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FORECASTS ABOUT PULSES PRODUCTION IN PAKISTAN: IMPLICATIONS FOR FOOD SECURITY AND CLIMATE CHANGE

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Abstract
This study evaluates historical trends and empirical growth rates of pulses production in Pakistan over a 10-year period (2015-2024) to highlight the sector's role in food security. It analyzes regional distribution and forecasts production for 2025-2029 across five major pulse crops. Chickpea/Gram (Cicer arietinum), Lentil/Masoor (Lens culinaris), Mung bean (Vigna radiata), Black gram/Mash (Vigna mungo), and Field pea/Mattar (Pisum sativum), using the Autoregressive Integrated Moving Average (ARIMA) method. Secondary time-series data were gathered from the Pakistan Bureau of Statistics, Ministry of National Food Security & Research, FAOSTAT, and the World Development Indicators. According to the statistics, domestic production growth for all crops except Lentil (3,900 tonnes) and Mash (5,600 tonnes) has consistently been poor. Automatically selected ARIMA (1,1,0) forecasts show a slight recovery in domestic production growth for Chickpea (235,000 tonnes) and further improvement for Mung bean (151,000 tonnes), while keeping domestic production growth for Lentil (3,900 tonnes) and Mash (5,600 tonnes) stable. The Gini ratio for the Chickpea sector is 0.485, import dependence exceeds 900,000 tonnes ($650M+ USD bill), and availability/per capita is 4.64kg/year, as revealed by spatial analysis. Urgent actions to address vulnerable rural households, especially strategic adaptations like certified seed subsidies, water-smart ridge sowing, and intercropping.

1. INTRODUCTION

Pulses are a significant part of Pakistan's agricultural and food value chain because they provide readily available plant protein, dietary energy, minerals, and macronutrients, and they play a critical role in sustainable agricultural production by fixing biological nitrogen. Gram, mung, mash, masoor, and other rabi and kharif pulses have been cultivated across Pakistan's agro-ecological zones for a long time. Pulses are relevant for food security as well as for climate-resilient agriculture, as their importance in human nutrition cannot be overlooked, and they play an important role in soil fertility, crop diversification, and resource-use efficiency. Pulses are acknowledged as crops with multiple benefits by

the Food and Agriculture Organization for nutrition, food security, soil health, biodiversity, and resilience to climate stresses (FAO, 2022).

Despite being nutritively and agronomically valuable, Pulses production in Pakistan has experienced a lot of ups and downs. Aggregate production of all pulses (gram, mung, mash, masoor, Mattar and kharif-rabi pulses) in 2006–07 was 1,089.3 thousand tons, which dropped to 755.3 thousand tons in 2007–08 and then saw significant fluctuations in the next few years, as presented in Agricultural Statistics of Pakistan 2023–24 (MNFS&R, 2024). Production was recorded at 992.4 thousand tons in 2008–09, 763.3 thousand tons in 2009–10, and 660.3 thousand tons in 2010–11. Total pulses production was down slightly to 441.4 thousand tons in 2011–12 but increased to 897.8 thousand tons in 2012–13. Pulses production subsequently declined to 544.3 thousand tons in 2013–14, 528.4 thousand tons in 2014–15 and reached a low of 437.0 thousand tons in 2015–16. Production recovered to 506.0 thousand tons in 2016–17, 478.3 thousand tons in 2017–18, and 713.6 thousand tons in 2018–19, followed by 667.6 thousand tons in 2019–20. Production was 484.5 thousand tons more recently in 2020–21, rose to 626.8 thousand tons in 2021- 22, and then dropped dramatically to 420.4 thousand tons in 2022-23 and 408.3 thousand tons in 2023-24. As per the figures, it can be observed that the production of pulses in Pakistan has not been consistent in terms of growth from one year to another; rather, there is a huge fluctuation in pulses production from year to year.

Special attention is needed for the future production scenario of pulses in Pakistan, and the long-term production pattern is of prime importance. The quantity of aggregates produced by pulses has decreased from 1,089.3 thousand tons in 2006–07 to 408.3 thousand tons in 2023–24, (MNFS&R, 2024) an overall drop of about 62.5% overall during this period. This equates to an annualized decline of approximately 5.48% for the 17 years between the beginning and end of production for the streams. Likewise, there was huge variation with regard to pulse area. The total pulse area decreased by about 27.1%, from 1,472.3 thousand hectares in 2006–07, to 1,072.9 thousand hectares in 2023–24. The reduction in the area and production points to the fact that historical performances of the sector cannot be attributed solely to area changes, but yield changes and changes in yield per area, weather, availability of inputs, and the level of production technology and other factors in agriculture may have also contributed significantly.

