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Original research article

Climate change variability adaptation and farmers decisions of farm exit and survival in Pakistan

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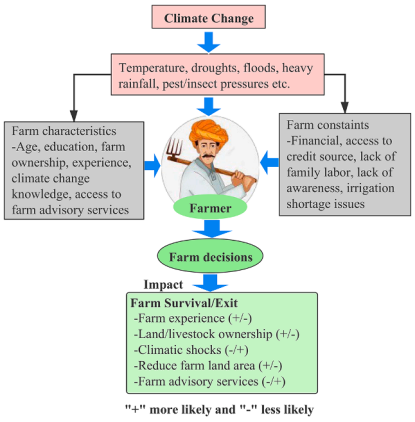
HIGHLIGHTS

- This study investigates climate change impact on farm exit and survival.
- About 31% adapters exit farm in the face of climate change.
- Climatic shocks have significant impact on farm exit.
- The most successful adaptation strategy was increasing livestock to survive farm.
- Mixed crop-livestock production system is helpful in emerging risks of climate change.

GRAPHICAL ABSTRACT



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ABSTRACT

Pakistan is listed among the countries that are extremely vulnerable to climate changes and it has experienced several climatic and natural disaster shocks with adverse impacts on its agricultural sector and farmers livelihoods. This study investigates adaptation to climate change as a means of farm survival and farm exit in Pakistan by using panel datasets and empirically employs Multinomial Logit Model (MLN) and the Theory of Planned Behavior (TPB). The results reveal, first, farm experience significantly increases the likelihood of climate change adaptation and decreases the likelihood of farm exit. Second, land and livestock ownership both have positive and significant impact on farm survival with adaptation strategies and decrease the probability of farm exit. Third, climatic disasters have positive and significant impact on farm exit. Four, extension services have negative and significant impact on adaptation strategies and increase the probability of farm exit for those farms who did not receive climate change adaptation strategies information timely. Finally, TPB results illustrate that non-adapters climate change future intensions are affected by attitude, perceived behavioral control and subjective norms. The study findings bring scholars and policymakers attentions towards next level of climate change

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impact on farm exit, and are useful for farm survival and recruiting new farmers by promoting mixed-crop livestock production systems in the face of climate change, and during viral diseases such as Lumpy Skin Disease (LSD) of animals that caused a large number of animals deaths nationally and internationally.

Practical Implications

Pakistan is listed among the countries that are extremely susceptible to climate changes and its resulted disastrous events. Furthermore, the adverse impact of these events pose significant challenges and threats to rural people livelihoods in context of farm survival in the future. Therefore, this study highlights this critical issue through farmers choices of climate change adaptation strategies and its impact on farm exit and suggests policymakers should prioritize and invest more in climate change adaptation programs that focus on providing farmers climate change knowledge, awareness, resources and incentives to adopt effective adaptation strategies to stop exit and survive farm as mean of livelihood sustainability. As our study reveals livestock and land ownership positively impacts on farm statuses of farm exit and survival, therefore, promoting livestock integration with crop production and promoting family farm policies can be beneficial to stop exit farm in the face of climate change. Hence, encouraging farmers to diversify their income streams by incorporating livestock rearing alongside crop cultivation that will not only enhance farmers resilience to climate-related risks but also will increase overall farm sustainability. Given that natural disasters such as floods, droughts and heavy rainfall have positive and significant impact on farm exit, there is still need to establish an effective early warning systems with farms livelihood diversification through crops and livestock i.e. mixed-crop livestock production systems. These systems can help farmers to anticipate extreme weather events and allow them to take protective measures for farm success to minimize crop losses in the face of climate change. This study finds extension services have negative impacts on farms adaptation strategies, and it calls for a reevaluation of the approach to delivering agricultural extension services at farm level. Policymakers and agricultural institutions should tailor extension services to the specific needs and conditions of farmers in different regions by ensuring farms timely access to those information to stop exit farm.

Since climate change poses various challenges in agricultural sector such as severe pests/insects attacks and other crop diseases that are associated with temperature and precipitation. In fact, majority of extensions services are provided by pesticides firms in Pakistan where sales representatives and input dealers/suppliers recommend farmers an excessive pesticide applications and do not share any effective and preventive pest control methods information due to private gains and sales volumes assigned by those firms. As a result, an excessive use of pesticides further increase resistance in crop pests/insects (Barres et al., 2016; Sun et al., 2021) and increase an extra expenses on farm (Sookhtanlou et al., 2022). Therefore, agricultural extension and plant protection departments can play an important role to provide information in the selection of pest management strategies in the face of climate change, through introducing integrated pest management strategies (IPM) techniques to make agriculture more resilient to climate-induced pests/insects pressures to reduce reliance on excessive pesticides, pest resistance and extra cost on farm as well. Policymakers should control on pesticide firm's extension workers to ensure with integrated pest management techniques knowledge to promote sustainable agriculture practices rather than solely focusing on sales volumes. There is need to regulate private extension firms, particularly strictly keep an eye on pesticides firms which are providing farm advisory services and they should make sure to share climate change knowledge and effective adaptation strategies with farmers to promote sustainable agriculture rather than solely focusing on their private gains and sales volumes. An access to reliable source of climate information is essential for farmers to make a right decision at right time to tackle adaptation strategies effectively to survive and stop exit farm. Policymakers should invest in improving weather forecasting and climate communication systems, ensuring that farmers receive timely and localized climate information to plan their agricultural activities effectively. Supporting research and innovation in agriculture can also help to develop context-specific solutions and technologies that align with local practices for farm sustainability. By executing all these practical implications can increase agricultural resilience, livelihoods sustainability and create a more sustainable and adaptive agricultural sector in the face of climate challenges nationally and internationally.

Data availability

Data will be made available on request.

1. Introduction

Globally, agricultural production system has become more vulnerable to climate change with its adverse impact on farm production and people livelihoods (Chevuru et al., 2023). As a result, agriculture has become more challenging profession to sustain farmers livelihoods (Ahmad and Ma, 2020b). For example, heat wave has been increased over the past few decades (Ayanlade et al., 2022; Founda et al., 2022), and would be more devastating in the future (Carpenter, 2022). One can say that agriculture is one of the most affected profession from unpredictable climate changes that are hurting farm households income and food security statuses directly or indirectly. On the other hand, extreme climate changes are also severely effecting animals and crops with fodder production, water availability, sever disease and pests/insects pressure, health and crop cultivation and production. For instance, with a 1°C rise in temperature, global staple food yields will drop with wheat, maize, rice and soybean being projected to decline by 6%, 7.4%, 3.2% and 3.1%, respectively (Zhao et al., 2017). Meanwhile, an increase in temperature can cause a huge loss to both animals diseases and uncontrolled pests/insects pressure in crops (Cotter et al., 2012). Most of the animals species are unable to cope with an increase in temperature and can reduce food intake by 3–5% if temperature increases by 1°C, causing parasites or pathogens and even increasing multiple diseases threating the animal population (Jasrotia et al., 2023).

In fact, developing countries are more vulnerable to climate change impact due to limited resources and fewer adaptations measures capacities to tackle the adverse impacts (Ahmad et al., 2020; Ahmad et al., 2023; Zahoor et al., 2023). The estimations showed that more than 11,000 climate disasters have been occurred in developing countries since last two decades (Cienfuegos, 2022). In addition, 95% people are more vulnerable to climatic shocks due to massive dependence on agriculture as primary source of income in Africa and Asia, and of these 73% have already faced severe livelihood losses due to these disastrous shocks (Alfieri et al., 2013). Similarly, more than 55 % South Asian households are involved with agriculture as livelihoods source (Rasul, 2021). In addition, these are facing several disastrous climatic shocks such as floods, droughts and heavy rain fall over the last two decades (Mukherjee et al., 2023) and have limited resources to adopt strategies against these events (Chapagain and Raizada, 2017). For example, Pakistan's more than 70% population is dependent on agriculture as a primary source of income (Zubair et al., 2022). The climate change

impact and its resulted shocks (e.g. floods, heavy rainfalls and droughts) are the major threats to country's agricultural sector sustainability (State Bank of Pakistan, 2015). Therefore, more than 60% of country population has been facing food security challenges despite being an agricultural based economy (Achakzai et al., 2020). This is the fact that agriculture plays an important and significant role in achieving Millennium Development Goals of food insecurity reduction by 25% (World Bank, 2014). On the other hand, the unpredicted climate changes and its adverse impact on farmers behaviour, when they fail to adopt adaptation strategies accordingly, then, "Do farmers exit or continue farm in the face of climate change?" is an interesting question to work on it. Therefore, this study takes into account several ways to fills those gaps that are missed in the earlier literature of climate change, and contributes to nationally and internationally literature by investigating climate change impact on farm exit and farm survival by following ways.

