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Polynomial Analysis on Tendu Leaves Collection - A Case Study for Guarella-Pendra - Marwahi District

Muskan Tamrakar* and Sindhu Shukla

Department of Agriculture Statistics and Social Science (L.), College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh-492012, India

**Corresponding author*

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A B S T R A C T

The purpose of this study is to look at the trends in collection and selling of Tendu leaves in the Guarella-Pendra-Marwahi district of Chhattisgarh. Chhattisgarh is the first state in India to produce high-quality Tendu leaves. For this study, the least square technique was used to fit curves and make short-term projections for Tendu Leaves collecting and sales. The data for this study came from Marwahi Van Mandal (which contains one District Union and sixteen Primary Co-operative Societies) for the years 2011 to 2020. These evaluations were carried out on a district, and societal level. The best fitted model was fourth order polynomial regression model in explaining the Tendu leaves collection and sales.

Introduction

Coromandel Ebony or East Indian Ebony (*Diospyros melanoxylon*) is a species of flowering tree in the family *Ebenaceae* that is native to India and Sri Lanka and that has a hard, dry bark (Sabar, *et al.*, 2016; Sahu, *et al.*, 2017). Its common name derives from Coromandel, the coast of southeastern India. Locally it is known as Temburini or by its Hindi name Tendu. In Chhattisgarh it is known as Tendu.

Chhattisgarh is a forerunner in India when it comes to generating the highest quality Tendu (*Diospyros melanoxylon*) leaves. Tendu leaves are produced in about 16.44 lac standard bags every year, accounting for about 20% of the country's total Tendu leave production. In Chhattisgarh, a regular bag of Tendu leaves consists of 1000 bundles of 50 leaves spices (Sharma, 2001). The collecting season in Chhattisgarh lasts from the third week of April to the second week of June but in Gaurella –Pendra-Marwahi from first week of may to the last week of may due to cold weather. In comparison to the northern half of the state, the collection season in the southern section of the state begins sooner (Mahapatra, 2000; Lele, *et al.*, 2015; Naik and Gawande, 2015).

Guarella –Pendra- Marwahi came into existence on 10^{th} February 2020 as the 28^{th} district of Chhattisgarh. The district is famous not only in the state of Chhattisgarh but the whole of the India because of its unique features of tribal background (Lakhera, 2020). As per census 2011, more than 57% of the population belong to a back ground tribal community declared special by the central government. One of the tribes, namely Baiga is called "President's Dattak-Putra". Actually, Guarella-Pendra-Marwahi is Chhattisgarh's first special scheduled area. Since this community generates its income by collecting and selling.

Materials and Methods

The current research is mostly focused on the Guarella-Pendra-Marwahi district of Chhattisgarh and the state of Chhattisgarh. Guarella-Pendra-Marwahi is a newly established district that was split from Bilaspur's mother district. The Guarella-Pendra-Marwahi district comprises the Marwahi district union, which has 16 registered societies (there were 22 before the division, and the societies were reduced from 22 to 16 in 2014). The 16 societies working under the Marwahi district.

The following statistical approaches to analyse the data:

Least Square Techniques

The least squares approach is the most common and generally used way of fitting mathematical functions to a set of data. An examination of the plotted data is frequently sufficient for determining the type of trend to utilise.

Model- 1 Straight Line Trend

"$Y_t = a + bt + e$ "

Where,

Y_t = estimated Tendu leaves collections / sales

a = constant

b = regression coefficients

t = time variable
e =error term

Model-II Exponential function

"$Y_t = ab^t + e$"

Where,

Y= estimated Tendu leaves collections / sales for different years

A = log a

B = log b

t = time variable

e = error term

Model- III 2nd order polynomial regression model

"$Y_t = b_0 + b_1 t^1 + b_2 t^2 + e$"

Where,

Y= estimated Tendu leaves collections/sales for different years

b_0, b_1, b_2 = estimated regression coefficient

t = time variable

e = error term

Model- IV 3rd order polynomial regression model

"$Y_t = b_0 + b_1 t^1 + b_2 t^2 + b_3 t^3 + e$"

