Forecasting wheat production using time series model: a case study of Punjab

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ABSTRACT

This study was conducted to forecast the production potential of wheat crop in Punjab province of Pakistan up to the year 2025-26. Production projections were worked out by the application of time series analysis "Auto Regressive Integrated Moving Average" (ARIMA model) on the secondary dataset of past 30 years i.e. from 1990-91 to 2020-21, taking area, yield and production of wheat into account. The results indicated a nominal increasing trend and no significant break-through has been projected in wheat crop production. The diminishing trend of minimum production potential of wheat would probably be due to the cropping pattern changes, uneconomic size of land holding, subsistence traditional farming and lack of high yielding varieties. At maximum probability of 95% confidence interval; the wheat production of Punjab is projected at 24199.30 thousand tons in 2025-26 against actual 20900 thousand tons in 2020-21. The probability of occurrence of an expected increase in production of wheat appears to be directly related to the expansion in area and rise in average yield. Better support price, high yielding varieties and pure fertilizer at subsidized rates may be the factors to increase the wheat production.
Key Words: ARIMA; Production Potential; Punjab; Wheat

INTRODUCTION

Forecasting is a technique that uses historical data as inputs to make estimates that are predictive in determining the direction of future trends. The production projections of agricultural commodities prove helpful for formulating government policies with regard to production, consumption, prices, procurement, marketing, storage and domestic and foreign trade. In Pakistani economy Agriculture is a vital sector, providing food to the fast-growing population of the country. Wheat is Pakistan's main staple crop and, therefore, essential for the food security of the country. It accounts for 9.2 percent of the value added in agriculture and 1.8 percent of the GDP (Govt. of Pakistan, 2020-21). Wheat is cultivated in various cropping systems such as rice-wheat, maize-wheat, cotton-wheat and sugarcane-wheat in Punjab, Pakistan. Rice-wheat and cotton-wheat contributed about 60% of the wheat area in the country (Latif *et al.* 2020). Over the past few years, Pakistan's wheat production has not increased at a rate to suffice local demand shifting the country from a wheat exporter to a wheat importer. This change may be due to climate change, lack of high-yielding research and minimal increase in support prices.

Thus the present study aimed at assessing the trends in acreage, yield and production in the Punjab during the last 30 years and estimating the production potential up to 2025-26 by using any suitable time series model.

MATERIALS AND METHODS

The Punjab province of Pakistan has 37 districts and seven divisions. Division Gujranwala consisting of six districts namely Hafizabad, Gujrat, M.B.Din, Narowal, Gujranwala and Sialkot being in the

jurisdiction of Adaptive Research Farm, Gujranwala, Agriculture Department, Govt. of Punjab was also considered for study area. The study was carried out on the basis of wheat productivity of Punjab province during the years 1990-91 to 2020-21 collected from secondary sources (Crop Reporting Services, Ministry of Agriculture, Govt. of Punjab). It was not an easy task to forecast the future production potential of agricultural crops because a large number of unpredictable exogenous and institutional factors are always involved. Moreover, the data on required variables may be usually lacking, incomplete and sometimes obsolete. A good number of approaches can be employed for forecasting such as purely judgmental approaches, structural econometrics models, time series models, etc (Coleman & Thigpen, 1991).

Time-series analysis is divided into four main forecasting models, namely the deterministic models, the smoothing models, the analytical models and the stochastic models. In this study, we use the type of stochastic models which is the Autoregressive Integrated Moving Average (ARIMA) model. The ARIMA model has chosen for analysis due to its suitability to our dataset and non-stationary nature of time series to be forecasted. The equation form of the model is as:

$$Y_t = \Phi_1 Y_{t-1} + \dots \Phi_p Y_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \dots - \theta_q \varepsilon_{t-q}$$

Where p and q refer to the orders of the auto regression and of the moving averaging, respectively, and Φ and θ denote the coefficients. If an original series is non-stationary and is transformed to a stationary series after d levels of differencing, the ARMA model is termed the ARIMA (Auto Regressive Integrated Moving Average) model and is referred to as ARIMA (p, d, q). This model is suitable even for non-stationary time series, has great statistical power for reliable forecasting from small datasets and requires data for only time series being forecasted but not for its determinants (Brockwell and Davis, 2003; Tsay, 2005; Wei, 2005). The analytical software Statistix 8 was used for time series analysis by adopting ARIMA (2, 0, 1) model.

RESULTS AND DISCUSSION

Area and production projections of wheat crop in Punjab have been worked out considering in view the variations in the area under cultivation and crop yield on the basis of last 30 years data i.e. from 1990-91 to 2020-21 (Table I). The projected results are described here under.

