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# Forecasting of Sweet Potato (*Ipomoea batatas* L.) Prices in India

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ABSTRACT

Due to the semi-perishable nature of sweet potato the price fluctuation occur based on demand and supply. Hence, it becomes necessary to precisely forecast market price of sweet potato. Price forecasting of sweet potato was carried out for six selected states in India using time series monthly market price, collected from AGMARKNET price portal from January 2010 to December 2021. Exponential Smoothing Models (ESM), Seasonal Autoregressive Integrated Moving Average (SARIMA) model and Time Delay Neural Network (TDNN) model were used for forecasting of sweet potato price. It was observed that among the forecasting models, the TDNN model predicted accurate future prices of sweet potato based on the lowest Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) than SARIMA and ESM. The forecast indicated that the average market price of sweet potato in selected states of India viz., Kerala, Odisha, Gujarat, Karnataka, Maharashtra and Telangana, would be in the range of Rs. 684 to Rs. 2757 per quintal during January 2022 to December 2022. The forecasted price of sweet potato would provide valuable information to the sweet potato growers, government institutions and other stakeholders in the sweet potato value chain to take appropriate decisions on production, marketing and consumption of sweet potato.

## INTRODUCTION

Sweet potato is one of the most important tuber crops in terms of production, economic values, contribution to calories and protein. Besides, it is also an important staple food for many developing nations. With an annual production of 92 million tones, it is ranked as fifth most important food crop in the world in terms of its fresh weight (FAOSTAT, 2021). In India, sweet potato serves as an important staple food crop among the disadvantaged population, and majority of farmers consider it as major source of food but used to a limited extent as animal feed and industrial raw materials (Prakash et al., 2017; Prakash et al., 2018; Srinivas & Nedunchezhiyan, 2020). Total area under sweet potato cultivation in India was 0.13 million hectares with a production of 1.5 million tons during 2017-2018. Even-though sweet potato is cultivated in almost all the states in India, it is mainly grown in Odisha (25%), Kerala (23%), Uttar Pradesh (15%) and West Bengal (15%) which contribute about 78 per cent of the total sweet potato production in the country (Government of India, 2019). About 2560 tons of sweet potato was exported to United Arab Emirates, Saudi Arab, United States, Oman, United Kingdom and Kuwait and 72 tons of sweet potato was imported from China, Thailand, United States and Australia during 2019-2020 (Government of India, 2020). In India, sweet potato is cultivated during both Kharif and Rabi seasons, usually takes three to four months to attain maturity. Due to high fluctuations between seasons, growers do not always capitalize on the best price for the crop (Beach et al., 1995; Farmer & Foley, 2009). Hence, there is a need to apply appropriate methods to aid in forecasting of price of different crops. Accurate price prediction of agricultural products is useful for planning

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agricultural production and for developing a balance between demand and supply (Zhang et al., 2014). Due to the semi perishable nature of sweet potato, price fluctuates occurs based on demand and supply. Further, it cannot be stored for longer time. These characteristics of sweet potato production make the farmers prone to exploitation by the traders and other actors in the supply chain. The farmers make production planning mainly on past year prices. The harvesting can be delayed or preponed to a certain extent based on current market prices whose knowledge is available with the farmers with the development of information and communication technologies (Nain et al., 2015; Kumbhare et al., 2019; Hadiya, 2019; Jat et al., 2021). Hence, forecasting of market price of sweet potato in different markets will help traders to make decisions on whether to import from other markets or to take advantage of higher prices in local markets compared to international markets. Forecasting of sweet potato prices can provide critical and useful information to sweet potato growers for making production and marketing decisions. It can provide valuable information to the entrepreneurs also to make decisions. In this context, the study was undertaken to develop a model for the price forecasting of sweet potato of major markets in India.

## METHODOLOGY

Time series data on monthly market prices of sweet potato from January 2010 to December 2021 for six selected states in India were collected from the AGMARKNET price portal (https://agmarknet.gov.in) and the data on the sweet potato prices prevailed in different markets for the past 12 years was analyzed. The econometric price forecasting methods viz., Holt winters multiplicative method of Exponential Smoothing Models (ESM), Seasonal Autoregressive Integrated Moving Average (SARIMA) model and Time Delay Neural Network (TDNN) model were employed. All the forecasting analysis was performed using R Software v. 1.4.1106.

