Assessing Food Availability Potential in the Drylands of South Punjab

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Introduction/Importance of Study: In South Punjab, Pakistan, unpredictable weather patterns and a heavy reliance on rain-fed agriculture pose significant challenges to food security. This study investigates how climatic variability affects food security in the region.
Objective: To evaluate the impact of climate variability on the per capita availability of wheat and rice in the districts of Bahawalpur, Rahim Yar Khan, and Rajanpur in South Punjab, Pakistan, from 1991 to 2021.
Novelty Statement: This study provides a unique analysis of the effects of climatic factors on food security in this under-researched region, offering a novel quantification of per capita wheat and rice availability over a three-decade period.
Material and Method: Temperature and precipitation data were sourced from the CHIRPS and APHRODITE datasets. Data on rice and wheat production were obtained from the Crop Reporting Service. The study assessed per capita availability of wheat and rice and explored correlations between climate data and farmer experiences.
Result and Discussion: From 1991 to 2021, per capita availability of wheat and rice fluctuated across Bahawalpur, Rahim Yar Khan, and Rajanpur districts. Key factors influencing these variations included population growth, water scarcity, extreme weather events, and climate variability. Surveys of farmers revealed the challenges they face in adapting to changing climatic conditions.
Concluding Remarks: Climate variability poses a significant threat to food security in South Punjab. Ensuring long-term food security in the region will require advancements in climate-smart agriculture, improved water management, and the implementation of early warning systems.

Keywords: Food Security, Climate Variability, Food Availability, South Punjab, Wheat, Rice, Arid Zone, Water Scarcity, Population Growth.

Introduction:

Food security is a global issue affecting both developed and developing countries. For instance, even in the highly developed USA, 10.5 percent of people experience food insecurity, including 3.9 percent with very low food security [1]. Pakistan, characterized by a highly variable agro-based climate and diverse topography, faces significant food security challenges. Its land area consists of nearly 51% extremely arid to arid regions, 31% semi-arid regions, and 18% humid regions [2]. Climate change threatens agriculture by altering productivity, which in turn jeopardizes biodiversity and human well-being. Many food crop species are highly vulnerable to rising temperatures. Climatic changes, including increased temperatures, shifting rainfall patterns, floods, and diminishing water resources, impact the production and export of crucial agricultural crops [3].

In developing nations, where small landholders dominate, yield gaps are notably pronounced. By optimizing water and nutrient management, there is potential to double global food production and make substantial progress toward food security goals [4]. As the global population increases, so does the number of undernourished individuals. Food security is defined as the availability of sufficient, nutritious food to ensure a healthy and active life for all individuals. It is influenced by various factors, including climatic, agronomic, economic, and political [5]. Ensuring that everyone meets their basic food needs is essential. In agrarian economies like Pakistan, increasing aridity and desertification pose major environmental challenges. Approximately 90% of Pakistan is either decertified or prone to desertification [6], with about two-thirds of the population dependent on drylands for their livelihoods [7]. Rajanpur, Rahim Yar Khan, and Bahawalpur each exemplify the challenges faced in Pakistan's drylands [8], making them crucial areas for study.

Food availability, a key component of food security, is determined by the supply side [9]. It refers to the sufficiency of food in terms of both quantity and quality at various levels, from households to national scales [10][11][12]. This encompasses aspects such as food production, distribution, exchange, trade, and food assistance programs [9][11]. Ensuring food security and increasing food availability are primary objectives for the agriculture sector. Although there is a consensus that global food demand will rise in the coming decades, there is debate about whether global agriculture can meet this demand by increasing food availability [13]. Regional food production is closely linked to food productivity and the availability of food at the household level [14]. Food availability is influenced not only by production, stock levels, and exchange volumes but also by people's ability to access and accept food as part of their lifestyle [15]. Lack of basic infrastructure, human resources, and education in rural areas presents significant challenges to food security, even if supply levels are adequate [16].