In order to make the series stationary for production differenced series was obtained by putting the value of 'p' equal to 2, the difference or 'd' value equal to 0 and finally the order of moving average value 'q' was set to be 1. Therefore, ARIMA (2, 0, 1) was used for estimating production of wheat by using this order. This confirms with the finding of a similar study by Najeeb *et al*. (2005). Employing 6 years ahead forecasts of wheat area, yield and production and their 95 % confidence intervals are given in Table 2.

The area was projected by manipulating linear relationship between area under cultivation of wheat and number of years by employing the said ARIMA Model. For Punjab province the area under wheat cultivation is predicted to increase from 14114 thousand acres in 1990-91 to 16147.80 thousand acre in 2025-26. This nominal increase in area may be due to land reclamation, high prices of the produce and increasing demand from wheat processing firms. At 5% probability, the maximum area under wheat might increase up to 17926.5 thousand acre in 2025-26. This nominal difference might be the outcome of shifting trends in the production of other crops, availability of canal water and government policy towards wheat. Similarly, for Gujranwala division the area under wheat cultivation is predicted to increase from 1969 thousand acres in 1990-91 to 2294.96 thousand acre in 2025-26. At 5% probability, the maximum area under wheat might increase up to 2639.92 thousand acre in 2025-26 (Table 2, Figure 1).

Based on the past 30 years trends, the average yield per acre indicated a nominal increasing trend and showed that no significant break-through has been projected in average yield per acre. The diminishing trend of minimum average yield of wheat would probably due to the expected cropping pattern changes,

uneconomic size of land holding, subsistence farming and lack of high yielding varieties. Similarly, the wheat production also indicated a nominal increasing trend and showed that no significant break-through has been projected in wheat crop production (Table 2, Figure 2 and 3).

Table 1. Past area, production and yield of wheat crop in Punjab and Gujranwala division

Year	Punjab Province			Gujranwala division		
	Area ('000' acre)	Production ('000' ton)	Yield (mound/acre)	Area ('000' acre)	Production ('000' ton)	Yield (mound/acre)
1990-91	14114	10514	20	1969	1407	18.93
1991-92	14009	11492	22	2006	1522	20.15
1992-93	14729	11742	21.4	2094	1633	20.7
1993-94	14260	11218	21.1	2011	1605	21.13
1994-95	14585	12713	23.4	2077	1753	22.42
1995-96	14761	12430	22.6	2084	1715	21.77
1996-97	14431	12371	23	2058	1713	22.02
1997-98	14665	13807	25.2	2036	1794	23.4
1998-99	14665	13212	24.1	2107	1818	22.75
1999-00	15272	16480	28.9	2242	2327	27.4
2000-01	15458	15419	26.72	2262	2042	23.5
2001-02	15078	14594	25.93	2238	2063	24.15
2002-03	15067	15355	27.3	2242	2203	25.95
2003-04	15458	15639	27.11	2329	2315	26.12
2004-05	15763	17375	29.53	2358	2534	28.3
2005-06	16021	16776	28.05	2380	2518	27.88
2006-07	15896	17853	30.09	2390	2497	27.62
2007-08	15820	15607	26.43	2479	2493	26.43
2008-09	16893	18420	29.21	2615	2726	27.4
2009-10	17084	17919	28.1	2593	2481	24.95
2010-11	16534	19041	30.85	2603	2820	28.62
2011-12	16020	17739	29.67	2598	2905	29.25
2012-13	16090	18587	30.95	2580	2900	29.65
2013-14	17054	19739	31.01	2635	2926	29.17
2014-15	17247	19282	29.95	2654	2378	23.93
2015-16	17085	19527	30.62	2558	2596	26.82
2016-17	16458	20466	33.32	2584	2873	29.58
2017-18	16210	19179	31.7	2548	2916	30.42
2018-19	16052	18377	30.67	2513	2494	26.28
2019-20	16100	19402	32.29	2145	2257	27.38
2020-21	16670	20900	31.34	2321	2769.44	29.83

Source: Crop Reporting Services, Agriculture Department, Govt. of Punjab. (2021)

The minimum and maximum production probability of wheat at 95% confidence interval was also projected to make the analysis more logical and authentic. The maximum probability of production of wheat is in Punjab estimated to be 24199.30 thousand tons in 2025-26 in comparison to actual 20900 thousand tons in 2020-21. Similarly, for Gujranwala division 3415.86 thousand tons is predicted during 2025-26 in comparison to actual 2769.44 thousand tons during 2020-21(Table 2).

From past 30 years dataset a rising trend in yield during some period might be due to the use of improved varieties of wheat, increased water supply through installation of tube wells, increased use of fertilizers, plant protection measures and also due to increase in stabilized demand for wheat for the industries. But the gloomy picture of some years might be attributed to adverse weather conditions, floods, heavy rains, and damage by disease etc. Hence it is concluded that there might be scarcity of wheat in the second decade of 21st century because of growing rate of population.

