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Resilience Approaches and Comparative Evaluation of Classical Time Series Models in Modeling and Forecasting Wheat Production

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ABSTRACT

Prediction is a complex task that is based on different statistical methods and scientific knowledge. Using statistical methods, the current study aims to forecast wheat output in the Pakistani province of Sindh. To forecast the wheat harvest, secondary data on acreage, output, and yields have been gathered over the past thirty years (1984–1985 to 2013–2014). The objectives of this work are to utilize moving averages (MA) and exponential smoothing (ES) consisting of two time series methods that indicate the time series variable (wheat) with less error and compare both methods. We apply the 3,5 and 7-year moving average techniques to check which of them is performing the best without losing the information. In the second technique, we use the exponential smoothing methods to evaluate and forecast the time series variable. The models are contrasted with one another and chosen using the lowest Key Performance indicators. The analysis is conducted on R software (3.4.1) and Minitab. Based on the results, it is found that exponential smoothing performed better than the moving average. Moreover, using these methods, it is observed that the study variable follows an upward-increasing trend.

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1. Introduction

Wheat is considered one of the basic food items. The grain crops that are cultivated most often worldwide are wheat. All over the world, wheat is the most important crop that is cultivated. Wheat is classified into five different classes. Categories of wheat are comprised of these five classes first one is red hard spring, the second one is red hard winter, the third one is red soft winter, the fourth one is white, and the last one is durum wheat. Cultivation trends are different for each class based on region-specific. Red hard winter wheat is mostly cultivated in the Great Plains, reaching from Montana to Texas, and this type of wheat is mainly used for bread flour. In northern grassland areas, the most cultivated wheat is red spring wheat, and the cultivation of Durum Wheat is mostly found in Dakota and Montana. This wheat is famous for producing an excellent quality of pasta, and the wheat that is used for breakfast is known as a white wheat category. In this green country, Pakistan, one of the main crops is wheat. Wheat cultivation is one of the high sources of income for rural people, with approximately 80 percent of farmers growing grain in an area of about 9 million hectares (the total cultivated land of the country is nearly 40%). The vital crop wheat contributed 21.73 percent value-added in the agricultural sector and 4.20 percent value-added in the gross domestic product (GDP) in winter or "Rabi." The Government of Pakistan also permitted a minimum of three million tons of wheat import duty-free between 2021 and 2022 to minimize domestic reserves in a marketing year. The Government of Pakistan resolves to prioritize keeping up a high amount of wheat stored because COVID-19 increases the demand and pressures of locust attacks in 2020, the

United States Department of Agriculture (USDA) Noted. According to internal information, the wheat review committee announced the final figures for wheat production in 2020/2021 and the current situation of wheat stock. The Punjab province produces the largest amount of wheat, 20.9 million tonnes. KPK and GB produce 1.445 million and 1.15 million tons of wheat, respectively, whereas Sindh province produces the second-highest amount of grain, 4.04 million tons. The expectation of wheat production in the 2021/2022 marketing year is approximately 27 million tonnes. Overall, 8 percent of production is an increase from the previous year, when Pakistan produced 25 million tonnes of wheat. Sindh produced a very healthy wheat crop in this season 2020/2021. The wheat collection has already started in lower areas of Sindh province, and many dealers are starting to purchase wheat for Flour Mills and Chapkis. Official figures indicate that Sindh has crossed its wheat target in this 2020-21 season. 100.10 percent of seeding was completed towards a target of 1,200,160 hectares. The government of Sindh set a target of 4 million tonnes for grain production in the current season. The government achieves this target because of a healthy wheat crop. Production, but last year, the government missed its target due to cultivation problems.

