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Spatio- Temporal Analysis of Capsicum Cultivation in Solan District (H.P.)

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Abstract

The study was undertaken to analyzed the growth rate, instability, contribution of area and yield of capsicum in Solan district of Himachal Pradesh using the Compound Annual Growth Rate (CAGR), Cuddy Della Valle Instability Index (CDVI) and Decomposition Analysis for a period of 25 years (1995-2020) using data obtained from Directorate of Agriculture and forecasted the area, production and productivity by adopting ARIMA model for the next five years (2021-2025). It was observed that the area, production and productivity of capsicum increased during the study period; however, the growth in production (15.13%/annum) was higher than the growth in area (7.59%/annum), whereas growth in productivity was seven per cent per annum. The stability index was found to be positive, indicating that there is less danger for cultivation in the district. Production decomposition analysis showed that the expansion of the area was the primary cause of the production growth, accounting for more than 50 per cent. By using R-studio software, ARIMA (0, 2, 1), ARIMA (0, 2, 1) and ARIMA (0, 2, 1) were identified for forecasting area, production and productivity and the forecast revealed that the area, production and productivity showed an increasing trend for the next five years.

Keywords: Auto regressive integrated moving average, growth rate, Cuddy Della Valle instability index, decomposition, capsicum, forecasting.

JEL Classification: Q00, Q10, C 22, R15

Introduction

India is one of the largest producer of vegetable crops and is known as vegetable basket of the world (Gandhi and Nambordiri, 2002, APEDA, 2021, Negi and Anand, 2014, Devi and Kumar, 2020, Kundu and Mandal, 2020).Vegetables are essential to Indian agriculture and nutritional security because of their short growing season, high yield, nutritional diversity, economic viability and ability to generate jobs both on and off the farm. (Schreinemachers *et al*, 2018). India benefits from a diverse array of agro-climatic conditions that allows cultivation of a vast variety of vegetables. India produced 197.23 million tonnes of vegetables across an area of 10.97 million ha (Anonymous, 2021). With a productivity of 17.70 tonnes per ha, India accounts for about 14 per cent of the global vegetable production (Sahani and Kumari, 2017).

Capsicum is a significant cash crop of India, cultivated over approximately 24,000 ha with an annual production of 326,000 tonnes (NHB, 2018). Vegetable productivity of India is comparable to the global average, ranging from 17.3 to 18.8 tonnes per ha (Tegar *et al.,* 2016). Himachal Pradesh leads capsicum production in India, contributing 57.41 thousand tonnes which is about 20 per cent. It serves as the primary supplier to the plains during the summer and rainy seasons. Major cultivation areas include Solan, Sirmour, Bilaspur, Mandi and the lower regions of Shimla district (Singh *et al.,* 2020). In the state, Solan district produce the highest yielding 34.85 thousand tonnes from an area of 1.22 thousand ha (Kumari *et al*. 2022).

Trend analysis is an aspect of technical analysis that attempts to explain the time series behaviour of a particular crop in the past and predict the future accordingly (Box *et al*. 2015). The growth rate of productivity plays a crucial role in driving agricultural transformation and serves as a key engine for farm economy growth. It enables farmers to escape poverty and the low income equilibrium trap, thereby contributing to broader economic development. To accomplish this, it is essential to intensify efforts aimed at boosting production while sustaining or enhancing

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productivity levels (Christiaensen and Martin, 2018). Agricultural growth and its associated instability have been topics of significant debate, not only in India but globally. While the necessity of enhancing agricultural production and growth is widely acknowledged, the rising instability in agricultural production is often viewed as detrimental for various reasons (Chand and Raju, 2009). Hence, it is crucial to analyze the trends of vegetable growth. The forecasting of the parameters is also essential. Without reliable predictions of vegetable production in the country, planning and programme development may become ineffective. Precise forecasts enable efficient management of surpluses and deficits, helping to stabilize prices and ensure farmers' profitability (Kumar *et al.,* 2020). Furthermore, accurate forecasting plays a vital role in strengthening policy decisions, ensuring food security, regulating imports and exports and enforcing price regulation (Badmus and Ariyo, 2011).Though many methods and approaches for trends analysis and forecasting of vegetable crops are available in the literature, this paper deals with compound annual growth rate, decomposition analysis, Cuddy Della Valli index (Cuddy and Valle, 1978)and Auto Regressive Integrated Moving Average (ARIMA) (Box and Jenkins. 1976). These are the most popular techniques that was successfully applied to study the trends and forecasting the vegetable crops and are the most widely used methods (Sharma., 2007, Swain., 2007, Verma *et al*., 2009, Chahbi *et al*.,2012, Dastagiri *et al*., 2013, Mishra *et al*., 2013, Savadatti, 2017, Mila and Parvin, 2019).

