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Climate change affects chilli production, profitability, and costs: implications for sustainable agriculture

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Abstract

Climate change significantly affecting the agriculture sector globally, the world population is projected to be 9.1 billion by the year 2050, and about 70% extra food will be required. One of the main challenges regarding food security is the negative effects of climate change on crops. The farming of chili is vulnerable to the adverse impacts of climate change, leading to a significant decline in production due to heightened rain and drought occurrences. Current research carried out to investigates the impacts of climate change on chili production and income, involving the entire cultivation process from planting to harvest in Sindh province of Pakistan. The findings of this study reveal that climate change (Drought or heavy monsoon rain) employs a visible impact on both production efficiency and the income derived from chili cultivation. Thus, overall net-revenue from per acre is Rs. 269760.25 in the rainy season and Rs. 209,281in the dry season. The calculated return cost ratio (R/C) is computed at 2.46 and 1.97 in rainy and drought season respectively, declares the continued feasibility of chili farming, despite the challenges posed by climate change, Cobb-Douglass, function, analysis reveals the influence of various factors on chili production during both the dry and rainy seasons. In the dry season, the production of chili is significantly (R^2= 0.82) affected by variables such as land area, seeds, manure, pesticides, and labor. Similarly, in the rainy season, all the parameters show positive signs, indicating that land area, seeds, manure, pesticides, and labor have a significant impact on

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chili production. Although variable of chemical fertilizer does non-significant effect on chili production in both seasons.

Keywords: Cobb-Douglass production model, Cost & returns, socioeconomic, characteristics.

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Introduction

The phenomenon of climate change has become a pressing global issue, particularly as it directly impacts vital sectors, with agriculture being a primary casualty (Ananda et al., 2019), there are negative impacts on agriculture sector, especially in terms of reduced crops yield (Chen et al 2018). Shifting patterns of the rainy season and unpredictable rainfall contribute to changes in planting and harvesting schedules (Rais et al., 2023). Consequently, these disruptions have the potential to interrupt the production and distribution of agricultural products, leading to broader socio-economic challenges (Hartono & Astuti, 2015). Additionally, climate change poses a serious threat to national food security, especially in the face of a growing global population that requires increased food supplies to meet expanding community needs (Mariyono & Sumarno 2015). Pakistan holds a prominent position as one of the leading contributors to global chilli production (Rais et al., 2021). Major chili-producing countries also include China, India, Bangladesh, Myanmar, Thailand, Romania, Vietnam, Mexico, and Nigeria (Russel & Paterson, 2007). Historical data reveals that worldwide chili production reached approximately 20 million tons during the 2011-2012 period. India was the largest producer with 13.1 million tons, followed by China with 3.2 million tons, and Pakistan contributing 139,687 tons (Patel, 2014). Pakistan's total chilli production during 2020 was amounted to 114 thousand tons, cultivated across 106.3 thousand hectares, with an average yield of 26.8 munds per hectare (Channa et al., 2020). Notably, 75% of the produced chili was consumed domestically, underscoring its significance in local cuisine, while 1.8 thousand tons were earmarked for export (Rais et al., 2023).

Sindh province in Pakistan plays a crucial role in the country's chilli production, contributing 85 % of the total output, with Kunri being the largest contributor at 55 %. The major chilli cultivation areas in Sindh are Mirpurkhas, Sanghar, Badin, Tando Muhammad Khan, Khairpur, Shikarpur, and Ghotki (Pathan et al., 2023). Despite favorable conditions, chilli production in Sindh declined from 130.4 thousand hectares in 2018 to 95.3 thousand tons in 2020 due to some biotic and abiotic factors (Rais et al., 2021; Pathan et al., 2023), particularly heavy monsoon rain during 2022 significantly destroy the agriculture sector of the Sindh Province (Dawn, 2023). The aim of current research is to conduct a comprehensive economic analysis of chilli production in Sindh, focusing on profitability, cost components, revenue generation, and critical factors influencing profitability. The study seeks to provide valuable insights for farmers, policymakers, and stakeholders to optimize farming practices and contribute to sustainable development and economic prosperity in the agricultural sector. This research focuses on assessing factors associated with climate change influencing chili production, profitability, and costs, aiming to provide insights for enhancing agricultural sustainability and to investigate and analyze the income of chili farmers in the dry season and the rainy season.