First, this is the most importance question to explore does climate change and its adverse impact could really impact on farmer's decisions of farm exit in the end, particularly when climate changes are becoming more erratic and their impact on farmers future. As agriculture in Pakistan provides 45% of employment and contributes 21% to gross domestic product (GDP) (Ahmad et al., 2023), whereas agricultural labor force has been decreased by 7% since last two decades (Siyal et al., 2018; PBS, 2019) which is our interest of question and motivate authors to explore farm exit in the face of climate change. Globally, Pakistan is ranked eighth among the most vulnerable countries to climate change and has longer history of several climatic disasters (e.g. floods of 2010, 2012 and 2014) that affected more than 20 million people and damaged over 20 percent of the land area (Ahmad and Ma, 2020a). Recently, the 2022 floods did even worse with significantly more rainfall by 180% (Arif, 2022) and severe droughts of 1999–2003 destroyed Pakistan agricultural sector and its economy. The future consequences of climate change seem more terrible for farm production that could increase food-insecurity in the country (Gorst et al., 2018; Achakzai et al., 2020). Therefore, this is crucial to investigate and identify those factors timely that could impact on farm exit and survival other than migration due to structural changes in the economy.

Second, a plethora of studies have addressed climate change and its impact on farm productivity and climate change adaption measures nationally and internationally (e.g. Nkwi, et al., 2023; Ortiz-Bobea et al., 2021; Arora, 2019; Bhattacharya, 2019; Ahmed et al., 2019; Raza et al., 2019; Huang et al., 2015; Abid et al., 2015; Gorst et al., 2018; Ahmad and Ma, 2020b; Khan et al., 2022; Gul et al., 2022; Munir et al., 2022). Similarly, few studies have investigated farm exit in different context such as farm occupational choices from developed countries (Mishra et al., 2014; Weiss, 1999; Breustedt and Glauben, 2007) and some from developing countries (Bhandari, 2013; Ahmad et al., 2020; Ahmad et al., 2023). However, none of studies investigated the impact of climate change on farm exit and survival so far. Therefore, we believe this study is timely, thorough and contributes to one of the most critical issue of climate change and farms successfully adaptation strategies to stop exit and survive farm particularly in erratic climate change regions and disasters hit areas to sustain local people's livelihoods. This work is one of its nature to help decision makers to understand the adverse impact of climate change could also lead to farm exit and prepare policy packs in advance for farmers livelihood sustainability in context of farm survival. This study brings scholars and policymakers attentions towards next level of climate change impact on farm statuses either to survive farm or say 'good bye' to agriculture.

Third, in this regard it is important to investigate farmers future concerns of climate change adaptation and its adverse impact on farm exit and survival in the face of climate change. Therefore, we employed Theory of Planned Behavior (TPB) and suggested a framework to investigate farmers behavioural intentions and subsequent behaviours. In fact, farmer behavioural intention is a factor in determining their actions and it depends on their beliefs and attitudes towards their behaviour, subjective norms effects the behaviour and perception of ability to control their behaviours (D'Souza, 2022; Zhang et al., 2020; Gansser and Reich, 2023; Villamor et al., 2023).

2. Study conceptual framework

The conceptual framework of the study is based on farm households livelihood vulnerability in the face of climate change, natural disaster shocks and farmers efforts to tackle these challenges at farm level to survive and exit farms. In fact, climate change and natural disasters are becoming more frequent with greater threat to farmers livelihoods and has become a huge challenge for farmers to respond accordingly during the disastrous events, particularly in agriculture economy based developing countries like Pakistan. As developing countries have limited resources, illiterate farms, follow traditional farming methods, limited knowledge and incapable to adaptation measures. The study (e.g. Ahmad et al., 2020) has investigated farm exit in context of farmers livelihood transition from on-farm to off-farm activities, however, they did not investigate farm exit in the face of climate change. Therefore, we included rich information of climate change adaptation strategies and other variables to investigate the associations between climate change adverse impact on farms statuses either exited or survived farm. This study defines adaptation to climate change as a means of farm survival in context of increasing temperature, droughts, floods, heavy rain falls and uncontrolled pest/insects attacks and other crop diseases that eventually cause farm's huge losses under unpredicted climate changes conditions and natural disasters. In this study we included effective and successful farmers climate change adapted strategies such as changing crops varieties, crop rotation, increase live stocks, decrease and increase farm cultivated land area to tackle above mentioned climatic challenges. For this purpose, we define farm households who stated climate change risks and adopted adaptation strategies accordingly to survive farm. In this regard, a farmer who implements any of climate change adaptation strategy at farm, we defined as an 'adapter' and otherwise 'non-adapter'. Similarly, it is assumed that a farmer chooses to adapt to climate change only if he/she is aware of the potential benefit of adaptation strategies (Abid et al., 2015). Furthermore, the benefit of theses adaptation strategies might comprise the reduction in farm losses, increase farms well-being and farmers willingness. However, we take into account this in different context and assume "if farmers are no more benefited from existing climate change adaptation strategies and are facing huge farm losses, this will reduce farms well-being and farmers willingness, then, farmers cannot survive to continue farm and they can decide to exit farm" in the face of climate change and chose alternate profession beyond the agriculture.

Fig. 1 demonstrates the conceptual framework of farm exit and survival in the face of climate change including some external and internal factors. We assumed that: i) if households perceived climate change and adopted certain adaptation measure, it could have a positive effect on farm survival and negative effect on farm exit (shown as green arrows in Fig. 1); ii) if households perceived climate change but did not adopt any measure, there would be a positive impact on farm exit (red arrows); and iii) if households did not perceive climate change, the impact may be positive or negative on both farm survival and exit (red and green arrows). Similarly, farms constraints may also have positive and negative impact on farm survival and exit, respectively. Furthermore, it is assumed that small and medium farms are more vulnerable to farm survival and have several constraints in climate change adaptation strategies than large farms. Those who exited farm could switch to other professions as a mean of livelihoods transition.

3. Methods and material

3.1. The data

This study uses Pakistan Rural Households Panel (PRHP) survey datasets from three provinces Punjab, Sindh and Khyber Pakhtoon

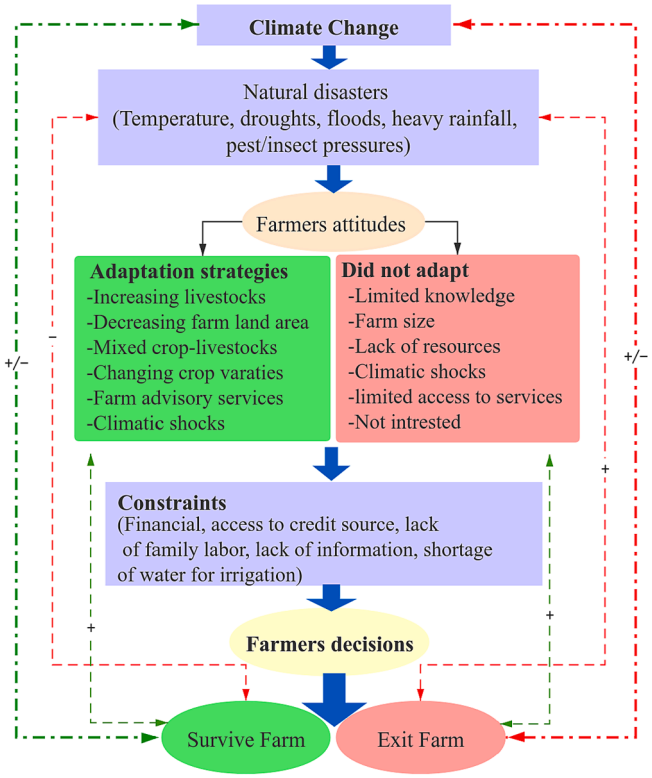

Fig. 1. Conceptual framework of the study.

khawa (KPK) conducted in four different rounds (IFPRI, 2014; IFPRI, 2015; IFPRI, 2016; IFPRI, 2017). The fourth province Baluchistan and its Federally Administered Tribal Areas (FATA) were not included in the survey because they were considered unsafe for the enumeration. Furthermore, four mouzas (the mouza is a subunit of the Union council, the Union council is a subunit of the Tehsil, and the revenue village/dehs is a subunit of the mouza) within each district were chosen as the Primary Sampling Units (PSU) using equal probability systematic selection. In this context, the lists of revenue villages/mouzas/dehs was used as a sampling frame, as provided by the Population Census, 1998. In each mouza, the enumeration teams conducted reconnaissance. These teams sectioned each mouza into enumeration blocks according to the prepared village map. Each block consists of a maximum of 200 households. Then, one enumeration block was randomly chosen from each mouza. Households within the PSU were considered the Secondary Sampling Units (SSU). A complete list of households was prepared for this chosen block, and then 28 households were randomly selected from this list. We defined households as, 'a family or group of people living in common accommodation (family members living in the same building or boundary wall) and cooking or sharing all their meals together'. The respondents were chosen (for interviews) the most knowledgeable family member and major decision maker in domestic affairs within the household. Similarly, a farm households who has been engaged in livestock raising and farming activities during Rabi-season (October-March), during which major crops include wheat, rapeseed, barley and mustard, and Kharif-season (July-October), during which major crops include cotton, rice, maize, sugarcane and millet is defined as farmer. A total of 19 districts were surveyed within the three provinces; 2 in KPK, 12 in Punjab and 5 in Sindh (Table 1, Figs. 2 and 3). The data includes rich information on farm productions (including livestock and crop production), farm and household assets, access to extension services, agricultural water use, households access to credit, household socio-economic and demographic characteristics, employment, household income, climate change and adaptation strategies. We analyzed the datasets as per our study objectives to classify farm exit and farm survival in the face of climate change. The original sample size in first round of survey was 2124 and of these 34 households refused to respond and, hence, 2090 households were surveyed with an attrition rate of 2.4%. Of these 942 households were doing farming and remaining were non-farm household. Finally, 925 farm households datasets are considered for the final analysis and matched with other rounds of panel survey datasets to identify "farm exit" and results found 15% (136) farm households left farming and we defined these 'farm exit' in this study. In addition, we also matched these exited farm household's identification numbers (id) with other survey rounds datasets and found remarks they had left farming, however, these households were interviewed in the rest of modules of panel survey data in all other rounds. Similarly, the rest of 789 (925–136) households continued farming in all three survey rounds and we defined these 'farm survival' households (Table 1). The adaptation strategies in response to climate change adopted by farmers 27%, 23%, 23% and 26% were mainly changing crop varieties, crop rotation, increase livestock and decrease farm land cultivation area, respectively at farm level.

