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# A Study of Tree Distribution in Diameter Classes in Natural Forests of Iran (Case Study: Liresara Forest)

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## ABSTRACT

Identification and estimation of quantitative characteristics of trees community are the initial requirements of forest planning. By applying common probability distributions, it is possible to predict the stand status in diameter class distribution. The aim of this study is providing the most appropriate model for *tree distribution in diameter classes in natural and uneven-aged forests. To obtain this purpose, a control plot which has grown with minimal interference was selected. At first, travel through the forest, a proper identification was obtained and considering that, this parcel consists of three separable stands, in each parcel a plot of one hectare was measured to study on selective sampling. One-hundred percent inventory was conducted in sample plots. Inventory started in welts, from down a slope to up, and then after identification of spices, all the trees having diameter more than 7.5 cm were measured for* the diameter at *breast height and were recorded in related forms. Data were analyzed, then the Normal, Lognormal, Exponential, Gamma, and Weibull distributions were fitted to diameter at breast height data. The results of Chi-square(* $\chi^2$*) and Kolmogorov-Smirnov (k-s) tests showed that only Lognormal distribution can determine the diameter distribution of trees, so it is appropriate.*

**Key words:** Distribution diameter of trees, Probability distribution, Liresara.

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## INTRODUCTION

The prediction of the diameter distribution of a stand is of great interest to forest managers, for the evaluation of forest resources and scheduling the future silvicultural treatment [1]. Diameter distribution and the related statistical model can play an important role in some forest science topics, including forestry and silvics, For example in some growth modeling, it is necessary to know the type of diameter distribution function and its parameters to identify the appropriate model [2].

Therefore, forest growth modeling has been an intrinsic part of forest management planning and research for more than two centuries. The majority of models operate at the stand-level and predict stand-level variables such as basal area or dominant height to provide information needed to estimate harvesting costs, expected yield, financial result, etc.

Diameter distributions can be used to indicate whether the density of smaller trees in a stand is sufficient to replace the current population of larger trees and to help evaluate potential forest sustainability [3].

Modeling the DBH distribution is usually a two-stage process: a probability density function (pdf) is fitted to the actual diameter distributions at the first stage, and then the pdf parameters are regressed against other, easily measured or a priori known stand attributes (parameter prediction method) [1].

A basic planning for natural resources requires qualitative and quantitative information, which usually obtain by measuring the characteristics of stands [4].

Correct management of forests is based on having accurate information about status of standing forest inventory and the types of spices. One of this basic information is the tree distribution in diameter classes, which allows the tree marker to interfere in stands more confidently to preserve the stand structure [5].

Namiranian (1990), studied the tree distribution in diameter classes in Gorazbon district of Kheyroudkenar forest. In this study, he used three Beta, Weibull and negative binomial distributions. Results of Chi-Square and Kolmogorov-Smirnov tests showed that Weibull and Beta distributions could determine diameter distribution of trees [6].

Mataji et al., (2000) in a study about tree distribution in diameter classes using probability distributions in uneven-aged stand in Gorazbon district of Kheyroudkenar forest and they fitted three Beta, Weibull and normal distributions. Results of tests showed that Weibull and Beta distributions can determine diameter distribution of trees, but the normal distribution cannot. In addition, the Beta distribution is more appropriate [5].

Fallah et al., (2000) investigated the structure of natural beech stands in Gorazbon district Kheyroudkenar forest of Noshahr. Models were tested, consisted of regression, Beta distribution, Weibull distribution, exponential model and power model. Among the tested models, first three were proved acceptable, especially regression model, because of the minimum value of chi-square ($\chi^2$) in the test was the best fitting and, thus suggested for planning and conducting beech stands in Kheyroudkenar forest [7].

Fallah et al., (2006) studied two Shastkalateh and Sangdeh districts to obtain an appropriate model for tree distribution in diameter classes in natural Caspian beech. Using statistical Beta and Weibull distributions, Mayer exponential, and power models, the points were assessed and their efficiency was evaluated by chi-square test. The results of these methods showed that the computed regression model was the best fitting, the power model in Shastkalateh and Sangdeh districts and the Beta distribution in Shastkalateh were fitted to that point cloud appropriately [8].

