Synchronized agricultural credit and diversification adoption to catastrophic risk manage for wheat production in Punjab, Pakistan

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Abstract
In developing countries, particularly in agrarian economies like Pakistan, agricultural production is severely affected by successive incidences of adverse catastrophic risks. Inadequate and limited risk management measures from farming community to overcome such severe financial, production, and marketing risks not enough so need of adoption farm-based feasible risk management strategies. In addressing this research gap, this study investigated the potential association and implementing synchronized agricultural credit and diversification adoption to catastrophic risk manage for wheat production in Punjab, Pakistan. The study used the data of 480 wheat farmers’ respondents and employed multinomial and bivariate probit regression models for empirical analysis. Empirical estimates illustrated the significant association in adoption of multiple risk management strategies as addressing the adoption single risk management strategy motivates farmers to adopt another strategy at same time. Furthermore, results also indicated as farmer schooling, age, family return, ownership of land, farm size, and farmer risk oppose character were highlighted the most influenced features for adopting various risk management strategies. Policy makers and state-based authorities can be assisted by these outcomes to evaluating plans of risk management and willingness of farmer in accept government supported regarding implementation of these catastrophic risk managing strategies.

Keywords Agricultural credit · Catastrophic risk · Diversification · Probit model · Pakistan

Introduction
Humanity is severely confronting with climate change as critical environmental challenge with implications for natural ecosystem, health, food production and supply of fresh water (Muricho et al. 2019; Ahmad et al. 2020; Eckstein et al. 2021). In the current couple of decades, climate change dynamics has raised the intensity and frequency of harmful severe effects of weather events such as storms, cyclones, floods and drought in global perspective (Teo et al. 2018; Carter 2019; Ahmad and Afzal 2021a, b). Natural hazards are mostly inclined by risk exposure, geographical locations and lifestyle choices (Doocy et al. 2013; Kreft et al. 2016; IPCC 2019; Ahmad et al. 2019) whereas having no economic, social, political, geographical and cultural boundaries of continents, countries and communities (Daniell et al. 2016; IPCC 2018; Ahmad et al. 2021a, b). Increasing frequency and severity of these natural hazards caused globally severe economic cost and human losses (Gorst et al. 2015; Abbas et al. 2017; Muricho et al. 2019). In current era, owing to increasing vulnerability of climate change, mounting tendency of sever of natural disasters was estimated with disastrous fatalities (IPCC 2019; Ahmad and Afzal 2021a, b) such scenario predicted as natural calamities regarding human fatalities expected to twice till 2050 (Doocy et al. 2013; Wilkinson and Brenes 2014). Floods among natural hazards are estimated recurrently and foremost reason of dead regarding human and commonly basis social and economic risks (Stocker 2014; Daniell et al. 2016).

In South Asian region, climate change is particular serious distress because of higher destruction owing to
ecologically and geographically diversities (Daniell et al. 2016; Muricho et al. 2019) where China, India Bangladesh and Pakistan indicated as supermarkets of natural disasters (Teo et al. 2018; Alam et al. 2020; Ahmad and Afzal 2021a, b). In global climate index scenario, Pakistan ranked 5th most climate change affected country of the world and expected to rise in temperature 2 to 3% and variations in rainfall till 2050 (Kreft et al. 2016; Eckstein et al. 2021). Climate change has raised concerns with its tremendous economic, environmental and social impacts in Pakistan (Ayal et al., 2018; Rehman et al. 2017; Ahmad and Afzal 2019). Pakistan is recurrently exposed of cyclones, drought and floods disasters (Abid et al. 2016; Ahmad and Afzal 2021a, b) as such disasters when pooled with vulnerability of agriculture sector (Lu et al. 2017; Arora et al. 2019) and variations in productivity and cropping as a result of weather variations will severely influences the country rural poor communities (Abid et al. 2016; Ahmad and Afzal 2021a, b). In Pakistan, agriculture employs 38.5% labor force and almost 64% population of country inhabited in rural areas (PBS 2021) where agriculture plays significant role in subsistence living of rural population and agricultural resilience from climate vulnerability is the most important for economic stability of the country (Akhtar et al. 2019; Alam et al. 2020; Adnan et al. 2021b, a).

Pakistan as agrarian economy is higher susceptible to climate variations effects due to higher dependency on agriculture and natural resources for livelihoods (Akhtar et al. 2019; Rizwan et al. 2020; Ahmad et al. 2021a, b). Agriculture considered Pakistan's economy lifeline because of providing nutritional needs of population and raw material to industrial sector (Alam et al. 2020; PBS 2021) whereas the variations in temperature influenced severely as expected to most lethal agriculture (Ahmad et al. 2019; Saqib et al. 2021; Ahmad and Afzal 2021a, b). Climate change based increasing frequency of disasters, pest attacks and land desertification has enhanced the risks of annual crop reduction and food security issues (Ahmad et al. 2019; Adnan et al. 2020). In Pakistan, climate based estimates illustrated as rise in 1°C temperature reduces 6 to 9% wheat yield (IPCC 2020; Adnan et al. 2021b, a) so wheat crop severely affected by climate change (Ahmad and Afzal 2019) which raised the issue of food security for population of the country (GOP 2020). In cereal crops, wheat is major sources of staple diet for population and Pakistan is 8th major wheat producer of the world (FAO 2020) where wheat crop contributes 9.2% in agricultural value added and share 1.8% in GDP of the country (PBS 2021). In the couple of decades, consecutive occurrence of climate based catastrophic threats such as floods, drought and storms severely affected the major crops more particularly the cereals crops (Kreft et al., 2016; Fahad et al. 2018a, b; Kukal and Irmak 2018; Ahmad and Afzal 2019), the reason of consecutive hail, storms, erratic rains and floods in harvesting season while drought in growing season (Fahad et al. 2015; Gorst et al. 2015; Fahad et al. 2017; Ahmad et al. 2019) which raised the food security issue in the country. In the reason of food security issue, in the current year of 2021/22 almost 3 million metric tons wheat was imported for meeting the nutritional needs for the population of the country (PBS 2021). In overcoming to such aspect of food security particularly for staple food wheat crop there exists needs for appropriate policy measures and strategies to reducing climate change policy measures (Fahad et al. 2016; Mekuyie et al. 2018; Rizwan et al. 2020; Ahmad and Afzal 2019). Climate based agricultural risks are major reason of transitory food insecurity and disturbance agricultural supply chain (World Bank 2016; FAO 2020). In the reason of climate change dynamics farmers are consecutively facing the risks of price and yield volatility which projected to more severe in future (Harrison et al. 2017; Fahad et al. 2018a, b; Akhtar et al. 2019). Furthermore, agricultural risks restrain agro-based production, potentially limits the access of finances and more likelihood of farmers to loans defaulting (Demeke and Balié 2016; Fahad et al. 2019).

