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Distribution Pattern of *Cinnamomum tamala* in Annapurna Conservation Area, Kaski, Nepal

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Abstract
To assess the ecological process and to find the factors responsible for pattern formation, analysis of spatial pattern of the species is of paramount importance. With a view to analyze the distribution pattern of the *Cinnamomum tamala* spp., this study utilized the data obtained from the phyto-sociological survey of natural vegetation carried out in Mijure Danda Village Development Committee during June and July of 2009. Nested quadrats of 10m×10m, 5m×5m, and 1m×1m were used to collect the data from tree, sapling, and seedling, respectively. Dispersion indices: variance to mean ratio (I), index of Morisita (I_δ), coefficient of Green (Cx), and the k exponent of negative binomial distribution were used to identify the distribution pattern of the species. Test of significance of I, and I_δ provided the information on rejection of null hypothesis: *C. tamala* does not follow the random distribution. The K exponent of negative binomial distribution suggests moderate contiguous pattern, which is in line with the previous studies of vegetation elsewhere. Since this study used the cross-sectional data, monitoring of species at different temporal and spatial scale focused around various level of sampling, and accumulation of significant data on other physical elements is prescribed for future study to fill the gap of information about this species.

Key words: *Cinnamomum tamala*, distribution pattern, dispersion indices, aggregation

Introduction
Cinnamomum tamala T. Nees & Eberm (family Lauraceae), commonly known as Tejpat (trade name Tamalpatra) is a moderate sized, evergreen, monoecious species and distributed from subtropical to temperate zone (1000-2100 masl) in Nepal. Natural stands of *C. tamala* are mostly found in shady and moist sites (Subedi & Sharma 2012). The bark has an aromatic odor and possesses aromatic, carminative, and stimulating properties (Nadkarni 2001). The oil of the bark is a powerful germicide and fungicide usually used as valuable flavoring ingredient (Dutta 2007).The leaves possess anti-diarrheal and anti-ulcer properties (Eswaran *et al*. 2010, Rao *et al.* 2008). It blooms during May-June and usually pollinated by small insects such as honey bees. Ripen fruits are dark purple in color and contain single seed; the fruits are ellipsoidal drupe and require approximately one year in attaining maturity (Sharma *et al.* 2009). In Neal *C. tamala* trees are especially managed for leaf and bark production, and are used in production of essential drugs under Ayurvedic system (Subedi & Sharma 2012). *C. tamala* is one of the highly traded medicinal plant species of Nepal and has received a priority for research and management as this species forms a major part of the non-timber forest products trade both by volume and economic value (DOF 2010, Subedi & Sharma 2012).

The spatial distribution pattern refers to the status of horizontal allocation or distribution of individual trees in a stand, which reflects the relations among individual trees in horizontal space. It is the fundamental characteristic of species' ecology unveiling the influence of multiple factors such as intra-specific, inter-specific and environmental condition with organisms that are closer to one another in space (Legendre & Fortin 1989). Determination of spatial distribution pattern of species has drawn central attention in ecological discourse (Condit *et al.* 2000). The analysis of spatial distribution pattern assists to evaluate the contribution of factors responsible for the formation of this pattern. These factors may include competition (Kubota & Hara 1995, Moeur 1997, Wolf 2005), establishment (Ledo *et al.* 2012), development (Palik *et al.* 2003), mortality (Peet & Christensen 1987, Das *et al.* 2008), and crown development (Stiell 1978). Plethora of researches carried out so far contributed in understanding the role of spatial pattern in the assembly, association and dynamics of vegetation that takes place in the ecosystem (e.g. Rohani *et al.* 1997, Perry *et al.* 2006, Martínez *et al.* 2010, Martínez *et al.* 2013). In a forest ecosystem, spatial distribution pattern may alter the canopy light environment (Sprugel *et al.* 2009) as well as understory plant abundance, composition, and diversity.

In nature, individuals of a population (both plants and animals) may be distributed in their habitat in a random, a clumped (aggregated), or a regular (uniform) pattern (Buschini 1999, Krebs 1999, Odum 1986, Pielou 1997). Perry *et al.* (2006) mentioned two spatial (global and local) pattern analysis techniques. The local spatial pattern analysis describes the variation of spatial arrangement of species within the study area. Pattern detection can be achieved by three ways: sampling plots, distances, and uniform angle index (Lan & Lei 2003).Since the quadrat based point pattern analysis, which is the area based definition of scale is popular in ecological studies (Heltshe & Ritchey 1984, Olsen *et al.* 1996, Pélissier *et al.* 2001), this study also used quadrat-based point pattern analysis of *C.tamala* in natural forest.

