Parameter Estimation of Weibull Growth Models in Forestry

Dimpal Jyoti Mahanta[1] and Munindra Borah[2]

Department of mathematical sciences, Tezpur University, Napaam, Tezpur, Assam, India, PIN 784001.

Abstract—The main aim of this paper is to discuss some certain properties of three Weibull growth models in forestry viewpoint. The parameters of these models are estimated using Newton-Raphson iteration method for the mean diameter at breast height data and top height growth data originated from the Bowmont Norway spruce thinning experiment, sample plot 3661. The average height of 12 weeping Higan Cherry trees planted in Washington, D.C. is also used. The initial value specifications of the parameters for use of any iterative methods of estimation are also provided.

Key words— Initial value, Parameter estimation, Weibull model, Newton-Raphson method, Growth model, derivative, Mathematical Properties.

I.   Introduction

The Weibull model was first introduced by Ernst Hjalmar Waloddi Weibull in 1951. Initially it was described as a statistical distribution. It has many applications in population growth, agricultural growth, height growth and is also used to describe survival in cases of injury or disease or in population dynamic studies [7]. In 1997, Lianjun Zhang [13] used this model to describe tree height-diameter data of ten conifer species. In the paper by Eckedulegn et al. [6] used this model for the top height data of Norway spruce from the Bowmont Norway spruce Thinning Experiment. Colbert et al. [1] have tried to define some character developments such as forest trees height growth and diameter development by using the model. The paper by Karadavut et al. [8] used the model to evaluate the relative growth rate of silage corn. Ozel and ertekin in 2011 [10] studied the Weibull growth model and applied it to the oriental beach Juvenilities growth. Weibull model is also used to study the height growth of Pinus radiate by Colff and Kimberley in 2013 [2]. Lumbres et al. [9] used this model to describe the diameter at breast height of Pinus Kesiya.

The Weibull growth model can be derived from the one parameter Weibull distribution function, which is given by

$$F(x) = 1 - exp(-x^\delta) \; ; x > 0, \tag{1}$$

where $\delta > 0$ is a shape parameter. The distribution function has the point of inflection at $x = [(\delta - 1)/\delta]^{\frac{1}{\delta}}$ and $F = 1 - exp(-(1 - \delta^{-1}))$. Then the eq. (2) can be used to get a sigmoidal growth curve for empirical use [12].

$$f(x) = \beta + (\alpha - \beta)F(kx; \theta) \tag{2}$$

For the Weibull distribution,

$$f(x) = \alpha - (\alpha - \beta)exp(-(kx)^\delta). \tag{3}$$

The form of the model (3) is the model that David Ratkowsky [11] calls the Weibull model. The equation (3) can also be written as,

$$w(t) = a - b \, exp(-ct^m). \tag{4}$$

Where $a = \alpha$, $b = \alpha - \beta$, $c = k^\delta$ and $m = \delta$. For this study, the model (4) will be considered as the Weibull model with four parameters. Philippe Grosjean [7] used a three parameter Weibull model with considering $\beta = 0$ in eq. (3), which is given in eq. (5). This eq. gives the Weibull model with three parameters.

$$w(t) = a(1 - exp(-ct^m)) \tag{5}$$

In 2000, Alistair Duncan Macgregor Dove [3] used a two parameters Weibull model to investigate parasite richness of nine species of fishes. He used

$$w(t) = a(1 - exp(-ct)). \tag{6}$$

This model can be derived from the Weibull model with three parameters by considering $m = 1$ to the eq. (5). Dove also defines the parameters of the model (6) for parasite richness of fishes as a is the maximum regional fauna richness and c is an index of the mean infracommunity richness.

The properties and the derivations of the Weibull models play a crucial rule for estimating the parameters. Proper understanding of the mathematics of these models avoids problems encountered in the method of parameter estimations of the models. This paper provided the most fundamental properties and careful observations of the first and second derivatives of the models. This paper also provides some useful definition of the parameters for initial estimates of the Weibull models, which is also a major requirement for estimating the parameters using any iteration method. Three well-known Forestry data sets are considered to estimate the parameters of these models.

