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Construction of Yield Prediction Model for Casuarina tree crops in Cuddalore District

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Abstract

The potential of multipurpose tree species in enhancing the diversity, sustainability and productivity of marginal ecosystem has received increased attention in recent years. This besides choice of alternative tree species to meet the raw material requirement of industries is the need of the hour. Casuarina species have been the farmer's favorite as they fit well in agrarian ecosystem. Casuarina is a major tree crop cultivated in Cuddalore district since from 1996. Construction of yield prediction model for fast growing and high yielding Casuarina species would help the farming community to easily predict the yield. This study has been designed to derive the yield prediction model for Casuarina grown in Cuddalore districts, based on the predicting ability and coefficient of determination (R^2) value, the validity of different models were tested in the curve expert software and it was found that Polynomial growth model ($y = cx^2+bx + a$) was best fitted for the present study. Different Polynomial equations were derived based on the spacing and different plant sources like Casuarina and Casuarina hybrid. The R^2 varied from0.933 to 0.995. Regarding the prediction of diameter at breast height (dbh) and height of Casuarina at 1 M spacing was $y = 0.058x^2+0494x+2.488$ and $y =0.027x^2+0.857x+1.810$ respectively. Regarding the prediction of diameter at breast height (dbh) and height of Casuarina at 1.5 M spacing was $y = 0.011x^2 + 1.445x + 1.361$ and $y = 0.023x^2 + 1.079x + 1.674$ respectively.

Key words: multipurpose tree, Casuarina, Polynomial growth model, yield prediction

Introduction

Casuarina species cultivation has steadily increased in private land due its multipurpose use such as fuel wood, making scaf - folds, rafts for barricades & sheds, pulp wood etc. Due to its high calorific value (4127 cal) it is primarily used as fuel wood, cones are used for firing clay wares in kilns, the wood is used for making scaf-folds, rafts for barricades and pulpwood purposes. Realizing the multi various use, many farmers are going for cultivating Casuarina species in their fields. The Casuarina cultivation is being encouraged by the Tamil Nadu Forest Department through schemes like Tree Cultivation in Private Lands and Emergency Tsunami Reconstruction Project, for paper making industries like TNPL, Seshasayee paper mills. Systematic efforts to test the yield prediction models for selected individuals of *Casuarina*. This study is designed to construct the yield prediction model for Casuarina plantations in Cuddalore district.

Materials and methods

Species under study

Casuarina, genus of the Casuarinaceae, consists of 96 species with four genera (Allocasuarina: 59 spp, Casuarina: 17 spp, Ceuthostoma: 2 spp and Gymnostoma: 18 species) (Johnson, 1980). They are found naturally in Australia and parts of Asia and Oceania. Only a few species are extensively planted even outside their natural range; others are little known, but have attributes that suggest they could be more widely utilized to improve the well being of people in developing countries. (Turnbull, 1990) Casuarina occur in a wide range of habitats, from rain forest to desert, from sea shore to high mountains and from cool temperate regions to the hot humid tropics. They have modest site requirements and most are rapid-growing trees. Many are salt tolerant, others are especially wind firm, and all seem adaptable to poor soils. Casuarina equisetifolia was introduced into Madras State in 1860 to fuel steam-locomotives. Villagers then spread it along the coasts of the Indian peninsula, especially on the eastern

coast. Later, farmers started planting it around their fields and homes (Raghavan, 1947).

Location

The data on Casuarina cultivation in Cuddalore district was collected from crop season report since from 1996 to 2013. The total geographical area of the district is 367781Ha.

Weather and climate

The mean annual rainfall of the region is 1310 mm, distributed over 80rainy days with North East monsoon contributing 80 per cent, South west monsoon contributing 10 per cent and summer showers 10 per cent of the total rainfall. The mean maximum and minimum temperatures are 34.5°C and 22.0°C, respectively.

Methodology

The investigations were varied out in the field locations located at cuddalore district during Jan 2014 to Dec 2014. the district is stratified in to taluk wise, year of plantation and village. Random samples were identified in order to represent the taluk and year of plantation. The actual field survey involved enumeration for survival and determination of growth attributes (height, diameter and volume) were carried out adopting random stratified linear sampling techniques.

Sampling techniques

The sampling intensity of 5 % was followed in all cases there by all area represents fully.

Survival percentage

The survival percentage of field was estimated by calculating the ratio between the number of plants survived and the total number of plants observed and expressed in percentage

$$\text{Survival Percentage} = \frac{\text{Number of plants survived}}{\text{Number of plants observed}}$$

Biometric observations

Biometric observations of height and diameter were recorded in different age groups from 6 Months After Planting (MAP), 12 MAP, 18 MAP, 24 MAP, 30 MAP, 36 MAP and 42 MAP.