Materials and Methods

The research aimed to fulfill its objectives through a comprehensive baseline survey that utilized focus group discussions, interviews, and personal observations. This initial survey played a crucial role in gathering essential information, determining the sample size, and validating the survey questionnaire. Interviews with chili growers provided valuable insights, leading to the refinement and expansion of the survey questionnaire for more in-depth investigations. Study areas were purposefully selected, with 480 chili farmers randomly chosen from various districts, talukas, and union councils. Additionally, a sample of 60 market arrivals from each district was included to explore marketing aspects, employing a multi-stage cluster sampling approach. The gathered data underwent statistical scrutiny, involving both descriptive statistics and regression analysis. This study conducts a comprehensive analysis to achieve its dual objectives. Firstly, it evaluates the income generated from red chili farming in both dry and rainy seasons, employing the return cost ratio (R/C) approach to gauge farming efficiency. The R/C values, indicative of the success of farming activities, are interpreted based on the revenue obtained for each unit of costs, considering components like seeds, fertilizers, pesticides, labor, and miscellaneous expenses. A higher R/C value signifies greater profitability and overall success for farmers. Secondly, the study delves into analyzing the factors influencing red chili production during these seasons, utilizing multiple linear regression with a logarithmic form. The Cobb-Douglas function is applied to model the relationship between production and influencing factors, such as seeds, fertilizers, pesticides, labor, and other expenses. This approach facilitates a statistical examination of the dynamics shaping chili farming, providing valuable insights into the production process and its determinants across different weather conditions.

- **Estimation of land inputs**

$$Fip = \frac{(As\ x\ Cr) + As + Rui)}{As}$$

- **Estimation of labour cost**

$$Fiw = \frac{(Mn) + Mwd + Wr) + (Bwd)}{As}$$

- **Estimation of capital inputs**

$$\frac{Cipu = (Qs\ x\ Pr) + (Of\ x\ Pr) + Qi\ x\ Pr)}{As}$$

- **Marketing cost**

$$Mc = \frac{Qm\ (RL + Tr + RuL)}{As}$$

- **Estimation of returns**

$$VP = \frac{(Qs\ x\ Pr)}{As}$$

- **Total cost of production**

$$TC = TFC + TV$$

- **Net returns**

$$NR = TI - TC$$

- **Costs-benefit ratio**

$$CBR = \frac{NR}{TC}$$

- **Benefit- Cost ratio**

$$BCR = \frac{TC}{NR}$$

- **Standard deviation**

$$SD = \frac{\sqrt{\sum(X - \bar{X})^2}}{\sqrt{n-1}}$$

- **Cobb-Douglas function:**

$$LnY = ln\beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + \beta_6 lnX_6 + \beta_7 lnX_7 + \beta_8 lnX_8 + \beta_9 lnX_9 + \beta_{10} lnX_{10} + \mu_i$$

Y= production $\beta_0 = intercept$ β_1 = estimated parameter $\mu_i = error\ term$ $X_1 = Land\ area\ in\ acre$ $X_2 = age$ $X_3 = education$ $X_4 = chemical\ fertilizer$ $X_5 = labour$ $X_6 = input\ cost$ $X_7 = market\ arrivals$ $X_8 = chilli\ prices$ $X_9 = Pesticide$ $X_{10} = manuare$

Results

Production, export, and consumption of chilli

Figure (1) presents trends on the production, import, export, and consumption of chilli over the years 2012-13 to 2021-22. The chilli production varies from 105.4 thousand tons in 2020-21 to 148.3 thousand tons in 2017-18. Import values range from 0.034 thousand tons in 2018-19 to a peak of 15.309 thousand tons in 2020-21, representing significant fluctuations. Similarly, export quantities fluctuate, with a notable increase to 5.905 thousand tons in 2016-17. Consumption figures generally follow the production trend, with a peak consumption of 147.851 thousand tons in 2013-14. These data provide insights into the dynamics of production, import, export, and consumption of the chilli over the specified years, highlighting variations and potential trends.

The socio-economic characteristics of farmers are presented in table 1, providing key insights into their demographic and economic profile. The average age of farmers is 40.5 years, with a range from 20 to 65 years. Household size among chili growers was found to be relatively small, having the minimum household size of 6 members. Education, a vital demographic factor, plays a significant role in influencing a farmer's decisions regarding crop cultivation and farming practices. In the study area, most chili growers had primary-level education, which can be attributed to a lack of awareness about higher education options.