1.4 million tonnes of wheat have been decided to obtain by the Sindh Government at a support price of Rs2,000 per 40kg, but still, this rate has not been reported so far. However, the fixed rate by the Federal Government is Rs1,640 per 40kg. Due to the timely start of the sugarcane crushing season in October 2020, more and more wheat was sown than the target, and most of the sugar factories had started crushing sugarcanes by that time. Had the opportunity to sow wheat on a land empty of sugarcane. Frequently, the sugarcane sowing target is generally between 310,000 hectares and 320,000 hectares, and in 2021-2022, the area under sugarcane has come down to about 7 percent. In Sindh, wheat holds significant importance as a crop. Wheat plays the most important role in Pakistan's economy by exporting things to different countries to earn exchanges, which is far from desired. According to the Agricultural, supply, and Price Department government of Sindh. According to the weather and mud conditions of the land, the lower part of the province (Hala, Hyderabad, and Tando Allahyar sub-Division), sangha, and Mirpurkhas districts are suitable for the wheat crop. In financial records, wheat of Sindh province accounts for 21.9% of stocks in (GDP) (Government of Pakistan, 2017). Wheat contributes 8.9% to agriculture and 1.6% to gross domestic product GDP. Wheat crops displayed marginal increases of 0.5 percent (GOP, 2019). The province of Sindh's rural sections consume more wheat than its urban counterparts. According to many infernal sources, among urban households, wheat ranks second in terms of consumption, whereas it is the primary item among rural households. In Sindh province, in the areas mentioned above, the wheat crop is affected by different things like shortage of water, high prices of basic cultivations, increasing values of basic chemicals input, situations of extraordinary points, etc. Other crops are common, but wheat is specific compared to other crops because it contributes a large amount to economic growth compared to other factors of the economy. However, in the previous few years, farmers faced many problems in cultivating wheat. Due to these issues, farmers experienced significant losses in the preceding years when wheat grain was abundant. The environmental conditions of Pakistan and the unpredictable nature of climates are different from those of other regions or countries. This climate system includes the variation in different variables like the amount of available water for both rains served agricultural lands and irrigated systems, which is the reason for the fluctuation in annual wheat yield. Many times, cold weather with heavy rain is highly effective on wheat crops, and it is also the reason to increase the reimbursed growth of herbs in the Field. It also extends the harvest period. That is the reason the sowing of the wheat crop is delayed for the next Kharif Crop. After sowing the wheat crop, rain is just the reason for minimizing the propagated wheat pits, and even at Harvest time, the final crop is severely damaged. Rising daytime temperature or late sowing increases the need for crop water at a particular stage. It can also cause early completion of the stage and early maturation of grain. For that reason, it gets sliced grain. Therefore, regarding the effect of climate change in this study, the permeates are analyzed to understand the changes in soil temperature and humidity on wheat crop development.

2. Literature Review

Pakistan's economy heavily depends on wheat, which is the country's most significant crop. It is crucial to make wheat predictions. Previous scientific trends are used to estimate this crop's genuine future production. According to the ARIMA model, wheat output in 2002–22 is expected to reach 29774.8 thousand tons. The manufacturing scope and high area are within

acceptable reach. Information sharing, soil protection and rehabilitation, agricultural training and instruction, and support for government policies about the nation's wheat agriculture are all important (Iqbal, Bakhsh, Maqbool, & Ahmad, 2005). The objective is to evaluate the possibilities for wheat output in the future. By evaluating the forecast model's parameters, Pakistan is obtained. Douglas Cob Wheat production is a profession with varying future values. Using a different ARIMA, inputs are obtained as dynamic forecasts. estimates for every province and every input. The wheat production function's parameters are then generated using it. wheat projection. The study's findings indicate that backward production, labor force, tractor use, and the combination of rainfall from November to March are the most significant variables for predicting wheat production per hectare. For the majority of the variables, the null hypothesis of mutual coefficients via provinces cannot be disproved. This indicates that the output of wheat in each of the four provinces is equally influenced by all variables.(Sher & Ahmad, 2008). Several machine learning techniques have been established in recent research to increase the precision of time series forecasts (Qureshi & Ahmed, 2022; Qureshi, Khan, Daniyal, Tawiah, & Mehmood, 2023). In this paper, they attempt to use artificial neural networks (ANN) to create a precise model of wheat production. Training and test data are derived from 71 years of wheat output data spanning 1948 to 2018. The following 14 years of wheat output are predicted by the model, which was developed using 53 years of data. The top 10 most significant factors are indicated out of the 16 indicators that are utilized as input variables for wheat production. The findings demonstrate that while certain anomalies and most trends of the original data are captured by the model. Salman, Jan, and Aslam, 2019). In a previous article, the lineage and descriptive variables of wheat production were assumed; the research of this article has confirmed that the relationship between wheat production and descriptive variables is essential for linear variety. While in an earlier article, the absolute three-month rainfall level for November- January was considered suitable for wheat production, statistical verification with alternative definitions of rainfall in this article failed to substantiate this assumption. Instead, they found that the seven-month (July-January) deviation from normal rainfall was more appropriate to explain the changes in wheat production. Using a seven-month deviation of rainfall, the earlier forecast was replaced by a revised wheat production forecast of 6.8 million tons of wheat during 1973-74. It compares favorably with the government's target of 6.5 million tons of wheat in Punjab and confirms that the actual production of wheat was higher than the target of 1973-74 (CHAUDHAR & KAMAL, 1947).