Socioeconomic factors have significant role in household preparedness regarding climate based natural disasters (Dolman et al. 2018; Zhang et al. 2020) where higher socioeconomic status households having tended to superior equipped to natural disasters than others (Hossain and Meng 2020; Zeng et al. 2021). Higher socioeconomic status household develop household disaster plans, collect first aid kits, purchasing insurance and store water and food (Caprario and Finotti 2019; Gwimbi et al. 2020) whereas lower socioeconomic status household inhabited in disaster prone areas having no preparedness actions (Yusof 2018; Bark and Sutherland 2019; Adeel et al. 2020). Socioeconomic factors have strong association with environmental sustainability about upcoming climate change disasters (Wahlstrom 2017; Yari et al. 2019; Bilgaev et al. 2020). During many decades, human being remained failed to having solid solution regarding frequent and severe developed environmental degradation shocks in shape of floods, drought, erratic rains and heavy storms (Mahmood and Rahman 2019; Handayani et al. 2019; Tripathi et al. 2022).

In developing countries, farmers more particularly use two type of risk management strategies such as risk managing strategies and risk lessening strategies (Ahmad and Afzal 2019; Adnan et al. 2021b, a) which further more specifically categorized as informal and formal strategies (Akhtar et al. 2019; Ahmad et al. 2019). Strategy applied at farm level known as informal strategy included the input subsidization, policies of crop insurance, pricing policy, microcredit
whereas government and institutional based policies are indicated as formal strategies (Daniell et al. 2016; Muricho et al. 2019). In Pakistan, agricultural credit, off-farm and on-farm diversification more preferred practices as applied by farmers regarding risk management strategies (Ahmad and Afzal 2021a, b). Redistributive of productive assets of farm estates which mostly consist of resources, other grower shares, equipment, and farm land properly known as on-farm diversification (Adnan et al. 2019). Alleviating the risks and differences regarding farmer income using the practices of diversification is more significant aspect as mostly practiced in farming community (Ahmad and Afzal 2019). Farming risk can more significantly reduced by diversifying agricultural enterprises and productive activities of agriculture (Lu et al. 2017; Arora et al. 2019) such as simultaneously producing various crops and specifying agricultural land for other crops or goods (Akhtar et al. 2019; Adnan et al. 2019).

To overcoming other financial risks or other related income variations all such are closely associated with adaptation of off-farm income diversification. Minimizing risks effects and boosting up family income, family members instead of off-farm practices take part in farming activities (Teo et al. 2018; Alam et al. 2020). Off-farm and on-farm diversification are closely interconnected with each other in reducing farming risks whereas adopt one as risk management strategy put together it more possible that adopt other concurrently (Ayala 2019; Arora et al. 2019). Agricultural credit particularly used for monetary needs to purchasing agricultural inputs such as machinery, soil cultivation, seeds and fertilizer as well as for using risk management adaptation (Ahmad et al. 2019; Adnan et al. 2020).

In literature, during the last couple of decades catastrophic risk management issue more specifically discussed where some significant studies addressed significant effect of socioeconomic factor on adoption catastrophic risk management strategies such as schooling level (Grace et al. 2015; Harrison et al. 2017; Ahmad et al. 2019; Adnan et al. 2020), respondent age (Ayala et al., 2018; Rehman et al. 2017; Ahmad and Afzal 2021b), size of family (Opioyo et al. 2015; Wako et al. 2017; Harrison et al. 2017; Akhtar et al. 2019), experience of farming (Kagunyu et al. 2016; Mekuyie et al. 2018; Adnan et al. 2020), size of land (Holdschlag and Ratter 2016; Akhtar et al. 2019; Ahmad et al. 2021a, b), income (Dong et al. 2016; Mekuyie et al. 2018; Rizwan et al. 2020; Ahmad and Afzal 2019), ratio of land ownership (Thornton and Gerber 2010; Zulfiqar et al. 2016; Arjumend 2018), risk attitude and risk perception (Hurst et al. 2012; Debela et al. 2015; Ambelu et al. 2017; Fanta et al. 2019; Ahmad et al. 2019; Saqib et al. 2021; Ahmad and Afzal 2021a, b). Some studies focused the aspect of catastrophic risk assessment (Seo and Mendelsohn 2008; Schlenker and Lobell 2010; Dadzie and Acquah 2012; Ayala et al. 2018; Nori et al. 2019), catastrophic risk mitigation (Bradshaw et al. 2004; Seager 2006; Metz et al. 2007; Saqib et al. 2018; Muricho et al. 2019) and adaptation of catastrophic risk management strategies (Bryan et al. 2009; Alam et al. 2012; Grace et al. 2015; Opioyo et al. 2015; Mugi-Ngenga et al. 2016; Harrison et al. 2018; Gkosikoma et al. 2018; Ahmad and Afzal 2019).

In literature, the aspect of adoption of farm diversification as catastrophic risk management strategies discussed in limited studies (McNamara and Weiss 2005; Thornton et al. 2007; Kabubo-Mariara 2008; Ahmed 2012; Ullah and Shivakoti 2014) where some studies focused the aspect of farm credit as catastrophic risk managing tool (Fayaz et al., 2006). In Pakistan, there is limited literature regarding diversification with single aspect as some studies discussed off-farm diversification and agricultural risk management (Ashaq et al., 2008; Tahir et al. 2012; Ullah and Shivakoti 2014; Iqbal et al. 2016; Ping et al. 2016; Nazir et al. 2018; Akhtar et al. 2019). The combined aspect of farm diversification (off-farm, on-farm) and agricultural credit as adoption measure to catastrophic risk about Pakistan not properly discussed in literature. In finding out this research gap, objective of this study is to investigate roles of farmer’s views, different socioeconomic farm characteristics and attitude about risk in selection of risk management measures to mitigate the risks caused by the adverse climate situation by using multinomial and bivariate probit models in Punjab, Pakistan. This study is classified in to five sections as introduction of the study explained in first section and material and method elaborated in section. Results indicated in third section whereas discussion illustrated in fourth section. Last section of the study highlighted the conclusion and suggestions section of the study.