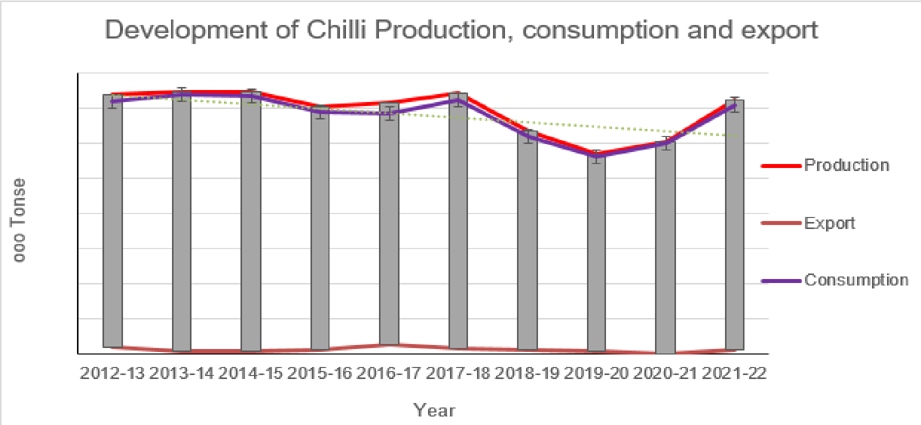

Figure 1. Status of chilli production, consumption, and export**.**

Table 1. Chilli Farmer's Socio-Economic Characteristics.

No.	Description	Unit	Mean	SD.	Max.	Min.
1	Age	Year	40.5	11.5	65	20
2	Education	Year	7	2.5	18	5
3	Experience	Year	10.5	2.7	20	2
4	Number of family members	No.	6	2	12	4
5	Number of family members involved in Agriculture	No.	4	1	7	1
6	Land area	No.	4.5	0.5	15.5	1
7	Monthly income	Rs.	40000	5235.34	60000	15000
8	Monthly Expenditure	Rs.	45000	7678.567	70,000	35000

Experience, another important factor, represents the knowledge and skills gained through involvement. In Sindh province, 65 % of chili growers have farming experience of up to 10.5 years. In terms of economic aspects, the monthly average income of chili growers' households in the study area is approximately Rs. 40,000, while household expenditure amounts to Rs. 45,000. This income falls below the national average monthly household income of about Rs. 41,545. Although the study revealed that household expenditure exceeds income for chili growers, leading them to borrow credit from friends or sell livestock to manage their households' financial needs. This highlights the financial challenges faced by chili growers in the study area.

Cost and Revenue Analysis

The rice and cotton are the predominant crops cultivated during the Kharif season, while wheat, sunflower, and vegetables are the primary crops grown in the Rabi season by chili growers in Sindh province. The significant cultivation of cotton and wheat can be attributed to the importance of wheat as a staple food crop and cotton as a major cash crop. Data in table 2 showed that based on the results of direct interviews with respondents, chili plants are harvested every 7 days after the age of the plant is 100 days. The average quantity of chili production in the rainy season is 23 munds, with an average price of Rs. 16500/ mund while in the dry season the average production of chili is 21 munds with an average price of Rs. 15000 / kg. Thus, overall net-revenue from per acre is Rs. 269760.25 in the rainy season and Rs. 209,281in the dry season. The Return Cost Ratio (R/C) is computed at 2.46 and 1.97 in rainy and drought season respectively, indicative of a positive outlook for the profitability of red chili farming under these circumstances.

Table 2. Production costs and income of red chili farming in one planting season.

