Unveiling the Dynamics of Crop Diversification in Punjab-Pakistan: Policy Implications for Sustainable Agriculture

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Abstract

Crop diversification is the most vital strategy for developing sustainable agriculture that enables farmers to maximize yields, minimize inputs, preserve the base of resources, and lower the risks associated with ecological and environmental concerns. The extent of crop diversification was calculated, and its determinants were analyzed using the Simpson index of diversification and Tobit data regression analysis, respectively. The study was conducted in four (4) districts, i.e. Faisalabad, Chiniot, Toba Tek Singh, and Jhang of mixed cropping zone, and data was gathered from 200 respondents. The mean diversification index for all the diversified farmers was estimated to be 0.7. The findings revealed that irrigation, fertilizers, and mechanization are the primary factors influencing the region's transition towards high-value commodities, which reduces diversification. Conversely, access to primary markets positively influences diversification. Further, several other factors, such as farmers' socioeconomic situation like age, years of formal education, availability of farm inputs, irrigation, extension services, membership of farmers' association, and cropping land shares, can greatly and significantly influence crop diversity sustainability, particularly for small-holder farmers who are engaged in crop diversity. The inferences drawn from the findings highlighted the need for policy support in the form of improved marketing infrastructure, inexpensive and easy access to agricultural credit for the construction of irrigation systems and farm mechanization, and suitable technologies to boost farm income and enhance farmers' crop diversity and livelihoods in the study areas.

Key words: Farmers; crop diversification drivers; Punjab province Pakistan

1. Introduction

Diversity in crop species is essential for robust and sustainable farming systems, seen as an effort to diversify cropping systems by increasing crop rotation, multiple cropping, or intercropping as opposed to specialized farming to boost crop yields, soil stability, and the provision of ecological services (Renard and Tilman, 2019; Rosa-Schleich, 2023). Sustainable agricultural systems, value chains for minor crops, and socioeconomic benefits can all be achieved by following this method (Meynard et al., 2018; Feliciano, 2019). Increasing the variety of crops grown is one method of crop diversification (Renard and Tilman 2019). It can reduce disease and pest pressure in the field (Storkey et al., 2019), better regulate biogeochemical cycles (Dwivedi et al., 2017), improve control weed populations (Weisberger et al., 2019), and promote the reduction of economic risks at the farm level (Li et al., 2019) when combined with a coherent set of crop species diversity practices. An agro-ecological, systems-based substitute for contemporary industrial farming is the practice of diverse crop systems (Puech and Stark, 2023).

Since farmers in developing nations quickly diversify their income sources, it is critical to understand this connection of crops diversification (Davis et al., 2012). Farmers who grow more diverse crops can provide a better quality of life for their families and the environment in the long run (Yaqoob et al., 2022). One approach households can utilize to lessen their exposure to environmental stresses like climate change is crop diversification. Crop diversification also helps farmers adapt better to changing market conditions and weather patterns by increasing their exposure to various markets and potentially teaching them new farming techniques (van-Zonneveld et al., 2020). According to Elahi et al. (2022), households can be better prepared for harsh situations if they cultivate various crops. Renard and Tilman (2019) discovered a correlation between higher year-over-year stability of the total national harvest of all edible crops and the variety of arable species at the national level. A key responsibility of farmers is to enhance their capacity to diversify their crops and produce more significant revenue, guaranteeing the swift advancement of agriculture and serving as the most effective means of utilizing the nation's scarce resources (Hufnagel *et al.*, 2020).

Subsistence farmers' cropping patterns in Punjab districts in Pakistan shifted significantly as agricultural commercialization began in developing nations, with an increase in the concentration of crop acreage in regions with more significant and increasing productivity (Rani et al. 2021). The agriculture sector is the second largest contributor to Pakistan's economy, though the shares steadily decline. Since 2014, the share has plummeted around 22 to 24%, with a shock in 2019 and 2020 due to the COVID-19 pandemic. Despite its declining share, agriculture absorbed 43.5 per cent of the country's labour force (Raza *et al.*, 2020).

Transitioning from low-value crops to high-value crops can be a viable strategy for farmers to maintain and even increase their income, especially given Pakistan's expanding population and the consequent need for food crops (Horst and Watkins, 2022). The size of the farmers' landholding, the age and education level, the farmer's level of farming experience, the farmers' income from sources other than farming, the proximity of the farm to a major road or market, and the availability of farm machinery can all influence the success of crop diversification (Aheibam *et al.*, 2023). However, the potential for increased income and financial security can serve as a strong motivator for farmers to consider crop diversification as a viable option.

