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Impact of climate-change risk-coping strategies on livestock productivity and household welfare: empirical evidence from Pakistan

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Abstract

Using the primary datasets collected from 700 livestock farmers from all four major provinces of Pakistan and Azad Jammu and Kashmir (AJK) and Gilgit Baltistan, this paper analyzes the impact of climate-change risk coping strategies on household welfare. A Poisson regression model was used to estimate the determinants of the livestock ownership and multivariate probit model to assess the determinants of the measures taken to manage the climatic-risk challenge for livestock. A propensity score matching approach (PSM) was used to assess the impact of the adopted climate-risk management strategies on livestock farmers. Findings indicated that in Pakistan livestock farmers generally adopt four main types of strategies to cope with climate risk: livestock insurance, selling of livestock, allocation of more land area for fodder and migration. The results show that age, education, wealth, access to extension services, and membership in NGOs, influence the livestock farmers' choice of climate-risk-coping mechanisms. The livestock farmers who adopted risk-coping mechanisms generally fared better. Increasing the land area allocated to fodder seems to

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increase production of milk and butter, resulting in higher income and lower poverty levels. Those who bought insurance had more milk production and a lower poverty level, while those who sold livestock to cope with climate risk decreased production but increased household income and lowered poverty levels. Migration seems to have a negative impact on production and income. Impact assessments confirm that purchasing livestock insurance and increasing fodder areas are more effective compared to the selling of livestock and migration. Agricultural climate policy should focus on creating awareness as well as increasing access to extension services among livestock farmers on climate risk and risk-coping strategies to mitigate the impact on rural livelihoods.

Keywords: Environmental science, Agriculture

1. Introduction

Globally, more than a billion impoverished people depend on animals for food and income. They provide jobs to 1100 million individuals, and most of them are living in developing countries (Hurst et al., 2005). Over 70% of the poor in rural areas of developing countries are dependent on livestock (Delgado et al., 1999). The majority of these poor families live in South Asia and sub-Saharan Africa and, for them, livestock is a crucial asset. Primarily, landless and smallholder farmers derive a substantial share of their incomes from livestock. Livestock contributes to food and nutrient security across the world, evidenced by the fact that livestock makes up 17% of the global kilocalorie consumption, and 33% of the protein consumption (Rosegrant et al., 2009).

Growth in livestock production can have a more favourable effect on poverty reduction than growth in crop production (Shukla and Brahmankar, 1999; Birthal et al., 2003) because livestock are more equitably distributed compared to land. In developing countries, income from livestock forms a significant share of farm households' income portfolios and a large proportion of rural farm households depend on livestock for livelihood; hence, climate change is expected to have a significant impact on more than 600 million people who depend on livestock for their livelihood (Thornton et al., 2002). As climate change poses a threat to the livelihood of farmers by reducing crop yield, food security and increasing poverty levels (Ali et al., 2017), steady investment via information provision, education of farmers, and extension and credit services would enhance farmers' perceptions about climate risk, and stimulate adoption of suitable strategies by farmers in Malawi (Mulwa et al., 2017) and in Pakistan (Rahut and Ali, 2017).

Livestock is central to the rural economy of Pakistan; the livestock sector contributes about 58.3% to agricultural value added and 11.4% to the overall GDP (Government

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of Pakistan, 2018). Livestock is a source of cash income, often the only source of income for the rural and most marginal people. In Pakistan, more than eight million families are involved in raising livestock and, on average, derive about 35% of their income from livestock production (Government of Pakistan, 2018). Livestock can play a fundamental role in poverty alleviation and in increasing foreign exchange earnings; the livestock sector contributed about 1,333 billion rupees to the gross value addition (Government of Pakistan, 2016/17).

In Pakistan, due to increasing human population and urbanization, demand for livestock products is also rapidly increasing. Concurrently, changing climatic conditions have a profound and persistent adverse effect on people, agriculture and livestock systems. Hence to meet the growing demand, and in light of rapid climate change, the Government of Pakistan should encourage public-private partnership in the livestock sector and support modernizing and stimulating the scientific excellence of the sector. Livestock products such as milk and meat form a significant part of the daily diet, and can help ensure food security, as the gross milk production was registered at 56,080 thousand tons, while the milk consumption by the population was only 45,227 thousand tons (Government of Pakistan, 2016/17).

Against the backdrop of increasing demand for livestock products in Pakistan, the adverse impact of climate change on livestock products and the importance of livestock for rural livelihood, this paper aims to do the following: first, understand the mechanisms adopted by rural households to cope with the impact of climate risk on their livestock; second, identify the factors influencing the choice of strategies adopted by farm households to cope with climate risk; and third, evaluate the effect of a climate-risk-coping measure on livestock production, compared to those who do not adopt such measures.

2. Background

In rural areas, livestock plays a vital role in the livelihood and well-being of poor farm households. First, it acts as an asset for investment which can be easily liquidated in times of need, i.e., it helps acts as a risk-coping strategy and minimizes risk to vulnerable individuals. Second, livestock is an essential source of nutrients and traction for poor farm households (Thornton, 2010). Over the past three decades, rural community dependence on livestock has increased manifold in South Asia (Delgado et al., 1999). However, the productivity of livestock in South Asia has been low, due to several reasons, but especially to the non-adoption of the modern and efficient technologies.