### Material and method

#### Study area

In four provinces of Pakistan, Punjab sharing almost 26% area and 53% population of the country also represents major fertile lands of the country (PBS 2020). On the basis of some considerable reasons Punjab mainly chosen for this study firstly, Punjab contributes major 53% agricultural GDP shares of the country (PBS 2020), secondly Punjab produces almost 77% total wheat production of the country (PBS 2019). Thirdly in the couple of decades due to climate change and extreme environmental variations, cereal crops more specifically rice and wheat were severely affected by consecutive occurrence of stormy rains, hail and drought particularly in harvesting and growing season of crops. Lastly, in recent decade, this country faced five repeated floods since 2010 to 2015 and as compared to other provinces Punjab was more rigorously affected by these floods with heavy losses of crops, livestock, human lives and
destruction of infrastructure (NDMA 2018; PDMA 2019) (Fig. 1).

In such state of affairs of above reasonable substantial factors, Punjab province particularly selected for this study and based on wheat production six districts were specifically categorized and purposively preferred (BOS, Punjab 2018).

In the scenario of study area selection, Dera Ghazi Khan and Layyah from low wheat producing districts, Muzaffargarh and Vehari from medium wheat producing districts and Rahim Yar Khan and Bahawalnagar from high wheat production districts were chosen (PBS 2019) as illustrated in Fig. 2. Divergence standing in these six districts was
estimated about socioeconomic structure, geographical variation and climate change and risk experience. In the couple of decades, higher environmental variation and unexpected climate change was estimated such as discrete pattern of monsoon rainfall season and dynamics of average temperature which caused frequent and sever natural hazards (Abid et al. 2015; Ahmad and Afzal 2019). Environmental scenario of province is hot in summer and cold in winter, Abid et al (2015) with disperse pattern as 70% rainfall from June to September (Ahmad and Afzal 2021a, b).

**Sampling framework**

In procedure of wheat farmer’s data collection and study area selection this study employed the multistage stratified random sampling approach. In the first stage, the reason of significant contribution (77%) in wheat production of country (BOS 2018), Punjab province was purposively selected, whereas based on categorized low, medium and high wheat production areas in province, six districts were randomly selected in the second stage. In the third stage, applying the stratified random sampling approach union councils from each districts were chosen whereas in fourth stage by using the accurate record of revenue department, villages from each union council were selected. In the last stage, for interviewing procedure framework eighty wheat farmers from each district were randomly selected and total 480 wheat farmers’ data was collected from these six districts as illustrated in the Table 1.

For accessing the appropriate information of wheat farmers related to their farm experience, age, schooling, farm size, family size, income, credit, diversification adoption, farmers risk perception and attitude to wheat crop, hailstorm, heavy wind, drought, diseases and pests, heavy rains and floods, this research work used the well-structural questionnaire. Enumerator the students of COMSATS University Vehari firstly trained for collection of data from the study area and for capturing missing information regarding data collection, questionnaire was pre-tested. In the study area data was collected from July to September in 2019 while former to data collection wheat farmers of the study area were well-informed regarding aim and application of data. Mostly farmers from the study area warmly participated in sharing their information regarding wheat crop whereas 34 farmers refused to participate as they replaced to other farmers as data collection procedure illustrated in Fig. 3.

**Empirical specification**

In numerous risk management preferences, agricultural credit and diversifications are some significant preferences particularly used like dependent variable for this study. Farmers have to select strategy base preferences out of four combinations in this multinomial probit model, (i) neither adopting any risk management strategy (neither agricultural credit nor diversification), (ii) adopting only diversification (off-farm or on-farm), (iii) adopting only agricultural credit strategy (iv) adopting both strategies (diversification and agricultural credit). Farmers risk management adopting preferences proportion illustrated in Table 2 which highlights as in overall sample farmers of the study area, 18.87% farmers adopted diversification strategy, 23.97% farmers used agricultural credit strategy, 21.63% farmers adopted both risk management strategies whereas 35.53% farmers adopted no risk management strategy.

**Description of variables**

**Dependent variables**

Agriculture credit and adoption of diversification considered dependent variables in this research work. Institutions (banks) provide any credit or loan for agriculture purpose particularly recognized as agricultural credit (Ahmad et al. 2019). Such types of financial credit facilitate farmers’ to buy farming inputs for smoothly running the farming operations. Losses and gains in farming practices are materialized by the completion of production and selling process of agricultural outputs. Consequently, for appropriate application of risk strategy in agriculture, credit access play significant

| Categorized wheat crop production zones | Range of wheat crop production | Sample of wheat crop study districts | Respondents wheat farmers in numbers |
|----------------------------------------|-------------------------------|--------------------------------------|-------------------------------------|
| Low wheat crop production zone         | Wheat production below 600,000 tonnes | Dera Ghazi Khan                      | 80                                  |
|                                       |                                | Layyah                               | 80                                  |
| Medium wheat crop production zone      | Wheat production in range of 600,000 to 900,000 tonnes | Muzaffargarh                         | 80                                  |
|                                       |                                | Vehari                               | 80                                  |
| High wheat crop production zone        | Wheat production above 900,000 tonnes | Rahim Yar Khan                       | 80                                  |
|                                       |                                | Bahawalnagar                         | 80                                  |
| Grand total of respondents             |                                |                                      | 480                                 |
role as this agriculture credit access includes as dependent dummy variable as indicating 0 for not using agriculture credit and 1 for highlighting using agricultural credit in farming practices. Diversification is considered as tactics for increasing off-farm and on-farm income sources by farming community from the dawn of agriculture (Rehman et al., 2017). Farming community for mitigating severe financial affects of climate change and enhancing their household income specifically uses diversification whereas inter-cropping and crop diversification are among few types of on-farm diversification (Akhtar et al. 2019; Ahmad and Afzal 2019). In this research work diversification indicated as dummy variable illustrating 0 as farmer not using diversification whereas 1 for farmers using diversification in their farming practices.

