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Characterization of diameter distribution of some tree species from Gilgit-baltistan using weibull distribution

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Abstract

Forty stands were sampled to investigate the overall diameter size classes of four dominant tree species of some forests from Gilgit-Baltsitan. On the basis of overall density of individuals of a species the size class structure was derived. *Pinus wallichiana* A.B.Jacks .occupied 128±21.1 mean stems ha^{-1}, *Picea smithiana* (Wall.)Boiss. attained 121±5 mean stems ha^{-1} ,*Betula utilis* D.Don had a density of 61±18.8 mean stems ha^{-1} while *Juniperus excelsa* M.Bieb. had 38±14.3 mean stems ha^{-1}.The DBH distribution of each species was characterized by a three parameter Weibull probability distribution. This distribution was selected as a model since it is flexible and has been demonstrated to provide a good-fit to the size-class structure. Using the maximum likelihood method of parameter estimation, Weibull parameters , a, b and c were estimated and the cumulative distribution was fitted to DBH of evergreen and broad-leaf tree species in which DBH served as an independent variable of the diameter distribution of the natural unevenaged forests. The model showed usually excellent fit to the distribution as indicated by high R^2 values. These models can prove to be very handy for an effective management of forest resources.

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Introduction

During the last few decades many studies have been conducted to analyze the current status and predict the future trends of forest vegetation from different localities of Pakistan. Ahmed (1988b) presented population structure of planted tree species in Quetta while population structure of *Juniperus excelsa* M.B. and *Pinus gerardiana* Wall.ex Lamb., from Balochistan was studied by Ahmed *et al.* (1990) and Ahmed *et al.* (1991) respectively. Ahmed *et al.* (2006) also presented structure of various Himalayan forests from different climatic zones of Pakistan. Wahab *et al.* (2008) presented dynamics of some pine forests of Afghanistan, close to the Pakistani border. Vegetation structure of *Olea ferruginea* forest of Lower Dir was examined by Ahmed *et al.* (2009). Phytosociology of *Pinus roxburghii* Sergeant was carried out by Siddiqui *et al.* (2009) in which special attention was paid to size structure of trees. Khan *et al.* (2010b) described the size structure of *Quercus baloot*, forest from District Chitral. Hussain *et al.* (2010, 2011) investigated the structure of communities from CKNP. Structural diversity, vegetation dynamics and anthropogenic impact on lesser Himalayan subtropical forests of Bagh district Kashmir has been studied by Shaheen *et al.* (2011).

However, none of the above mentioned workers have so far attempted to describe the size distribution in terms of a probability distribution in order to quantify the given size structure. In ecology as well as in forestry many workers in European countries or in the USA have attempted to fit a variety of probability distributions such as gamma, Weibull and exponential distributions (Rennolls *et al.*1985; Maltamo *et al.*1995, 2000, Liu *et al.*2002;Embory *et al.* 2000), among these, Weibull distribution has generally provided better results compared to other distributions (Podlaski,2005,2008; Rynikes *et al.* 2006) for successful description of diameter distribution of various tree species.

In forestry the application of Weibull model for the description of tree diameter seems to be first introduced by Baiely and Dell (1973). They advocated this model as an important tool to investigate the distribution pattern of size classes because it has the potential to explain a wide range of unimodal distributions i.e. reversed J-shaped, exponential, normal frequency distribution and closed cumulative density functional form (Schreuder and Swank 1974; Schreuder *et al.* 1979; Rennolls *et al.* 1985; Mabvurira *et al.* 2002). The Weibull probability distribution has been of vital importance for the description of diameter frequency distributions within boreal forest types (Kilkki *et al.* 1989). For various size distributions, Weibull model has yielded better fits compared to other distributions (Liu *et al.* 2004; Newton *et al.* 2004, 2005). Hyink and Moser (1983) also explored the application of Weibull distribution to estimate the stand–level diameter frequency distribution as a function of stand level variables. Hitimana *et al.* (2004) and Coomes and Allen (2007) reported that in any forest the tree size classes and number of individuals, may change considerably. In the forest around the world many causal factors i.e regeneration pattern, successional disturbances, competition for nutrition, climatic conditions influences tree size distribution (Denslow 1995, Coomes *et al.* 2003, Webster *et al.* 2005). Moreover, the size class distribution of trees are mostly used in assessing the possible outcome due to the disturbances within the forest (Hett and Loucks 1976, Denslow 1995, Baker *et al.* 2005, Coomes and Allen 2007), the distribution may also be helpful in exploration of successional pathway and structural development of forest (Goff and West 1975, Poorter *et al.* 1996, Zenner 2005). On the basis of the present status of the forest the future trends may be predicted (Feeley *et al.* 2007). In addition, the tree size classes may vary among the natural forest but they also show some similarities i.e reverse J-shaped DBH distribution (Hough 1932, Robertson *et al.* 1978, Kohyama 1986, Niklas *et al.* 2003).

