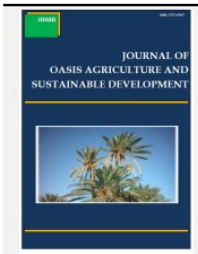

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Crop rotation as an economic strategy for small-scale farmers: evidence from Punjab, Pakistan

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Abstract

This study examined the economic feasibility of crop rotation as a farming technique for small-scale farmers in Punjab, Pakistan, in 2022. Employing a mixed-methods approach, the study integrated qualitative and quantitative data to comprehensively assess the financial impact of crop rotation. The research focused on two key regions in Punjab renowned for small-scale farming: Sargodha and Chakwal. These areas were selected due to their prevalent small-scale farming practices and diverse agricultural methods. The study included a control group of farms that did not practice crop rotation, alongside farms actively implementing this technique. Through surveys of farm owners, input costs (such as seeds, fertilizers, and labor), market prices, crop yields, and total farm revenues were quantified over a three-year period. Soil health indicators were evaluated through soil sample analyses. Qualitative insights into farmers' perspectives on the benefits, challenges, and financial decision-making processes related to crop-rotation were gathered via in-depth interviews and regional focus groups. The findings from 2022 demonstrated advantages for farms practicing crop-rotation, evidenced by consistently higher yields and reduced seed costs. These farms also reported significantly greater profitability. The qualitative analysis highlighted local dynamics influencing the adoption of crop rotation. The study underscored the need to address challenges such as weather fluctuations and market conditions. The insights from this 2022 research can greatly benefit policymakers and agricultural practitioners in promoting sustainable farming practices among small-scale farmers in Punjab, Pakistan. Crop rotation emerges as a strategy capable of enhancing agricultural productivity and bolstering the financial resilience of small-scale farming communities.

1. INTRODUCTION

The significance of small-scale farming in the global agricultural context is highlighted in this passage, underscoring its crucial contributions to both cultural preservation and food security in developing nations. Small-scale farms, characterized by limited land, traditional farming techniques, and reliance on family labor, make significant contributions to food production, conservation of biodiversity, and local food supplies (Giller et al., 2021; Samberg et al., 2016). Apart from providing a means of livelihood for a substantial portion of the population, these farms also play a crucial role in safeguarding native crop varieties and indigenous knowledge associated with sustainable land management (Hilson et al., 2016). Despite their pivotal role, small-scale farmers face various challenges, including limited access to land, financial resources, and

modern technology, which put them at a distinct disadvantage (Jouzi et al., 2017). These challenges are further compounded by the effects of climate change, leading to increased variability in weather patterns, crop failures, and decreased yields. Market fluctuations, resulting from inefficiencies in the supply chain and market dynamics, pose a significant risk, often leading to reduced prices for the agricultural produce cultivated by small-scale farmers (Kumar et al., 2016).

Crop rotation in Punjab, Pakistan, is substantiated as an indispensable economic strategy for small-scale farmers. The cultivation of wheat and maize, both of which are staple foods, guarantees food security, while the inclusion of mungbean enhances the nutritional value (Tan et al., 2020; Hashmi et al., 2023). Moreover, sesame and peanuts serve as profitable cash crops, thus contributing to both income generation and soil fertility through the mechanism of nitrogen fixation. This multifarious crop rotation system not only optimizes the utilization of resources but also alleviates the adverse effects of pests and diseases, thereby exemplifying its efficacy and sustainability as an economic approach for local farmers (Kumar et al., 2023).

The core objectives of sustainable agriculture, namely economic viability, environmental preservation, and efficient resource utilization, aim to enhance overall sustainability, resilience against climate change, and optimal utilization of water and land resources (Velten et al., 2015). Through the adoption of sustainable practices, small-scale farmers can mitigate the risks associated with market fluctuations and climate change, ensuring a stable and sufficient income (Srivastav et al., 2021). Agriculture in this region is of utmost importance to a large number of people and makes a substantial contribution to food security (Abbas et al., 2022). Small-scale farmers, who constitute a significant portion of the farming community, face challenges such as limited market access, high input costs, unpredictable climate patterns, and restricted access to modern agricultural technologies (Ahmed et al., 2017; Mahmood et al., 2019). These challenges not only affect the farmers' profitability but also pose a threat to the overall food security of the region (Jabbar et al., 2022).

