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MODELLING AND FORECASTING OF JOWAR PRODUCTION BEHAVIOR OF INDIA AS WELL AS INSTABILITY AND DECOMPOSITION ANALYSIS

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ABSTRACT

The present investigation was an attempt to study the area, production, and productivity behavior of jowar in India and the factors affecting it from 1950 to 2020. The best-fit ARIMA models were chosen based on the autocorrelation function and partial autocorrelation function at different lags, and their forecasting performances were chosen based on their minimum AIC, RMSE, MAE, MAPE, and maximum R2 values. Model parameters were estimated using Microsoft Excel and the Gretl software. The results indicated that the ARIMA (1,1,2) model for area, the ARIMA (1,1,2) model for production, and the ARIMA (1,1,5) yield model was found to be appropriate for predicting the future of jowar in India with a 95% accuracy level. There are also three parts to the entire time. We looked at the sources of development and instability during Period I (1950–1973), Period II (1974–1997), and Period III (1998–2020). The highest levels of yield, output, and area instability occurred during Period III. Over time, the area's contribution to production change has greatly increased while the yields have declined. Additionally, this study will aid in the development of sound policies about the jowar production scenario.

***Keywords* :** ARIMA, Modeling, Forecasting, Instability, Decomposition.

Introduction

Millets are one of the oldest foods known to humans and are the basic cereals that are crucial to the security of food and nutrition in developing nations. A large percentage of Indians from lower socioeconomic classes eats millets. Millets are small-grained cereal crops that require little chemical input, such as insecticides and fertilizers, and are resilient to drought and other unfavorable weather conditions. Since most of the nutrients needed for regular bodily functions are found in millet crops, which are mostly indigenous to India, they are commonly referred to as nutri-cereals. Major millets and little millets are the two categories of millets according to the size of their grains. Pseudo millets are so named because they are not members of the Poaceae botanical family, which includes 'real' grains, yet they are nutritionally identical and employed in similar ways (Ministry of Electronics and Information Technology, 2023).

Millets, such as Sorghum (Jowar), Pearl Millet (Bajra), Finger Millet (Ragi/Mandua), Minor Millets (Kanngani/kakun), Proso Millet (Cheena), Kodo Millet (Kodo), and Barnyard Millet (Sawa/Sanwa/Jhangora), have been classified as "Nutritional Cereals" by the Ministry of Agriculture and Farmers Welfare. As a result of government initiatives, millet production increased from 14.52 million tonnes in 2015–16 to 19.96 million tonnes in 2021–22. Millets are non-allergenic and gluten-free. By lowering triglycerides and C- reactive protein, millet eating helps to avoid cardiovascular disease. All millets have a lot of nutritional fibre. Dietary fibre has the ability to bulk up and absorb water. It lengthens the time that food spends in the digestive tract, which lowers the risk of inflammatory bowel disease and serves as a cleansing agent for the body.

Sorghum (*Sorghum vulgare* Pers.), also referred to as jowar, is the most significant crop in dryland agriculture for both food and fodder. In a given year, it produces 8–10 million tonnes and covers 17–18 million hectares. India and Africa are where sorghum first appeared. The USA and European nations are reported to have imported it from Abyssinia, where it is also claimed to have its origin. Jowar is primarily found in central and the peninsula of India. India grows sorghum on 4.82 million hectares, yielding 9.89 kg/ha and 4.78 million tonnes (Agricultural Statistics at a glance, 2022). The main states where jowar is grown are Tamil Nadu, Gujarat, Rajasthan, Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh, and Uttar Pradesh (including the Bundelkhand region). Sorghum is grown in small plots for fodder in some states. The sorghum grain is mostly consumed by humans in a variety of dishes including roti, bhakri (unleavened bread), or rice. Additionally, sorghums are popped, malted, and used in a variety of regional preparations. The most crucial roughage for cow feed nationwide is green and dry hay. Although there is a lot of potential, the use of grain sorghum as a cow feed, poultry diet, and other industrial applications is currently not very substantial.

Materials and Methods

The methodologies for the major approaches to the research problem are discussed here:

Source of data

The data gathered is entirely secondary. The data on jowar production from 1950 to 2020 was collected from Agricultural Statistics at a Glance.

