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Evaluating Wheat Cultivation Trends and Yield Performance in Nigeria, India, and Pakistan: An ARIMA-Based Approach

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Abstract

This study uses secondary data from the Food and Agricultural Organization (FAO) database, to examine trends in wheat production performance in Nigeria, India, and Pakistan from 1982 to 2022. We examine important indicators such as cultivated area, productivity, and production to comprehend the changing patterns of wheat production in these countries. According to the data, India's cultivated area grows at an average rate of 0.82%, while production grows at a rate of 2.39% and yield grows at a rate of 1.57%. Pakistan exhibits a similar pattern, with yield growth at 1.68%, production rising by 2.24%, and cultivated area growing at a pace of 0.56%. On the other hand, although Nigeria's agricultural area increased by 2.62%, its average yield decreased. The ARIMA model predicts that India's yield will fluctuate from 3.34 to 4.46 t/ha, while Pakistan's yield will range from 2.82 to 3.58 t/ha. Nigeria's yield is expected to range from 0.67 to 1.78 t/ha. A LOESS trend plot shows the trends in each variable, demonstrating significant patterns in growth rates among countries. The findings show that whereas India leads in total production, Nigeria has significant yield challenges while growing its cultivated area. This study emphasizes the necessity for specific agricultural policies and investments to improve wheat production efficiency in this region.

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Intoduction

Cereal grains have been considered the major component of the human diet for thousands of years and have played a major role in shaping human civilization. Wheat is the most important grain worldwide based on grain parcel and is ranked second when it comes to the total production volume, It ranks second among the most important cereal crops in the world, after rice [1-3]. Wheat is cultivated mainly in the temperate and sub-temperate regions of the world. Although several species of wheat are recognized in the world, only three species of wheat namely; Triticum aestivum (Bread wheat), T. durum (Macaroni wheat), and T. dicoccum (Emmer wheat) are commercially cultivated in India. Wheat is globally the leading source of carbohydrates in human food, with a content of about 71 percent, apart from this, it also contains 13 percent proteins which is very high as considered to be cereals and hence is also a major source of proteins around the world [4]. Over the past decade, global consumption has steadily increased in conjunction with population growth. Global consumption is projected to increase to 775 metric tons by 2020, driven by expanding population [5]. By 2030, the global population is estimated to exceed 8 billion, leading to a 55% rise in food consumption (Annual Report, 2011-12).

Wheat flour is used in Nigeria for bread and cake (85-99%). Semovita (1 0%), biscuit (about 4%), pasta (below 1 %), macaroni, and spaghetti (below 1 %) (FAO, 2012). Throughout history, the Nigerian government's efforts to increase wheat production led to the ban on wheat importation in 1987, and the Accelerated Wheat Production Programme (AWPP) was implemented to encourage local production Nigeria's wheat production rose from 50,000MT to 450,000MT within three years of the program [6]. After maize and rice, wheat is the third most consumed grain in Nigeria, According to the Foreign Agricultural Service of the US Department of Agriculture, with 206 million people, the country's population growth is driving consumption, which is expected to reach 6.06 million tons of wheat in 2022-23, To meet this demand, Nigeria is expected to harvest 160,000 tons of wheat and import 6.5 million tons [7]. Nigeria is the net wheat importer to the extent that it overlooked domestic production due to the high import dependency [8].

Similarly, Wheat is grown extensively in Pakistan on a subsistence basis for home consumption. On average, households incur 12.55 percent of their monthly expenditures on wheat and wheat flour [9]. The per capita wheat production in Pakistan is 131kg per year, while per capita wheat consumption is 118kg per year, the highest in the world [10].

Even though India is the world's third largest wheat producer, domestic output is insufficient to fulfill the country's food and livestock feed demands [11]. According to data from several sources, India has a lower wheat production than other countries. As a result, there is an urgent need to solve this yield gap by adopting improved land management strategies for various environmental situations [12,13]. Understanding the tools involved in crop-environment interactions, as well as the variables that influence crop development, is an important first step in achieving this objective. The ICAR also analyzed that wheat production should be increased by 140 million metric tons by 2050. Uttar Pradesh, Punjab, Haryana, and Madhya Pradesh together constitute about 82% of the country's wheat production, India, on average, imports one million tons of wheat and, for various reasons, exports an average of 0.7 million tons [14].

