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Forecasting area, production and productivity of mango in Gujarat by using an artificial neural network model

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Abstract
The present study conducted to forecasting area, production and productivity of mango in Gujarat by using different models. The secondary data on area, production and productivity of mango in Gujarat (1991-92 to 2017-18) were collected from Directorate of Horticulture, Gujarat. Time series secondary data on area, production and productivity of mango were collected for the period 1958-59 to 2017-18. The collected data were analyzed in R Studio (version 3.5.2) software. Different Artificial Neural Network models employed to forecast area, production and productivity of fruits crops and also find out best models through comparison of all models. 4:1s:1l, 2:2s:1l & 2:2s:1l ANN architectures, were the most appropriate model for predicting its area, production and productivity with forecasted value for 2018-19 144.95 thousand hectares, 809.91 thousand metric tonnes and 7.17 metric tonnes per hectare respectively, where area, production and productivity are likely to go down for upcoming year.

Keywords: Forecasting, area, production, productivity, mango and artificial neural network model

Introduction
In most of the developing countries, horticulture plays an important role to the economic growth. India is the second largest producer of fruits in the world and it contributes nearly 90 per cent to horticulture along with vegetables. The production rate of fruits in Gujarat is around 35 per cent per annum and mango is mostly produced as well as exported to all over the world. Overall 56,761 hectares of land has been used to cultivation of fruits in 2019-2020 and produced around 9,49, 115 metric tonnes of fruits. Fruits are having elements which is aid to maintain good health and shielding against number of diseases. In India, 20317 thousand tonnes of mango produced from 2294 thousand hectares of land with average productivity of 8.9 metric tonnes per hectare during the period 2019-20. In Gujarat, 1424.87 thousand tonnes of mango produced from 162.77 thousand hectares with average productivity of 7.42 metric tonnes per hectare during the period 2017-18 (Ministry of Agriculture & Farmers Welfare). Artificial Neural Network (ANN) model holds different features which attract the researchers at same time it is contrast to many traditional techniques. In Bangladesh, production of major fruit crops such as mango, banana and guava had forecasted by using Box- Jerkins Arima Model. The study found that ARIMA (2,1,3), ARIMA (3,1,2) and ARIMA (1,1,2) were the best model to forecasted the mango, banana and guava. Comparison between original series of data and forecasted series which shown same manner indicating fitted model were statically behaved well to forecast the fruits production in Bangladesh (Hamja, 2014) [4]. In Bangladesh, banana production was forecasted by using Auto- Regressive Integrated Moving Average (ARIMA) model with help of secondary data which has collected over the period 1972 to 2013. ARIMA (0, 2, and 1) selected best model to forecasting the production of banana crop. Observed and forecasted data comparison indicated fitted model behaved statistically well during and beyond the estimation period (Hossain *et al*, 2016) [5]. Mango and banana yield forecasted in Karnataka, India by using linear, nonlinear and non-parametric statistical models. Auto-Regressive Integrated Moving Average (ARIMA) model found as better to forecasting of banana yield rather than other models (Rathod and Mishra, 2018) [9-10]. In Varanasi region, pigeon pea yield was forecasted by using statistical models. Different linear and non-linear models like multiple linear regression (MLR), autoregressive integrated moving average (ARIMA) and artificial neural network (ANN) models were used to analyze 27 years data from 1985-86 to 2011-12. The best suited model was identified based on root mean squared error (RMSE). The study revealed that ANN model was best model with lowest RSME which