Previous researches have demonstrated the positive relationships between household income, crop diversity, and dietary diversity (Sibhatu and Qaim, 2018; Murendo et al., 2018; Chegere and Stage, 2020). This is noteworthy in light of recent variations in crop patterns and income sources in Pakistani agriculture systems (Wah et al., 2022). Farm households that cultivate new crop varieties have access to higher household incomes and sustainable food production (Waseem et al., 2023).

In the past few decades, rural areas in Pakistan have begun to experience significant shifts in agricultural practices and revenue streams. Due to limited resources, low income, and subsistence farming, the farm diversification of households has declined (Shah et al., 2021). A more significant part of Pakistan's average farm family's income is agriculture (Chaiya et al., 2023). Extreme weather occurrences, insect invasions, and market price fluctuations are just a few of the threats facing the agricultural industry of Pakistan (Abbas et al., 2023).

Nevertheless, diversification measures are rarely implemented because of a need for more required investments in machinery, infrastructure expertise, and research evidence (Meynard et al. 2018). However, crop diversification is widely accepted as an effective risk management strategy that may protect farm enterprises from climatic and commodity market hazards (Nazir and Lohano, 2022). Nevertheless, the implementation of diversified farming practices has been discouraged by policies that support cereal production through subsidies and rural planning (Ali and Gillani, 2023). Alternative sources of other essential micronutrients have also been neglected, particularly in rural areas (Tacconi et al., 2023). Nonetheless, alleviating poverty, increasing income, and protecting the environment in emerging nations like Pakistan remain serious policy issues (Esty, 2023).

According to Singh et al. (2021), a survey indicated that reduced crop diversification impacts the environment, increases farmer income risk, and leads to the overuse of natural resources. The intense monoculture of wheat and paddy negatively impacted the Punjab province of Pakistan's foundation of natural resources (Ahmad and Ma, 2020; Ghuman, 2022). The districts' main issues now include excessive use of chemical pesticides and fertilizers, pollution, a falling water table and rising water logging, soil salinity, and others (Jabbar et al., 2021). Moreover, market access is a significant barrier to the crop diversification of smallholder agriculture (Curtin et al., 2024).

Researchers have conducted numerous studies on farming diversification's environmental and social benefits (Shahbaz et al., 2017; Delgado and Siamwalla, 2018; Tamburini et al., 2020). Still, it is important to consider the elements influencing the adoption of crop farm diversification. Several limitations affect farmers' day-to-day operations, and even with the advantages mentioned above, they might need more means or opportunities to embrace, preserve, or expand agricultural diversity. Therefore, this study aims to determine the primary drivers and constraints of crop diversification and its policy implications in Punjab, Pakistan.

2. Materials and Method

2.1 Description of the Study Area

The Punjab province of Pakistan was the location for the current research because of the predominant crop production that contributes more than half of the country's gross domestic product (GOP, 2022). This region is endowed with fertile soil, essential for agricultural production in Pakistan (Ali and Rose, 2021). The agricultural sector is responsible for 75% of

Pakistan's total exports, with the province of Punjab accounting for 60% of this amount. Punjab province is divided into three zones: the rice-wheat cropping zone, the mixed cropping zone, and the cotton-wheat cropping zone. The province of Punjab contains more than sixty percent of the country's mixed cropping zones, having distinct climates, geography, and agriculture, making the ecology suitable for producing different crops. The region is ideal for growing rice, fruits, wheat, sugarcane, and vegetables.