As recorded by, rice yields in Nigeria are poor, averaging around 1.8 tons per hectare, compared to the national potential of 3 tons per hectare for uplands and 5 tons per hectare for lowlands. Nigeria transitioned from being self-sufficient in food in the 1960s to becoming a significant importer in the 1980s due to weak agricultural output increase [15]. Between 1981 and 2003, agricultural productivity increased by only 5.4 percent. wheat production in Nigeria was limited to the Chad basin, with farmers producing it on a modest scale using outdated technologies and preparing it into meals, because temperate varieties were mostly employed, output was limited to the cold dry season of November to March, demanding irrigation, these challenges can be adequately managed by understanding the direction of wheat cultivation over previous years [16]. Climate change harms agricultural productivity by altering temperature, precipitation patterns, and frequency of extreme weather conditions.

The agriculture sector is susceptible to long-term trends and weather fluctuations in Pakistan, hence

analyzing the growth rate of the major determinant of wheat cultivation will give insight into the degree of effect and possible adjustment to ensure stability of wheat production in Pakistan [17]. The report analyzes wheat consumption and demand in India, including projections for 2030 and 2050, indicating that the future demand will be very high, this paper will adequately address the issue of the possibility of meeting the future demand [18].

Daniel & Ochoche have found a huge imbalance between wheat supply and demand in Nigeria from 1990 to 2020, with supply ranging from 32,600 to 169,961 tons and demand ranging from 427,575 to 8,142,811 tons, resulting in a 99% difference [15,16]. examined grain production patterns in India and Nigeria, finding that Nigeria observed a positive increase in area (1.056), production (1.247), and productivity (0.189), all of which were statistically significant at various probability levels. emphasized the need for long-term solutions to increase Nigeria's wheat self-sufficiency, recommending domestic wheat markets and limited imports to overcome wheat production issues [19].

Abid et al., utilized a semi-log trend model to assess trends and growth rates in wheat area, yield, and output in Pakistan, indicating an overall rise in wheat area in Punjab, Sindh, and Baluchistan, with a little loss in Khyber Pakhtunkhwa from 1981-85 to 2011-15. investigated technical efficiency (TE) in agriculture in India, Pakistan, Ghana, and other African nations, finding that India's TE ranged from 68% to 89%, Pakistan's rice output showed a wider range (24% to 73%), and Ghana had moderate to high TE (73%). These findings provide insight into boosting wheat yield efficiency in Nigeria by implementing best practices observed in these locations [20,21].

Kumar et al., examined the area, production, and productivity of vegetables in Haryana and India, finding significant increases from 1990-91 to 2020-21, with compound annual growth rates (CAGR) of 7.00%, 8.13%, and 1.06% in Haryana and 3.18%, 4.65%, and 1.43% in India [22].

Potato output was the greatest in both areas in 2020-21. Bhusanar et al. studied groundnut production patterns in Rajasthan and discovered a positive and substantial increase in area, production, and productivity, with CAGRs of 3.2%, 6.4%, and 2.8%, respectively, indicating increasing patterns in groundnut cultivation.

As revealed from the literature, the developments in wheat agriculture in India, Nigeria, and Pakistan, demonstrate significant growth patterns in area, yield, and output. India's tendency is constant growth, powered by high technical efficiency and increased productivity throughout time. Nigeria, despite good production trends, continues to face a widening supply-demand imbalance for wheat. Pakistan has diverse patterns, with most regions seeing development while others, such as Khyber Pakhtunkhwa, indicate modest reductions. Forecasting future wheat yields and trend analysis will provide a comparative view that demonstrates prospects for enhancing wheat production in each country, thereby promoting strategic agricultural planning and sustainability.

Objective of the Research

- To conduct a comprehensive analysis of the trends in area, production, and productivity of wheat in Nigeria, India, and Pakistan.
- To evaluate and compare the yield efficiency of wheat crops in Nigeria, India, and Pakistan through the application of the ARIMA model.

Material and Methods

Data Source: The study was primarily based on the secondary data published from various authentic sources and records. Data on wheat crop area, production, and productivity for Nigeria, India, and Pakistan from the period (1982 to 2022) were collected from the Food and Agricultural Organization (FAO) database.

Descriptive Statistics: it serves as a basic comparison for immediate variability across the data for each country.

Seasonal Trend Decomposition by LOESS (STL)

This tool decomposes the time series data into trend, seasonality, and residual. LOESS is widely used in the time series analysis as reflected by Bussay et al., in their paper "Improving operational maize yield forecasting in Hungary" [23].

In this study, we used the LOESS (Locally Estimated

Scatterplot Smoothing) approach to smooth and examine fluctuations in wheat land area, yield, and production across time. LOESS is a nonparametric method that employs localized polynomial regression to fit a smooth curve over data points, allowing us to capture non-linear patterns without assuming a specific functional form. This technique is very useful for displaying gradual changes in agricultural trends.