Where,

Y= estimated Tendu leaves collections/sales for different years

b_0, b_1, b_2, b_3 = estimated regression coefficient

t = time variable

e = error term

Model- V 4th order polynomial regression model

"$Y_t = b_0 + b_1 t^1 + b_2 t^2 + b_3 t^3 + b_4 t^4 e$"

Where,

Y= estimated Tendu leaves collection/sales for different years

b_0, b_1, b_2, b_3, b_4 = estimated regression coefficient

t = time variable

e = error term

The following formula will be used to perform a "t" test to determine the significance of the regression coefficient:

"$t = b_1 / S.E.(b_1)$ with n-2 degree of freedom"

Where,

b_1 = estimated value of b_1

$S.E.(b_1)$ = Standard Error of b_1

n = number of observations

Results and Discussion

Curve fitting of Tendu leaves collection and sales in Gaurella-Pendra-Marwahi (G.P.M.)

Curve fitting of Tendu leaves collection in Gaurella-Pendra-Marwahi (G.P.M.)

Polynomial regression up to fourth order and exponential regression was present in table 4.1 to 4.5 respectively. The table 4.1revealed that the fitted regression line is not good fit since F calculated was not found significant. Second order, third order and exponential regression models were not good fitted since F calculated values were not found significant as shown in Table no. 4.2,4.3 and 4.5. Table 4.4 represent the ANOVA for fourth order regression equation. It was observed from the table that the fitted model in significant.

Thus, the equation and R^2 value of the best fitted model for Tendu leaves collection are given in Table 4.6. The observed and fitted curve for the model was shown in Fig. 4.1.

The critical observation of Table 4.6 indicated that fourth order regression model was best fitted model in explaining the Tendu leaves collection The fourth order regression model shows R^2 (84.17%) value. The ANOVA table shows the significance levels at 5% and 1%.

Curve fitting of Tendu leaves sales in Marwahi District Union for Guarella-Pendra-Marwahi

Polynomial regression up to fourth order and exponential regression was present in table 4.7 to 4.11 respectively. The table 4.7 revealed that the fitted regression line is not good fit since F calculated was not found significant. Second order, third order and exponential regression models were not good fitted since F calculated values were not found significant as shown in Table no. 4.8,4.9 and 4.11. Table 4.10 represent the ANOVA for fourth order regression equation. It was observed from the table that the fitted model in significant.

Thus, the equation and R^2 value of the best fitted model for Tendu leaves sales are given in Table 4.12. The observed and fitted curve for the model was shown in Fig. 4.2.

The observation of Table 4.12 indicated that fourth order regression model was best fitted model in explaining the Tendu leaves sales. The fourth order regression model shows R^2 (32.69%) value. The ANOVA table shows the signifiance levels at 5% and 1%.

Table.1 ANOVA for straight line

	DF	SS	MS	F	Significant F	
Regression	1	206330.8	206330.8	0.007	0.937	
Residual	8	243406104.6	30425763.1			
Total	9	243612435.3				
	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***
Intercept	19738.92	3768.12	5.239	0.0007	11049.63	28428.21
Year(X)	-50.00	607.29	-0.083	0.937	-1450.42	1350.39

Table.2 ANOVA for Second order polynomial regression model

	DF	*SS*	*MS*	*F*	*Significance F*	
Regression	2	7214774.9	3607387.5	0.107	0.900	
Residual	7	236397660.4	33771094.4			
Total	9	243612435.2				
	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***
Intercept	17204.3	6834.97	2.518	0.039	1042.17	33366.4
Year(X)	1217.4	2854.57	0.427	0.683	-5532.67	7967.3
X^2	-115.3	252.91	-0.456	0.663	-713.24	482.9