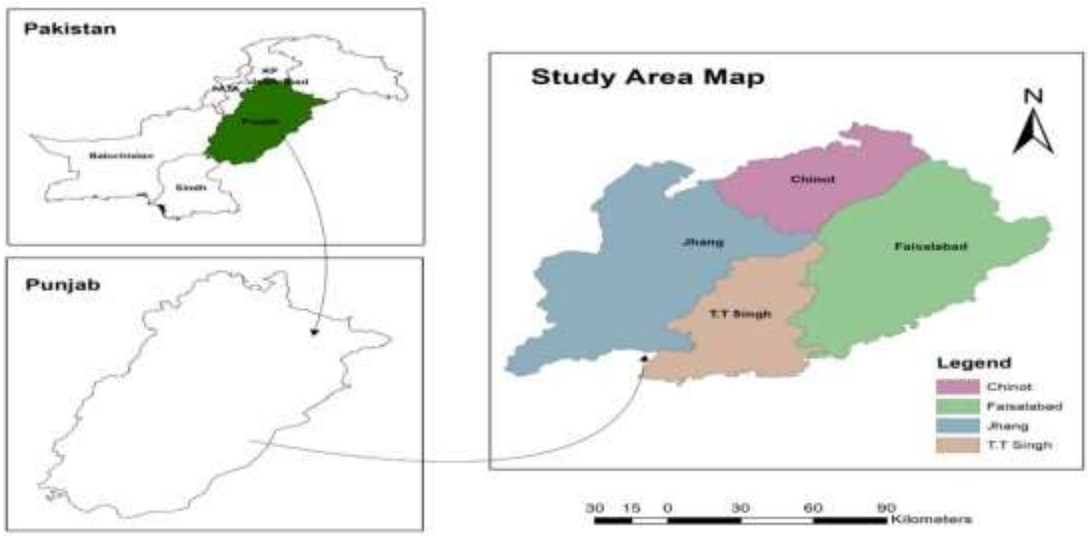

Fig 2: Study Area Map

Source: Authors' computation, 2024.

2.2 Data Collection and Analysis

Punjab province and the four (4) districts of mixed cropping zones (Toba Tek Singh, Chiniot, Jhang, and Faisalabad) were selected purposively was selected purposively due to the high percentage of cropped area and prevalence of mixed cropping zones. A proportionate sampling technique was used to select villages: Faisalabad District 13, Chiniot District 11, Toba Tek Singh 12, and Jhang District 6, giving 40 settlements. A simple random sampling technique was employed to get ten (10) respondents per village to arrive at a sample size of 200 diversified crop farmers' households. A semi-structured questionnaire was administered to garner the data for the study. The sample size was determined using the formula adopted by Adam 2021 because of the known population of the diversified crop farmers.

$$n = \frac{N}{1+N(e)^2} \quad \ldots \quad (1)$$

n= sample size; N = target population; e = level of precision (0.05)

Descriptive statistics like mean, frequency and percentages were used to capture the diversified cropping patterns according to respective growing seasons:

$\bar{X}= \frac{\sum fx}{N}$……………………………………………………………………………………(2)

$\bar{X}= \frac{\sum fx}{N}$ *100……………………………………………………………………….....(3)

$\bar{X}$ = mean; $\sum$= summation; f = frequency; x =variable; N = total frequency; $\bar{X}$*100 = Percentage

$Pi \; \frac{A_i}{\sum_{i=1}^{n} A_i}$……………………………………………………….. ………………………… (4)

$SDI = \sum_{i=1}^{n} P_i^2$……………………………………………………………………………… (5)

$CDI = 1 - \sum_{i=1}^{n} P_i^2 = 1 - Hi$ ………………………………………………………………. (6)

SDI = Simpson diversification index; CDI = crop diversification index; Pi= share of the i^{th} crop cultivated; Ai = Area under i^{th} Crop; $\sum_{i-1}^{n} A_i$ = Total cropped Area and i = 1,2,3…n (number of crops grown)

Tobit model is used to examine the factors that lead to farmers' choice of crop diversification:

$y_i^* = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k + U$ ……………………………………………………. (7)

y_i^* = Crop diversification index; β_0 = Constant; β_1, β_2,…β_k = the regression coefficients; X_1, X_2…X_k = predictor variables; K = number of predictor variables; U = Stochastic error; X_1 = Age of the farmer; X_2 = Farming experience; X_3 = years of formal schooling; X_4 = Family labor ; X_5 = Hired labor; X_6 = Household size; X_7 = Membership of farmers association; X_8 = Access to information; X_9= whether agricultural graduate; X_{10} = Extension Contact frequency; X_{11} = Farm size (acre); X_{12} = Irrigation services; X_{13} = Number of parcels; X_{14} = Distance from farm to market (Km); X_{15} = Access to credit and X_{16}= On-farm income (PKR).