Table 1
Study provinces and sample size.

Province	Number of districts	Farm exit	Farm survival	Total sample
Punjab	12	62	460	522
Sindh	5	60	216	276
KPK	2	14	113	127
Total	**19**	**136**	**789**	**925**

3.2. Empirical approaches

This study takes into account climate change adapters and non-adapters as dependent variables that are dichotomous in nature, therefore, we employed Binary Logistic Regression model by assuming that farmers who perceived climate change and adapted accordingly, can minimize the risk of farm production and ultimately increase farm well-being. The adaptation measures involved to implement a set of strategies (e.g. changing crop varieties, crop rotation, increase livestock, decrease farm land cultivation area, shifting planting date and adopting soil and water conservation strategies etc.) or implement at least one of the adaptation strategy. Meanwhile, it is also assumed that those who did not adapt are called non-adapters and cannot survive and may exit farm. Therefore, a binary variable (Y) is constructed for farmers decisions consisting on following two codes:

$$Y = \begin{cases} 1 = \textit{if the farmer adapts to climate change and survives farm} \\ 0 = \textit{if the farmer does not adapt to climate change and exits farm} \end{cases}$$

The probability of adaptation to climate change is written as:$p = P_r(y = 1)$. Similarly, for non-adapters the probability can be written as: $1 - p = P_r(y = 0)$, and the probability of positive outcome is determined by following equation:

$$\delta = \frac{P_r(y=1)}{P_r(y=0)} = \frac{P_r(y=1)}{1 - P_r(y=1)} \tag{1}$$

The linear form of logit model is given as:

$$logit[\delta(x)] = \log\left\{\frac{\delta(x)}{1-\delta(x)}\right\} = \beta_0 + \beta x, \text{ whereas } \frac{\delta(x)}{1-\delta(x)} = odds \tag{2}$$

The odds $= exp(\beta_0 + \beta x)$, the odds will be treated with logarithm to calculate the logit as following equation:

$$logit[\delta(x)] = \log[exp(\beta_0 + \beta x)] = \beta_0 + \beta x \tag{3}$$

where β parameters can be estimated with the increasing or decreasing rate in S-shaped curve of $\delta(x)$. Above all, it is noticed that the sign of β parameters specifies either the curves ascends $(\beta > 0)$ or descends

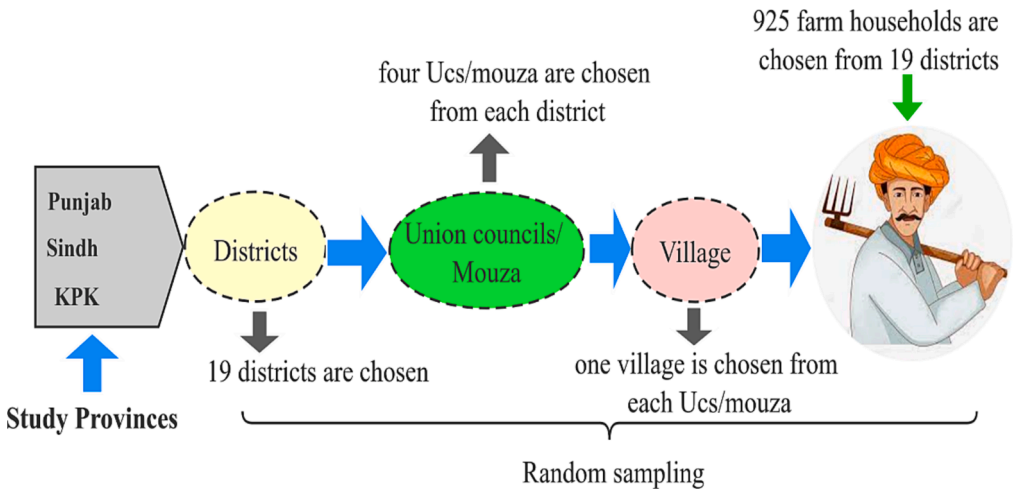

Fig. 2. Households sampling process of Pakistan Rural Household Panel Survey (PRHPS, 2012–2014).

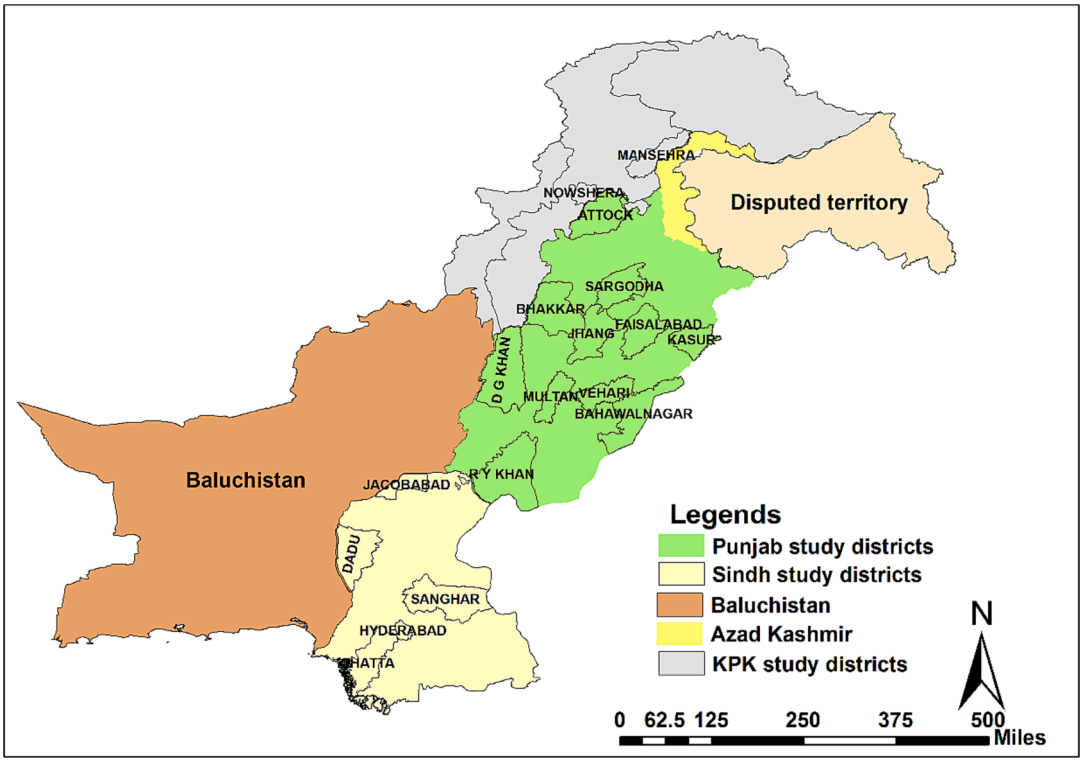

Fig. 3. Map of study provinces and districts in Pakistan.

($\beta < 0$), then β parameters increases as the degree of difference increases. Then, marginal effects are estimated by following equation:

$$Marginal\ effect = \frac{\partial P_r(Y = 1|x)}{\partial x_k} \quad (4)$$

Several studies employed Multinomial Logit (MNL) model to estimate the association between different categories (Destaw and Fenta, 2021; Wale and Yalew, 2007; Dragos and Dragos, 2009). MNL model is also appropriate for making decisions across more than two categories and nature of discrete variables (Deressa et al., 2009; Akankwasa et al., 2013). As our study takes into account binary outcome variables (either exit or survive farm), therefore, we also employed MNL model with several climate change adaptation strategies which are binary variables and impact of the some other variables (socio-economic and institutional factors) that are effecting climate change adaptation choices and allow households independently in the selection of climate change adaptation strategies (Gebru et al., 2020). For example, earlier studies employed MNL model to investigate climate change adverse impact on crops production (Hassan and Nhemachena, 2008; Kurukulasuriya and Mendelsohn, 2008) and livestock (Seo and Mendelsohn, 2008) as a farmer choices method to increase farm well-being. According to Tazeze et al. (2012) and Owoeye (2020), the utility or profit maximization framework is used to guide farmers decisions of whether or not to use adaptation strategies in the face of climate change. Therefore, MNL is useful in analyzing the factors that could affect farmers choices of adaption strategies at farm level and frequently used in adoption decision studies that involve several choices (Hassan and Nhemachena, 2008). With the assumption that the available options are incompatible, then MNL model is valuable for evaluating the casual that a specific option will be chosen over other alternatives (Megersa et al., 2022).

