Chapter 28
Resilience Through Crop Diversification in Pakistan

Adnan Nazir and Heman Das Lohano

Key Messages

- Crop diversification is a potential strategy to enhance community resilience to climate change impacts.
- Farm size, farmer's risk attitude, and the previous exposure to flood or excessive rainfall influence farmer's decision on crop diversification.
- Location-specific factors, such as soil quality, climatic, and agro-ecological condition, determine the extent of crop diversification.

28.1 Introduction

Pakistan was the fifth most affected country globally in terms of the impact of extreme weather events during the period 1999–2018 according to the Global Climate Risk Index 2020 report (Eckstein et al., 2019). The agriculture sector is the most vulnerable to climatic changes as precipitation and temperature are direct inputs into agriculture

A. Nazir (✉)
Department of Economics, University College of Zhob (UCoZ), BUITEMS, Zhob 85200, Pakistan
e-mail: adnannazir@gmail.com

H. Das Lohano
Department of Economics, Institute of Business Administration, Karachi 75270, Pakistan
e-mail: hlohano@iba.edu.pk

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production (Deschênes & Greenstone, 2007) and flooding is quite common (Ahmed, 2021, Chap. 7 of this volume). The agriculture sector faces a variety of risks including extreme weather events, pest attacks, and market price fluctuation among others. The existence of these risks has resulted in the development of a number of agricultural risk management instruments and strategies (Velandia et al., 2009).

Information dissemination such as seasonal climate forecast (Manjula, Rengalakshmi, & Devaraj, 2021, Chap. 18 of this volume) and crop diversification including the traditional varieties (Tshotsho, 2021, Chap. 6 of this volume) are recognized as effective risk management strategies (McCord et al., 2015) that can serve to buffer farm businesses from risks including yield risk associated with climatic conditions and price risk associated with commodity markets (Hardaker, Huirne, & Anderson, 1997). It can improve community resilience by creating better ability to suppress pest outbreaks and dampen pathogen transmission, which may worsen under future climate scenarios (Lakhran, Sandeep, & Bajiya, 2017). Adaptation to climate change through climate-smart agricultural practices can transform marginal lands from environmental burdens into productive lands. Some crops such as oil seeds, legumes, cereals, medicinal plants, and some kinds of fruit can adapt in marginal environments such as salinity, waterlogging and drought (Hussain et al., 2020). Thus, crop diversification has been identified as a potential coping strategy for climate change impacts (Bradshaw, Dolan, & Smit, 2004). The National Climate Change Policy of Pakistan also recognizes crop diversification as a method of adaptation to climate change (Government of Pakistan, 2012).

Various studies have been conducted to examine the determinants of crop diversification (Chen, 2007; Kasem & Thapa, 2011; Kumar, Nayak, & Pradhan, 2020; Lin, 2011). Previous studies have examined the determinants of crop diversification such as socioeconomic characteristics of farmers and farms (Burchfield & Poterie, 2018). Likewise, Roesch-McNally, Arbuckle, and Tyndall (2018) examined factors that may influence farmers' decisions to use more diversified crop rotations in the American Corn Belt. Similarly, Shahbaz, Boz, and Haq (2017) investigated the factors influencing the behavior of farmers toward crop diversification at the farm level in Punjab province of Pakistan.

Previous exposure to extreme weather events may influence farmer's decision of crop diversification as the farmer can learn from past experiences and use crop diversification as a coping strategy to climate change. Huang (2014) examined the determinants of crop diversification and found that the decision to diversify crops is influenced by past experience to extreme weather events in China. However, this study did not include the risk attitude of farmers, which is an important determinant of crop diversification (Sarwosri & Mußhoff, 2020). The relationship between crop diversification behavior and exposure to extreme weather events has hardly been examined, especially in Pakistan. This study examines the determinants of crop diversification and investigates how past exposure to extreme weather events, risk attitude, and other farmer and farm characteristics affect the decision on crop diversification in Sindh province of Pakistan.