Compound Annual Growth Rate (CAGR):

The average least square method (OLS) in Eviews estimates the growth rate equation.

$\ln(Y)=\beta 0+\beta 1t+\varepsilon t$…….. (1)

Where; ln(Y) is the logarithmic form of dependent variable Y (area, production, or yield), β0 is the constant, β1 is the coefficient, t is the dependent variable time, and εt is the error term.

β1 Represents the growth rate which can be computed as;

percentage growth rate= β1*100……. (2)

Autoregressive Integrated Moving Average (ARIMA):

The ARIMA model developed by (Box and Jenkins 1987), is used to predict the export quantity of cashew nuts in Nigeria.

The lag structure is obtained as usual by carefully plotting the autocorrelation function (ACF) for the Moving Average (MA) component and the partial autocorrelation function for the Auto Regressive component (AR), the Augmented Dickey-Fuller test for stationarity is used for the order of integration of the variable.

The equation is given by;

$\phi(L)(1-L)\,d_{yt} = \theta(L)\,\varepsilon t$

Where yt denotes cashew nuts export quantity, $\phi(L)$ is the Auto Regressive operator, $(1-L)^d$ is the differencing operator, $\theta(L)$ is the Moving Average operator, L is the lag operator, εt is the error term. The respective components are; $\phi(L) = 1-\phi_1 L-\phi_2 L^2-\cdots-\phi_p L_p$ for the Autoregressive part, $(1-L)^d$ is the differencing part, and $\theta(L)=1+\theta_1 L+\theta_2 L^2+\cdots+\theta_q L_q$ is the moving average component. Similarly, p, d, and q are the number of autoregressive terms (AR), the number of differencing applied (I), and the number of moving average parts (MA) respectively.

Result and Discussion

Trend Analysis of Wheat Crop

The descriptive statistics for the basic comparison of area, production, and yield of wheat crop in Nigeria, India, and Pakistan are presented in Table 1.

Table 1: Descriptive Statistics

	Decades	Yield(t/ha)	Area(ha)	Production Quantity(tons)
Nigeria	1982-1991	1.658	43400	683000
	1992-2001	1.926	33020	587400
	2002-2011	1.31	52404.5	660440.62
	2012-2022	1.25	68242.18	904320
	Mean	1.52829268	49729.4878	69150.25902
	Minimum	0.83	10000	26000
	Maximum	2.64	100000	139000
India	1982-1991	1.983	23491812.8	466428832
	1992-2001	2.539	25703220.4	653636900
	2002-2011	2.755	27231310	751408600
	2012-2022	3.26	30415028.18	1090225050
	Mean	2.6495122	26800701.02	72236570.29
	Minimum	1.69	22144400	37451808
	Maximum	3.54	31470000	109586500

Pakistan	1982-1991	1.704	7512590	128217200
	1992-2001	2.121	8209520	174267900
	2002-2011	2.534	8531960	216609800
	2012-2022	2.84181818	8939454.273	279402460
	Mean	2.31341463	8314017	19475545.37
	Minimum	1.48	7222900	10881900
	Maximum	3	9223723	27464081