It is challenging to meet the global demand for livestock products due to two opposing issues: increasing demand, resulting from population growth and urbanization on one hand, and the adverse impact of climate change on livestock production on the other. Demand for livestock products in developing countries is increasing rapidly and will

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continue to increase in the future (Delgado et al., 1999) fueled by rapid urbanization, population growth and increase in income (Jones and Thornton, 2009). The global population is projected to rise by 33% from 7.2 billion to 9.6 billion by 2050 (UN, 2013) which would further increase demand for livestock products. The number of people living in urban regions has burgeoned from 751 million in 1950 to 4.2 billion in 2018, and the proportion of urban inhabitants to the total population is anticipated to surge from 55.3% today to 68.4% by 2050 globally, and in Pakistan it is likely to rise from 35.8% today to 53.8% (United Nation, 2018).

Household income levels are also rising, and are expected to grow significantly, which will increase the demand for livestock products. The annual global per capita GDP is expected to increase from US$9,644 in 2010 to US$13,874. During the same period, the GDP per capita of South Asia is projected to increase from US$1,283 to US$3,890. It is projected that the demand for livestock products will double by 2050 owing to improvements in the standard of living (Garnett, 2009; Rojas-Downing et al., 2017).

A number of studies have found that climate change can adversely affect livestock productivity through changes in the availability of natural resources such as water, changes in the quality and quantity of forage, livestock diseases and heat stress (Garnett, 2009; Thornton et al., 2009; Thornton, 2010; Rojas-Downing et al., 2017). Increases in temperature and CO_2 levels, and changes in the amount and timing of rainfall, affects the production of fodder crops and forage (Easterling et al., 1993; Campbell et al., 2004; Hatfield and Prueger, 2011; Sanz-Sáez et al., 2012), which is deleterious to livestock production. Due to prolonged drought, the dry period of dairy livestock is extended (Maurya, 2010), and therefore the volume of milk production is lowered.

As a result of increases in the demand for water from competing sources, and depletion of water resources resulting from climatic changes, it is estimated that about 64% of the global population will face water distress (Rosegrant et al., 2009), which will, in turn, reduce the availability of water for livestock sectors. Further, the rise in temperature is expected to augment water intake by animals (Nardone et al., 2010). Prompt policy measures will be needed to address these increasing demands and competition for water (Thornton et al., 2009). The heat stress induced by climate change also results in decreases in production of livestock products (Nardone et al., 2010; Seerapu et al., 2015) owing to alterations in the nutrient content of the forage (Thornton et al., 2009).

The changing climate also increases the incidence of livestock diseases and mortality (Jones and Thornton, 2009; Thornton et al., 2009; Amin et al., 2010; Herrero et al., 2010; McDermott et al., 2010; Nardone et al., 2010; Rojas-Downing et al., 2017), and leads to a drop in livestock production. Climate-induced livestock diseases are manifesting across the globe, threatening the income, livelihood and food security of the people living in developing countries.

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As climate change adversely affects livestock assets, rural households, which are largely dependent on agriculture, implement measures to cope with climate change. A wide range of options are available, and households choose the coping strategies depending on availability and affordability. Some of the widely-used mechanisms are selling livestock, migration, and insurance.

Climate change is expected to cause an increase in weather-related hazards, which can severely affect livestock, especially in developing countries. Researchers and policymakers agree that the most significant impact of climate change can be seen in the livestock sector (Thornton, 2010; Naqvi and Sejian, 2011). However, most of the work on climate change has focused on the crop sector, and only a few studies have documented the impact of climate change on livestock productivity (Thornton et al., 2009; IPCC, 2014).

The primary objective of this paper is to assess the measures adopted by farm households to cope with the negative effects of climate change on livestock, and the impact of adopting coping strategies on livestock productivity. There are three novel aspects of this research. First, it is one of the few papers that uses a large primary household-level dataset to understand the coping strategies adopted by farm households to manage the impact of climate risk on livestock income. Second, it assesses the factors influencing the adoption of these coping strategies. Third, it estimates the impact of the coping strategies on livestock productivity and rural livelihoods. Hence, this paper provides promising research which could enhance the well-being of rural farm households dependent on livestock for food security and livelihood.

Table 1 illustrates the trend in livestock assets in Pakistan. The number of cattle increased by 8% from 42.8 million in 2015/16 to 46.1 million 2017/18 and buffalo increased from 36.6 million to 38.8 million. The number of goat/sheep increased by 4%, from 101.1 million to 104.6 million.

Table 1. Estimated livestock population in Pakistan (in millions).

	2015−16	2016−17	2017−18
Cattle	42.8	44.4	46.1
Buffalo	36.6	37.7	38.8
Sheep	29.8	30.1	30.5
Goats	70.3	72.2	74.1

Source: Economic survey of Pakistan, 2016−17.

3. Theoretical framework

Fig. 1 below depicts the flowchart of the conceptual framework. Data shows that climate change affects livestock production through a decline in feed and forage, water availability, heat stress and livestock diseases. As a result of this adverse effect,

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farm households adopt a number of strategies, such as livestock insurance, increasing the area for fodder, selling livestock, and migration to cope with the negative impacts of climate change. Those farm households who adopt strategies to cope with the adverse impacts of climate change on livestock are better off than those who do not.