Table.3 ANOVA for third order polynomial regression model

	DF	SS	MS	F	Significant F	
Regression	3	43300235.4	14433411.7	0.433	0.738	
Residual	6	200312199.9	33385366.65			
Total	9	243612435.3				
	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***
Intercept	26478.09	11213.89	2.362	0.057	-961.335	53917.6
Year(X)	-7008.07	8405.36	-0.834	0.437	-27575.2	13559.1
X^2	1668.22	1733.74	0.963	0.374	-2574.09	5910.6
X^3	-108.09	103.964	-1.039	0.338	-362.48	146.31

Table.4 ANOVA for fourth order polynomial regression model

	DF	SS	MS	F	Significant F	
Regression	4	205054684.6	51263671.2	6.648	0.031	
Residual	15	38557750.61	7711550.2			
Total	19	243612435.2				
	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***
Intercept	-7529.9	9175.21	-0.821	0.449	-31115.5	16055.8
Year(X)	36591.9	10341.49	3.539	0.017	10008.4	63175.6
X^2	-14285.5	3581.667	-3.989	0.011	-23492.4	-5078.4
X^3	2071.9	478.607	4.329	0.007	841.62	3302.22
X^4	-99.09	21.636	-4.579	0.006	-154.71	-43.474

Table.5 ANOVA for Exponential function

	DF	SS	MS	F	Significant F	
Regression	1	0.0016	0.0016	0.0926	0.7687	
Residual	18	0.1301	0.017			
Total	19	0.1316				
	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***
Intercept	12.885	28.296	0.456	0.661	-52.366	78.135
Year(X)	-0.005	0.015	-0.305	0.769	-0.037	0.029

Table.6 Fitted curve and R^2 values of Tendu leaves collection for Marwahi District Union (G.P.M.)

Model	Equation	R^2
Fourth order polynomial regression model	$Y = -99.091x^4 + 798763x^3 - 2E{+}09x^2 + 3E{+}12x - 2E{+}15$ (21.635)**(478.607)**(3581.667)*(10341.49)*(9175.20)	0.8417

**significant at 1% level &
*significant at 5% level

Table.7 ANOVA for straight line

	DF	SS	MS	F	Significant F	
Regression	1	5.37677E+15	5.37677E+15	2.59110968	0.146131178	
Residual	8	1.66007E+16	2.07508E+15			
Total	9	2.19774E+16				
Intercept	***Coefficients***	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***
Year(X)	45635877.67	31118689.92	1.466510248	0.180683597	-26123949.91	117395705.2
	8072979.297	5015230.989	1.609692418	0.146131178	-3492164.094	19638122.69

Table.8 ANOVA for Second order polynomial regression model *DF*

	DF	*SS*	*MS*	*F*	*Significance F*	
Regression	2	6.8596E+15	3.4299E+15	1.5882	0.2699	
Residual	7	1.511E+16	2.1597E+15			
Total	9	2.1978E+16				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	8766882.917	54658588.52	0.160393511	0.877101597	-120480141	138013906.9
Year(X)	26507476.67	22827730.89	1.161196301	0.283623891	-27471529.39	80486482.74
X^2	-1675863.398	2022451.102	-0.828629872	0.434654035	-6458200.32	3106473.524

Table.9 ANOVA for third order polynomial regression model

	DF	*SS*	*MS*	*F*	*Significance F*	
Regression	3	1.4872E+16	4.95732E+15	4.18606	0.0643	
Residual	6	7.10548E+15	1.18425E+15			
Total	9	2.19774E+16				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	146955059.3	66788210.1	2.200314383	0.070071832	-16469803.2	310379921.8
Year(X)	-96058027.09	50060934.08	-1.918822109	0.103434918	-218552719.7	26436665.54
X^2	24898785.91	10325873.74	2.411300635	0.052480864	-367716.8746	50165288.69
X^3	-1610584.806	619193.39	-2.601101394	0.040602217	-3125696.463	-95473.14952

