Agro Economist - An International Journal
Citation: AE: **9**(02): 145-149, June 2022
DOI: 10.30954/2394-8159.02.2022.7
Peer Reviewed Journal

AAEBM
ASSOCIATION OF AGRICULTURAL ECONOMICS & AGRI-BUSINESS MANAGEMENT

Non Linear Growth Model Approach for Estimation of Compound Growth Rate of the Area and Production of Potato & Onion Crops in Haryana

Vikash Kumar Sumit, Manoj Kumar*, Sarita Rani, Hemant Poonia and Sunil Kumar

Department of Mathematics and Statistics, Chaudhary Charan Singh Haryana Agriculture University, Hisar, Haryana, India

*Corresponding author: m25424553@gmail.com

Received: 17-03-2022 **Revised:** 26-05-2022 **Accepted:** 04-06-2022

ABSTRACT

Nonlinear growth models are widely used to study the growth pattern of various biological entities. We require initial values for different iterative procedures to get the final estimates of coefficients. These are usually taken up by visualizing the data, results from previous experiments, or a close guess. In this study, an attempt had made to figure out the initial values of coefficients of nonlinear growth models. Further, the compound annual growth rate (CAGR) had computed for the area and production of Potato and Onion crops in Haryana from 1992-93 to 2018-19. The idea of growth rate helps the policymakers in the formulation and implementation of crop-specific agriculture schemes. The models used for these purposes were Logistic, Gompertz, and Monomolecular. The initial values for different models had obtained using the method of three selected points, the method of partial sums, and Yule's method with the help of R-Studio software. The SPSS software was used to get the final parameters of the above models using the Levenberg-Marquardt algorithm. The Monomolecular model had the best model for the area and production of potato and Onion. The acreage and production of Potato recorded an average CAGR of 3.94% and 6.25%, respectively, while, Onion had a mean CAGR of 8.63% and 10.43% for its area and production, respectively.

Keywords: Logistic model, Gompertz model, Monomolecular model, Initial values, CAGR

Growth models are applied in many fields like biology, zoology, botany, agriculture science, forestry, ecology, etc. The growth in living organisms is measured using response variables like height, weight, the girth of trees, area, production, and other related variables. In economics growth of a nation occurs in terms of gross domestic product.

Agriculture is a vital sector of Haryana economy, and most of the population is directly or indirectly dependent on agriculture and its allied activities. Horticulture has recently gained huge status due to increased productivity, generating employment, and enhancing exports. Horticulture is also a significant diversified activity for nutritional security. Haryana is emerging as one of the leading states in the field of Horticulture in India, where almost all types of fruits, vegetables, spices, mushrooms & flowers are

How to cite this article: Sumit, V.K., Kumar, M., Rani, S., Poonia, H. and Kumar, S. (2022). Non Linear Growth Model Approach for Estimation of Compound Growth Rate of the Area and Production of Potato & Onion Crops in Haryana. *Agro Economist - An International Journal*, **09**(02): 145-149.

Source of Support: None; **Conflict of Interest:** None

being grown. Horticultural crops covered 4.78 lakh hectares area, which is 7.27 %of the gross cropped area (GCA) of the State. Production from horticultural crops in the state was 80.67 lakh metric tons during 2019-20. Out of the total area under horticultural crops, around 83 % was under vegetables & rest under fruits, spices, and mushrooms. The total area under vegetable crops was 3.97 lakh hectares in 2019-20, with a production of 67.38 lakh tons. In 2010-11, vegetable crops covered 3.46 lakh hectares' area and produced 46.49 lakh tons (Data source: Economic Survey of Haryana 2020-21). There is a 15 % and 45 % increase in the area and production of vegetable crops in Haryana in the last decade. The growth rate is one of the prime considerations in agriculture. Study of time series data of the area, production, and productivity of different crops and computing their growth rate helps in analyzing the growth pattern of various crops, the formulation, modification, and execution of agricultural policies which influence farm decisions, planning of future operations, comparison of current performance with the expected ones, prediction or estimation or forecasting, comparing the changes in the values at different times or places, etc.

In this study, an attempt had made to figure out the initial values of coefficients of nonlinear growth models. Further, the compound annual growth rate (CAGR) had computed for the area and production of Potato and Onion crops in Haryana from 1992-93 to 2018-19.