Climate change affects food availability both directly, through alterations in agro-ecological conditions, and indirectly, by impacting agricultural productivity and income distribution. This can lead to changes in land suitability, potential yields, and current cultivars, making cropland in lower latitudes less suitable for crop growth [17]. Studies [18][19][5] use food availability metrics to assess food security by calculating per capita availability and analyzing the effects of climatic parameters on productivity. In Pakistan, Punjab province is a major agricultural hub, with wheat and rice being key crops [18]. Rising temperatures could reduce yields of these cereals by 6-11 percent by 2080 [20]. Extreme weather conditions during the rainy and winter seasons have notably impacted wheat and rice crops across Pakistan, with monsoon rainfall variability significantly affecting wheat production worldwide [21].

Food security is adversely impacted by climate variability and extremes. Each degree Celsius rise in global mean temperature is projected to decrease major crop yields by 3.1% to 7.4% globally [22]. Rural populations, including farmers and other residents, are particularly vulnerable since their income sources are closely tied to agriculture [23]. About 63% of Pakistan's population lives in rural areas, with 39% engaged in agriculture according to FAO

statistics. Thus, even minor disruptions in the agriculture sector can cause widespread damage. The rural population of Pakistan is extremely vulnerable to climate change and its impacts [24][25]. Limited economic diversification and other social factors exacerbate food security issues in rural areas [26]. In Punjab, food security conditions are particularly poor, with 49% of rural households reported as food insecure [27].

Objectives:

The objectives of this study are:

- To evaluate the impact of climate variability on the per capita availability of wheat and rice in the Bahawalpur, Rahim Yar Khan, and Rajanpur districts of South Punjab, Pakistan, from 1991 to 2021.
- To provide a unique quantification of the per capita availability of wheat and rice in these districts over a three-decade period, emphasizing the role of climatic factors in influencing food security.

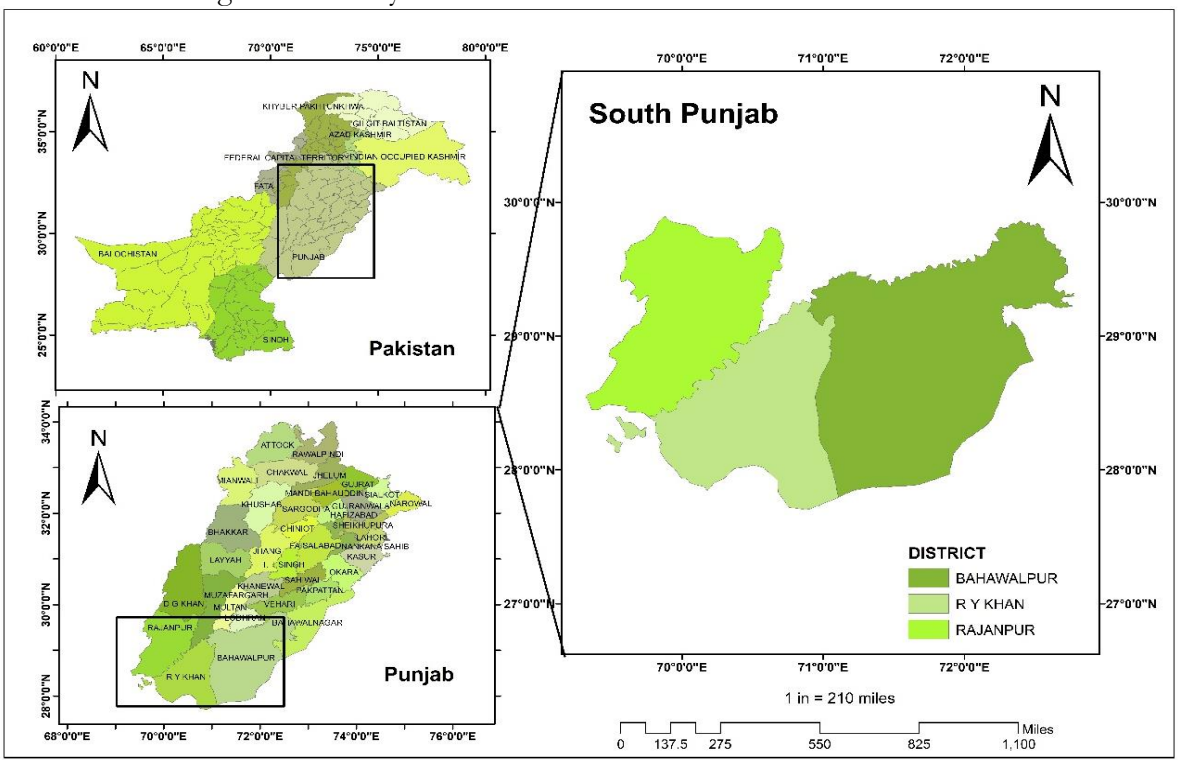

Figure 1: Study area of South Punjab

Study Area:

South Punjab, Pakistan, faces a critical challenge in ensuring food security for its population. The region is marked by a hot, arid climate with limited rainfall, and studies indicate that nearly 90% of the land is either decertified or at risk of desertification. Climate change is expected to exacerbate these conditions, further affecting agricultural productivity and water availability. Despite these challenges, agriculture remains the backbone of South Punjab's economy. However, food availability is a persistent concern. The region produces crops such as wheat and cotton, but the arid conditions and reliance on rain-fed agriculture result in inconsistent yields. Coupled with a growing population, this creates a precarious situation where food availability can vary significantly. Additionally, limited resources for food storage and preservation increase the risk of spoilage and waste. These factors contribute to the high levels of food insecurity in South Punjab, where nearly half of rural households struggle to maintain a consistent and nutritious diet.

Methodology:

Crops:

This study focuses on Pakistan's staple crops: wheat, rice, and maize. Data on production (in thousands of tonnes), yield (in thousands of hectares), and area (in thousands of acres) for these crops, spanning from 1991 to 2021, is sourced from the Crop Reporting Service.

Population:

The population trends for the three districts from 1991 to 2021 were obtained from the Macrotrends website. In the absence of annual census data, estimates were based on projected population growth rates.

Field Survey:

A field survey was conducted in January 2019, targeting rural farmers reliant on agriculture or livestock herding. Using Slovin's formula, a sample size of 399 respondents was determined. Disproportional stratified random sampling was employed to ensure equal representation from each district. Data collection was carried out through one-on-one interviews using a structured questionnaire.

Food Availability:

The Malthusian approach is utilized to evaluate food security by analyzing aggregate and per capita food availability. This approach emphasizes the balance between population growth and food supply. Per capita food availability is determined by dividing the total production of wheat and rice by the total population over time. This method is supported by several studies [19][18].

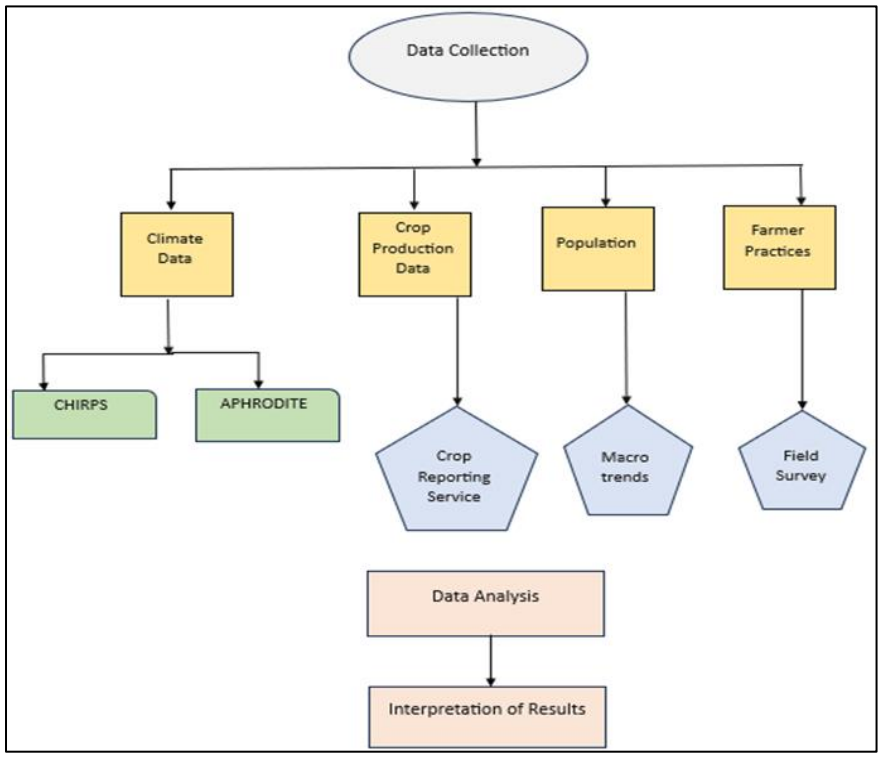

Figure 2: Methodology

Limitation:

Due to the lack of annual population data, estimated figures were utilized. For Rajanpur Tehsil, estimates from the D.G. Khan district were used as proxies.

Table 1: Summary of food security variables

Pillar	Datasets	Analysis
Food Availability	Wheat and rice production	Per capita rice availability
	Population estimation	Per capita wheat availability

Results:

To evaluate food availability in the study area, wheat and rice are used as proxy indicators due to limited dietary variety and preference. Population trends from 1991 to 2021 are employed to quantify the availability of these crops in the districts of Bahawalpur, Rahim Yar Khan, and Rajanpur, and per capita availability is calculated.

Bahawalpur:

The results, as shown in Fig. 2, indicate a steady increase in the population of the district, while per capita wheat availability experienced several fluctuations over time. From 1992 to 1993, per capita wheat availability rose from 1.42 kg to 1.75 kg, likely due to increased wheat production. However, in 1994, this availability declined to 1.3 kg, possibly as a result of the locust attack in May 1993 [28], which reduced the area under wheat cultivation and, consequently, production. These locust attacks, exacerbated by climate change, have significantly impacted the region's food security.

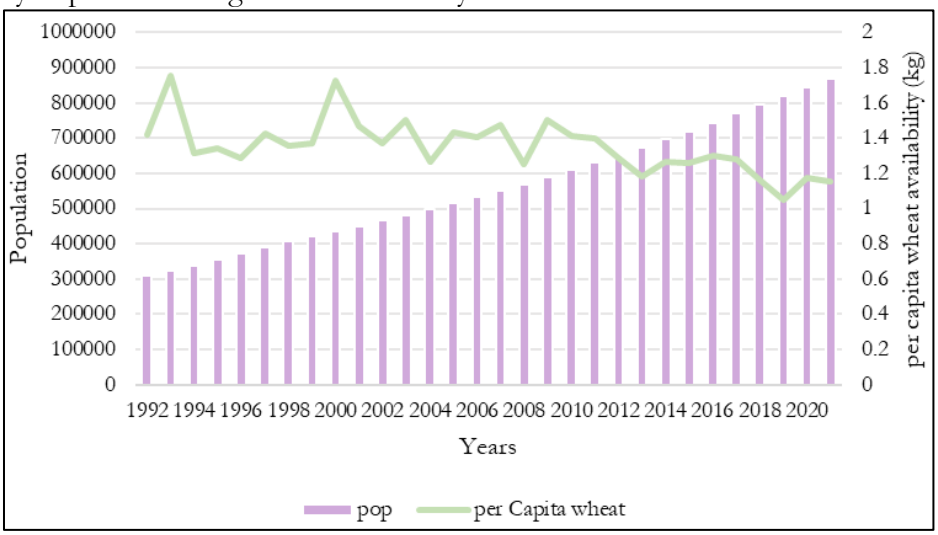

Figure 3: Per capita wheat availability of Bahawalpur from 1991 to 2021

Here is a refined version of the paragraph:

In the year 2000, per capita wheat availability increased to 1.7 kg. However, in the following year, it declined primarily due to reduced water storage and high prices of DAP fertilizer in Pakistan. From 2001 to 2002, per capita wheat availability fell further due to aphid and rust attacks on wheat crops, as well as high temperatures affecting wheat productivity [29]. In 2004, inflation and higher wheat imports caused per capita availability to drop from 1.5 kg to 1.2 kg [30].