**Independent variable**

In literature, farmers’ education, age, family income, farming experience, farm proprietorship, and farm area consider significant factors for influencing and assessing farmers risk attitude toward climate change (Akhtar et al. 2019; Adnan et al. 2020; Ahmad and Afzal 2019).

**Assessing risk perception**

Risk perception more properly illustrate by Wang and Roush, (2000), as imminent state of affairs in screening the mode of a bit going away incorrect and its forthcoming cost. Likelihood outcomes and its forthcoming product properly level risk detailed the same as a risk factor (Cooper et al. 2005). Risk of hailstorm, risk of heavy wind, risk of drought, risk of diseases and pests, risk of heavy rains and flood risk were categorized as high-flying risks in this study. In the scenario of farm potential in sequence of measuring incidence and severity regarding risk of farmer this study used Liker Scale which varies from 1 to 10. Several important studies Senkondo, (2000); Fahad et al., (2018a, b); Ogurtsov et al., (2008), Akhtar et al., (2018) and Adnan et al., (2021b, a) used this approach for risk perception in which respondents were reported to risk matrix, these scores were ranged accordingly higher risk severity 6 to 10 and lower risk severity 1 to 5 (Cooper et al. 2021) as indicated in Fig. 4. In estimation procedure, risk perceptions were used like in view of no risk specified as 0 whereas for high risks pointed out as 1.

**Assessing risk attitude**

In literature risk attitude measured through various approaches where two most appropriate approaches frequently applied for risk attitude measurement properly renowned as direct and indirect approaches (Dadzie and Acquah, 2012). Direct method generally known as interview process related to favorites of farmer’s elicitation more used to name of Neumann and Morgenstern (Anderson et al 1977). Several significant studies in literature Torkamani, (2005), Iqbal et al., (2016); Smidts (1990),
Hardaker and Lien (2010); Ahmad et al., (2019); Ogurtsov et al., (2008), Ahmad and Afzal (2019); Rizwan et al., (2020); Saqib et al., (2018) and Adnan et al., (2021b, a) applied Equally Likely Certainty Equivalent Method (ELCEM) by diverse methods which is properly identified adapted version of Neumann-Morgenstern (N-M) model.

In the proxy of economic scenario Elicit Utility model is frequently used to ELCEM while Certainty Equivalents (CE) is subdivision of sequence the risky outcomes in contrasting values of utility (Binici et al., 2003). In relevant to series work of Binici et al., (2003) utility function employed this research works denoted as wealth symbol as perception income of household. There is close and direct relationship illustrated regarding monetary proportion and risk, higher risk as higher monetary value. In such state of affairs, respondents were provoked to show the value of specific outcome to make possible prepared them indifferent in choose connecting risky outcomes by particular of overall income of household in monetary term changeable.

Table 2 Study variables descriptive statistics

| Study variables                        | Description of variables                        | Mean value | Standard deviation |
|----------------------------------------|------------------------------------------------|------------|--------------------|
| Agricultural credit                    | Agriculture credit access 1 otherwise 0         | 0.53       | 0.49               |
| Diversification                        | Adopted diversification1 otherwise 0           | 0.47       | 0.46               |

Independent variables

Socioeconomic and farm characteristics

| Study variables                        | Description of variables                        | Mean value | Standard deviation |
|----------------------------------------|------------------------------------------------|------------|--------------------|
| Schooling status                       | Respondents schooling in years                  | 3.97       | 5.76               |
| Respondent age                         | Respondent age in years                         | 36.83      | 12.98              |
| Family monthly income                  | Family total monthly income in PKRs             | 29,549.879 | 18,876.265        |
| Experience of farming                  | Farmer agriculture farming experience in years   | 17.871     | 13.546             |
| Size of farm                           | Farm land total area in (acres)                 | 7.428      | 2.981              |
| Size of family                         | Family members in numbers                       | 6.324      | 2.872              |
| Ownership of farmland                  | Respondent owner 1 otherwise 0                  | 0.438      | 0.491              |

Perception of risk

| Study variables                        | Description of variables                        | Mean value | Standard deviation |
|----------------------------------------|------------------------------------------------|------------|--------------------|
| Heavy rain                             | High risk of heavy rain 1 otherwise 0           | 0.71       | 0.48               |
| Flood                                  | High risk of flood 1 otherwise 0                | 0.74       | 0.42               |
| Drought                                | High risk of drought 1 otherwise 0              | 0.43       | 0.41               |
| Diseases and pests                     | High risk of pest diseases 1 otherwise 0        | 0.79       | 0.46               |
| Hailstorm                              | High risk of hailstorm 1 otherwise 0            | 0.39       | 0.40               |
| Heavy wind                             | High risk of heavy wind 1 otherwise 0           | 0.47       | 0.44               |

Risk attitude

| Study variables                        | Description of variables                        | Mean value | Standard deviation |
|----------------------------------------|------------------------------------------------|------------|--------------------|
| Risk aversion                          | Respondent risk averse nature 1 otherwise 0     | 0.77       | 0.45               |

Number of total observations 480

Wheat farmers adopted different combinations of risk management strategies

| Strategies of risk management          | Respondents numbers | Percentage of respondents |
|----------------------------------------|----------------------|---------------------------|
| Agricultural credit usage              | 132                  | 27.50%                    |
| Diversification usage                  | 109                  | 22.70%                    |
| Usage of agricultural credit and diversification | 97                  | 20.21%                    |
| Usage of no risk management strategy   | 142                  | 29.59%                    |

Sources: authors own survey collected data 2019

Fig. 4 Risk matrix
as 300,000(PKR) to 0 with related possibility of as 0.5 in loss and income scenario. In such scenario, farmers were assured outcome of income 200,000(PKR) it carry on to be indifferent. The outcome chain was particular wedged in 0 to 200,000(PKR) as leftover of respondent be indifferent 100,000(PKR). In further procedure farmer by wish sequence connecting of 100,000(PKR) states similar assure via 0 and indicate the indifferent with 50,000(PKR). In advance procedure sum as 40,000(PKR) in indifferent classification of farmer, as such assessment was continual. In higher chain of 200,000(PKR) to 300,000(PKR), farmers have to make a decision and continue indifferent in 180,000(PKR). In more sequence of 180,000(PKR) to 300,000(PKR), farmers stay indifferent in 220,000(PKR). In such situation of reappearance of examination through association of likelihood, some number CE spots were consequential. In such scenario, value of utility used of 50,000(PKR) estimated as

\[ U(50,000) = 0.5u(0) + 0.5u(100,000) = 0.5(0) + 0.5(1) = 0.5 \]  

