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Modeling the diameter distribution of gymnosperm species from central Karakoram National Park, Gilgit Baltistan, and Pakistan using weibull function

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Abstract

This investigation focuses on modeling the tree diameter distribution using Weibull function of three gymnosperm species, i.e. *Picea smithiana*, *Pinus wallichiana* and *Juniperus excelsa* dominating the forests of Central Karakoram National Park, Gilgit-Baltistan. Various workers have attempted to model the population structure of trees in their respective study areas. A number of probability distributions have been employed to find a good fit to the observed distributions. A number of recent studies have indicated the three parameter Weibull distribution as a possible model for describing the size class structure of trees. Thus, the Weibull model was selected to describe the diameter distribution of the three conifer tree species under study. The parameters for each tree distribution were estimated by a program CumFreq that employs the maximum likelihood method. The cumulative distributions of each tree species were tested against the fitted distribution. In all cases the Weibull distribution gave excellent fit to the observed data as indicated by high efficiency coefficient R. The result showed that the tested gymnosperm species are deteriorating due to anthropogenic disturbance. The lack of recruitments alarming for future sustainability of these forests. The possible implications of these models in the management of the respective forests are discussed.

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Introduction

Central Karakorum National Park is an important national park which is spread in three districts of Gilgit-Baltistan. The area of this national Park is 10000 sq.km. Due to unique flora and fauna it was declared as National Park in 1993. Some important gymnosperm tree species in the forest include *Picea smithiana*, *Pinus wallichiana* and *Juniperus excelsa* that are widely spread in this park. These species are very important and commonly found (2000-400m a.s.l) in the Karakoram Range of Pakistan. The entire area has been exposed to disturbance of natural and anthropogenic for many years. However, the density of the forests, due to the diversity in composition and nature structure of forest stands, makes stand-level models possible. Exploring the structure of these forests many researchers investigated the present status and future trend of these forests. Ahmed *et al*., (1990 a, b) described the status and population structure of *Juniperus excelsa* in Baluchistan. Ahmed *et al*., (1991) also worked on the vegetation structure and dynamics of *Pinus gerardiana* forest of Baluchistan. Malik (2005) studied with special reference to range conditions on the vegetation of Ganga Chotti and Bedori Hills District Bagh of Azad Jammu Kashmir. Ahemd *et al.,* (2006) also investigated the structure of different climatic zones of Pakistan. Other workers (Nafeesa,2007, Wahab, 2008, Ahmed *et al.,*2009, Khan, 2010, Siddiqui *et al.,* 2011), Hussain *et al.,* 2010,2011) and Akbar *et al.,* 2010, 2011) described the vegetation composition and structure of forests from different locations of Gilgit-Baltistan.

In this paper we developed and the statistical distribution model for tree diameter distribution using Weibull function which is introduced by Bailey and Dell (1973) to describe the distribution of forest. Many distribution functions, such as normal, gamma, Johnson's SB, Gram-Charlier, beta and Weibull, have been used in describing diameter distributions for forest stands (Von-Gadow, 1984; Borders *et al*., 1987) .Several researchers have reported Weibull function as the most suitable one to portray the diameter distributions (Bailey and Dell 1973, Von-Gadow, 1984; Borders *et al*., 1987). The reputation of the Weibull function is based on its relative simplicity and flexibility (Bailey and Dell, 1973. Kinerson *et al.,* (1974) fitted a nonlinear least squares model to cumulative crown class frequency data. The model gave a satisfactory fit to their data. The diameter distribution model can be used to obtain the distribution of trees into diameter classes. (Hyink and Moser, 1983). Diameter distribution is also used in the possible outcome of disturbances in the forests. (Hett and Louks, 1976: Denslow, 1995; Baker *et al.,* 2005; Cooms and Allen,2007). This function is also helpful to explore the structure development of forest (Goff and West, 1975; Poorter *et al*.,1996 and Zenner,2005.

In Pakistan, many researchers focused on phytosociology of the forest which are discussed above in detail while no such type of study has been conducted to explore diameter distribution in terms of probability distribution from the Central Karakoram National Park .The gymnosperm species of this important national park is deteriorating with the passage of time due to many natural and environmental causes. The improper management and lack of awareness is also responsible for the degrading of these forests. Therefore, this study is anticipated to play an important role in modeling diameter distribution and elsewhere in Pakistan. This type of modeling is widely used in forestry elsewhere to monitor the degrading forest and future consequences. Diameter distribution models are used to obtain an estimate of tree size distribution. This predicted distribution is needed for the further computation of forest volume characteristics and effective management of forests.