MATERIALS AND METHODS

The data for the area and production of Potato and Onion crops for 1992-93 to 2018-19 in Haryana were collected from the Horticulture Department, Government of Haryana. The sources like Economic Survey of Haryana, Statistical Abstract of Haryana, and Horticulture Department (Government of India) have been used to fill the unclear values. In some cases, linear interpolation between two known points was used to fill the ambiguous data points. In this method, a straight line between the two known points around the missing point is created, and then using that line, we impute the missing value. The models used for computing the growth rates were Logistic, Gompertz, and Monomolecular, respectively. Method of three selected points and Yule's method was employed for the Logistic model, while the method of partial sums were used for Gompertz and Monomolecular model for finding the initial values using the R-software

The goodness of fit criteria were used for viz. coefficient of determination (R^2), mean squared error (MSE), and root means square error (RMSE) were used to find out the best fit model.

The growth rates have calculated by the formula given in Prajneshu, and Chandran (2005).

RESULTS AND DISCUSSION

Table 1 depicts the initial values of parameters of nonlinear growth models for the area and production of Potato and Onion crops.

Table 2 shows the final values of parameters of nonlinear growth models for the area and production of Potato and Onion crops obtained from nonlinear regression analysis using NLR option in SPSS.

Table 1: Initial values of parameters of nonlinear growth models for area (in hectares) and production (in tons) of Potato and Onion crops in Haryana from 1992-93 to 2018-19

		Logistic Model		Gompertz Model		Monomolecular model	
	Initial value of parameters	**Area**	**Production**	**Area**	**Production**	**Area**	**Production**
Potato	p_0	50854.52	$1.15*10^6$	12871.86	305.48	13434.59	46759.11
	q_0	3.67	7.41	-0.26	-2.82	-5292.91	-4.03
	r_0	0.07	0.11	-0.09	-0.0092	-0.12	-0.08
Onion	p_0	44713.70	950724	59816.19	2648787	-27241.56	-196623.10
	q_0	8.79	14.63	-8.63	-11.45	23797.80	1.36
	r_0	0.12	0.15	0.06	0.04	-0.02	-0.05

Table 2: Final values of parameters of nonlinear growth models for area (in hectares) and production (in tons) of the Potato and Onion crop in Haryana from 1992-93 to 2018-19

		Logistic Model		Gompertz Model		Monomolecular model	
	Final value of parameters	**Area**	**Production**	**Area**	**Production**	**Area**	**Production**
Potato	*p*	$1.90*10^{11}$	$1.02*10^{12}$	4121.02	17.46	8691.97	46866.44
	q	$1.65*10^{7}$	$6.16*10^{6}$	-1.13	-9.20	-0.5	-2.79
	r	0.04	0.06	-0.02	-0.01	-0.07	-0.07
Onion	*p*	39284.23	1136000.00	49441.91	2295466.42	-1390097.75	-378413.33
	q	7.16	14.79	2.51	3.63	1.00	1.11
	r	0.13	0.13	0.06	0.04	-0.0008	-0.04

Table 3: Test of independence and normality of nonlinear growth models for the area (in hectares) and production (in tons) of Potato and Onion crops in Haryana from 1992-93 to 2018-19

		Logistic Model		Gompertz Model		Monomolecular model	
		Area	**Production**	**Area**	**Production**	**Area**	**Production**
Potato	Mean	35.45	615.40	1.65	168.70	0.00	0.00
	S.D.	1589.65	50744.67	1456.71	50643.90	1416.29	50422.30
	No. of runs	10	12.00	12	10.00	12	12.00
	Z	-1.56^{NS}	-0.78^{NS}	-0.78^{NS}	-1.52^{NS}	-0.78^{NS}	-0.78^{NS}
	Shapiro-Wilk test value	0.98^{NS}	0.96^{NS}	0.98^{NS}	0.96^{NS}	0.98^{NS}	0.96^{NS}
Onion	Mean	-44.77	-368.11	-24.96	-126.45	2.75	0.00
	S.D.	2288.44	46198.73	2229.46	46240.70	2166.22	46455.53
	No. of runs	6.00	8.00	6.00	8.00	8.00	8.00
	Z	-3.14^{NS}	-2.32^{NS}	-3.14^{NS}	-2.25^{NS}	-2.32^{NS}	-2.32^{NS}
	Shapiro-Wilk test value	0.95^{NS}	0.98^{NS}	0.97^{NS}	0.98^{NS}	0.97^{NS}	0.97^{NS}
	Shapiro-Wilk test value	0.95^{NS}	0.96^{NS}	0.97^{NS}	0.97^{NS}	0.96^{NS}	0.98^{NS}

NS-Not significant at 0.01% level of significance.