Therefore, this study employed MNL model to estimate farmers choices of climate change adaption strategies and further decisions of either to survival or exit farm under erratic climate change. According to Alauddin and Sarker (2014) MNL can be written as:

$$ln\delta_{m|b}x = ln\frac{P_r(y=m|x)}{P_r(y=b|x)} = x\beta_{m|b}; m = 1, \cdots J \quad (5)$$

Where b is the baseline category logit:

$$P_r(y=m|x) = \frac{exp(x\beta_{m|b})}{\sum_{j=1}^{j} exp(x\beta_{m|b})} \quad (6)$$

Where x is case-specific vector regressor. As Y is a binary variable that indicates farm household decision of climate change adaptation strategies can be written as:

$$Y = \beta_0 + \beta_1 HH_c + \beta_2 FM_c + \beta_3 INS_a + \beta_4 CLS + \varepsilon \quad (7)$$

Where, HH_c is household characteristics (includes household head age, family size, education, farming experience), FM_c is farm characteristics (includes farm size, land ownership, livestock ownership, on-farm income, off-farm income, canal irrigation, water shortage, soil fertility),INS_a is institutional accessibility (includes distance to Micro Finance Institutions (MFIs), access to extension services, distance to commercial market, distance to nearby off-farm work source, government role in sharing climate change knowledge), CLS is climate shocks (includes yearly floods, consistent shocks over the last five year, heavy rainfall, droughts uncontrolled pest/insects pressure and other crop diseases) that severely effect farms and livelihoods, and ε is random error term. Furthermore, farmers each adopted strategy was investigated and indicated by R and then MNL model was employed for maximum likelihood estimation as following:

$$R_{si|N} = \beta_{0,si|N} + \beta_{1,si|N} HH_c + \beta_{2,si|N} FM_c + \beta_{3,si|N} INS_a + \beta_{4,si|N} CLS + \varepsilon;$$

$$i = 1, \cdots, J \quad (8)$$

Where S_i is an adaptation strategy, N is baseline category (no adaptation) and ε is random error term. In addition, we tested for multicollinearity among the explanatory variables using the Variance Inflation Factor (VIF). The maximum VIF value was under 3 (below 10), which is econometrically problematic (Wooldridge, 2015).

3.3. Theory of Planned behavior (TPB) and influencing factors

Non-adapters datasets (including farm survived and exited farm households) were analyzed to estimate farmers attitudes and intentions of climate change and adaptation strategies based on TPB approach. In fact, TPB is an extension of the Theory of Reasoned Action (TRA) and employed by several researchers (e.g. Chen, 2016; Borges et al., 2014) to estimate farmers intensions in the face of climate change. TPB approach has three key factors shaping peoples intended behavior such as farmers adaptive intentions: i) SN (subjective norms) includes community weight to observe the behavior, ii) PBC (perceived behavioral control) refers how individuals perceive the control factors over engaging in a behavior, and iii) ATT (attitudes towards the behavior) could be negative or positive. TPB also makes sense of that people are more likely to engage in positive behaviors when they believe in positive outcomes, receive support from others and have confidence in achieving their goals (Klöckner, 2013; Chin et al., 2016). Therefore, non-adapters were asked about their intentions of adaptation by using well-known 'Likert five-point' method. Attitude (ATT) was estimated by: i) the importance of future adaptation strategies perceived by farmers (from 1 least important to 5 the most important); and ii) the perceived outcome of adaptation strategies (from 1 least useful to 5 most useful). Subjective norms (SN) were measured by farmers perception of the dominant individual on adaptation, and perceived social factors influencing individual behavior such as those related to family, neighbor farmers and local government (5 for strongly agree and 1 for strongly disagree). Finally, perceived behavioral control (PBC) was assessed to adjust farming practices (5 for strongly agree and 1 for strongly disagree) by using scope of self-assurance.

4. Results and discussion

4.1. Descriptive statistics

Table 2 represents bivariate differences between households who survived and exited farms. The results illustrate farm survival households have an older age of household head, larger family sizes and more farming experience than those exited farms. These results show that household head age, family size and farming experience are significantly contributing to farm survival. Among the farm characteristics, land ownership has significant impact on farm survival and exit decisions. However, statistics show that 43% farms with land ownership exited farm and are less than that of farm survived households (77%). This result is surprising and has serious concerns for the future of family farms in the country. Apparently, it seems that such farm households met severe crop losses due to unusual climate changes, severe crop diseases, climatic shocks, lower yields and higher input costs could lead to rent out land (Ahmad et al., 2020). Livestock ownership is a key factor for both exited and survived farm because 71% households exit farm despite having an ownership of livestock, whereas 87% survived farm due to livestock ownership (Table 2). This seems strange in case of exited farm because livestock ownership plays an important role in mixed crop-livestock production system in Pakistan for livelihood sustainability (Ahmad and Ma, 2020b), however, the possible explanations for these results are; first, it is a common practice in rural areas of Pakistan that landless or off-farm households raise shared-in livestock from friends, relatives or landlords and they are also provided animals feeds (e.g. fodder) from the real owners. Second, mostly women take the responsibility of raising animals by harvesting, crop sowing, collecting grass and herbs from someone else agricultural field as fodders and do not produce animals feeds through cultivating on own land. Finally, when farmers face massive crops losses, then they may switch from crop farming to livestock farming by increasing the number of livestock at farm, and they grow only fodder crops (e.g. sorghum, barseem and maize fodder etc.). Importantly, farm and off-farm incomes both have significant impact on farm survival and results show that farm survived households had slightly higher on-farm and off-farm incomes than those who exited farm (Rs. 134,083 vs. Rs.173714 and Rs. 30,449 vs. Rs. 32854, respectively). Similarly, farm access to canal irrigation also played an important role in farm survival, whereas irrigation shortage in the cropping seasons led to farm exit with an insignificant impact. Additionally, farm household distance to all-weather road of exited households was far than that of those survived farm (52.69 vs. 40.85 km).

Regarding institutional accessibility, the distance to MFIs, off-farm source and extension services played a significant role in farm exit decisions. This is because households near to commercial working zones such as factories might have greater opportunities of off-farm employment that may encourage farm exit (Ahmad et al., 2020). This may be the reason that 89% farm households left farming when they had nearby off-farm working opportunities. The role of government appeared poor in sharing climate change and livelihoods diversification information with farmers in the face of climate change, as a result, 34% exited and 31% survived farm households reported they did not receive any climate change adaptation strategies information from government institutions. Most importantly, the descriptive statistics show that the adverse impact of climate change and its resulted shocks or disasters have significant impact on farm exit. To assess farmers perception of climate change (e.g. change in temperature, precipitation, droughts and floods etc.) respondents were asked how they perceived climate change trends over

Table 2
Variables definition and descriptive statistics.

Dependent variables	Definition	Farm exit (n = 136)	Farm survival (n = 789)	All sample (n = 925)	Significance difference
Adaptation to climate change	1 if farmer adapts climate change; 0 otherwise	0.31	0.78	0.71	
Crops varieties	1 if farmer changes crop varieties; 0 otherwise	0.28	0.23	0.23	
Crop rotation	1 if farmers practices crop rotation, 0 otherwise	0.02	0.22	0.19	
Decrease farm land	1 if farmers decreases cultivated land area; 0 otherwise	0.03	0.22	0.19	
Increase livestock	1 if farmer increases the number of livestock; 0 otherwise	0.20	0.22	0.21	
Explanatory variables					
Socio-demographic characteristics:					
Household head age	Years	44.26	47.03	46.62	−2.77**
Family size	Number of people residing in household	6.09	6.84	6.73	−0.75*
Head education	Number of completing schooling years	3.99	3.49	3.56	0.5
Farm experience	Years	19.96	28.02	26.84	−8.06***
Farm characteristics:					
Farm size	Total cultivated land (acres)	4.69	8.92	8.30	−4.23***
Land ownership	1 if farmer cultivates on own land; 0 otherwise	0.43	0.77	0.60	−0.34***
Livestock ownership	1 if farmer owns livestock (sheep, buffalo, cow, goat etc.); 0 otherwise	0.71	0.87	0.85	−0.16***
On-farm income	Household total annual farm income in Rupees (farm revenue -variable costs)	134083.11	173714.22	167887.34	−39631.11
Non-farm income (Rs.)	Household total annual off-farm income in Rupees	30448.90	32854.09	32500.46	−2405.19
Canal irrigation	1 if household accesses to canal irrigation source; 0 otherwise	0.60	0.74	0.72	−0.14***
Water shortage	1 if farmer faces irrigation shortage during crop seasons; 0 otherwise	0.41	0.45	0.44	−0.04
Soil fertility	1 if farmer cultivates on fertile soil; 0 otherwise	0.26	0.28	0.27	−0.02
Access to all weather road	Farm access to main district markets (kilometers)	52.69	40.85	42.59	11.84***
Institutional accessibility:					
MFIs distance (Km)	Kilometers	14.27	17.87	17.34	−3.6***
Access to extension services	1 if farmer receives farm advisory services of climate change, 0 otherwise	0.21	0.39	0.24	−0.18
Extension services interval	Post-visit field farm advisory services interval (days)	41.25	11.01	15.46	30.24**
Distance to commercial market	Farmer access to nearby agricultural input and output markets (kilometers)	20.55	16.66	17.24	3.89
Off-farm source (factory/ industries)	1 if off-farm source locates less than 20 km from village; 0 otherwise	0.89	0.66	0.70	0.23***
Local government role	1 if local government does not share climate change knowledge with farmers; 0 otherwise	0.34	0.03	0.08	0.31***
Climate shocks/Natural disasters:					
Yearly shocks	1 if farm faces natural disasters every year; 0 otherwise	0.56	0.33	0.37	0.23***
Consistent shocks over the last 5 years	1 if farmer faced natural disaster shocks for last 5 year; 0 otherwise	0.60	0.37	0.41	0.23***
Uncontrolled pest/insect	1 if farm faces severe and uncontrolled crop diseases; 0 otherwise	0.90	0.68	0.71	0.22***
Punjab	1 if farmer belongs to Punjab province; 0 otherwise	0.56	0.56	0.56	0.00
Sindh	1 if farmer belongs to Sindh province; 0 otherwise	0.40	0.32	0.32	0.08**
KPK	1 if farmer belongs to KPK province; 0 otherwise	0.04	0.12	0.11	−0.08**

Notes: The significance level was at 1%, 5%, and 10%, ***, ** and * respectively.