		Rainy Season			**Drought season**		
	Unit	Quantity	Price/unit	Value	Quantity	Price	Value
Average per acre capital cost							
Seed	Pake	15	1000	15000	15	900	13500
Manure	Truck	2.5	2332	5830	2.5	2335	5837.5
Fertilizer cost	bag	4.23	2665	11,196	4.5	2343	10543.5
Urea	bag	2	1800	3600	2	1800	3600
Irrigation	Qty	6	2000	12000	5	1100	5500
Fungicide	Qty	2.94	1500	4410	2.94	1500	4410
insecticide	bottle	1.25	1763	2203.75	1.25	1763	2203.75
Pesticide	Rs.	0	0	0		8624	8624
Capital cost	Rs.			54239.75			54,219
Labour cost	Rs.			12000			13500
Management cost	Rs.			40000			35000
Marketing cost	Rs.			3500			3000
Total cost calculated				109739.8			105,719

Per acre output	23 munds (920 kg)*	21 munds (840 kg)*
Per acre revenue*	23*16500 = 379,500	21* 15000 = 315000
Total cost	109739.75	105719
Net revenue	269760.25	209,281
R/C	2.46	1.97

Factors affecting chilli production

The results of the estimation of the production function in table 5 show that the Cobb-Douglass production function formed is quite good and has described the behavior of farmers in the production process. The coefficient of determination (R^2) of the average production function obtained is worth 0.823 for the dry season and 0.535 in the rainy season. The research findings reveal that several key factors significantly influence chili production. Higher input costs and labor costs are associated with increased production, as are larger land sizes, greater market arrivals, higher chili prices, elevated education levels, older age, and larger agricultural areas. These effects are all supported by statistically significant coefficients and suggest that various aspects of production, economic conditions, and human resources play pivotal roles in shaping chili yields.

Table 3. Impact of Various Factors on Chili Production.

		Dry Season		Rainy Season	
Variable	**Unit**	**Coefficient**	**P-value**	**Coefficient**	**P-Value**
Input cost	Rs	0.5	0.005	2.038	5.13
Labour cost	Rs	0.023	0.003	0.175	1.59
Land size	acre	0.02	0.002	0.0608	1.5
Market arrivals	Munds	0.03	0.004	0.12	1.8
Chilli prices	Rs	0.003	0.003	0.005	0.01
Education	average	0.04	0.001	0.14	1.71
Age	years	0.3	0.002	0.025	0.63
Area	Acre	0.002	0.004	0.68	1.39
R-Square	0.82345			0.552	
Standard error	0.0206278			0.0353	
Rs= Pakistani rupees Munds= 40 kilograms					

Discussion

Trends of chilli production, consumption, and export during last ten years. Total production of chilli was increased from 54.1 thousand tons to 147.2 thousand tons during 2011-2013. Total production of chilli was decrease from 148.3 to 114 thousand tons in year 2017-18 and 2019-20. This decline is due to several factors including poor quality seed, mal-cultural practices, and aflatoxin (Shah et al., 2021). Overall results show maximum part of chilli production has consumed domestically; furthermore, very small amount has export. The trends of export highlighted issues with the export of chilli from Pakistan to other countries as data show that amount of chillies exported from Pakistan declined from 3.585 thousand tons in year 2009-10 to 3.268 thousand tons in year 2019-20 (ASP, 2020). Pakistan's chilli exports will shrink, and we will have to rely on imports to meet domestic needs. Pakistan's chilli production is increasing at a far slower rate than the rest of the globe, meaning that Pakistan is losing its competitive edge in the global chilli market (PCP, 2020)

Findings of current research reveal that a considerable percentage of chili farmers in Sindh province fall the average age of farmers 40.5 years, with a range from 20 to 65 years. These findings align with similar results reported in studies conducted by Ali et al. (2018), Channa (2020), and Khan (2012). They all indicate a distribution of chili farmers across different age groups, with presence of younger and middle-aged individuals. Furthermore, the level of education among chili farmers plays a crucial role in their ability to adopt new technologies and adopt better production practices. The current study indicates that the majority, majority chili growers, have an education level up to seven years, while 29 % are illiterate. These findings closely resemble the results of Channa (2020), where 25 % of chili farmers in Umerkot district had education levels up to primary, and 21.3 % were illiterate.

These results are consistent with the findings of Khokhar, (2018), Mohammed et al. (2017), and Khan & Ali (2013), which further support the educational trends observed in the current research. Educated farmers are more likely to adapt and apply new agricultural technologies and best practices, contributing to the overall improvement of the agricultural sector. The current research findings indicate that the majority, specifically 49 %, of chili growers possess 11 to 20 years of farming experience in the study area. This aligns with the results reported by Channa et al. (2020), who noted that 43% of chili growers in Umerkot district had 11-20 years of chili farming experience.