Stability of the pulse sector is also further illustrated by the recent production numbers. The aggregate pulse production increased from 484.5 thousand tons in 2020–21 to 626.8 thousand tons in 2021–22, which was an increase of about 29.4%. But this improvement was not maintained. Production declined by approximately 32.9%, from 626.8 thousand tons in 2021–22 to 420.4 thousand tons in 2022–23, and declined by a further 2.9% to 408.3 thousand tons in 2023–24 (MNFS&R, 2024). The harvested area, however, in all the pulses was reduced by 1133.5 thousand hectares and 1072.9 thousand hectares for the years 2022-23 and 2023-24, respectively, from 1240.9 thousand hectares for 2021-22. The recent evidence suggests, therefore, that the pulse sector in Pakistan remains very vulnerable to changes in the area and total production.

Another aspect of food security which needs attention, particularly in the context of the country, is the organization of production of pulses, which is comparatively small number of crops, particularly gram and mung. According to the Ministry of National Food Security and Research, most of the pulses grown in the country are major pulse crops and grams are the predominant pulse crop (MNFS&R, 2024). This could lead to a significant production shock to the primary pulse crops, such as bad weather, disease outbreaks, input scarcity, or other production shocks, which would affect the aggregate domestic supply and hence increase the risk of shortages. In addition, agricultural statistics released by the Ministry reveal that although the production of pulses is not sufficient to meet the needs of the country, imports are a vital component of the supply of pulses (PBS, 2024; USDA FAS, 2023).

Pakistan's case is unique, where the linkage between food security and pulses production is

particularly crucial due to the growing human population that relies on domestic production for their needs, while considering the constraints of land, water, technology, and climatic conditions. In the past, it was seen that besides the food production in the country, food availability has also been affected because of the increase in dependence on imports in Pakistan including that of cooking oils and pulses. This has also strengthened the linkage between population growth, water requirements and food demand of the country in the projections of agricultural production during the historical period in Pakistan. Therefore, the fluctuations in domestic production of pulses may impact food availability, food market supply, consumer prices, and dependence on external sources (PBS, 2024; USDA FAS, 2023).

One advantage of pulses is their nutritional properties, which further enhance their food-security relevance. Pulses are a source of plant-based protein and are an important food source in areas where animal-sourced proteins are relatively scarce and expensive. Therefore, any decrease in domestic pulse production has impacts on physical food access, as well as the food price costs and nutritional quality of household diets (FAO, 2022). A recent study on the pulse situation in Pakistan, as a case study, revealed low consumption of pulses and a poor supply of recommended pulse consumption standards, as well as inadequate land available for pulse production and yield as significant constraints to increasing Pakistan's pulse production. These results highlight the importance of not only increasing the production of pulses in the short term, but also boosting their volumes and stability. The uncertain nature of climate change adds to the uncertainty of future pulse production in Pakistan. Climatic variables such as temperature and rainfall are critical factors in crop production and can influence crop development, flowering, grain filling, and yield. The vulnerability of agriculture to climate risks in Pakistan is especially high due to the use of irrigation water and high spatial and temporal variability in precipitation. Empirical estimates of the long-run elasticities of production of the major crops (gram, wheat, rice, cotton and sugarcane) during 2000-2019 showed that the estimated values of long-run elasticity of production were significant and negative for the respective crops, whereas the long-run elasticity of cultivated area and fertilizer application were positive. From these observations, it is suggested that agricultural production in the future will be climate dependent.

The importance of climate change to pulses is not just worrying about the decrease in production. Pulses' contribution to climate adaptation and mitigation action because of their biological nitrogen-fixing capacity and rotation and diversified production capabilities also should be considered. When grown globally, the nitrogen pulses that can be fixed from the atmosphere could be substantial and decrease the use of nitrogen-based synthetic fertilizer, and so also the resulting greenhouse gas emissions, according to estimates by FAO (FAO, 2022). Crop rotation with RYG pulse can also enhance soil quality and resilience. Hence, boosting the pulse sector could have a concurrent effect on food security, soil management, resource use efficiency, and climate resilience, if production constraints are tackled properly.

Under this scenario, forecasting future production of pulses is relevant for agricultural planning and food security. The range of prices seen over the past 18 years – from 1,089.3 thousand tons in 2006–07 to 408.3 thousand tons in 2023–24 – suggests that growth or constant production across the sector might not be a good assumption. Historical production prediction models (historical models) can provide quantitative historical production expectations and possibly can alert to the possibility that the reduction and variability in historical production rates will continue. Information on this can be used by policymakers and agricultural stakeholders for assessing potential production shortfalls, planning for imports, giving policy guidance for supporting production, and assessing technology and institutional options (Raghav et al; 2022).

