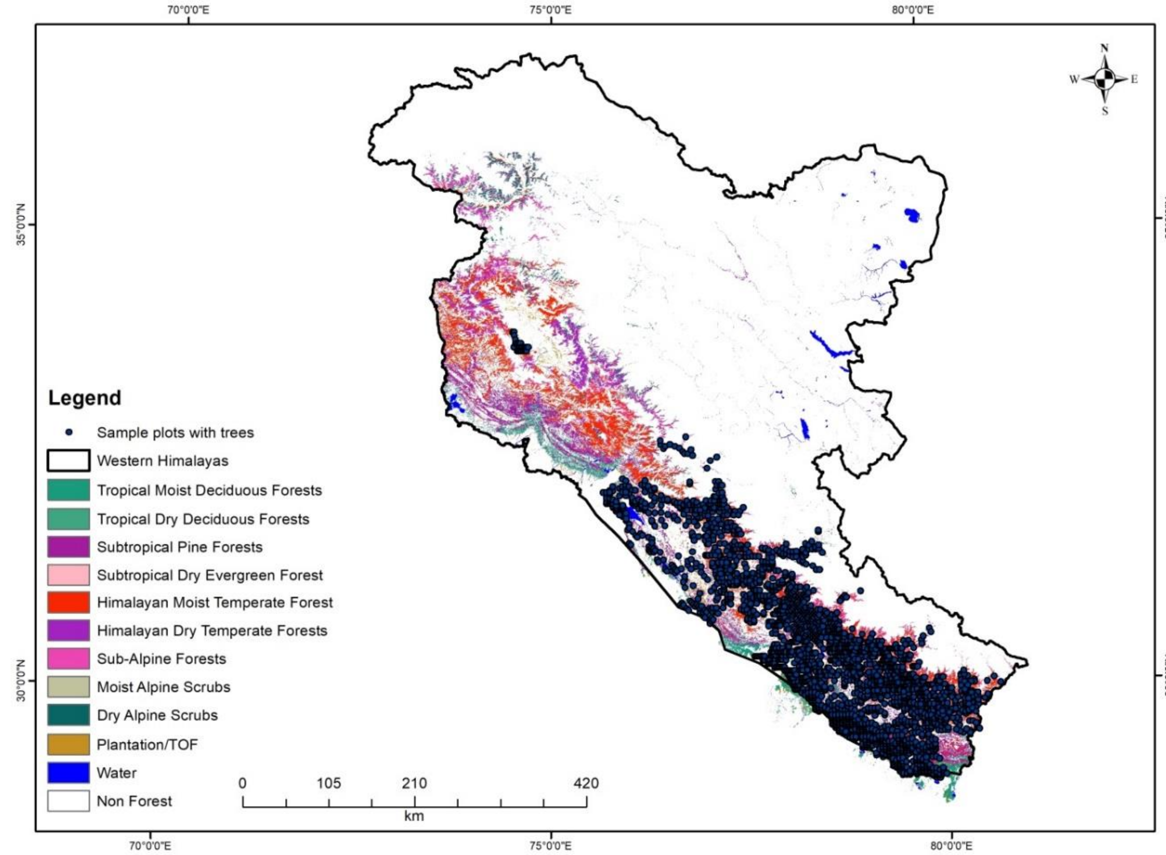

Figure 3. Distribution of sample plots over nine major forest types found in WH

Data analysis

All data were stored in a Microsoft Excel database and analyzed quantitatively using this software. Vegetation composition was evaluated by analyzing the abundance and frequency as per Mishra (1968) and Curtis and McIntosh (1951). Abundance is determined as the number of individuals of different species in the community per unit area. It is represented by the equation:

Abundance = Number of the individuals of the species/Total number of plots in which species is present

Important wild fruit tree species identified through literature review was analyzed for abundance and relative frequency. Frequency indicates the degree of dispersion of individual species in an area and is expressed in percentage. It reflects the spread, distribution or dispersion of a species in a given area. For example, if a species is distributed uniformly in an area, there is greater probability of its occurrence in all quadrants and it would have maximum frequency. In another case, a species may be clustered only in a part of the area, thus would have lesser frequency. The % frequency of a species in a given area is calculated by the following formula:

Frequency (%) = Number of plots in which species occurred / total number of plots *100

The RAD is prepared for 226 tree species based on the estimated population of tree species, which was derived from the number of stems found on the proportionate area of RFA in WH. The RADs have been linked to environmental conditions and gradients (Magurran, 2004; McGill *et al.*, 2007; Dornelas *et al.*, 2011). One of the opinions is that the lognormal RADs prevail in stable, undisturbed environments, while log-series RADs will be found in disturbed habitats with higher temporal or spatial variability (Hamer *et al.*, 1997; Hill and Hamer, 1998).

Spatial exploration aims to identify and describe the spatial patterns by two approaches: a) first order statistics, which includes the aggregation indices (variance to mean ratio; Morisita's index, Green's index etc.)

based on species abundance data. These detect trends and indicate whether the spatial pattern exists or not, but not its intensity. However, there exist a limitation of being not identifying pattern intensity. Here comes the role of b) second order statistics (Ripley's K, Moran's I etc.) allowing the quantification of small-scale spatial pattern intensity (i.e. magnitude, degree) and scale (spatial) and are sensitive to outlier data (Fortin, 1999).

The data were analyzed by calculating the abundance, frequency, mean, variance and dispersion indices - Whitford index, variance-to-mean ratio (VMR), Morisita's dispersion index (I_δ) to diagnose the distribution pattern.