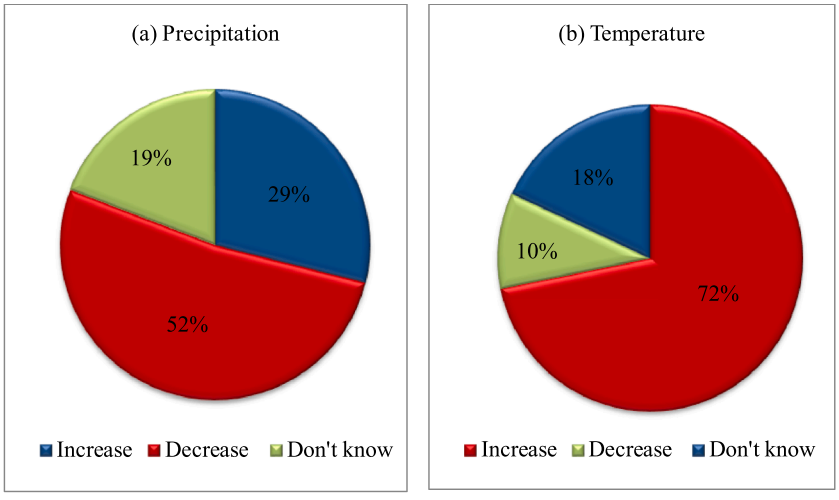

Fig. 4. Farmers perceptions of change in precipitation and temperature.

the last twenty years (either increase–decrease or do not know). Fig. 4(a) illustrates that 29%, 52% and 19% farm households responded the increase, decrease and do not know the change in precipitation, respectively. Similarly, Fig. 4(b) shows 72%, 10% and 18% farm households reported increase, decreases and do not know the change in temperature, respectively. These findings represents farmers perceive poor climate changes and are unaware to adopt adaptation strategies and needs active role of institutions for their participation in sharing those information and adaptation strategies with farmers. Interestingly, traditional farmers did not have faith in climate changes and did not observe climate related changes at farm and still believe on indigenous knowledge to decide crop selection and plantation time in Pakistan. Farmers also link perceived behavior of climate change with their surroundings movements (e.g. animals, insects and birds). For example, if clouds seem stretch similar to a bridge before sunrise, farmers put their faith and believe that there will be a great chance of heavy rain within two days and they do not need to irrigate crops or apply pesticide. Similarly, farmers believe that ants carrying eggs or small grain of pieces predict precipitation and they consider their traditional knowledge work effectively in their agricultural practice. However, mostly farmers reported that it is tough to forecast climate change through traditional indicators in recent years due to unusual climate change over the past few decades. Fig. 5(a) displays 63% households exit farm due to less experience of farm activities. Fig. 5(b) shows households 40%, 54% and 6% exited farms were small, medium and large farms, respectively. These results indicate that small and medium farm future is under huge threats to survive in the face of climate change.

Fig. 6(a) illustrates that overall 71% farms adapted climate strategies across three study provinces, of these 27% adapted changing crop varieties for changing in planting and harvesting time to reduce crop losses (e.g. drought resistance or short duration varsities), 23% practiced crop rotation due to lack of irrigation during cropping season, 23% decreased cultivated land area due to consistent huge crop losses in previous cropping season and 26% increased livestock numbers at farm and shifted to livestock farming as an effective adaptation strategy to survive farm. Similarly, Fig. 6(b) shows 78% households survived farms due to successful adaptation strategies, of these 23% adopted crop changing varieties, 25% practiced crop rotation, 21% decreased cultivated area due to consistent huge crop losses in previous cropping season and 3% increased livestock at farms. The same explanation can be made for exited farms. Fig. 7 depicts that 84% farms faced financial constraints, of these 54% had no knowledge of climate change and adaptation strategies, 28% had irrigation shortage challenges during cropping seasons. In fact, 54%, 80% and 30% farm households had no knowledge of climate change, financial constraints and no access to finical institutions, respectively and decided to exit farm in the face of climate change. These results are consistent with Bryan et al. (2009) who found farmers knowledge of climate change and farms constraints are more likely to apply traditional practices rather than to adopt effective climate change strategies.

4.2. Econometric analysis

Table 3 presents results of MNL model marginal effects and findings reveal that household's size has positive and significant impact on adaptation strategy of increasing livestock and negative impact on farm exit. This result implies that as rural farm households are less educated and unskilled labor and cannot find off-farm opportunities, hence, they prefer to connect with agricultural activities to overcome family labor constraint in planting, fertilizing, weeding, transplanting and harvesting in developing countries (Ahmad et al., 2023; Bhandari, 2013). This finding is consistent with Ahmad et al. (2020), who found positive and significant association between farm exit households and individual in a family with number of working-age members. Our results also recommend that household with larger families are significantly less likely to exit farm, and less likely to adopt all adaptation strategies except increasing livestock in response to climate change than their smaller counterparts. This means large households size would opt to livestock farming in the face of climate change in near future because keeping more livestock seems less risky and more profitable compared with crop growing in context of climate change. On the other hand, Pakistan is a country where Muslims celebrate Eid-ul-Adha[1] by buying and selling halal animals every year that create greater marketing opportunities for farmers, hence, livestock keepers seem keen in rearing and increasing livestock to increase their income because the prices of animals are at the highest on this occasion. These results are consistent with study of Ahmad and Ma (2020b) who concluded that farm households might shift their livelihoods from cropping to livestock farming in the face of climate change in Pakistan.

Education played a significant and positive role in farm exit decisions, but negative in climate adaptation strategies. The result in context of farm exit is understandable, as education leads to perceptions of agriculture as a '3D job' (difficult, dirty and dangerous) and encourage educated people to avoid traditional farming as an occupation (Porru and Baldo, 2022). Therefore, well-educated households preferred to exit farm and moved to off-farm activities as part of a livelihood transition strategy (Ahmad et al., 2023; Bhandari, 2013). Similarly, Agarwal and Agrawal (2017) also argued that higher education is associated with less interest in agricultural activities and a higher likelihood of pursuing off-farm work. However, education result is negative but insignificant in context of climate change adaptation and is not consistent with findings of Arunrat et al. (2017). Additionally, Deressa et al. (2011) and Croppenstedt et al. (2003) also determined that farmers with advanced schooling level were more likely to undertake adaptation strategies than their less educated counterparts because an improve education level enables farms to adopt new technologies and adaption measures at farm level. Ahmad et al. (2020) also pointed out that farmers did not adapt to climate change because they have stronger interest in off-farm work than in farming, and they did not perceive farming as a permanent source of income. In this regard, farm activity seems to be a less reward occupation and well educated farms are likely to exit farm to grab off-farm opportunities. Therefore, educated households tend to exit farm activities and may involve in off-farm work with higher return compared to farming. To conclude, a literate family head has more probability to quit agricultural activities despite adapting all climate strategies, and results of all coefficient are positive.

Farm experience significantly increases the likelihood of adaptation strategies and decreases the likelihood of farm exit. This result implies that experienced farmers have more information and climate change knowledge than those less experienced, and this result is align with Hossain et al. (2022) and Tanti et al. (2022). The findings conclude that farmers with more agricultural practices have greater possibility to implement adaptation strategies and suggest that experienced farms tend to have more knowledge of crop varieties, crop rotation and farmers choices of decisions either to increase/decrease farm cultivated area or increase live stocks to survive farm in the face of climate change.

Farm ownership and size both determine the association between adaptation strategies and households decisions of farm exit. In fact, large farms are well resourced and are tend to adopt more climate change adaptation strategies than small farms (Ahmad et al., 2020; Williams et al., 2022). Our result reveal that as the farm size increases, farmers are more likely to change crop varieties and practice crop rotation as an adaptation strategies at farm level. Additionally, land ownership encourages farmers to increase their investments on adaptation strategies

[1] Eid-ul-Adha is a "Festival of Sacrifice" which is one of the most significant festival in the Muslim calendar. The celebration honors the prophet Ibrahim (AS) readiness to offer his son to sacrifice at God command. Muslims all over the world are urged to make any kind of sacrifice for the moral, social, economic and spiritual advancement of humanity and they purchase and slaughter Halal animals.

