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Growth trend in vegetable production- A time series analysis

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Abstract

Vegetables are higher in productivity, short duration, and provide a valuable source of income leading to improved livelihood. This study analyzes the growth trends over the years in vegetable area, production and productivity across different states and forecast the future values with the existing growth pattern of vegetables in India.Vegetable area, production and productivity have grown at the rate of 2.17, 4.29 and 2.07 %, respectively from 1961-62 to 2017-18. Further, vegetable production in future is going to increase by 1.75 folds from 197.17Mt by 2020, 242.99Mt by 2030, 284.7 Mt by 2040 and 322.64 Mt by 2050. There would be a surplus production of vegetables ranging from 75 to 133 million tons during 2030-2050 if the same scenario of growth prevails. Highest significant growth rate in vegetable production was seen in the states like Nagaland followed by MP and Tripura. Crops like bottle gourd, brinjal, capsicum, carrot, green chilli, onion, peas, potato, sweet potato, tapioca, musk melon and water melon have more than 50% of their production coming from their 3 highest producing states. These states have to be recognized as hub for the respective crops and encouraged for direct export of surplus after meeting the demand from other consuming states. Processing and market infrastructure should be encouraged in these states for effective utilization and to minimize the wastage of surplus production.

Key words: Growth rate, forecast, vegetable area, production, productivity

Introduction

In the global endeavor for food and nutritional security, the diversity of vegetable crops and their nutritional value are of special importance. Vegetables are higher in productivity, short duration, and provide a valuable source of income leading to improved livelihood. Thus, the growth in vegetable sector has played an important role in the country's food and nutritional security, health and economic development. Around 60% of the horticulture production comprises of vegetables among which, many vegetable crops have year round production and consumption in the country. India is the second largest producer of vegetables in the world producing around 11 % of the world vegetable production.

The country has witnessed significant growth in vegetable production over the years increasing the availability of vegetables for consumption for the people. Vegetable area, production and productivity have grown at the rate of 2.17, 4.29 and 2.07 %, respectively from 1961-62 to 2017-18 over the past 57 years.

The three major vegetable crops *i.e.*, potato (28%), onion (12 %) and tomato (11%) together comprise of around 51 % of the total vegetable production in the country. Brinjal (7%), cabbage (5%), cauliflower (5%), okra (3%), peas (3%), tapioca (3%) and other vegetables comprise of 23% of the total vegetable production. These vegetables are the major source of essential micronutrients, vitamins and minerals. Consumption pattern over the years in the country has shifted from the staple cereal based diet towards a healthy and nutritive diet increasing the portion of vegetables in the food basket of consumers both in rural and urban areas. This rising demand for vegetables has led to its diversification from cereal based crops to high value crops like vegetable cultivation in the country. GOI, 2017 reported that the growth of agriculture has increased through the diversification towards high-value crops (HVC), particularly horticulture (mainly fruits and vegetables). This has augmented the sustainable growth in vegetable production, area and productivity over the decades. These growth trends over the years provide a base for the future forecast of vegetable production which can be a surplus or a shortfall in production which needs to be managed in an efficient way to meet the domestic requirements. This would provide us the ways to build a futuristic insight in crop planning and channelizing resources for catering the domestic requirements, reducing post-harvest losses; provide value chain facilities, export of the surplus produce and the necessary infrastructure development. Hence the objective of this study was to analyze the growth trends over the years in vegetable area, production and productivity across different states and to forecast the future values with the existing growth pattern of vegetables.

Materials and methods

Time series data from 1961-62 to 2017-18 was collected from Horticulture statistics, Department of Agriculture, Co-operation and Farmer's Welfare, Ministry of Agriculture & Farmers' Welfare. Statewise data on vegetable area, production and productivity was also collected from 2008-09 to 2017-18. Time series analysis using the historic data of last 57 years was analyzed using R software and forecasted the values for 2020, 2030, 2040 and 2050. Then the decade wise data was used to analyze the growth trend and instability over the period.