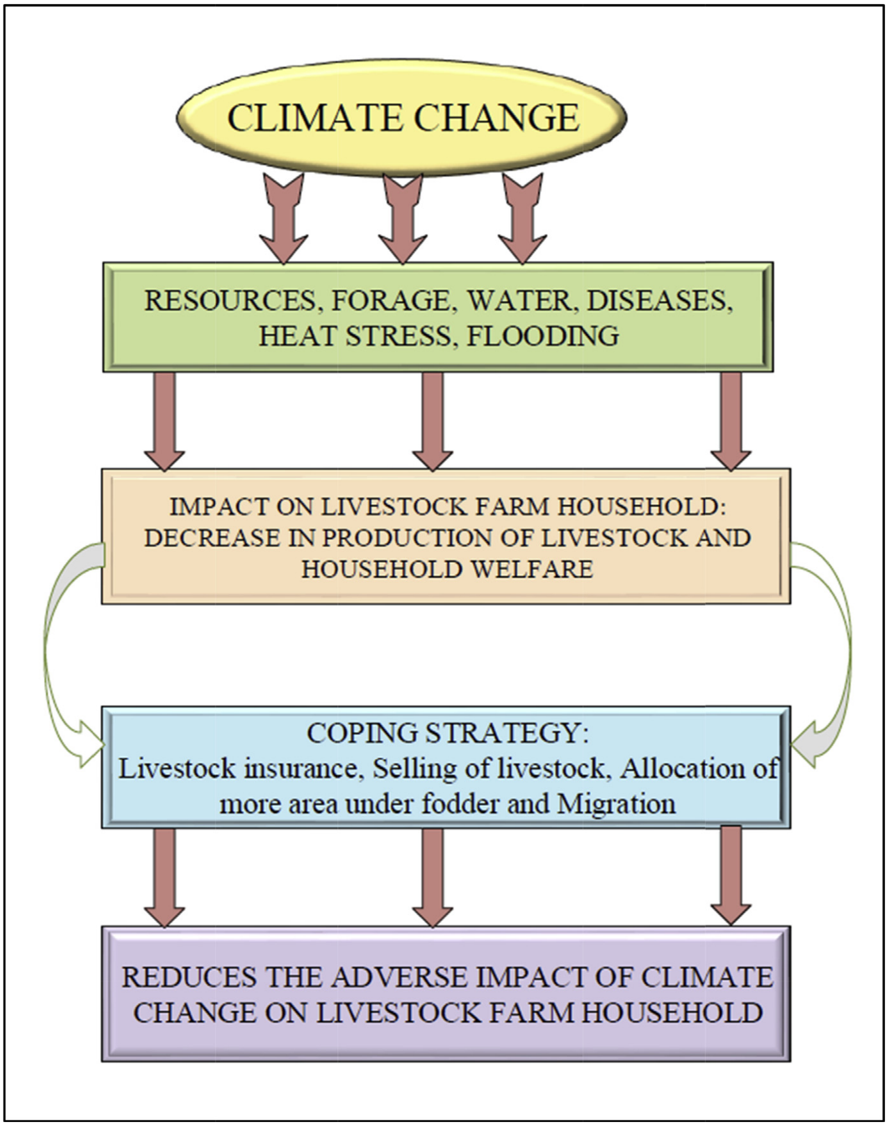

Fig. 1. Conceptual framework.

4. Materials and methods

The primary dataset was collected through a field survey of 700 livestock owners in 2017 from four major provinces (Sindh, Punjab, Balochistan, and KPK) and AJK and Gilgit Baltistan. We used a comprehensive questionnaire covering a wide range of variables to collect the data. Prior to the implementation of the survey, we

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conducted a pilot test to validate the questionnaires. We followed multi-staged sampling. In the first stage we selected all four major provinces of Pakistan and AJK and Gilgit Baltistan. In the second stage, we selected *tehsil*/villages, and in the third stage we selected a farm household for the survey. Table 2 and Fig. 2 below show the sampling methodology and distribution of the sample.

Table 2. Sample *tehsil*/village.

Selected area	*tehsil*/village
Sindh (90)	Khan Garh, Hyderabad, Matiari, Kandiyaro, MoroRohri, Saleh Pat, Tando Allah yar, Kunri, Pithoro, Summaro, Umar Kot
Azad Jammu and Kashmir (AJK) (25)	Bagh, Hattian Bala, Kotli, Muzaffarabad, Aath Maqam, Hajeera, Rawalakot, Palandri, Sadhnoti, Tarar khal
Gilgit Baltistan (35)	Gilgit, Ali Abad, Sikandarabad, Chillas, Darail, Tangir
Punjab (190)	Kasur, Chinot, Bowana, Behra, Taxila, Shalimar, Okara, Depalpur, Tandalainwala, Sahiwal, Pakpatten, Arifwala, Burawala, Mian chanu, Kamalia
Balochistan (110)	Killa Abdullah, Gulistan, Killa Saifullah, Muslimbagh, Duki, Mekhtar, Bori, Kad Kocha, Dashat, Mastung, Pishin, Huramzai, Karezat, Zhob
Khyber Pakhtunkhwa (KPK) (250)	Tangi, Charsada, Mardan, Takhtbai, Katlang, Nowshara, Pabi, Peshawar, Topi, Swabi