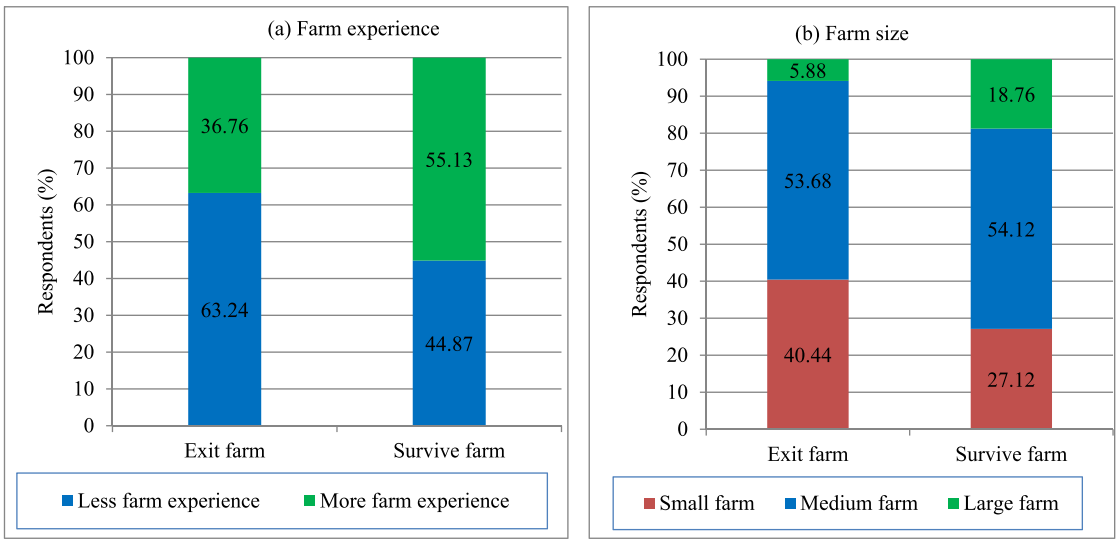

Fig. 5. Farm exited and survived households distribution across farm experiences and farm sizes.

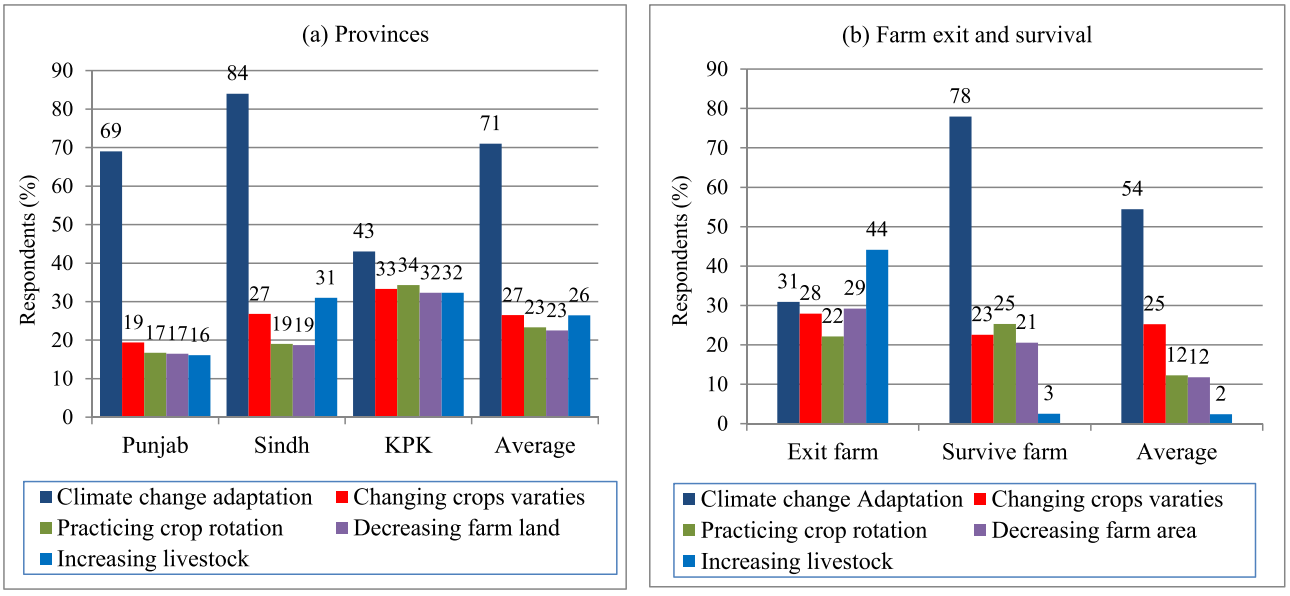

Fig. 6. Farmers climate change adaptation strategies across all study provinces and farm statuses (note: The sum is greater than 100 because some adaptation measures can be selected simultaneously).

(Hossain et al., 2022), because it has further shifting rights to next generation which enables family farms to adopt excellent management strategies for the success of farms. Therefore, land ownership plays an important role in farming decisions (Duncan et al., 2022; Bradfield et al., 2023), particularly in case of applying for agricultural loan and other financial assistance for the betterment of farms even in context of climate change adaptation strategies and so on. Our findings of farmland ownership also increase the probability of climate change adaptation strategies and have positive and significant impact on all adaptation strategies, therefore, this further decreases the probability of farm exit in the face of climate change. Farm income has a significant impact on climatic change adaptation strategies, as farm income increases, farmers are more likely to adopt different strategies. On the other hand, non-farm income decreases the probability of farm exit but the result is insignificant. These findings imply that farms with higher income are more likely to adopt different climate change strategies due to strong financial background that capable these farms to invest on diverse strategies to survive farm. These results are consistent with Arunrat et al. (2017) who found positive association between farm income and agricultural invention as an adaptation strategy.

Livestock ownership has positive and significant impact on farm survival and increases the probability of adaptation strategy of practicing crop rotation with increasing more livestock at farm. In Pakistan, livestock sector contributes 56% of value added to agriculture and 11.9% to GDP (Rehman et al., 2017), provides 3.1% in foreign exchange to total exports, source of income for 35–40% of the population and providing food security for over 8 million rural families (PBS, 2019). Our results are plausible with Ahmad et al. (2020), who empirically found negative and significant association between livestock keepers and farm exit households. Globally, as water availability for farm irrigation has become one of the major constraints in agriculture. In Pakistan, canal source of irrigation is considered among the best in the world, however, ground water is still regarded as a dependable source of irrigation due to several limitation such as quality and expensive in pumping due to high fuel and electricity prices. Therefore, canal source of irrigation is cheap and has significant and positive impact on all adaptation strategies that

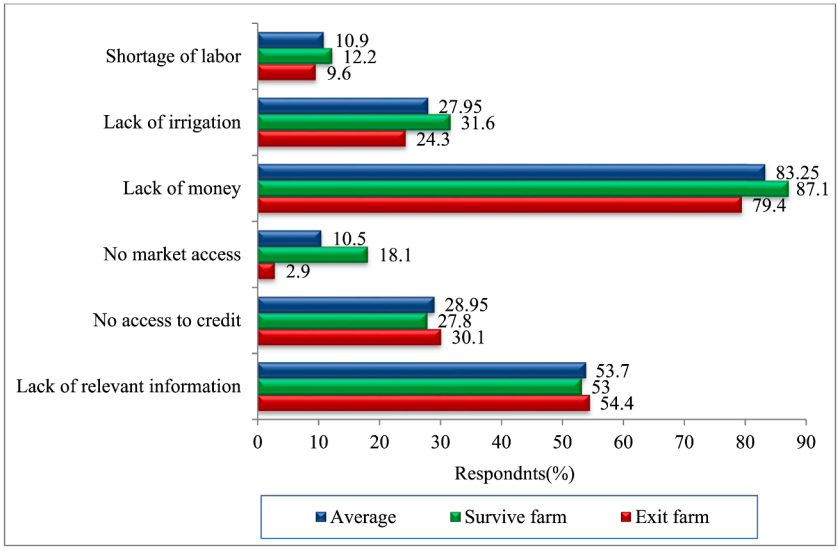

Fig. 7. Farms constraints in adoption of climate change adaptation strategies across farm exit and survive households.

Table 3
Marginal effects of farms decision on adaptation to climate change and farm exit.

