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RESEARCH NOTES

Estimation of Annual Compound Growth Rates of Citrus Fruits in Haryana Using Non-Linear Model

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ABSTRACT

Many of the research works have used the parametric approach for computation of annual growth rate but not used the concept of non-linear model. In this study an attempt has been made for computation of growth rates through non-linear model approach of citrus fruits in Hisar and Haryana State as a whole The time series data for annual area and production of citrus fruits in Hisar district of Haryana and Haryana as a whole from 1990-91 to 2015-16 were taken from the Department of Horticulture site of Haryana. Growth rates were computed through best fitted non-linear models. It was found that Logistic model could be best fit for computation of growth rates of area and production for citrus fruit in Hisar and Haryana state as a whole. For fitting the non-linear growth model and computation of growth rates R and excel software have been used. The average annual growth rate for area and production of citrus fruit was observed to be 11.29 per cent and 15.35 per cent for Hisar district whereas it was observed to be 9.64 per cent and 14.90 per cent for Haryana state as a whole.

Keywords: Annual growth rate, Coefficient of determination, Nonlinear model, Relative mean square error

JEL.: Q11, Q13

I

INTRODUCTION

Being a rich source of vitamins, proteins, nutrition and indirect diversity the fruits are essential for human diets. Citrus fruits ranked second after grapes in respect of both area and production in the world. As reported by Khalid (2013) about 7.13 million tonnes of citrus is produced annually through the world. India being the home of many citrus fruits, and their cultivated area is spread more than 0.953 million hectares with the production of 11.66 million tonnes (Vijaya *et. al*.,2017). The cultivated area under citrus fruits (kinnow) fruit is being extended from arid and semi-arid regions due to its growing demand in domestic and international consumer markets. Haryana is a progressive agricultural state, has only 1.4 per cent cultivable geographical area of India. The state ranks 13th in terms of citrus fruit production (Kumar, 2011). The cultivated area under citrus fruits was 3,189 hectares in the year 1991-92 which increased to 5,041 hectares in the year 2005-06 (Horticulture Anonymous, 2005-06). In the year 2014, citrus was grown on 19.4-thousand-hectare area with the production of 235.4 thousand MT in Haryana (Horticulture Anonymous, 2014-15). Kinnow covers

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majority (more than 80 per cent) of cultivated area under citrus fruits in Haryana (interaction with Horticulture experts, DHO Panchkula). Estimation of growth rates plays an important role in agricultural and economic research to study the growth pattern of a particular commodity. Many researchers have studied the growth rates for area, production and productivity of various agricultural commodities [Rajarathinam *et al*. (2010), Acharya *et al*. (2012), Singh *et al.* (2018), Singh, *et al*.(2019), and Kumar *et al*. (2019a)] on the usual parametric approach. Prajneshu and Chandran (2005) pointed that method of computation of growth rates on the basis of semi-logarithmic growth model has a number of serious lapses like there is no way to compute standard errors of estimates of original parameters from the corresponding values of the transformed model so there is chance of inflated error in the estimation of regression coefficients. As data follow the S-shaped curve so is better to compute the compound growth rate using non-linear growth model approach for better results. A well-known drawback of semi-logarithmic growth model is that the response variable y_t tends to infinity as $t \rightarrow \infty$, which cannot happen in reality. Keeping in view the above, the present study has been undertaken to estimate the compound annual growth rates for area and production for Hisar and Haryana state as a whole on the basis of nonlinear growth models like Logistic, Monomolecular and Gompertz models.