(1)

In situation for more managing diverse CE, furthermore matching them with utility values, cubic utility function was applied for estimation utility for each entity respondents. Cubic utility function highlighted in given Eq. 2.

\[ U(\text{wealth}) = a_1 + a_2\text{wealth} + a_3\text{wealth}^2 + a_4\text{wealth}^3 \]  

(2)

Risk attitude of farmers based on many factors whereas wealth of farmer illustrated as w even as a detailed parameters as specified in Eq. 2. Cubic Utility Function has close association by risk indifferent attitude, aversion risk and preferring risk, (Binici et al. 2003).

Utility frequently evaluated by method of ordinary scale whereas form of utility function regarding ordinary scale be capable to transformed risk aversion in level of quantitative nature know as absolute risk aversion (Pratt 1964; Raskin and Cochran 1986; Arrow 2000). Arithmetic appearance of absolute risk aversion can be specified as

\[ r_a(\text{wealth}) = - \frac{U'(\text{wealth})}{U''(\text{wealth})} \]  

(3)

Absolute risk aversion illustrated as \( r_a(W) \) in Eq. (3) whereas derivatives of second order and first order of wealth (w) indicated as \( U' \) and \( U'' \). In such situation respondent income status reported as their wealth (Olarininde et al., 2007). Coefficient sign illustrated the respondent risk behavior; respondents risk likely behavior indicated as negative sign, respondents indifferent risk behavior shows zero value coefficient whereas coefficient of positive sign highlights the respondents absolute risk aversion. Range of 0 or 1 shows respondents risk attitude whereas no risk aversion attitude of respondent is explained as 0 while risk aversion attitude as 1.

**Model specification**

In analyzing the farmer’s agricultural credit and adaptation decisions on diversification this study used both multinomial and bivariate probit models. Bivariate probit model is employed for likelihood of simultaneous association of different decisions for put in to practice diverse risk management policies (Ullah et al. 2015; Ahmad and Afzal 2019; Adnan et al. 2021b, a) whereas for contrasting the estimates individual probit model was employed. Bivariate probit model equation as illustrated.

\[ Y_{ij} = X_{ij}^\alpha + \epsilon_{ij} \]  

(4)

In above equation, agricultural credit or diversification as adopted risk management strategies indicated as \( Y_{ij} \) with ith respondents (i = 1, 2, 3…….). Observed variables vectors that posses the influences on adoption procedure of risk management strategies indicated as \( X_{ij} \) whereas the evaluated vectors of unknown parameters indicated as \( \beta_{ij} \) and error term of unobserved shown as \( \epsilon_{ij} \). In this equation, \( Y_{ij} \) indicated as binary variable that illustrated the m equation format as indicated in the below equations

\[ Y_{11} = \alpha_{11} + X_1^\beta_1 + \epsilon_{11} \]  

(5)

\[ Y_{21} = \alpha_{21} + X_2^\beta_2 + \epsilon_{21} \]  

(6)

In the above Eqs. 5 and 6 latent variables are denoted by the notion of \( Y_{11}^* \) and \( Y_{21}^* \) which highlighting to emphasizing any decisions regarding risk managing approach. Multinomial probit regression used the set of probable arrangements rather than alternative risky decisions (Adnan et al. 2020). In this research work the two risk management strategies indicated probable combination whereas the multinomial probit regression illustrated as in Eq. 7.

\[ Y_{ij} = X_{ij}^\alpha + \epsilon_{ij} \]  

(7)

In Eq. 7, \( Y_{ij} \) shows the several combination of risk management choices reported as \( \{Y_{1} = 1, 2, 3, 4…m\} \) as ith choices (ij = 1, 2, 3,……n) from the respondents whereas \( X_{ij} \) highlights the vectors (1xk) that shows the observed variables which impacts on the making choice. In this equation unknown parameters are illustrated by \( \beta \) and unobserved random error denoted as \( \epsilon_{ij} \). In such scenario \( \epsilon_{ij} \) highlighted is presumptuous as the multivariate standard with variance covariance and with zero mean.
Results

Research work variables descriptive statistics has elaborated in Table 2. Respondent farmers illustrated higher perception of floods, heavy rains, pests, and diseases major risk factors in the study districts to wheat crop production rather than drought and hail storm. Farmers in the study area adopted some significant adaptation strategies to stooping costs from various environmental risks. In the study area, 47% farmers used off-farm or on-farm diversification adaptation strategy for risk management whereas majority of farmers as 53% used various form of credit to wheat production. Majority of farmer 77% were found to be risk averse in the study area. Agricultural credit usage 27.5% indicated as significant adaptation measure for risk management as compared to diversification 22.7% whereas almost one third 29.59% farmers have adopted no risk management strategy in the study area.

Bivariate probit and individual probit models estimates are indicated in Table 3, which determined the correlation coefficient of agricultural credit and diversification for purpose of risk managing technique by using the probit estimations. In Bivariate probit and individual probit models, positive correlation coefficient regarding both risk control methods as verified the estimated by sustaining null hypothesis indicating as risk management decision error term is correlated. Regarding these estimates instead of using the regression probit of two independent it is more suitable to involve bivariate probit model. Positive correlation coefficient illustrates the indication as selection of one risk management strategy significantly influences the other strategy. Wald $\chi^2$ test (154.98) and test of log likelihood $p_{kj}$ (3.8971) more preferably specifies the bivariate probit regression usage and confirms rejection of hypothesis $H_0$ with conjoint nullity of $p_{kj}$.