Independent variables	Adaptation to climate change	Farm exit	Climate change adaptation strategies			
			Chang crops varieties	Practice crop rotation	Decrease farm cultivated land	Increase livestock
Explanatory variables						
Household head characteristics:						
Household head age	0.000	−0.001	0.000	0.001	0.001	0.000
Family size	−0.005	−0.005*	−0.006	−0.004	−0.004	0.010***
Head education	−0.002	0.003*	0.002	0.001	0.002	0.000
Farm experience	0.002***	−0.001*	0.001*	0.001*	0.001*	0.001
Farm characteristics:						
Farm size (Acres)	0.002	−0.008***	0.001*	0.001*	0.001	0.001
Land ownership	0.026	−0.044**	0.055*	0.082*	0.081**	0.045*
Livestock ownership	0.020	−0.100***	−0.001	0.054*	0.044	0.051*
Farm income	5.31E-08*	−5.56E-08**	2.86E-08**	1.45E-08***	−8.02E-09*	1.07E-08*
Non-farm income (Rs.)	1.32E-07	7.00E-08	−6.05E-09	2.95E-08	5.02E-08	6.71E-08
Canal irrigation	0.12c9***	−0.106***	0.154***	0.384***	0.352***	0.164***
Water shortage	−0.010	0.060**	−0.060*	−0.086***	−0.085***	−0.023
Soil fertility	0.028	−0.012	0.012	0.028	0.023	0.038
Access to all weather road	0.001*	0.001**	−0.006***	−0.008***	−0.007***	−0.005***
Institutional accessibility:						
MFIs distance	0.004*	−0.003**	0.007***	0.009***	0.008***	0.008***
Access to extension services	−0.050*	0.080***	−0.066*	−0.126***	−0.134***	−0.099**
Distance to commercial market	−0.003**	0.000	0.004***	0.005***	0.005***	0.002**
Distance to off-farm source	−0.189***	0.072**	0.088***	0.080***	0.085***	0.191***
Local government role	−0.143***	0.230***	0.097*	−0.028	−0.026	0.106**
Climate shocks:						
Yearly shocks	−0.084	0.060*	0.113*	0.048	0.041	0.079
Consistent shocks over the last 5 years	0.001	0.106**	−0.119*	−0.082*	−0.080	−0.039
Uncontrolled pest/insect	−0.012	0.157***	0.075*	−0.002	−0.008	−0.016
Farm households savings for an emergency	0.078*	−0.069*	0.003	0.061	0.043	−0.019
Punjab	0.158***	0.192***	−0.198***	−0.360***	−0.318***	−0.206***
Sindh	0.346***	0.149***	−0.045	−0.225***	−0.186***	−0.055

Notes: The significance level was at 1%, 5%, and 10%, ***, ** and * respectively

further increases and decreases the likelihood of farm survival and exit, respectively. In addition, shortage of irrigation has negative and significant impact on farm survival, especially during drought seasons. Meanwhile, the results in all models show that farm households were less likely to adopt any climate change adaptation strategy when they have water shortage for irrigation during cropping season, which further increases the probability of farm exit. Similarly, farms distance to all-weather road also has negative impact on climate change adaptation and contribute to farm exit. As farmers have limited access to all-weather road that could inhibited their ability in receiving crop production materials and selling products in main commercial markets, and this results is align with Tessema et al. (2013). Therefore, it makes farmers less interested in adaptation strategies and leads to farm exit decisions. Access to microfinance institutions (MFIs) significantly increases the likelihood of all adaptation strategies with negative and significant impact on farm exit. Farms access to financial institutions or agricultural loans are more likely to survive farm. The limited access to MFIs increase farmers financial constraints that further reduce essential

assets or capital to maintain agricultural activities at farm level (Miled et al., 2022). Moreover, farm access to financial assistance has positive association between innovation and adoption of novel farming techniques, and our result is consistent Hassan and Nhemachena (2008), who found farmers access to financial sources increase the likelihood of climate change adaptation strategies.

Extension or farm advisory services play an important role in assisting farmers during farm management (Paul et al., 2023). Surprisingly, our results in all models show negative and significant link between extension services and climate change adaptation strategies, and increase the probability of farm exit. In other words, household who survived farm received extensions services after each 15 days, and those who exit farm received extensions services after each 41 days (refer to Table 2). Importantly, local government role in sharing extreme climate change knowledge and information with farmers decrease the probability of climate change adaptation strategies and, henece, increases the likelihood of farm exit. These results are in line with Ahmad and Ma (2020b), who found poor role of local government in sharing climate change knowledge adaptation that increases farm household livelihood vulnerability in rural Punjab, Pakistan. The possible reason for this results is, as more than 80% farms are small in Pakistan (Ahmad et al., 2023), and farm advisory services focus on large farms who are willing and able to pay for the services (Norton and Alwang, 2020). On the other hand, limited human resources, population growth, inadequate funding, administrative constraint and policy failures also lead to significant setbacks in extension services systems (Maertens et al., 2021). As a result, this system is facing criticism for their inefficiency in addressing the needs and technological hurdles encountered by farmers (Munthali et al., 2018). Thus, farmers lack of access to farm advisory services and inadequate advisory system management hinder farms adoption of innovative agricultural practices (Verma and Sinha, 2018; Baloch and Thapa, 2019; Takahashi et al., 2019), and according to our results, it further leads to farm exit in the end.

Farm distance to commercial market (e.g. output and input markets) has negative and significant impact on adaptation to climate change and has positive impact on farm exit, but result is insignificant. As less distances to commercial market creates more ease to farm households to sell/buy crop outputs and agricultural inputs from nearby commercial markets. However, as the distance increases, it also increases the probability of adaptation to all strategies and results are positive and significant. These findings are consistent with Amani et al. (2022) who found farmers markets access positively and significantly increases the likelihood of farm household in climate change resilient crop varieties as an adaptation strategy. Farm exit and all adaptation strategies have positive and significant impact on off-farm sources such as mills and factories to improve households off-farm income. In fact, some studies found negative association between off-farm income and farm exit (Breustedt and Glauben, 2007), some found positive (Pfeffer, 1989; Weiss, 1999) and some with mixed results (Goetz and Debertin, 2001). Therefore, our results suggest that by adoption of these strategies could increase and decrease the likelihoods of farm survival and exit, respectively in the face of climate change.

Globally, erratic climate changes are resulting floods, droughts, heavy rainfalls and uncontrolled crop pests/insects attacks which are severely affecting rural farm households livelihoods. Additionally, these disastrous events are also greater threats to adaptation of climate change strategies (Ahmad et al., 2023). As Pakistan is most vulnerable country to climate change and has longer history of several super disastrous floods (e.g. floods of 2010, 2012 and 2014) which affected more than 20 percent of the land area (Ahmad and Ma, 2020a). Our results reveal that adverse impacts of climate shocks have significant impact on farmers decisions of farm exit and survival. Farm households who are severely affected by climatic shocks are less likely to adopt adaptation strategies and more likely to exit farm. Furthermore, results reveal that household faced natural disaster such as floods either affected by yearly or consecutive over the last five years shocks have positive and significant impact on farm exit. However, the magnitude of marginal effect of five year shocks is greater than yearly shocks. Therefore, farm households in Pakistan have lower capacity to cope with theses climatic disastrous events, as a result, this is leading them to farm exit.

Furthermore, farmers showed severe concerns of increasing crops inputs costs, lower outputs prices and extra burden of expenses on farms especially while using excessive pesticide applications on farms. Since cotton crop was severely damage in the study areas due to uncontrolled insects/pests attacks (e.g. as whitefly control is positively associated with temperature) and other crops diseases during the survey time. The uncontrolled attack of whitefly has become more severe on cotton crop due to rise in temperature over the last decade. Therefore, our results find crop losses due to uncontrolled pests/insects pressures is one of the most important factors that has positive impact on households decisions of farm exit. In fact, majority of farm advisory services are provided by private sector in Pakistan, which are pesticides firms (multinational, national and local firms) and these firms hire sales teams or sales representatives (such as Sales Officers, Territory Managers, Regional Officers, Zonal Managers, Task Force, Field Assistant and Field Officers etc.) who provide farm advisory services to farmers. Sales representatives and input dealers/suppliers are assigned special sales volume tasks form pesticides firms, as a result, they visit several farms and motivate farmers in the extensive and unnecessary pesticides to get control on pests/insects by solely focusing on to increase firm's sales volumes. Therefore, firm's representatives do not share any effective and preventive pest control strategies with farmers due to negative impact on their sales volumes and private gains. As a result, this excessive use of pesticides further increase resistance in crop pests/insects (Barres et al., 2016; Sun et al., 2021) as well as increase extra expenses on farm (Sookhtanlou et al., 2022). In this regard, agricultural extension and plant protection departments can play an important role to provide information in the selection of pest management strategies in the face of climate change, through introducing integrated pest management strategies (IPM) that involves preventive pest control methods to reduce pest resistance and reduce reliance on excessive pesticides as well as reduce extra cost on farm to stop exit farm. More importantly, policymakers should make sure and increase investments in the trends and promotion of preventive and eco-friendly pests/insects farming practices to reduce extra costs on farm by reducing reliance on excessive pesticides to stop exit and survive farm. These findings highlight that there is need to regulate private extensions firms and strictly keep an eye on pesticides firms which are providing farm services and make sure that they should also sharing climate change information and adaptation strategies with farmers to promote sustainable agriculture rather than solely focusing on their private gains and sales volumes.

Household ability of saving for an emergency decreases the likelihood of farm exit and increases the likelihood of adaptation to climate change. This result is relevant with findings of Aryal et al. (2021) who concluded farms households savings could remove farms constraints and increase the probability of farms preparedness for future intensions of response to climate change. Farm households who faced massive crop losses due to severe crop diseases and extreme climatic shocks, are more likely to exit farm. As a result, climate shocks, water shortages, increasing input cost and decreasing output prices are the major contributing factors that are declining country's agricultural growth and productivity (PBS, 2019). In particular, climatic shocks are driving farm households into poverty and food insecurity which further urges farm households to diversify livelihoods beyond agriculture (Bhandari, 2013). Meanwhile, these shocks continuously increase crop losses and farmers outstanding loans, as a result, it leads farms either quit or suicides in the end (Agarwal and Agrawal, 2017). Our results are steady with previous study of climate change and livelihood vulnerability in Pakistan (Ahmad and Ma, 2020b; Ahmad et al., 2020). In nutshell, in order to stabilize farmers income and adaptation to climatic change, farmers should not rely solely on on-farms activities, they should be provided part-time off-farm employment opportunities to survive farm

in the face of climate change. In addition, introducing crop insurance policies can play an important role to stop exit farm in the face of climate change, unfortunately, no crop insurance policy has been released by the government of Pakistan in the country so far.