Tree height

Regarding the height measurement, the total height of each tree was initially measured by using manually prepared tree scale after one year digital clinometers were used. The height was expressed in meters.

Plant basal diameter

The basal diameter was measured at 15 cm above ground at 6 MAP and after one year it was recorded as diameter at breast height (dbh) at 1.37 m by using digital calipers and is expressed in cm. The diameter of the trees recorded quarterly and mean diameter was calculated and given in the tables.

Volume

It was calculated using the following formula and expressed in m^3.

$$V = D^2h \times F_f$$

Where, D = Diameter at breast height

h = Total height of the tree

F_f = Form factor (0.6) (Chaturvedi and Khanna, 2000)

(F_f = Varies with species to species)

Development of yield prediction growth Model

Various tree growth models viz., Linear, Exponential, Logistic, Gompertz, Champman- Richards, Slodaba and Weibull were tried to derive the growth function of by using easily measureable and keen variables (dbh and volume) (Prasad and Rawat. 1992; Ajit *et.al.*, 2000). Based on the predicting ability and co efficient of determinations (R^2) value, the validity of the different models was tested for suitability of model.

Statistical analysis

The recorded value of biometric observations, biomass estimation and soil analysis were subjected to analysis of variance, following Panse and Sukhatme (1967).

Results and Discussions

Establishment of Yield Prediction Model for Casuarina

With respect to the height of the Casuarina species, the maximum height was recorded by Casuarina hybrid (10.27 m) at 1.5 m spacing on 42 MAP. The least was recorded by Casuarina (9.23 m) at 1m spacing on 42 MAP. Regarding the tree diameter of the Casuarina species, the maximum diameter was recorded by Casuarina (12.05 cm) at 1.5 m spacing on 42 MAP. The least was recorded by Casuarina (9.12 cm) at 1m spacing on 42 MAP. (Table 1)

Table 1. Tree growth rate at different age of Casuarina tree

Sl.No	Species	6 MAP	12 MAP	18 MAP	24 MAP	30 MAP	36 MAP	42 MAP
		Tree Diameter in Cm at Spacing 1 M x 1 M						
1.	Casuarina	2.88	3.76	4.81	5.50	6.23	7.15	9.12
2.	Casuarina Hybrid	1.92	2.88	3.92	5.23	6.24	7.34	9.30
		Tree Diameter in Cm at Spacing 1.5 M x 1.5 M						
3.	Casuarina	3.02	4.22	5.13	7.80	9.26	10.12	12.05
4.	Casuarina Hybrid	1.96	2.96	5.01	7.74	9.28	10.25	11.95
		Tree Height in M at Spacing 1 M x 1 M						
5.	Casuarina	2.68	3.66	4.63	5.67	6.89	7.80	9.23
6.	Casuarina Hybrid	1.99	2.70	3.91	5.81	7.10	8.05	9.42
		Tree Height in M at Spacing 1.5 M x 1.5 M						
7.	Casuarina	2.92	3.92	4.84	6.10	8.07	9.23	10.10
8.	Casuarina Hybrid	1.95	3.21	4.19	6.25	8.24	9.28	10.27

MAP- Months After Planting

Among the different spacing and plant sources viz Casuarina and Casuarina hybrid various tree growth models viz., Linear, Exponential, Logistic, Gompertz, Champman- Richards and Weibull were tried to derive the growth function of dbh and height. Based on the predicting ability and co efficient of determination (R^2) value, the validity of different models were tested and it was found that Polynomial growth model ($y = cx^2+bx + a$) was the best fitted for the present study. Different polynomial equations were derived based on the spacing and different plant sources. The R^2 varied from0.933 to 0.995. (Table.2). By using the polynomial growth model, the dbh (cm) and height (m) of Casuarina tree was predicted at time of rotation (42 MAP) then using this predicted dbh (cm) and height (m) we calculated the volume of the tree and then yield of Casuarina plantations. (Table 4 & 5)

Table. 2. Polynomial Equations for prediction of tree height in Casuarina Plantations

Sl.No	*Casuarina*	
	Spacing 1 m x 1 m	Spacing 1.5 m x 1.5 m
1.	$y = 0.027x^2 + 0.857x + 1.810$ ($R^2 = 0.998$)	$y = 0.023x^2 + 1.079x + 1.674$ ($R^2 = 0.989$)
	***Casuarina* Hybrid**	
	Spacing 1 m x 1 m	Spacing 1.5 m x 1.5 m
1.	$y = 0.009x^2 + 1.218x + 0.508$ ($R^2 = 0.991$)	$y = -0.014x^2 + 1.582x + 0.149$ ($R^2 = 0.987$)