Majority of natural environment are found with clumped distribution caused by environmental heterogeneity (Krebs 1999, Levinton 1972, Odum 1986) and non-linearity of biological process (Pacala & Levin 1997). Though some species are tolerant of wide range of environmental conditions others are limited only to a narrow range, but each species best functions usually over a limited part of the gradient is called as "species optimal range". Detecting and describing non-random spatial pattern is fundamental to intensify the understanding the population structure and growth of the individual trees, and in formulation of conservation and management plan of the species. However, this information about *C. tamala* in natural forests of Nepal is still missing (Subedi & Sharma 2012). Therefore, this study aimed at detecting the distribution pattern of the species. Such information is of utmost importance for better insight into the population dynamics and spatial aspect of the distribution of individuals in relation to the species ecology and habitat characteristics.

Methodology

The study was conducted at Mijure DandaVillage Development Committee (VDC) of Kaski district, Nepal to prepare a management plan for *C. tamala* and other important tree species in the site. The site occurs within the Annapurna Conservation Area Project (NTNC/ACAP) in geographic location [28° 132 573 - 28° 202 573 N, 84° 082 533 - 84° 122 423 E]. The site is a part of the humid sub-tropical monsoon climatic zone, with hot and wet summer and fairly cold winter, with mean temperature of 17.68^{o}C, and12.14^{o}C respectively in summer and winter. The mean annual precipitation is reported to be 3710 mm. The site comprised of *C. tamala* as a dominant species while its major associates are *Schima wallichii*, *Castanopsis indica*, *Madhuca latifolia*, *Macaranga postulata*, *Sapium insigne*, *Semecarpus anacardium*, *Cydia cylicina*, *Perceao dorantisima* and *Diospyrus malabericum*.

We carried phyto-sociological survey in the month of June and July, 2009. The data utilized in this study were collected through systematic sampling with a plot size of 10m×10 m. Each plot was nested into 5m×5m at opposite corner, and 1m×1m in four corners of the main plot. The uses of quadrats of different sizes were used to evaluate the effect of plot size by analyzing the pattern variations among them.

The data were analyzed by calculating the mean, variance and dispersion indices, to diagnose the pattern of species distribution. The indices used were: variance-to-mean ratio (I), Morisita's dispersion index (I_δ), coefficient of Green (Cx), and k exponent of negative binomial distribution (k).

Variance-to-mean ratio (I)

This index was used to measure the departure from a randomness arrangement; the index was calculated using the formula of Rabinovich (1980), which is:

$$I = \frac{s^2}{\hat{m}} = \frac{\sum_{i=0}^{n}(x_i - \hat{m})^2}{\hat{m}(n-1)}$$

Where: s^2 = sampling variance; $\hat{m}$= sampling mean; x_i= number of *Cinnamomum tamala* found in the sampling units; n =number of sampling units.

Chi-square test with *n*-1 degree of freedom in the variance-to-mean ratio was used to test the departure from randomness, which can be expressed as:

$X^2 = I(n-1)$. This can be further written as,

$$X^2 = \frac{s^2(n-1)}{\hat{m}} = \frac{\sum_{i=0}^{n}(x_i-\hat{m})^2}{\hat{m}(n-1)} \sim \chi^2(n-1)$$

Index of Morisita (I_δ)

The index of Morisita was calculated by the formula developed by (Morisita 1962) is:

$$I_\delta{}^2 = n\frac{\sum[x(x-1)]}{\sum x(\sum x-1)} = \frac{\sum x^2-\sum x}{(\sum x)^2-\sum x}$$

Where: n= number of sampling units; *x* = number of *Cinnamomum tamala* found in the sampling units; $\sum x$= sum of individuals present in the sampling units.