Sindh is located in the intense heat zone, and rise in temperatures due to climate change is further aggravating the conditions. Furthermore, it is located in the southern part of the Indus River and thus stands to suffer not only from the local climatic and weather changes but also from the climate in the upstream Indus area and from the coastal environment (Rasul et al., 2012). Floods in Sindh have mostly been associated with precipitation and excess flow of water from the upper part of the Indus River. Similarly, the effects of shortage of water and droughts in Sindh are aggravated by decrease in precipitation and reduced flow of water from the upper part of Indus River. In addition, the coastal areas of Sindh are affected by sea water intrusion and the rising sea level in the Arabian Sea (Rasul et al., 2012). These factors may affect both crop yields and returns to farmers.

28.2 Methodology

28.2.1 Study Area

Sindh province in southeastern Pakistan spreads over 44,016 miles^2 (17.7%) out of 307,376 miles^2 of Pakistan's total area (Government of Pakistan, 2019a). The weather in the province is usually dry and hot, which puts it in the arid subtropical zone. The temperature can reach over 50 °C in summer and fall as low as 6 °C in winter. In the last two decades, the province has experienced major floods in 2003, 2006, 2007, 2010, 2011, and 2012 (Kazi, 2014).

Figure 28.1 shows the study area. For this study, seven districts of Sindh province—Badin, Tando Allahyar, Mirpurkhas, Umarkot, Sanghar, Benazirabad, and Sujawal—were selected.

28.2.2 Sampling Strategy and Data Collection

Farm-level data was collected from 480 farmers using multistage stratified random sampling technique. In the first stage, seven districts listed in the earlier section were selected where there was an existing surface drainage system along with other parts of the district without a proper drainage system. In the second stage, two subdistricts (*Talukas*) were selected from each district, with one subdistrict from the drainage area and the other from the area without a proper drainage system. In the third stage, using systematic random sampling, 40 farmers each were selected from 10 subdistricts which are Tando Adam and Shahdadpur from Sanghar district, Digri and Jhuddo from Mirpur Khas district, Pithoro and Samaro from Umarkot district, Jhando Marri and Chamber from Tando Allahyar district, Badin and Golarchi from Badin district. Similarly, 20 farmers each were selected from the remaining four subdistricts which are Daur and Nawabshah from Benazirabad district and Shah Bander and Jati from Sujawal districts. Face-to-face interviews were conducted for collecting data from May to September 2016. Before starting the data collection,