Decomposition analysis

Minhas (1964) used the Decomposition analysis model, which is shown below, to determine the relative contribution of area and yield to the overall output of the jowar crop.

Po = Ao x Yo and

Pn = An x Yn (1)

Area, production, and yield in the base year are Ao, Po, and Yo, respectively, whereas An, Pn, and Yn are the relevant variable values in the nth-year item.

Where,

Ao and An = Area Yo and

Yn = yield in the base year and nth year respectively.

Pn - Po = ΔP An - Ao = ΔA Yn - Yo = ΔY ......(2)

For equations (1) and (2) we can write

Po + ΔP = (Ao + ΔA) (Yo + ΔY)

Hence,

$$P = \frac{A_0 \Delta Y}{\Delta P} \times 100 + \frac{Y_0 \Delta A}{\Delta P} \times 100 + \frac{\Delta Y \Delta A}{\Delta P} \times 100$$

Production = Yield effect + area effect + interaction effect (Srivastava *et al.,* 2022b)

As a result, the overall change in production can be broken down into yield effect, area effect, and interaction effect due to yield and area changes.

Instability and Its Measure

For assessing the instability in the production, the index certain by Cuddy and Della (1978) and used by Verma *et al.* (2024): $CV_t = (CV) \times \sqrt{1-R^2}$

$$C.V. = \frac{\sigma}{\overline{X}} \times 100$$

Where, σ = Standard Deviation

$\overline{X}$ = Mean

R^2 = coefficient of determination of the variable's linear trend model.

CV_t = Coefficient variant around the trend

Modelling and Forecasting

The data in this study pertains to jowar production in four key producing states as well as India from 1970 to 2019, with ARIMA and Holt's linear trend model being utilized to model and anticipate jowar production. Because they are simple to apply and give accurate projections, these models are the two most often used methods for modeling and forecasting. The data sets were divided in two, with 20% used for model validation and 80% used for model construction. The data were modeled, validated, and forecasted using Gretl software and MS Excel.

(ARIMA) Auto-Regressive integrated moving average model

Box and Jenkins (1976) proposed the (ARIMA) model, widely known in the literature as the Box

Jenkins approach. The ARIMA model is a combination of an autoregressive (AR) and a moving average (MA) model (ARMA). The ARIMA model is employed with non-stationary data, whereas the other models function well with stationary data (Tekindal *et al.,* 2020). ARIMA (p, d, q) model is made by subtracting the data differences from the *d* degree for the stabilization process, followed by the addition of the ARMA (p, q) model. In the ARIMA (p, d, q) model, p indicates the AR model's degree, q represents the MA model's degree, and d specifies the number of differences to be taken to stabilize the data (Yonar *et al.,*2020). The equation for the ARIMA (*p*, *d*, *q*) model is as follows:

$$Yt=\phi 1Yt\text{-}1 + \phi 2Yt\text{-}2 + ... + \phi pYt\text{-}p + \alpha 1\text{-}\theta 1\text{-}\alpha t\text{-}1$$

$$-\alpha 2\text{-}\theta\ \alpha t\text{-}2\text{-} ... \text{-}\ \alpha q\text{-}\theta q\,\alpha t\text{-}q$$

where,

ϕp indicates the AR operator's argument values.,

αq denote coefficient of the error term,

θ denote the parameter values relating to the MA operator and,

Yt represents the data with differences of the actual data (Brockwell *et al.,* 2016; Gujarati *et al.,* 2012). The following steps can be applied for fitting time-series data to an ARIMA model.

Step 1: Check for stationary first. A normal root analysis or the autocorrelation function (ACF) and partial autocorrelation (PACF) can be computed.

Step 2: Take data differences until the data is stationary.

Step 3: To choose the best ARIMA model from the selected models, use the maximum value of R^2 and the least value of RMSE, MAE, MAPE, and MPE. Analyze the autocorrelation function (ACF) and partial autocorrelation function (PACF) to determine the suitable p and q parameters.