<u>Whitford index</u>

The spatial distribution of trees was determined following Whitford index WI = abundance/frequency (A/F Ratio) (Whitford 1949). A value <0.025 would imply a regular distribution, values between 0.025-0.05 means a random distribution and a value >0.05 would mean a contagious distribution.

<u>VMR or Index of Dispersal (ID)</u>

Dispersion of a population can calculated by variance to mean ratio (VMR); i.e.

$VMR = s^2/\bar{x}$

where s^2 = sample variance, $\bar{x}$ = sample mean

A VMR value of 1.0 indicates a random distribution; zero (or < 1) indicates uniform while, more than one indicates the clumped one. The significance of VMR can be tested by chi-square ($\chi 2$) test. $\chi 2$ is a good approximation with N-1 degrees of freedom (Ludwig and Reynolds, 1988). The test static Chi-square was used to test the departure from randomness and is expressed as:

$\chi 2 = I\ (n-1)$

The test static assumes the null hypothesis as no difference between the observed distribution and a distribution resulting from a random process (i.e. VMR = 1). The difference determines whether an observed VMR value differs significantly from one (theoretical random result).

<u>Morisita's Index of Dispersion</u>

Morisita's index (MI) of dispersion ($I\delta$) has been comprehensively used to evaluate the degree of dispersion/aggregation of spatial point patterns (Morisita, 1959; Tsuji and Kasuya, 2001; Rayburn, 2011). This index is closely related to the simplest and oldest measures of spatial pattern, the variance: mean ratio (Dale *et al.*, 2002) and to other dispersion indices. It can be measured as:

$I_\delta = n\ (\sum x_i^{\ 2} - \sum x_i)\ /\ (\sum x_i)^2 - \sum x_i$

where x_i = number of individuals in each sampling units, n= number of sampling units

MI is 1 for a random distribution, >1 for a clumped distribution, and <1 for a regular distribution.

Chi sq test:

$\chi 2 = (n \sum x_i^{\ 2} / N) - N$

n = total number of plots

N = total number of individuals in all plots

Variance-to-mean ratio-based indices are often criticized for being dependent on the sampling unit size (Rossi and Higuchi, 1998; Costa *et al.*, 2010). However, it hardly influences the MI therefore most often used in ecological studies (Rossi and Higuchi, 1998).

Spatial pattern may be determined at different stages generated by different biological and physical factors (Maynou *et al.*, 2006; Foldvik *et al.*, 2010). The factors responsible for shaping the distribution pattern may vary at small or larger scale, morphologically or environmentally (Bouxin and Gautier, 1982) and therefore explaining the causal factors is a different issue.

Results and Discussion

A log normal curve is observed on developing the of RAD based on relative abundance of 226 species vs species rank distribution, characterized by a comparably high number of species with intermediate abundance and smaller numbers of very abundant and very rare species (Figure 4). The tail of the curve is slightly flattened, depicting a proportionately small fraction of large number of tree species falling in the rare category. The estimated number of stems was based on the total recorded forest land of WH., which also revealed 45 out of 226 tree species contributes to half of the total estimated population of trees and are therefore responsible to major proportion of Himalayan ecosystem services.

Few of the most abundantly found tree species (abundance > 10) in WH are *Tectona grandis, Quercus oblongata, Pinus roxburghii, Quercus semecarpifolia, Shorea robusta, Quercus glauca, Cedrus deodara, Rhododendron arboretum, Trewia nudiflora, Diploknema butyracea, Juniperus polycarpos var. seravschanica, Pinus wallichiana and Eucalyptus spp.* All these except *T. nudiflora, D. butyracea* and *Eucalyptus* species form major forest type or sub type forest in WH. *T. nudiflora* is an important associate of moist terai sal forest and occur between 234 m to 976 m (as in NFI). *D. butyracea* is found in sub-Himalayan tract between 1044 m to 1596 m asl (as in NFI) especially in Garhwal and Kumaun region of Uttarakhand. Twelve species of *Eucalyptus* have been well represented in WH as per Bhatt *et al.* (2016). The most frequently found tree species (frequency > 10) are *Pinus roxburghii, Quercus oblongata, Rhododendron arboreum, Lyonia ovalifolia, Mallotus philippensis, Shorea robusta, Lannea coromandelica and Pinus wallichiana.*

