Original Research Article

Modeling and Monitoring Walnut (Juglans regia) Area & Production Based on Parametric and Non-Parametric Regression Models

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ABSTRACT

Walnut (Juglans regia L.) occupies an important position in the horticulture industry of Jammu and Kashmir. It has the monopoly of producing excellent quality of walnuts contributing more than 90 per cent of Indian walnut production. The temperate climatic conditions favor its cultivation and offer Jammu and Kashmir an exceptional edge to surpass the other states in terms of walnuts. Being organic in nature (which is its USP), as no fertilizers or sprays are used on walnut plants and its yield, and high in nutrients with immense health benefits, Kashmiri walnut has seen growing demand and acceptability in the domestic and international market. The present study is an attempt to find past trends of walnut in Jammu and Kashmir using parametric, non-parametric and semi-parametric regression methods. The performance of each method is compared using high value of R and low value of residual criteria. It is found that non-parametric/semi-parametric regression comes out to be a good fit for trend in walnut production in comparison to parametric regression. Even semi parametric spline is selected as the best fit model for trend analysis. It is inferred that the area under walnut cultivation in J&K is increasing from 1998-2017 and the productivity has also shown an increasing trend except for some years where the trend is found declining.

Keywords

Walnut (Juglans regia), Vitamin E and A

Introduction

Walnut (Juglans regia L.) is economically important tree species, highly valued for its timber and edible nuts (Pollegioni et al., 2017). Walnut has the age of hundreds of years and it grows up to the height of 25 to 30 meters. Native to Central Asia, Mediterranean climate with cold winters and mild summers is most suitable for this dry fruit. A walnut tree is harvestable after 4 to 6 years and reaches its full productivity by 11 or 12 years of age (Simpson, 2016). Rich in Vitamin E and Vitamin A and a perfect source of Omega 3 is considered best for the human brain.

Jammu and Kashmir with its extensive potential of the production of temperate fruits supported by its vibrant geo-climatic conditions play marvelous role in the development of the walnut industry. The state is also well known for the production of
numerous types of fruits like apple, cherry, pear, apricots and in dry fruits category it also produces walnuts (Taufique and et al., 2017) hence takes the lead in the walnut production in India. Walnuts became the viable horticulture industry in India since 1980’s particularly in the valley of Kashmir (Pandey and Shukla, 2007). Jammu and Kashmir occupy almost 90 per cent share of walnut industry in India (Mir et al., 2016). Recently Jammu and Kashmir have been declared as an ‘Agri-Export Zone’ for ‘walnuts’ (Shah, R.A, 2017). Walnut produced in Jammu and Kashmir is purely organic as it is grown in the naturally induced conditions without the heavy doses of fertilizers and sprays. The aroma, flavor and taste of its excellent capacity make the walnut of Jammu and Kashmir one of the best in Indian and abroad as well. (Chandran, 2004) has applied nonparametric regression to study the growth rates of total foodgrain production of India during the period 1987 to 2001. Teczan (2010) has studied the nonparametric regression technique to find out the growth rate trends of various crops. Sahu and Pal (2004) used nonparametric regression (Lowess) and semi-parametric (spline) for modeling of pest incidences. Dhekale et al., 2017, employed the nonparametric regression model to study the trends of tea in India. Yasmeen et al., (2018, 2019) employed non parametric and parametric regression models to study the trend of Area, Production and productivity of Apple and cherry in Kashmir. The current study is aimed to develop appropriate parametric and nonparametric regression models to fit the trends in area, production and productivity of Walnut in Kashmir.

Materials and Methods

For present study, to study the trends and growth rates, long term data for last 20 years pertaining to the area, production and productivity of Walnut is collected from Directorate of Horticulture.

The descriptive measures of central tendency and dispersions along with the simple and compound growth rates are used to explain the features of the data (Mishra et al., 2012).

Trend Models

Parametric Regression Models

To find out the path of the production process different parametric trend models are fitted. Among the fitted models, the best model is selected on the basis of their goodness of fit ($R^2$) value and significance of the coefficients. The dependent variable $Y$ is area, production and productivity and independent variable $X$ is the time points (years)
Non-parametric and semi-parametric regression models

The model considered here is of the form

\[ y_i = m(x_i) + e_i, x_i = i/n, i = 1, 2, ..., n \]

Where, \( y_i \) is observation of \( i^{th} \) time point, \( m(.) \) is trend function which is assumed to be smooth and are \( e_i \) random errors with mean zero and finite variance. Since there is no assumption of parametric form of function, this approach is flexible and robust to deviations from an assumed model form. To obtain an estimate of the mean response value at a point \( X \), most of the smoothers are averaging the \( Y \) – values of observations having predictor values closer to the target value \( X \). The averaging is done in neighborhoods around target value. The main decision to be made in any of the smoothing techniques is to fix the size of neighborhood which is typically expressed in terms of an adjustable smoothing parameter or bandwidth. Intuitively, large neighborhoods will provide an estimate with low variance but potentially high bias, and conversely for small neighborhoods. Lowess regression, introduced by Cleveland (1979), is obtained on the basis of the data points around it within a band of certain width.