Loess Trend Analysis

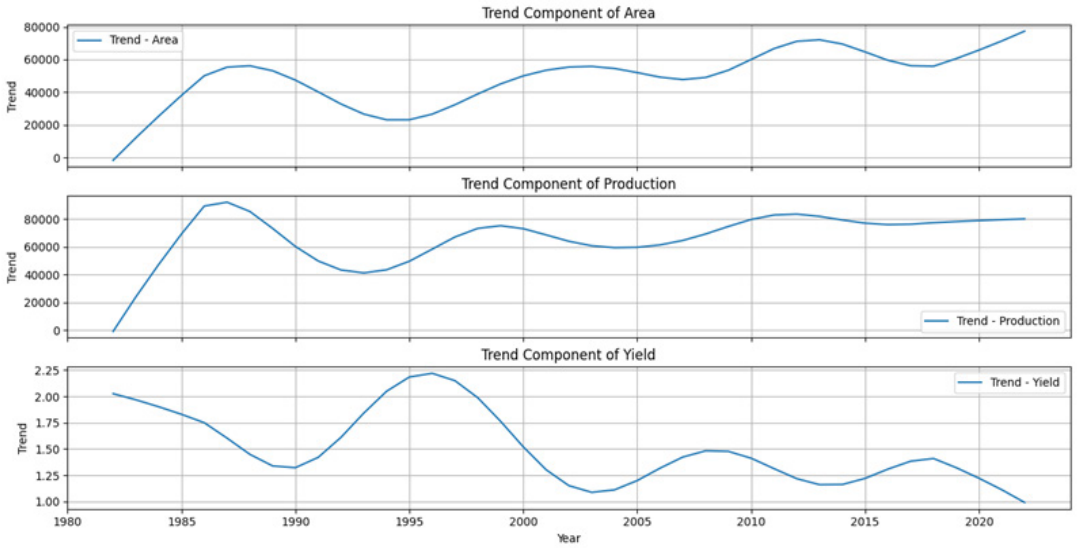

Figure 1: Trends in Area, Production, and Productivity in Nigeria

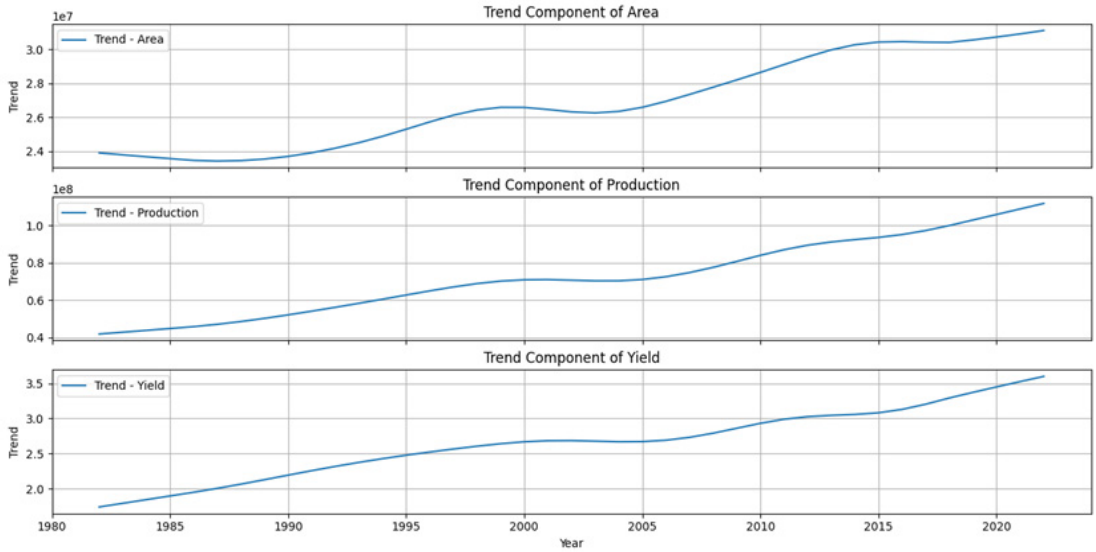

Figure 2: Trends in Area, Production, and Productivity in India

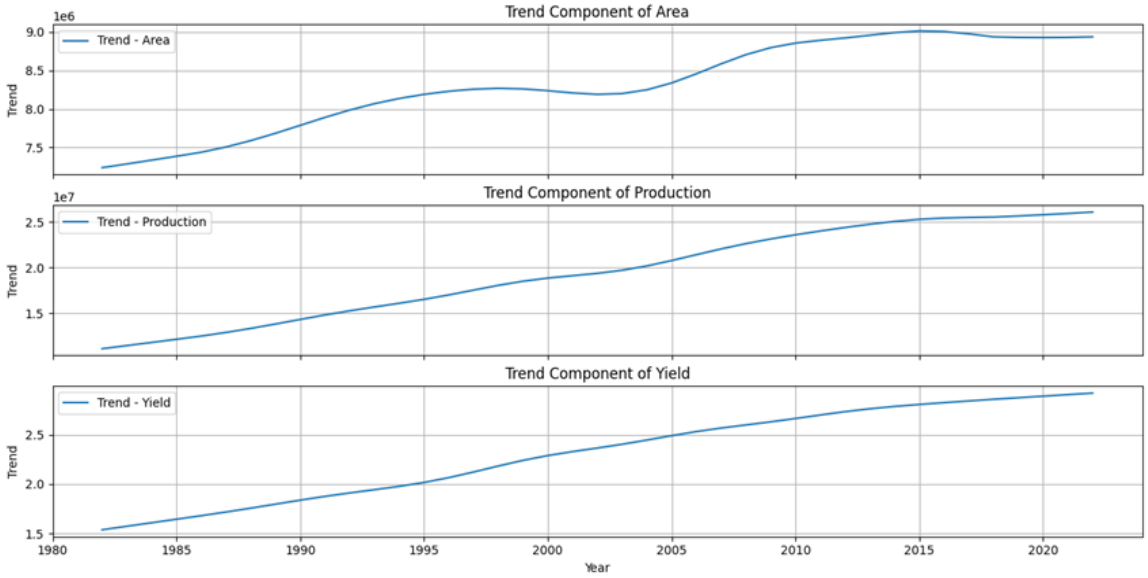

Figure 3: Trends in Area, Production, and Productivity in India

Table 2: Estimated Growth Rate of Wheat Crop in Nigeria, India, and Pakistan

Countries	Variables	Growth rate (%)	R-squared	Std. error	t-Statistics	P-value
Nigeria	Area	0.0262	0.31	0.006297	4.159759	0.0002
	Production	0.0146	0.17	0.005225	2.794046	0.008
	Yield	-0.0115	0.19	0.00381	-3.01289	0.0045
India	Area	0.0082	0.91	0.000416	19.74089	0
	Production	0.0239	0.95	0.000833	28.69247	0
	Yield	0.0157	0.92	0.000749	20.9496	0
Pakistan	Area	0.0056	0.85	0.000374	14.8713	0
	Production	0.0224	0.94	0.000912	24.55132	0
	Yield	0.0168	0.93	0.000734	22.93803	0