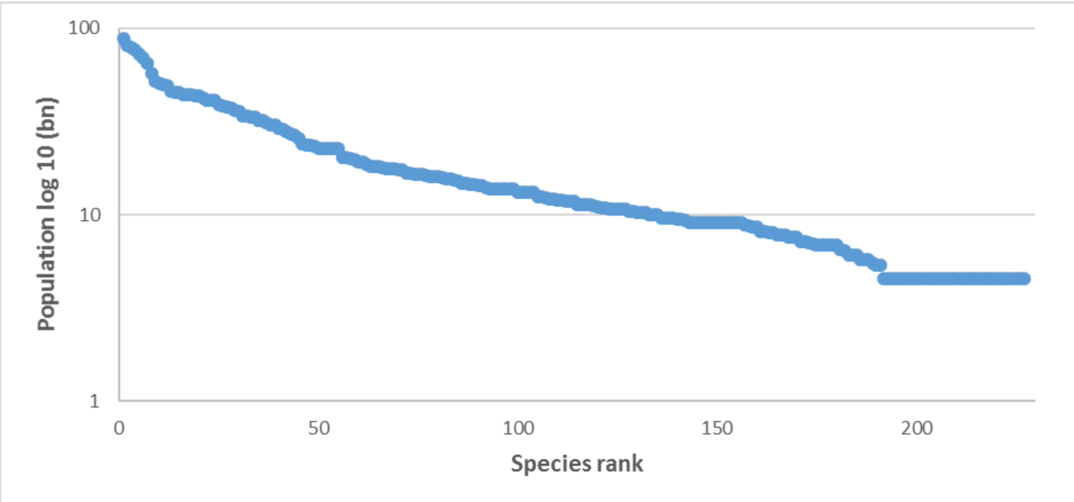

Figure 4. A rank abundance diagram of 226 tree species in WH

Few important planted tree species like *Eucalyptus* species, *Tectona grandis, Populus* species were also inventoried within RFAs in the WH (Figure 5). *Eucalyptus* species occurred in Solan and Shimla district of HP while in UK it was observed in Dehradun, Almora and Nainital. It occurred abundantly in Nainital district where 220 out of 239 *Eucalyptus* trees were found at 16 different locations while very few were observed in other districts. In case of teak, about 6% of sal bearing forested area of Uttarakhand state has been converted to teak plantations (UKFD, 2008). The analysis revealed that with 657 trees out of 831 total trees of teak occurred at 31 locations in Nainital district. Apart from it, 108 trees of teak occurred at 6 locations in Pauri Garhwal, 62 trees from 4 locations of Dehradun. Another most popular planted tree species i.e. *Populus* species was also inventoried though in small number but quiet widely distributed within RFAs in Lahul and Spiti, Kullu, Mandi, Shimla, Kinnaur, Uttarkashi, Pithoragarh and Nainital.

The Whitford index indicated all the species were showing clumped distribution, which is very unusual. However, we get different results when MI and VMR are used. It means these three indices have different level of sensitivity towards distribution depiction. Table 1 lists various tree species showing different distribution pattern as per MI and VMR.

Table 1. Overall distribution pattern of tree species in WH

Species found in Regular distribution pattern as per MI and VMR	**Significance of result**
Albizzia procera, Bauhinia racemosa, Gardenia turgida, Grewia elastica, Melia azadirachta, Murraya paniculata, Punica granatum, Randia dumetorum, Robinia pseudocacia, Wendlandia exserta	Result is **Not-Significant*** as per Chi-square test
Species found in Random distribution pattern as per MI and VMR	
Acacia auriculiformis, Albizzia julibrissin, Carissa carandas, Casearia graveolens, Casearia species, Cordia dichotoma, Diospyros montana, Ficus racemose, Ficus virens, Lindera pulcherrima, Gymnosporia emarginata, Olea europaea subsp. cuspidata, Lyonia villosa, Pittosporum napaulense, Premna species, Prosopis species, Psidium guajava, Rhododendron barbatum, Sapium sebiferum, Schrebera swietenioides, Spondias pinnata, Symplocos lucida, Salix acmophylla, Zanthoxylum armatum, Jatropha curcas	Result is **Not-Significant*** as per Chi-square test
Species found in Clumped distribution pattern as per MI and VMR	
Acacia nilotica, Acacia lenticularis, Acer laevigatum, Haldina cordifolia, Ailanthus altissima, Ailanthus excelsa, Albizzia chinensis, Alnus nepalensis, Bauhinia malabarica, Bauhinia variegate, Betula cylindrostachya, Bischofia javanica, Bombax ceiba, Bridelia retusa, Careya arborea, Casearia tomentosa, Castanopsis hystrix, Toona ciliate, Cinnamomum tamala, Cocculus laurifolius, Cordia myxa, Cordia species, Crataeva religiosa, Dillenia pentagyna, Diospyros melanoxylon, Ehretia acuminata, Cassine glauca, Phyllanthus emblica, Eugenia species, Euonymus lacerus, Feronia limonia, Ficus carica, Ficus religiosa, Ficus species, Flacourtia indica, Flacourtia species, Fraxinus species, Glochidion heyneanum, Gmelina arborea, Grevillea robusta, Grewia asiatica, Grewia oppositifolia, Helicteres isora, Hymenodictyon excelsum, Lonicera quinquelocularis, Machilus odoratissimus, Madhuca latifolia, Mangifera indica, Meliosma species, Mitragyna parviflora, Moringa species, Pithecolobium dulce, Populus ciliata, Putranjiva roxburghii, Randia species, Rauwolfia serpentina, Rhus species, Rhus succedanea, Salix alba, Santalum album, Sapindus mukorossi, Falconeria insignis, Schleichera oleosa, Semecarpus anacardium, Mitragyna diversifolia, Sterculia villosa, Stereospermum suaveolens, Stranvaesia nussia, Strychnos potatorum, Syzygium samarangense, Terminalia arjuna, Terminalia bellirica, Ulmus wallichiana, Wrightia arborea, Ziziphus jujuba, Zizyphus xylopyrus	Result is **Significant* for both MI and VMR** as per Chi-square test
Abies spectabilis, *Abies pindrow, Acacia catechu, Acer acuminatum, Acer oblongum, Acer pictum, Acer species, Aegle marmelos, Albizia species, Alnus nitida, Alnus species, Anogeissus latifolia, Azadirachta indica, Acacia sp., Bauhinia species, Cornus capitata, Betula alnoides, Betula utilis, Boehmeria species, Buchanania cochinchinensis, Butea monosperma, Buxus wallichiana, Carpinus viminea, Cedrus deodara, Celtis australis, Cinnamomum species, Cornus macrophylla, Corylus colurna, Cotoneaster bacillaris , Cupressus species, Cupressus torulosa, Dalbergia latifolia, Diospyros species, Diploknema butyracea, Ehretia laevis, Engelhardtia spicata var. integra, Engelhardtia spicata, Erythrina suberosa, Eucalyptus species, Ficus bengalensis, Garuga pinnata, Grewia species, Grewia tiliifolia, Holoptelea integrifolia, Illex species, Juniperus polycarpos var. seravschanica, Juniperus species, Kydia calycina, Lagerstroemia species, Leucaena leucocephala, Limonia acidissima, Limonia species, Litsaea*	Result is **Not- Significant* for both MI and VMR** as per Chi-square test