Exponential smoothing models (ESM) were proposed in the late 1950s and were emerged as one of the most successful forecasting methods. Forecasts produced using exponential smoothing methods are weighted averages of past observations, with the weights decaying exponentially as the observations gets older. There are three main types of ESM viz. i) single exponential smoothing, ii) Holts linear trend method and iii) Holt-winters seasonal method. In this case, Holt winters multiplicative method was used and determined following Holt (1957) & Winters (1960).

Seasonal ARIMA model is most used for forecasting time series. Appearance of past values and past forecasted errors in the models are the autoregressive and moving average. An ARIMA model is determined following Jha & Sinha (2013); Areef et al., (2020); Kumar et al., (2021); Goyal et al., (2021). ARIMA model are denoted as ARIMA (p, d, q) where p is the non-seasonal AR order (number of time lags); d is the non-seasonal differencing (number of times the data have had past values subtracted) and q is the non-seasonal MA order. ARIMA models have been applied on a time series of prices of some of the horticultural crops without considering the seasonal effects (Ansari and Ahmad, 2001). In this study included seasonal effects to predict sweet potato prices as there is strong seasonal variation in prices. The seasonal ARIMA incorporates non-seasonal and seasonal factors in a multiplicative model. The SARIMA models are denoted as ARIMA (p, d, q) X (P, D, Q) s, Where, is the number of observation per year; P is the seasonal AR order; D is the seasonal differencing and Q is the seasonal MA order. The different stages in establishing a forecasting model are determined following Amarender Reddy (2019).

Time delay neural network model (TDNN) has emerged as an efficient tool for modeling and price forecasting (Lama et al., 2021). TDNN at various combinations of the input nodes (lags) and hidden nodes was implemented. As a result, different numbers of neural network models were tested for each series before reaching at the final structure of the model. A typical TDNN structure with one hidden layer is denoted by I: Hs: Ol, where I is the number of nodes in the input layer, H is the number of nodes in the hidden layer, O is the number of nodes in the output layer, s denotes the logistic sigmoid transfer function and l indicates the linear transfer function. Figure 1 shows a graphical representation of the employed time-delay neural network.

The accuracy of the forecasted model is assessed with the use of mean absolute percentage error, mean absolute error, and root mean square error was determined following Kumar et al., (2021).

## RESULTS AND DISCUSSION

The average monthly market price of sweet potato prevailing in different markets was analyzed and the results are presented in Table 1. It was observed that the highest price prevailed in the Kerala market (Rs. 2079 per quintal) followed by Odisha (Rs. 1526 per quintal), Gujarat (Rs. 1497 per quintal), Maharashtra (Rs. 1444 per quintal), Telangana (Rs. 1058 per quintal) and Karnataka (Rs. 571 per quintal). Further, price behavior based on the seasonality index shows that the highest price of sweet potato was observed in the Kerala market prevailed during September followed by October and November. The lowest price was observed in the Karnataka market during July and December. Thus, it is revealed that the markets viz., Kerala, Odisha, and Gujarat have provided an opportunity for both farmers and traders to exploit economics of scale and take advantage of recent institutional changes in agricultural marketing like the National Agriculture Market (eNAM).

### Exponential smoothing model

Under exponential smoothing models, Holt winters multiplicative techniques was considered for forecasting the prices of sweet potato for the selected states in India and the results are presented in Table 2. Forecast indicated that the average market price of sweet potato in selected states of India viz., Kerala, Odisha, Gujarat, Karnataka, Maharashtra and Telangana would be in the range of Rs. 788 to Rs. 2854 per quintal during the period January 2022 to December 2022.

### Seasonal autoregressive integrated moving average model

A seasonal autoregressive integrated moving average model was used for forecasting of sweet potato prices. It was observed that the SARIMA (1,1,1) (1,1,1), SARIMA (2,1,1) (0,1,1), SARIMA (1,1,1) (0,1,1), SARIMA (0,1,3) (2,0,0), SARIMA (0,1,2) (0,1,1) and SARIMA (2,1,1) (0,1,1) were found suitable for Kerala, Odisha, Gujarat, Karnataka, Maharashtra and Telangana respectively. These