Additionally, Mari (2009) observed that the farming experiences of chili and onion farmers in Sindh were 20.2 % and 17.1 %, respectively. It is worth noting that farming experience is a significant factor in enhancing agricultural productivity and increasing revenue, as highlighted by Ibekwe & Adesope (2010). Skilled management of resources and knowledge gained through experience are crucial for achieving maximum production, as mentioned by (Umer et al., 2015). The current study reveals that 56 % of respondents are small growers, with land holdings ranging from 1 to 10 acres. In contrast, 33 & of respondents are medium growers with land holdings of 11-20 acres. These findings are in close agreement with the results of Mari (2009), which indicated that the average land holdings were 4.6 acres for chili, 8.1 acres for tomato, and 4.7 acres for onion crops.

In the current investigation, the mean per-acre expenses for chilli cultivation in Sindh province amounted to Rs. 197,000. However, the overall average per-acre capital cost of chilli was Rs. 54,239.75 during the rainy season and Rs. 54,219 during the dry season. The average per-acre management cost stood at Rs. 40,000 and Rs. 35,000 in the rainy and dry seasons, respectively. In the rainy season, the average chili production quantity is 23 munds, priced at Rs. 16,500/mund, while in the dry season, the average production is 21 munds with an average price of Rs. 15,000/kg. Consequently, the overall net revenue per acre is Rs. 269,760.25 in the rainy season and Rs. 209,281 in the dry season. The Return Cost Ratio (R/C) is calculated at 2.46 and 1.97 for both seasons, indicating a positive outlook for the profitability of chilli. The literature (Rajur et al., 2008; Muhammad et al., 2017) shows that the chilli production cost benefit ratio has been 1.73 or greater than two. Vasudev et al., (2006) indicate that average cost in rupees was 168508, 181706 and 184739 per hectare for small, medium, and large farmers respectively. The net return for chilli crop in rupees was 80619, 93009 and 107,721 per hectare and the input-output ratios was 1.4 (small farmers), 1.51 (medium farmers) and 1.58 (large farmers) recorded by Jorwar et al., (2018) Also, previous literature shows that chilli is a profitable crop. Daundkar and Bairagi (2017) mentioned that the average cost chilli production was Rs. 125,260.00 in India respectively.

The Cobb-Douglass production function analysis performed in this study provides valuable insights into the factors affecting chili production. The findings indicate that multiple variables, including input cost, labor cost, land size, market arrivals, chili prices, education levels, age, and agricultural area, all have significant impacts on the quantity of chili produced. The overall model's high R^2 value of 0.82 indicates that approximately 82.35% of the variation in chili production can be explained by the combined effects of these factors. This implies that the selected independent variables collectively play a substantial role in explaining the variance in chili production. Zumi et al., (2020) also indicated that all parameter signs on the production function for the rainy season are positive as expected. Variable land area, seeds, manure, pesticides, and labor have a significant effect on the production of red chili. Variable of chemical fertilizer had no significant effect on chilli production.

Conclusion

It is concluded from the present research that; expenditure is greater than income of household during interview chilli growers mentioned they borrow credit from friend or sell livestock to manage expenditure of household. The Cobb-Douglass production function analysis conducted in this study sheds light on the multifaceted factors that impact chili production. It is evident that a range of variables, including input and labor costs, land size, market conditions, chili prices, education, age, and agricultural area, play significant roles in determining the quantity of chili produced Climate factors significantly impact chili production efficiency and farm income, with notable differences between dry and rainy seasons. During the dry season, limited water resources prompt farmers to reduce harvested areas, contributing to lower average income. Additionally, the diminished R/C (return-to-cost) ratio in the dry season is exacerbated by the low market price of chili. Conversely, in the rainy season, increased pest and disease pressures raise production costs due to the necessity of purchasing pesticides. However, the relatively high market price of chili during this period compensates for the elevated costs, resulting in an R/C ratio greater than one.

Recommendation

- Importance of enhancing farmers' resilience to climate change is highlighted.
- Increase farmers knowledge of chili planting systems suitable for specific climate conditions.
- Implement strategies to regulate cropping patterns.
- Utilize drought and disease-resistant chili varieties for improved resilience.
- Focus on maintaining average production capacity to meet consumer demands.
- Provide concise climate change information through mobile messages for timely and relevant insights.
- Empower farmers with the necessary knowledge and tools to adapt to changing climate conditions.

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Disclosure statement

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