The present study is based in part on a phytosociological study in which composition and structure of 40 stands of Gilgit, Astore and Skardu district were analyzed and some aspects have been described in Akbar *et al.* (2010, 2011) where stand-wise information was provided. Whereas in this paper we focus on the cumulative distribution of size distribution of four tree species employing Weibull distribution for the first time and explain the distribution pattern of on an overall basis to discloses size class pattern of four dominant species namely, *Pinus wallichiana, Picea smithian, Betula utilis and Juniperus excelsa* from the study area. It is hoped that this study would provide better information about present status and future trends of the dominant species in these forests.

Aims an Objective

1. To evaluate overall size class structure of the forest.
2. To identify natural and human induce disturbances around forested areas.
3. To provide suggestions and recommendations for conservation.

Material and methods

Study area

The study was conducted during June 2009 to June 2011. Sampling was focused on some selected forested valleys which included three districts i.e Gilgit, Astore and Skardu of Gilgit-Baltistan, situated between 74°.04 to76°.06 East longitude and 34°.42 to 36°.07 on North latitude. The elevation ranged from 2616m to 3775m above sea level whereas the slope angle ranged from 5° to 45°.

Sampling

Sampling in the study area was performed using point centered quarter (PCQ) method of Cottam & Curtis (1956) .Twenty points were taken at 20-meter intervals. The criteria for the selection of a stand were: 1) It contained trees at least (60 cm DBH) and 2) covering at least two hectares (ha) in area, and 3) minimal recent anthropogenic disturbance. Environmental characteristics i.e Geographical coordinates, aspect, slope angle, and elevation, were recorded using a GPS.

Statistical analysis

Density of each stand was calculated according to the method described by Mueller-Dombois & Ellenberg (1974) and Ahmed and Shaukat (2012).

Size class Structure

Diameter at breast height (DBH) of each tree in a stand was divided into (10cm DBH) classes. A total of 11 size classes were made according to the DBH which was lesser than (120 cm).Various size classes and size structure of individual stands were made using MS-Excel 2003 and 2007.The dominant tree species were selected following the method described by Ahmed (1984) and followed by Siddiqui (2011), Wahab (2011) and Khan (2011).

Weibull distribution model

To evaluate the overall size class distribution of dominant tree species we arranged the DBH of each class of individual tree species then used these values in CumFreq software (cumulative frequency analysis with probability distribution fitting) selecting three parameter Weibull distribution which was applied for first the time by Baiely and Dell (1973) in forestry. The three-parameter Weibull probability distribution function is given by.

$$f(x; a, b, c) = \left(\frac{c}{b}\right)\left(\frac{x-a}{b}\right)^{c-1} exp\left(-\left[\frac{x-a}{c}\right]^{c}\right)$$

$$x \geq a$$

Where a, b and c are the location, scale and shape parameters of the Weibull distribution respectively and x is the tree DBH.

The cumulative distribution function of the Weibull model is

$F(x) = 1\text{-}exp\,[- \{(x\text{-}a)/b\}^{c}]$ where $0 \leq x < +\infty$, a, b > 0

Results and discussion

Overall DBH size class distribution of dominant species

A total of 40 stands were sampled among which *Pinus wallichiana,Picea smithian, Betula utilis* and *Juniprus excelsa* found to be the dominant species.