monopetala, Litsaea species, Lyonia ovalifolia, Macaranga denticulata, Machilus species, Macropanax dispermus, Miliusa velutina, Morus alba, Morus species, Murraya koenigii, Myrica esculenta, Nyctanthes arbortristis, Osmanthus fragrans, Ocotea lancifolia, Phoenix sylvestris, ***Picea smithiana****, Pinus wallichiana, Pinus gerardiana, Pinus roxburghii, Pongamia pinnata, Prosopis guliflora, Prunus cornuta, Pterocarpus marsupium, Pyrus species, Quercus floribunda, Quercus glauca, Quercus lanata, Quercus oblongata, Quercus semecarpifolia, Quercus species, Rhododendron arboreum, Rhododendron species ,Salix species, Saurauja nepaulensis , Shorea robusta, Syzygium cumini , Symplocos cochinchinensis, Taxus baccata ,Tectona grandis, Terminalia species, Trewia nudiflora , Vitex negundo, Xylosma longifolium, Zizyphus glabrata*	
Aesculus indica, Albizzia lebbek, Cassia fistula, Dalbergia sissoo, Fernandoa adenophylla, Holarrhena pubescens, Juglans regia, Lagerstroemia parviflora, Lannea coromandelica, Mallotus philippinensis, Desmodium oojeinense, Pistacia chinensis subsp. integerrima, Populus species, Prunus species, Pyrus pashia, Terminalia tomentosa, Thuja occidentalis, Terminalia chebula, Symplocos paniculata	Result is found **Significant by MI, but Not-significant by VMR,** as per Chi-square test

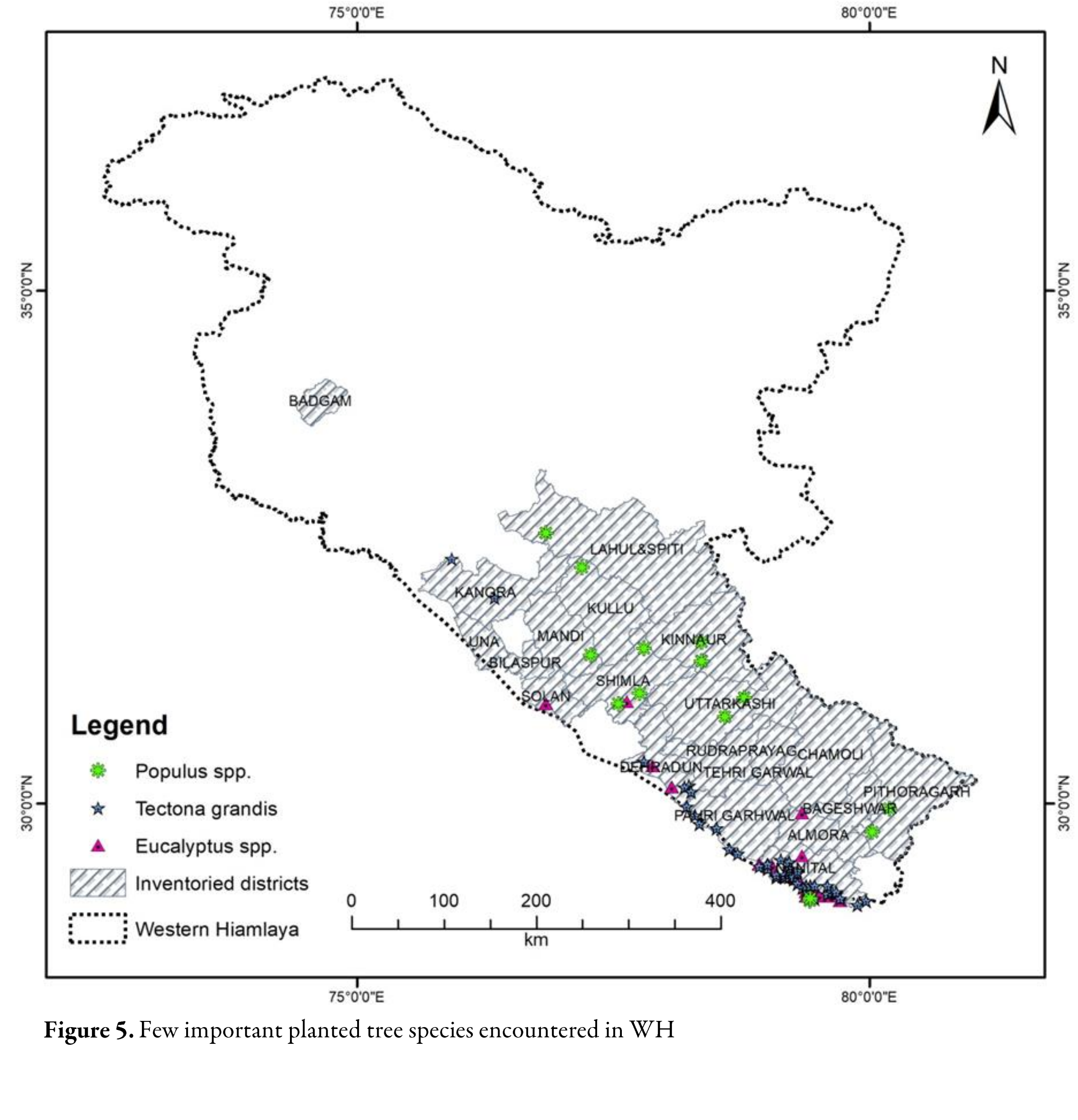

Figure 5. Few important planted tree species encountered in WH

Ten species were found to have the regular distribution pattern (just 4.38% of total tree species encountered in NFI exercise) by both VMR and MI. They were all widely distributed in the WH (Figure 6). Singh *et al.* (2016) found not even a single tree in regular distribution pattern in oak dominated forest of Garhwal Himalaya.