Table 4: Model comparison of fitted modelsusing goodness of fit tests

		Logistic Model		Gompertz Model		Monomolecular model	
		Area	**Production**	**Area**	**Production**	**Area**	**Production**
Potato	R^2	0.95	0.95	0.96	0.95	0.96	0.95
	RMSE	1560.73	49799.89	1429.48	49697.47	1389.82	49479.74
	MAE	1265.47	38485.44	1145.67	38563.70	1110.84	38355.83
Onion	R^2	0.94	0.96	0.94	0.96	0.94	0.96
	RMSE	2246.10	45336.62	2187.93	45376.49	2125.73	45587.12
	MAE	1936.90	36865.36	1836.72	35996.36	1754.87	36276.55

The assumption of independence of error terms for different models has been analyzed using the Run test in SPSS. Normality tests have been performed using Shapiro-Wilk test in SPSS. Results of both the tests have been given in Table 3. Z is the statistic for the Run test, i.e., test for independence of error terms. No significant value in the Run test suggests that error terms are independent, while the Shapiro-Wilk test, it tells error terms are normally distributed. The model which had a minimum mean of residuals and independent error terms were given priority in the selection of best-fitted model.

The goodness of fit tests for model comparison has been shown in Table 4. Model with high R^2 and low RMSE and MAE is desirable.

Based on Table 3 and 4, it is found that the monomolecular model is the best-fitted model for the area and production of both crops. Based on the fitted model, the predicted area and production of Potato and Onion crops and compound annual growth rate have been put in Table 5 and 6, respectively. The average CAGR for Potato area and production was 3.94% and 6.25%, respectively. Onion area and production recorded an average CAGR of 8.63% and 10.43%, respectively.

Table 5: Predicted area and production and their compound annual growth rate of Potato crop based on best-fitted model

Time (in years)	Predicted Area (in hectares)	Compound Annual Growth Rate in area	Predicted Production (in tons)	Compound Annual Growth Rate in production
1992-93	13326.29	0.0243	183936.56	0.0535
1993-94	13661.28	0.0254	194998.25	0.0545
1994-95	14020.48	0.0265	206801.31	0.0555
1995-96	14405.64	0.0277	219400.07	0.0564
1996-97	14818.65	0.0289	232853.19	0.0573
1997-98	15261.51	0.0300	247223.96	0.0581
1998-99	15736.38	0.0312	262580.78	0.0589
1999-00	16245.58	0.0325	278997.50	0.0597
2000-01	16791.59	0.0337	296553.98	0.0604
2001-02	17377.06	0.0349	315336.54	0.0611
2002-03	18004.85	0.0361	335438.58	0.0617
2003-04	18678.03	0.0373	356961.14	0.0623
2004-05	19399.86	0.0385	380013.61	0.0629
2005-06	20173.87	0.0397	404714.47	0.0634
2006-07	21003.83	0.0409	431192.05	0.0640
2007-08	21893.78	0.0421	459585.47	0.0644
2008-09	22848.06	0.0432	490045.56	0.0649
2009-10	23871.32	0.0444	522735.93	0.0653
2010-11	24968.54	0.0455	557834.12	0.0657
2011-12	26145.08	0.0466	595532.88	0.0661
2012-13	27406.66	0.0477	636041.54	0.0665
2013-14	28759.43	0.0487	679587.56	0.0668
2014-15	30209.99	0.0497	726418.15	0.0671
2015-16	31765.40	0.0507	776802.17	0.0674
2016-17	33433.24	0.0516	831032.11	0.0677
2017-18	35221.64	0.0526	889426.29	0.0680
2018-19	37139.31	0.0535	952331.33	0.0682

Table 6: Predicted area and production and their compound annual growth rate of Onion crop on the basis of best fitted model

Time (in years)	Predicted Area (in hectares)	Compound Annual Growth Rate in area	Predicted Production (in tons)	Compound Annual Growth Rate in production
1992-93	3723.18	0.0076	56317.78	0.2926
1993-94	4811.12	0.0081	73114.59	0.2341
1994-95	5899.92	0.0086	90560.37	0.1963
1995-96	6989.56	0.0091	108680.21	0.1699
1996-97	8080.05	0.0097	127500.16	0.1504
1997-98	9171.40	0.0103	147047.25	0.1355
1998-99	10263.59	0.0109	167349.59	0.1236
1999-00	11356.64	0.0115	188436.35	0.1140
2000-01	12450.55	0.0122	210337.85	0.1061
2001-02	13545.30	0.0129	233085.57	0.0995
2002-03	14640.91	0.0137	256712.19	0.0938
2003-04	15737.38	0.0144	281251.68	0.0889
2004-05	16834.70	0.0152	306739.30	0.0847
2005-06	17932.88	0.0161	333211.70	0.0810
2006-07	19031.91	0.0169	360706.91	0.0777
2007-08	20131.80	0.0178	389264.47	0.0748
2008-09	21232.56	0.0188	418925.41	0.0722
2009-10	22334.17	0.0197	449732.37	0.0698
2010-11	23436.64	0.0207	481729.62	0.0677
2011-12	24539.97	0.0217	514963.16	0.0658
2012-13	25644.16	0.0227	549480.75	0.0640
2013-14	26749.22	0.0238	585332.00	0.0624
2014-15	27855.13	0.0249	622568.44	0.0610
2015-16	28961.91	0.0260	661243.60	0.0596
2016-17	30069.56	0.0271	701413.06	0.0584
2017-18	31178.06	0.0283	743134.56	0.0572
2018-19	32287.44	0.0294	786468.06	0.0561