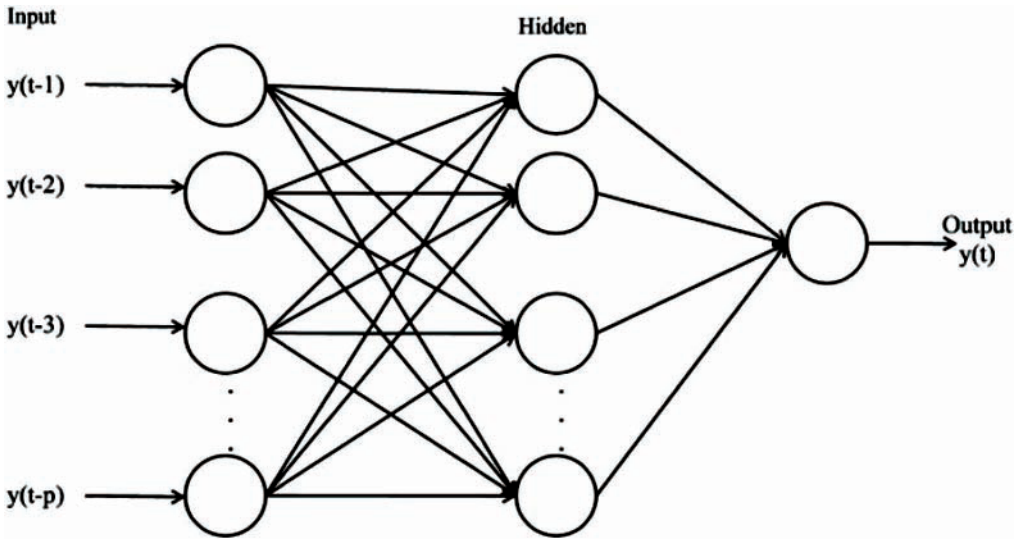


**Figure 1.** Schematic illustration of TDNN

**Table 1.** Average monthly market price of sweet potato in selected markets in India during 2010-2021 (Rs. per quintal)

| Months | Kerala | Odisha | Karnataka | Gujarat | Maharashtra | Telangana |
|---|---|---|---|---|---|---|
| January | 2039 | 1450 | 527 | 1185 | 1250 | 910 |
| February | 2030 | 1655 | 542 | 1246 | 1305 | 850 |
| March | 1966 | 1633 | 593 | 1331 | 1248 | 768 |
| April | 1941 | 1760 | 572 | 1312 | 1326 | 727 |
| May | 1877 | 1839 | 570 | 1401 | 1440 | 901 |
| June | 1834 | 1709 | 551 | 1703 | 1454 | 1210 |
| July | 1850 | 1441 | 483 | 1772 | 1669 | 1322 |
| August | 2182 | 1388 | 572 | 1907 | 1667 | 1491 |
| September | 2364 | 1649 | 729 | 1888 | 1942 | 1478 |
| October | 2336 | 1287 | 671 | 1437 | 1536 | 1155 |
| November | 2298 | 1192 | 532 | 1428 | 1266 | 926 |
| December | 2225 | 1316 | 515 | 1349 | 1225 | 957 |
| Average price | 2079 | 1526 | 571 | 1497 | 1444 | 1058 |