The line graph in Figure 3 shows a significant trough in per capita wheat availability in 2008. In 2012, Pakistan faced severe challenges in wheat supply due to lower production and poor agricultural planning in Punjab, coupled with inaccurate predictions [31]. By 2013, per capita wheat availability fell below the population's needs for the first time. This decline was attributed to a sharp increase in mean annual temperatures, coupled with population growth, poor planning, and incorrect estimates by authorities.

Bahawalpur, with limited rice production due to insufficient rainfall and irrigation, experienced low per capita availability of rice. According to Figure 4, per capita rice availability decreased from 0.05 kg in 1994 to 0.02 kg in 1997, reflecting a shortfall in meeting the population's needs. In 2000, per capita availability rose slightly to 0.03 kg. However, in 2013, it reached its lowest historical point of 0.008 kg due to the 2013 floods [32], which devastated crops. Subsequently, per capita availability increased due to rising temperatures and expanded rice cultivation areas, supported by economic relief measures for farmers [33]. In 2018, per capita rice availability declined again due to hailstorms, torrential rains, and gusty winds [34].

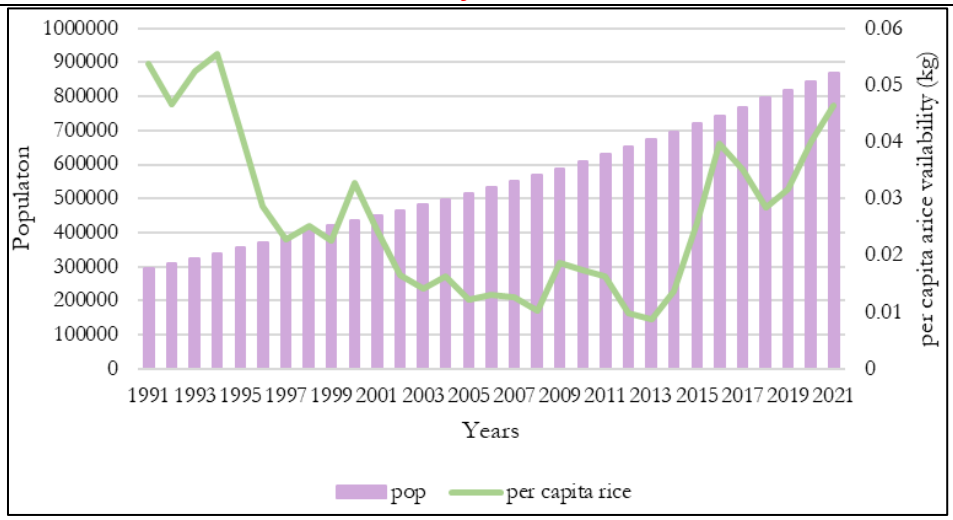

Figure 4: Per capita rice availability of Bahawalpur district from 1991 to 2021

Rahim Yar Khan:

The per capita availability of wheat in Rahim Yar Khan exhibited notable trends in 1994, 1995, 2000, 2008, and 2018. In 1994, a locust attack in 1993 [28] reduced the area under wheat cultivation, leading to decreased production and lower per capita availability. Despite this, the availability remained sufficient to meet the population's needs. In 1995, per capita availability increased again, even though other factors affecting wheat production were declining. The rise in 2000 was validated by a report [35] confirming increased per capita availability and wheat production. However, in 2008, per capita availability declined sharply. According to [36], Rahim Yar Khan experienced an acute water crisis, impacting the irrigation system and causing per capita wheat availability to reach its lowest point in history, resulting in food shortages.