3. Results

3.1 Cropping Pattern of Diversified Farmers

The cropping pattern, which is the spatial representation of crop diversification among the diversified farmers, is presented in Tables 1 and 2. The crops are categorized based on the season, such as summer and winter crops. Summer crops are grown at the onset of the monsoon; they are generally harvested around September and November. In contrast, winter crops are planted around November–December and harvested in March–April in Pakistan.

3.1.1: Summer Crops

Table 1 shows the lists of main crops cultivated by the diversified farmers in the summer season. As per the survey data, rice, sugarcane, and maize are the dominant and significant crops grown by 62.5%, 48%, and 39% of the farmers, respectively. The total rice production area was 362.5

acres, representing 21.85% of all the respondents' cropped area. The mean and maximum rice farm area were 4.51 acres and 10 acres, respectively. Similarly, the total sugarcane area was 297 acres, representing 17.90% of the total area under cultivation. The mean cultivated area under sugar cane cultivation was 4.05 acres, and the maximum was found to be 20 acres. Other summer crops grown by the diversifiers include cotton, cultivated by 94 diversified farmers, representing 47% of the respondents. The total farm area under cotton production was 172 acres, representing 10.37% of the total farm area. The mean farm size under cotton production was 4.91 acres, with a maximum of 10 acres.

Furthermore, the result in Table 1 indicated that diversifiers cultivate various types of vegetables, fruits, and oil seeds in the summer season. Cucumber, lady finger, bitter guard, and watermelons are the most important vegetables. It is evident from the table that the percentage of farmers engaged in various vegetable productions is watermelon (11%), lady finger (9%), bitter gourd (7.5%), and cucumber (6.5%). Among the oil seed crops, only sesame is produced during the summer season. The result indicated that only 16 respondents, representing 8% of the respondents, are into sesame production. The mean cropped area was 3.86 acres.

Table 1: Cropping Pattern in the Summer Season (Diversified Farmers, n=200)

Variables	Number of farmers	Land Area Sown (acres)	% of the total cropped area	Mean cropped area	Max	SD
Rice	125 (62.5)	362.5	21.85	4.51	10	2.4
Sugarcane	96(48)	297	17.90	4.05	25	3.6
Maize	78(39)	197	11.88	4.04	10	2.3
Bajra	11(5.5)	133.5	8.05	4.05	15	2.7
Ladyfinger	18(9)	25.2	1.52	2.1	5	1.4
Bitter gourd	15(7.5)	29	1.75	2.9	7	1.9
Cucumber	13(6.5)	19.5	1.18	2.79	12	1.6
Sesame	16(8)	313	18.87	3.86	4	2
Cotton	94(47)	172	10.37	4.91	10	2.6
Water melons	22(11)	47	2.83	4.7	10	2.6

Sunflower	18(9)	35	2.11	4.38	10	2.5
Ridged Guard	19(9.5)	13.2	0.80	2.2	5	1.6
Guava	16(8)	15	0.90	2.5	4	1.1
crop area	200(100)	1345.9	100.00	3.59		

** Figures in parenthesis are % to the number of farmers

Source: Authors' computation, 2024.

3.1.2: Winter Crops

There are 16 crops grown by the diversified farmers during the winter season (Table 2). The major ones are wheat, canola, mustard, citrus, tomato, cabbage, and potato. The main crops grown during winter by diversified farmers are wheat, of which 93% accounted for cultivation with 38% of the cropped area in the winter season, and the mean and maximum acres of 4.92 and 15 acres, respectively, per farmer. The principal vegetable crops grown by the diversifiers in the winter are potato (13%), garlic (11%), spinach (8%), onion (6%), peas (6%), turnips (5.5%) and phalia (4%). The result shows that, although farmers diversified their production into vegetables, the involvement rate still needs to be encouraging.

Moreover, the result indicated that a relatively high percentage of the farmers are into oilseed crops (Canola and Mustard). From the result, 36% of the farmers cultivate canola, representing 10.23 % of the total cropped area. The mean crop area devoted to canola was 3.67 acres, with a maximum of 10 acres. For mustard, 34% of the farmers cultivate it, with a total land area of 251 acres representing 9.34 % of the total cropped area. Citrus was also grown by 33 farmers, representing 16.5% of the farmers. The total area of land devoted to citrus was 191 acres, with a mean of 4.06 acres and a maximum of 20 acres. This result indicated that citrus is moderately grown by farmers in the study areas.