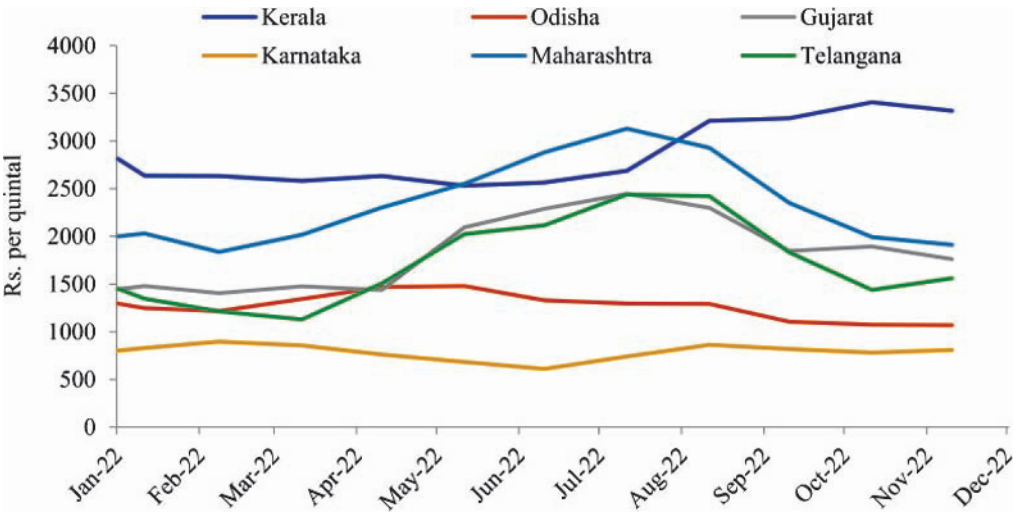


**Figure 2.** Forecasted price of sweet potato in selected states of India

were found to be the best fit models as they had the lowest Akaike information criteria (AIC) and Bayesian information criteria (BIC) values. So, a unique model does not apply to different markets of sweet potato. The parameters estimated through an iterative process using a least square technique which gave the best model were presented in Table 2. The coefficients were also found to be statistically significant and hence the selected models were considered best fit and were used for forecasting.

Ex-ante forecast prices of sweet potato for the selected markets in India was done for the month of January 2021 to December 2021 using the identified models and they were compared with actual prices of the same period (Table 3). Further, ex-post

**Table 2.** Coefficients of SARIMA model estimated of major markets in India

| Market | | Coefficient | Standard error | Z-value | Pr(>\|z\|) |
|---|---|---|---|---|---|
| Kerala | AR(1) | 0.665 | 0.089 | 7.496 | 6.607e-14 *** |
| | MA(1) | -0.930 | 0.050 | -18.644 | < 2.2e-16 *** |
| | SAR(1) | -0.157 | 0.092 | -1.700 | 0.08921 |
| | SMA(1) | -1.000 | 0.147 | -6.822 | 8.953e-12 *** |
| | $\sigma^2$= 90890; log likelihood=-949.17 | | | | |
| | AIC=1908.34; AICc=1908.82; BIC=1922.71 | | | | |
| Odisha | AR(1) | 0.658 | 0.091 | 7.240 | 4.473e-13 *** |
| | AR(2) | -0.110 | 0.088 | -1.252 | 0.2106 |
| | MA(1) | -1.000 | 0.038 | -26.104 | < 2.2e-16 *** |
| | SMA(1) | -0.889 | 0.132 | -6.741 | 1.574e-11 *** |
| | $\sigma^2$=350626; log likelihood=-1032.28 | | | | |
| | AIC=2074.55; AICc=2075.03; BIC=2088.93 | | | | |
| Gujarat | AR(1) | 0.473 | 0.089 | 5.290 | 1.227e-07 *** |
| | MA(1) | -0.968 | 0.033 | -29.065 | < 2.2e-16 *** |
| | SMA(1) | -0.798 | 0.099 | -8.057 | 7.813e-16 *** |
| | $\sigma^2$=95642; log likelihood=-943.25 | | | | |
| | AIC=1894.51; AICc=1894.83; BIC=1906.01 | | | | |
| Karnataka | MA(1) | -0.274 | 0.083 | -3.311 | 0.0009308 *** |
| | MA(2) | -0.362 | 0.087 | -4.172 | 3.026e-05 *** |
| | MA(3) | -0.222 | 0.083 | -2.678 | 0.0074171 ** |
| | SAR(1) | 0.167 | 0.084 | 1.995 | 0.0460431 * |
| | SAR(2) | 0.199 | 0.091 | 2.178 | 0.0294451 * |
| | Intercept | 6.259 | 3.052 | 2.051 | 0.0402846 * |
| | $\sigma^2$=26700; log likelihood=-929.85 | | | | |
| | AIC=1873.69; AICc=1874.52; BIC=1894.43 | | | | |
| Maharashtra | MA(1) | -0.518 | 0.083 | -6.218 | 5.032e-10 *** |
| | MA(2) | -0.306 | 0.088 | -3.468 | 0.0005239 *** |
| | SMA(1) | -0.754 | 0.096 | -7.832 | 4.817e-15 *** |
| | $\sigma^2$=87007; log likelihood=-935.04 | | | | |
| | AIC=1878.08; AICc=1878.39; BIC=1889.58 | | | | |
| Telangana | AR(1) | 0.437 | 0.085 | 5.138 | 2.783e-07 *** |
| | AR(2) | 0.257 | 0.086 | 2.999 | 0.002707 ** |
| | MA(1) | -1.000 | 0.050 | -20.041 | < 2.2e-16 *** |
| | SMA(1) | -0.625 | 0.076 | -8.234 | < 2.2e-16 *** |
| | $\sigma^2$=43830; log likelihood=-889.23 | | | | |
| | AIC=1788.47; AICc= 1788.95; BIC=1802.85 | | | | |

***, ** and * significant at 1, 5 and 10 percent level

forecasts for the period January to December 2022 was made and the accuracy of the forecasts was tested using the test statistics. It was observed that the forecasted price of sweet potato in selected markets was very close to the actual value. The accuracy of the models was empirically verified with the help of MAPE, MAE and RMSE statistics.