As we have already mentioned that most of the authors have computed growth rates on the basis of nonlinear growth model approach for various crops and commodities, In this context**,** Prajneshu and Chandran have computed growth rate by using growth models, viz., monomolecular, logistic and Gompertz for the total food grain production of our country during the period 1980 to 2001. The compound growth rates, on the basis of logistic and Gompertz models, were respectively obtained as 2.36 per cent and 2.38% per cent. Mukherjee *et al.* (2016) studied the application of non-linear growth model for estimation of annual compound growth rates of major pulses in Telangana state and observed that both the Logistic and the Gompertz model gave almost similar results. But in some cases the Logistic model proved to be better fit as compared to the Gompertz model. The estimated compound annual growth rates revealed that the area, production and yield of arhar has shown an increasing trend over the study period but there was a decreasing trend for moong in Telangana state. Kumar *et al*. (2019b) has observed growth rates of guava for two districts (Hisar, and Kurukshetra) and Haryana state as a whole using different non-linear models. Growth rates were computed through best fitted non-linear models. It was found that Logistic model could be best fit for computation of growth rates of area for guava fruit in Hisar and Kurukshetra district and Haryana state as a whole whereas Gompertz model was best fit for Yamunanagar district based on high R2 and least MSE and RMSE values. It was also observed that monomolecular model was best fit for production of guava fruits in Hisar and Yamunanagar district whereas Logistic model was best fit for production of guava fruit in Kurukshetra and Haryana state as a whole because of high R2 and least MSE and RMSE values.

II

MATERIAL AND METHODS:

Non-Linear Growth Models: The description of the studied growth models was taken from Draper and Smith (1998). The details of the model have been given as:

Logistic Model: In this model it is assume that growth rate is proportional to the product of the present size and the future amount of growth, p being some limiting growth value.

Mathematically, $\frac{dy}{dt} = \frac{ry(p-y)}{p}$, $r > 0$ …. (1)

On integrating (1) gives,

$$y = \frac{p}{\{1+qe^{-rt}\}}, \quad \text{…. (2)}$$

where r is intrinsic growth rate, q is function of initial value or $\frac{p-y(0)}{y(0)}$, and p is carrying capacity.

Equation (2) is known as logistic or autocatalytic growth function. It has S shaped curve and is symmetric about its point of inflection.

Gompertz Model: If the growth rate has differential equation

$$\frac{dy}{dt} = rylog\left(\frac{p}{y}\right) \quad \text{…. (3)}$$

then solving this equation yields Gompertz model

$$y = pe^{-qe^{-rt}} \quad \text{…. (4)}$$

It also has S-shaped curve like the logistic but not symmetrical about its point of inflection.

Monomolecular Model: If a growth situation in which it is assumed that the rate of growth at a particular time t is directly proportional to the amount of growth yet to be achieved, then

$$\frac{dy}{dt} = r(p-y) \quad \text{…. (5)}$$

Solving this equation gives the monomolecular model

$$y = p(1-qe^{-rt}) \quad \text{…. (6)}$$

It has no point of inflection.

Goodness of fit for a nonlinear growth model

Following tools are used for deciding the goodness of fit for a nonlinear growth model: Coefficient of Determination (R^2):

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \breve{y})^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \quad \ldots. (7)$$

The value of R^2 lies between 0 and 1. The model is said to be best fit if it has R^2 value close to 1. It tells the amount of variability in response variable that can be explained by explanatory variables.

Mean Squared Error (MSE):

It is defined as the average of the squared difference between estimated and observed values.

$$MSE = \frac{1}{n}[(y_i - \breve{\bar{y}}_i)^2 \quad \ldots. (8)$$

Root mean square error (RMSE):

It is calculated as,

$$RMSE = \sqrt{\frac{1}{n}[(y_i - \breve{\bar{y}}_i)^2} \quad \ldots.(9)$$

Model with lowest RMSE is considered as best fitted model.

Computation of compound growth rates

The growth rate which is given by $\frac{d[ln ln\,(y)\,]}{dt}$ or $\frac{1}{y}\left(\frac{dy}{dt}\right)$. ….(10)

The annual growth rate of nonlinear models for each period (t_i, t_{i+1}), $i = 0,1, \ldots n-1$ where n represent data points is given by:

$$R(Logistic) = r\left[1 - \left(\frac{y_t}{p}\right)\right] \quad \ldots. (11)$$

$$R(Gompertz) = r\left[ln\, ln\, \left(\frac{p}{y_t}\right)\right] \quad \ldots. (12)$$

$$R(Monomolecular) = r\left[\left(\frac{p}{y_t}\right) - 1\right] \quad \ldots. (13)$$

By taking arithmetic mean, compound growth rate over a given period can be computed.