One hundred ninety-two tree species were contagiously distributed across the physiographic zone of WH and found to form major proportion (around 83.77%). Many of them reportedly found to show similar distribution pattern in local small area study (Table 1). When tested for significance, 76 species were jointly accepted (calculated value greater than critical value), 96 species were jointly rejected by VMR and MI while 19 species were rejected by VMR and accepted by MI (Table 1)

About twenty-five randomly distributed tree species were found as single individual but spatially were widely distributed throughout the WH (Figure 7). They form around 10.96% of total tree species encountered in WH. Their less count is expected out of random distribution however all of them were represented by single individual is a matter of concern. Since the NFI counts all individuals above 10 cm diameter, there exists a probability of finding their young ones in less than 10 cm dia class/regeneration stage. These species when analyzed in detail, six were found to be in big timber class (≥ 30 cm dia) rest all were lying either in small timber or pole crop (≤ 30 cm dia class). Eighteen species among these were reported to be medicinally important in literature.

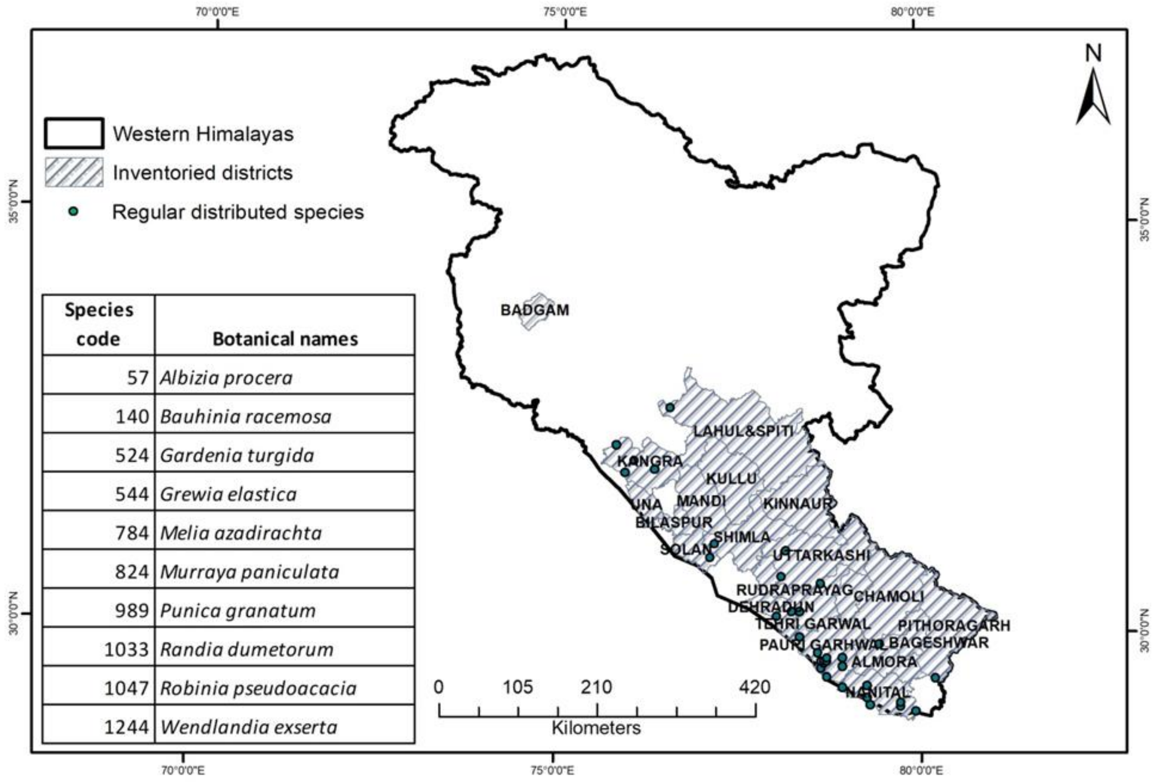

Figure 6. Uniformly (Regular) distributed (widely) tree species encountered in WH