Step 4: Plotting the ACF and PACF relating to the residuals to check the best model's chosen residuals. Try a different model if it doesn't appear white noise (Supriya *et al.,* 2023).

Step 5: Calculate forecasts when the residuals appear to be white noise.

Result and Discussion

Decomposition Analysis

The general pattern of growth and the direction of changes were shown by the growth study of the jowar crop's area, production, and yield. However, this approach does not determine the precise contribution of area and yield to the increase in jowar output. In order to determine which factor is substantially lagging behind and to pinpoint the causes or limitations of that, it is essential to pin point the sources of change in jowar production. It will also aid in our comprehension of the factors that have increased jowar production. Therefore, it is necessary to investigate the jowar output's sources. The overall change in production is split into three effects, namely the area impact, yield effect, and interaction effect, to analyse the sources of output for jowar.

According to Table 1, the area effect was the most significant factor influencing changes in India's jowar production over periods II and III. The yield effect led to the largest shift in India's jowar output between periods I and II. With an area effect of 35.28 percent and an interaction effect of 6.29 percent, the maximum yield effect, or 58.43 percent, was noted during the period I. In contrast, the yield effects during periods II and III were 29.61 and 10.56 percent, respectively, with the area effect coming in at 67.14 and 87.25 percent, respectively, and the interaction effect coming in at 3.25 and 2.19 percent. Area effect, yield effect, and interaction effect were observed at 80.11 and 12.42 throughout the total time.

Table 1: Percent contribution of area, yield and their interaction for change in production of Jowar.

S. No.	Period	Area Effect	Yield Effect	Interaction Effect
1	**Period I (1950-1973)**	35.28	58.43	6.29
2	**Period II (1974-1997)**	67.14	29.61	3.25
3	**Period III (1998-2020)**	87.25	10.56	2.19
4	**OVERALL**	80.11	12.42	7.47

Note: Sum of all three effects =100

Instability analysis jowar

During the instability analysis, the de-trend coefficient of variation was measured for Period-I (1950 to 1973), Period II (1974 to 1997), Period III (1998-2020) and Overall period (1950-2020). The results of such an exercise will be discussed

An examination of the Jowar area Table 2 depicts the volatility of Jowar in India. The table clearly showed that the coefficient variant around trend (CV_t) in the area of Jowar has decreased from 8.3673(period 3) to 6.8282 (period 2), indicating that the highest instability was sown in period 1 from 1950 to 1973. Still, after 1973, instability began to decline, indicating that the area has expanded. An examination of Jowar production table 2 clearly revealed that the coefficient variant around trend (CV_t) first decreased from period 1 to period 2 but increased from 13.7819 (period 2) to 21.671 (period 3), indicating that the most instability was planted in period 3 from 1996 to 2020. Analysis of Jowar yield in India, the coefficient variant around trend (CV_t) decreased from 18.1708 (period 3) to 7.4911(period 1).

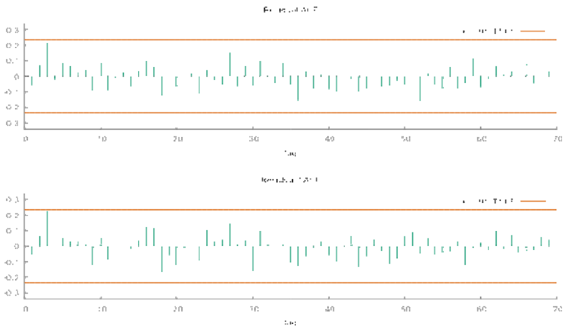
Thus, based on the analysis of the Jowar area, production, and yield instability, it can be concluded that instability is recorded in the area and yield has decreased, but production has increased instability in recent years, implying that a greater emphasis has been placed on minimizing volatility and optimizing processes in Jowar area and yield. The advent of new technologies, on the other hand, has increased the insecurity of Jowar production. It affects farmer income, increases the risk of farm output, and influences the choice to invest in lucrative agricultural technologies. Price stability and low-income households' vulnerability are also impacted.