Where, x = time (1= 6 Months, 2= 12 Months, 3= 18 Months, …..7= 42 Months) y = Height of the tree (M)

Table. 3. Polynomial Equations for prediction of tree diameter at breast height (dbh) in Casuarina Plantations

Sl.No	*Casuarina*	
	Spacing 1 m x 1 m	Spacing 1.5 m x 1.5 m
1.	$y = 0.058x^2 + 0.494x + 2.488$ $R^2 = 0.983$	$y = 0.011x^2 + 1.445x + 1.361$ $R^2 = 0.985$
	***Casuarina* Hybrid**	
	Spacing 1 m x 1 m	Spacing 1.5 m x 1.5 m
1.	$y = 0.056x^2 + 0.743x + 1.167$ $R^2 = 0.995$	$y = -0.050x^2 + 2.149x - 0.561$ $R^2 = 0.986$

x = time (1= 6 Months, 2= 12 Months, 3= 18 Months, …..7= 42 Months)

y = diameter at breast height of the tree (Cm)

Table 4 . Yield prediction for Casuarina plantation at the time of rotation (42 Months)

Sl.No	Spacing 1 m x 1 m				Spacing 1.5 m X 1.5 m			
	Height (M)	dbh (Cm)	Utilizable wood (Kg tree^{-1})	Approximate Yield (MT ha^{-1})	Height (M)	dbh (cm)	Utilizable wood (Kg tree^{-1})	Approximate Yield (MT ha^{-1})
1.	9.23	9.12	24.2	240	10.10	12.05	45.85	183.45

Table 5. Yield prediction for Casuarina Hybrid plantation at the time of rotation (42 Months)

Sl.No	Spacing 1 m x 1 m				Spacing 1.5 m X 1.5 m			
	Height (M)	dbh (Cm)	Utilizable wood (Kg tree^{-1})	Approximate Yield (MT ha^{-1})	Height (M)	dbh (cm)	Utilizable wood (Kg tree^{-1})	Approximate Yield (MT ha^{-1})
1.	9.42	9.30	25.5	250	10.27	11.95	46.01	184.05

By using the polynomial growth model, the highest predicted yield of 250 MT ha^{-1} was recorded at spacing (1 m x1 m) with Casuarina hybrid at the end of 42nd month. This was on par with 240 MT ha^{-1} of spacing (1 m x 1 m) with Casuarina Similar finding was also stated by Lugo *et al.* (1990) that in *C. equisetifolia*, AGB at the end of 1st year of growth was 13.6 t/ha and it increased to 199.7 t/ha at the age of 5 years.

Jain alaudeen (2011) revealed that in a well maintained Casuarina plantation where fertilizers were also applied the yield goes up to 70 to 90 tonnes per acre in a 4 years rotation. Venkatesan and Srimathi, (1989) reported that in Tamil Nadu, *C. equisetifolia,* at age of 4 years produces 60 to 80 t ha^{-1} under dry conditions and 80 to 200 t ha^{-1} under irrigated conditions. Jinedra Kumar Jain and Murali Moahan, (2010) reported that the yield was doubled with Casuarina hybrid clones reaching up to 130-160 t/ha at 4 years than seed based Casuarina. The Casuarina plantations with irrigation and fertilizer application yielded air dried wood of 100 to 150 t ha^{-1} (40 to 60 tonnes $acre^{-1}$) in 4 years rotation period under 1m x 1m spacing (Nicodemus 2009).

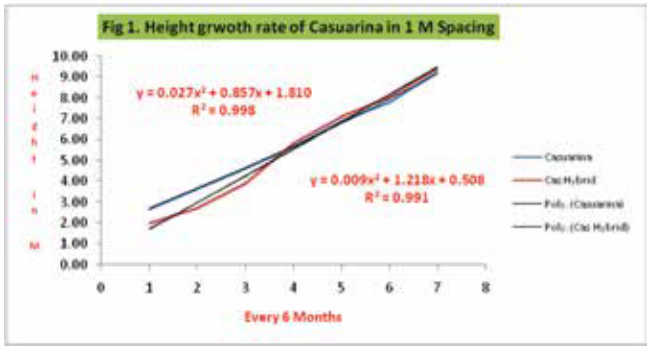
Similar growth models were also derived by Ping Zhou *et.al* (2010) developed biomass prediction model for *Casuarina equisetifolia* that regression analysis was used to build the model, a total of 10 model equations were made based on the field measurements and biomass estimates. The correlation (R^2) ranged from 0.664 to 0.994. Khan *et al*. (1993) also derived the linear equations for predicting the timber and total wood volume of *Hardwickia binata*, against DBH, two regression models were also computed for *Pinus caribaea* plantations