The significance of the forecast is especially relevant to this case since it is not only production that is affected by poor pulse supply, but the various other components of the farm enterprise

also. If domestic production falls short of the consumption demand, however, the gap could be filled with imports. Greater dependence on imports may lead to global economic price volatility, currency devaluation and destabilization of international supply chains, as well as increased transport expenses. However, improved productivity within the country could reduce the pressure on the supply side and strengthen the contribution of pulses to the food security of the country. Therefore, the production projections present a useful quantitative tool to explore the potential link between domestic production, food availability, and dependency on importation in the future. (PBS, 2024; USDA FAS, 2023)

Historically, however, forecasting production should consider agricultural productivity. The production of pulses is a function of the cultivated area and yield; the yield is influenced by climatic, technological, biological, and socioeconomic factors. Therefore, a drop in aggregate production does not necessarily mean that productivity on the farms went down because the area under cultivation can be significant as far as aggregate production is concerned. Likewise, a growing output in one year does not necessarily mean that the structure of the production system has improved, but simply a temporary improvement in weather conditions. It is especially helpful for long-term forecasting and in forecasting production trends as opposed to temporary fluctuations.

This need is also warranted when considering the significant differences that can be observed over the last 2 decades in the pulse sector of Pakistan. There is also a wide range of production within the two series: the series of 2006-07 recorded a production of 1,089.3 thousand tons; the series of 2023-24 recorded a production of 408.3 thousand tons (MNFS&R, 2024). This difference between the two observations is about 681.0 thousand tonnes. In addition, output in 2023-24 had declined by some 37.5% compared with that in 2006-07. These quantitative figures provide a strong justification for considering the future production trajectory instead of the production trajectory for one year.

The present study under the title "Forecasts About Pulses Production in Pakistan: Implications for Food Security and Climate Change" is focused on the past performance of pulse production in Pakistan and future projections of production. The study links the production pattern to the wider picture of food security and climatic change and recognizes that future production of pulses is a product of the synergy between production trends, agricultural resources, climatic variability and changing food needs. The study aims to make a quantitative evaluation of the value of future production to add to the body of knowledge on the Pakistan pulse sector and to provide evidence to help guide agricultural planning, food-security assessment and strategies to enhance the resilience and sustainability of Pakistan's pulse production.

2. MATERIALS AND METHODS

Data Sources: Secondary time-series data of ten years baseline period (2014-2024) and provisional data of (2024-25) were collected from official sources like Pakistan Bureau of Statistics (PBS), Agriculture Statistics of Pakistan (MNFS&R), FAOSTAT Crop.

Data from the Production Database, Economic Surveys of Pakistan and WDI Indicator tables of the World Bank (PBS, 2024; MNFS&R, 2024; FAO, 2024; Government of Pakistan, 2024; World Bank, 2024).

Semi-Log Trend Model: To evaluate compound growth rates across the 10-year period, a semi-log regression model was estimated as:

$$ln\,(Y_t) = b_0 + b_{1t} + \epsilon_t$$

with Y_t representing production or area in year t, b_0 as the intercept, b_1 as the instantaneous growth rate, and et as the random error term.

Automatic ARIMA Forecasting: Five models of Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) were developed for each of the pulse crops. Akaike Information Criterion, standard identification, estimation, diagnostic checking (Ljung-Box Q-statistic), and model selection were used for model specification (Box & Jenkins, 1976; Akaike, 1974; Ljung & Box, 1978). Criterion (AIC). The quality of the forecasts was judged using three standardized error measures:

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{t=1}^{n}(Y_t - \hat{Y}_t)^2}$$

$$\text{MAE} = \frac{1}{n}\sum_{t=1}^{n}|Y_t - \hat{Y}_t|$$

$$\text{MAPE} = \frac{100}{n}\sum_{t=1}^{n}\left|\frac{Y_t - \hat{Y}_t}{Y_t}\right|$$

Lorenz Curve and Gini Coefficient: The inequality of the distribution of chickpea cultivation across the districts was calculated using the Gini ratio (G).

$$G = \frac{2\sum_{i=1}^{n} i\,A_i - (n+1)\sum_{i=1}^{n} A_i}{n\sum_{i=1}^{n} A_i}$$

where Ai is the acres planted in the ordered district, and n is the number of producing districts. **(Lorenz 1905)**

3. RESULTS

The results of the empirical statistics are detailed below for each crop, for regional land concentration, for growth trends, and for country comparisons in food security.