Table 2: Cropping Pattern in the Winter Season (Diversified Farmers, n=200)

Variables	Number of farmers	Area Sown (Acres)	% to the total crop area	Mean crop area	Max	SD
Wheat	186(93)	1021	38.00	4.92	15	2.5
Cabbage	29(14.5)	40.5	1.51	2.53	6	1.6
Tomato	28(14)	99	3.68	2.83	10	1.3

Brinjal	16(8)	18	0.67	2.25	6	1.03
Canola	72(36)	275	10.23	3.67	10	1.8
Mustard	68(34)	251	9.34	3.98	10	1.7
Spinach	16(8)	266	9.90	3.55	10	1.7
Peas	12(6)	162	6.03	3.45	8	1.6
Potato	26(13)	23	0.86	2.88	5	1.3
Turnip	11(5.5)	204	7.59	3.24	10	1.7
Phaliya	8(4)	72	2.68	3.27	6	1.6
Citrus	33(16.5)	191	7.11	4.06	20	2.8
Tobacco	9(4.5)	13	0.48	2.6	5	1.5
Onion	12(6)	43	1.60	3.58	10	2.3
Garlic	22(11)	8.65	0.32	1.44	3	1.1
Total		2687.15	100.00			

** Figures in parenthesis are % to the number of farmers

Source: Authors' computation, 2024.

3.2: Acreage Allotted under Various Crops by Diversified Farmers

The findings presented in Fig. 3 indicated that wheat was cultivated on 1,021 acres, representing 34.02% of the winter season cropped area of the diversified farmers. Sugarcane occupied 297 acres, representing 22.07% of the summer season cropped area. Vegetables, mostly winter crops, occupied 22.44% of the entire cropped area (both winter and summer), closely followed by oilseed crops (20.96%). The diversifiers devoted less cropped area for fruits, less than 6.5%, representing only 253 acres of land. Spices and stimulants represent only 1.11% of the cropped area. The farmers' inability to diversify to fruits is probably because, unlike vegetables and oil crops, most fruits are perennials, and farmers have small land holdings that only allow them to venture into such enterprises.

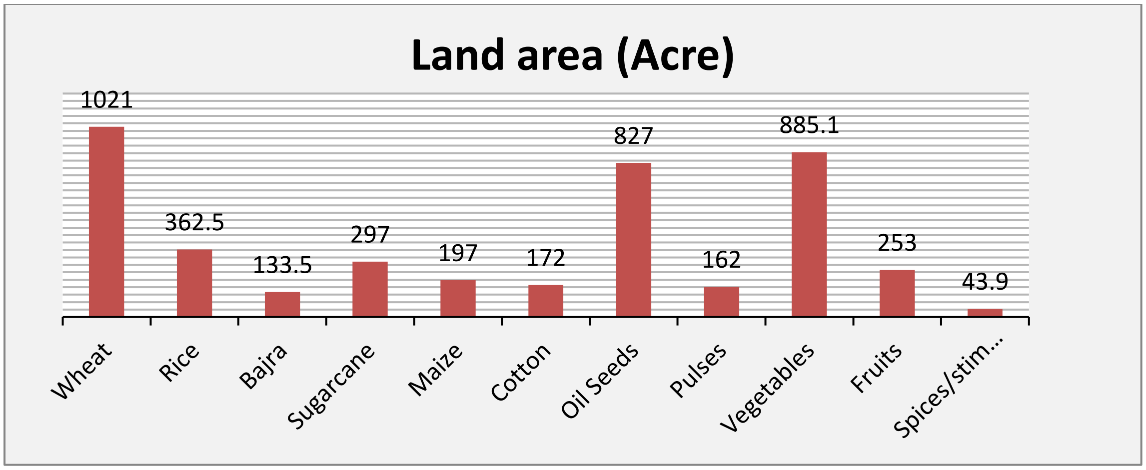

Figure 3: Average Land Area under cultivation of various crops among the crop Diversifiers
Source: Authors' computation, 2024.