Time plot of the data from 1961-62 to 2017-18 on vegetable area, production and productivity showed non-stationary and an increasing trend, hence the unit root test proposed by Dickey and

Fuller (1979) also known as Augmented Dickey Fuller (ADF) test for testing the stationarity in the series was applied and found the data series is non-stationary. After first order differencing, again the test was repeated and found the series stationary for all the 3 variables.

ARIMA model: Univariate Box-Jenkins' Autoregressive integrated moving average (ARIMA) was used for the forecast of the data based on the past values of the selected variable (Box, Jenkins and Reinsel, 2007). It was carried out in three stages namely identification, estimation and diagnostic checking. Integrated Autoregressive (AR) and Moving average (MA) model, denoted by ARIMA (p, d, q) is given by the equation,

$\varphi(B)(1-B)^d y_t = \theta(B)\varepsilon_t$

Where, $\varepsilon_t \sim WN(0, \sigma^2)$ and WN is white noise. The integration parameter d is a nonnegative integer giving the order of differencing. The three components of ARIMA model p, d, q represents the orders of autoregressive, differencing and moving average components. The estimation of these orders after testing for the stationarity of the series was made in the model identification stage. Parameters of the model were obtained in the estimation stage. The best model among the different p and q orders was obtained based on the low Akaike information criteria (AIC) values. Autocorrelation function (ACF) and Partial autocorrelation function (PACF) graphs showed the significance of orders at different lags. The goodness of fit for the model was tested by plotting the ACF & PACF graphs for the residuals in the fitted model. The overall adequacy of the model was then tested by analysis of the residuals through Box-Pierce test.

Validation of the forecasts obtained in terms of accuracy of the predicted values was carried out by the measures of Mean absolute error (MAE), Root mean squared error (RMSE), Mean absolute per cent error (MAPE) and Standard error (SE). Standard error of a forecast is the standard deviation of the error term estimated using the sample mean which provides the precision of the forecasts.

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|e_i|$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}e_i^2}$$

Where, e_i are error terms calculated as (e_i, i = 1, 2… n)

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right|$$

Where, A_t is the actual value and F_t is the forecast value

Compound annual growth rate (CAGR) and instability index (II): The state wise time series data on area, production and yield of vegetables in India were collected from Division of Horticulture, Ministry of Agriculture, Co-operation and Farmer's Welfare. Compound annual growth rate (CAGR) of area, production and productivity of vegetables for different states was computed using the following formula

$Y_t = Y_0(1+r)^t$

After logarithmic transformation,

$Ln(Y_t) = A + B_t + e$

Where, $A = \ln Y_0$ and $B = \ln(1+r)$ are the parameters to be estimated by ordinary least square regression, where t = time trend in years. And finally, r = CAGR (%) = (Exp (B) -1)*100

The level of instability was computed from Cuddy Della Valle index (Cuddy and Della, 1978),

Instability index (II) = $CV * \sqrt{(1-R^2)}$

Where, CV is the co-efficient of variation.

R^2 is the co-efficient of determination from time trend regression adjusted by the number of degrees of freedom.

Results and discussion

The ADF test showed that the series is non-stationary. After first order differencing, again the test was repeated and found the series stationary for all the 3 variables (Table 1). The parameter estimates of ARIMA model was obtained for each variables and the best model among the different p & q orders was selected based on the AIC values (Table 2). Further, the overall adequacy of the model was tested by analyzing the residuals through Box-Pierce test. The results showed that the residuals are independent (Table 4). Accuracy of the predicted values was obtained using the ME, RMSE, MAE, MPE, MAPE and MASE (Table 5).