The model was validated for the accuracy; it was observed that there were wide variations between upper and lower confidence limits of forecast prices of sweet potato from January 2022 to December 2022. The forecast indicates that the average market prices of sweet potato in selected states of India viz., Kerala, Odisha, Gujarat, Karnataka, Maharashtra and Telangana, would be in the range of Rs. 1178 to Rs. 3187 per quintal during January 2022 to December 2022 (Table 4).

**Time delay neural network**

The time delay neural network model was applied for forecasting sweet potato prices in selected states of India and the results are presented in Table 5. The neural network architecture used consists of single hidden layer, six input nodes and one output node was selected for modelling and forecasting of sweet potato prices. The forecasted average market price of sweet potato in selected states of India viz., Kerala, Odisha, Gujarat, Karnataka, Maharashtra and Telangana, would be in the range of Rs. 684 to Rs. 2757 per quintal during January 2022 to December 2022. The prices would be high in some markets viz., Kerala (Rs. 2757 per quintal), Odisha (Rs. 2202 per quintal), Maharashtra (Rs. 1928 per quintal) and Gujarat (Rs. 1898 per quintal) and low in other markets viz., Karnataka (Rs. 684 per quintal) and Telangana (Rs. 1712 per quintal).

Among the different forecasting techniques, the time delay neural network model predicted accurate future prices of sweet potato in selected states of India as compared to Seasonal auto regressive integrated moving average and exponential smoothing models based on the lowest MAPE, MAE and RMSE. Findings from other studies reported that ANN model predicted accurate future prices of paddy and onion in Nizamabad and Bangalore market compared with ARIMA and exponential smoothing models (Areef et al., 2020). ARIMA models predicted accurate future prices of vegetables compared with exponential smoothing models,

**Table 3.** Comparison of forecasted (F) and actual (A) prices of sweet potato (Rs. /quintal)

| Month, | Kerala | | Odisha | | Gujarat | | Karnataka | | Maharashtra | | Telangana | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year 2021 | F | A | F | A | F | A | F | A | F | A | F | A |
| January | 3161 | 3397 | 2121 | 2562 | 1497 | 1502 | 1032 | 980 | 1750 | 1976 | 1324 | 1132 |
| February | 3198 | 2980 | 2629 | 2579 | 1563 | 1514 | 979 | 1275 | 1962 | 1955 | 1263 | 1000 |
| March | 2998 | 3096 | 2409 | 2597 | 1542 | 1499 | 1221 | 1365 | 1840 | 1542 | 960 | 1000 |
| April | 3066 | 2901 | 2568 | 2615 | 1648 | 1261 | 1304 | 1487 | 1767 | 1703 | 893 | 1000 |
| May | 2888 | 2906 | 2531 | 2632 | 1573 | 982 | 1390 | 1508 | 2069 | 1677 | 1282 | 1367 |
| June | 2956 | 2860 | 2322 | 2650 | 1684 | 2057 | 1348 | 1428 | 1911 | 2080 | 1953 | 1565 |
| July | 2924 | 2859 | 2278 | 1237 | 2174 | 2266 | 1308 | 1250 | 2252 | 2718 | 1762 | 1762 |
| August | 3280 | 2681 | 1394 | 1132 | 2506 | 1962 | 1294 | 1397 | 2475 | 3331 | 2095 | 1960 |
| September | 2996 | 2991 | 1851 | 1067 | 2068 | 2054 | 1489 | 1050 | 2979 | 2710 | 1927 | 2157 |
| October | 3037 | 2752 | 1098 | 1440 | 1662 | 1933 | 976 | 864 | 2325 | 1762 | 1648 | 1613 |
| November | 2910 | 2985 | 1605 | 1545 | 1884 | 1870 | 1000 | 770 | 1688 | 1847 | 1298 | 1468 |
| December | 2992 | 2950 | 1888 | 1156 | 1616 | 2161 | 965 | 735 | 1854 | 1889 | 1452 | 1638 |
| *Accuracy tests* | | | | | | | | | | | | |
| MAPE (%) | 8.44 | | 23.54 | | 15.19 | | 20.18 | | 12.35 | | 13.46 | |
| MAE | 172.02 | | 369.64 | | 209.35 | | 117.74 | | 186.76 | | 135.48 | |
| RMSE | 283.13 | | 556.09 | | 291.57 | | 159.38 | | 278.10 | | 196.61 | |