forecasted pigeon pea yield well during 2012-13 for Varanasi region (Kumari Prity *et al*, 2016). Kumari Prity *et al* (2017) [7] studied forecasting models for predicting pod damage of pigeon pea in Varanasi region. Autoregressive integrated moving average (ARIMA) and artificial neural network (ANN) with multiple linear regression models were used to predicting perc cent pod damage in pigeon pea by pod borer in Varanasi region, Uttar Pradesh by using 27 years of data (1985-86 to 2011-12). The best suited model was assessed by root mean squared error (RSME). The study revealed that ANN was found best model with lowest RSME having forecasted per cent of pod damage in pigeon pea 2012-13. Sathish Kumar M and Kumari Prity (2021) [11] used different artificial neural network models for predicting area, production and productivity of sapota in Gujarat. They found that area, production and productivity of sapota was best explained by 4:1s:1l, 4:1s:1l and 2:2s:1l ANN architectures, with forecasted value for 2018-19, 28.48 (‘000’ Ha.), 320.89 (‘000’ MT) and 10.51 (MT/Ha.) respectively, where area, production and productivity are likely to go decrease for the next year. Kumari Prity and Sathish Kumar M (2021) [11] forecasted area, production and productivity of Citrus in Gujarat-An application of artificial neural network. Times series data were collected for this study from 1991-92 to 2017-18 and different artificial neural network models were used. This study found that area, production and productivity of citrus was best explained by 4:1s:1l, 2:2s:1l & 3:2s:1l ANN architectures, with forecasted value for 2018-19, 41.43 (‘000’ Ha.), 4143.00 (‘000’ MT) &10.20 (MT/Ha.) respectively, where area, production & productivity are likely to go down for the next year.

Objectives

To evaluate appropriate Artificial Neural Network (ANN) for forecasting area, production and productivity of mango.

To compare the performance of developed models and estimate the forecast for area, production and productivity of mango.

Methodology

Source of data

Secondary data on area, production and productivity of Mango in Gujarat were collected from Directorate of Horticulture, Govt. of Gujarat from 1991-92 to 2017-18. Time series secondary data on area, production and productivity of Mango were collected for the period 1958-59 to 2017-18.

Analytical framework

In the present study, different neural network architectures were used to compare their ability for predicting area, production and productivity of four major fruit crops in Gujarat. Analysis was done by R Studio (version 3.5.2) software.

Artificial neural network (ANN)

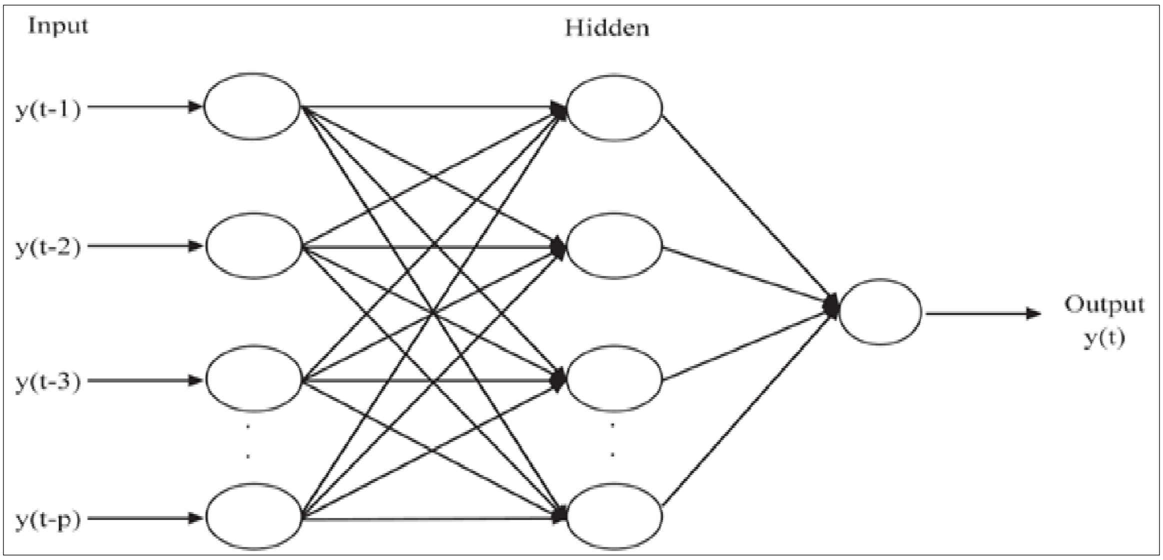

Fig 1: Time-Delay Neural Network (TDNN) with one hidden layer

ANNs are nonlinear data-driven models capable to perform modeling without a prior knowledge about the relationships between input and output variables. Its generalizing ability, after learning the data presented to structure, can often correctly infer the unseen part of a population even if the sample data contain noisy information. Time series can be modelled with the structure of a neural network by the use of time delay, which can be implemented at the input layer of the neural network. Such an ANN is termed as Time Delay Neural Network.