The diameter size class distributions of the dominant tree species are presented in Fig.1. Results shows that *Pinus wallichiana* prevailed with highest mean 128±21.1 stems ha^{-1} among the four tree species showing platykurtic Gaussian distribution with slight positive skewness. The size class distribution of this species indicates low recruitment of seedling because the first class show low mean density while in size class number four the mean density increases whereas it decreases within the higher size classes while the last two higher size classes have no individuals due to the cutting of old trees. This pattern may control promoting seedling regeneration and requires taking immediate action about the illegal harvesting of trees. The second dominant tree was *Picea smithiana* which occurred with low mean density 121±30.5 stems ha^{-1} as compared to *Pinus wallichiana* this species showed low mean density in earlier size classes. The density increases with respect to the middle size classes gradually then decreases towards the higher size classes. Size class model of *Picea smithiana* shows close to symmetrical distribution. This implies low recruitment of seedling is occurring and the old trees are cut down excessively. An angiospermic tree species *Betula utilis* showed mean density of 61±18.8 stems ha^{-1}.The first attained few individuals while the other lower and middle size classes showed better mean density showing roughly Gaussian distribution. *Juniperus excelsa* showed mean density of 38±14.3 stems ha^{-1}.This species showed better recruitment of seedling with the maximum individuals in the lower size classes but the frequencies declines gradually in the meddle size classes and large size classes which reflects the influence of anthropogenic disturbance. The shapes of size class of *Pinus wallichiana, Picea smithiana* and *Betula utilis* do not show any ideal size classes distributions pattern with low number of individuals in younger as well as mature or old classes whereas the size classes of *Juniperus excelsa* show an inverse J-shaped distribution which is promising pattern with the higher individuals in lowers size classes which decline gradually within the higher size classes.

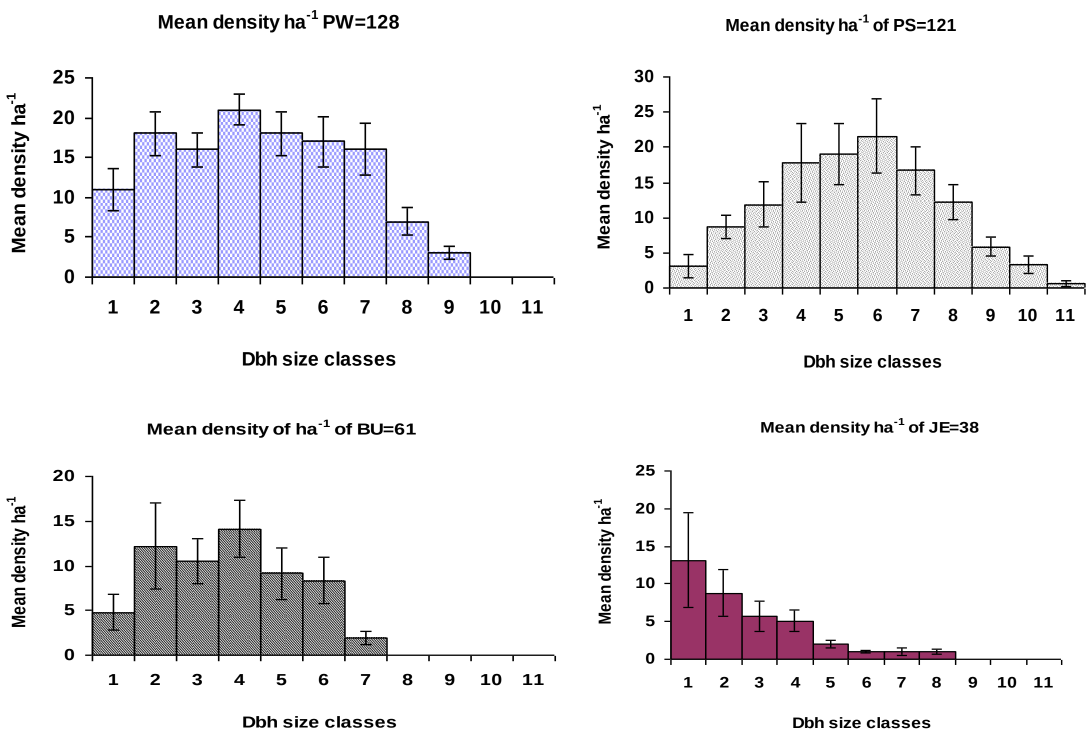

Fig. 1. Over all Dbh Size class Structure of dominant tree species of study area on the basis of density ha^{-1}. Size classes 1= 10.1-20 cm, 2= 20.1-30, 3= 30.1-40, 4=40.1-50, 5=50.1-60, 6=60.1-70,7=70.1-80, 9=80.1-90, 9=90.1-100, 10=100.1-110,11=110.1-120.