III

RESULTS AND DISCUSSION

The data from 1990-91 to 2015-16 for the area and production of citrus fruits in Hisar and Haryana state as a whole was taken from the Department of Horticulture Board Haryana (Anonymous, 2015) which was indicated in Table 1. Table 2 shows

TABLE 1. AREA AND PRODUCTION OF CITRUS FRUITS IN HISAR AND HARYANAFOR THE YEAR 1990-91 TO 2015-16

Year	Hisar		Haryana	
	Area (ha)	Production (MT)	Area (ha)	Production (MT)
(1)	(2)	(3)	(4)	(5)
1990-91	314	3300	2944	30900
1991-92	362	3800	3189	32630
1992-93	358	3300	3361	23380
1993-94	366	3000	3580	27719
1994-95	396	2900	3824	28500
1995-96	429	3600	4043	32400
1996-97	484	5000	4278	37800
1997-98	309	2300	4590	42900
1998-99	344	4000	4895	39154
1999-00	382	3800	5301	37509
2000-01	410	3350	5657	44889
2001-02	418	2903	5576	57830
2002-03	421	5235	5428	49735
2003-04	374	2661	5360	48465
2004-05	247	1446	4292	51395
2005-06	327	5040	5041	69558
2006-07	457	3190	6419	77433
2007-08	639	7834	8414	66842
2008-09	958	5244	11223	63164
2009-10	1191	7322	13837	98333
2010-11	1579	7973	17151	129996
2011-12	1701	15276	17664	214168
2012-13	1930	21435	18775	225054
2013-14	1989	24823	19382	235345
2014-15	1893	32086	19499	302065
2015-16	1863	33259	19652	301764

Source: Department of Horticulture, Government of Haryana.
Retrieved from http://hortharyana.gov.in/en/statisticaldata.pdf

TABLE 2. PARAMETER ESTIMATION OF NON-LINEAR GROWTH MODEL FOR AREA OF CITRUS IN HISAR DISTRICT OF HARYANA DURING PERIOD 1990-91 TO 2015-16

Parameters	Monomolecular	Logistic	Gompertz
(1)	(2)	(3)	(4)
a	4.09	0.114	0.061
b	-129.42	649.30	1.79
c	1637903	75886.6	1878.31
R^2	0.674	0.865	0.527
MSE	137829.30	57043.59	199938.10
RMSE	371.25	238.83	447.14

the parameter estimate and goodness of fit criteria of different model, i.e., Monomolecular, Logistic and Gompertz model for area of Citrus in Hisar district. It was observed that relative mean square error, mean square error, mean absolute error were less for logistic model as compared to other studied models. It was also observed that value of coefficient of determination was very high (0.86) for Logistic model. Therefore, it was concluded that logistic model is best fit model for computation of compound growth rate of area in citrus fruits for Hisar district only. Table 3 shows the predicted value for area under citrus fruits for the time period 1990-91 to 2015-16 of in Hisar district of Haryana using Monomolecular, Logistic and Gompertz model. On the basis of best fit of logistic model, the average annual growth rate found to be 11.29 per cent which is observed by taking the mean of annual growth rates.