Finally, TPB approach is employed to describe the intentions of non-adapter and their intention of adaptation is considered as a dependent variable by employing Hierarchical regression analysis, where SN, PBC and ATT are included in the first step, and then farm experience, non-farm income, extension service and substituting crops by increasing livestock are included in the second step (Table 4). The results specify that SN has significant impact on climate change adaptation intention followed by PBC and ATT. The value of R^2 in model-I indicates SN, PBC and ATT account for 31% of the variance in adaptation intention and farm survival in the face of climate change. Furthermore, with addition of farm experience, non-farm income, extension services and increasing livestock also increase the value of R^2 from 0.17 to 0.48 in model-II. The results in model-II portray that all additional variables have significant impact on farmers climate change adaptation intentions. These results are consistent with Lam (2006) and Greaves et al. (2013) who suggested that TPB is useful for predicting farmers attitude and behavior than other explanatory variables.

5. Conclusion and implications

This study explores adaptation to climate change as a means of farm survival and farm exit in Pakistan by using nationally panel datasets, it employs empirically approaches of Multinomial Logit Model (MLN) and the Theory of Planned Behavior (TPB). Farmers mainly adopted strategies are changing crops varieties, crop rotation, decrease-increase farm cultivated area and increase livestock to survive farm. This article brings scholars and policymakers attentions towards ultimate impact of erratic climate changes on farm survival to sustain rural farm households livelihoods.

5.1. Conclusion

According to statistics and modelling results, we have produced the following major findings:

First, farm households did not perceive climate changes timely and accurately due to less education level and did not have faith in that something happening with climate to observe related changes at farm level. Moreover, elderly farmers still believe on traditional farming methods in planting crops and time in some part of rural Pakistan. This requires an active role of local government to assist farms in the face of climate change immediately, because our results find inactive role of government in sharing climate change information at farm level.

Second, farm experience has significantly increased the likelihood of climate change adaptation and decreases the likelihood of farm exit. This implies that experienced farmers have more knowledge and information of adaptation strategies than those less experienced, particularly, the large farms adopt more adaptation strategies due to well resources than small farmers.

Third, land and livestock ownership both have positive and significant impact on farm survival with all adaptation strategies and decreased the probability of farm exit. As land ownership encourages farmers to increase invest on adaptation strategies, because it has further shifting rights to next generation which enables family farms to adopt excellent management strategies for the success of farms. In fact, land ownership plays an important role in farming decisions, particularly in case of applying for an agricultural loan and other financial assistance for the betterment of farms in context of climate change adaptation strategies and so on. As Pakistan is one of the countries in the world where mixed crop-livestock production system is an important source of people income and as well as food. Livestock sector contributes to value added to agriculture and GDP and also acts as a major source of rural people income and providing food security in Pakistan. Therefore, the most successful climate adaptation strategy adopted by farmers was increase livestock while reducing farm cultivated land to survive farm.

Four, climate shocks such as natural disasters including floods, droughts and heavy rainfalls have positive and significant impact on farm exit. Farm households either affected by yearly shocks and consecutive five years shocks both have positive and significant impact on farm exit. As Pakistan is most vulnerable to climate change and has massive threats to agricultural sector due to farmers lower capacity to cope effectively with theses unpredictability of climate change, which are resulting to farm exits.

Finally, extension services have negative and significant impact on climate change adaptation strategies and increase the probability of farm exit. Farm households who survived farm were receiving extensions services timely and regularly than those who exited farms. Importantly, local government role in sharing extreme climate change knowledge and information with farmers decrease the probability of climate change adaptation strategies and increases the likelihood of farm exit. The TPB approach exemplifies that non-adapters future intensions towards climate change were affected by SN followed by ATT and PBC variables of adaptation and farm survival.

5.2. Implications

Based on all of these considerations, how can policymakers make sure to stop exit farm in the face of climate change is clearly a big challenge. Based on our results and modelling findings, we are trying to provide the following policy implications:

First, policymakers should introduce targeted educational interventions and addition of new potential farms recruitment policies with updated and relevant climate change adaptation information. Government should collaborate with non-governmental organizations and private farm advisory services to implement awareness programs that could enhance farmers understanding of climate change impacts and adaptation strategies to stop exit farm.

Second, inactive role of government in sharing climate change information is a significant concern and policymakers should prioritize to develop effective communication channels to publicize timely and accurately climate change knowledge and use of technology in remote areas. Acknowledging the persistence of traditional farming beliefs among elderly farmers, efforts should be made to integrate traditional

Table 4
Hierarchical regression results for non-adapters farm (n = 268)[a].

Model-I	Std. Coeff.	R^2	Model-II	Std. Coeff.	R^2
Attitude (ATT)	0.274***	0.31	Attitude (ATT)	0.234***	0.48
Subjective Norms (SN)	0.399***		Subjective Norms (SN)	0.363***	
Perceived Behavioral Control (PBC)	−0.218***		Perceived Behavioral Control (PBC)	−0.535***	
			Farm experience	−0.096*	
			Non-farm income	0.103*	
			Extension service	0.17***	
			Increasing livestock	0.535***	

Notes: Std. Coeff. = Standardized coefficient; ***, * Significant at 1% and 5% level, respectively.
[a] The n = 268 includes only non-adapters farm households, of these 94 households exited farm and 174 survived farm (n = 94 + 175 = 268).

knowledge with modern climate-smart practices. Local government initiatives should include targeted support and guidance to ensure a smooth transition to more climate-resilient farming methods for farm survival.

Third, promoting and supporting experienced farmers successful and effective climate change adaptation strategies activities with other farms could be more helpful to stop exit farm. Extension services can play an important role in sharing best practices and innovative adaptation strategies of experienced farms with beginners and less experienced farms to increase the likelihood of farm survival. Importantly, tailored support programs for small farms are necessary to ensure their participation in climate-resilient practices because experienced and skilled farms are better equipped and are more likely to adjust their farms to adapt to climate change and vice versa. Policymakers should review Pakistan's agricultural land use and climate change adaptation policies for small and medium farms that are most vulnerable to survive farm in the face of climate change.

Four, policymakers should introduce financial assistance programs and incentives for farmers to promote mixed crop-livestock production systems that contributes to increased resilience against climate-related challenges to stop exit farm. To counter the negative association between extension services and farm exit, efforts should be directed towards strengthening and expanding extension services. This involves ensuring the timely and regular provision of information, technical assistance and training the farmers through increasing funding, improved infrastructure and collaboration with agricultural experts.

Five, addressing the significant impact of climate shocks on farm exit, local governments should focus on disaster preparedness and risk mitigation measures through early warning systems, infrastructure development and community-based disaster management initiatives to enhance farm household ability to cope with natural disasters. Government should provide off-farm employment opportunities to stabilize farmers income to improve farm climate change resilience. Additionally, introducing crop insurance policies could play an important role to stop exit farm, but no crop insurance policy has been released so far by Pakistan's government at farm level.

Finally, government should keep an eye on private extensions services such as pesticide firm's and their sales workers, who solely focus on sales volumes and private gains during farm advisory services. Therefore, they need to share integrated pest management techniques (IPM) with farmers to make agriculture more resilient to climate changes pests/insects pressure to reduce reliance on excessive pesticides, pest resistance and extra cost on farm as well. Similarly, to better support farmers in adopting climate-smart practices, policymakers should focus on understanding and addressing the influence of subjective norms (SN), attitudes (ATT) and perceived behavioral control (PBC) on their adaptation intentions. This can be achieved through community engagement programs, peer-to-peer learning and initiatives aimed at boosting farmers confidence in adaptation of climate-smart practices.

This study has touched on several critical issues of climate change impact on farm exit and survival in Pakistan. However, this study did not discuss the current statues of exited farms whether they exited temporary or permanently nor discuss whether any household member inherited family farms as a successor or not. Nevertheless, this would be an interesting to revisiting those households after a decade to discover their current statuses. This study also has future research directions, firstly, this would be an interesting to investigate livestock keepers adapting strategies in Pakistan during Lumpy Skin Disease that resulted a large number of animals deaths in 2022, for future policy designing for farm survival. Secondly, as studying farmers decisions of farm exit in the face of climate change is a complex and multidimensional task that requires a thorough investigation including economic, environmental and other several factors that influence farmers decisions nationally and internationally.

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Code availability

Stata-2014 and MS excel 2010 software are used for the data analysis.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

CRediT authorship contribution statement

Muhammad Irshad Ahmad: Conceptualization, Investigation, Methodology, Formal analysis, Visualization. **Hengyun Ma:** Writing – review & editing. **Qiong Shen:** Supervision, Writing – review & editing. **Abdul Rehman:** Writing – review & editing. **Les Oxley:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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