Table.10 ANOVA for fourth order polynomial regression model

	DF	**SS**	**MS**	**F**	**Significant F**	
Regression	4	1.7588E+16	4.39699E+15	5.008567004	0.053494372	
Residual	5	4.38947E+15	8.77895E+14			
Total	9	2.19774E+16				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	7601272.75	97896287.73	0.07764618	0.94112096	-244049146.2	259251691.7
Year(X)	82600673.62	110340079.9	0.748600814	0.487796191	-201037531.3	366238878.5
X^2	-40474056.85	38215144.37	-1.0591104	0.33800889	-138709212.8	57761099.08
X^3	7322350.229	5106570.604	1.433907567	0.21105292	-5804507.402	20449207.86
X^4	-406042.5016	230848.4381	-1.758913792	0.138917605	-999457.303	187372.2998

Table.11 ANOVA for Exponential function

	DF	SS	MS	F	Significant F	
Regression	1	0.1067	0.1067	2.9489	0.1243	
Residual	8	0.2895	0.0362			
Total	9	0.3961				
	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***
Intercept	-77.85	91.627	-0.849	0.421	-289.139	133.443
Year(X)	0.043	0.046	0.938	0.377	-0.063	0.148

Table.12 Fitted curve and R^2 value of Tendu leaves sales in Guarella-Pendra- Marwahi District

Model	Equation	R^2
Fourth order polynomial regression model	$y = -406043x^4 + 3E+09x^3 - 1E+13x^2 + 1E+16x - 7E+18$ (230848.44)(5106570.61)(38215144.37)(110340079.9)(97896287.73)	0.8003