**Table 4.**Forecasted price of sweet potato in selected states of India (Rs. /quintal)

| Month, Year 2022 | Kerala Estimate | Odisha Estimate | Gujarat Estimate | Karnataka Estimate | Maharashtra Estimate | Telangana Estimate |
|---|---|---|---|---|---|---|
| January | 2985 | 1673 | 1827 | 902 | 2016 | 1589 |
| February | 3057 | 2132 | 1732 | 1065 | 2048 | 1489 |
| March | 2995 | 2246 | 1663 | 1134 | 1909 | 1335 |
| April | 3020 | 2401 | 1675 | 1243 | 2000 | 1234 |
| May | 2958 | 2448 | 1688 | 1262 | 2176 | 1531 |
| June | 2922 | 2268 | 2148 | 1253 | 2284 | 1968 |
| July | 2956 | 1933 | 2279 | 1222 | 2546 | 2011 |
| August | 3384 | 1884 | 2444 | 1322 | 2735 | 2288 |
| September | 3546 | 2205 | 2349 | 1317 | 2758 | 2251 |
| October | 3552 | 1837 | 1912 | 1169 | 2327 | 1791 |
| November | 3473 | 1764 | 1921 | 1103 | 2010 | 1493 |
| December | 3397 | 1938 | 1800 | 1141 | 1957 | 1607 |
| Average price | 3187 | 2061 | 1953 | 1178 | 2230 | 1716 |

**Table 5.** Forecasted price of sweet potato in selected states of India (Rs. /quintal)

| Month, Year 2022 | Kerala | Odisha | Gujarat | Karnataka | Maharashtra | Telangana |
|---|---|---|---|---|---|---|
| January | 2887 | 1596 | 1814 | 781 | 1906 | 1768 |
| February | 2872 | 1780 | 1645 | 656 | 1897 | 1520 |
| March | 2812 | 2442 | 1672 | 601 | 1602 | 1295 |
| April | 2821 | 3654 | 1462 | 635 | 1640 | 1231 |
| May | 2771 | 3904 | 1359 | 655 | 1965 | 1367 |
| June | 2778 | 2782 | 1683 | 656 | 2357 | 1856 |
| July | 2729 | 2250 | 1800 | 635 | 2333 | 1600 |
| August | 2765 | 1899 | 2063 | 640 | 2076 | 2669 |
| September | 2669 | 1798 | 2558 | 689 | 1941 | 2318 |
| October | 2717 | 1453 | 2291 | 828 | 1780 | 1789 |
| November | 2645 | 1599 | 2187 | 752 | 1759 | 1481 |
| December | 2620 | 1269 | 2241 | 682 | 1885 | 1652 |
| Average price | 2757 | 2202 | 1898 | 684 | 1928 | 1712 |
| *Accuracy tests* | | | | | | |
| MAPE (%) | 6.18 | 15.54 | 9.20 | 11.80 | 7.71 | 10.65 |
| MAE | 118.49 | 214.31 | 127.91 | 64.39 | 108.94 | 94.22 |
| RMSE | 154.88 | 329.16 | 168.02 | 86.09 | 148.45 | 129.47 |

generalized autoregressive conditional heteroscedasticity and SARIMA models (Weron, 2014).

## CONCLUSION

The study employed three forecasting time series models in order to know the best model for forecasting sweet potato prices in the selected states of India. Based on the indicators viz., MAPE, MAE and RMSE values, the TDNN model is adjusted as the best and accurate forecasted method. The forecasted price of sweet potato would provide empirical evidence to the farmers for making production decisions and alternative market avenues. It will also help the government and policy makers to make decisions about market intervention. Further it will also help all the stakeholders involved in the sweet potato value chain to plan for their future activities.

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