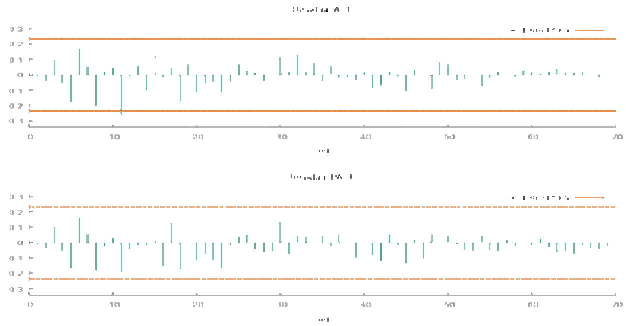
Table 2 : Instability analysis of jowar in area, production and yield

Statistics	Period 1	Period2	Period3	Overall
AREA				
R^2	0.7597	0.2663	0.6300	0.0239
CV	16.5432	7.9718	13.7566	16.8184
CV_t	8.1100	6.8282	8.3673	16.6167
PRODUCTION				
R^2	0.5395	0.4684	0.1572	0.5261
CV	19.6013	18.9031	23.6064	28.1313
CV_t	13.3010	13.7819	21.6718	19.3666
YIELD				
R^2	0.6794	0.4280	0.5538	0.6256
CV	11.4634	9.3137	27.2029	32.9681
CV_t	7.4911	7.0440	18.1708	20.1722

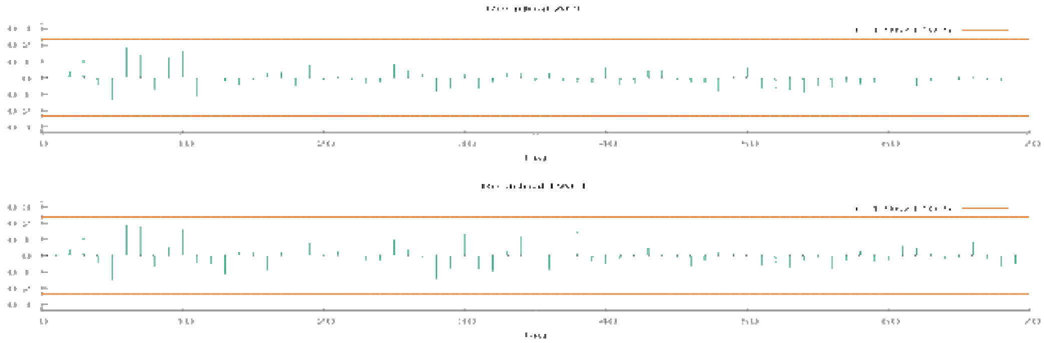
Modeling and Forecasting

For the purpose, the Box-Jenkins methodology was adopted. The model was built using data from 1950 to 2020, and it was validated using data from 2015 to 2020. It was found that from (0, 1, 0) ARIMA model to (1, 1, 5) models are suitable in modeling and forecasting the production behavior of jowar. None of the series was stationary in the jowar area, production, and yield data. All of the series were therefore rendered stationary by first differencing with the original data.: constant mean (μ) and constant variance (σ). With the differenced series, the study estimated ARIMA equations for all the parameters using the data from 1950 to 2018 and made forecasts up to 2025, using Gretl software to get the result. ARIMA models were tested, and the top models were chosen from the competitive models using the lowest values of RMSE, MAE, MAPE, AIC, and the maximum value of R^2. However, use the ACF and PACF graph in figure 1 to perform a diagnostic check on the residuals.





AREA ARIMA (1,1,2) PRODUCTION ARIMA (1,1,2)



YIELD ARIMA (1,1,5)

Fig. 1 : ACF and PACF of residual for the best-fitted model of jowar area, production and productivity in India

The area, production, and yield best-fit model following the ACF and PACF plot of the area, production, and yield first difference value under jowar presented in Table 3, Figures 1, 2 and 3. It suggested that the tentative value of p and q that would be suitable for the area under jowar was p=1 and q=2, the uncertain value of p and q that would be suitable for production under jowar was p=1 and q=2, and the uncertain value of and that p and q that would be suitable for yield under jowar was p=1 and q=5.