In risk management decisions for selecting agricultural credit as risk management tool in wheat farming, socioeconomic factors play significant role. In coming to a decision the adaption of agricultural credit to reducing unfavorable catastrophic risks in wheat production of Pakistan

| Table 3 Bivariate and individual probit model estimated parameters |
|---------------------------------------------------------------|
| Study independent variables | Individual probit | Bivariate probit |
|                             | Agricultural credit | Diversification | Agricultural credit | Diversification |
| Socioeconomic and farm characteristics |                     |                  |                      |                  |
| Schooling status           | 0.0491*** (0.0176)  | 0.0314*** (0.0183) | 0.0486*** (0.0168)  | 0.0311*** (0.0179) |
| Respondent age             | -0.0287*** (0.0129) | 0.0283*** (0.0114) | -0.0279*** (0.0126) | 0.0281*** (0.0112) |
| Family monthly income      | -0.00004*** (0.0000) | 0.00005*** (0.0000) | -0.00004*** (0.0000) | 0.00005*** (0.0000) |
| Experience of farming      | -0.0786 (0.0691)    | -0.1179 (0.0594)  | -0.0781 (0.0587)    | -0.1293 (0.0598)  |
| Size of farm               | 0.0579*** (0.0189)  | -0.0248* (0.0109)  | 0.0587*** (0.0174)  | -0.0239* (0.0113)  |
| Size of family             | -0.0138 (0.0248)    | 0.0147 (0.0231)    | -0.0129 (0.0243)    | 0.0138 (0.0227)    |
| Ownership of farmland      | -0.6891*** (0.1761) | 0.7984*** (0.1798) | -0.6799*** (0.1741) | 0.7821*** (0.1752) |
| Perception of risk         |                     |                  |                      |                  |
| Heavy rain                 | 0.4483 (0.1798)     | 0.1289 (0.1765)    | 0.4329 (0.1716)     | 0.1243 (0.1741)    |
| Flood                      | -0.6147 (0.1987)    | -0.2378 (0.1799)   | -0.6098 (0.1924)    | -0.2289 (0.1765)   |
| Drought                    | 0.0236 (0.2076)     | 0.1897 (0.1875)    | 0.0218 (0.1987)     | 0.1861 (0.1811)    |
| Diseases and pests         | 0.5798 (0.1869)     | 0.1986 (0.1821)    | 0.5776 (0.1834)     | 0.1954 (0.1799)    |
| Hailstorm                  | -0.1797 (0.2281)    | -0.0139 (0.2457)   | -0.1785 (0.2232)    | -0.0134 (0.2434)   |
| Heavy wind                 | -0.0597 (0.3394)    | -0.1187 (0.2921)   | -0.0582 (0.3411)    | -0.1178 (0.2947)   |
| Risk attitude              |                     |                  |                      |                  |
| Risk aversion              | 1.0798 (0.2289)     | 0.8789 (0.2186)    | 1.0654 (0.2276)     | 0.8783 (0.2197)    |
| Value of log likelihood    | -189.7865           | -181.9132          | -378.4317           |                   |
| Wald $\chi^2$              | 154.98***           |                   |                      |                   |
| Ratio of log likelihood $p_{kj}$ | 3.8971***          |                   |                      |                   |
| Ratio of log likelihood $\chi^2$ | 78.56***           | 97.43***           |                      |                   |
| Pseudo $R^2$               | 0.1867              | 0.2178             |                      |                   |
| Coefficient correlation    | 0.389***            |                   |                      |                   |
| Total number of observation| 480                 |                   |                      |                   |

Values in parenthesis reports the standard error
*** indicate at 1% level of significance, ** at 5% level of significance, *at 10% level of significance
farmers schooling, age, family income, farm practices, farm land ownership status, farm size and farmers risk averse nature are considered as most essential factors as showed in Table 3. Farmer schooling and size of farm indicated positive correlation with using agricultural credit as adoption of risk management tool. These estimates illustrated as farmers with higher schooling more preferably to using agricultural credit as risk management tool rather than illiterate farmers whereas large farm size farmers more willing to use agricultural credit as risk management tool rather than small farm size farmers. Negative and significant correlation was estimated regarding farmers age and farmer monthly income with using of agricultural credit as risk management tool. Elderly farmers less willing to using agricultural credit as risk management tool rather than young farmers because young farmer more conscious about farming risks. Farmers having increasing monthly income not willing to taking agricultural credit for using as risk management tool whereas farmer with less monthly income more willing to using agricultural credit for risk managing measure. Estimates of the study indicated the negative correlation of farming experience and farmland ownership with using agricultural credit for risk management tool. Estimates illustrated as experienced farmers less willing to using agricultural credit as risk management tool whereas inexperienced more willing to using it as tool of risk management. In this study area, tenants farmers have higher probability of taking and using agricultural credit for risk management whereas farmers having their ownership of farmland no motivation to using this management measure.

Farmers perceptions regarding the risks of heavy rain, drought, pest and diseases highlighted the favourable affect regarding the adaption of agricultural credit for minimizing the adverse castrophic risks on crops whereas negative perception on agricultural credit was estimated regarding risks of flood, hailstorm and heavy wind. Majority of farmers in the study area having risk averse attitude and such nature of farmers significantly influences in agricultural credit adaptation. On the other hand, risk perception decisions of farmers have slanted nature and possible the effect to further factors in the process of decision making.

In scenario of risk management decisions for choosing diversification in wheat farming, socioeconomic factors such as farmers schooling, age, family income, farm practices, farm land ownership status, farm size and farmers risk averse nature play significant role as illustrated in Table 3. Estimates illustrated the positive and significant correlation in respondent’s ages and schooling with adoption of diversification strategy. These estimates show as aged farmers rather than young farmers and literate farmers rather than illiterate farmers more willing to adopting diversification as risk management strategy. In such scenario increasing schooling and age raises the probability of more prepared to adopting diversification. Positive and significant coefficient correlation of family monthly income and diversification in estimates elaborated increasing family income raises probability of farmers to adaption diversification. Estimates illustrated the negative relation of farming experience and farmers family size with adoption of diversification strategy. These results indicated when farmers experienced increases and their farm size increases they mostly evade to adoption diversification rather than less experienced farmers and small farm size farmers. Small farm size farmers and less farming experience farmers more likely to adopting diversification. Positive and significant coefficient correlation of ownership farmland with diversification adaption illustrates as compared to tenant farmers land owner more inclined to adoption of diversification so there is favorable effect of farm land ownership on adoption of diversification regarding climate risks.