TABLE 3. ANNUAL GROWTH RATE CALCULATED ON THE BASIS OF BEST FITTED MODEL FOR AREA OF CITRUS IN HISAR DISTRICT OF HARYANA FROM 1990-91 TO 2015-16

Years	Monomolecular	Logistic	Gompertz	Annual Growth Rate through Logistic Model
	Predicted area(ha)	Predicted area(ha)	Predicted area(ha)	
(1)	(2)	(3)	(4)	(5)
1990-91	-	130.76	348.15	0.1138
1991-92	4.48	146.51	384.50	0.1138
1992-93	71.43	164.15	422.16	0.1138
1993-94	138.38	183.92	460.97	0.1137
1994-95	205.32	206.06	500.74	0.1137
1995-96	272.26	230.85	541.31	0.1137
1996-97	339.20	258.62	582.47	0.1136
1997-98	406.14	289.72	624.07	0.1136
1998-99	473.07	324.54	665.93	0.1135
1999-00	540.00	363.52	707.88	0.1135
2000-01	606.93	407.17	749.77	0.1134
2001-02	673.86	456.02	791.45	0.1133
2002-03	740.78	510.69	832.80	0.1132
2003-04	807.70	571.86	873.67	0.1131
2004-05	874.62	640.31	913.98	0.1130
2005-06	941.53	716.86	953.60	0.1129
2006-07	1008.44	802.47	992.45	0.1128
2007-08	1075.35	898.19	1030.46	0.1127
2008-09	1142.26	1005.17	1067.56	0.1125
2009-10	1209.16	1124.69	1103.70	0.1123
2010-11	1276.06	1258.19	1138.82	0.1121
2011-12	1342.96	1407.24	1172.89	0.1119
2012-13	1409.85	1573.58	1205.89	0.1116
2013-14	1476.75	1759.11	1237.79	0.1114
2014-15	1543.64	1965.94	1268.58	0.1110
2015-16	1610.52	2196.36	1298.25	0.1107

Similarly, the Table 4 shows the parameter estimate and goodness of fit criteria of Monomolecular, Logistic and Gompertz model for area of Citrus fruits in Haryana state as a whole. It was observed that relative mean square error, mean square error, mean absolute error were less for logistic model as compared to other models. It was also observed that value of coefficient of determination was very high (0.91) for Logistic model. Therefore, it is concluded that logistic model is best fit model for computation of compound growth rate in citrus fruits for Haryana state as a whole.

TABLE 4. PARAMETER ESTIMATION OF NON-LINEAR GROWTH MODEL FOR AREAOF TOTAL CITRUS IN HARYANA DURING PERIOD 1990-91 TO 2015-16

Parameters (1)	Monomolecular (2)	Logistic (3)	Gompertz (4)
a	5.64	0.098	0.009
b	1007.74	302.22	12.72
c	12612623	531038.90	5.25
R^2	0.785	0.917	0.914
MSE	8799692	3414885	3511993
RMSE	2966.43	1847.94	1874.03
MAE	2378.05	1424.61	1471.87

Table.5. shows the predicted value for area of Citrus fruits for the time period 1990-91 to 2015-16 of in Haryana State as a whole using Monomolecular, Logistic and

TABLE 5: ANNUAL GROWTH RATE CALCULATED ON THE BASIS OF BEST FITTED MODEL FOR AREA OF TOTAL CITRUS IN HARYANA DURING PERIOD 1990-91 TO 2015-16

Years	Monomolecular	Logistic	Gompertz	Annual growth rate through Logistic Model
	Predicted Area(ha)	Predicted Area(ha)	Predicted Area(ha)	
(1)	(2)	(3)	(4)	(5)
1990-91	296.56	1933.07	1747.04	0.0976
1991-92	414.48	2133.66	1954.97	0.0976
1992-93	1125.49	2354.96	2185.44	0.0976
1993-94	1836.46	2599.11	2440.65	0.0975
1994-95	2547.39	2868.43	2722.95	0.0975
1995-96	3258.28	3165.49	3034.92	0.0974
1996-97	3969.13	3493.11	3379.35	0.0974
1997-98	4679.94	3854.40	3759.23	0.0973
1998-99	5390.71	4252.75	4177.82	0.0972
1999-00	6101.44	4691.90	4638.62	0.0971
2000-01	6812.13	5175.95	5145.42	0.0970
2001-02	7522.78	5709.40	5702.27	0.0969
2002-03	8233.40	6297.17	6313.56	0.0968
2003-04	8943.97	6944.65	6984.00	0.0967
2004-05	9654.51	7657.74	7718.64	0.0966
2005-06	10365.00	8442.87	8522.90	0.0964
2006-07	11075.46	9307.06	9402.59	0.0963
2007-08	11785.88	10257.97	10363.93	0.0961
2008-09	12496.26	11303.93	11413.59	0.0959
2009-10	13206.59	12453.99	12558.68	0.0957
2010-11	13916.89	13717.97	13806.80	0.0955
2011-12	14627.15	15106.50	15166.05	0.0952
2012-13	15337.37	16631.06	16645.09	0.0949
2013-14	16047.56	18304.02	18253.12	0.0946
2014-15	16757.70	20138.68	19999.93	0.0943
2015-16	17467.80	22149.29	21895.93	0.0939