Materials and methods

Sampling method

This study was conducted during July 2010 to July 2012. For quantitative sampling, Point Centered Quarter Method of Cottam & Curtis (1956) was used. Twenty points were taken from each stand at 20

meter intervals. Absolute density/ha values of each stand were calculated according to the method described by Mueller –Dombois & Ellenberg (1974) and Ahmed and Shaukat (2012). Diameter at breast height (DBH) of each tree is divided into 10 cm interval classes.

Overall diameter of size class is also taken following by Ahmed (1984), Siddique (2011), Khan (2011) and Wahab (2011).

Weibull distribution

For diameter distribution and histograms CumFreq program was used with option of Weibull function .

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

$F(x) = 1\text{-}exp[-\{(x - a)/b\}^{c}]$

$0 \leq x < +\infty$

$a, b > 0$

Results and discussion

Overall diameter distribution of the gymnosperm species

Overall diameter distribution of *Picea smithiana, Pinus wallichiana* and *Juniperus excelsa* is shown in the Fig. 1. The dominant species *Picea smithiana* attained 92±20.67 mean density ha^{-1} while associated species *Juniperus excelsa* and *Pinus wallichiana* have 69±27.18 and 43±10.7 mean density ha^{-1} respectively. The plot of *Picea smithiana* is negatively skewed unimodal which shows that small classes have low frequency of recruitments while middle classes have abundant frequency which declined gradually. The diagram of *Pinus wallichiana* is unimodal platykurtic which shows that some small classes are totally absent while in the medium classes number of trees increasing, with the passage of time these trees are deteriorating in large classes. More or less similar situation is observed in *Juniperus excelsa*. This is not an ideal situation because this is the all over diameter distribution of these species, therefore it is concluded that the individual distribution of these species may have gaps in different classes. These species are in dangerous situation and may be vanished with the passage of time. Therefore a special attention is need to save this forest of important National Park.

The Weibull function

Cumulative distribution function (CDF) of *Picea smithiana, Pinus wallichiana* and *Juniperus excelsa* is shown in Figs. 2. In *Picea smithiana* average median was 15 while standard deviation is observed 21.01. The cumulative frequency attains 11.1 % with 0.8765 efficiency coefficient. Location (a), scale (b) and shape parameter (c) is recorded respectively 0.3183,-0.3183 and 3.28.The cumulative function of *Pinus wallichiana* shows that the average median was 3 with 9.95 standard deviation while the cumulative frequency is recorded 10.17 % with 0.5982 efficiency coefficient. The location (a), scale (b) and shape parameter (c) is obtained respectively 0.1505,-0.171 and 3.12. The CDF of *Juniperus excelsa* shows that the average median was 10 with the standard 20.10 while the cumulative frequency was 10.82 % with 0.8837 efficiency coefficient (Table 1).On the basis of the above results it is concluded that Weibull model gave a good fit for all three tree species examined. The Weibull model was found to be promising to diameter at breast height (DBH) of gymnosperm tree species in which DBH is an independent variable of the diameter distribution of the natural unevenaged forests. Kilkki *et al.,* (1989) demonstrated that very few stands variables in addition to those directly describing the diameter distribution have significance in the estimation of parameters of Weibull distribution. When applying any distribution it should be borne in mind that every measurement variable existing in the stand variable will accentuate in the estimates of distribution parameters and that

Weibull parameters estimates are no exception. This type of models can be very useful for the better management of the forests under study.

Table 1. The Weibull function parameters of three dominant conifer species of CKNP.

Species	M.D/ha	Median	S.D	E.C	Location(a)	Scale (b)	S.P (c)	C.F
PS	98±20.67	15	21.01	0.8765	0.3183	-0.378	3.28	11.1
PW	43±10.7	3	9.95	0.5982	0.1505	-0.171	3.12	10.17
JE	69±27.18	10	20.10	0.8837	0.2723	-0.357	3.71	10.82

Note: PS=*Picea smithiana*, PW= *Pinus wallichiana,* JE=*Juniperus excelsa*, M.D= Mean density/ha, S.D= Standard deviation, E.C=Efficiency coefficient, S.P= Shape parameter, C.F=Cumulative frequency.