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Crop rotation, a cornerstone of sustainable agriculture, involves the sequential cultivation of diverse crop species on the same land. This practice bolsters crop yields, mitigates the buildup of pests and diseases, and preserves soil health (Francis et al., 2020). By rotating crops with varying nutrient requirements and growth patterns, farmers can optimize soil nutrient utilization and disrupt pest and disease cycles (Dias et al., 2015). With historical roots tracing back to ancient China and Rome, crop rotation has evolved over time, aligning with advancements in soil science, plant pathology, and agronomy (Shah et al., 2021). Supported by scientific evidence, crop rotation enables small-scale farmers to diversify their crop production, reduce reliance on external inputs such as chemical pesticides and fertilizers, and ensure sustainable land use. The development of crop rotation has been significantly influenced by advancements in agricultural science and the growing demand for environmentally friendly farming practices. Tailored to suit local conditions, crop preferences, and cultural traditions, crop rotation demonstrates versatility and efficiency, particularly in the context of small-scale farming, especially in developing countries (Schöning et al., 2021). This study highlights the significance of crop rotation in small-scale farming, showcasing its numerous benefits and accompanying challenges. Crop rotation emerges as a vital strategy for optimizing resource utilization, conserving soil fertility, and promoting sustainable agriculture practices. This is supported by research suggesting that crop rotation effectively manages resources and preserves soil fertility (Benincasa et al., 2017). Additionally, alternating nitrogen-consuming crops with leguminous crops reduces reliance on synthetic fertilizers, decreasing production costs and environmental degradation (Iqbal et al., 2019).

Crop rotation also promotes biodiversity on farms, leading to a more diverse ecosystem and facilitating beneficial interactions with other organisms (Jankielsohn et al., 2018). This diversity is positively correlated with increased biodiversity in agricultural landscapes. From an economic perspective, crop rotation provides advantages to small-scale farmers, enabling diversified revenue streams and enhancing resilience to market fluctuations (Barzman et al., 2015). By cultivating multiple crops, small-scale farmers are less susceptible to market volatilities, ensuring a more stable income base. Moreover, crop rotation improves soil health over time, yielding higher harvests and ensuring food security and rural economic stability (Yu et al., 2022). However, crop rotation poses challenges for small-scale farmers, including crop selection, seed acquisition, and financial risks associated with deviating from conventional practices (Shah et al., 2021). Addressing these obstacles requires concerted support and knowledge dissemination efforts from governmental agencies, agricultural extension services, and research institutions.

This study highlights the need for a detailed economic analysis of crop rotation in small-scale farming, particularly in Punjab, Pakistan (Brankatschk et al., 2015; Von et al., 2016). Previous research has focused on ecological and agronomic aspects, overlooking the economic implications crucial for small-scale farmers (Duong et al., 2019). The primary objective is to assess the financial benefits of crop rotation for small-scale farmers and its impact on sustainability and financial stability in Punjab's agricultural sector (Lindblom et al., 2017). The research aims to evaluate the economic impact by analysing crop yields, input costs, and farm revenues over time (Hassan et al., 2021). Additionally, it seeks to understand farmers' experiences with crop rotation through in-depth interviews and focus groups, capturing their perspectives, challenges, and rewards in economic decision-making (Yousafzai et al., 2021). The ultimate goal is to inform policy and extension services, bridging the research-practice gap and providing evidence-based recommendations to enhance small-scale farming viability and financial stability in Punjab (Iqbal et al., 2020). In conclusion, this research aims to contribute to agricultural economics by providing a comprehensive economic analysis of crop rotation's impact on small-scale farming in Punjab, Pakistan, addressing the existing research gap and offering practical recommendations for sustainable farming practices (Hassan et al., 2021).

2. MATERIALS AND METHODS

2.1. Research Design

This study employs a mixed-methods approach, combining quantitative and qualitative data collection and analysis to investigate the financial impacts of crop rotation on small-scale farming.

2.2. Study Area and Farm Selection

The research will be conducted in Sargodha and Chakwal, two districts in Punjab, Pakistan, known for small-scale farming and diverse agricultural practices. A control group of non-crop rotating farms will be selected from a sample of small-scale farms in each district.

2.3. Sampling Method

A purposive sampling technique will be used to select farms in each district, considering factors such as farm size, crop diversity, and farming practices.

2.4. Data Collection

Quantitative Data

Farm owners will be surveyed to collect data on crop yields, input costs, market prices, and total farm earnings over the past three years. Soil samples will be collected from selected farms to assess soil health indicators.

Qualitative Data

In-depth interviews with farmers will explore their perceptions of crop rotation benefits and challenges, as well as decision-making processes related to financial management. Focus groups will discuss the local-level impacts of crop rotation in each district.