Heavy rains, floods, drought, hail storm, heavy wind, pest, and diseases are six significant independent variables of risk perception. Farmers risk perception regarding heavy rain, drought, pest and diseases showed the positive correlation. These estimated highlighted as farmers have higher risk perception about heavy rains, drought, pest and diseases and more willing to adopting diversification as risk management tool rather than those farmers who have lower risk perception regarding these risks. Farmers risk perception about flood, hailstorm and heavy wind showed the negative correlation indicating as farmers have lower risk perception regarding these risks so less willing to using diversification as risk management strategy rather than those farmers having higher risk perception regarding these risks. Estimates of risk attitude category showed positive correlation illustrating as majority of farmers in study area have risk averse attitude as seeking more risk and eager to using diversification.

Agricultural credit and diversification are two more significant risk managing strategies measured in this study which includes four various risk management strategies adoption of agricultural strategy, adoption of diversification, both strategies simultaneous adoption and not adopting any risk management strategy. In estimation of multinominal probit various combinations as illustrated in Table 3 indicated as dependent variable (Yi = 1…0.4). Estimates of multinominal probit regression model reported in Table 4 where in estimation procedure basic choice is taken the combined no adoption of risk management strategy. Diversification adaptation significantly influenced by farmer schooling, age, monthly income, land area, farmland ownership, farm area, risk perception about to drought, heavy rain, diseases and pest and risk aversion farmer nature. Major findings of factors are alike with previous results rather than farm size and year of farming experience, because these factors negative impact on individual and bivariate
probit estimation, whereas multinominal probit model was positively impacted.

Adoption of agricultural credit decisions are significantly influenced factors of farmer’s monthly income, farmers schooling, ownership of farmland status risk perception about drought, heavy rains, disease and pests. Farmer’s tendency regarding risk averse attitude motivates farmers in adoption of agricultural credit for risk management. Major findings are alike individual and bivariate probit regression estimates except ownership of farmland and size of family. Robustness in estimates has indicated the reason of major significant variables both of diversification and agricultural credit in bivariate model showed similar effects like multinominal. In combination 4, farmers adaptation decisions are significantly influenced by factors of farm area, monthly income of farmer, ownership of land risk perception about heavy rain, drought and pest and diseases also with risk farmers risk aversion status. In the same way, experience of farming and farmers schooling have positive while insignificant on farmers decisions building procedure about agricultural credit adoption for risk managing. Particularly in this research evaluating identification of casual is difficult. Diversification impact related to level of saving is unsure which might have influence agricultural credit adoption for managing castrophic risk.

Discussion

In socioeconomic factors, positive correlation regarding farmers schooling and adoption of diversification strategy was estimated. According to estimates it is observed as qualified farmers more preferably focus to access advance knowledge regarding on-farm or off-farm or both type of diversification measures for improving stability of farm management and enhancing farming income as these finding are in line with the studies of Iqbal et al. (2016), Ahmad et al. (2019) and Adnan et al. (2020). On the other hand, these findings are in contradiction with the studies of Mesfin et al. (2011), Rehima et al. (2013) and Ullah et al. (2015) illustrated as higher educated farmers less willing to adopting diversification in farm activities. Positive relation in age of farmer and diversification in farm activities indicated in this study illustrating as aged farmers mostly are more experienced and more willing to using farm diversification regarding the severe impacts of castrophic risks. Some studies Abbas et al., (2017), Ahmad and Afzal (2019) and Adnan et al., (2021b, a) are in line with these findings as indicating positive relation of age and diversification adaption whereas some studies Ali et al., (2019), Abbas et al., (2015) and Shah et al., (2021) illustrated negative impact of age with diversification adoption so mix scenario related to age and farm diversification estimated.
in literature. Higher probability of diversification regarding higher income was indicated in this study illustrating as higher income motivates farmers for adopting more diversification to generating more income sources. Some studies Ahmad and Afzal (2019), Alam et al. (2020) Shah et al., (2021) and Adnan et al., (2021b, a) findings are in line with estimate of this study whereas the study of Ullah et al. (2015) indicated the reverse causality as negatively related of higher income regarding on-farm diversification and positive effect of higher income to off-farm diversification. Farming background of farmers more properly known experienced farmers harmed the adoption of diversification strategy. Experienced farmers are mostly skillful focus higher priority to traditional measures for overcoming catastrophic risks rather than using advance technical skill and diversification strategies. These findings are in line with the studies of Abbas et al., (2015) Ali, (2018) and Rahman et al., (2020) indicating as negative correlation of experience of farming and adoption of diversification strategy whereas some studies Ashfaq et al., (2008), Iqbal et al., (2016) and Ahmad et al., (2019) showed positively related of farming experience and diversification adoption. Farm size and adoption of diversification strategy illustrated the negative correlation in the findings of this study indicating as small farm size farmers for overcoming catastrophic risks more prefer to adopt the strategy of diversification whereas large farm size farmers slightly require to risk management tools due to enlarged capacity of risk bearing. Small farm size farmers the reason of limited resources having minimal capacity of risk bearing causes to focus adopting risk management strategy like diversification rather than large farm size farmers as these findings are in line with the studies of Ahmad and Afzal (2019), Rizwan et al., (2020) and Adnan et al., (2021b, a). Some studies Kouamé (2010), Saqib et al. (2016a, b) and Ali, (2018) indicated the positive correlation of farm size and diversification, showing as large farm size farmers more need adoption strategies to risk managing measure rather than small farm size farmers. Findings of this research illustrated the positive correlation of farmland ownership with adoption of diversification for overcoming the catastrophic risks management the reason of that owner of farmland as compared to tenants can easily and directly made decisions regarding diversification adaption as risk management decision. These findings are in line with the study of Ashfaq et al., (2008), Iqbal et al., (2016), Ahmad and Afzal (2019) and Adnan et al., (2021b, a) and in contrast with the study of Velandia et al., (2009) illustrated as farmland owner higher capacity regarding risk management due to access of significant resources rather than tenants so use minimal measures for risk management. In choosing the strategy of diversification adoption, the impact of farmers risk perception about drought, heavy rain, pest, and diseases is positive whereas impact of negative risk perception regarding flood, hail storm and heavy wind. Flood risk perception in contrast with studies of Ali et al., (2019), Akhtar et al., (2019) and Ahmad et al. (2020) whereas in consistent with the studies of Ullah et al., (2015) and Adnan et al., (2021b, a). The positive drought perception of farmers regarding to wheat crop indicating as wheat crop in Pakistan is grown in winter season where water availability for wheat crop is low causes more issue of drought while flood scenario is extremely low in winter and more probability of summer season. Diversification strategy is mostly adopted by farmers in avoiding production losses and generating income sources through off-farm activates to minimal the risk losses. Water scarcity and catastrophic risk causes to yield losses of wheat crop which consequently reduces net returns of wheat cultivation. Hail storm and heavy rain threats deterred farmers for adopting diversification as risk management strategy. In decision making process, risk perception of farmer influence indicated as additional determinant. Risk aversion behavior of farmer affects their decisions of diversification regarding adopting the risk management strategy as study findings indicating as majority of farmers in the study area having risk averse nature. These findings are consistent with the studies of Alam et al. (2019) and Ahmad and Afzal (2019).