The acreage under vegetable cultivation and vegetable production has increased by 3.6 and 9.96 folds, respectively from 1961-62 (2.78 Mha & 18.47 Mt) to 2017-18 (10.06 Mha & 184.04 Mt) in the country. The forecast data showed that the area under vegetables may increase by another 1.6 folds in next 30 years to 10.83 Mha by 2020, 12.70 Mha by 2030, 14.45 Mha by 2040 and 16.08 Mha by 2050.Vegetable production may increase 1.75 folds to 197.17 Mt by 2020, 242.99 Mt by 2030, 284.7 Mt by 2040 and 322.64 Mt by 2050. Vegetable productivity has increased by 2.75 folds from 1961-62 (6.64 t/ha) to 2017-18 (18.29 t/ha) and it may rise by another 1.29 folds from 2018-19 to 2050-51 (Table 3).

The decadal growth rate was highest in area (4.12 %) and production (6.48 %) during 2001-10, whereas productivity

Table1. Stationarity test

Series		ADF test	*P* value
Vegetable area	Level	0.614	0.99
	Differenced	-4.288	0.01
Vegetable production	Level	-0.271	0.98
	Differenced	-4.989	0.01
Vegetable productivity	Level	-2.128	0.52
	Differenced	-4.175	0.01

Note: H_o: Non stationary, H_1: Stationary

Table 2. Parameter estimates of ARIMA model

Series	Model	Parameter		Sigma square	Log likelihood	aic value
		AR(1)	MA(1)			
Vegetable area	ARIMA (1,1,1)	0.993 (0.012)	-0.916 (0.058)	0.047	5.64	-5.29
Vegetable production	ARIMA (1,1,1)	0.991 (0.015)	-0.873 (0.064)	15.53	-159.76	325.51
Vegetable productivity	ARIMA (1,1,1)	0.999 (0.015)	-0.979 (0.109)	0.231	-39.79	85.58

Note: Figures in parentheses of parameter are the values of standard error (SE)

Table 3. Time series forecast for area, production and productivity of vegetables in India

Year	Area (million ha)	Production (million tons)	Productivity (ton/ha)
2020	10.83	197.17	18.32 (18.21)
2030	12.70	242.99	20.10 (17.13)
2040	14.45	284.70	21.85 (19.70)
2050	16.08	322.64	23.58 (20.06)

Table 4. Box-Pierce Test for testing the goodness of ARIMA model fit

Series	Box-Pierce test statistic	Degrees of freedom	*P* value
Vegetable area	0.774	1	0.38
Vegetable production	0.119	1	0.73
Vegetable productivity	0.073	1	0.79

Note: Ho: Residuals are independent, H1: residuals are not independent

Table 5. Forecast evaluation using ARIMA (1,1,1) residuals

Series	Vegetable area	Vegetable production	Vegetable productivity
ME	0.039	0.805	0.083
RMSE	0.215	3.907	0.476
MAE	0.136	2.177	0.291
MPE	0.557	1.117	0.763
MAPE	2.381	2.449	2.328
MASE	0.752	0.647	0.916

Note: ME-Mean Error, RMSE-Root Mean Squared Error, MAE-Mean Absolute Error, MPE-Mean Percentage Error, MAPE-Mean Absolute Percentage Error,

growth (3.04 %) was highest in 1991-00 during the actual data period. In forecasted data, the trend in growth rate was found decreasing from 2021-30 to 2041-50 for area (1.59, 1.29 and 1.06 %) production (2.07, 1.57 and 1.24%) and productivity (0.92, 0.84 and 0.76%) of vegetables in India. Instability index (II) was highest in vegetable area (5.36) and productivity (5.88) during the decade 1991-00, whereas the vegetable productivity (4.28) showed highest instability during the period 2001-10 when it witnessed highest growth rate in area and production of vegetables (Table 6). The instability got reduced from 2021-30 in the forecast data period. All the growth rates were found highly significant at 1% level of significance.