3.1 Chickpea / Gram (Chana) Production Forecast

In Pakistan, chickpea is the main winter (Rabi) pulse crop contributing ~66% of the country's pulse production. The production is very irregular, and it relies on rain in the Thal desert of Bhakkar, Layyah, Khushab, and Mianwali. (MNFS&R, 2024)

In 2023, production fell to 172000 tons, down from 399,000 tons in 2014, owing to adverse climatic conditions, and in 2024, it rose to 262000 tons (MNFS&R, 2024).

The best ARIMA (1,1,0) model forecast is that production will become stable at 235,470 tons around 2029, and the error metrics from the model were found to be 22.83%, 1.84%, and 2.24% for MAE, MSE, and RMSE, respectively.

RMSE = 154.76
MAE = 105.62
MAPE = 34.27%.

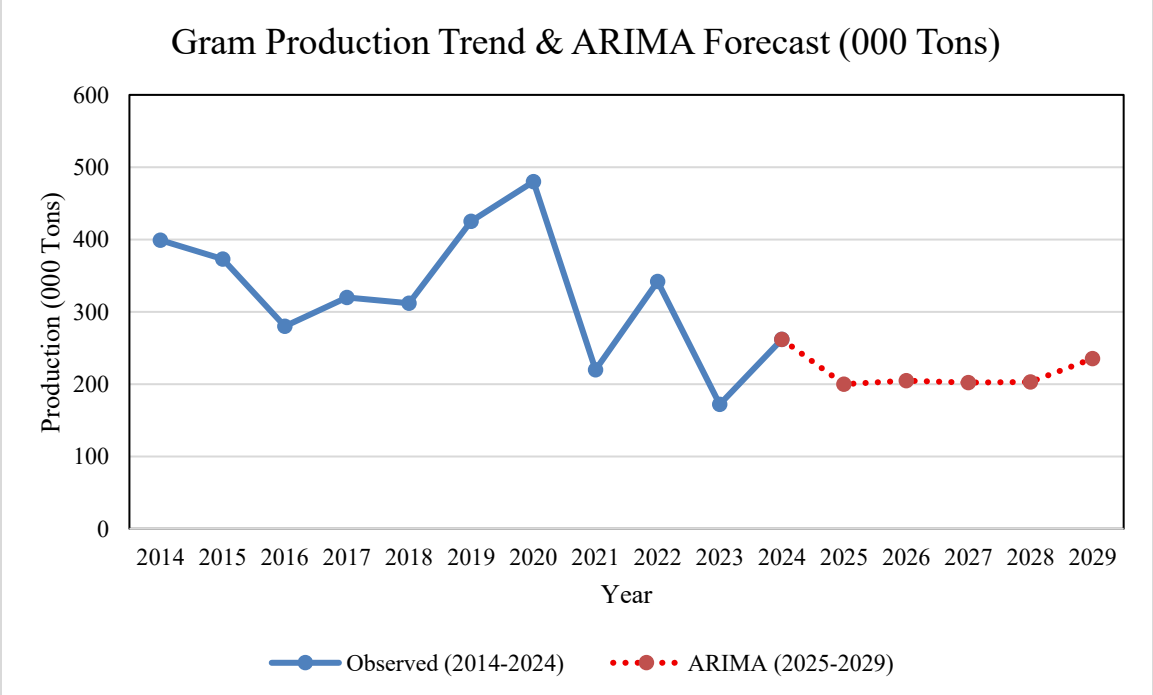


Figure 1: Chickpea (Gram/Chana) Production Trend (2014–2024) and ARIMA Forecast (2025–2029) with ±2 S.E. Band.

3.2 Mung Bean (Moong) Production Forecast:
Mung bean is the most important summer crop (Kharif) and has been a successful crop in Pakistan. Production rose from 98600 tons in 2014 to 261800 tons in 2021, driven by high-yielding nuclear-seed mutant varieties developed by NIAB/NIFA (FAO & IAEA, 2022; PARC, 2023). The current production in 2024 was 151,100 tons (MNFS&R, 2024). The ARIMA (1,1,0) forecast model projects steady production reaching 150,810 tons by 2029 (RMSE = 57.22, MAE = 38.74, MAPE = 27.71%).