The structure of the neural network consists of:

1. Input Layer
2. Hidden Layer
3. Output Layer

The general expression for the final output value y_{t+1} in a multilayer feed forward time delay neural network is given by equation:

$$y_{t+1} = g\left[\sum_{j=1}^{q} \alpha_j f(\sum_{i=0}^{p} \beta_{ij} y_{t-i})\right]$$

Where

f and g denote the activation function at the hidden and output layers, respectively.

P is the number of input nodes (tapped delay),

q Is the number of hidden nodes,

β_{ij} is the weight attached to the connection between i^{th} input

node to the j[th] node of hidden layer,
α_j is the weight attached to the connection from the j[th] hidden node to the output node, y_{t-i} is the ith input (lag) of the series. The main task of activation function is to map the outlying values of the obtained neural input back to a bounded interval such as [0, 1] or [-1, 1].

Research Results
Area, production and productivity of mango were analyzed through this study by using different neural network architecture. The empirical findings of mango crop are as follow.

Forecasting of area for Mango
Fig. 2 illustrates chart series of area dataset for mango from1991-92 to 2017-18. Also, the characteristics (basic statistics) of the data set used were presented in the Table 1.

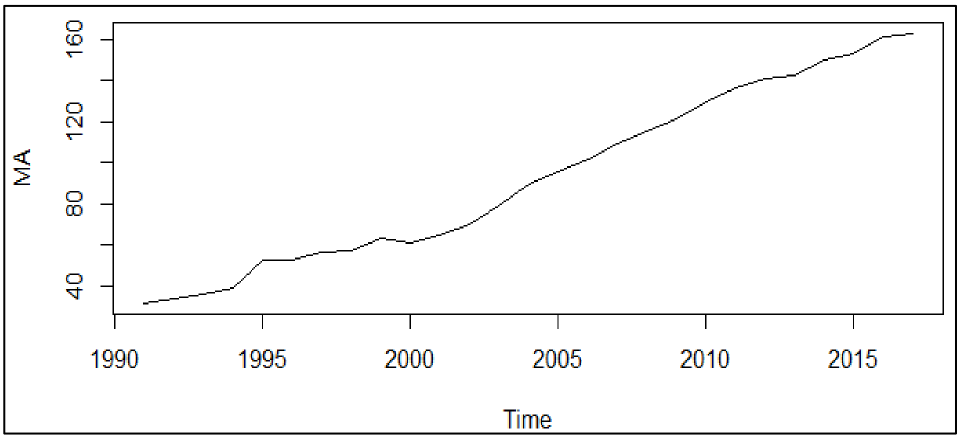

Fig 2: Area (In ' 000 Hectare) under Mango in Gujarat

Table 1: Summary statistics of mango area time series

No. of observations	27
Minimum	32
Maximum	162.77
Mean	93.04
Median	89.72
Standard Deviation	43.27
Sem	8.33
Skewness	0.17
Kurtosis	-1.49

Various architectures of neural network were tried considering the availability of data. Further, the model performance in training set and testing data set is given in Table 2.

Table 2: Forecasting performance of ANN model for mango area time series

Model	**Parameters**	**RMSE**	
		Training	**Testing**
2-1S-1L	5	117.826	3.154
3-1S-1L	6	118.184	3.254
4-1S-1L	7	114.312	2.780
2-2S-1L	9	117.062	3.015
3-2S-1L	11	116.214	2.846

Based on the lowest training RMSE, ANN models 4:1S:1l is selected. Also, this architecture is assessed based on its hold out sampling (testing set) forecasting performance which is least out of all five neural network architecture. Therefore, neural network architectures4:1s:1l was used to forecast area of mango in Gujarat.
Table 3 reflects that the estimates of all weights associated with nodes of different layer. Input layer lag1, lag2, lag3 and lag4 are denoted by I1, I2, I3 & I4, Hidden layer node1 is denoted by H1 and output node is denoted by O, where biases of two nodes are given by the notation H_{B1}& O_B. The forecasted value of mango area in Gujarat for the year 2018-19 by 4:1s:1l neural network architecture was obtained as 144.95 (‘000’ Hectares) with confidence interval 138.30 to 150.48.