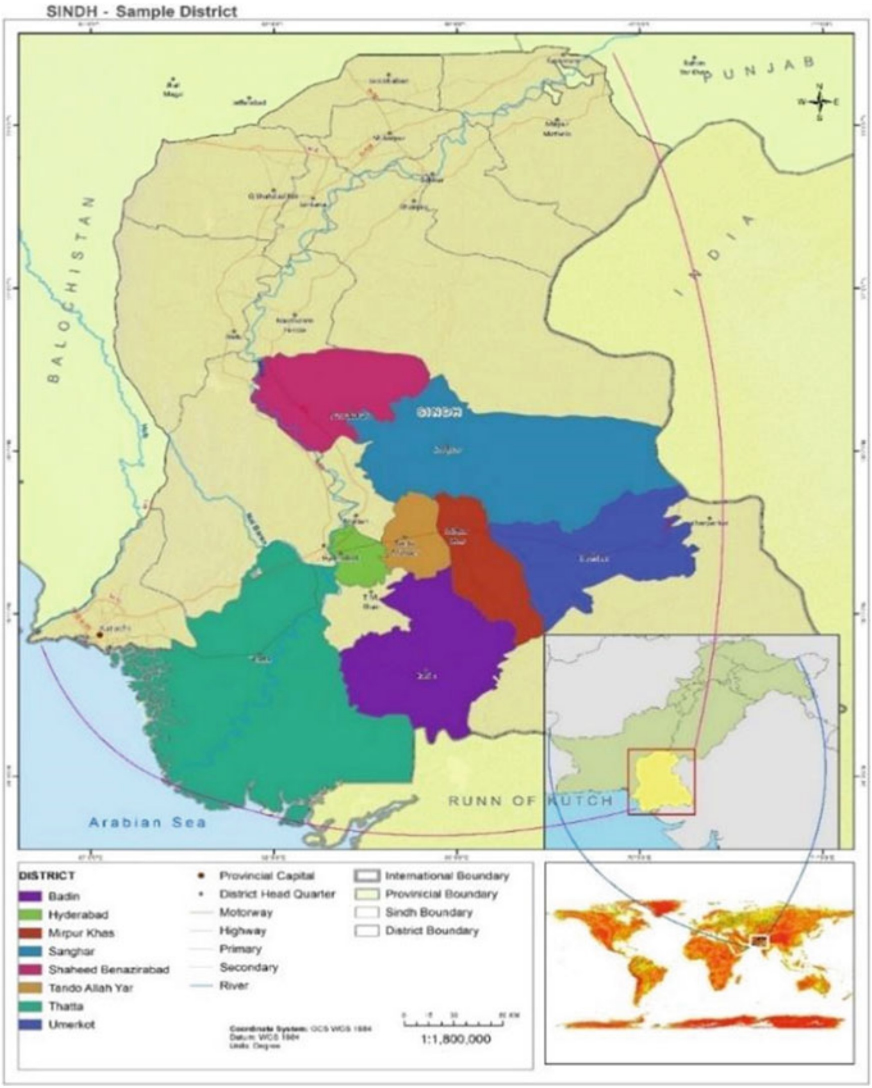

Fig. 28.1 Study area in Sindh province, Pakistan. *Source* Developed by authors using ArcGIS (ESRI 2016)

enumerators were trained in-field and off-field about the study. Questionnaire and data collection methods were properly explained to the enumerators. Further, the questionnaire was pretested in the field for improving the quality of survey data and to avoid missing any important data.

28.2.3 Determinants of Crop Diversification

Crop diversification is the dependent variable in this study. In Pakistan, there are mainly two cropping seasons, namely Rabi (from November to April) and Kharif (from May to October). In the study area, crops cultivated in the Rabi season include wheat, rapeseed, sunflower, sugarcane, tomato, and onion, and crops cultivated in Kharif season include cotton, rice, chillies, and banana. Crop diversification is a count variable and is measured as the number of crops grown by a farmer on his/her farm in the past one year. The determinants of crop diversification include farm characteristics, farmer characteristics, previous exposure to flood or excessive rainfall, community- and location-specific characteristics.

Farm characteristics that may affect crop diversification include farm size and distance from farm to nearest main city. Farm size is an important determinant to examine whether a relatively large farmer grows more crops on the farm or focuses on fewer crops. Moreover, the distance from farm to nearest main city indicates the accessibility to markets and information, and thus may also influence crop diversification decisions. Main city was defined as the city where farmers can purchase farm inputs and sell the produce.

Farmer characteristics that may influence crop diversification decisions include farmer's age, education level, and attitude toward risk. Farmer's age is an important factor to examine whether crop diversification is adopted by relatively older farmers who may have more farming experience or younger farmers who may be willing to take more tasks. Education can increase the knowledge of farmers and access to information and influence farmer's decision on crop diversification. Farmer's risk attitude measures the risk preferences and determines whether the farmer is risk averse or not (risk neutral or risk prone), which was estimated using equally likely certainty equivalent (ELCE) method (Anderson, Dillon, & Hardaker, 1977; Hardaker et al., 2015). Following this method, each farmer was given two risky outcomes (0 and his/her maximum monthly income with 50–50 probability) and was asked the amount of certainty equivalent. These income levels were assigned utility values using a scale from 0 to 1. Next, the farmer was given two other risky outcomes (0 and certainty equivalent in the first round) and was asked the amount of certainty equivalent. This procedure was repeated seven times, and then a cubic utility function was estimated using the data from the responses of the farmer. Using estimated utility function, absolute risk aversion was estimated for each farmer at the average monthly income. If the absolute risk aversion is greater than 0, the farmer is risk averse, otherwise he/she is risk neutral or risk prone. In this study, a dummy variable was created and was equal to 1 if the farmer is risk averse and 0 otherwise. This approach of measuring risk attitude is commonly used in the previous studies (e.g., Saqib et al., 2016).

Previous exposure to flood or excessive rainfall may influence farmer's decision of crop diversification as the farmer can learn from past experiences and can use crop diversification as a coping strategy for climate change. This factor has been used in previous study by Huang et al. (2014) for examining the determinants of crop diversification. In this study, we measure the previous exposure to flood or excessive rainfall by estimating the monetary value of crop losses during the previous event of flood or excessive rainfall in 2011–2012. The monetary value of crop loss was estimated by collecting information on the expected yield and actual yield received by the farmer during the disaster year.