Departure from randomness can be tested by:

$$X_\delta{}^2 = I_\delta{}^2(\Sigma x_i-1)+n-\Sigma x_i \sim \chi^2(n-1)$$

Coefficient of Green (Cx)

This index is acceptable for comparisons between contagious distributions (Green 1996). It is based on the distribution's variance to mean ratio and is given by:

$$C_x = \left[\frac{(s^2/\hat{m})-1}{\sum_{i=0}^{n}(x_i-1)}\right]$$

Departure from randomness can be tested by:

$$C_{x_{1-a}} = \frac{[\chi^2_{1-\alpha}/(n-1)-1]}{(n\hat{m}-1)}$$

K exponent of negative binomial distribution (*k*)

k values were calculated by the moments methods as recommended by (Anscombe 1949), is:

$$\hat{k} = \frac{\hat{m}^2}{s^2-\hat{m}}$$

Another k values were computed using maximum likelihood method that is more accurate (Elliott 1979). This method used for finding the $\hat{k}$ value that balances both members of the equation (Bliss & Fisher 1953). The estimation method is iterative and based on trial and error until equality is achieved between both members of the equation. We started the calculation from the initial *k* value obtained by the method of moments as used by (Costa *et al.* 2010) to achieve convergence value more quickly. Iterative equation of Bliss and Fisheris:

$$N\ln\left(1+\frac{\hat{m}}{\hat{k}}\right) = \sum_{i=1}^{nc}\frac{Ax_i}{\hat{k}+x_i}$$

where: N = number of sampling units; $\ln$ *= Napierian logarithm;* $\hat{m}$ *= sampling mean;* $\hat{k}$ *= k value estimate;*x_i*= number of Tejpat found in sampling units; A(Bouxin and Gautier) = sum of frequencies of values higher than* x_i*; nc = number of classes in the frequency distribution.*

Table 1 depicts the criteria of detection of pattern based on the values obtained from the above calculation and hypothesis testing of randomness.

Table 1. Detection of distribution pattern and criterion of hypothesis testing of randomness

Index	Value	Pattern or degree of pattern	Randomness rejection condition
Variance-to-mean ratio (I):	=1	Random	$X^2 \geq \chi^2_{\alpha,(n-1)}$
	<1	Regular/uniform	
	>1	Contagious	
Index of Morisita (I_δ)	=1	Random	$X_\delta{}^2 \geq \chi^2_{\alpha,(n-1)}$
	<1	Regular/uniform	
	>1	Contagious	
Coefficient of Green (Cx)	=0	Random	$C_x > C_{x_{1-a}}$
	=1	Maximum contagious	
K exponent of negative binomial distribution (*k*)	<2	Highly contagious	
	2-8	Moderate contagious	
	>8	Random	

Results and Discussion

The field work listed 196 trees of Tejpat with a mean ($\hat{m}$) value of 8.167 and variance (s^2) 443.33. The indices variance-to-mean ratio (I), Morisita (I_δ), Green index (Cx) and k value of negative binomial distribution revealed a clumped (contagious) pattern. Table 2 showed the calculated value and decision for the detection of spatial distribution pattern of Tejpat.

Table 2. Detection of distribution pattern and criterion of hypothesis testing of randomness

Index	Threshold value	Pattern or degree of pattern	Calculated value	Detection of pattern and its degree
Variance-to-mean ratio (I):	=1	Random		
			2.3602	Contagious
	<1	Regular/uniform		
	>1	Contagious		
Index of morisita (I_δ)	=1	Random		
			1.1604	Contagious
	<1	Regular/uniform		
	>1	Contagious		
Coefficient of Green (Cx)	=0	Random		
			0.2733	Contagious
	=1	Maximum contagious		
K exponent of negative binomial distribution (*k*)	<2	Highly contagious		
			4.7516	Moderate contagious
	2-8	Moderate contagious		
	>8	Random		

The value obtained for the variance-to-mean ratio was greater than 1 indicating the contagious pattern. The Index of Morisita (I_δ) also denoted for the contagious pattern with value just over the threshold value i.e. 1.16 (see Table 2).

Greens coefficient (Cx) analysis resulted the value (0.2733) which is higher than zero and indicated the aggregate distribution (Davis 1993). This distribution pattern (contagious/aggregate) was confirmed by the k value of the negative binomial distribution (Table 2) by the maximum likelihood method which resulted the positive value less than 8 (i.e. 4.7151) indicating the highly contagious. Although the Green index and K exponent of negative binomial distribution though could not be tested, the data supported for aggregation with the result $Cx>Cx_{(1-\alpha)}$ which is (0.2733>-0.0053). To examine whether these index values are significantly different from 1.0 (Null hypothesis; $H_0:I=I_\delta$),we performed the statistical test to reach the correct conclusion. Significant deviations from 1.0 (random) were assessed by calculating a chi-square value. Chi-square value for Variance-to-mean ratio is equal to (χ^2) and for Morisita index ($\chi 2_\delta$). Not surprisingly, both and ($\chi 2_\delta$) are identical. These values were then compared with a critical value, using the appropriate degrees of freedom n (which is n - 1) at 1% chance of committing type-I error. Test of significance of two indices variance-to-mean ratio and Morisita index (Table 3) explicitly provided information on rejection of null hypothesis i.e., Tejpat did not follow the random distribution. Variance-to-mean ratio based indices are often criticized of being strongly dependent on the sampling unit size (Costa *et al.* 2010, Rossi & Higuchi 1998). However, index of Morisita is less affected by the size of sampling units therefore most often used in ecological studies (Rossi & Higuchi 1998).