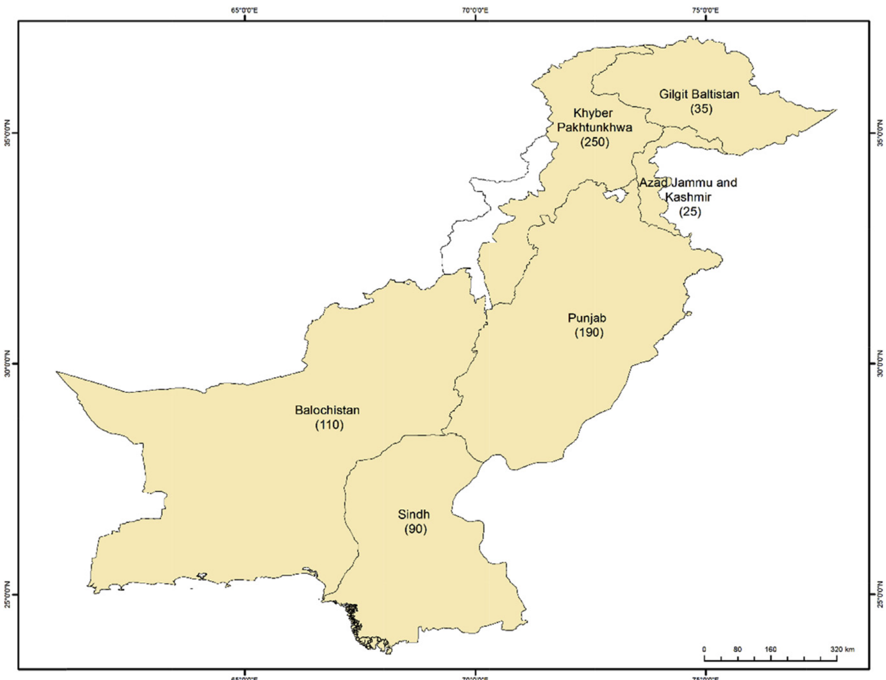

Fig. 2. Map showing sample distribution.

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We used propensity score matching (PSM) methods to appraise the effect of climate-change risk-mitigating strategies on livestock productivity, household income, food security and poverty levels, as it controls for selection bias. PSM creates the condition of a randomized experiment, and then matches the households adopting climate change risk management strategies to those not adopting climate-change risk-management strategies.

To assess the robustness of the findings, we have to evaluate the matching quality using techniques such as median absolute bias before and after matching, the value of R^2 before and after matching, and the p-value of joint significance of covariates before and after matching (Sianesi, 2004; Caliendo and Kopeinig, 2008).

5. Descriptive statistics

In Table 3 we present the description of the variables used in the analysis. The average age of the farmers was 47 years, and the mean livestock rearing experience was 28 years, which shows that the farmers were middle-aged and with a substantial amount of experience in farming. The mean age of the household head was 62 years, which means that the households are headed mostly by a senior member. Only in 43% of the cases, the farmer himself was the household head, which means the farmers are not necessarily the head of the household. About 64% of the farmers were married, and the number of members of the household stood at 9.28, which shows that family size was quite large. About 62 % were living in joint/extended family systems in which all the family members lived together, and generally, these were large families, compared to the nuclear family, typically comprising only husband, wife, and children.

Table 3. Description of variables.

Variable	Description	Mean	Standard deviation
Demographic			
Age of farmer	Age of the farmer (in years)	47.00	8.21
Experience	Experience in livestock rearing	28.00	5.89
Age head	Age of the household head (in years)	62.00	14.23
Head relationship	1 if farmer is himself head, 0 otherwise	0.43	0.25
Gender farmer	1 if farmer is male, 0 female	1.00	0.00
Married	1 if farmer is married, 0 otherwise	0.64	0.33
Family size	Number of family members living in the household	9.28	5.36
Human capital			
Education	Education of the farmer (in years)	5.00	2.76
Land assets			
Owner	1 if farmer is owner of land, 0 otherwise	0.46	0.25

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Table 3. (*Continued*)

Variable	Description	Mean	Standard deviation
Land owned	Land owned by the farmer (in hectares)	2.14	0.97
Fodder area	Area allocated for fodder production (in hectares)	0.36	0.29
Access to infrastructure and facilities			
Veterinary center	1 if the village has veterinary center, 0 otherwise	0.27	0.11
Veterinary center benefitted	1 if the farmer benefitted from veterinary center, 0 otherwise	0.44	0.31
Livestock helpline	1 if the farmer benefitted from livestock helpline, 0 otherwise	0.07	0.49
AI facility	1 if the farmer used AI facility, 0 otherwise	0.10	0.05
Crop-livestock interaction	1 if the farmer opted for the crop-livestock interaction, 0 otherwise	0.49	0.26
Fodder shortage	1 if the farmer experienced fodder shortage, 0 otherwise	0.77	0.23
Farm and household assets			
Tractor	1 if the farmer owned a tractor, 0 otherwise	0.23	0.11
Car	1 if the farmer owned a car, 0 otherwise	0.25	0.24
Television	1 if the farmer owned a television, 0 otherwise	0.81	0.50
Mobile	1 if the farmer owned a mobile, 0 otherwise	0.92	0.28
Climate change experience and coping strategies			
Info climate change	1 if the farmer had information about climate change, 0 otherwise	0.97	0.55
Update weather information	1 if the farmer is following updates on weather information, 0 otherwise	0.63	0.41
Experienced climate change	1 if the farmer is aware of climate change impacts, 0 otherwise	0.92	0.38
Insurance	1 if the farmer opted for livestock insurance, 0 otherwise	0.21	0.13
Increase in fodder area	1 if the farmer increased area for fodder, 0 otherwise	0.55	0.26
Sold livestock	1 if the farmer sold livestock at a lower price, 0 otherwise	0.14	0.05
Migration	1 if the farmer migrated to other areas, 0 otherwise	0.14	0.07

The mean years of schooling for the sampled farmers was five, which is within the national level. The average land owned by the sampled farm households was about 2.14 hectares; land holding size is comparatively low because the sampled households were livestock farmers who are mostly dependent on livestock rather than

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cropping. The area under fodder production was approximately 0.36 hectares, which is 17% of their total land holding.

Though the sampled households were livestock-rearing farmers, only 27% of the villages had a veterinary center, 44% of the livestock farmers reported to have benefitted from veterinary services, and only 7% benefitted from the livestock helpline. Approximately 10% of the farmers have availed themselves of the artificial insemination facility for cattle. A large number of farmers reported that they experienced fodder shortages (77%), and 66% of the farmers have experienced various diseases in their livestock.