In findings of the study, positive correlation in farmers schooling and credit access as risk management strategy illustrates as literate farmers are more familiar regarding advantages of agricultural credit access rather than illiterate farmers. Higher schooling facilitates farmers in proper understanding regarding credit access terms and conditions and appropriately managing all proper documentations. These findings are in line with the studies of Saqib et al., (2018), Ahmad et al., (2019), Rahman et al. (2020) and Adnan et al., (2021b, a). Regarding the estimates of the study indicated the negative correlation of farmer’s age and adoption of agricultural credit access as risk management strategy. Aged farmers as compared to young farmers less motivated to access agricultural credit for risk management strategy due to it complicated procedure and inadequate information regarding its usage mostly in developing countries and more specifically in Pakistan. Elderly farmers have to face a number of issues regarding complicated documentation of agricultural credit which causes to discourage access of credit. These findings are in line with the studies of Zulfiqar et al., (2016), Rizwan et al., (2020) and Ahmad and Afzal (2019). Findings of the study indicated the negative correlation in farmer’s higher income and diversification adoption. Higher income farmers due to their own saving particularly invest to on-farm for risk managing issues rather than access to agricultural credit to increasing their financial burden. Results biasness can be as if indicating
reverse causality as large farms need more capital from disasters recovery. Accordingly, large farm required more resources for risk management in contrast to small farms and agricultural credit can be as significant tool to managing these catastrophic risks. These findings are consistent with the studies of Abid, (2017), Alam et al. (2019) and Ahmad et al. (2020). Farm size and agricultural credit indicated the positive correlation illustrating as large farms as compared to small farms more need to additional capital for managing catastrophic farming risks. These findings are consistent with the studies of Ullah et al. (2016), Alam et al. (2019) and Adnan et al., (2021b, a) while in contrast with the study of Saqib et al. (2016a, b). Adverse affect of farmland ownership and agricultural credit estimated in the estimates of this study illustrating as lower attention of farmland owner to access of credit is due to having more stability and assets with enhanced capacity of risk management. These findings are in line with the study of Ali, (2018), Ahmad and Afzal (2019) and Rizwan et al., (2020). Risk perception of farmers regarding to heavy rain, hail storm, drought and heavy wind correlated negatively whereas positive concerning to flood, diseases, and as pests affects on agricultural credit acceptance to minimize disadvantageous climatic risk in agriculture. Agriculture credit mostly used by farmers by choice for lowering and mitigating the major losses from ex-post shocks, crop failure and crop cultivation. More specifically in Pakistan, farmer’s income is significantly influenced by these catastrophic risks which directly affects clothing and food expenditures. In due course, without financial support it is not easy for farmers to restart cultivation and production for next production season. Farmers are extremely discouraged in adoption of agricultural credit in drought, heavy rain, hailstorm and heavy wind as these findings are in line with the studies of Ullah et al. (2016), Abid, (2017), Ahmad et al. (2020) and Adnan et al. (2021b, a). In drought situation, majority of farmers avoid participating in crop cultivation and production so not prefer to use credit for such production process. Heavy rain, hailstorm and heavy wind also have severe affects on crop cultivation and production causes to less prefer the usage agricultural credit. Risk averse nature of farmers more preferably motivates farmers to usage of agricultural credit for adaptation measures to catastrophic risks and majority of the study area farmer showed the risk averse nature as these findings are in line with the studies Saqib et al. (2016a, b), Abbas et al., (2017) and Ahmad and Afzal (2019).

**Conclusion and suggestions**

Multiple risk management strategies are mostly adopted by farmers to overcoming the catastrophic risks of agricultural production. This study used the multinomial and bivariate probit regression sought to find out the factors influencing farmer’s choices of agricultural credit and diversification strategy for managing risks in Pakistan, moreover the potential relationship in these choices. Results of the study indicated the correlation in farmer’s adoption of agricultural credit and diversification strategy to managing risks. Findings of the study concluded as farmers adoption of one risk management strategy motivates them at the same time as to adopting other risk managing strategies. Estimates illustrated the significant relationship in risk tolerance nature and socioeconomic factors of farmers related to their adoption the strategy of risk management. In this study, six production based categorized wheat growing districts of Punjab Pakistan were preferably focused as these outcomes can be extended to various region of country and particularly the other developing countries regarding to availability of various risk managing strategies. Policy makers and state based authorities can be assisted by the accumulated information of multinomial and bivariate probit regression models in evaluating plans of risk management and willingness of farmer in accept government supported risk managing strategies in incidence of traditional practices for managing farmhouse risk. In the same way this study discussed limited researcher’s choices and interviewer’s decisions because of study focused only limited area of research such as six districts of Punjab Pakistan. In this research, promising conclusions for selecting the poverty and food safety are further than of this study so future research can find out such significant outcomes.

**Author contribution** DA analyzed data, methodology, results and discussion, conclusion and suggestions and manuscript write up whereas both DA and MA finalized and proof read the manuscript and both authors read and approved the final manuscript.

**Data availability** The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Declarations**

**Ethics approval** Ethical approval taken from the COMSATS University Vehari campus, ethical approval committee.

**Consent to participate** Not applicable.

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