2.5. Crop Selection

The study will focus on common crops in the selected areas, including wheat, maize, and mungbean in Sargodha, and wheat, sesame, and peanuts in Chakwal. These crops were chosen based on their economic importance and prevalence in small-scale farming in these districts.

2.6. Data Analysis

Quantitative Analysis

Statistical analysis will compare yields, expenses, and revenues between farms that implement crop rotation and those that do not. Soil health data will be analyzed to establish a relationship between crop rotation practices and yields. Correlation analysis using Pearson's correlation coefficient will investigate the relationship between crop rotation and higher yields.

Qualitative Analysis

Thematic analysis of focus group and interview recordings will identify recurring themes related to the economic impacts of crop rotation. Descriptive statistics will summarize farmers' adoptability of crop rotation, challenges faced, and crops grown. A simple t-test will compare means between crop rotation and non-crop rotation farms to identify significant differences.

Limitations and Challenges

This study may face challenges related to weather pattern fluctuations, market condition variations, and differences in farming practices and geographical features, which could impact the generalizability of the findings.

3. RESULTS & DISCUSSION

Our study investigated the adoption and impact of crop rotation methods among 60 small-scale farmers in Chakwal and Sargodha, Punjab, Pakistan. We aimed to evaluate the economic viability of crop rotation as an agricultural technique.

3.1. Results of Qualitative Analysis

Farming Experience and Adoption of Crop Rotation

Our findings show that the average farming experience among our respondents is 20.3 years, indicating a wealth of knowledge in traditional and innovative farming practices. Notably, 56.7% of farmers have adopted crop rotation (Table 2), aligning with global trends that highlight the importance of crop rotation and farming diversification in response to environmental concerns and market needs (Liang et al., 2023; Vialatte et al., 2021).

Crop Diversity and Regional Specifics

The popularity of wheat in the region reflects the emphasis on agriculture and market demands (Table 2). The variety of crops grown, including maize, mungbean, peanuts, and sesame, demonstrates farmers' adaptability to meet market and environmental demands. Crop rotation's effectiveness relies on this diversity, promoting soil recovery and disrupting pest cycles, leading to more sustainable farming practices (Liu et al., 2022).

Perception and Challenges of Crop Rotation

While 43.3% of farmers viewed crop rotation favorably, 56.7% held unfavorable opinions (Table 2). This perception gap may be attributed

Table 1. Years of farming experience

Statistical Measure	Value
Count	60
Mean	20.3 years
Standard Deviation	11.29 years
Minimum	1 year
25th Percentile	11.75 years
Median (50th Percentile)	20 years
75th Percentile	29.25 years
Maximum	40 years

Table 2. Categorical data

Category		Count
Location	Sargodha	30
	Chakwal	30
Use of crop rotation	Yes	34
	No	26
Main crops	Wheat	20
	Others	40
Perceptions of crop rotation (Opinion)	Positive	26
	Negative	34
Challenges faced	Weather variability	13
	Other challenges (financial issues and transport issues)	47

to factors such as lack of immediate benefits, additional labor requirements, or limited knowledge of effective crop rotation systems (Hessel et al., 2022). Addressing these attitudes is crucial, as they significantly influence the adoption of sustainable practices. Financial constraints and transportation-related logistical obstacles emerged as significant challenges, highlighting the need for a comprehensive approach to address these issues (Sashika et al., 2024).

3.2. Impact of Weather Variability and Future Directions

Weather Variability

Climate change poses significant challenges, including weather variability, as reported by 21.7% of farmers. Crop rotation offers a valuable adaptation strategy as different crops have varying levels of tolerance to climatic stress. This approach can help maintain stable yields in the face of environmental challenges (Yu et al., 2011).

Future Directions

Our study demonstrates the potential of crop rotation in Punjab, Pakistan, but also highlights the need for improved knowledge and adoption among farmers. From an economic perspective, crop rotation is a promising strategy that considers market dynamics and environmental issues (Zuberi et al., 2024). Future research directions may include:

- Addressing barriers to crop rotation adoption, such as education and training on implementation, and exploring ways to reduce logistical and financial constraints (Sharma et al., 2022).
- Enhancing crop rotation systems' resilience to weather fluctuations, supporting sustainable and climate-resilient farming practices.