Cryptocurrency prices were forecast by using the same methodology in (Qureshi & Ahmed, 2022). Similar studies can be found in (Iftikhar, Daniyal, Qureshi, Tawiah, Ansah, & Afriyie, 2023; Qureshi, Ahmad, Ullah, & ul Mustafa, 2023; Qureshi, Khan, et al., 2023; Tawiah, Daniyal, & Qureshi, 2023). The current study provides evidence in favor of the creation and use of fuzzy time series models for projecting agricultural output in the near future. Forms for existence studies might be a helpful starting point. Planning is being done by local companies to meet their raw material requirements and to improve post-harvest management. Fuzzy time series can be predicted by management. Most useful in the management of agriculture. (Ahuja, Kumar, & Kumar, 2010). Numerous scholars have worked to develop a wheat forecasting model for Pakistan. Research was done in the 1970s and 1980s during difficult times for Pakistani wheat production. Labor, tractor, temperature, fertilizer, and rain are input models (Iqbal et al., 2005). Publications indicate that wheat production will increase to 29.77 million tons in 2022, according to the ARIMA model (Iqbal et al., 2005). Many studies have been done to predict and determine the barriers to major production. Crops like wheat, cotton, and rice in Pakistan. (Raza, Naheed, Anwar, & Masood, 2015). The experimental study of rice modeling and forecasting time series data production in Pakistan used the ARIMA model, which is frequently used to predict the future. To adopt appropriate measures in terms of internal consumption and export requirements Muhammad, Siddique, Bashir, and Ahmad (1992) forecasting is a crucial tool for crop production in any country. Trustworthy agricultural data offer a strong basis for agricultural planning and function as a standard for gauging the advancement of agriculture (Amin, Amanullah, & Akbar, 2014). The capacity of forecasting approaches to anticipate crop acreage, production/yield, and the incidence of crop pests and diseases is indicative of their relevance in agriculture (Ramasubramanianv, 2009).

Several studies on prediction techniques in agricultural research have been found through a review of the literature. These studies involve predicting rice and wheat prices in Pakistan Abbasi, Ayesha Tahir, Irum Raza, Saleem Abid, and Khan (2015), significant the

pulses and their cost evaluation in Pakistan (Rani & Raza, 2012), analysis of trends of tea purchase (Raza et al., 2015), and barley (Naheed, Raza, Anwar, Habib, Zahra, & Siddiqui, 2015). Time series models were employed in a different investigation by Ahmad, Chani, and Humayon (2017) to predict the area, yield, and output of main crops. The primary goals of this research are to first apply several time series, linear, and nonlinear models to the data and then, using the best-fitting model, forecast the output of wheat harvests in Pakistan. Numerous research on the topic of predicting wheat output and area on a national and worldwide scale may be found in the literature. One of these studies, by Najeeb Iqbal, Khuda Bakhsh, Asif Maqbool, and Ahmad (2005), projected Pakistan's wheat output and area until 2022. In a different work, Sabir (2012) tried to predict wheat production using exponential smoothing. Furthermore, Karim, Awal, and Akter (2010) projected Bangladesh's wheat output using regression and analysis of trends approaches.

3. Methodology

An investigation was carried out to gather data to examine the forecasting methods for wheat cultivation in Sindh province. Information on the wheat crop, production, and area in Sindh Province between 1984 and 2014. The source of the information was "Agriculture Statistics of Pakistan." Using time series analysis, the area, data on production, and production patterns were examined. Methods from 1984 until 2014. We utilize SPSS for data analysis purposes. Additionally, exponential smoothing was performed using Microsoft Excel. The projected trends, moving averages, and exponentials were briefly described and are summarized in the section that follows.

3.1. Moving average model

A moving average model is to predict trends and identify patterns in time series data, econometricians typically employ models, a sort of time series analysis model. The linear combination of the time series' previous white noise error terms determines the current value of the time series in moving average models. Mathematically it can be shown as

$$\hat{Y}_{t-1} = (\boldsymbol{Y_t} + \boldsymbol{Y_{t-1}} + \cdots \boldsymbol{Y_{t-p}+1})/\boldsymbol{p} \quad (1)$$

Where,
$\hat{Y}_{t+1}$ the forecasted value for year t+1,
Y_t is the reported value for the year t,
and p is the number of terms specified in the moving averaging.