Solan district of Himachal Pradesh was selected for the study area as it leads the state capsicum production with 34.85 thousand tonnes produced overall from 1.22 thousand ha. Agarwal *et al*. (2014) and Dhakre and Bhattacharya (2013) study the growth performance, instability and decomposition of vegetable crops in Madhya Pradesh and West Bengal, respectively. Thapa *et al.* (2022) used the Box-Jenkins ARIMA Model to forecast area, production and productivity of vegetable crops in Nepal. Although several studies have been done in India and aboard to forecast the area, production and productivity of vegetables crops, it was noticed that a very few studies have been conducted for capsicum in mid-hill zone of Himachal Pradesh. Hence, using time series data, the current study was carried out to assess and forecast the area, production and productivity of capsicum.

Data Sources and Methodology

The time series data of area and production were collected from Directorate of Agriculture, Shimla, Himachal Pradesh for the period 1995-2020. The time series data have been divided into five sub periods: 1995-2000, 2001-2005, 2006-2010, 2011-2015 and 2016-2020. Standard statistical methods were used to process and analyse the data. Some of the methods used for data analysis are given below.

Compound Annual Growth Rate (CAGR): To determine the compound growth rates for different variables, an exponential function was fitted to the area, productivity and production of capsicum in the research region as mentioned in Patil and Yeledhalli (2016). The following power function was fitted using the ordinary least squares methods: $Y=ae^{bt}$. With the aid of log arithmetic transformation, it was transformed into a log linear function as shown below:

$$LnY= Ln\ a\ +t\ b. \quad (1)$$

Where, Y = Dependent variable (area, production and productivity etc.)

t = Independent variable (time in a year).

The following formula was used to determine the compound annual growth rate (CAGR):

$$CAGR = b*100$$

Cuddy Della Valle Instability Index: The Cuddy-Della Valle Index was developed by Cuddy and Valle (1978) to quantify the trend driven instability of time series data. The variability coefficient has been computed by Krishan and Chanchal (2014) and Manohar and Udhayan (2022).

$$IX= CV*\sqrt{(1-R^2)}$$

Where;

IX= Instability Index

CV= Coefficient of variation

R^2= Adjusted estimated coefficient of determination.

Decomposition Analysis: According to Sharma (2007), a decomposition method was used to provide a wide range of the relative impact of area expansion and yield improvement on vegetable production growth..

$$P = A * Y$$

$$(P+ \Delta P) = (A + \Delta A) * (Y + \Delta Y)$$

$$\Delta P = \Delta A\,Y + \Delta Y\,A + \Delta A\,\Delta Y$$

Change in production = Yield effect + Area effect + Interaction effect

ARIMA model: Auto Regressive Integrate Moving Average (ARIMA) model is the most commonly utilized method for forecasting time series data (Box and Jenkins. 1976). The method utilizes historical time series data along with an error term to project future values. Specifically, it integrates a general autoregressive model (AR), Integrated (I) and a general moving average model (MA) where AR component relies on past values of the dependent variable for making forecasts, while MA component utilizes the average of the series and prior errors to generate predictions. The process of differentiating the time series data until it achieves stationary is part of the Integrated (I) concept. A non seasonal ARIMA is represented as ARIMA (p,d,q) where p indicates the number of autoregressive terms, d represents the count of differences required for stationary and q refers to the number of lagged forecast errors included in the prediction equation.. Mathematically, an autoregressive model of order p can be represented as

$y_t = \phi_1 y_{t-1} + \phi_2 y_{t-2} + \ldots\ldots + \phi_p yt\text{-}_p + a_t$

where, $\phi_1 \ldots\ldots \phi_p$ represents parameters; d represents degree of differencing

Mathematically, a moving average model of order q can be expressed as

$y_t = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \theta_3 a_{t-3} - \ldots\ldots\ldots - \theta_q a_{t-q}$

where, θ_1, θ_2,.. θ_q represents parameters; a_t represents error residual and a_1, a_2,……. a_{t-q} represent previous values of error.