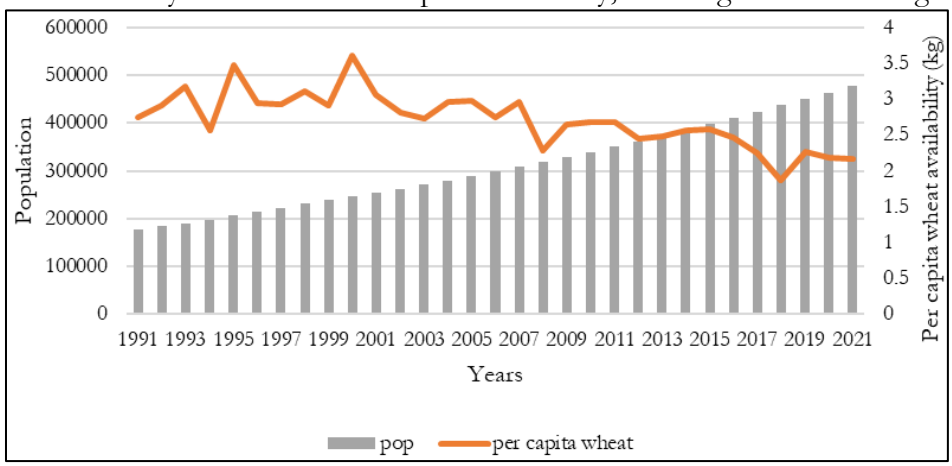

Figure 5: Per capita wheat availability of Rahim Yar Khan from 1991 to 2021

Per capita rice availability exhibited frequent fluctuations, as shown in Figure 6, with notable variations in 1998, 2000, 2003-2008, and 2020. In 1998, a significant reduction in the area under rice cultivation led to decreased production and lower per capita availability. Additionally, from 1998 to 2000, Rahim Yar Khan was severely impacted by droughts, as noted by [37]. The increase in per capita rice availability in 2000 was attributed to improved irrigation methods [38] and a notable rise in the area under rice cultivation, which enhanced production. However, from 2003 to 2008, extensive rice cultivation led to lower overall rice production. In 2020, the area under rice cultivation in Rahim Yar Khan increased dramatically from 50,000 acres in 2019 to 217,000 acres, resulting in a significant rise in per capita rice availability.

Rajanpur: The results of the per capita availability of wheat (Figure 7) in Rajanpur exhibited fluctuations similar to those observed in other districts. In 1994, the per capita availability of

wheat fell to 1.17 kg, a decline attributed to the locust attack of May 1993 [28], which reduced both the area under wheat cultivation and overall production. These locust attacks, exacerbated by climate change, significantly impacted the region's food security. By 1998, per capita availability had increased, aligning with the wheat production targets for Punjab province. However, in 2012, per capita availability dropped to 1.14 kg, falling below the population growth rate and marking the beginning of food insecurity issues in the district. The situation improved in 2016, when wheat production rose again, and per capita availability increased due to the installation of new irrigation facilities to support local agriculture [38].