Mohammad Alizade et al., (2009) investigated the tree diameter at breast height in uneven-aged stands and fitting a statistical distribution to them. After preliminary analysis the three exponential distributions, Gamma and Lognormal were used for fitting to data. The results of tests shows that the exponential distribution cannot determine the diameter distribution of trees and between two other distribution, Gamma distribution is more appropriate for this purpose [2]. Nanang (1998) in a study of neem (*Azadirachta indica*) plantations in Ghana fitted the Normal, Lognormal and Weibull distributions to diameter distributions data. Weibull distribution parameters were assessed by three Maximum likelihood, Moment and Percentile methods. Among these methods, the Maximum likelihood and Moment predictions were close to estimates were obtained by an empirical method. Results of Kolmogorov-Smirnov test showed that in age-group estimation, lognormal distribution is suitable for fitting. In mixed age group, Weibull distribution with Moment method is appropriate, but Normal distribution cannot describe the data appropriately [9]. Nord- Larson and Cao (2006) had a study to develop a diameter distribution model for even-aged stands of European beech in Denmark using the Weibull distribution. Parameters of the model were estimated by fitting the cumulative density function using a non-linear least squares procedure. The data of this study were gathered from permanent sample plots. Care should be taken when the model is applied to young stands (<40 years) [10].

Bullock.B.P & Boone.E.L (2007)studied diameter distributions of loblolly pine trees (*Pinus taeda L.*) in both Virginia and North California. They studied Normal, Gamma, Weibull and Beta distributions for fitting data, and they found that sometimes it happens that none of distributions is appropriate for all ages, like their study, so in that situation the Bayesian Model, averaging distribution, is appropriate [11].

## MATERIALS AND METHODS

Forestry project of Liresara with the name of “series 6” has located in watershed No.45 in north forest of Iran. The area has located in longitude 51° 33' 2" to 54° 29' 51" and latitude 36° 33' 29" to 36° 37' 20" and the minimum height above sea level in this series is about 70 m and the maximum is about 632 m. Total area of this series is 2058 ha. Since there is no forest operation in control plot, it was selected as an area without any interference. The parcel 12 of this series is “Lubon” forest with the area of 64.5 ha.

After forest travel in control parcel (parcel 12), three sample plots were selected in size 100 × 100 m. It is worth to say that in selecting sample plots in forest , the characteristics like uneven age (trees in all diameter and height classes) were important and also status of standing forest inventory and general conditions were considered to be optimal [8].

One-hundred percent inventory was conducted in sample plots. Inventory started in welts, from down a slope to up, and then after identification of spices and their locations, all the trees having diameter more than 7.5 cm were measured the diameter at breast height by Caliper to a precision of millimeters and were recorded in related forms.

Data were analyzed by software SPSS and STATGRAPHIC. Descriptive statistics such as mean, median, standard deviation and range changes were calculated and histograms were drawn.

In this study, the exponential distribution (single parameter), gamma (two parameters), log normal (two parameters), and Weibull were used for the diameter at breast height, and their values were estimated.

For goodness of fit, the goodness of fit tests and graphical methods were used. Among them, the two chi-square and Kolmogorov - Smirnov tests are very common [2] so well in this study, the above two tests were employed.

## RESULTS

**Descriptive Statistics**
The results shows the diameter at breast height data with mean 31.93, standard deviation 18.4 and standard error 0.61, and it has been distributed between the two values 7.5 and 120.

Diagram of distribution in diameter classes shows that the stand is in uneven-aged and reducing age classes. Considering the high range of diameter classes and the decrease in graph of distribution in diameter classes, it can be said that the studied stand is an uneven-aged and erratic stand.

**Parameter Estimation**
Estimated values of the parameters associated with Weibull, exponential, gamma, lognormal and normal distributions are presented in Table 1.

All investigated distributions in this study are from continuous probability distributions. Normal distribution is one of them, which is described by its mean vector and covariance matrix. The mean value and standard deviation of diameter at breast height in this region estimated 18.39 and 31.93 respectively (Fig. 1 A).

Lognormal distribution, a distribution that its natural logarithm has the normal distribution with parameters $\mu$ and $\delta$, and their values of diameter at breast height in this region are 32.07 and 19.77 respectively (Fig. 1 B).

Gamma Distribution is another continuous probability distribution and has two scale parameters $\theta$ and shape parameter k. The values of these parameters for diameter at breast height are 0.1049 and 3.35. (Fig 1 C)

Exponential distribution is a distribution with the parameter $\lambda$; this parameter is the inverse mean of distribution (Mathematical Expectation). Exponential distribution is a special type of gamma distribution with shape parameter $k = 1$ and scale parameter $\theta = 1/\lambda$, and its value in this study is 31.93, Which is, in fact, the average estimate (Fig 1 D).

Weibull distribution is another continuous distribution with shape parameter k and scale parameter $\theta$, and their values for diameter at breast height in this region are 1.86 and 36.16 respectively. (Fig. 1 E).