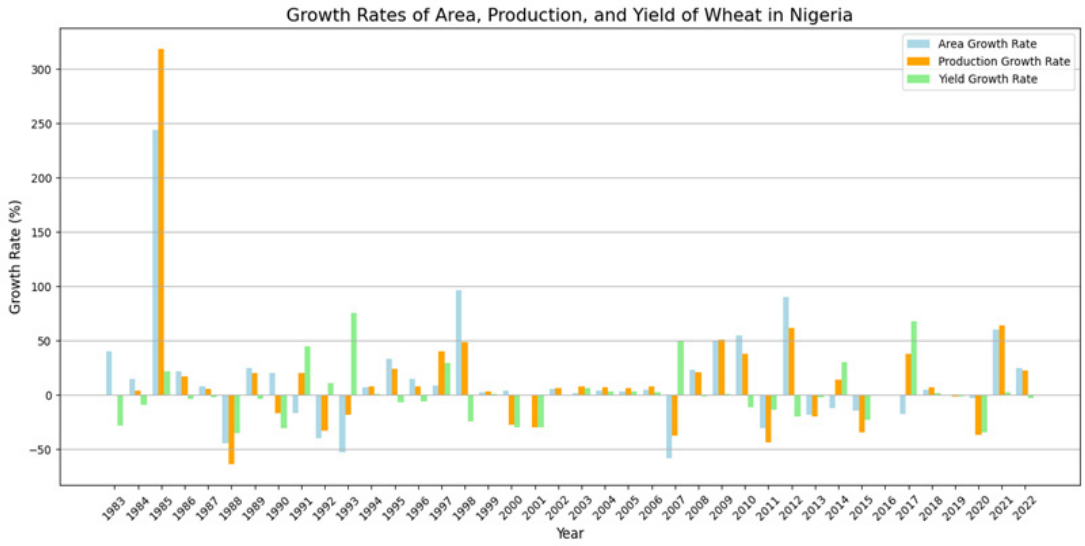

Figure 4: Trend and growth pattern of wheat production in Nigeria

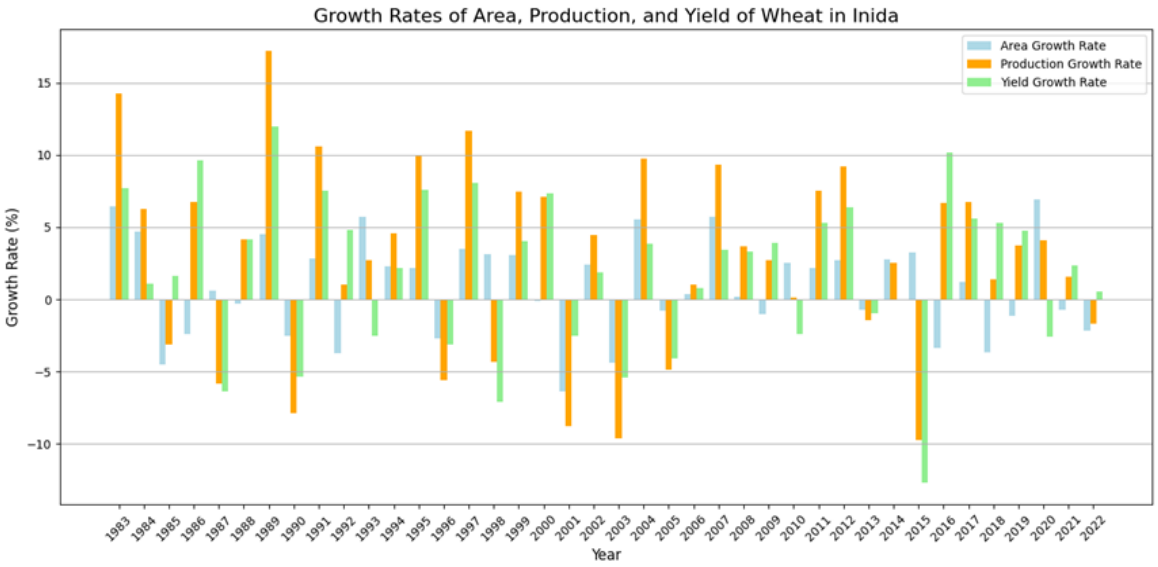

Figure 5: LOESS Trend and Growth pattern of wheat production in India

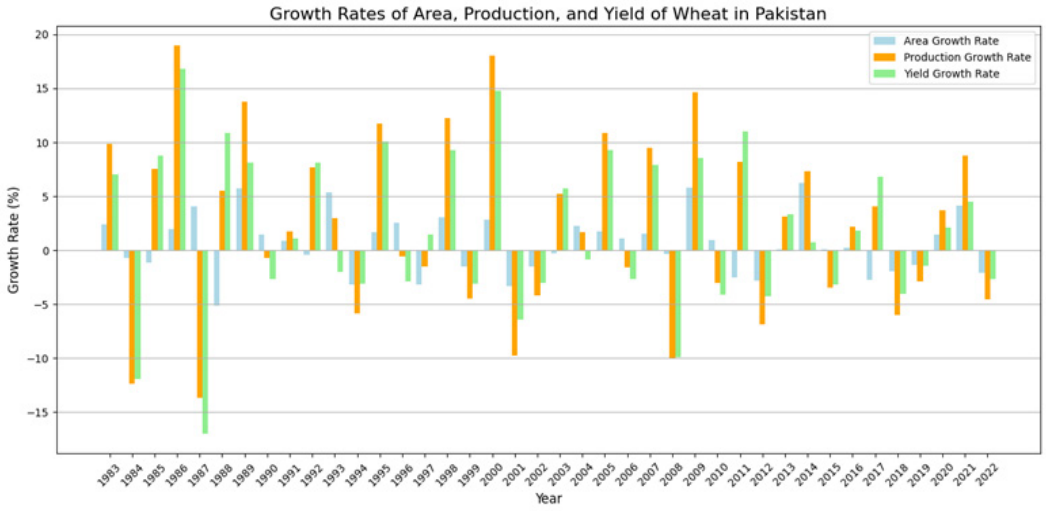

Figure 6: LOESS trend and growth pattern of wheat production in Pakistan

From Table 2. The area under wheat cultivation in Nigeria expanded at an average rate of 2.62%, indicating a huge increase. Much of the increase in food production in Nigeria has been achieved through the expansion of the area, Similarly, wheat output has increased somewhat, with an average growth rate of 1.46%. However, yield growth has been more variable, with an overall negative trend and an average growth rate of -1.15% [15].

This shows that while the area of cultivation and output has risen, wheat yield per unit area has decreased, showing difficulty in improving productivity despite the increased cultivation efforts in Nigeria. The recent decline indicates the negative effect of COVID-19 as emphasized by Ikuemonisan & Akinbola, similarly, the work of Aderinoye-Abdulwahab and Abdulbaki, which discusses the Nigerian government's efforts to encourage wheat cultivation through subsidies and incentives to reduce wheat import dependence [24,25]. Figure 1. Illustrates the growth rates of wheat cultivation area, output, and yield in Nigeria from 1983 to 2022. All three variables show large fluctuations, with significant increases, particularly during 1984-1985, followed by more mild variations in subsequent years.

The average growth rate for wheat cultivation area in India is 0.82%, indicating that wheat cultivation land is steadily increasing. Wheat production has grown at a faster average growth rate of 2.39%, indicating an increase in overall output. The yield growth rate is

1.57%, indicating an average production increase per unit area. Overall, India has experienced a consistent increase in wheat output and yield, although the area planted has grown more slowly. According to Chand Ramesh, agricultural land growth in India has slowed due to urban development and competition for arable land [26]. Studies by Bhattarai et al., show that India's wheat production growth has been determined by higher productivity per unit area due to improved irrigation, fertilizer use, and mechanization [27].