Model Prediction: Box-Jenkins' methodology was employed for predicting and validating the model of area, production and productivity of capsicum (Durdu, 2010 and Thapa *at el*., 2022).

Model Identification: To assess whether the stationarity of the time-series data, the Augmented Dickey- Fuller (ADF) was utilized. The null hypothesis, indicating non-stationarity, was rejected when the ADF test statistic exceeded the critical value at a five per cent significance level. The test confirmed that the time series became stationary after differentiation of order 'd'. Subsequently, the autocorrelation function (ACF) and partial autocorrelation function (PACF) were plotted to identify significant spikes. The appropriate ARIMA model order (p, d, q) for each time series of the area, production, and productivity was then determined using the auto-ARIMA function from the R Studio forecasting package.

Model Estimation: The Maximum Likelihood (ML) method, recognized as one of the most effective and widely used techniques for parameter estimation in ARIMA models was employed to estimate the model parameters after selecting the appropriate model (Box and Jenkins 1976).

Diagnostic checking: ARIMA model which is best fit was selected based on two performance metrics: AIC and RMSE. The model having the minimum value of these criteria was identified as the superior model. According to Verbeek, 2004, AIC is the most effective and crucial standard for choosing the optimal model. The value of 'p' and 'q' were determined using trial-and –error approach by experimenting with various combinations of 'p' and 'q' and the model that had the lowest Akaike's Information Criterion (AIC) and Root Mean Square Error (RMSE) was selected.

$AIC = -2\log(L) + 2(p+q+k+1)$

Where, L is the likelihood of the data, k=1 if c≠0 c ≠ 0 and k=0 if c=0.

$RMSE = \sqrt{1/n\, \Sigma\{(logG_t + 1 - log\,(M_t + 1)\}^2}$

Where, n represents the specified number of time periods, G_t denotes the initial value at a given time and M_t indicates the forecasted value for time period t.

Model Forecasting: The model was used to forecast the area, production, productivity of capsicum in Solan district of Himachal Pradesh for the next five years (2021 to 2025).

The modelling and forecasting were carried out using R studio (4.2.1 version) software.

Results and Discussion

Trends in area, production and productivity of capsicum: Table 1 presents trends in the area, production and productivity of capsicum from 1995 to 2020, to facilitate a more effective comparison of the growth rates of area, production and productivity in the study area over time, the period was broken down into five sub-periods. Between 1995 and 2020, the average area was 0.78 thousand ha, with an average productivity of 15.16 tonnes per ha and output of 14.72 thousand tonnes. Similar findings were reported by Sharma in 2007. It is observed that the rise in productivity was seven per cent per annum, while the growth in production was 15.13 per cent annually, greater than the growth in area (7.59% annually). The analysis of the area's growth trend by sub-period indicates that all study sub-periods had positive growth rates with declining trends. There were variations from year to year when the sub-periods were being studied. The sub-period 2001-2005 showed the highest area variability (21.84%), while the sub-period 2011-2015 showed the lowest fluctuation (3.24%).

The average production grew eight times at a significant growth rate of 15.13 per cent per annum from 1995-2000 to 2016-2020. The sub-period analysis revealed a positive growth rate in production, with the exception of the 2016–2020 sub-period, which saw an annual growth rate of -4.02 per cent. The sub-period 2001–2005 showed the most fluctuations in capsicum output (36.58%), whilst the sub-period 2016–2020 showed the lowest fluctuations (7.43%). The trend of production variability decreased. According to the data, between 1995-2000 and 2016-2020, the average yield of capsicum increased from 17.83 MT/ha to 25.59 MT/ha. The productivity of capsicum recorded a significant growth rate of seven per cent per annum during 1995-2020. However, negative growth trend (2.60 %/annum) and (8.28 %/annum) was observed in the first and last sub - period i.e. 1995-2000 and 2016-2020, respectively. All the other sub-periods showed positive growth rate with the highest (18.99%/annum) observed in sub-period 2011-2015. The degree of variation found in productivity was about 21 per cent for the period 1995-2000 to 2020-21. The highest (17.22%) variability in capsicum productivity was observed during sub-period 2001-2005, while the lowest (4.01%) variability was found during sub-period 2006-2010.