Table 3: ANN model parameter mango area time series

Weights between nodes		**Biases**	
I1:H1	-0.158	Hidden node	
I2:H1	1.204	H_{B1}	-1.360
I3:H1	0.076	Output node	
I4:H1	-0.499	O_B	3.517
H1: O	0.631		
Forecasting (2018-19)		**C.I.**	
144.95		138.30	150.48

Forecasting of production for mango

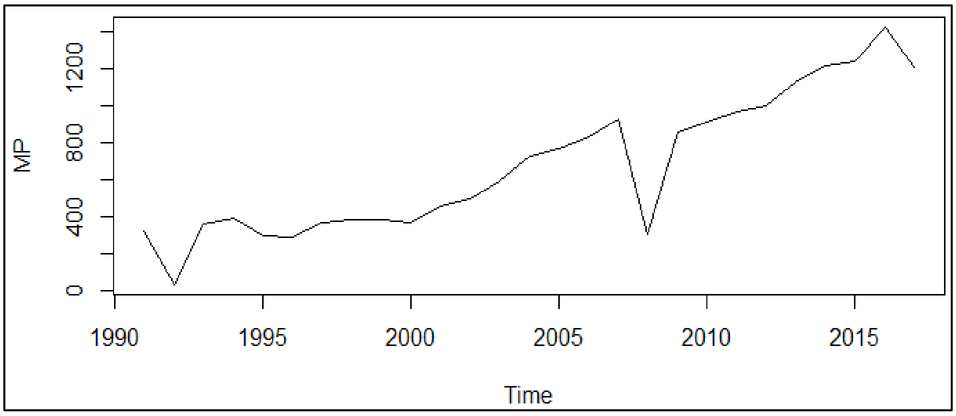

Fig 3: Production (In '000 MT) of mango in Gujarat

Fig. 3 illustrate chart series of production dataset for mango from 1991-92 to 2017-18. Also, the characteristics (basic statistics) of the data set used were presented in the Table 4.

Table 4: Summary statistics of mango production time series

No. of observations	27
Minimum	34
Maximum	1424.87
Mean	676.09
Median	595.21
Standard Deviation	374.77
Sem	72.12
Skewness	0.31
Kurtosis	-1.21

Various architectures of neural network were tried considering the availability of data. Further, the model performance in training set and testing data set is given in Table 5.

Table 5: Forecasting performance of ANN model for mango production time series

Model	Parameters	RMSE	
		Training	Testing
2-1S-1L	5	931.592	138.168
3-1S-1L	6	990.121	139.081
4-1S-1L	7	901.469	139.665
2-2S-1L	9	920.635	134.438
3-2S-1L	11	969.017	100.046

Based on the lowest training RMSE, two ANN models 4:1S:1l & 2:2S:1l are selected. Further, it is assessed by its hold out sampling (testing set) forecasting performance where 2:2S:1l architecture has lowest testing RMSE. Therefore, neural network 2:2s:1l was used to forecast production of mango in Gujarat.

Table 6: ANN model parameter mango production time series

Weights between nodes		Biases	
I1:H1	2.396	Hidden node	
I2:H1	1.960	H_{B1}	-0.571
I1:H2	3.647	H_{B2}	4.311
I2:H2	3.070	Output node	
H1: O	1.030	O_B	-2.795
H1: O	4.511		
Forecasting (2018-19)		**C.I.**	
809.91		530.25	1087.63

Table 6 reflects that the estimates of all weights associated with nodes of different layer. Input layer lag1and lag2 are denoted by I1& I2, Hidden layer node1& node 2are denoted by H1 & H2 and output node is denoted by O, where biases of three nodes are given by the notation H_{B1} H_{B2} & O_B. The forecasted value of mango production in Gujarat for the year 2018-19 by 2:2s:1l neural network architecture was obtained as 809.91('000' MT) with confidence interval 530.25 to 1087.63.

Forecasting of productivity for mango

Fig. 4 illustrate chart series of productivity dataset for mango from 1991-92 to 2017-2018. Also, the characteristics (basic statistics) of the data set used were presented in the Table 7.