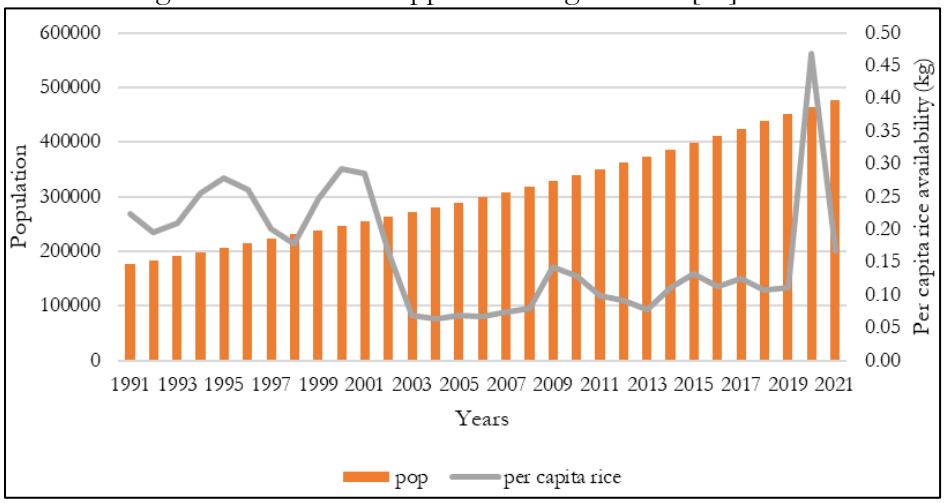

Figure 6: Per capita rice availability of Rahim Yar Khan from 1991 to 2021

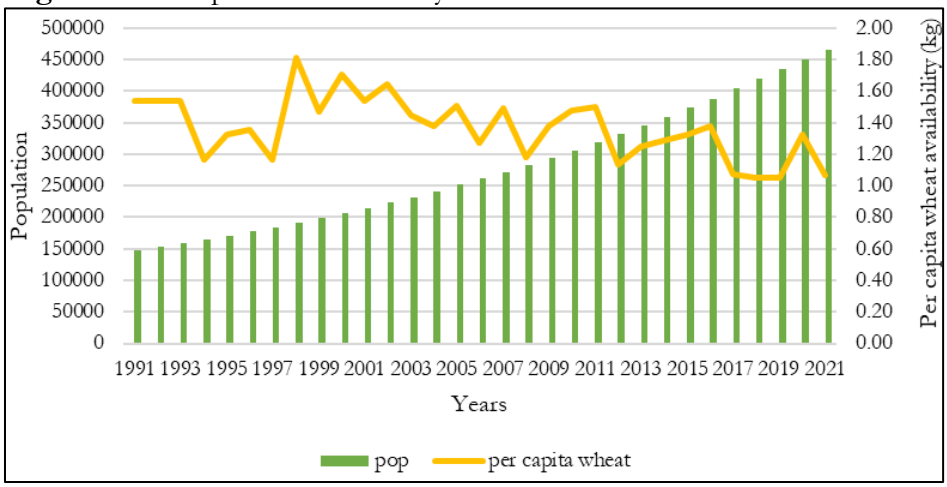

Figure 7: Per capita wheat availability of Rajanpur district from 1991 to 2021

However, the per capita availability of wheat remained inadequate given the district's rapidly growing population. Data indicate that from 2018 to 2019, per capita wheat availability hit a historical low of 1.05 kg due to damage caused by hailstorms, torrential rains, and gusty winds earlier in the week, which affected up to 150,000 tons of mature wheat crops in Punjab [34]. In 2020, per capita wheat availability in Rajanpur was expected to improve, attributed to an increase in temperature and cultivation area—from 28.15°C and 456,000 acres in 2019 to 35.67°C and 597,000 acres in 2020. Both factors positively influenced wheat production and, consequently, per capita availability. However, in 2021, a decrease in the area under wheat cultivation led to a reduction in per capita wheat availability, falling below population requirements. This suggests that food insecurity persists in Rajanpur.

The per capita availability of rice in Rajanpur (Figure 8) began at 0.14 kg in 1991 but decreased to 0.03 kg by 2002. This decline is likely due to a reduction in the area under rice cultivation, which decreased from 25,000 acres in 2001 to just 15,000 acres in 2002. Per capita

rice availability then increased from 0.05 kg in 2009 to 0.08 kg, but subsequently fell sharply to 0.02 kg in 2011, as illustrated in Figure 8. However, it rose again from 0.05 kg in 2020 to 0.12 kg in 2021

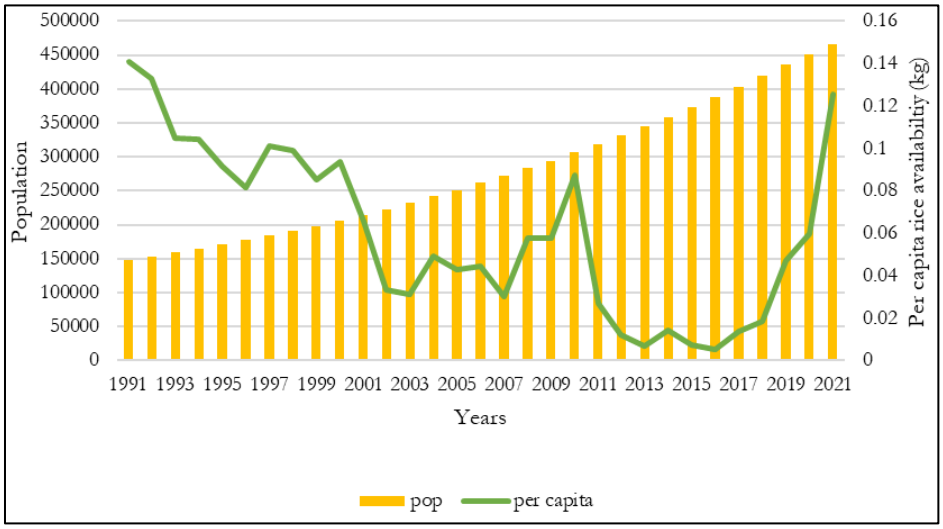

Figure 8: Per capita rice availability of Rajanpur district from 1991 to 2021

Discussion:

The analysis of per capita availability of wheat and rice in Bahawalpur, Rahim Yar Khan, and Rajanpur districts from 1991 to 2021 reveals a complex interplay of environmental, socio-economic, and agricultural factors impacting food security. The observed fluctuations highlight the vulnerability of agricultural output to climatic events, pest infestations, and economic conditions, underscoring the need for resilient agricultural strategies and effective resource management. In Bahawalpur, the variability in wheat availability is significantly influenced by environmental factors such as locust attacks, high temperatures, and water storage issues. The persistent population growth amid these fluctuations suggests a high risk of food insecurity. Additionally, low rice availability, worsened by limited rainfall and inadequate irrigation, points to the need for improved agricultural practices and better resource allocation.

Rahim Yar Khan displayed distinct trends, notably impacted by locust infestations and water crises. The severe water shortage in 2008, which resulted in the lowest per capita wheat availability in the district's history, underscores the critical reliance on stable water sources. Rice availability fluctuated significantly due to droughts and improvements in irrigation, demonstrating the positive effects of effective water management. In Rajanpur, trends in wheat and rice availability reflect the impacts of climatic events and agricultural practices. The decline in wheat availability due to locust attacks and climatic challenges highlights ongoing vulnerabilities. Variations in rice availability, driven by changes in cultivation areas and extreme weather, underscore the need for adaptive strategies. The sharp decline in rice availability in 2011 followed by a subsequent increase in 2021 illustrates the importance of strategic agricultural planning.

Overall, the study highlights the need for integrated approaches that address both environmental and socio-economic factors to enhance agricultural resilience and ensure food security. Policymakers should prioritize adaptive agricultural practices, efficient water management, and effective pest control measures to mitigate adverse effects and promote sustainable development in Bahawalpur, Rahim Yar Khan, and Rajanpur districts.

Conclusion & Recommendations:

This study examined food availability in the drylands of South Punjab, Pakistan, specifically focusing on the districts of Bahawalpur, Rahim Yar Khan, and Rajanpur. The analysis reviewed the per capita availability of wheat and rice from 1991 to 2021, uncovering a complex

interplay of factors affecting food security in the region. Climate variability emerged as a significant factor, with fluctuations in temperature and precipitation directly influencing agricultural productivity and consequently the availability of wheat and rice. Additionally, adverse events such as locust infestations, floods, and droughts further exacerbate food security challenges. Water scarcity is another critical issue, as the arid conditions and reliance on rain-fed agriculture make consistent crop production challenging. Inadequate irrigation infrastructure further limits food production and availability, compounding the difficulties faced by the region.

South Punjab's population continues to grow, and while food production has seen increases in certain years, it has not always kept pace with this growth. This imbalance is particularly concerning in Rajanpur, where food insecurity remains a persistent issue. Based on the study's findings, several recommendations can be made to enhance food availability in South Punjab's drylands. Promoting climate-smart agriculture—such as adopting drought-resistant crop varieties and implementing efficient irrigation practices—can improve the region's resilience to climate variability. Additionally, investing in water management infrastructure, including canal systems and rainwater harvesting, is essential for sustaining agricultural productivity. Enhancing storage and transportation facilities can help reduce food waste and ensure consistent availability throughout the year. Establishing early warning systems for extreme weather events will enable timely interventions to protect food production and livelihoods. Furthermore, implementing social safety net programs, such as food assistance, can support vulnerable populations during periods of food scarcity. By addressing these challenges with a comprehensive approach, policymakers and stakeholders can work towards achieving long-term food security for South Punjab's drylands. Future research into alternative crops, improved storage solutions, and technological innovations can offer valuable insights for optimizing food availability in the region. This study provides a roadmap for building resilience against climate change and contributes to a deeper understanding of food security dynamics in arid regions, highlighting actionable recommendations and linking findings to existing research.

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