## Goodness of fit

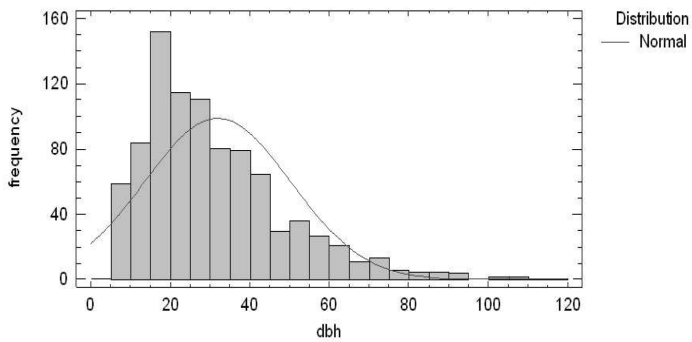
For study the goodness of fit and choosing the best distribution, two Chi-Square and Kolmogorov-Smirnov tests were used. Results of tests are presented in Table 2. They show that only lognormal distribution can determine the distribution of diameter at breast height data.

Based on the results of chi-square test of all distributions, given that all values are less than one percent, the null hypothesis, following these tests is rejected with a probability of 99%. According to Kolmogorov-Smirnov test, the null hypothesis is rejected for normal, gamma, exponential and Weibull distribution with a probability of 99%, and only lognormal distribution is accepted.

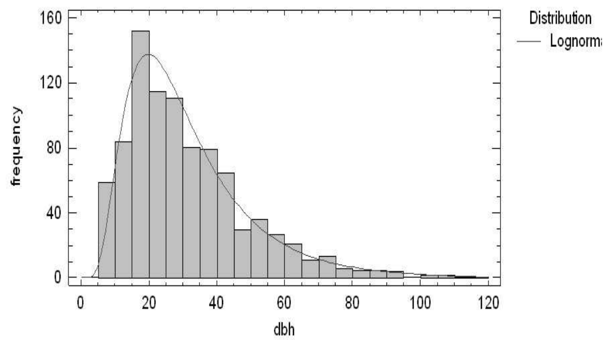
Point cloud via distribution of diameter classes in five models of normal, log normal, gamma, exponential and Weibull shows that lognormal distribution makes an appropriate fitting in distribution points (Fig. 1 F)

**Table1-Parameters of the tests for goodness of fit**

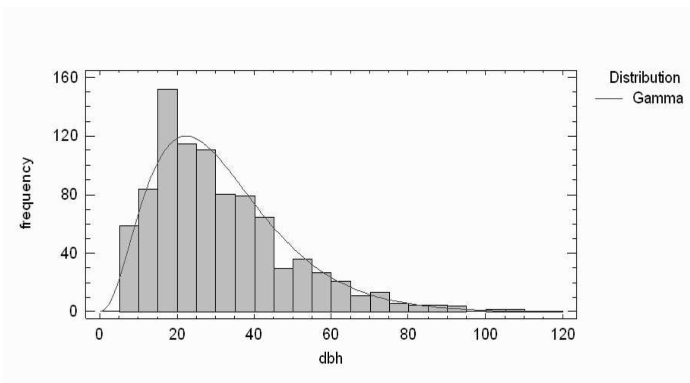
| Normal | Lognormal | Gamma | Exponential | Weibull |
|---|---|---|---|---|
| μ=31.9303<br>s.d = 18.3973 | μ=32.0738<br>s.d = 19.7706 | shape = 3.35145<br>scale = 0.104962 | mean = 31.9303 | shape = 1.86266<br>scale = 36.1634 |
| | | Log scale: mean = 3.30701<br>Log scale: std. dev. = 0.5675 | | |