Table 6. Decadal growth rates (CAGR %) and Instability Index (II) of area production and productivity of vegetables in India

Period	CAGR (%)			II		
	Area	Production	Productivity	Area	Production	Productivity
Actual data period						
1961-70	2.14	3.78	1.62	1.98	1.12	1.77
1971-80	2.19	3.22	1.00	0.66	1.00	0.76
1981-90	1.03	3.02	1.97	3.13	0.9	2.31
1991-00	2.15	5.24	3.04	5.36	3.97	5.88
2001-10	4.12	6.48	2.30	3.29	4.28	2.03
2011-20	2.17	2.68	0.54	1.32	1.63	1.2
Forecasted data period						
2021-30	1.59	2.07	0.92	0.48	0.62	0.28
2031-40	1.29	1.57	0.84	0.39	0.47	0.25
2041-50	1.06	1.24	0.76	0.32	0.37	0.23

Note: * All the values in the table are significant at 1% level of significance
** Figures from the period 2019 to 2050 are based on forecasted values of ARIMA (1, 1, 1)

Table 7. Vegetable area and production requirement based on the population growth

Year	Population (Billion)	Actual production requirement (MT)	Surplus veg. production = Forecasted veg. production - Actual production requirement (MT)	Actual area requirement under veg. cultivation (MH)	SVA
2030	1.53	167.54	75.46 (45.0 %)	12.1	0.60 (5.0 %)
2040	1.62	177.39	107.31 (60.5 %)	12.8	1.65 (12.9 %)
2050	1.73	189.44	133.21 (70.3 %)	13.7	2.38 (17.4 %)

Note: Actual production requirement was calculated considering the RDA recommendation of 300g/person/day of vegetable consumption for a healthy adult, and at the average productivity of vegetables at 18 tons/ha. * MT (Million Tons), MH (Million ha), SVA: Surplus veg. area= Forecasted area - Actual area requirement under vegetable cultivation (MH)

Requirement of area under cultivation of vegetables in India by 2030, 2040 and 2050 was calculated by taking into consideration the population growth (Table 7). The actual vegetable production requirement for feeding the growing population was analyzed according to the standard RDA recommendation of around 300g/person/day of vegetable consumption requirement for a healthy adult. According to Sandeep *et al*., 2013, there was no difference noticed in vegetable consumption across rural-urban divide. The total production requirement was calculated after adjusting to around 30 percent of vegetable production for post-harvest losses, processing and exports. Considering the average productivity of vegetables at 18 t/ha, the area requirement under vegetable cultivation given the production requirement estimates was calculated.

The area expansion under cash/commercial crops is happening especially for short duration vegetable crops as they yield higher and early returns to the farmers. Therefore, according to the forecasted values of area under vegetables show that the area would surpass the area required under vegetable cultivation by 5 to 17% from 2030 to 2050. Similarly according to the forecasted vegetable production, there would be a surplus production of vegetables in the coming years if the same scenario of growth prevails ranging from 75 to 133 million tons during the given period. High degree of harvest and post-harvest losses, particularly in fruits and vegetables accounted for significant economic losses (GOI, 2017). With the surplus vegetable production, India should boost its processing, value addition, storage, post-harvest technologies, marketing infrastructure and for the efficient utilization of the surplus produce both in domestic and international markets.

State wise analysis of growth and instability in vegetable area, production and productivity: The vegetable production in the country is dominated by few states like Uttar Pradesh, West Bengal, Madhya Pradesh, Bihar and Gujarat (Fig. 1). These five states are the leading producers of most of the vegetables accounting for more than 50% of the total vegetable production. Uttar Pradesh is the leading highest producer of total vegetables in India accounting for around 15 per cent