Wiebull distribution modeling

According to the overall DBH size classes of *Pinus wallichian, Picea smithiana, Betula utilis and Juniperus excelsa* derived applying the Cumulative frequency function of the three-parameter Weibull distribution are presented in (Fig. 2) while the calculated parameters are given in Table.1.The results show *Pinus wallichiana* distributed with the mean of 48, and standard deviation 115 and the observed data is fitted with the cumulative distribution with the Efficiency coefficient (R) and Efficiency coefficient (R) of calculated and observed data values X=(0.99996) *Peica smithiana* which has a low mean 60 with standard deviation 33 . The Efficiency coefficient (R) of calculated and observed cumulative frequency Y=(0.8933)and Efficiency coefficient (R) of calculated and observed data values X=(0.99999) .The overall size classes distribution of an angiospermic tree *Betula utilis* was recorded with mean 44 diameter at breast height with standard deviation 46.8. The value of Efficiency coefficient (R) of calculated and observed cumulative frequency was Y=(0.8539)and Efficiency coefficient (R) of calculated and observed data values X=(0.99996) .*Juniperus excelsa* recorded with a low mean 33 with 29 standard deviation compared to the other dominant species this species is distributed between the value of Efficiency coefficient (R) of calculated and observed cumulative frequency Y=(0.9271)and Efficiency coefficient (R) of calculated and observed data values X=(0.99999). Thus the Weibull model gave good fit for all tree species tested. Using parameter estimation methods the Weibull model was fitted to DBH of evergreen and Broad-leaf tree species in which DBH served as an independent variable of the diameter distribution of the natural unevenaged forests. The parameters of Weibull distribution differed with species of these parameters the most important is the shape parameters. In case of *Juniperus excelsa* the shape parameters is much lower (1.65) that reflect invers-J distribution. These models can be very handy for an effective management of forest resources.

Table 1. showing the statistical description of Weibull functions.

S.No	Spp Name	Mean Density ha^{-1}	S.E	a	b	c
1	*Pinus wallichiana*	128	21.7	0.5	-0.4	2.25
2	*Picea smithiana*	121	30.5	0.5	-0.5	2.5
3	*Betula utilis*	60	18.8	0.07	-0.1	7.79
4	*Juniperus excelsa*	38	14.3	0.64	-0.28	1.65

Note: Sp= Species, S.D= Standard Deviation, a= location, b= scale, c= shape parameters.

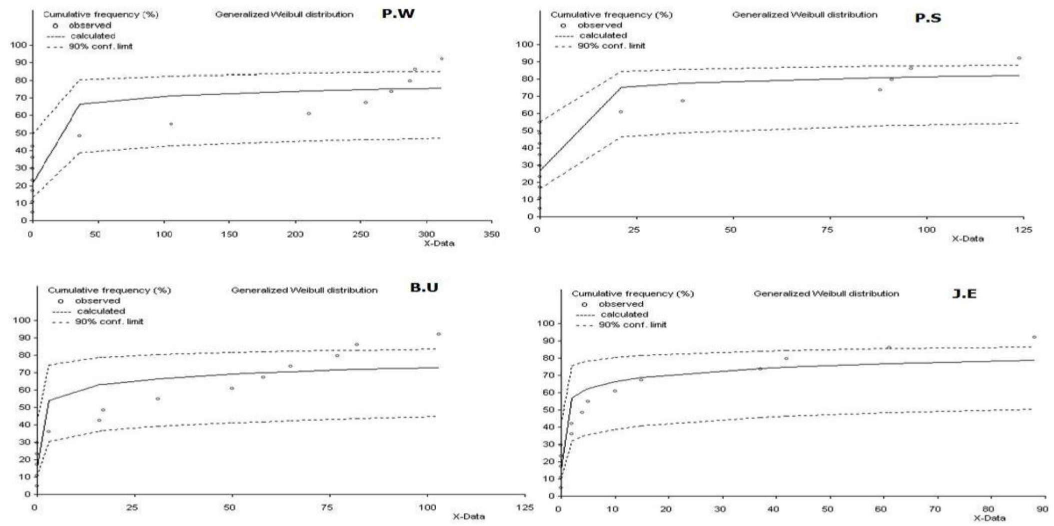

Fig. 2. Showing the Dbh Size classes of Dominant tee species using Weibull distribution fitting model.
Note: P.W= (*Pinus wallichiana*), P.S= (*Picea smithiana*), B.U= (*Betula utilis*), J.E= (*Juniperus excelsa*).

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