Based on the maximum value of R^2, the minimum value of RMSE, MAPE, MAE and AIC. As a result, it showed to be the best for the jowar area, production, and yield under jowar was ARIMA (1,1,2), ARIMA (1,1,2) and ARIMA (1,1,5). Predicted Value of Jowar in Indi**a** presented in Table 4 Jowar was planted on an area of jowar in 2020-21 was 4240 thousand hectares, compared to the 4400 thousand hectares predicted. For 2030-31, 2210 thousand hectares was expected to be available respectively. Jowar production in 2020-2021 was 47800 thousand tonnes as compared to the 45100 thousand tonnes projected. The year 2030-31 was expected to be 43000 thousand tonnes. Jowar yield 1128 kg/ha in 2020-2021 compared to 1030 kg/ha predicted. For 2030-31, they were expected to be 1073.16 Kg/ha respectively.

Table 3 : Model fitting for jowar in India

ARIMA	R^2	RMSE	MAPE	MAE	AIC
AREA					
ARIMA(0,1,0)	0.981292	0.6329	4.226	0.74666	138.619
ARIMA(0,1,1)	0.981905	0.62648	4.1266	0.46992	139.2026
ARIMA(0,1,2)	0.981864	0.62619	4.0991	0.46602	141.1395
ARIMA(0,1,3)	0.981851	0.62589	4.1128	0.467761	143.0745
ARIMA(0,1,4)	0.981865	0.62547	4.0999	0.46576	144.9893
ARIMA(0,1,5)	0.982051	0.62225	4.0723	0.47101	146.9361
ARIMA(1,1,0)	0.981884	0.62629	4.1078	0.46725	139.1608
ARIMA(1,1,1)	0.981883	0.62628	4.1072	0.46716	141.1608
ARIMA(1,1,2)	0.982071	0.61618	**3.9075**	**0.44796**	**137.1619**
ARIMA(1,1,3)	0.982166	0.61422	3.9122	0.44897	142.7563

ARIMA(1,1,4)	0.982688	0.60521	4.0686	0.46448	143.3484
ARIMA(1,1,5)	**0.983115**	**0.59716**	3.9456	0.45856	143.6909
PRODUCTION					
ARIMA(0,1,0)	0.62839	1.43060	13.13800	1.11520	252.92090
ARIMA(0,1,1)	0.69441	1.23830	12.00700	0.99627	**234.92090**
ARIMA(0,1,2)	0.69710	1.23420	12.11300	0.99737	236.50170
ARIMA(0,1,3)	0.70864	1.21390	11.86400	0.98332	236.26710
ARIMA(0,1,4)	0.70837	1.21360	11.89900	0.98631	238.22560
ARIMA(0,1,5)	0.70870	1.21340	11.89100	0.98523	240.20760
ARIMA(1,1,0)	0.67496	1.29720	12.09400	0.99856	241.26970
ARIMA(1,1,1)	0.69567	1.23620	12.06900	0.99438	236.70880
ARIMA(1,1,2)	0.70875	**1.20760**	**11.74900**	**0.97594**	236.86340
ARIMA(1,1,3)	0.70844	1.21360	11.89500	0.98584	238.22790
ARIMA(1,1,4)	0.70838	1.21360	11.89900	0.98631	240.22450
ARIMA(1,1,5)	**0.71071**	1.20790	11.77400	0.97701	241.62740
YIELD					
ARIMA(0,1,0)	0.72595	99.43200	11.42800	79.90600	846.57740
ARIMA(0,1,1)	0.79254	84.37400	9.51160	65.74300	826.71010
ARIMA(0,1,2)	0.81334	79.83400	9.06910	62.25300	823.69010
ARIMA(0,1,3)	0.79353	84.26500	9.44350	64.59300	829.84120
ARIMA(0,1,4)	0.83253	75.56500	8.76740	59.13500	**819.74680**
ARIMA(0,1,5)	0.83360	75.33500	8.54650	57.56900	821.12510
ARIMA(1,1,0)	0.76076	91.22600	9.97520	69.03300	836.69050
ARIMA(1,1,1)	0.81322	79.83600	9.11850	62.83200	823.54980
ARIMA(1,1,2)	0.81455	79.58500	9.11200	62.26300	825.37500
ARIMA(1,1,3)	0.81475	79.52800	9.09680	62.17600	827.24160
ARIMA(1,1,4)	0.83271	75.52400	8.71220	58.76600	821.53360
ARIMA(1,1,5)	**0.84248**	**73.36100**	**8.44600**	**56.58200**	820.01110