basis of best fit of logistic model, the average annual growth rate found to be 9.64 per cent which is observed by taking the mean of annual growth rates.

Similar results were also observed for production of total citrus fruit in Hisar and Haryana State as a whole. Again it is clear from the Table 6 and Table 8 that Logistic model was found to be the best for both Hisar and Haryana State as a whole. On the basis of best fit of logistic model, the average annual growth rate for Hisar and Haryana state as a whole was to be 15.35 per cent and 14.90 per cent respectively by taking the mean of annual growth rates shown in Table 7 and Table 9.

TABLE. 6. PARAMETER ESTIMATION OF NON-LINEAR GROWTH MODEL FOR PRODUCTION OF CITRUS IN HISAR DISTRICT OF HARYANA DURING PERIOD 1990-91 TO 2015-16

Parameters	Monomolecular	Logistic	Gompertz
(1)	(2)	(3)	(4)
a	3.14X10-	0.115	0.017
b	-3637.21	-32.32	18.23
c	28013261	-23509.30	4.77
R^2	0.537	0.923	0.911
MSE	42456352	7083795	8158327
RMSE	6515.85	2661.54	2856.27
MAE	5053.10	2172.71	2438.21

TABLE 7. ANNUAL GROWTH RATE CALCULATED ON THE BASIS OF BEST FITTED MODEL FOR PRODUCTION OF CITRUS IN HISAR DISTRICT OF HARYANA FROM 1990-91 TO 2015-16

Years	Monomolecular Predicted Production (MT)	Logistic Predicted Production (MT)	Gompertz Predicted Production (MT)	Annual Growth Rate through Logistic Model
(1)	(2)	(3)	(4)	(5)
1990-91	-	844.98	77.48	0.1191
1991-92	-	951.72	104.24	0.1197
1992-93	-	1072.54	139.56	0.1202
1993-94	-	1209.46	185.94	0.1209
1994-95	757.19	1364.82	246.57	0.1217
1995-96	1635.98	1541.39	325.44	0.1225
1996-97	2514.75	1742.40	427.58	0.1235
1997-98	3393.49	1971.68	559.24	0.1246
1998-99	4272.21	2233.81	728.20	0.1259
1999-00	5150.89	2534.25	944.08	0.1274
2000-01	6029.55	2879.62	1218.71	0.1291
2001-02	6908.18	3277.98	1566.59	0.1310
2002-03	7786.78	3739.25	2005.44	0.1333
2003-04	8665.36	4275.80	2556.74	0.1359
2004-05	9543.90	4903.19	3246.54	0.1390
2005-06	10422.42	5641.33	4106.18	0.1426
2006-07	11300.92	6516.07	5173.31	0.1469
2007-08	12179.38	7561.64	6492.89	0.1520
2008-09	13057.82	8824.28	8118.51	0.1582
2009-10	13936.23	10368.12	10113.68	0.1657
2010-11	14814.61	12284.67	12553.45	0.1751
2011-12	15692.97	14709.33	15526.18	0.1870
2012-13	16571.29	17851.21	19135.48	0.2023
2013-14	17449.59	22051.40	23502.40	0.2229
2014-15	18327.87	27906.65	28767.91	0.2515
2015-16	19206.11	36564.36	35095.56	0.2939