Several questions on issues related to climate change were included. An overwhelming majority of the farmers (97%) reported that they had heard about climate change and 92% reported that they had experienced the impact of climate change. Despite being aware of climate change, only 63% were following weather updates. In the studied areas, farm households generally adopted four different strategies to mitigate the impact of climate change on livestock: increasing the area allocated to fodder (55%), opting for livestock insurance (37%), selling livestock (14%) and migrating (14%). Information on the number of households and farm-level assets was collected: about 23% of the households owned a tractor, 25% owned a car, 81% owned a television and 92% owned a mobile phone. According to the farmers, the severe climatic conditions during both summer and winter have affected milk and butter productivity.

Information about livestock inventory is presented in Table 4. Farm households kept cows for milk, meat and reproduction, which helped the growth of livestock assets. The average numbers of cows owned by the farmers was 2.39. Similarly, buffaloes were kept for milk and traction force, and the average number of buffaloes per household was 1.64. The average number of oxen owned by farmers was only 0.85 as they are kept for traction and meat, not milk. Sheep and goats are basically kept for meat and milk. The average number of sheep and goats per household is 5.09 and 7.75 respectively. The average numbers of donkeys, mules, and horses are 1.12, 0.57 and 0.35 respectively, and they are kept for carrying loads.

Table 4. Livestock inventory.

Livestock	Mean	Standard deviation
Cows	2.39	0.22
Oxen	0.85	0.25
Buffaloes	1.64	1.28
Sheep	5.09	2.53
Goats	7.57	3.56
Donkeys	1.12	0.95
Horses	0.57	0.24
Mules	0.35	0.20

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6. Empirical results and discussion

6.1. Determinants of livestock ownership

The determinants of livestock ownership were estimated by employing the Poisson regression[1] model, and the results are presented in Table 5. The dependent variable was the number of livestock owned by the farmers. The age coefficient is positive and significant at 1% level of significance, indicating that older farmers normally own more livestock. The family type was included as a dummy variable, i.e., 1 for the joint family and 0 for the nuclear family, and the coefficient is positive and significant, indicating that farmers living in a joint family normally keep a higher number of livestock. It may be due to the fact that joint families have surplus labor, which is needed to take care of the livestock. Likewise, the family size was positive and significant at 1%, which illustrates that households with more members rear more livestock because of the availability of the manpower needed to manage the livestock.

Table 5. Determinants of livestock ownership (Poisson regression).

Variable	Coefficient	t-value
Demographic		
Age (years)	0.013***	3.81
Family type (dummy)	0.01*	1.73
Family size (number)	0.03***	2.85
Human capital		
Education (years)	0.02***	2.46
Land assets		
Area for fodder (hectares)	0.13***	2.80
Land entitlement (dummy)	0.01**	2.14
Farm and household assets		
Tractor (dummy)	0.005	1.08
Car (dummy)	−0.07	−1.22
Television (dummy)	0.13	1.49
Mobile	0.02***	3.05
Access to facilities and infrastructure		
Extension (dummy)	0.02**	2.30
Met department (dummy)	0.02	1.43
NGOs (Dummy)	0.05	0.93
Constant	0.04**	2.18

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[1] The Poisson regression model was estimated keeping in view the normal distribution. In case of non-normal distribution negative binomial model is estimated.

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Table 5. (*Continued*)

Variable	Coefficient	t-value
Number of observations	700	
Pseudo-R^2	0.44	
LR-χ^2	483.51	
Prob > χ^2	0.000	

Note: The results (***, **, *) are significant at the 1%, 5% and 10% levels respectively.

Education is positive and highly significant at 1% level of significance, highlighting the fact that educated farmers tend to own more livestock. The area under fodder positively influenced the ownership of the livestock. Results show that the farm households with land entitlements (i.e., 1 for the owner and 0 otherwise) own more livestock compared to those without land entitlements. Household assets like tractors, cars, and televisions are non-significant, indicating that ownership of these assets does not influence livestock ownership. However, the mobile phone ownership dummy was positive and significant, which may be linked with access to information.

The contact with extension agent dummy shows that the farmers with extension contact usually have more livestock. Access to the meteorology department and NGOs were included as dummy variables, and the coefficients are positive and non-significant.

The value of R^2 is 0.44, which means that independent variables explain 44% of the variation in the dependent variable.

6.2. Climatic-risk-coping strategies adopted by livestock farmers

In the areas studied, the farmers generally adopted livestock insurance, the selling of livestock, the allocation of larger areas for fodder, and migration, as primary climatic-risk-coping strategies, which is used as the dependent variable. Migration was mostly forced due to drought, and livestock owners moved from one place to another in search of water and fodder. We employed a multivariate probit model because these four dependent variables are mutually inclusive, which means a farm household could use more than one climate-risk-coping strategy. The cross-equation correlation in Table 6 also shows the suitability of the multivariate probit model to estimate the factors influencing the choice of climate-risk-coping strategies.

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Table 6. Climate-change coping strategies adopted by livestock owners (multivariate probit estimates).