3.2. Exponential Smoothing (ES) Model

One time series technique for predicting time series with univariate data is exponential smoothing. The foundation of time series approaches is the idea that a forecast is equal to the balanced linear sum of previous observations or lags. The way the Exponential Smoothing time series approach operates is by giving historical data exponentially decreasing weights. The reason for its name is that each demand observation's weight is exponentially reduced. The model assumes that the foreseeable future will resemble the recent past in some ways. The level of demand, or the average value around which demand fluctuates over time, is the sole pattern that Exponential Smoothing picks up from demand history. Mathematically, this model can be represented as

$\boldsymbol{s_0} = A_0$
$\boldsymbol{s_t} = \boldsymbol{\alpha} A_t + (\boldsymbol{1} - \boldsymbol{\alpha})\ \boldsymbol{s_{t-1}},\ 1 > \boldsymbol{0}$
α= Coefficient
t = Time
A= Variable

4. Result Interpretation and Discussions

The data used for predicting is sourced from the https://www.pbs.gov.pk/content/agriculture -statistics website. Time series methods were used to analyze data for trends in region, production, and yield from 1984 to 2014. The 3, 5, and 7-year moving averages (MA) of the grain from 1984 to 2015–15 are displayed in the first table. From 1984 to 2014, the area's 3-year moving average data shows a lowest value of 849.87 acres and a maximum of 1129.4 hectares. From 1984 to 2014, the area's five-year moving average data reveals a low value of 863.04 acres and a maximum value of 1111.58

hectares. The area's minimum value of 890.09 acres and greatest value of 1109.6 hectares between 1984 and 2014 are shown by the 7-year moving average (MA) data.

Table 1: Moving Average (MA) Values of Wheat Price (3, 5, 7- Years) 4

Time (Years)	3 Years MA Forecast	5 Years MA Forecast	7 Years MA Forecast
1984-85			
1985-86			
1986-87			
1987-88	1032.20		
1988-89	1030.53		
1989-90	1035.33	1033.32	
1990-91	1038.23	1036.30	
1991-92	1047.80	1040.84	1037.83
1992-93	1052.20	1045.32	1041.91
1993-94	1071.87	1061.10	1052.33
1994-95	1089.23	1073.18	1062.27
1995-96	1090.77	1076.84	1067.73
1996-97	1077.87	1079.14	1070.56
1997-98	1078.27	1088.82	1079.43
1998-99	1097.33	1092.12	1088.96
1999-00	1116.90	1095.74	1098.29
2000-01	1129.37	1111.98	1104.07
2001-02	1026.20	1061.12	1061.94
2002-03	943.367	1014.80	1035.11
2003-04	849.867	963.500	1006.36
2004-05	872.367	914.400	973.700
2005-06	876.433	863.040	940.443
2006-07	899.600	887.540	913.229
2007-08	934.267	908.940	890.086
2008-09	968.433	934.180	915.686
2009-10	1001.17	964.820	938.000
2010-11	1037.87	1005.80	970.657
2011-12	1089.37	1048.04	1008.69
2012-13	1095.30	1061.44	1031.80
2013-14	1094.73	1081.58	1054.29
2014-15	1087.13	1099.62	1074.20

The findings indicate that the 3-year moving average minimal area of wheat was discovered in 2001–02 and its highest area in 1998–99. A 5-year moving average revealed that the least grain area occurred in 2004–05 and the greatest occurred in 1999–2000. The wheat area's lowest and maximum moving average (MA) during 7 years was determined in 2006–07 and 1999–2000, respectively. Additionally, it was noted that the quantity of land under cultivation varied from year to year in terms of growth and decrease in size. On the other hand, the area grew primarily during 1987–1988 and 2000–2001. Once more, from 2001–02 to 2008–09, this fell. After that, it began to rise from 2009–10 to 2011–12. In the preceding 2014–15 years, the area predicted by the 3, 5-, and 7-year averages that moved was 1087.13, 1099.62, and 1074.20 acres. Each started to increase between 2009–10 and 2011–12. The area predicted for the 3, 5, and 7-year moving averages in the most recent 2014–15 years was 1087.13, 1099.62, and 1074.20 acres.