Community and location-specific fixed effects account for the unobservable factors that are specific to the communities and location such as knowledge and preferences of community, soil quality, and climatic and agro-ecological conditions. In this study, we use subdistrict fixed effects to control for these unobservable factors.

28.2.4 Estimation Methods

As the dependent variable is a count variable, we employ the Poisson regression model to examine the determinants of crop diversification. The Poisson model's probability density function is specified as follows (Greene, 2018):

$$Pr(x_i = n) = \frac{e^{-\lambda_i}\lambda_i^n}{n!}, \quad n = 1, 2, 3, \ldots \tag{28.1}$$

It is worth noting that the parameter λ_i is both the mean and the variance under the Poisson distribution. The Poisson model is appropriate as there is no over-dispersion in the data of crop diversification variable, that is, the variance is not greater than the mean value of the variable. It is common to specify the parameter as an exponential function since it is necessary that $\lambda_i > 0$:

$$\lambda_i = \exp(z_i\beta) \tag{28.2}$$

The Poisson model is estimated using maximum likelihood estimation method. For interpreting the results, we compute the marginal effect for each explanatory variable. In the results, we also report the regression results using the ordinary least squares (OLS) method for comparison.

28.3 Results and Discussion

28.3.1 Descriptive Statistics

Summary statistics of variables used in the analysis are reported in Table 28.1. The extent of crop diversification varies from farm to farm, with minimum two crops and maximum eight crops in the study area. On an average, farmers cultivated 3.76 crops in a year. Similar findings were also reported by Huang et al. (2014) who found three

Table 28.1 Descriptive Statistics

Variables	Mean	Standard deviation	Min	Max
Dependent variable				
Crop diversification (Number of crops grown in a year)	3.76	1.35	2	8
Independent variables				
Farm characteristics				
Farm size (acres)	43.09	85.21	2	900
Small farms (1 if farm size <12.5 acres)	0.34	0.47	0	1
Medium farms (1 if farm size from 12.5 to 50 acres)	0.26	0.44	0	1
Large farms (1 if farm size > 50 acres)	0.41	0.49	0	1
Distance from nearest main city (km)	11.44	4.77	3	50
Farmer's characteristics				
Age (years)	46.23	9.45	21	74
Age squared	2,226	896	441	5,476
Education (years)	8.50	3.31	0	16
Risk aversion (1 if risk averse, 0 otherwise)	0.79	0.41	0	1
Previous exposure to flood or excessive rainfall				
Value of crop loss in PKR (USD)	416,482 (3,978)	825,895 (7,888)	614 (5.86)	10,388,377 (99,220)

Source Authors' computations based on survey data. *Note* Value of crop loss in USD, reported in parenthesis, is computed using exchange rate PKR 104.7 per USD during 2016–17 (Government of Pakistan, 2019b)

crops as the average number of crops cultivated by households in China. On average, the farm size in the study area was 43 acres. In the sample, 34% of the farms were small farms (with farm size less than 12.5 acres), 26% were medium farms (12.5–50 acres), and 41 percent were large farms (greater than 50 acres). Average distance from the farm to the nearest main city was 11.44 kms. Average age of farmers was 46 years while their average level of formal education was 8 years. Majority of the farmers (79%) in the study area were risk averse in nature as these farmers tend to avoid risk when they face risky circumstances. We measured the previous exposure to flood or excessive rainfall by estimating the monetary value of crop losses during the previous event of flood or excessive rainfall. The average losses during the previous event were Pakistani rupees 416,482 (USD 3978).

28.3.2 Regression Results

Table 28.2 presents the results of ordinary least square (OLS) regression and Poisson regression to examine the factors that affect crop diversification by a farmer. The parameter estimates from OLS regression directly provides the marginal effects. For the Poisson model, we compute the marginal effects using the coefficient estimates.

Results show that the farm size has statistically significant and positive effects on crop diversification. The extent of crop diversification was higher on medium farms by around 1 crop relative to small farms. Furthermore, crop diversification on large farms was higher by 1.13 crops as compared to small farms. We find that the risk-averse attitude of farmers has a statically significant and positive effect on crop diversification. The extent of crop diversification was higher by 0.43 in farmers who were risk averse relative to farmers who were risk neutral or risk prone.