Variable	Livestock insurance	Selling of livestock	Allocation of more area for fodder	Migration
Demographic				
Age	−0.11***(−2.58)	0.02** (1.97)	−0.02***(−3.14)	−0.01** (2.85)
Family size	−0.03***(−3.46)	0.02*** (3.11)	0.01** (1.98)	0.03** (1.30)
Family type	0.01 (1.34)	0.02*** (2.41)	−0.01***(−2.45)	0.10* (1.42)
Human capital				
Education	0.02** (2.17)	−0.01 (−1.25)	0.01*** (2.78)	0.07* (1.80)
Land assets				
Landholding	0.04*** (2.65)	−0.02***(−2.53)	0.03*** (2.52)	−0.02** (2.14)
Land entitlement	0.01*** (3.10)	−0.01*(−1.86)	0.01** (2.12)	−0.01* (1.90)
Farm & household assets				
Tractor	0.04*** (2.82)	−0.02***(−3.14)	0.02* (1.85)	−0.02*(−1.84)
Car	0.01 (1.12)	−0.02**(−2.31)	0.01 (1.45)	−0.01*(−1.93)
TV	0.02*** (2.69)	−0.01 (1.23)	0.02** (2.14)	−0.06**(−2.11)
Mobile	−0.01*(−1.88)	0.02** (2.54)	−0.01*** (2.55)	0.01 (1.41)
Access to facilities and infrastructure				
Extension	−0.01*(−1.76)	0.02* (1.82)	0.01*** (3.37)	−0.14*(−1.70)
NGOs	0.02*** (2.53)	0.01*** (3.48)	0.01** (2.05)	0.05* (1.03)
Met department	0.02 (1.32)	0.01 (1.54)	0.03 (0.78)	0.06* (1.82)
Constant	0.03** (2.55)	0.04*** (2.71)	0.03** (2.44)	0.01 (1.33)
Number of observations		700		
Pseudo-R^2		0.39		
LR-χ^2		310.05		
Prob > χ^2		0.000		
Cross equation correlations	ρ_{12} 0.24*** (3.45) 0.11** (2.15)	ρ_{13} 0.36*** (3.16) 0.13*** (3.05)	0.44** (2.09)	ρ_{23} 0.21* (1.86)

Note: The results (***, **, *) are significant at the 1%, 5% and 10 % levels respectively.

The age coefficient was negative and significant in the cases of livestock insurance, allocation of more area to fodder crops, and migration, indicating that young farmers use these strategies to mitigate the impact of climate risk on livestock. However, the age coefficient for selling livestock was positive and significant, indicating that older farmers sell livestock to cope with climate-change risk. Family size was negative and significant for livestock insurance, while positive and significant for selling of livestock and allocation of more areas for fodder.

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The education level of the farmer positively influenced the household decision to adopt livestock insurance, allocate more area for fodder, and to migrate as a strategy to mitigate the adverse effects of climate change. Land holding and land entitlement was positive and significant for the adoption of livestock insurance and allocation of more area for fodder, while negative and significant for selling of livestock and migration, highlighting that farmers with larger land holdings and landowners mostly adopted livestock insurance and allocated more area for fodder because of their affordability. Poor farmers tended to either sell livestock or migrate to cope with the climate risk.

A number of household assets were also included in the model like tractors, cars, and televisions, and the coefficients were positive and significant in the cases of crop insurance and allocation of more area for fodder, while negative and significant in the cases of selling livestock and migration. This indicates that farmers with more assets mostly do not sell livestock, choosing a different strategy to combat the risks of climate change.

The extension contract was included as a dummy variable, and the coefficient is negative and significant for livestock insurance and migration, while positive for selling livestock and the allocation of more area for fodder. The NGOs were included as a dummy variable, and the results were positive and significant for livestock insurance, selling livestock, and allocation of more area for fodder, which means that NGOs discouraged migration and induce farmers to take up insurance, allocate more land for fodder and sell livestock. The meteorology department was included as a dummy variable, and the results were non-significant.

6.3. Impact of climate change on household income, food security and poverty levels

We used a propensity score matching approach to assess the impact of different climate change-risk-coping strategies on the production of milk, butter, household income, poverty levels and livestock diseases (see Table 7). In this approach, the nearest neighbor matching (NNM) algorithm was employed for the estimation, as nearest neighbor matches with the similar nearest neighbor in the opposite group.[2] The average treatment affect in the case of PSM analysis for the treated (ATT) indicates the difference in outcomes for the farmers who have adopted climate-change-mitigating strategies and for those who have not.

[2] According to Sianesi (2004) it is always better to use more than one matching algorithm.

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Table 7. Impact of climate-change risk-coping strategies on livestock production and efficiency.

Outcome	ATT	t-values	Critical level of hidden bias	Number of treated	Number of controls
Insurance					
Milk (liters/day)	0.76***	2.57	1.15−1.20	130	472
Butter (kg/month)	1.20	1.46	-	130	472
Household income (rupees)	2400	2.05	1.25−1.30	130	472
Poverty levels (Head count index)	−0.04***	−2.53	1.10−1.15	130	472
Livestock diseases (dummy)	0.02**	2.43	1.25−1.30	130	472
Fodder area					
Milk (liters)	0.83***	2.50	1.35−1.40	216	309
Butter (kg)	1.55***	2.67	1.55−1.60	216	309
Household income (rupees)	3600***	3.56	1.70−1.75	216	309
Poverty levels (Head count index)	−0.04***	2.78	1.40−1.45	216	309
Livestock diseases (dummy)	−0.015*	−1.92	1.35−1.40	216	309
Selling of animals					
Milk (liters)	−1.20**	−2.17	1.40−1.45	155	242
Butter (kg)	−0.84	1.27	-	155	242
Household income (rupees)	1400***	−3.05	1.20−1.25	155	242
Poverty levels (Head count index)	0.01	1.34	-	155	242
Livestock diseases (dummy)	−0.02**	−2.17	1.30−1.35	155	242
Migration					
Milk (liters)	−0.62**	−2.06	1.20−1.25	43	251
Butter (kg)	−0.25*	−1.72	1.25−1.30	43	251
Household income (rupees)	−837**	2.14	1.45−1.50	43	251
Poverty levels (Head count index)	0.01	1.55	-	43	251
Livestock diseases (dummy)	−0.05*	1.83	1.25−1.30	43	251

Note: PSM was implemented by employing the Nearest Neighbor Matching (NNM) algorithm. The ATT stands for the average treatment affect for the treated. The results (***, **, *) are significant at the 1%, 5% and 10 % levels respectively.