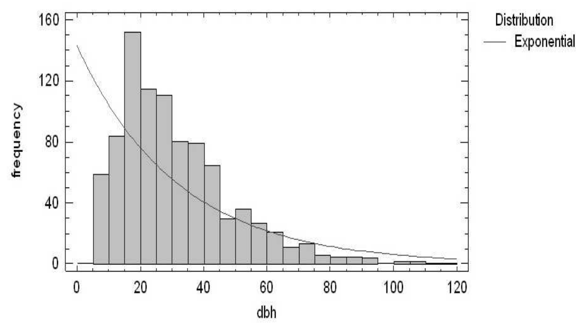

**(A)**



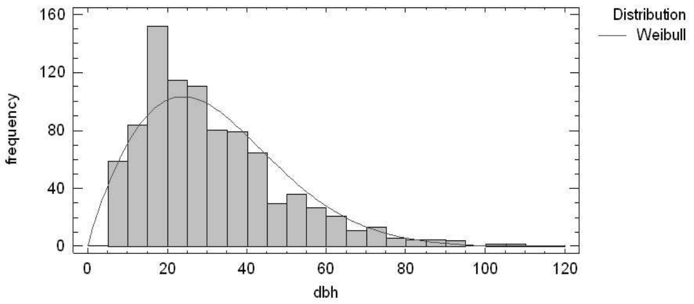

**(B)**

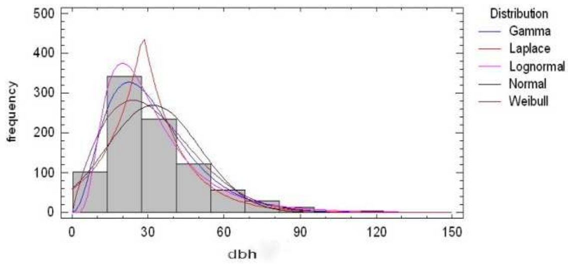



**(C)**




**(D)**




**(E)** **(F)**

**Dbh (diameter at breast height) classes, cm**

**Fig.1. Histograms (A) Normal (B) lognormal (C) Gamma (D) Exponential (E) Weibull diameter distribution models (F) all of them together**

**Table2-Results of the tests for goodness of fit**

| | Normal | Lognormal | Gamma | Exponential | Weibull |
|---|---|---|---|---|---|
| Kolmogorov-Smirnov | 3.53033 | 1.11594 | 1.66387 | 7.33182 | 2.09154 |
| P value | <0.01 | 0.169162 | 0.0082407 | <0.01 | 0.000340625 |
| Chi-Square | 292.776 | 42.3202 | 45.5008 | 404.795 | 88.6922 |
| P value | <0.01 | 0.00160419 | 0.000205013 | <0.01 | <0.01 |

## CONCLUSION

There is an unevenness of age in this stand studied. Since there were no interference in control plot, The unevenness of age is made by nature. So estimation of tree distribution in diameter classes can be used as a model to manage other stands in uneven-aged high forests in this district [8].

Using appropriate probability theories to predict trees distribution in a forest stand is important in estimation of productivity in different ages. In addition, it is useful in planning for thinning out in forests and it would guarantee a productive economic, optimized biologic and stable stands.

In addition to histograms as a graphic tool, the main mathematical tools used to study the diameter distribution of trees are statistical distributions [2]. Results show that among studied distributions, only lognormal distribution can determine the diameter distribution of trees and the result of goodness of fit test confirms it. So it can be used as a pattern in order to planning and scheduling for stands in this region to establish stable and resistant forests with maximum biological production. According to this study and other studies in this area, it can be concluded that the probability distributions are applied to estimate the diameter distribution, and statistical methods are used to provide diameter distribution models.

Namiranian Studies (1990), Mataji et al., (2000), in Gorazbon district of Kheyroudkenar forest in Noshahr show that the Weibull and Beta distributions are appropriate to fit diameter at breast height data in this area [5 & 6].

Mohammadalizadeh et al, (2009) in Gorazbon district studied Gamma distribution with other distributions and concluded that the gamma distribution in compare with the rest distributions has more ability to determine the diameter at breast height distribution [2].

In another study, Fallah et al (2006) investigated the beech stands in the same district. They concluded that regression distribution can determine the diameter distribution of trees [8]. Fallah et al (2006), did this study in other regions and the results were different [8].

Study on diameter structures of uneven-aged stands using statistical methods in Iran is just in the beginning. So according to few studies in Iran, different results and different habitat conditions, cannot be properly compared. Since the results in Gorazbon are closer and there is more complete and accurate data as more studies in this area, it can be concluded that these differences could be due to different structures of stands and habitat conditions. Therefore, it is worthy to study the performance of different diameter distribution models in other areas, and further study is needed to attain the desired results.

Comparing the results of this study with other countries studies is not eligible, because the most studies have done on needle-shaped leaves and even-aged stands. But totally it can be concluded from these studies that the statistical distributions can describe and determine the diameter distribution and all of these studies have done in uneven-aged stands with the decrease in the graph. It seems that finding an appropriate model of uneven-aged structure in a forest differs in regards to conditions and habitat features of that forest, and selected statistical distribution can be used only for that studied area.

Diameter at breast height is one of the most important and most applied bioassay variables in forest trees, so it should be studied. Frequency distribution or Diameter distribution is a new subject, and a few studies have done in Iran. This study not only is applied in determining the diameter structure of stand or forest, but it is used in growth modeling. Further and more comprehensive study in this area is recommended. More studies are needed to achieve more applied results.

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