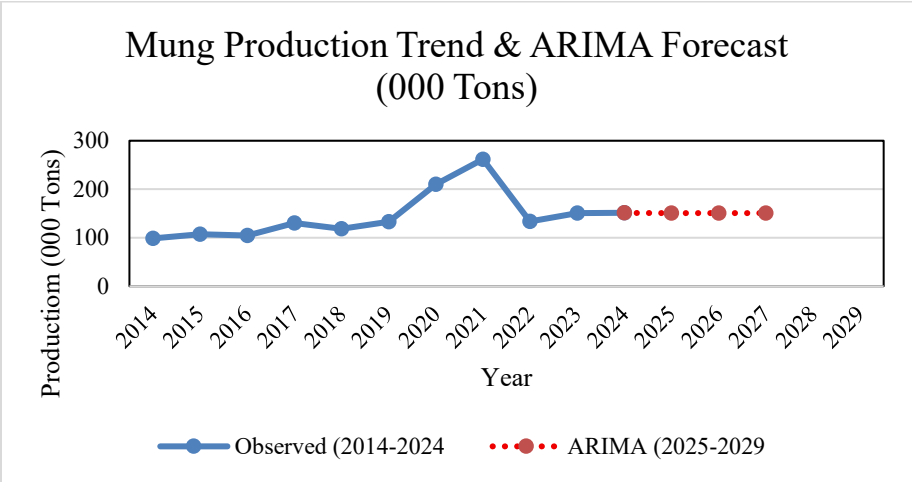


Figure 2: Mung Bean (Moong) Production Trend (2014–2024) and ARIMA Forecast (2025–2029) with ±2 S.E. Band.

3.3 Lentil (Masoor) Production Forecast:
Lentil is highly susceptible to diseases and is under high stress due to irrigated wheat production in the country. The area today is ~6,000 ha, and production has dropped from 8,800 t in 2014 to 3,900 t in 2024, and depends entirely on imports, with over 95% imported (PBS, 2024; USDA FAS, 2023). The ARIMA (1,1,0) model projects stagnant future output around 3,900 tonnes (RMSE = 2.74, MAE = 1.30, MAPE = 18.85%).

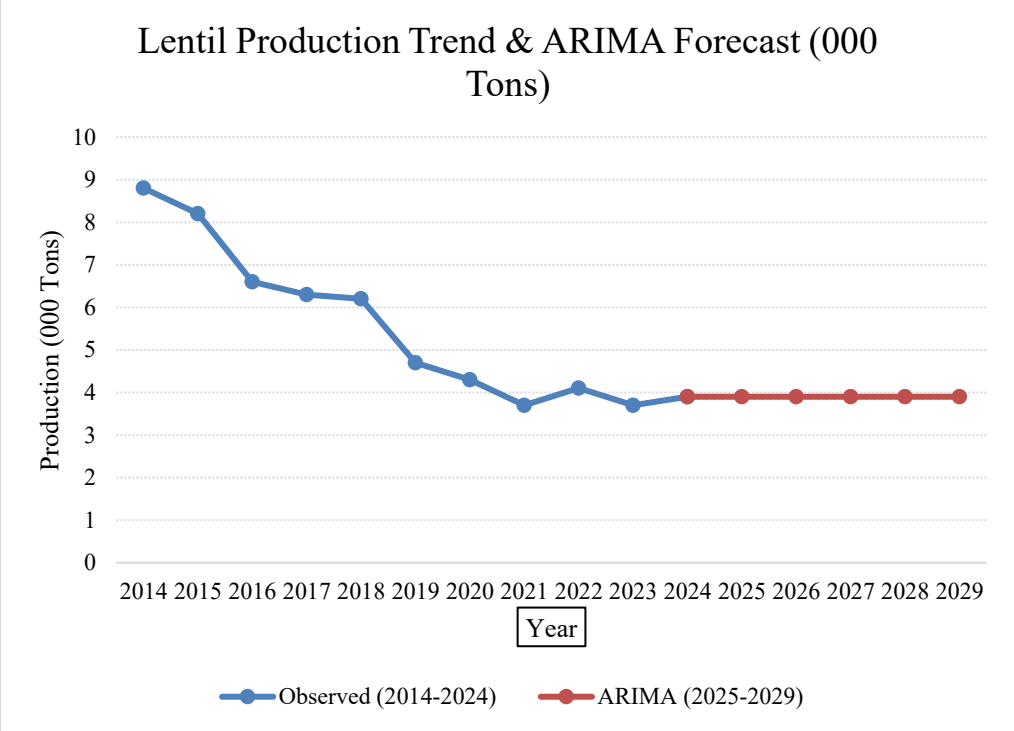


Figure 3: Lentil (Masoor) Production Trend (2014–2024) and ARIMA Forecast (2025–2029) with ±2 S.E. Band

3.4 Black Gram (Mash) & 3.5 Field Pea (Mattar) Forecasts

The output of Black gram (Mash) has been continually decreasing from 10,200 tonnes in 2014 to 5,600 tonnes in 2024 (MNFS&R, 2024). The ARIMA forecast indicates flat future output at 5,600 tonnes (RMSE = 3.13, MAE = 1.33, MAPE = 14.82%). Compared to this, Field pea (Mattar) has shown consistency, growing modestly from 12,500 tonnes to 15,800 tonnes in 2024 (MNFS&R, 2024), with forecasts projecting 15,680 tonnes by 2029 (RMSE = 3.83, MAE = 1.73, MAPE = 13.11%)

Table 1: Summary of ARIMA Model Specifications, Fit Diagnostics, and Production Forecasts for Pakistan Pulses.