**significant at 1% level
*significant at 5% level

Fig.1 Fitted curve for Tendu leaves collection in Guarella- Pendra-Marwahi

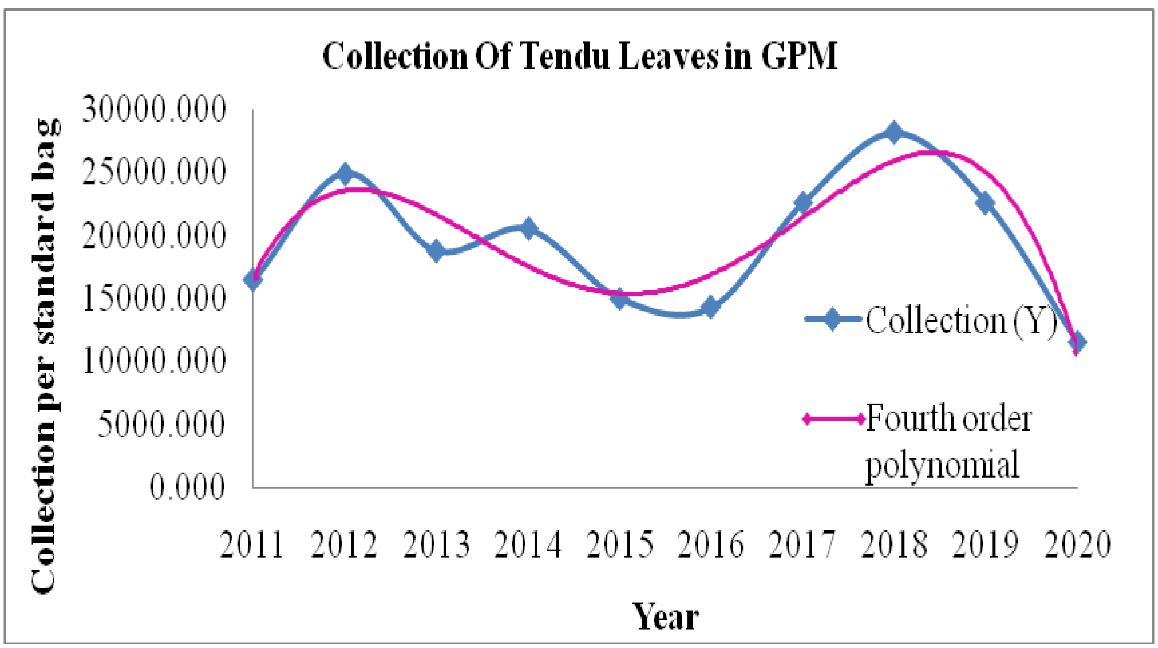
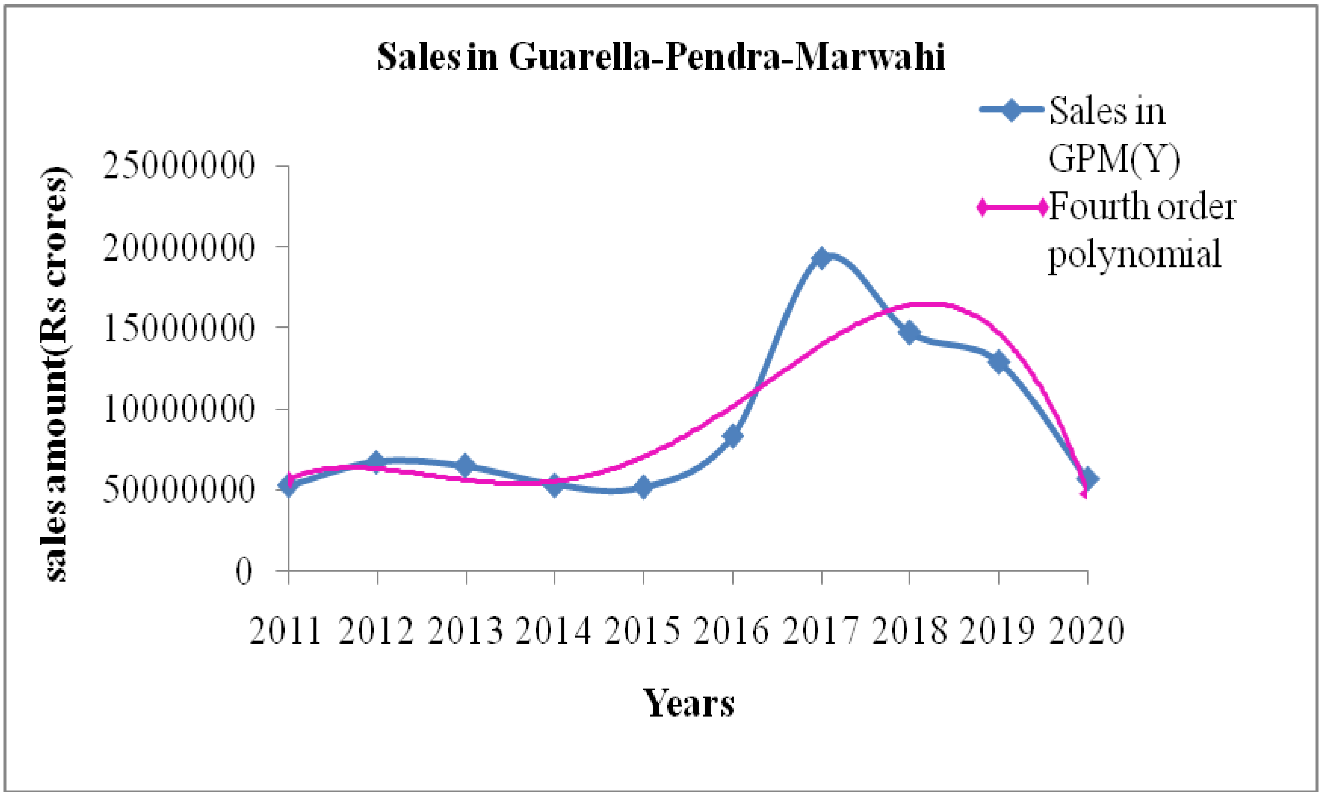


Fig.2 Fitted curve for Tendu leaves sales in Gaurella –Pendra- Marwahi



In Guarella-Pendra-Marwahi District, for Tendu leaves collection, the significant decreases trend shows the best fitted model was Y =-99.091x^4 + 798763x^3 - 2E+09x^2 + 3E+12x - 2E+15 which showed R^2 value 84.17%.

For Tendu leaves sales, the significant decreases trend shows the best fitted model was Y =2E+06x^4 - 2E+10x^3 + 5E+13x^2 - 7E+16x + 3E+19 which showed highest R^2 value 32.69%.

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