3.3: Extent of Crop Diversification in Study Area

To estimate the degree of crop diversification among farmers in the selected districts, as shown in Table 3, the Simpson Diversification Index (SDI), which ranges from 0 to 1, as adopted by Agyeman *et al.* (2014) and Batool *et al.*, (2017), was estimated. Cut-off values < 0.5 and ≥ 0.5 are categorized as low and high diversity scores, respectively, as used by (Umar *et al.*, 2020; Mamman *et al.*, 2021). Table 3 presents the cumulative result of the diversification index for the entire study area. The result showed that 82.36% of the diversifiers had a higher diversity index, while 17.64% had a low diversity index. The mean diversity index was 0.71; the minimum and maximum diversity scores were 0.21 and 0.89, respectively. The standard deviation and standard error, excellent measures to identify the degree of internal dispersion, showed a value of 0.18 and 0.34, respectively, indicating a good range of the diversity index score. A higher CDI value means that there is a lot of crop diversification, while a lower CDI value means that there is less crop diversification. This means there is a lot of crop diversification among smallholder farmers in the study area since most of the diversifiers had a high CDI value.

Table 3: Extent of Crop Diversification in the Punjab Province

Variables	**Frequency**	**Percentage**
High diversify (≥0.5)	170	82.36
Low diversify (< 0.5)	30	17.64
Total	100.00	100
Mean	**0.71**	

Source: Authors' computation, 2024.

3.3.1: Extent of Crop Diversification (District Wise)

The result in Table 4 provides details of the extent of diversification separately for each district. The estimated result showed that 88.06% of the farmers had a high crop diversity index in the Faisalabad district. In comparison, 11.04% had low crop diversity scores with the mean, minimum, and maximum degree of diversification of 0.75, 0.26, and 0.89, respectively.

Similarly, in the district of Chiniot, the result indicated that most respondents (84.62%) had a high crop diversification index, with the mean, maximum, and minimum indexes of 0.75, 0.31, and 0.89, respectively. In Toba Tek Singh, 84.62% of the respondents had a high diversity index. The mean, maximum, and minimum diversity scores in Toba Tek Singh were found to be 0.69, 0.23, and 0.87, respectively. Moreover, in the district of Jhang, the result indicated that 81.48% had a high diversity index, with a mean, minimum, and maximum diversity index of 0.66, 0.21, and a maximum of 0.84.

Table 4: Degree of crop diversification (District Wise)

Location	Frequency	Percentage
Faisalabad		
High diversify (≥0.5)	59	88.06
Low diversify (< 0.5)	8	11.94
Total	67	100
Mean	0.73	
Chiniot		
High diversify (≥0.5)	33	84.62
Low diversify (< 0.5)	06	15.38
Total	39	100
Mean	0.75	
Toba Tek Singh		
High diversify (≥0.5)	56	83.58
Low diversify (< 0.5)	11	16.42
Total	67	100.00
Mean	0.69	
Jhang		
High diversify (≥0.5)	22	81.48
Low diversify (< 0.5)	5	18.52
Total	27	100.00
Mean	0.66	

Source: Authors' computation, 2024.

3.3.2: Mean Comparison of the Crop Diversity Scores across the Selected Districts

A t-test was employed to assess whether there exists a mean difference between the diversity scores across the districts. The result (Table 5) indicated no statistical differences between the mean diversity scores of districts Faisalabad and Chiniot. The mean diversity score of the two districts was statistically the same. The result also indicated that the mean diversity index scores between Jhang and Toba Tek Singh were statistically similar. Results in Table 4.6 further revealed that the mean diversity scores between Faisalabad and Toba Tek Singh were statistically different at a 10% probability level. This could be interpreted as Faisalabad farmers diversifying more than their counterparts. There were also significant differences between the mean diversity scores of diversifiers in Chiniot and Jhang at a 1% probability level. The result also indicated that the mean diversity score between Faisalabad and Jhang was statistically different at a 5% probability level.

Furthermore, Table 5 depicted a variation in the extent of crop diversification among the districts in the study area. Although the importance of diversification between Faisalabad and Chiniot and that of Jhang and Toba Tek Singh were statistically similar, the result revealed that the trends in area growth have shown that Punjab agriculture is changing from old-style sustenance agriculture to high-value agriculture. However, this transformation is uneven across regions.

Table 5: Mean Comparison of the Crop Diversity Scores across the Selected Districts

Paired	**Paired Difference**			**95% confidence interval**		
	Mean	**Std. Dev**	**Std. Err**	**Lower**	**Upper**	**T-value**
Faisalabad - Toba Tek Singh	-.0512	.1927	.0272	-.1060	.0036	-1.88*
Faisalabad- Chiniot	.0404	.2243	.0317	-.0234	.1042	1.27^{NS}
Faisalabad- Jhang	.1006	.3201	.0453	.0096	.1916	2.22**
Chiniot – Toba Tek Singh	.0916	.2348	.0332	.0249	.1583	2.76**
Chiniot – Jhang	.1518	.3026	.0428	.0658	.2378	3.55***
Jhang – Toba Tek Singh	-.0602	.3260	.0461	-.1528	.0324	-1.31^{NS}

*** Significant at 1%, **significant at 5%, * significant at 10%

Source: Authors' computation, 2024.