TABLE.8. PARAMETER ESTIMATION OF NON-LINEAR GROWTH MODEL FOR PRODUCTION OF TOTAL CITRUS IN HARYANA DURING PERIOD 1990-91 TO 2015-16

Parameters	Monomolecular	Logistic	Gompertz
(1)	(2)	(3)	(4)
a	3.88	0.149	0.012
b	35493.40	5.55	16.19
c	2.42	3.63	4.54
R^2	0.682	0.939	0.933
MSE	2.6	4.98	5.48
RMSE	51013.82	22325.03	23410.82
MAE	40998.53	17794.15	18842.00

TABLE.9 ANNUAL GROWTH RATE CALCULATED ON THE BASIS OF BEST FITTED MODEL FOR PRODUCTION OF TOTAL CITRUS IN HARYANA DURING PERIOD 1990-91 TO 2015-16

Years	Monomolecular Predicted Production (MT)	Logistic Predicted Production (MT)	Gompertz Predicted Production (MT)	Annual Growth Rate through Logistic Model
(1)	(2)	(3)	(4)	(5)
1990-91	-	7601.55	5412.31	0.1490
1991-92	-	8826.69	6519.75	0.1490
1992-93	-	10249.27	7836.81	0.1490
1993-94	2005.49	11901.14	9399.79	0.1490
1994-95	11379.30	13819.23	11250.67	0.1490
1995-96	20752.74	16046.46	13437.88	0.1490
1996-97	30125.82	18632.65	16017.17	0.1490
1997-98	39498.54	21635.65	19052.60	0.1490
1998-99	48870.89	25122.64	22617.57	0.1490
1999-00	58242.89	29171.62	26796.09	0.1490
2000-01	67614.51	33873.18	31684.03	0.1490
2001-02	76985.78	39332.48	37390.67	0.1490
2002-03	86356.68	45671.64	44040.23	0.1490
2003-04	95727.22	53032.48	51773.70	0.1490
2004-05	105097.40	61579.66	60750.75	0.1490
2005-06	114467.20	71504.38	71151.89	0.1490
2006-07	123836.70	83028.66	83180.79	0.1490
2007-08	133205.70	96410.28	97066.80	0.1490
2008-09	142574.50	111948.60	113067.70	0.1490
2009-10	151942.80	129991.20	131472.70	0.1490
2010-11	161310.80	150941.80	152605.80	0.1490
2011-12	170678.50	175268.90	176829.10	0.1490
2012-13	180045.70	203516.70	204546.50	0.1490
2013-14	189412.60	236317.30	236208.20	0.1490
2014-15	198779.20	274404.20	272314.60	0.1490
2015-16	208145.40	318629.60	313421.30	0.1490

Table10 shows the computation of area and production of Hisar and Haryana state as a whole on the basis of calculated average annual growth rate.

TABLE.10. FORECAST OF AREA AND PRODUCTION OF TOTAL CITRUS IN HISAR AND HARYANA FOR THE YEAR 2016-17 TO 2020-21 ON THE BASIS OF AVERAGE GROWTH RATE

Year	Hisar		Haryana	
	Area (ha)	Production (MT)	Area (ha)	Production (MT)
(1)	(2)	(3)	(4)	(5)
2016-17	2073.333	37013.94	21546.45	346726.8
2017-18	2307.412	41192.82	23623.53	398389.1
2018-19	2567.919	45843.48	25900.84	457749.1
2019-20	2857.837	51019.21	28397.68	525953.7
2020-21	3180.487	56779.28	31135.22	604320.8

IV

CONCLUSION

Several packages like R, SAS and SPSS are readily available to fit the nonlinear growth model for computation of growth rates. In this paper R and excel software has been used for computation of average compound growth rate of guava fruit**.** The average annual growth rate for area and production of citrus fruit was observed to be

11.29 per cent and 15.35 per cent for Hisar district whereas it was observed 9.64 per cent and 14.90 per cent for Haryana state as a whole.

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