4.1. Utilizing exponential smoothing to analyze trends in wheat area

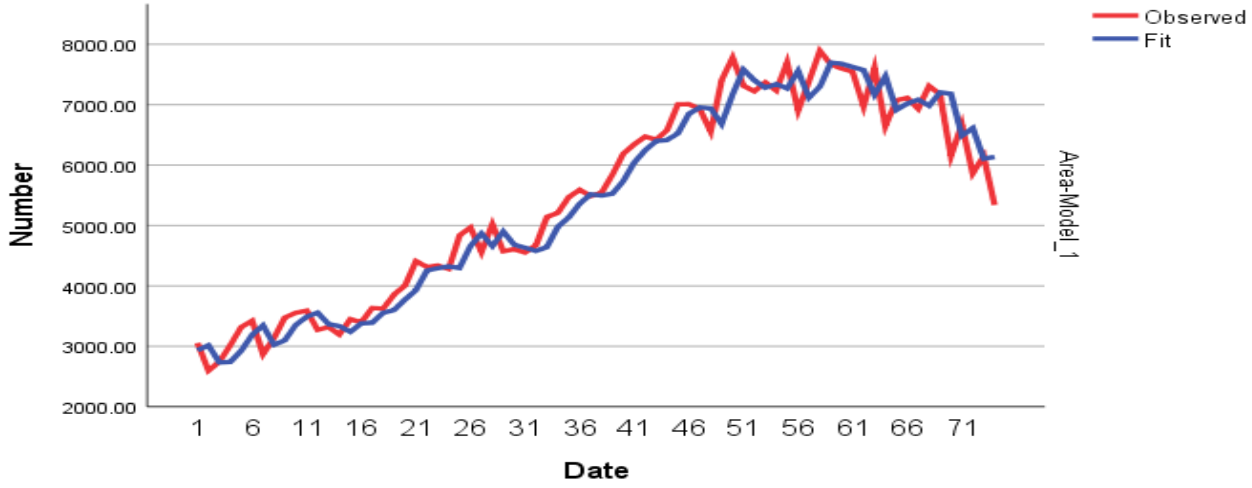
The red (actual) and blue (fitted) curves in Figure 1 closely correspond to one another, suggesting that the model (fit) accurately captures the trends and changes in the observed data. This indicates that the fitted model is a good predictor of the trend during this time since it fits the observed data well. Yet, there is the opportunity for improvement in the fit as the model does not adequately account for all of the noise and oscillations in the observed data. Table 2 shows the estimated values of the ES model. It is found from the results that the smoothing constant value is 0.90. A smoothing constant around 1 (such as 0.90) increases the forecast's responsiveness to recent changes in the data. Measures of the forecast accuracy are provided by the MSE of 4773.36 and MAD of 35.53. The extremely low MPE (0.01) suggests that the forecast has very little bias. Based on the exponential smoothing model with the given

smoothing constant, the forecast value of 1118.18 is the expected value for the upcoming period.

Table 2: Estimated Parameters for exponential smoothing

Smoothing Constant	0.90
MSE	4773.36
MAD	35.53
MPE	0.01
Forecast	1118.18

Figure 1: Wheat area exponential smoothing graph



6. Conclusion, Recommendation, and Policy

The outcomes are summed up in this section. From 1984 to 2014, the area hectares had a low value of 849.87 and a maximum value of 1129.4 hectares, according to three years of moving average data. Transferring five years' worth of moving average data shows that the area decreased to 863.04 hectares at minimum and increased to 1111.58 hectares at maximum between 1984 and 2014. The data for seven moving averages shows that the area decreased to 890.09 hectares at minimum and increased to 1109.6 hectares at maximum between 1984 and 2014. Economic smooth analysis in this study indicated that production and area are trending upward, however the projection indicates that output will drop in 2014–2015 whenever production and area increase. It is found that there was a large rise in production as well as a decline in trend with area, production, and wheat cultivation. Thus, in the case of undercast, wheat cultivation's area and production will increase over the next several days. Despite this, wheat was produced despite the scarcity of irrigation water. The results of this study, which uses exponential smooth analysis, indicate rising trends in productivity, production, and area. On the other hand, the pattern indicates that in 2014–2015, this is the region where output and production growth declined. It is stated that up-to-date, precise information on wheat crops is needed by the government. As a result, area, production, and production may all be supported by precise wheat prediction. Decisions over the province's import, demand, and supply of wheat are made by policymakers.

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