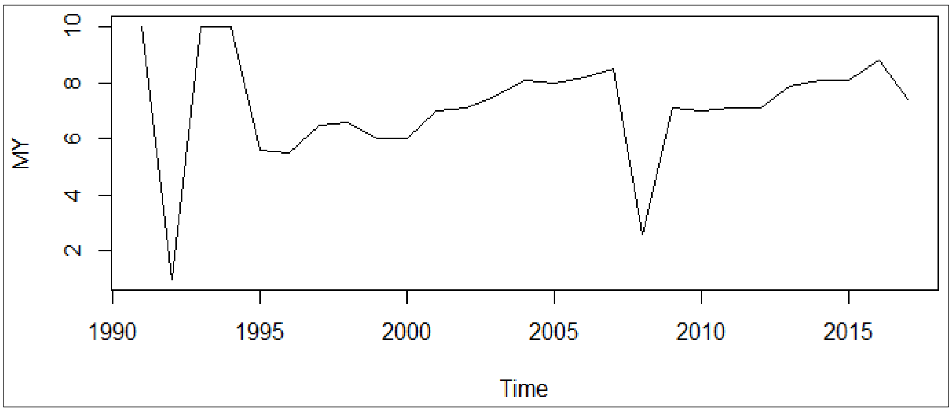

Fig 4: Productivity (In MT/Ha.) of Mango in Gujarat

Table 7: Summary statistics of mango productivity time series

No. of observations	27
Minimum	1
Maximum	10
Mean	7.14
Median	7.10
Standard Deviation	1.98
Sem	0.38
Skewness	-1.23
Kurtosis	2.07

Artificial neural network architectures were tried considering the availability of data. Further, the model performance in training set and testing data set is given in Table 8.

Table 8: Forecasting performance of ANN model for mango productivity time series

Model	Parameters	RMSE	
		Training	Testing
2-1S-1L	5	1.779	1.123
3-1S-1L	6	1.889	1.230
4-1S-1L	7	1.894	0.761
2-2S-1L	9	1.138	0.709
3-2S-1L	11	1.487	0.884

Based on the lowest training RMSE, ANN model 2:2S:1l is selected. Further, it is assessed by its hold out sampling (testing set) forecasting performance, Table 8 shows this model is having lowest testing RMSE too. Therefore, neural network 2:2s:1l was used to forecast productivity of mango in Gujarat.

Table 9: ANN model parameter mango productivity time series

Weights between nodes		Biases	
I1:H1	-53.675	Hidden node	
I2:H1	37.439	H_{B1}	0.624
I1:H2	53.930	H_{B2}	-1.955
I2:H2	6.810	Output node	
H1: O	-25.632	O_B	-0.448
H1: O	-18.585		
Forecasting (2018-19)		**C.I.**	
7.17		4.47	8.81

Table 9 reflects that the estimates of all weights associated with nodes of different layer. Input layer lag1 and lag2 are denoted by I1 & I2, Hidden layer node1 & node 2 are denoted by H1 & H2 and output node is denoted by O, where biases of three nodes are given by the notation H_{B1} H_{B2} & O_B. The forecasted value of mango productivity in Gujarat for the year 2018-19 by 2:2s:1l neural network architecture was obtained as 7.17 (MT/ha.) with confidence interval 4.47 to 8.81.

Table 10: Performance of different models for mango

Model for crops		Area (In '000' Ha.)	Production (In '000 MT)	Productivity (MT/Ha.)
Mango	Model	4:1s:1l	2:2s:1l	2:2s:1l
	RMSE	114.31	920.63	1.13
	Forecast	144.95 (162.77)	809.91(1207.78)	7.17(7.42)
	C.I.	138.30 to 150.48	530.25 to 1087.63	4.47 to 8.81

*values within in parenthesis are previous year APY of all crops

Table 10 shows 4:1s:1l, 2:2s:1l & 2:2s:1l ANN architectures, were the most appropriate model for predicting its area, production and productivity with forecasted value for 2018-19 144.95 thousand hectares, 809.91 metric tonnes and 7.17 metric tonnes per hectare respectively, where area, production and productivity are likely to go down for the next year.

Conclusion

The study found that artificial neural network model performance was quite well than classical time series model. Area, production and productivity of mango in Gujarat was forecasted with hybrid time series model and found that ANN was best model among all other models. Hence, ANN model recommended to forecast all agricultural and horticultural crops which will helpful to both farmers and policy makers to make effective decision in advance.

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