Table 3. Test of significance of indices

Index	Value	χ^2 calculated value	χ^2critical value	Decision
Variance-to-mean ratio (I):	2.3602	54.2857	41.638	Rejection of null hypothesis i.e. presence of non-randomness
Index of Morisita (I_δ)	1.1604	54.2857	41.638	Rejection of null hypothesis

Plethora of research found that majority of natural environments are patchy and environmental heterogeneity tends to cause spatial aggregation of the species (Heip 1975, Levinton 1972). As aggregation of species can occur on different temporal and spatial scales (Thrush 1991, Ysebaert & Herman 2002) and often varies during different stages of an organisms' life cycle (Armonies 1986, Flach & Beukema 1994; Haubois *et al.* 2004). Therefore spatial pattern of the species may be determined at different stages as shaped by the different biological and physical factors (Foldvik *et al.* 2010, Maynou *et al.* 2006). However, this study does not cover the explanation of the factors shaping distribution pattern because it can morphological at a small scale and environmental at large one or sociological at one scale and environmental at another (Bouxin & Gautier 1982) and therefore detection of distribution pattern and explaining the factors causing this is separate problem (Jayaraman 2000). Since, this study is limited to detection of distribution pattern at secondary forest with cross-sectional data, the result of the study is recommended not to generalize for the large range of area.

The result of this study suggests the contagious distribution of the *C. tamala* within the study area based on the cross-sectional data. Since the distribution pattern of the species varied at different temporal and spatial scale shaped mainly by the existence of specific environmental conditions hierarchical sampling to determine species associations as well as to identify the differences in micro habitats is recommended for the future research.

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References

Anscombe, F.J. 1949. The statistical analysis of insect counts based on the negative binomial distributions. *Biometrics***5**:165-173.

Armonies, W. 1996. Changes in distribution patterns of 0-group bivalves in the Wadden Sea: Byssus-drifting releases juveniles from the constraints of hydrography. *Journal of Sea Research***35** (4): 323-334.

Bliss, C.I. and R.A. Fisher. 1953. Fitting the negative binomial to biological data, note on the efficient fitting of the negative binomial. *Biometrics* 9:176-200.

Bouxin, G. and N. Gautier. 1982. Pattern Analysis in Belgian Limestone Grasslands. *Vegetatio 49*(2):65-83.

Buschini, M.L.T. 1999. Spatial distribution of nests of *Nasutitermes sp.*(Isoptera: Termitidade) in a cerrado area in southeastern Brasil. *Environmental Entomology***28**(4):618-621.

Condit, R., P.S. Ashton, P. Baker, , P. Bunyavejchewin, S. Gunatilleke, N. Gunatilleke, S.P. Hubbell, R.B. Foster, A. Itoh, J. V. LaFrankie, , H.S. Lee, E. Losos, N. Manokaran, R. Sukumar and T. Yamakura. 2000. Spatial patterns in the distribution of tropical tree species. *Science* **288** (5470):1414–1418.

Costa, M.G., J.C. Barbosa, P.T. Yamamoto, and R.M. Real. 2010. Spatial distribution of Diaphorina citri Kuwayama (Hemiptera: Psyllidae) in citrus orchards. *Science Aagricola***67**(5):546-554.

Das, A., J. Battles, P. J. van Mantgem and N. L.Stephenson. 2008. Spatial elements of mortality risk in old-growth forests. **Ecology 89**(6): 1744-1756.

Davis, P.M. 1993. Statistics for describing populations. Handbook of sampling methods for arthropods in agriculture. Editors : L.P. Pedigo and G.D. Buntin. CRC Press, Boca Raton, FL, USA. 33-54 p.

DOF. 2010. Hamro ban. Extention Division, Babaharmal, Kathmandu.

Dutta, I.C. 2007. Non-Timber Forest Products of Nepal (identification, classification, ethnic uses and cultivation). Hill side press, Kathmandu p421-423.

Elliott, J.M. 1979. Some Methods for the Statistical Analysis of Samples of Benthic Invertebrates. Freshwater Biological Association, Ambleside, Columbia, England.