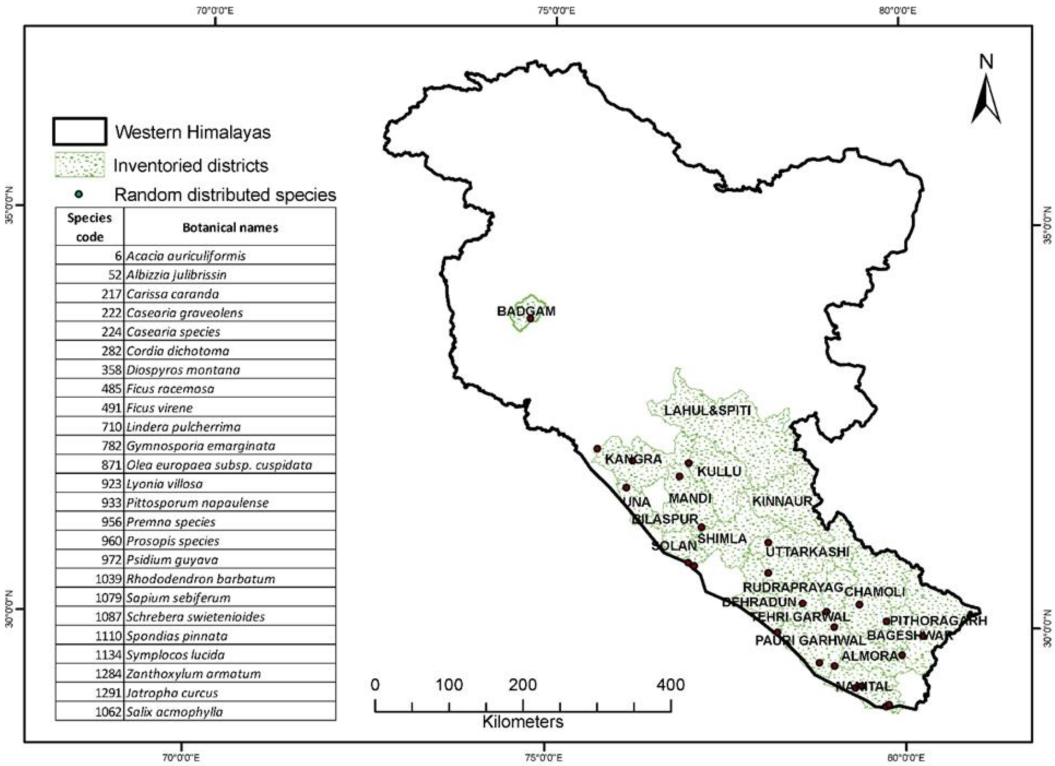

Figure 7. Randomly distributed (widely) tree species encountered in WH

The literature reports more than 60% of tree species (found in NFI) were used as major fodder by inhabitants of WH. Apart from these, fourteen tree species occurred in NFI, were used as wild edible fruit (reported in literature) were analyzed (Figure 8). *Myrica esculenta,*and *Aegle marmelos* were the most abundantly occurring tree species whereas *Myrica esculenta, Syzygium cumini* and *Pyrus pashia,* were among the most relatively frequently occurring wild fruit yielding tree species (when species is encountered in more than 10 sample plots). These species (apart from fodder tree species) can be considered in social forest and joint forest management programs in forest fringe areas to enhance and sustain the provisional ecosystem services in WH.

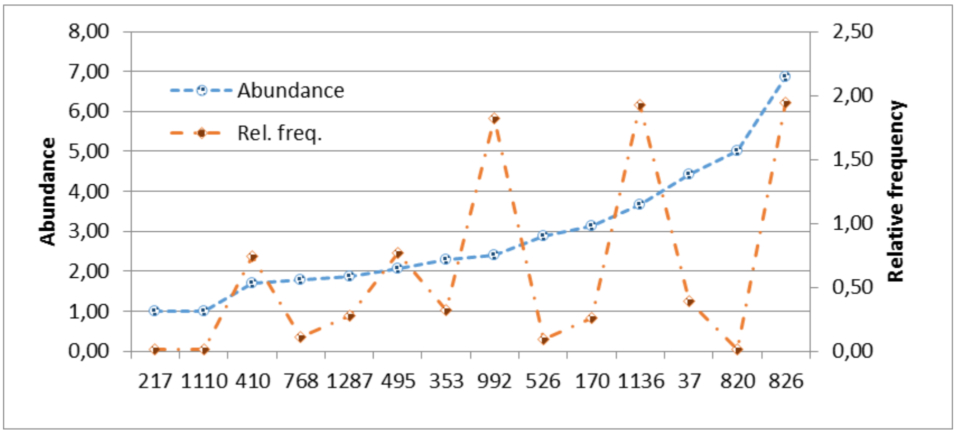

Figure 8. Abundance and relative frequency of tree species used as fruit source found in WH. *Carissa carandas* (217), *Spondias pinnata* (1110), Phyllanthus emblica (410), *Mangifera indica* (768), *Ziziphus jujuba* (1287), *Flacourtia indica* (495), *Diospyros melanoxylon* (353), *Pyrus pashia* (992), *Garuga pinnata* (526), *Buchanania cochinchinensis* (170), *Syzygium cumini* (1136), A*egle marmelos* (37), *Morus alba* (820), *Myrica esculenta* (826)

Conclusions

With this study, it seems that approximately 20% of the tree species constitutes half of the total tree population and therefore they should be taken care of while adopting appropriate conservation approach for the existing biodiversity of WH. We also reject the null hypothesis that there is no difference in the distribution pattern of tree species and conclude that tree species are majorly contagiously distributed (83.77%) supporting the reported results in literature from other parts of the world where tree species tended to be clumped (Condit *et al.*, 2000). Among the most abundantly found tree species in WH, it is important to carry out relevant studies to identify those tree species such as *T. nudiflora* and *D. butyracea* which does not form any specific distinct ecological forest type or sub type but are equally or more aggregated as forest forming dominant tree species and try to understand whether they are creating their own niche. It's also interesting to find that *Eucalyptus* species comes among the most abundantly found tree species in recorded forest area probably as a consequence of most commonly planted species in India. We know it's an exotic species but have been an important species under various plantation programs in India. The plantation of wild edible fruit yielding tree species in the forests/ community lands available in the villages would be helpful in checking unsustainable harvesting of wild edibles from their natural populations, and thus will lead to their conservation in wild in the longer term.