3.3. Results of quantitative analysis

Crop Yields and Crop Rotation

Our analysis revealed significant differences in crop yields between farms that implemented crop rotation and those that did not. In Sargodha, crop rotation farms, which primarily grew wheat, maize, and mungbean, had an average yield of 2766 kg per ha-1, compared to 2297 kg/ ha-1 for non-rotational farms. Similarly, in Chakwal, where wheat, sesame, and peanuts are commonly grown, rotating farms had an average yield of 2988 kg per ha-1, while

non-rotational farms had an average yield of 2394 kg per ha-1 (Table 3). These findings demonstrate the significant benefits of crop rotation in enhancing agricultural yields, which is crucial for food security, increasing agricultural income, and supporting the financial stability of small-scale farmers (Shah et al., 2021). Crop rotation offers several advantages, including breaking pest cycles, reducing soil erosion, and increasing nutrient availability, all of which contribute to higher yields (Nadeem et al., 2019).

Input cost optimization

Our study found that crop rotation farms reported lower seed prices, which can be attributed to the benefits of crop rotation in disrupting pest cycles and enhancing soil health. This reduces the need for expensive, specialized seeds and leads to cost savings in agricultural inputs (Nadeem et al., 2019). The diverse farming strategy based on crop rotation is responsible for the decrease in seed costs. In Sargodha, rotational farms reported an average seed cost of $132 per ha-1, compared to $155 for non-rotational farms. Similarly, in Chakwal, rotational farms spent $143 per ha-1 on seeds, compared to $160 for non-rotational farms (Table 4). In Pakistan, the price of wheat seed ranges from $90-100 per ha-1, and peanut seed costs between $180-200 per ha-1. Crop rotation offers significant financial advantages, including lower seed costs. Rotation systems often require less expensive seed varieties or fewer inputs (Singh et al., 2021), benefiting small-scale farmers with limited financial resources. Reduced input costs increase the overall profitability and financial resilience of farming operations (Neal et al., 2021).

Profitability surge

Our study reveals a remarkable increase in farm profitability associated with crop rotation, a crucial finding given the economic challenges small-scale farmers often face. In Sargodha, crop rotation farms reported an average profit per ha-1 of $2346, significantly higher than the average profit per ha-1 of $1778 for non-rotational farms. Similarly, in Chakwal, rotational farms generated an average profit per ha-1 of $2717, compared to $2100 for non-rotational farms (Table 5). These results demonstrate that crop rotation not only enhances profitability but also supports small-scale farmers' economic

Table 3. Impact of crop rotation on agricultural yields: A comparative analysis in Sargodha and Chakwal regions

Location	Crops	Rotation Type	Average Crop Yield (kg/ha-1)
Sargodha	Wheat, Maize, Mungbean	Crop Rotation	2766
Sargodha	Wheat, Maize, Mungbean	Non-Rotational Farm	2297
Chakwal	Wheat, Sesame, Peanuts	Crop Rotation	2988
Chakwal	Wheat, Sesame, Peanuts	Non-Rotational Farm	2394

Table 4. Economic benefits of crop rotation: A comparative analysis of seed costs in Sargodha and Chakwal regions

Location	Rotation Type	Average Seed Cost per ha-1 ($)
Sargodha	Crop Rotation	132
Sargodha	Non-Rotational Farm	155
Chakwal	Crop Rotation	143
Chakwal	Non-Rotational Farm	160

Table 5. Economic impact of crop rotation: A comparative analysis of profitability in Sargodha and Chakwal farming regions

Location	Rotation Type	Average Profit per ha-1 ($)
Sargodha	Crop Rotation	2346
Sargodha	Non-Rotational Farm	1778
Chakwal	Crop Rotation	2717
Chakwal	Non-Rotational Farm	2100

resilience. By providing a stable source of income, crop rotation acts as a buffer against economic uncertainty, which small-scale farmers often encounter (Sekaran et al., 2021). Our findings highlight the critical role of crop rotation in ensuring a consistent revenue stream, thereby supporting the economic viability of small-scale farming operations.

4. CONCLUSIONS

Our study, "Crop Rotation as an Economic Strategy for Small-Scale Farmers: Evidence from Punjab, Pakistan," demonstrates the vital role of crop rotation in enhancing the financial sustainability of small-scale farming enterprises in Punjab, Pakistan. A significant proportion of farmers in the region already practice crop rotation, aligning with global trends and recognizing its potential benefits. However, there is a need for further education and awareness to address the existing perception gap. Our quantitative results show that crop rotation significantly improves yield, reduces input costs, and increases profitability for small-scale farmers. This strategy not only enhances food security but also supports farmers' financial resilience in the face of economic uncertainty. To fully harness the benefits of crop rotation, we recommend conducting further research, promoting policy initiatives through government incentives for sustainable agricultural practices, and launching educational campaigns to disseminate information on best crop rotation practices. By adopting these measures, we can support small-scale farmers in Punjab, Pakistan, and contribute to the region's food security and economic stability.

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