Eswaran, M.B., S. Surendran, M. Vijayakumar, S.K. Ojha, A.K.S. Rawat, and C.V. Rao. 2010. Gastroprotective activity of *Cinnamomum tamala* leaves on experimental gastric ulcers in rats. *Journal of Ethnopharmacology***128**(2):537-540.

Flach, E.C. and J.J. Beukema. 1994. Density-governing mechanisms in populations of the lugworm Arenicola marina on tidal flats. Marine Ecology in Progress Series **115**:139-149.

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

Green, R.H. 1996. Measurement of non-randomness in spatial distributions. *Researches on Population Ecology* **8**:1-7.

Haubois, A.G., J.M. Guarini, P. Richard, A. Hemon, E. Arotcharen, and G.F. Blanchard. 2004. Differences in spatial structures between juveniles and adults of the gastropod Hydrobia ulvae on an intertidal mudflat (Marennes-Oléron Bay, France) potentially affect estimates of local demographic processes. *Journal of Sea Research* **51**:63-68.

Heip, C. 1975. On the significance of aggregation in some benthic marine invertebrates, in: Barnes, H. (Ed.), Proc. 9th Europ. Mar. Biol. Symp. Aberdeen University Press, Aberdeen. Pp. 527-538.

Heltshe, J.F. and T.A., Ritchey. 1984. Spatial pattern detection using quadrat samples.*Biometrics* **40**: 877–885.

Hurlbert, S.H. 1990. Spatial distribution of the montane unicorn. *Oikos* **58**:257-271.

Jayaraman, K. 2000. A Statistical Manual for Forestry Research. Forestry Research Support Programme for Asia and the Pacific (FORSPA) Food and Agriculture Organization of the United Nations Bangkok. pp 240.

Krebs, C.J. 1999. Ecological methodology. Harper and Row, New York, USA. pp 607.

Kubota, Y. and T. Hara. 1995. Tree competition and species coexistence in a sub-boreal forest, northern Japan. *Annals of Botany* **76**(5):503–512.

Lan, G.Y. and R.D. Lei. 2003. Brief introduction of spatial methods tio distribution patterns of population. *Journal of Northwest Forestry University* **18**(2):17-21.

Ledo, A., F. Montes and S.Condés. 2012. Different spatial organisation strategies of woody plant species in a montane cloud forest. *ActaOecologica* **38**:49–57.

Legendre, P. and M.J. Fortin. 1989. Spatial pattern and ecological analysis. Plant Ecology **80**:107-138.

Levinton, J. 1972. Spatial distribution of *Nucula proxima* Say (Protobranchia): an experimental approach. P. 175-183 in Biological Bulletin.

Li, M.H., F.H. He, and Y. Liu. 2003. Analysis methods of stand spatial distribution pattern. *ActaEcologicaSinica* **22**(1):77-81.

Liebig, J. 1982. Animal chemistry or organic chemistry in its application to physiology and pathology. Johnson Print Corporation New York. pp 347

Martínez, I., F. González Taboada, T. Wiegand and J.R. Obeso. 2013. Spatial patterns of seedling-adult associations in a temperate forest community. *Forest Ecology and Management* **296**:74–80.

Martínez, I., T. Wiegand, F. González-Taboada and J.R.Obeso. 2010. Spatial associations among tree species in a temperate forest community in North-western Spain. *Forest Ecology and Management* **260**(4):456–465.

Maynou, F., M.P. Olivar, and M. Emelianov. 2006. Patchiness of eggs, larvae and juveniles of European hake Merluccius merluccius from the NW Mediterranean fish. *Ocenography* 15:390-401.

Moeur, M., 1997. Spatial models of competition and gap dynamics in old-growth Tsugaheterophylla/ Thujaplicata forests. *Forest Ecology and Management* **94**:175–186.

Morisita, M. 1962. I_d-index, a measure of dispersion of individuals. *Researches on Population Ecology* **4**:1-7.

Nadkarni, K.M. 2001. Plants and Drugs with their Medicinal Properties and Uses. Asiatic publishing house, New Delhi.

Odum, E.P. 1986. Ecologia. Gunabara, Koogan, Riio de Janeiro, RJ, Brazil.

Olsen, W.K., Schmid, J.M. & Mata, S.A., 1996. Stand characteristics associated with mountain pine beetle infestations in ponderosa pine. *Forest Science* 42:310–327.