The point \( x_i \) is the midpoint of the band. The data points within the band are assigned weights in a way so that \( x_i \) has the highest weight. The weights for the other data points decline with their distance from \( x_i \) according to a weight function. The weighted least squares method is used to find the fitted value corresponding to \( x_i \), which is taken as the smoothed value. The procedure is repeated for all the data points. The spline method of estimation make use of the penalized least squares method (Simonoff, 2012), which balances the fitting of the data closely. The objective is to estimate \( m \) by means of a function that fits the data well and is as smooth as possible. A measure of smoothness of \( m \) is the integral of the square of its second derivative as

\[ \sum_{i=1}^{n} (Y_i - m(x_i))^2 + \lambda \int_{a}^{b} (m''(x))^2 dx \]

Where \( \lambda > 0 \) is a fixed constant and \( x_i \in [a, b] \)

The first term is the sum of squares of the residuals; it provides a measure of how well the function \( m \) fits the data. The integral of the above equation is a measure for the roughness/smoothness of the function. The functions which are highly curved will result in a large value of the integral; straight lines result in the integral being zero. The roughness penalty, controls the emphasis which one wishes to place on smoothness. By increasing the value of, one places more emphasis on smoothness; as becomes large the function approaches a straight line. On the other hand, a small value of \( \lambda \) emphasizes the fit of \( m \) to the data points: as \( \lambda \) approaches a function that interpolates the data points.

Results and Discussion

The maximum growth rate is observed in production of walnut over the years, whereas the minimum growth rate is exhibited by area of the walnut.

The positive compound growth of production (0.078 per annum) reveals that there is no decrease in the production of walnut over the years with a maximum of 0.17 million kilogram and minimum of 0.04 million kilogram. Similarly, the simple growth rate (2.59 per annum) is observed in production indicates an increase in the production of walnut in Kashmir over the years (Table 1 and 2).
This is due to the fact that a large area of land is being brought under agriculture. We have noticed a compound growth rate of area (0.03 per annum) under walnut cultivation indicating that a large portion of the land is being utilized for the latter.

**Table 1** Performance of Walnut production in Kashmir during 1998-2017

| Area (‘000 hectares) | Production (‘000 MT) | Productivity (Quintals per hectare) |
|----------------------|----------------------|-------------------------------------|
| Minimum              | 32.65                | 44.85                               | 13.26                               |
| Maximum              | 56.98                | 169.42                              | 31.30                               |
| Mean                 | 47.58                | 109.39                              | 22.08                               |
| Standard Deviation   | 8.27                 | 34.92                               | 6.206                               |
| CV(%)                | 17.38                | 31.08                               | 28.07                               |
| Skewness             | -0.75                | -0.07                               | 0.146                               |
| SGRA                 | 0.61                 | 2.59                                | 1.23                                |
| CGRA                 | 0.029                | 0.078                               | 0.047                               |

CV= coefficient of variation, SD= standard deviation, SGAR= simple growth rate per annum, CGAR= compound growth rate per annum

**Table 2** Trends in area, production and productivity of Walnut in Kashmir Division

| Area | R-Square | Constant b0 | b1 | b2 | b3 | RMSE | MAPE | MAE | MaxAPE | MaxAE |
|------|----------|-------------|----|----|----|------|------|-----|--------|-------|
| Area | 0.84     | 29.74       | 1.73 | 0.08 | -0.005 | 4.37     | 0.46  | 1.25  | 6.59   | 3.3   |
| Production | 0.82 | 42.71       | -0.2 | 1.05 | 0.03 | 12.42 | 0.78  | 4.55  | 25.28  | 39.23 |
| Productivity | 0.87 | 13.19      | 0.14 | 0.1  | 0.003 | 5.56  | 0.51  | 0.77  | 22.25  | 35.68 |

Area in ‘000 hectares, Production in ‘000 metric tons, Productivity in quintals per hectare

**Table 3** Trends in area of Walnut in Kashmir using non-parametric and semi-parametric regression

| Loess | Splines |
|-------|---------|
| Bandwidth | 0.37 | 0.28 |
| R-Square  | 0.91 | 0.94 |
| AICc      | 1.70 | 1.23 |
| RMSE     | 0.75 | 0.67 |
| MAPE     | 0.11 | 0.10 |
| MAE      | 0.75 | 0.70 |
| MaxAPE   | 4.09 | 3.39 |
| MaxAE    | 1.6  | 1.39 |
Table 4 Trends in production of Walnut in Kashmir using non-parametric and semi-parametric regression

|               | Loess | Splines |
|---------------|-------|---------|
| Bandwidth     | 0.62  | 0.43    |
| R2            | 0.93  | 0.98    |
| AICc          | 6.17  | 3.15    |
| RMSE          | 9.58  | 2.05    |
| MAPE          | 0.246 | 0.11    |
| MAE           | 2.55  | 1.18    |
| MaxAPE        | 17.28 | 4.24    |
| MaxAE         | 26.23 | 5.46    |