3.4: Determinants/Drivers of Crop Diversification

The Tobit model results (Table 6) revealed the factors influencing crop diversification. The SDI index is the dependent variable, whereas the independent variables estimated are the farmers' socio-demographic characteristics. The study found that the respondents' age was negative and statistically significant, which implied that younger farmers may be more innovative and willing to take risks in farm activities. In contrast, elderly farmers are mostly conservative in their agricultural practices. Similarly, the findings indicated that the respondents' education and farming experience significantly and positively impacted crop diversification. A farmer with a college education is more likely to comprehend the market condition and be able to mitigate the impact of uncertain events. The results demonstrated that the likelihood of crop diversification increases as farm size increases. A positive and statistically significant coefficient exists between household size and crop diversification. This is probably because larger households have more access to family labor and can handle the increased labor intensity associated with cultivating more commodities. There was also a positive and significant relationship between the frequency of extension and crop diversification: the more extension delivery services, the higher the farmers' probability of diversifying their production. Extension services are essential tools through which government new ideas and policies are transferred to farmers. The positive sign of extension showed that agriculture extension is critical in updating farmers about crop diversification. The results showed that distance from the market was a negative but statistically significant determinant of crop diversification. This could imply that the farther a farming family is from the primary market, the less they diversify their production. The negative sign on distance to markets showed that the closer the farmers are to the market, the more likely they will diversify. Access to credit was found to be positive and statistically significant (prob. < 0.05) for diversification. This implies that farmers with access to credit have a greater probability of diversifying than farmers with little or no access to credit facilities.

Furthermore, the analysis revealed that farmers' association membership was positive and significantly related to diversification (prob. < 0.05). This means that farmers who are members of the association have a higher probability of diversifying than their counterparts. Likewise, the result found that access to information and being an agricultural graduate was not statistically significant and did not impact crop diversification (pro. > 0.05). The result further indicated that, although joyful, the coefficient of irrigation service is statistically insignificant. It was also observed that in regions where constructing irrigation infrastructure is challenging, small-scale farmers with land sizes less than 0.5 ha and between 0.5 and 1 ha tend to focus on cultivating crops such as fruits, oilseeds, jute, and fibers. This was done to fulfill their financial requirements, unlike farmers in districts with access to irrigation facilities. Specifically, the findings disclosed that for every 1-acre decrease in land size, there was a corresponding 15.8% reduction in the probability of adopting crop diversification. Farm income was positive and statistically significant; as farm income increases, a farmer is likely to practice diversification. This is probably because more income means more money to buy additional input and buy or rent more farms.

Table 6: Determinants of Crop Diversification

Variables	Coeff.	Std. error.	T-value
Age of the farmer (Years)	**-0.0223**	0.0073	-3.05***
Farming experience (Years)	0.0456	0.0088	5.19***
Formal schooling (Years)	0.0048	0.0018	2.60**
Family labor (Mandays)	0.1230	0.6570	0.19NS
Hired labor (Man-days)	0.0053	0.0059	0.89NS
Household size (#)	0.2460	0.0876	2.81**

Membership of Farmers Association (Dummy)	0.0118	0.0057	2.09*
Access to information (Dummy)	0.0033	0.0023	1.41NS
Whether agricultural graduate (Dummy)	0.5820	0.6850	0.85NS
Extension Contacts frequency	0.0987	0.0369	2.67**
Farm size (acre)	0.0035	0.0011	3.20***
Availability of Irrigation services	0.0256	0.0157	1.63NS
Number of Parcels	-0.0432	0.0220	-1.96*
Distance from farm to market (Kms)	-0.0576	0.0451	-1.28NS
Access to credit (Dummy)	0.0021	0.0008	2.68**
On-farm income (Rs./Annum)	0.0245	0.0119	2.06*
Constant	1.8530	0.2340	

***, **, and * = significant at 1%, 5% and 10% respectively

Source: Authors' computation, 2024.