Pulses Crop	Scientific Name	Season	2024 Output (000 t)	2029 Forecast (000 t)	Best Model	RMSE	MAPE (%)
Chickpea (Gram)	Cicer arietinum	Rabi	262.00	235.47	ARIMA (1,1,0)	154.76	34.27%
Mung Bean (Moong)	Vigna radiata	Kharif	151.10	150.81	ARIMA (1,1,0)	57.22	27.71%
Lentil (Masoor)	Lens culinaris	Rabi	3.90	3.90	ARIMA (1,1,0)	2.74	18.85%
Black Gram (Mash)	Vigna mungo	Kharif	5.60	5.60	ARIMA (1,1,0)	3.13	14.82%

Field Pea (Mattar)	Pisum sativum	Rabi	15.80	15.68	ARIMA (1,1,0)	3.83	13.11%

3.6 Spatial Distribution & Regional Inequality (Lorenz Curve)

The spatial concentration of chickpea production is quite high in Pakistan, with more than 80% of the total area in four districts of Thal, namely Bhakkar (310,000 ha), Layyah (185,000 ha), Khushab (120,000 ha) and Mianwali (95,000 ha) of Thal (rain-fed) in Pakistan (**MNFS&R, 2024**). The regional Lorenz Gini coefficient is 0.485, which means that the concentration of land regionally is high. This geographical concentration increases the country's vulnerability to national supply issues resulting from local climate disasters.

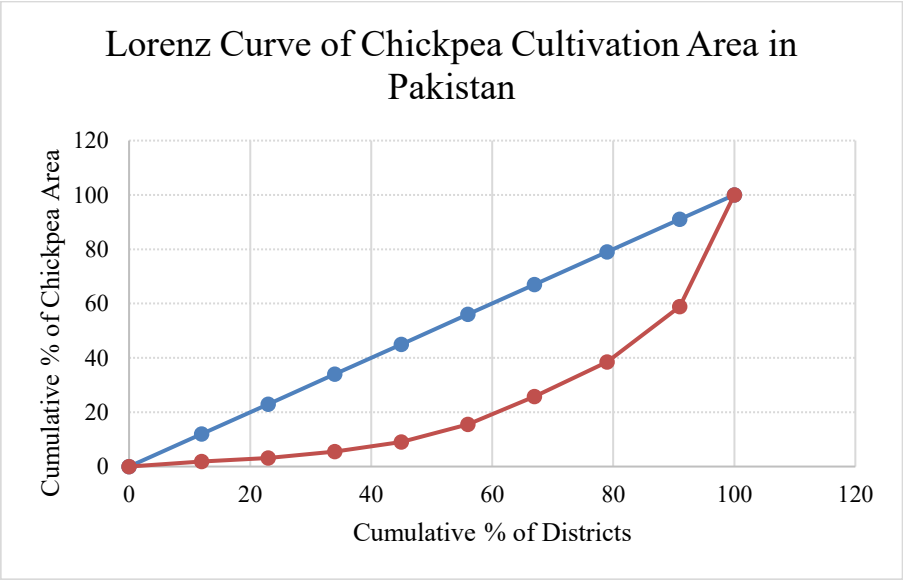
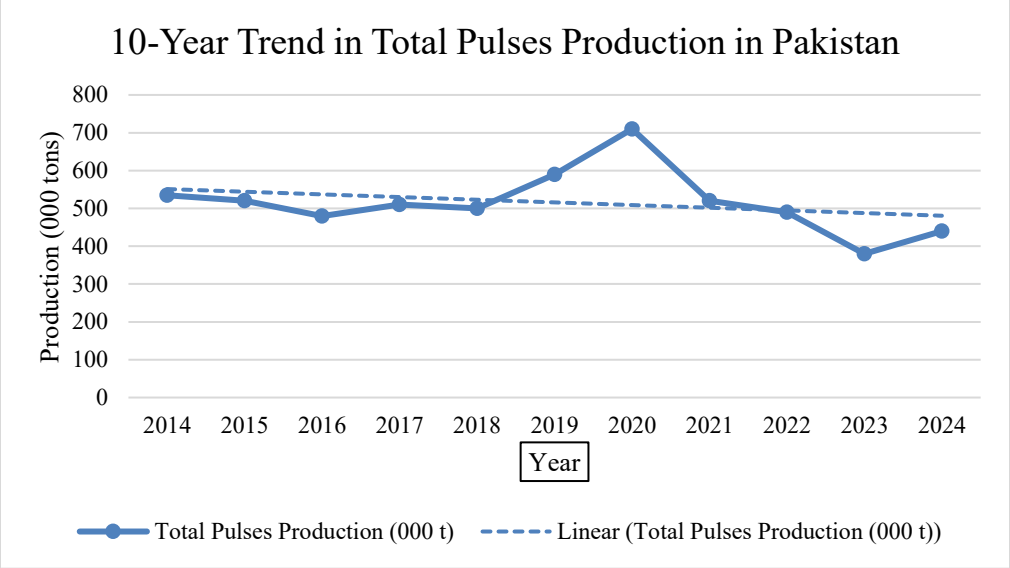