SUMMARY AND CONCLUSION

The compound growth rate of various crops varies with different geographical and climatic conditions. Another factor that indirectly affects this variation is the demand and supply of various commodities at different locations. The idea of growth rate helps the policy makers in the formulation and implementation of crop-specific agriculture schemes.

The three popular nonlinear growth models, viz. Logistic, Gompertz, and Monomolecular were chosen for the study after several readings of related literature in different crops at various global locations. Two methods for the estimation of CAGR parameters were available in the literature. The conventional approach uses the linear transformation of the Malthus model and then utilizes the concept of linear regression to estimate its parameters. The modern methodology uses nonlinear growth models and iterative procedures to estimate the coefficients. The most popular and widely used iterative procedure is the Levenberg-Marquardt algorithm The R Software was used to find the initial values, and the rest analytics were done using SPSS. . The method of three selected points, the method of partial sums, and Yule's method was used to obtain the initial values rather than taking a guess or by visualizing the data. Monomolecular model was best suited for the Potato area and production. The average compound annual growth rates of its area and production were 3.94% and 6.25%, respectively. The monomolecular model was the best fit for the area and production of Onion, with an average CAGR of 8.63% and 10.43%, respectively.

REFERENCES

Anonymous, 2019. Horticulture Statistics Division, Ministry of Agriculture and Farmer Welfare, Government of Haryana. Retrieved from http://hortharyana.gov.in/en/statistical-data.

Anonymous, 2021. Department of Economic and Statistical Analysis. Economic survey of Haryana 2020-21, Government of Haryana. Retrieved from http://esaharyana.gov.in/en-us/Economic-Survey-of-Haryana

Anonymous, 2021. Horticulture Statistics Division, Ministry of Agriculture and Farmer Welfare, Government of Haryana. Retrieved from http://hortharyana.gov.in/en/about-us.

Draper, N.R. and Smith, H. 1998. Applied Regression Analysis, 3rd Edn., New York, USA: John Wiley & Son.

Gupta, S.C. and Kapoor, V.K. 2007. Fundamentals of Applied Statistics. New Delhi: Sultan Chand & Sons.

Kumar, M., Battan, K.R. and Sheoran, O.P. 2019. Pre-harvest forecast model for rice yield using principal component regression based on bio-metrical character with R-software. *Int. J. Agricult. Stat. Sci.*, **15**(1): 323-326.

Montgomery, D.C., Peck, E.A. and Vining, G.G. 2012. Introduction to linear regression analysis, **5**: 12-18. John Wiley & Sons.

Panghal, P., Kumar, M. and Rani, S. 2019. Estimation of annual compound growth rates of guava (*Psidiumguajava* L.) fruit in Haryana using nonlinear model. *J. Appl. Nat. Sci.*, **11**(4): 778-784.

Prajneshu, and Chandran, K.P. 2005. Computation of Compound Growth Rates in Agriculture: Revisited. *Agric. Econ. Res. Rev.*, **18**: 317-324.

Rajarathinam, A., Parmar, R.S. &Vaishnav, P.R.2010. Estimating Models for Area, Production and Productivity Trends of Tobacco (*Nicotiana tabacum*) Crop for Anand Region of Gujarat State. *Indian J. Appl. Sci.*, **10**: 2419-2425.

Rambabu, V.S., Md, F. and Paul, K.S.R. 2014. Estimating growth rates, decomposition analysis and instability of groundnut crop production in Andhra Pradesh. *Int. J. Dev. Res.*, **4**(1): 81-85.

RStudio Team. 2020. R Studio: Integrated Development for R. Boston (MA): RStudio PBC. http://www.rstudio.com/.

Singh, P.S.; Adarsha, L.K., Nandi; A.K. andJopir, O. 2018. Production Performance of Fresh Mango in India: A Growth and Variability Analysis. *Int. J. Pure Appl. Biosci.*, **6**(2): 935- 941.

Singh, R., Kumar, M., Dahiya, M. and Baloda, S. 2019. Development of growth model for Ber powdery mildew in relation to weather pa-rameters. *Indian Phytopathology*. pp. 1-7 72(1).