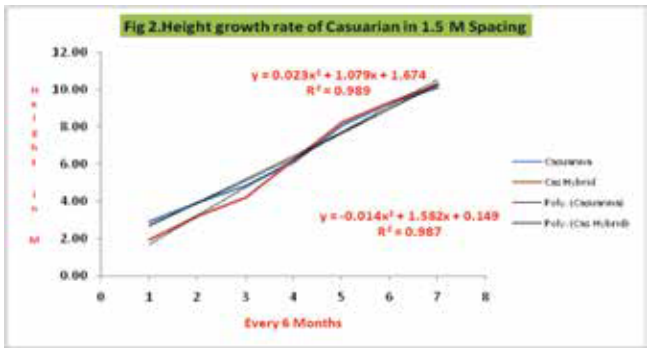
A linear (empirical model) models for the assessment of timber volume of young *Eucalyptus tereticornis* (Ajit *et al*., 2000); *Eucalyptus* hybrid (Chaturvedi and Khanna, 1982) were also been developed by various scientist.

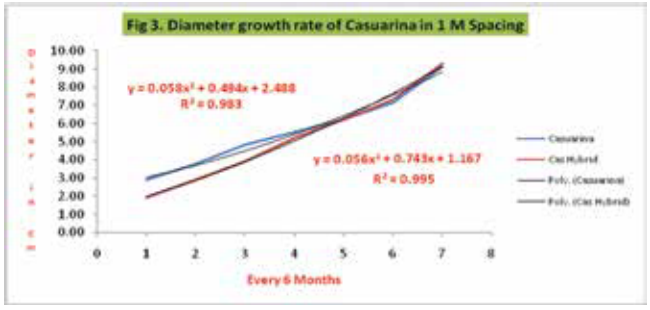
Linear regression volume equations have been fitted to sample tree data and used to drive volume tables for *Gmelina arborea* in India (Sharma and Jain, 1977); Malaysia (Freezaillah and Sandrasegaran, 1996; Sandrasegaran, 1973) and Nigeria (Greaves, 1978; Okojie, 1976). Under the present studies site specific polynomial models have been derived the predicted yield of Casuarina and Casuarina hybrid.

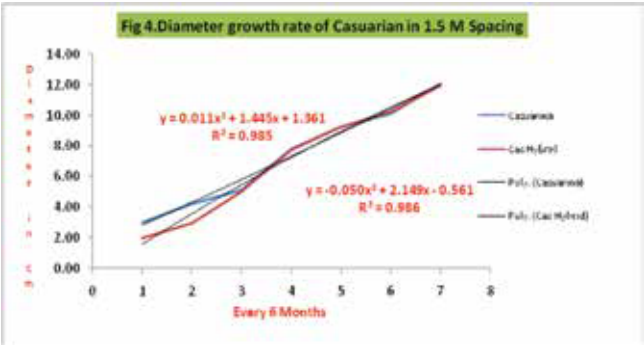
Validity of Model (Chi-Square goodness of fit test)

By using the method of Ordinary Least Square (OLS) the derived model was tested. The chi-square calculated and table values used were analysed, and it was found not significant. Therefore the above test indicated that the linear fit growth model was the best for the present study. Moreover the R^2 value varied from 0.933 to 0.995. And it was significant both at 1 per cent and 5 per cent so both the tests indicated that the model was very well suited for the present study.









Conclusion

Based on the predicting ability and co efficient of determination (R^2) value, the validity of different models were tested and it was found that polynomial growth model ($y = cx^2+bx + a$) was best fitted for the present study. Different polynomial equations were derived based on the spacing and different plant sources viz Casuarina and Casuarina hybrid. The R^2 varied from0.933 to 0.995. Regarding the prediction of diameter at breast height (dbh) and height of Casuarina at 1 M spacing was $y = 0.058x^2+0494x+2.488$ and $y =0.027x^2+0.857x+1.810$ respectively. Regarding the prediction of diameter at breast height (dbh) and height of Casuarina at 1.5 M spacing was $y = 0.011x^2 + 1.445x + 1.361$and $y = 0.023x^2 + 1.079x + 1.674$ respectively.

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