The average growth rate of the area under wheat cultivation is 0.56%, suggesting a slow and steady increase in the area covered by wheat crops.

The average rate of production increase, which is 2.24%, indicates a more significant increasing trend, indicating improvements in the total amount of wheat produced. With an average growth rate of 1.68%, yield growth suggests a moderate increase in wheat production per unit area. Pakistan has generally had continuous increases in yield and production, notwithstanding a relatively slower rate of cultivated area growth over this period. Shah et al., confirm that the increase in the wheat area has been minimal in recent years due to land constraints. [17]

Similarly, found that Pakistan's wheat production has seen a considerable increase due to improvements in agronomic practices and better water management, despite slow area expansion [28]. There are clear trends when examining the rates of wheat cultivation in Pakistan, India, and Nigeria. Nigeria experienced the largest growth in the area under wheat cultivation, with a rate of 0.0262, compared to 0.0082 for India and 0.0056 for Pakistan, showing a more vigorous growth in cropland.

However, Nigeria's output growth rate is relatively moderate at 0.0146, following India and Pakistan, which recorded greater production increases at 0.0239 and 0.0224, respectively. Nigeria faces a significant difficulty in yield growth, since the rate is negative (-0.0115), indicating a decrease in productivity despite the additional cultivated area. Conversely, Pakistan and India both have positive yield growth, with Pakistan slightly surpassing India at 0.0168 against 0.0157, indicating productivity increases. Overall, India and Pakistan have seen a more balanced increase in output and yield, with Pakistan showcasing the highest overall performance across all parameters. At the same time, Nigeria concentrates on expanding its cultivation area.

Wheat Productivity Comparison in Nigeria, India, and Pakistan

Table 3: ARIMA (1, 0, 0,) Result

Metric	Value	Residual Test	P-value
AIC	17.3	ADF test	0.0479
BIC	22.4	Ljung-Box Test	0.318
RMSE	0.276	ACF1	0.0914
MAE	0.224		
MPE	-4.151		
MAPE	16.66		

Table 4: Wheat Crop Yield in Nigeria

Year	Forecasted Yield (t/ha)	Lower_80	Upper_80	Lower_95	Upper_95
2023	1.22	0.86	1.58	0.67	1.78
2024	1.29	0.87	1.72	0.64	1.95
2025	1.34	0.89	1.79	0.66	2.02
2026	1.37	0.91	1.82	0.67	2.06
2027	1.38	0.93	1.84	0.68	2.09
2028	1.40	0.94	1.85	0.69	2.10
2029	1.40	0.94	1.86	0.70	2.11

2030	1.41	0.95	1.87	0.70	2.11
2031	1.41	0.95	1.87	0.70	2.11
2032	1.41	0.95	1.87	0.71	2.11

According to the ARIMA model from Table 3&4, Nigeria's wheat yield will gradually increase from 1.22 t/ha in 2023 to 1.41 t/ha by 2032, showing a gradual increase in productivity. The predicted values exhibit narrow confidence intervals, with the 80% boundaries ranging from 0.86 to 1.87 t/ha, and the 95% intervals showing moderate uncertainty. The model's validity is demonstrated by residual tests, where stationarity is indicated by an ADF test p-value of 0.0479 and no significant autocorrelation as indicated by a Ljung-Box test p-value of 0.318. Despite this positive forecast, Nigeria has obstacles in achieving these yield improvements, including limited access to better seeds, insufficient irrigation, and poor agronomic practices Tanko et al., Addressing these limits and investing in agricultural technology will be critical to achieving the projected yields [29,30].

Table 5: ARIMA (0, 1, 1,) Result

Metrics	Value	Residual Test	P-value
AIC	-45.96573317	ADF test	0.01584
BIC	-40.89909481	Ljung-Box Test	0.771
RMSE	0.1243674	ACF1	0.0773
MAE	0.0901884		
MPE	-0.0437812		
MAPE	3.428646		
MASE	0.7438219		

Table 6: Wheat Crop Yield in India

Year	Forecasted Yield (t/ha)	Lower_80	Upper_80	Lower_95	Upper_95
2023	3.59	3.43	3.76	3.34	3.85
2024	3.64	3.45	3.82	3.36	3.92
2025	3.68	3.48	3.89	3.38	3.99
2026	3.73	3.51	3.95	3.40	4.06
2027	3.78	3.54	4.01	3.42	4.13
2028	3.82	3.57	4.07	3.44	4.20
2029	3.87	3.61	4.13	3.47	4.26
2030	3.91	3.64	4.18	3.49	4.33
2031	3.96	3.67	4.24	3.52	4.39
2032	4.00	3.71	4.30	3.55	4.46