4. Discussion

There is no question whatsoever that Punjab's crop diversification has been steadily declining due to monoculture. To comprehend this pivotal moment in Punjab's economy, one must be aware of the variety of the crop mix and the forces behind the change in the cropping pattern. As per the survey data, rice, sugarcane, and maize are the dominant and significant crops grown by farmers in the Punjab province. Most farmers cultivate those three major crops during the summer growing season. Few farmers indulged in diversified farming, such as growing vegetables, fruits, and oil seeds. The pattern of crop production in the winter is highly monoculture, as most of the farmers in the Punjab province are involved in wheat cultivation.

Similarly, as in the summer period, a small number of farmers were involved in farm diversification during winter. The prevailing incentive structure affected farmers negatively regarding crop diversification in the Punjab province. Most incentives are given to farmers engaged in mono-cropping, like rice, sugarcane, and corn in the Punjab province (Gulati et al., 2021). Also, higher sugarcane production is associated with the crop's market value due to the growing number of sugar industries and its consumption in its raw form in Pakistan (Safdar, 2015).

Additionally, large acreage allotted under various crops by diversified farmers in the study area was devoted more to major crops like wheat, rice, sugarcane, vegetables, and oilseeds. The crop diversity score among farmers in the study areas was limited, possibly connected to land and irrigation water availability (Elahi et al., 2020; Nasir et al., 2021). However, it is noteworthy that over the years, wheat and paddy have constituted the main crops that have covered the most portion of the gross planted area in Punjab, and wheat dominated the region (Singh et al., 2021). Moreover, the results revealed a lot of crop diversification among smallholder farmers in the study area. Variations in the extent of crop diversification among the districts were statistically similar and significant. The trends in area growth have shown that Punjab agriculture is changing from old-style sustenance agriculture to high-value agriculture. However, this transformation is uneven across districts (Gulati et al., 2021). A similar outcome was obtained by studying reforms in Indian agriculture's access to resources like land, water, farm machinery, and extension services (Gulati et al., 2020).

Moreover, the study found that age was a critical variable, which implied that younger farmers may be more innovative and willing to participate in farming diversification than aged farmers. Asante *et al.* (2018) found that the age of the respondents positively affects farmers' diversification decisions. Formal education and farming experience signified a positive impact on crop diversification by farmers in the study areas (Mengistu et al., 2021)—furthermore, the more extension delivery services, the higher the farmers' probability of diversifying their production. Suitable agricultural extension services encourage farmers to diversify their crops (Asante et al., 2018). The determinant of crop diversification was also associated with distance from the market, good irrigation service, Farm income, and availability of formal credit facilities (Mekuria and Mekonnen, 2018; Kemboi et al., 2020). This can significantly motivate and facilitate farmers' interest in crop diversity.

5. Conclusion

The study's findings are of significant importance, revealing that Punjab is shifting away from crop diversity and towards mono-cropping wheat and paddy in response to new patterns in sharing different crops and the Modified Entropy Index. This shift has profound implications for the region's agricultural landscape. It is crucial to foster a shared conceptual understanding of crop diversification, enhance cropping systems, create new value chains and friendly ecological systems, and offer other socioeconomic benefits. The study's primary focus is to evaluate the main drivers and constraints of crop diversification and its policy implications in Punjab, Pakistan. As the findings suggest, enhancing the agricultural diversity of small farming households, which are numerous, might be better achieved by cultivating a wider variety of crops and establishing more diverse local commodities markets. Several factors, such as the farmers' socioeconomic situation: age, years of formal education, availability of farm inputs, irrigation, extension services, Farmers' association, and cropping land shares, can significantly influence crop diversity sustainability, particularly for small-holder farmers who are engaged in crop diversity.

The study paves the way for policy support in the form of enhanced marketing infrastructure, simple and affordable agricultural credit, the construction of irrigation systems, farm mechanization, crop insurance, and the need to provide farming communities with appropriate technologies to increase crop diversity for a healthier environment and better livelihoods. These policy recommendations, if implemented effectively, have the potential to transform the agricultural landscape of Punjab, offering a brighter future for farmers and the environment. Similarly, to improve agricultural crop diversity production, it is necessary to simplify the involvement of the private sector to enable lending, technical assistance, timely input provisioning, and the dissemination of knowledge through planning farmers' days or demonstration plots.

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