Table 4 : Validation of Predicted Value of Jowar in India

YEAR	OBSERVED	PREDICTED (ARIMA)
AREA		
2015	6080	6190
2016	5620	5810
2017	5020	5160
2018	4090	4080
2019	4820	4710
2020	4240	4140
PRODUCTION		
2015	42400	45600
2016	45700	46800
2017	48000	48200
2018	34800	34900
2019	47700	48200
2020	47800	45100
YIELD		
2015	697	642.91
2016	812	876.6
2017	956	901.04
2018	849	887.8
2019	989	909.37
2020	1128	1180.3

Then we create forecast with a forecast interval of 80% and 95%. Table 5 show the forecast and forecast interval obtained by the specific model ranging from 80% to 95%. In this table, Lo80 and Hi80 represent the predictive interval's lower and upper bounds for significance levels below 0.20 and less than 0.05, respectively, while Lo95 and Hi95 stand for the lower and upper bounds, respectively.

According to the forecast, the jowar region's production and productivity will rise in the following year. Figure 2 shows the forecast visual which support the above observation. The main factor sustaining this trend will be agricultural finance, For long-term production, price support, improved management techniques, research staff, etc.

Table 5 : Jowar Forecasting for India

YEAR	FORECASTING	LO80	HI80	LO95	HI95
Area					
2021	4050	3260	4850	2850	5260
2022	3830	2820	4850	2280	5390
2023	3620	2390	4850	1740	5490
2024	3400	1970	4830	1220	5590
2025	3190	1570	4820	0710	5680
2026	2990	1170	4810	0210	5770
2027	2790	0780	480	-0290	5860
2028	2590	0390	4790	-0770	5950
2029	2400	0010	4780	-1250	6050
2030	2210	0370	4780	-1730	6140
Production					
2021	44700	29300	60200	21100	68400
2022	45500	27900	6300	18700	72300
2023	44300	25700	62800	15900	72700
2024	44800	24600	6500	13900	75700
2025	43800	22700	65100	11500	76200
2026	44200	21600	66800	09700	78700
2027	43300	19900	66800	07400	79200
2028	43600	18900	68300	05800	81400
2029	42800	17300	68400	03800	81900
2030	4300	16300	69700	02200	83800
Yield					
2021	1046.09	952.08	1140.11	902.31	1189.88
2022	1023.22	923.46	1122.98	870.65	1175.78
2023	1075.57	974.88	1176.25	921.58	1229.55
2024	1034.28	929.95	1138.61	874.72	1193.85
2025	1024.23	916.16	1132.33	858.91	1189.56
2026	1042.14	933.09	1151.19	875.36	1208.92
2027	1045.85	936.56	1155.15	878.7	1213.01
2028	1056.78	947.42	1166.13	889.53	1224.02
2029	1064.04	954.67	1173.41	896.77	1231.31
2030	1073.16	963.78	1182.54	905.88	1240.44