The result from Tables 5&6 of the ARIMA model predicts an increase in wheat yield in India from 3.59 t/ha in 2023 to 4.00 t/ha by 2032, revealing a favorable trend in productivity over the next decade. The predicted yields have narrow confidence ranges, with 80% boundaries spanning from 3.43 to 4.30 t/ha and 95% intervals covering a slightly wider range. The model's validity is verified by an ADF test p-value of 0.01584, indicating stationarity, and a Ljung-Box test p-value of 0.771, indicating no significant autocorrelation in residuals. Technological developments, new seed varieties, and efficient regulation all help the agriculture sector in India to improve wheat yields [31]. However, concerns such as climatic uncertainty and soil health require constant monitoring to maintain this favorable trend [1,32]. Overall, while the ARIMA model predicts higher wheat

yields in India, maintaining and increasing productivity demands further investments in farming practices and technology.

Table 7: ARIMA (0, 1, 2,)

Metrics	Value	Residual Test	P-Value
AIC	-60.25	ADF test	0.05
BIC	-53.5	Ljung-Box Test	0.759
RMSE	0.10006	ACF1	0.0322
MAE	0.08083		
MPE	-0.17712		
MAPE	3.61029		
MASE	0.61582		

Table 8: Wheat Crop Yield in Pakistan

Year	Forecasted Yield (t/ha)	Lower_80	Upper_80	Lower_95	Upper_95
2023	3.03	2.89	3.16	2.82	3.23
2024	3.04	2.91	3.18	2.83	3.25
2025	3.08	2.94	3.22	2.86	3.29
2026	3.11	2.97	3.26	2.89	3.33
2027	3.15	3.00	3.29	2.92	3.37
2028	3.18	3.03	3.33	2.95	3.41
2029	3.22	3.07	3.37	2.98	3.45
2030	3.25	3.10	3.41	3.01	3.49
2031	3.29	3.13	3.45	3.04	3.53
2032	3.33	3.16	3.49	3.08	3.58

Pakistan's wheat yield is expected to increase gradually from 3.03 t/ha in 2023 to 3.33 t/ha by 2032, according to the ARIMA model from Table 7&8, reflecting a moderate but favorable trend in productivity growth. The predicted yields are confirmed by tightly confidence intervals, showing a moderate degree of uncertainty, with the 95% intervals being considerably wider and the 80% boundaries slightly between 2.89 and 3.49 t/ha. ADF test p-value of 0.05, confirming stationarity, and Ljung-Box test p-value of 0.759, indicating no significant autocorrelation in the residuals, both validate the model's reliability. This prediction is in line with previous research that links gradual but consistent increases in Pakistan's wheat production to developments in agricultural practices, specifically the use of better management techniques and improved varieties [34,35]. Nonetheless, there are still issues that could affect projected output increases, such as water scarcity and climate change [35,36]. Although Pakistan's wheat production is predicted by the ARIMA model to be relatively cautious, productivity will not increase without ongoing investment in agricultural technology and sustainable farming practices.

Conclusion and Recommendation

The study of wheat cultivation trends and yield forecasts in Nigeria, India, and Pakistan indicates diverse patterns of productivity and development potential. India has the most robust growth in both yield and production, whereas Pakistan has a consistent but small increase, and Nigeria has issues despite large area expansion. The ARIMA estimates suggest that yields would gradually improve in all three countries, with India dominating in productivity. To sustain these trends, policy-makers and stakeholders must invest in agricultural research and development, increase access to high-quality seeds, and implement effective irrigation systems [22,37].

In addition, optimizing wheat production in these areas will require addressing the effects of climate change and promoting sustainable practices. Further studies need to concentrate on the impact of climate changes on wheat yields, the significance of precision agriculture in optimizing inputs, and the socio-economic factors affecting farmer decisions on wheat production. Such kinds of research can offer valuable insights to develop particular strategies to increase wheat production sustainably.

Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this paper.

Data Availability Statement

The data that support the findings of this study are available from the Food and Agricultural Organization (FAO) database [https://www.fao.org/faostat], which is publicly accessible. Other data were sourced from World Bank.

Ethics Statement

This study used secondary data and did not involve any human participants or animals; therefore, ethical approval was not required.

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