Acknowledgements

This paper is a part of the work carried out for the award of Doctor of Philosophy Arun K. Thakur. The authors would like to acknowledge Mr Anmol Kumar, Ex – DG, FSI, Mr S. Aashutosh, DG, FSI and Dr. VP Tewari, Director, HFRI for allowing me to pursue this study. The authors are thankful to Mr. Harendar Negi, Sr. Tech. Associate, for helping in bringing the dataset to required format to carry out the analysis. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data Availability

Data available from Forest Inventory Unit of Forest Survey of India, Dehradun where author is employed. Due permission has been granted from the Director General of FSI, for carrying out PhD Arun K. Thakur on NFI data.

Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

References

Basiri RS, Tabatabaee A, Bina H (2011). Statistical analysis of spatial distribution pattern for five tree species in Kurdestan region. World Journal of Science and Technology 1(50):36-42.

Bhatt D, Chandra Sekar K, Rawal RS, Nandi SK, Dhyani PP (2016). Tree diversity of Western Himalaya. G.B. Pant Institute of Himalayan Environment & Development, Almora, Uttarakhand, India.

Bisigato AJ, Bertiller MB, Ares JO, Pazos GE (2005). Effects of grazing on plant patterns in arid ecosystems of Patagonian Monte. Ecography 28:561-572.

Bouxin G, Gautier N (1982). Pattern analysis in Belgian limestone grasslands. Vegetatio 49(2):65-83. *https://doi.org/10.1007/BF00052760*.

Costa MG, Barbosa JC, Yamamoto PT, Real RM (2010). Spatial distribution of *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae) in citrus orchards. Science Agricola 67(5):546-554. *http://dx.doi.org/10.1590/S0103-90162010000500008*.

Condit R, Ashton PS, Baker P, Bunyavejchewin S, Gunatilleke N, Gunatilleke, … Yamakura T (2000). Spatial patterns in the distribution of tropical tree species. Science 288:1414-1418.

Curtis JT, McIntosh RP (1951). An upland forest continuum in the Prairie-forest border region of Wisconsin. Ecology 31476-496.

Dale MRT, Dixon PM, Fortin MJ, Legendre P, Myers DE, Rosenberg MS (2002). Conceptual and mathematical relationships among methods for spatial analysis. Ecography 25:558- 577. *https://doi.org/10.1034/j.1600-0587.2002.250506.x*

Dornelas M, Soykan CU, Ugland KI (2011). Biodiversity and disturbance. In: Magurran AE, McGill BJ (Eds.) Biological diversity: frontiers in 593 measurement and assessment. Oxford University Press Oxford, pp 237-251.

Foldvik A, Finstad AG, Einum S (2010). Relating juvenile spatial distribution to breeding patterns in anadromous salmonid populations. Journal of Animal Ecology 79:501-509.

Fortin MJ (1999). Spatial statistics in landscape ecology. In: Klopatek JM, Gardner RH (Eds). Landscape ecological analysis: issues and applications. Springer-Verlag, New York, pp 253-279.

Fortin MJ, Boots B, Csillag F, Remmel TK (2003). On the role of spatial stochastic models in understanding landscape indices in ecology. Oikos 102:203-212.

FSI (2019). Forest Survey of India: India State of Forest Report 2019. Dehradun: FSI, Ministry of Environment and Forests. Government of India.

Gairola S, Sharma CM, Suyal S, Ghildiyal SK (2011). Species composition and diversity in mid-altitudinal moist temperate forests of the western Himalaya. Journal of Forest Science 27:1-15.

Hamer KC, Hill JK, Lace LA, Langman AM (1997). Ecological and 610 biogeographical effects of forest disturbance on tropical butterflies of Sumba 611 Indonesia. Journal of Biogeography 24:67-75. *https://doi.org/10.1111/j.1365-2699.1997.tb00051.x*

Hill JK, Hamer KC (1998). Using species abundance models as indicators of habitat 618 disturbance in tropical forests. Journal of Applied Ecology 35:458-460. *https://doi.org/10.1046/j.1365-2664.1998.00310.x*

Kessler M (2001). Patterns of diversity and range size of selected plant groups along an elevational transect in the Bolivian Andes. Biodiversity and Conservation 10:1897-1921. *https://doi.org/10.1023/A:1013130902993*.

Law R, Janine I, Burslem DFRP, Gratzer G, Gunatilleke CVS, Gunatilleke IAUN (2009). Ecological information from spatial patterns of plants: insights from point process theory. Journal of Ecology 97:616-628. *https://doi.org/10.1111/j.1365-2745.2009.01510.x*.

Ludwig JA, Reynolds JF (1988). Statistical ecology: a primer on methods and computing. John Wiley and Sons, New York, USA, pp 354.

Mathur M, Sundaramoorthy S (2012). Studies on distribution patterns for an endangered semi-arid plant, *Blepharis sindica*. Vegetos 25(2):66-75.

Maynou F, Olivar MP, Emelianov M (2006). Patchiness of eggs, larvae and juveniles of European hake *Merluccius merluccius* from the NW Mediterranean fish. Oceanography 15:390-401. *https://doi.org/10.1111/j.1365-2419.2005.00398.x*.

Magurran AE (2004). Measuring biological diversity. Blackwell Oxford.

McGill BJ, Etienne RS, Gray JS, Alonso D, Anderson MJ, Benecha HK, … White EP (2007). Species abundance distributions: moving beyond single prediction theories 672 to integration within an ecological framework. Ecology Letters 10:995-1015.