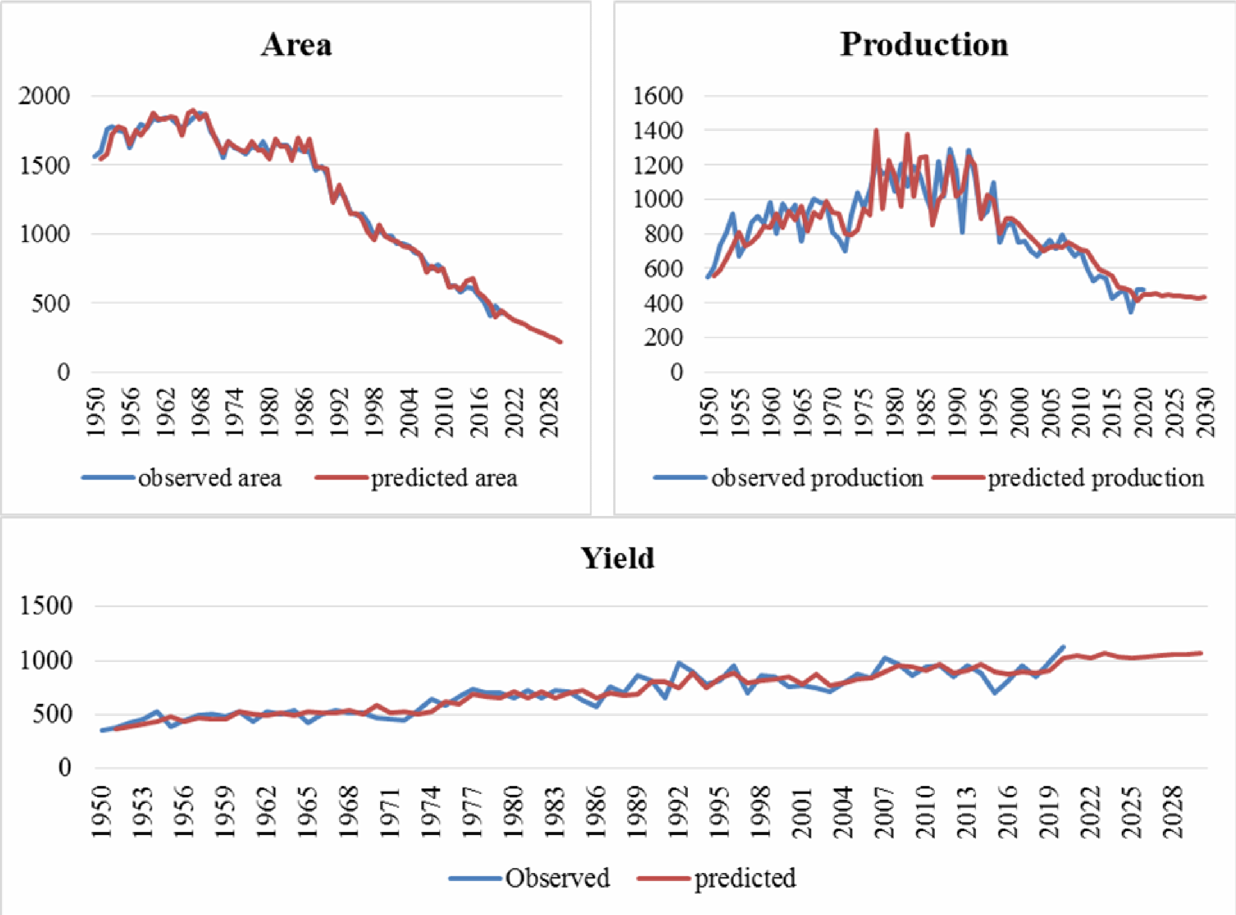


Fig. 2 : Using the best model of Jowar's area, production, and productivity in India, point forecasts and 80 and 95 percent prediction ranges were derived.

Conclusion

We infer from the discussion above that the best models for forecasting jowar with an Area, production, and yield in India are represented by the ARIMA models (ARIMA 1,1,5), (ARIMA 1,1,5), and (ARIMA 1,1,2). The findings of employing the best models to anticipate jowar output from 2020 to 2030 reveal that production will decrease in India. The results of this study prove beyond a shadow of a doubt that India will have the lowest anticipated value in 2030. However, after 2019, there would be a fall in India.

According to the study, instability is increasing in India. Instability raises the risk of agricultural production, which has an impact on farmer income and the decision to use high-paying technologies. And according to the decomposition analysis. The yield effect was in charge during the overall periods, whereas the area effect was the main driver of the shift in Jowar production in India. Funding for agriculture, price support programs, better management techniques, research personnel, and other factors influencing long-term output will be crucial to maintaining this trend. This kind of initiative helps with long-term planning for a particular crop and the implementation of policies. The cultivation of this crop would increase the income of the growers, but it would also help close the gap between demand and supply at the state and national levels.

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