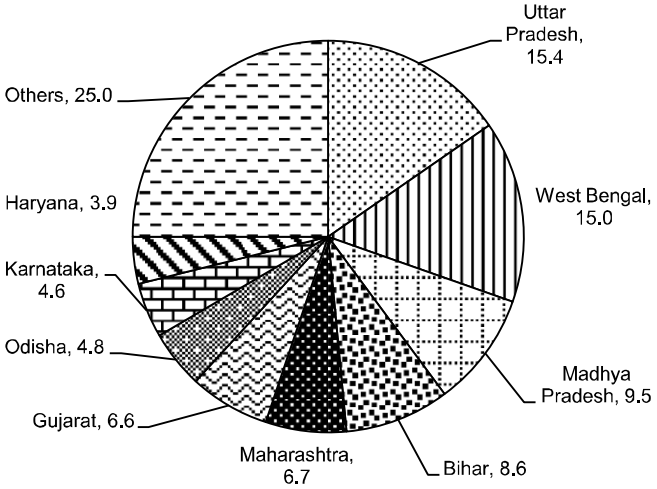

Fig. 1. State wise share of vegetable production in India (2017-18)

Table 8: State wise compound annual growth rate (CAGR) and Instability index (II) of total vegetable area, production and productivity from 2008-09 to 2017-18

States	CAGR (%)			(II)		
	Area	Production	Productivity	Area	Production	Productivity
Nagaland	21.51***	30.79***	7.64***	22.91	25.22	15.24
Madhya Pradesh	16.05***	22.38***	5.46**	15.10	23.25	13.58
Tripura	6.56***	10.57***	3.76***	10.67	14.65	6.69
Chhattisgarh	6.12***	9.3***	2.3***	1.80	5.12	5.21
Gujarat	5.4***	7.26***	1.76***	6.64	8.33	2.61
Haryana	4.16***	6.37***	2.12***	4.07	4.69	1.87
Maharashtra	5.00***	6.9***	1.82*	11.94	8.65	8.30
Punjab	3.76***	4.03***	0.26NS	5.01	2.49	2.90
Meghalaya	1.77**	4.15***	2.33**	6.26	9.63	8.38
Himachal Pradesh	1.96***	3.59***	1.61***	3.38	3.27	2.14
Rajastan	2.03NS	8.11***	5.97*	17.86	17.59	23.27
West Bengal	0.76***	1.42NS	0.65NS	1.02	7.43	7.26
Karnataka	1.23*	1.31NS	0.08NS	5.18	7.95	5.63
Manipur	12.76***	7.42***	-4.74***	19.41	9.85	10.44
Mizoram	15.13***	5.5NS	-8.4**	28.34	27.50	37.30
Uttar Pradesh	5.38**	5.00***	-0.36NS	15.33	12.68	5.77
Assam	2.6***	0.72NS	-1.84NS	2.25	18.43	18.39
Jharkhand	1.82NS	-1.64NS	-3.39***	16.51	14.88	4.95
Uttarakhand	2.26***	-0.42NS	-2.62***	4.39	5.34	2.63
Andhra Pradesh	-8.13*	-1.22NS	7.52***	42.14	39.75	17.71
Bihar	-0.08NS	0.89NS	0.97NS	1.92	5.79	5.24
Kerala	-2.74***	-7.08**	-4.46NS	5.67	19.84	22.30
Odisha	-0.56NS	0.22NS	0.79*	7.73	7.08	3.17
Tamil Nadu	-1.31NS	-2.75**	-1.46***	7.27	7.95	3.29
India	2.82***	3.73***	0.88***	2.27	3.16	1.99

* indicates statistical significance at 10%, ** indicates significance at 5%, *** indicates significance at 1%, NS indicates Non-Significance

of the total national production. More than 50 per cent of the total national area and production of many vegetable crops are dominated by few states in case of bottle gourd, brinjal, capsicum, carrot, onion, peas, potato, sweet potato, tapioca and musk melon. This shows that India is dependent on these few major states for vegetable production in the country.

The highest significant growth in acreage under vegetable cultivation was witnessed by Nagaland (21.51 %) followed by Madhya Pradesh (16.05 %), Mizoram (15.13 %) and Manipur (12.76 %), whereas highest significant growth rate in vegetable production was seen in Nagaland (30.79 %) followed by Madhya Pradesh (22.38 %) and Tripura (10.57 %). Punjab had significant growth in area (3.76 %) and production (4.03 %) of vegetables, whereas Rajasthan had positive significant growth in terms of production (8.11 %) and productivity (5.97 %). Gujarat and Maharashtra witnessed significant positive growth in vegetable area, production and productivity due to diversification towards fruits and vegetables in the recent past years (GOI, 2017).