Mehta JP, Shreshthamani, Bhatt VP (2015). Regeneration potential and distribution pattern of tree species along altitudinal gradient in Central Himalaya. International Journal of Scientific and Research Publications 5(5):2250-3153.

Morisita M (1959). Measuring of interspecific association and similarity between communities. Memoirs of the Faculty of Science, Kyushu University 3:65-80

Misra R (1968). Ecology workbook. Oxford and IBH Publishing Company, Calcutta.

Negi SS (2000). Himalayan forests and forestry. 2nd revised edition. Indus Publishing company.

Odum EP (1971). Fundamentals of ecology. Saunders Company, Philadelphia, USA.

Raturi GP (2012). Forest community structure along an altitudinal gradient of district Rudraprayag of Garhwal Himalaya, India. Ecologia 2:76-84. *https://scialert.net/abstract/?doi=ecologia.2012.76.84*

Rawat C (2009). Phytosociological analysis and distribution patterns of tree species: a case study from Govind Pashu Vihar, National Park, Uttarakhand. New York Science Journal 2(4):1554-0200.

Rawat YS, Vishvakarma SCR, Oinam SS, Kuniyal JC (2010). Diversity, distribution and vegetation assessment in the Jahlmanal watershed in cold desert of the Lahaul valley, north-western Himalaya, India. iForest 3:65-71

Rayburn PA (2011). Caused and consequences of plant spatial patterns in natural and experimental great basin plant communities. PhD. Thesis, Utah State University, Logan, Utah, pp 161. *https://doi.org/10.2111/REM-D-10-00130.1*

Rayburn AP, Monaco TA (2011). Using a chrnosequence to link plant spatial patterns and ecological processes in Grazed great basin plant communities. Range Ecology Management 64:276-282.

Rossi LMB, Higuchi N (1998). Aplicao de methodos de analise do padrao espacial em oito species arboreas da florest a tropical umida. In: Costa MG, Barbosa JC, Yamamoto PT, Real RM (Eds.). Spatial distribution of *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae) in citrus orchards. Manaus, AM, Brazil.

Salas C, LeMay V, Nunez P, Pacheco P, Espinosa A (2006). Spatial pattern in an old-growth *Nothofagus obliqua* forest in South Central Chile. Forest Ecology Management 231(1-3):38-46.

Schmidt I, Zebre SJ, Betzin, Weckesser M (2006). An approach to the identification of indicators for forest biodiversity in the Solling mountains (NW Germany) as an example. Restoration Ecology 14(1):123-136.

Sharma CM, Baduni NP, Gairola S, Ghildiyal SK, Suyal S (2010). Effects of slope aspects on forest compositions, community structures and soil properties in natural temperate forests of Garhwal Himalaya. Journal of Forestry Research 21:331-337. *https://doi.org/10.1007/s11676-010-0079-y*.

Sharma CM, Ghildiyal GK, Gairola S, Suyal S (2009). Vegetation structure, composition and diversity in relation to the soil characteristics of temperate mixed broadleaved forest along an altitudinal gradient in Garhwal Himalaya. Indian Journal of Science and Technology 2:39-45.

Singh H, Kumar M, Sheikh MA (2009). Distribution pattern of oak and pine along altitudinal gradients in Garhwal Himalaya. Nature and Science 7(11).

Singh S, Malik ZA, Sharma CM (2016). Tree species richness, diversity, and regeneration status in different oak (*Quercus* spp.) dominated forests of Garhwal Himalaya, India. Journal of Asia-Pacific Biodiversity 9:293-300. *https://doi.org/10.1016/j.japb.2016.06.002*

Stoll P, Begius E (2005). Pattern and Process: Competition Causes Regular Spacing of Individuals within Plant Population. Journal of Ecology 93:395-403. *https://doi.org/10.1111/j.0022-0477.2005.00989.x*.

Steege TH, Pitman NC, Sabatier D, Baraloto C, Salomao RP, Guevara JE, … Monteagudo A (2013). Hyper-dominance in the Amazonian tree flora. Science 342(325-334).

Tewari VP, Kleinn C (2015). Considerations on capacity building for national forest assessments in developing countries with a case study of India. International Forestry Review 17(2):244-254. *https://doi.org/10.1505/146554815815500633*.

Thakur AK, Kumar R, Verma RK (2018). Analyzing India's current national forest: inventory for biodiversity information. Biodiversity and Conservation 27(12):3049-3069. *https://doi.org/10.1007/s10531-018-1587-x*

Tsuji K, Kastiya E (2001). What do the indices of reproductive skew measure? The American Naturalist 158(2):155-165.

Turak E, Brazill-Boast J, Cooney T, Drielsma M, DelaCruz J, Dunkerley G, … Williams K (2016). Using the essential biodiversity variables framework to measure biodiversity change at national scale. Biological Conservation. *http://dx.doi.org/10.1016/j.biocon.2016.08.019*.

Uttarakhand Forest Department (2008). Uttarakhand forest statistics 2007-08. Uttarakhand Forest Department, Dehradun.

Valiente-Banuet A, Verdu M (2008). Temporal shifts from facilitation to completion occur between closely related taxa. Journal of Ecology 96:489-494. *https://doi.org/10.1111/j.1365-2745.2008.01357.x*

Verma RK, Kapoor KS (2016). Assessment of vegetation along an altitude gradient in Khajrot beat of Kalatop Wildlife Sanctuary of district Chamba, Himachal Pradesh. Indian Journal of Forestry 39(1):1-8.

Whitford PB (1949). Distribution of woodland plants in relation to succession and clonal growth. Ecology 30:199-288.