Table 2. Projected Area, Production and Yield of Wheat crop

Year	Projected Area ('000' acre)			Projected Production ('000' ton)			Projected Yield (mound/acre)		
	WOCI*	WCI**		WOCI*	WCI**		WOCI*	WCI**	
		Min.	Max.		Min.	Max.		Min.	Max.
Punjab Province									
2020-21	15935.90	14709.70	17162.20	18891.00	16200.20	21581.80	32.52	29.11	35.92
2021-22	16458.40	15227.70	17689.10	20528.10	17825.20	23231.10	31.49	28.01	34.97
2022-23	15863.30	14281.30	17445.30	18679.20	15013.40	22345.10	32.68	27.78	37.58
2023-24	16286.80	14702.60	17871.10	20185.90	16512.60	23859.30	31.64	26.69	36.59
2024-25	15804.50	14027.00	17581.90	18484.40	14161.50	22807.30	32.84	26.79	38.90
2025-26	16147.80	14369.10	17926.50	19871.00	15542.70	24199.30	31.79	25.70	37.89
Gujranwala division									
2020-21	2145.37	1923.71	2367.03	2239.28	1691.79	2786.78	28.89	24.62	33.16
2021-22	2311.27	2089.04	2533.50	2696.77	2148.91	3244.64	28.37	23.41	33.34
2022-23	2155.34	1858.49	2452.18	2234.58	1507.95	2961.20	27.73	21.98	33.48
2023-24	2302.63	2005.45	2599.80	2633.42	1906.58	3360.26	27.38	21.38	33.38
2024-25	2164.18	1819.44	2508.92	2230.47	1392.94	3068.00	26.95	20.63	33.26
2025-26	2294.96	1949.99	2639.92	2578.19	1740.52	3415.86	26.71	20.28	33.13

*Without confidence interval; **with 95% confidence interval
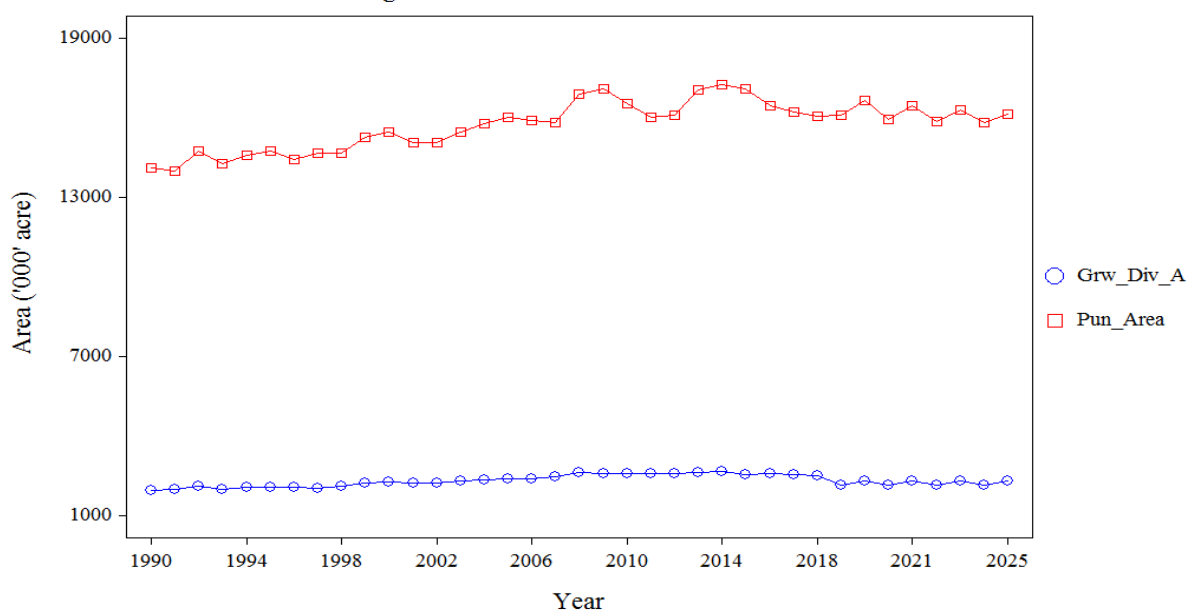