Figure 4: Lorenz Curve and Gini Ratio (0.485) of Chickpea Cultivation Area across Producing Districts in Pakistan

3.7 10-Year Production Growth Trend & Regional Food Security Linkages

The semi-log regression on production of national pulses for 2014-2024 gives a negative growth trend coefficient (R^2 = 0.42), which signifies the displacement of acreage in the pulses due to competitive subsidized cash crops (wheat and sugarcane) (MNFS&R, 2024). High import dependency is also being observed in Pakistan: In cross-country comparison, using World Bank indicators on WDI, its Pulses Production Index (82) is below the index of India (135) and Bangladesh (118) despite its per-capita GNI PPP ($5,800) increasing. (World Bank, 2024)



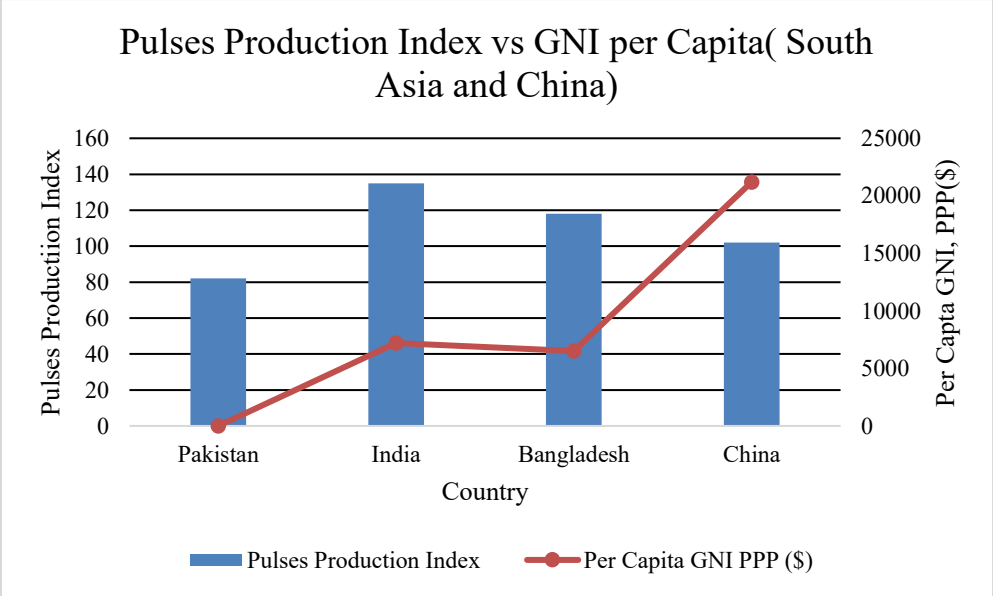


Figure 5: Total Pulses Production Semi-Log Growth Trend (Left) and Cross-Country Pulses Production Index vs GNI Per Capita (Right).

The surge in pulse production during 2019-2021 was primarily driven by the National Agriculture Emergency Program (2019), which provided certified seed subsidies for Mung Bean and Chickpea (MNFS&R, 2020; GoP, 2021). Furthermore, favorable rainfall in major rainfed zones (Thal region) and better market prices promoted farmers to temporarily expand pulse acreage (PARC, 2021; Habib et al., 2022).

4. CLIMATE CHANGE, ADAPTATION, AND MITIGATION

Pulses are inherently low-carbon and, of course, are nitrogen fixers (FAO, 2022). But the rain-fed areas are vulnerable to climate change, which could impact the production of crops. A summary of key adaptation options (KA), technical feasibility, economic effects, and supporting

government institutional actions in Pakistan is provided in Table 2.