Pacala, S.W. and S.A. Levin (eds.). 1997. Biological generated spatial pattern and the coexistence of competing species. In: Tilman, D., Kareiva, P. (Eds.), Spatial Ecology: the role of space in population dynamics and interspecific interactions. Princeton University Press, Princeton. Pp 204-232.

Palik, B., R.J. Mitchell, S. Pecot, M. Battaglia and M. Pu. 2003. Spatial distribution of overstory retention influences resources and growth of longleaf pine seedlings. Ecological Application **13**: 674–686.

Peet, R.K. and N.L.Christensen. 1987. Competition and tree death. *Bio. Science* **37**(8):596–595.

Pélissier, R., F. Goreaud, R.. Pelissier, F. Goreaud. 2001. A practical approach to the study of spatial structure in simple cases of heterogeneous vegetation. *Journal of Vegetation Science* **12**: 99–108.

Perry, G.L.W., B.P. Miller and N.J. Enright. 2006. A comparison of methods for the statistical analysis of spatial point patterns in plant ecology. *Plant Ecology* **187**(1):59–82.

Perry, J.N., A.M. Liebhold, M.S. Rosenberg, J. Dungan, M. Miriti, A. Jakomulska and S. Citron-Pousty. 2002. Illustrations and guidelines for selecting statistical methods for quantifying spatial pattern in ecological data. *Ecography* **25**:578-600.

Pielou. 1997. Mathematical Ecology. Wiley, New York. pp 385.

Rabinovich, J.E. 1980. Introduction to the ecology of animal populations. Editorial Continental, In: Costa, M.G., Barbosa, J. C., Yamamoto, P.T. Real, R. M.Spatial distribution of Diaphorina citri Kuwayama (Hemiptera: Psyllidae) in citrus orchards. Ciudad de México, México. (in Spanish).

Rao, C.V., M. Vijayakumar, K. Sairam, and V. Kumar. 2008. Antidiarrhoeal activity of the standardised extract of cinnamomum tamala in experimental rats. *Journal of Natural Medicine* **62**:396-402.

Rohani, P., T.J. Lewis, D. Grunbaum and G.D. Ruxton. 1997. Spatial self-organization in ecology: Pretty patterns or robust reality? *Trends in Ecology and Evolution* **12**:70–74.

Rossi, L.M.B. and N. Higuchi. 1998. Aplicao de methodos de analise do padrao espacial em oito species arboreas da florest a tropical umida In: Costa, M.G., Barbosa, J. C., Yamamoto, P.T. Real, R. M.Spatial distribution of Diaphorina citri Kuwayama (Hemiptera: Psyllidae) in citrus orchards. Manaus, AM, Brazil,.

Sharma, G., B.P. Nautyal and A.R. Nautyal. 2009. Seedling emergence and survival in *Cinnamomum tamala* under varying micro-habitat conditions: conservation implications. *Tropical Ecology* **50**(1):201-209.

Sprugel, D. G., K. G. Rascher, R.Gersonde, M. Dovèiak, J. A. Lutz and C. B. Halpern. 2009. Spatially explicit modeling of overstory manipulations in young forests: effects on stand structure and light. *Ecological Modelling* **220**(24): 3565-3575.

Stiell, W.M. 1978. How uniformity of tree distribution affects stand growth. *The Forestry Chronicle* **54**(3):156–158.

Stiling, P. 2002. Ecology:Theories and applications. Asoke K. Ghosh, Prientice-Hall of India Private Limited. pp 403.

Subedi, M.R. and R.P. Sharma, 2011. Allometric biomass models for bark of Cinnamomumtamala in Mid-hill of Nepal. *Biomass and Bio. energy* **47**(12): 44-49

Thrush, S.F. 1991. Spatial patterns in soft-bottom communities. *Trends in Ecology and Evolution* ***6(3)***:75-79.

Wiens, J.A. 2000. Ecological heterogeneity: ontogeny of concepts and approaches. In: Hutchings, M.J., Jones, E.A., Stewart, A.J.A. (Eds.), The Ecological Consequences of Environmental Heterogeneity. Blackwell Science, Oxford. pp 9-31.

Wolf, A. 2005. Fifty year record of change in tree spatial patterns within a mixed deciduous forest. *Forest Ecology and Management* **215**(1-3): 212–223.

Ysebaert, T.J. and P.M.J. Herman. 2002. Spatial and temporal variation in benthic macrofauna and relationships with environmental variables in an estuarine, intertidal soft-sediment environment. *Marine Ecology Progress Series* **244**:105-124.