The impact of livestock insurance as a risk-coping strategy is positive and significant for milk and butter production, household income and disease levels, while negative and significant for poverty levels. The ATT results show that farmers who adopted livestock insurance as a coping mechanism had a higher milk yield by up to 0.76 kg per day compared to the households who did not adopt it. The ATT results for the butter yield are also higher by up to 1.20 kg per month, and the ATT results for household income are higher by about 2,400 Pakistani rupees, a 5% level of significance. The ATT results for poverty are negative and significant indicating that the poverty level is up to 4% lower for those farm households who adopted the livestock insurance. With livestock insurance, farmers are able to obtain compensation for any

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damage resulting from climate shock; hence farmers with insurance have greater resilience.

The PSM results for allocating more area for fodder are positive and significant for milk and butter production as well as household income, while it is negative and significant for poverty levels and livestock diseases. The ATT results for milk are 0.83 liters per day highlighting that the farmers who allocated more area for fodder were able to obtain higher milk production because of the availability of a sufficient quantity of diverse fodder and sufficient nutrients. The ATT results for butter yields are 1.55 kg per month, suggesting that butter production is more for households who allocated more area for fodder. The increase in butter may be due to increased production of milk. The ATT results show that household income levels are higher by up to 3,200 Pakistani rupees for this strategy, and the poverty levels are lowered by up to 4%. Increase in milk and butter production lead to an increase in income and reduction in poverty levels. The ATT results for livestock diseases demonstrate that disease levels are lowered by up to 15%, which may be due to the availability of required nutrients.

The results regarding the selling of animals are negative and significant for milk and butter production while positive for household income. The results are negative for poverty and disease levels. When the household sells their livestock, it generates cash income in the short run, but in the long run, it reduces regular generation of income, which is evident from the fact that milk and butter production of the households who sold livestock as a strategy to cope with climate risk, is lower.

In some areas, especially areas with less water, households use migration as a climate-change risk-mitigating strategy. The ATT results for the milk yield are negative and significant, demonstrating that migrant households have lower milk production by up to 0.62 kg/day. The butter production is negative and significant, with an ATT value of 0.25 kg/month. The household income is lower by up to 837 Pakistani rupees. Poverty and disease levels are higher. Hence migration should be the least favoured strategy to cope with climate risk.

The results regarding the critical level of hidden bias and the numbers of treated and control groups are reported in Table 7. The critical level of hidden bias indicates the level up to which the households which adopted the climate-change risk-management strategies and those who did not, differ from each other due to unobservable characteristics.

As the main purpose of the PSM is to balance the covariates before and after matching, we employed a number of matching tests such as median absolute bias before and after matching, the value of R^2 before and after matching, and

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the joint significance of covariates before and after matching. The results are presented in Table 8. The median absolute bias was considerably reduced after matching, and the percentage bias reduction is in the range of 64−81. Similarly, the value of R^2 has been reduced considerably after matching, signifying that after matching both the groups are very similar to each other. The P-value of the joint significance of covariates is significantly higher after matching, which indicates that after matching both categories of the farmers (adopter and non-adopters) were very similar to each other. In other words, the covariates were balanced, and both groups are quite similar to each other. The imposition of the common support condition and the balancing of the covariates results are also reported in Fig. 3.

Table 8. Indicators of Covariates Balancing (before and after estimates).

Outcome	Bias before matching	Bias after matching	% Age bias reduction	Value of R^2 before matching	Value of R^2 after matching	LR-χ^2 before matching	LR-χ^2 after matching
Insurance							
Milk	24.53	6.82	72.20	0.362	0.002	0.001	0.721
Butter	22.42	7.35	67.22	0.228	0.003	0.002	0.673
Household income	20.01	5.12	74.41	0.316	0.005	0.001	0.584
Poverty levels	22.63	6.26	72.34	0.245	0.004	0.002	0.492
Livestock diseases	20.14	6.38	68.32	0.192	0.003	0.005	0.234
Fodder area							
Milk	22.36	5.82	73.97	0.194	0.004	0.002	0.268
Butter	20.53	7.19	64.98	0.205	0.002	0.002	0.342
Household income	21.72	6.38	70.63	0.316	0.001	0.004	0.265
Poverty levels	17.39	5.23	69.93	0.268	0.003	0.002	0.337
Livestock diseases	20.45	7.35	64.06	0.215	0.001	0.002	0.321
Selling of animals							
Milk	20.23	6.22	69.25	0.265	0.001	0.003	0.418
Butter	21.52	7.38	65.71	0.384	0.003	0.002	0.364
Household income	18.73	3.40	81.85	0.286	0.002	0.004	0.296
Poverty levels	19.46	4.15	78.67	0.251	0.004	0.001	0.371
Livestock diseases	18.50	4.72	74.49	0.384	0.003	0.003	0.372
Migration							
Milk	17.21	5.29	69.21	0.278	0.000	0.001	0.441
Butter	19.51	5.41	72.14	0.264	0.002	0.000	0.385
Household income	20.25	6.78	67.05	0.341	0.004	0.002	0.234
Poverty levels	23.41	4.60	80.71	0.291	0.005	0.006	0.176
Livestock diseases	21.13	5.21	75.26	0.281	0.006	0.000	0.255