Table 5 Trends in productivity of Walnut in Kashmir using non-parametric and semi-parametric regression

|               | Loess | Splines |
|---------------|-------|---------|
| Bandwidth     | 0.80  | 0.72    |
| R2            | 0.90  | 0.96    |
| AICc          | 2.76  | 1.98    |
| RMSE          | 1.92  | 0.24    |
| MAPE          | 0.23  | 0.08    |
| MAE           | 0.11  | 0.39    |
| MaxAPE        | 20.48 | 2.89    |
| MaxAE         | 5.85  | 0.67    |

Fig. 1 Observed and expected trends of area under Walnut cultivation using spline in Kashmir
Fig. 2 Fits with specified smooths for area

Fig. 3 Observed and expected trends of Production under Walnut cultivation using spline in Kashmir

Fig. 4 Fits with specified smooths for production
**Trend analysis of area, production and productivity**

**Parametric techniques**

The linear models used here are the cubic model or the third degree polynomial model and the quadratic model or second degree polynomial model. The value of $b^3$ for area is negative which indicates that area under walnut cultivation decreased in the last part of the cultivation period and the value of $b^1$ and $b^2$ being positive clearly indicates that there was an increase in the cultivation area. Further, the negative value of $b^1$ for production is an indication of the decrease in the production during the initial period of the study and the positive values of $b^2$ and $b^3$ indicates an increase in the production.

**Non-parametric and semi-parametric regression**

Trend analysis of area, production and productivity using nonparametric (Loess) and semi-parametric (spline) regression are
presented in the tables 3, 4 and 5. In Table 3 the value of R2 is 0.91 for Loess and 0.94 for Spline regression. The AICc, RMSE, MAPE, MAE, MaxAPE and MaxAE values comes out be small for Spline regression for the area under walnut cultivation. The area under the walnut cultivation has increased over the years of study and is shown in figure 1.

On comparing the values of AICc, RMSE, MAPE, MAE, MaxAPE and MaxAE for production and productivity the spline regression has the smallest values. The increasing trend in the production and productivity over the years of study is shown in the figure 3 and 5. It can be observed that upto 2013-14 there is sharp increase in production and productivity. However, a decline in production and productivity can also be observed during the year 2014-15 is observed which is due to the floods that occurred during the said year (Islam and Shrivastava, 2017).

The values of area are initially fitted at the smoothing parameters in order to obtain the best fit of the data points we obtain the graph of the data points in the neighborhood of the smoothing parameters and look for the curve which covers all the points of the data. The one which covers maximum points is the best fit of the data points. In figure 2 the smooth curve fits are obtained for area in the neighborhood of smoothing parameters i.e., at 0.25, 0.375, 0.60 and 0.80. It is observed that the best fit is obtained at smooth=0.375. In figure 4 smooth fits for production are plotted in the neighborhood of the smoothing parameter at 0.15, 0.20, 0.35 and 0.62 and it is observed that the best fit obtained for smooth=0.62. Figure 6 provides the fits for productivity in the neighborhood of the smoothing parameters i.e., at smooths equal to 0.25, 0.35, 0.45 and 0.75. The best fit is observed to be at the smooth=0.75

Even values of RMSE, MAE, MAPE, MaxAE and MaxAPE for area production and productivity of Kashmir for non-parametric regression has observed lower values than the parametric regression (Tables 3, 4, 5). This is clear indication of the superiority of these techniques over the parametric models. These models perform very well in visualizing the past trends where the parametric models fails to.

Among the nonparametric and semi-parametric regression, the spline regression has shown the lowest values of AICc, RMSE, MAPE, MAE, MaxAPE and MaxAE for area, production and productivity of walnut in Kashmir hence spline regression is the best fitted model for walnut production in Kashmir (Fig. 5). Various scientist viz. Aydin (2007) and Pal (2011) observed similar results where the spline gave the better results than the Loess smoothing.

In the above study, three types of modeling are discussed parametric, semiparametric, nonparametric modeling. Nonparametric and semi-parametric regression models are flexible compared to parametric models. Semi-parametric is hybrid of both parametric and nonparametric which allow to have the best of both worlds: a model that is understandable and offering a fair representation of the data in the real life. However, semi/nonparametric regression requires larger sample sizes than regression based on parametric models because the data must supply the model structure as well as the model estimates (Mahmoud, 2019). From the above study it is observed that there is dramatic increase in the area under walnut cultivation and in the production as well as productivity. In order to maintain the trend more and more land is to be brought under the walnut cultivation. Parametric regression usually utilized in studying the trend seems not to perform better than the nonparametric
and semi-parametric regression. And out of the nonparametric and semi-parametric regression methods the semi-parametric regression (spline) is the best fit for the trend analysis of the walnut production of Kashmir.

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