Decomposition analysis of capsicum production: The purpose of the decomposition study was to investigate the variables influencing the variations in capsicum production across different time periods. Area and yield are thought to

Table 1: Trends in area, production and productivity of capsicum during 1995 to 2020

Period	Area			Production			Productivity		
	Average (000'ha)	CDVI	CAGR (%)	Average (000'MT)	CDVI	CAGR (%)	Average (MT/ha)	CDVI	CAGR (%)
1995-2000	0.36	11.51	11.92** (0.04)	2.95	12.11	9.01** (0.03)	17.83	14.40	-2.60 (0.04)
2001-2005	0.41	21.84	17.38 (0.10)	3.96	36.58	28.41 (0.13)	9.20	17.22	9.40 (0.06)
2006-2010	0.77	10.61	12.35** (0.04)	10.89	14.72	17.65** (0.05)	13.87	4.01	4.71** (0.01)
2011-2015	1.09	3.24	6.90* (0.01)	24.16	14.76	27.20* (0.05)	21.67	11.22	18.99** (0.02)
2016-2020	1.37	5.30	4.65*** (0.02)	34.54	7.43	-4.02 (0.03)	25.59	11.14	-8.28 (0.05)
1995-2020	0.78	8.09	7.59* (0.005)	14.72	24.71	15.13* (0.014)	15.16	20.62	7.00* (0.01)

CDVI- Cuddy-Della Valle instability index
Figures in parentheses are the standard errors of the compound growth rates.
**** represents significance at 1, 5 and 10 per cent level, respectively*

play a significant role in the production of capsicum. Using the Narula and Vidyasagar (1973) model, the contribution of each of them to the production was displayed.

The yield effect, area effect and interaction effect were used to break down the relative contributions of the various components in capsicum growth. The results are shown in Table 2. It illustrates how area, yield and their interactions contributed as a percentage to the growth in capsicum output between 1995 and 2020. The results clearly showed that from 1995 to 2020, the area effect was the primary driver of rising production. Sethi *et al.* (2022) have also obtained similar results. The area effect was 52.26 per cent which was more than interaction effect (41.37%) and yield effect (6.36%). The study of the sub-periods revealed negative yield (-72.80%) and interaction effect (-74.53%) in first and (-109.16%) negative area effect in fifth sub-period, while positive influence of area, yield and interaction was observed in rest of the sub-periods. This clearly showed that increased capsicum production in Solan district of Himachal was the cumulative effect of acreage expansion.

ARIMA forecast for the area, production and productivity of capsicum:

Yearly area, production and productivity data of capsicum were used to fit suitable ARIMA model. The series was not stationary; therefore, the second difference of area, production and yield was taken to make the series stationary. The number of AR(p) and MA(q) were identified by trial-and-error method by trying different combinations of p and q values and then selecting the model with lowest AIC and RMSE values which is a criterion to select the best model. Based on these values, ARIMA (0, 2, 1), ARIMA (0, 2, 1) and ARIMA (0, 2, 1) were selected as best fitted model for forecasting the area, production and productivity, respectively which have been presented in Table 3.

Based on the selected models, the forecasted value with 95 per cent confidence interval values are shown in

Table 2: Decomposition analysis of capsicum production, 1995 to 2020

(Percentage)

Years/Components	Area effect	Yield effect	Interaction effect
1995-2000	247.32	-72.80	-74.53
2001-2005	37.43	40.60	21.97
2006-2010	65.60	23.26	11.14
2011-2015	19.76	63.89	16.35
2016-2020	-109.16	174.63	34.53
1995-2020	52.26	6.36	41.37

Table 3: Identification of the ARIMA (p, 2, q) model of capsicum

	ARIMA (p, d, q)	AIC	RMSE
Area	0,2,0	306.07	131.09
	0,2,1	293.72	90.90
	1,2,0	301.46	133.54
	1,2,1	295.57	90.98
	2,2,2	299.3	90.92
Production	0,2,0	474.37	436.78
	0,2,1	468.82	348.99
	1,2,0	472.75	403.79
	1,2,1	469.97	349.86
	2,2,2	472.43	402.67
Productivity	0,2,0	145.72	4.64
	0,2,1	136.75	3.45
	1,2,0	143.16	4.20
	1,2,1	138.74	3.46
	2,2,2	138	3.98

Table 4. For 2021, the forecast area was 1.63 thousand ha with lower and upper limits of 1.44 and 1.82 thousand ha while area forecast of 2025 was 1.85 thousand ha with lower and upper limits of 1.38 and 2.31 thousand ha which showed an increasing trend (Fig 1). Similarly, the forecast for production of capsicum showed an increasing trend. The forecast production for 2021 was 29.96 thousand MT with lower and upper limits of 22.54 and 37.38 thousand tonnes, respectively while, the forecast for 2025 was 34.24 thousand tonnes with a lower limit of 16.42 thousand tonnes and upper limit of 52.05 thousand tonnes (Fig 2).