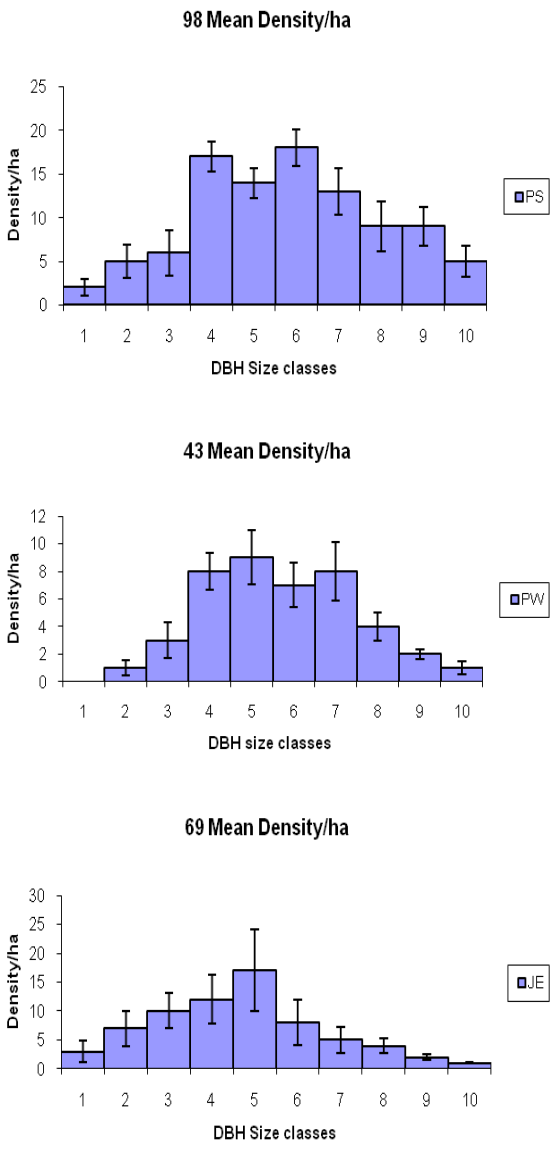

Fig. 1. Overall DBH size class structure of dominant conifer tree species on the basis of mean density/ha
Note: PS= *Picea smithiana,* PW= *Pinus wallichiana*, JE=*Juniperus excelsa*

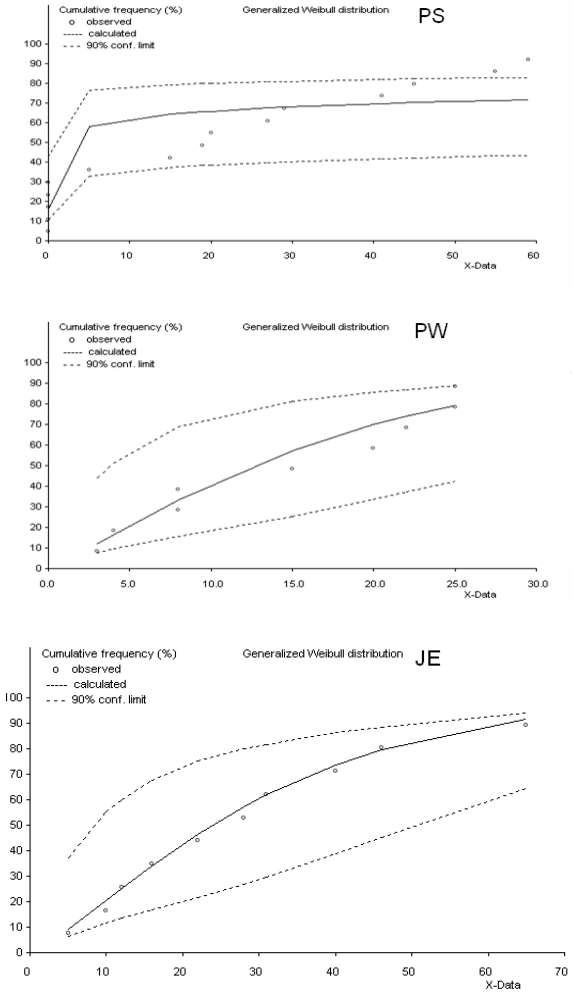

Fig.2. Generalized Weibull distribution models of dominant coniferous species
Note: PS= *Picea smithiana,* PW= *Pinus wallichiana*, JE=*Juniperus excelsa*

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