Results further show that the value of crop losses during the previous exposure to flood or excessive rainfall has statistically significant and positive impact on adopting crop diversification as an ex-ante risk-absorbing instrument. The farmers who faced higher crop losses in a previous event of flood or excessive rainfall had higher levels of crop diversification. These findings are consistent with Huang et al. (2014).

The community- and location-specific fixed effects are statistically significant. This indicates that the unobserved factors, such as soil quality, climatic and agro-ecological conditions, influence the farmer's decision of crop diversification. For example, soil quality and agro-ecological conditions in Digri, Jhudo, Pithoro, and Samaro subdistricts are suitable for producing different types of crops such as wheat, cotton, tomatoes, chillies, vegetables, and other condiments, whereas Badin and Golarchi subdistricts have saline soils and thus farmers in these districts have limited choices for crop selection, such as wheat, rice, oilseeds, and sugarcane.

28.4 Conclusion

Agriculture sector in Sindh province of Pakistan is very vulnerable to climatic changes and extreme events as it is located in the southern part of the Indus River and thus stands to suffer not only directly from the local climatic and weather changes but also from the climate in the upstream Indus and from the coastal environments. Crop diversification is recognized as a potential strategy to enhance resilience to climate change impacts. This study examines how a farmer's decision of crop diversification is affected by past exposure to extreme weather events, risk attitude, and other farmers' and farm characteristics in Sindh. Using farm-level data from 480 farmers, findings of this study show that crop diversification is affected by farm size, farmer's risk attitude, and the previous exposure to flood or excessive rainfall. Furthermore, other location-specific factors, such as soil quality, climatic and agro-ecological condition, determine the extent of crop diversification.

Table 28.2 Regression results

	OLS regression		Poisson regression Marginal effects	
	Coefficient estimates	Standard errors	Coefficient estimates	Standard errors
Dependent variable: crop diversification (Number of crops grown in a year)				
Intercept	1.212	1.082	–	–
Farm characteristics				
Medium farms	0.899***	0.142	0.993***	0.248
Large farms	1.036***	0.138	1.130***	0.235
Distance from main city (km)	0.007	0.012	0.008	0.019
Farmers characteristics				
Age (years)	0.040	0.044	0.041	0.075
Age squared	0.000	0.000	0.000	0.001
Education (years)	-0.013	0.018	−0.012	0.030
Risk aversion attitude	0.404***	0.149	0.433*	0.256
Previous exposure to flood or excessive rainfall				
Value of crop loss (Million PKR)	0.229***	0.072	0.171*	0.098
Community- and location-specific fixed effects (Dummy variable for each subdistrict)				
Shahdadpur	0.650*	0.262	0.723	0.469
Digri	0.512*	0.263	0.588	0.469
Jhudo	1.298***	0.264	1.313***	0.451
Jhando Marri	1.249***	0.263	1.317***	0.456
Chamber	0.842***	0.262	0.927**	0.460
Pithoro	0.715***	0.262	0.793*	0.462
Samaro	1.128***	0.263	1.156***	0.450
Badin	0.182	0.265	0.201	0.488
Golarchi	0.422	0.264	0.470	0.477
Daur	0.834***	0.322	0.923*	0.559
Nawabshah	0.706**	0.320	0.779	0.563
Shah Bander	1.118***	0.322	1.176**	0.542
Jati	0.935***	0.322	1.016*	0.552
Number of observations	480		480	
R^2	0.291		–	
F-value	0.000		–	
LR chi^2 (12)	–		68.27	

(continued)

Table 28.2 (continued)

	OLS regression		Poisson regression Marginal effects	
	Coefficient estimates	Standard errors	Coefficient estimates	Standard errors
Prob > chi^2	–		0.0000	
Pseudo R^2	–		0.0393	
Log likelihood	–		−834.683	

Source Authors' computations based on survey data. Notes: $***$, $**$, $*$ Indicate significance at the 1, 5, and 10% level, respectively. Small farms (less than 12.5 acres) are a reference category in farm size categories. Tando Adam is a reference subdistrict in fixed effects for subdistricts

Crop diversification can improve resilience by enhancing the capacity and ability of farmers to cultivate different crops with different levels of tolerance to excess water or droughts. Furthermore, it can improve resilience by creating a better ability to suppress pest outbreaks and dampen pathogen transmission, which may worsen under future climate scenarios.

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