Table 2: Feasible Adaptation and Climate Mitigation Options for Pakistan's Pulses Sector.

Strategy / Option	Agronomic Mechanism	Feasibility	Cost & Impact	Relevant Policy Initiative
Drought-Tolerant Varieties (PARC, 2023)	Deep root structure & early maturity (NIAB/PARC)	High	Low Cost / High Yield (+25%)	Subsidized certified seed Distribution
Ridge Sowing & Deficit Irrigation (Government of Punjab, 2024)	Optimizes soil moisture retention in rainfed sandy soils	High	Medium Cost / Water Savings (+35%)	Punjab Command Area Enhancement Project
Cereal Intercropping (AARI, 2024)	Mungbean intercropped with Sugarcane & Spring Maize	Very High	Low Cost / Land Utilization (+40%)	AARI Faisalabad Extension Drive
Kissan Card Subsidies (Government of Punjab, 2024)	Direct financial support for fertilizer/pesticide inputs	High	High Impact on Smallholder Income	Government of Punjab Kissan Card Scheme
Certified Seed Renewals (Government of Punjab, 2024)	Increase certified seed availability from <2% to >20%	High	High ROI / Disease Protection	Federal Seed Certification & Registration Dept

5. DISCUSSION

The results of this paper indicate the existence of an important structural imbalance in the agricultural policy framework in Pakistan. While recent federal initiatives under the national Agricultural Emergency Program have provided targeted subsidies for certified seeds and machinery, pulses still lack institutional credit guarantees and comprehensive Minimum Support Price (MSP) coverage compared to major cereal staples (wheat and rice). Consequently, the absence of assured price risk protection remains a major gap in the pulse policy framework (Government of Punjab, 2024). This means that only about 35% of domestic production supplies domestic demand, resulting in the country having to import more than $650 million USD of this product each year (PBS, 2024; USDA FAS, 2023). For domestic pulse production, if proactive measures are not taken, our ARIMA model indicates that production will not surpass the ~415,000 tons by 2029, falling severely short of the projected domestic demand of ~1450,000 tons driven by the population growth, leaving a supply deficit of over 1 million tons (Raghav et al., 2022; MNFS&R, 2024). The spatial concentration of chickpea is high (Gini = 0.485) in Thal, and the country will be vulnerable to extreme climatic conditions like dry spells or unexpected floods (MNFS&R, 2024; PARC, 2023). The cultivation of mungbean intercropping in central Punjab and short-duration lentils in rice fallow are soon to be available as import substitution options. (FAO & IAEA, 2022; PARC, 2023)

6. CONCLUSIONS AND POLICY IMPLICATIONS

This research finds that the pulses sector needs immediate structural reform in Pakistan to reverse the trend of the decrease in area and geographical concentration, which are associated with climate

vulnerability (MNFS&R, 2024). The following policy recommendations are proposed: Establishment of announced Minimum Support Prices (MSP) for Chickpea and Mung bean for price stability and farmers' protection (Government of Punjab, 2024). Increase PARC/ NIAB certified seed production to increase the seed replacement rate beyond 20% (PARC, 2023). Encourage water harvesting, ridge sowing, and micro-irrigation using solar pumps in Thal and rain-fed ecology (PARC, 2023; Government of Punjab, 2024). Promote and encourage the cropping of pulses in the rice-wheat fallow in the whole of KP and Sindh region to reduce regional land concentration. Furthermore, prioritizing import substitution will significantly curb the country's $650+ million annual import drain and insulate local markets from global price shocks (PBS, 2024; USDA FAS, 2023). Strengthening direct smallholder support through input subsidies and expanding drought-tolerant, high-yielding crop varieties will be crucial to securing domestic supply, achieving climate resilience, and ensuring national food security by 2029.

Moreover, institutionalizing climate-smart agronomic practices such as cereal intercropping and robust extension services will empower smallholder farmers to enhance resource-use efficiency and soil fertility (FAO, 2022; FAO & IAEA, 2022). Addressing these multi-dimensional challenges through coordinated federal and provincial policy interventions is essential to transforming Pakistan's pulse sector from a vulnerable import-dependent market into a self-sustainable, climate-resilient component of national food security.

Ultimately, bridging the gap between empirical econometric forecasts and practical on-ground implementation requires active public-private partnerships, enhanced agricultural research funding, and comprehensive value-chain development. By treating pulses not merely as minor subsistence agriculture. Pakistan can successfully alleviate nutritional insecurity, mitigate environmental degradation, and build a robust, climate-adaptive future for its farming communities.

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