Productivity for 2021 was 18.84 MT/ha with lower limits of 11.23 MT/ha and upper limit of 29.57 MT/ha and for 2025, the forecast production was 20.93 MT/ha with lower and upper limits of 2.33 and 37.59 MT/ha, respectively which showed an increasing trend (Fig 3).

Conclusion and Policy Implications

The growth analysis of area, production and yield of capsicum was significant during 1995-2020. Area and productivity increased at 7.59 and seven per cent per annum, respectively, whereas, production increased at a high rate with

Table 4: Forecast of area, production and productivity of capsicum up to 2025

Years	2021	2022	2023	2024	2025
Area(000'ha)					
Forecasted Value	1.63	1.68	1.74	1.79	1.85
LCL	1.44	14.05	1.39	1.37	1.38
ULC	1.82	1.96	2.09	2.20	2.31
Production (000'tonnes)					
Forecasted Value	29.96	31.03	32.10	33.17	34.24
LCL	22.54	20.34	18.77	17.50	16.42
ULC	37.38	41.72	45.43	48.83	52.05
Productivity (ton/ha)					
Forecasted Value	18.84	19.34	19.86	20.39	20.93
LCL	11.23	8.41	6.12	4.13	2.33
ULC	29.57	29.57	32.51	35.14	37.59

LCL – Lower Confidence Level at 95%, UCL – Upper Confidence Level at 95%

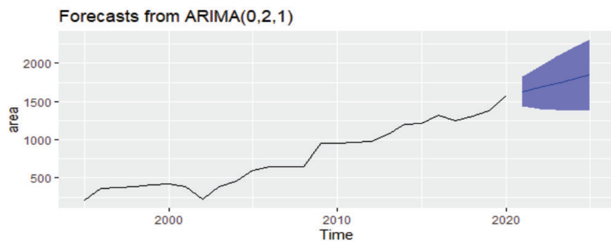

Figure 1: Plot of the ARIMA forecast of area.

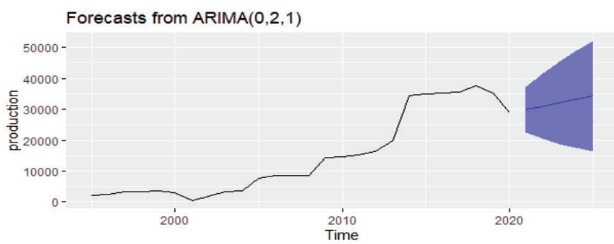

Figure 2: Plot of the ARIMA forecast of productivity.

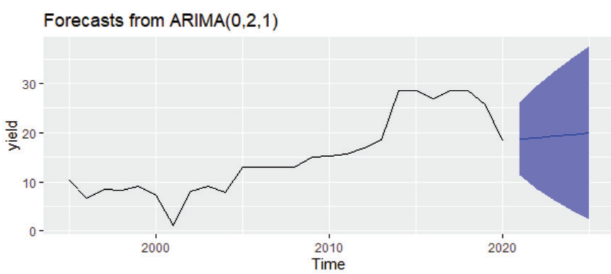

Figure 3: Plot of the ARIMA forecast of production.

15.13 per cent per annum. Instability analysis of the area, production and yield suggests that production showed higher variation than area and yield. Production showed 24.71 per cent, whereas, 8.09 per cent and 20.62 per cent variation was observed in area and yield, respectively. The study of the relative contribution of the area, yield and interaction effect on production revealed that area contributed more than 50 per cent increase in the production, whereas, 41.37 per cent increase was due to the interaction of area and yield, hence in order to enhance production and yield, enhancement approach should be adopted through improved agronomic practices including improved varieties and giving training. The best ARIMA models identified were ARIMA (0, 2, 1), ARIMA (0, 2, 1) and ARIMA (0, 2, 1) for forecasting area, production and productivity. The forecast revealed an increasing trend in area, production and productivity of capsicum.

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