Figure 1: Time Series Plot on Area
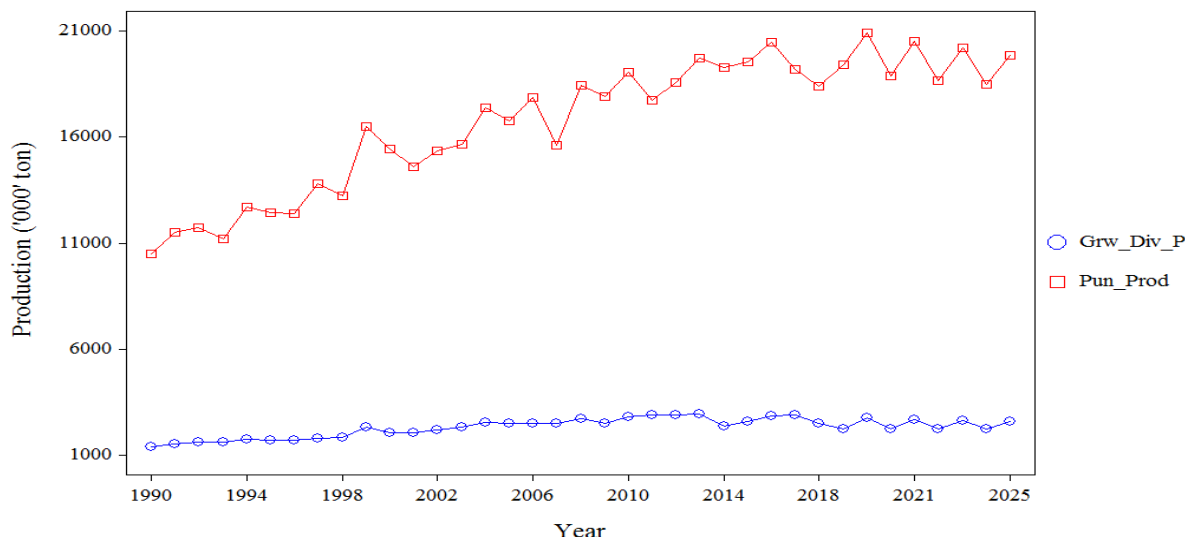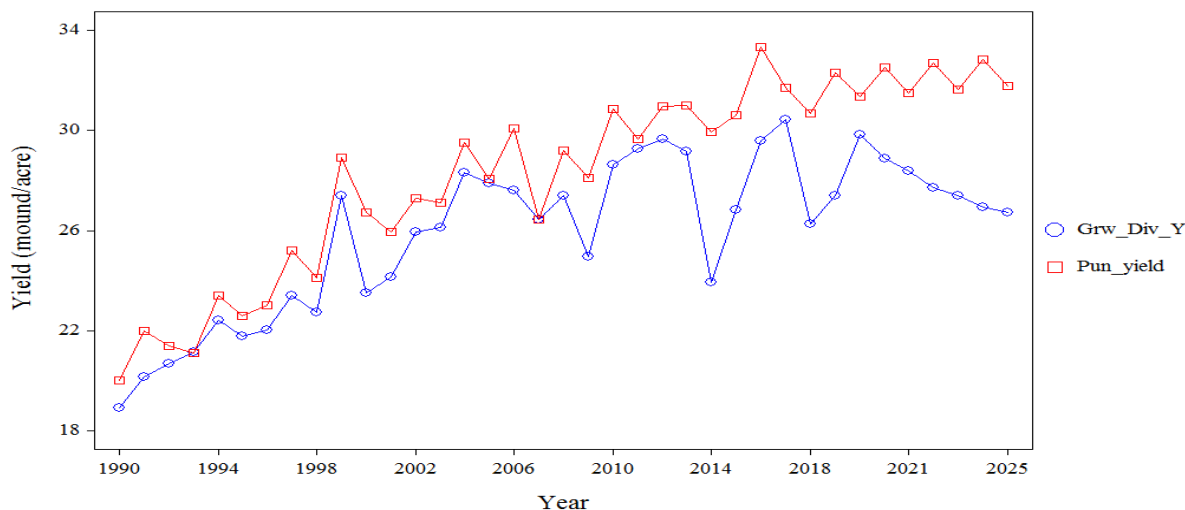
Figure 2: Time Series Plot on Production

Figure 3: Time Series Plot on Yield

CONCLUSIONS AND SUGGESTIONS

The wheat production indicated a nominal increasing trend and showed that no significant break-through has been projected in wheat crop production. The diminishing trend of minimum production of wheat would probably be due to the expected cropping pattern changes, uneconomic size of land holding, subsistence traditional farming and lack of high yielding varieties. In this way the probability of occurrence of an expected future increase in production of wheat appears to be directly related to the expansion in area and rise in average yield per acre.

It is suggested that the main focus should be on the production and promotion of new high yielding disease & pest free varieties there by making such varieties, pure fertilizer & pesticides available to the farmers through mobilizing the agricultural extension staff. Similarly, the incentive in the shape of support price of wheat is the major contributor to increase the overall production of wheat in Punjab province of Pakistan. The prices should be kept at par with the international prices and the cost of production.

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