Highest vegetable productivity growth was observed in Nagaland (7.64 %) followed by Andhra Pradesh (7.52 %) and Madhya Pradesh (5.46 %) during the period 2008-09 to 2017-18. Whereas, West Bengal and Karnataka witnessed a significant infinitesimally small growth during the period only in terms of area under vegetable cultivation not significantly contributing to vegetable production and productivity.

Highest vegetable area, production and productivity growth among all the Indian states was seen in Nagaland. Nagaland had 346.9 % increase in vegetable production from 2003-14 followed by Manipur (249.7 %) and Tripura (103.15 %) in the study conducted by Roy *et al*, 2015. Manipur, Mizoram, Uttar Pradesh and Assam had increased significant positive growth in area and production of vegetables but had a negative growth in vegetable productivity. Jharkhand (-3.39 %), Uttarakhand (-2.62 %) and Tamil Nadu (-1.46 %) had significant negative growth in productivity leading to negative non-significant growth rates in production of vegetables in these states. Same result of negative growth was seen in Tamil Nadu in fruits and vegetable production from 2011-12 to 2016-17 in the study conducted by GOI, 2017. Kerala had a significant negative growth in area (-2.74 %) under vegetables and production (-7.08 %). Andhra Pradesh had significant negative growth rate in area (-8.13 %) which may be due to separation of Telangana as separate state in 2014-15 making a non-significant contribution to vegetable production, but witnessed a high significant growth in terms of vegetable productivity (7.52%) during the period.

The instability index (II) was highest in vegetable area and production for Andhra Pradesh (42.14, 39.75) followed by Mizoram (28.34, 27.50) and Nagaland (22.91, 25.22) whereas vegetable productivity was highly instable in Mizoram (37.30), Rajastan (23.27) and Kerala (22.30). The average significant growth rate for vegetable area, production and productivity in India was 2.82, 3.73 and 0.88 per cent, respectively for the given period with low instability index of 2.27, 3.16 and 1.99, respectively.

Despite, achieving the required production of vegetables in future, the major challenges posed in vegetable sector is the stagnant growth in productivity of vegetables. Any increase in production largely depends on area expansion, which is happening due to crop diversification. The current year production of 184 million tons of vegetables which has surpassed the target production of the year and the same scenario is also been predicted in the coming years. There is a need for the preparation and planning for handling the surplus production of vegetables through processing, creating adequate cold storage facilities and export of the surpluses to other parts of the world. The supply-demand gap in total vegetables reveals that there will be substantial shortage of vegetables unless post-harvest losses are minimized, which is as high as 24 percent (Kumar, Joshi and Mittal, 2016).The post-harvest losses are high in case of vegetables (around 24 %) which pose another bigger challenge in this sector which can be reduced through processing, value-addition for which there is requirement of adequate marketing infrastructure and value chain expansion benefitting a large number of stakeholders involved in the supply chain. The recent 3 important ordinances passed by GOI for the benefit of farmers would play an important role in vegetable marketing by eliminating the barriers to inter and intra state trade & commerce outside the physical market premises which came under APMCs. Crops like bottle gourd, brinjal, capsicum,

carrot, green chilli, onion, peas, potato, sweet potato, tapioca, musk melon and water melon have more than 50% of their production coming from their 3 highest producing states. These states have to be recognized as hub for the respective crops and encourage for direct export of surplus after meeting the demand from other consuming states. Processing and market infrastructure should be encouraged in these states for effective utilization of surplus production. The farmers (empowerment and protection) Agreement on price assurance and farm services ordinance, 2020 would help the farmers in reducing market risks. Removal of onion and potatoes from the list of essential commodities would attract investors for cold storage and processing facilities for vegetable crops.

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