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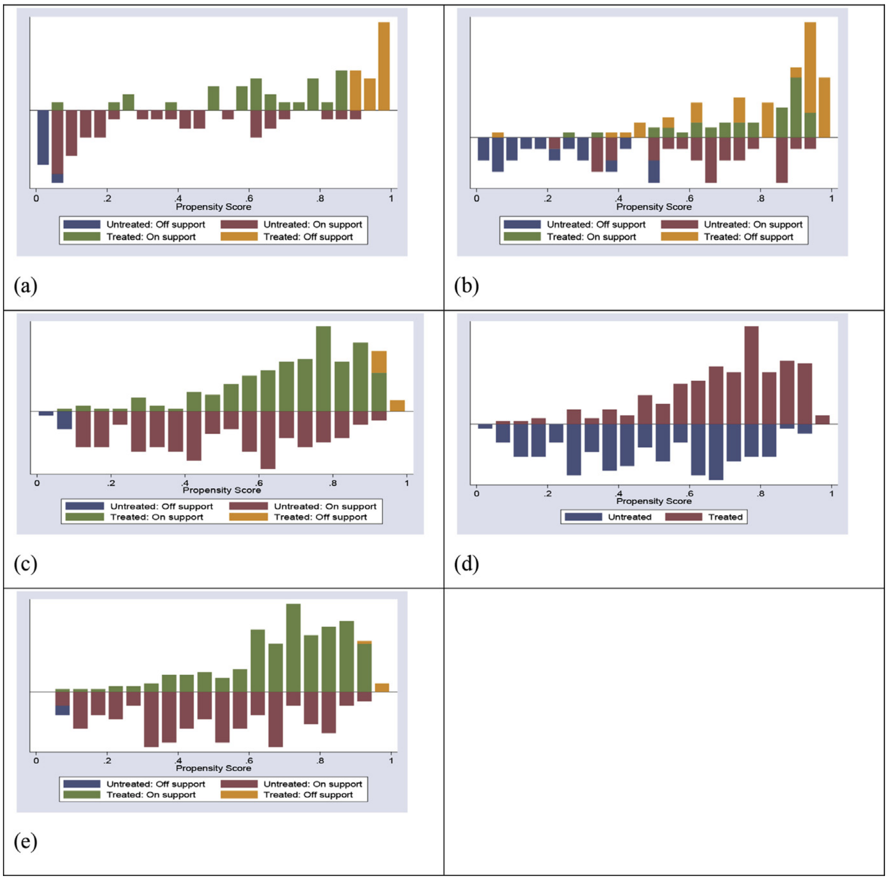

Fig. 3. Indicators of the covariates balancing. Note: In the above figure (a) Impact on milk productivity (b) Impact on butter productivity (c) Impact on household income (d) Impact on poverty levels and (e) Impact on livestock diseases. Treated on support were the farmers being able to find suitable match in the opposite group, treated off support were the farmers being unable to find suitable match in the opposite group. Untreated on support were the farmers in the control group who were able to find suitable match in the opposite group, while the untreated off support were the farmers who were in the control who were unable to find suitable match in the opposite group.

7. Conclusions

This research uses a rich primary dataset, collected from four major provinces of Pakistan and AJK and Gilgit Baltistan, to understand the climate risk faced by livestock farmers and the strategies adopted by them to cope with such risk. Even though livestock is an integral part of rural livelihoods and a large number of livestock farmers are facing climate risk, only a small number of villages have a veterinary center, and a limited number of farmers have benefitted from the meteorological department and livestock veterinary services. Under the changing climatic conditions, the land size, family size, and access to extension services positively influence livestock ownership in rural Pakistan.

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As climate change is threatening the livelihood of livestock farmers in Pakistan, farm households are adopting measures to mitigate the adverse effects of climate change. Farm households in this study primarily implemented four main risk-coping strategies, which included livestock insurance, allocation of more area for fodder, selling livestock, and migration.

We find that households with older heads tend to pursue selling livestock to cope with climate risk while households with younger heads are likely to go for livestock insurance, allocation of more area for fodder and migration. Households with larger families are less inclined to use livestock insurance and more inclined to sell livestock, allocate more land to fodder and migrate as strategies to cope with climate change. Households with a more educated head pursue livestock insurance, allocate more land for fodder and migrate to lessen the impact of climate change on livestock. Wealthier households who own land and have more land assets are likely to opt for livestock insurance, or the allocation of more land for fodder to manage climate risk and are unlikely to sell livestock and/or migrate. Households who are members of NGOs are likely to pursue all four climate-risk mitigating strategies while those with contact with extension services are more likely to sell livestock and/or allocate more land for fodder.

The PSM results indicate that climate-risk-coping strategies have a positive impact on household welfare, as the adopters have higher milk and butter yields, as well as household incomes compared to non-adopters. Similarly, the incidence of poverty levels is lower for those households which adopt measures to mitigate the impact of climate change. As the adoption of a strategy to reduce the impact of climate change on livestock leads to the improvement in the well-being of rural families, policies should focus on implementing and strengthening measures, particularly livestock insurance and allocation of more land for fodder, to cope with climate risk. A policy such as training and education on climate risk, enhancing extension services and increasing asset endowments would support the mitigation of climate-change risk on livestock.

Declarations

Author contribution statement

Dil Bahadur Rahut: Conceived and designed the experiments; contributed to writing of the paper; Analyzed and interpreted the data.

Akhter Ali: Performed the experiments; Analyzed and interpreted the data; Contributed to materials and methods, analysis tools, or data; Wrote the paper.

Competing interest statement

The authors declare no conflict of interest.

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