II.   Material and methods

The growth models considered for this study are Weibull model with two parameters (6), Weibull model with three parameters (5) and Weibull model with four parameters (4). For these three models consider, w is the dependent growth variable, t is the independent variable, a, b, c and m are parameters to be estimated, log is the natural logarithm and $exp(e)$ is the base of the natural logarithm. The properties of

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Theoriae causalitatis principia mathematica Ilija Barukcic,2025-01-06 Dive into a treasure trove of knowledge with over 1 332 equations 34 detailed figures and 81 comprehensive tables Perfect for students researchers and enthusiasts seeking clarity and precision This book is your definitive guide to mastering the subject of causality *P and R Order of Plithogenic Neutrosophic Cubic sets* S.P. Priyadharshini,F. Nirmala Irudayam,2021-12-01 The paper presents a new concept called P Order Union and Intersection and R Order Union and Intersection of the Plithogenic Neutrosophic Cubic Sets PNCS We derived some of the primary properties of the internal and external PNCS of P and R Order We also proved that P Union and P intersection of Truth T resp falsity F indeterminacy I external PNCS may not be T resp F I external PNCS and R Union and R intersection of T resp F I internal PNCS may not be T resp F I internal PNCS with the numerical examples This principle is extremely appropriate for analyzing problems that involve multi attribute decision making since this PNCS is defined by many values of attribute and the reliability of the data is also so accurate Collected Papers. Volume X Florentin Smarandache,2022-06-01 This tenth volume of Collected Papers includes 86 papers in English and Spanish languages comprising 972 pages written between 2014 2022 by the author alone or in collaboration with the following 105 co authors alphabetically ordered from 26 countries Abu Su an Ali Hassan Ali Safaa Sadiq Anirudha Ghosh Assia Bakali Atiqe Ur Rahman Laura Bogdan Willem K M Brauers Erick Gonz lez Caballero Fausto Cavallaro Gavril Calefariu T Chalapathi Victor Christianto Mihaela Colhon Sergiu Boris Cononovici Mamoni Dhar Irfan Deli Rebeca Escobar Jara Alexandru Gal N Gandotra Sudipta Gayen Vassilis C Gerogiannis Noel Batista Hern ndez Hongnian Yu Hongbo Wang Mihaiela Iliescu F Nirmala Irudayam Sripati Jha Darjan Karaba evi T Katican Bakhtawar Ali Khan Hina Khan Volodymyr Krasnoholovets R Kiran Kumar Manoranjan Kumar Singh Ranjan Kumar M Lathamaheswari Yasar Mahmood Nivetha Martin Adrian M rgean Octavian Melinte Mingcong Deng Marcel Migdalovici Monika Moga Sana Moin Mohamed Abdel Basset Mohamed Elhoseny Rehab Mohamed Mohamed Talea Kalyan Mondal Muhammad Aslam Muhammad Aslam Malik Muhammad Ihsan Muhammad Naveed Jafar Muhammad Rayees Ahmad Muhammad Saeed Muhammad Saqlain Muhammad Shabir Mujahid Abbas Mumtaz Ali Radu I Munteanu Ghulam Murtaza Munazza Naz Tahsin Oner Gabrijela Popovi Surapati Pramanik R Priya S P Priyadharshini Midha Qayyum Quang Thinh Bui Shazia Rana Akbara Rezaei Jes s Estupi n Ricardo R dvan Sahin Saeeda Mirvakili Said Broumi A A Salama Flavius Aurelian S rbu Ganeshsree Selvachandran Javid Shabbir Shio Gai Quek Son Hoang Le Florentin Smarandache Dragi a Stanujki S Sudha Taha Yasin Ozturk Zaigham Tahir The Houw Iong Ayse Topal Alptekin Uluta Maikel Yelandi Leyva V zquez Rizha Vitania Luige Vl d reanu Victor Vl d reanu tefan Vl du escu J Vimala Dan Valeriu Voinea Adem Yolcu Yongfei Feng Abd El Nasser H Zaied Edmundas Kazimieras Zavadskas **Neutrosophic Sets and Systems, Vol. 47, 2021** Florentin Smarandache,Mohamed Abdel-Basser,Said Broumi,2021-12-30 Papers on neutrosophic statistics neutrosophic probability plithogenic set paradoxism neutrosophic set NeutroAlgebra etc and their applications

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