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ORIGINAL ARTICLE

What Defines Livelihood Vulnerability in Rural Semi-Arid Areas? Evidence from Pakistan

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Abstract
Rural livelihoods in semi-arid Pakistan are increasingly exposed to climate impacts such as rising temperatures, erratic rainfalls and more intense and frequent climate-related extreme events. This is introducing new risks to the already vulnerable and marginalised societies that lack development and have high poverty rates. This study uses the IPCC Livelihood Vulnerability Index (LVI) approach to analyse the determinants of household livelihood vulnerability defining vulnerability in terms of exposure, sensitivity and adaptive capacity. It also determines various adaptation responses that farmers apply and elucidates the reasons why some farmers choose not to adapt to climate change. It focuses on three semi-arid districts in Pakistan (Faisalabad, D.G. Khan and Mardan) and uses a sample of 150 rural agricultural households. As per the LVI scores, D.G. Khan is the most vulnerable district to climate change impacts, followed by Mardan and Faisalabad, respectively. Results show that (a lack of) adaptive capacity plays quite an important role in shaping households' livelihood vulnerability for any given degree of exposure and sensitivity. Besides lower exposure and sensitivity to climate change, extremely low levels of adaptive capacity make Mardan more vulnerable to climate change compared to Faisalabad. The paper argues on people-centric development for rural areas through strengthening of agriculture sector as well as providing rural household opportunities for off-farm livelihoods.

Keywords Climate change · Vulnerability · Adaptation · Rural livelihoods · Semi-arid regions

1 Introduction

Rural areas are characterised by high dependence on agriculture, low human development levels, low adaptive capacities and receive little attention from policymakers (Skoufias et al. 2011; Dasgupta et al. 2014; Panthi et al. 2015). According to the IPCC Fifth Assessment Report (Dasgupta et al. 2014), climate change introduces grave implications for rural areas through a direct toll on rural livelihoods. Rural economies in semi-arid regions are primarily natural resource based. In this regard, rural livelihoods are shaped by complex political, economic, institutional and biophysical conditions (Abid et al. 2016). This implies that farmers' livelihoods are affected by factors such as government policy on agriculture, the taxing structure, availability of extension programmes, subsidies, market structures, connectivity and infrastructure in addition to the characteristics of natural resources such as soil quality, fertility, and water availability (Belliveau et al. 2006). Climate change and its impacts add another dimension by introducing risks that further complicate livelihood activities (Salik et al. 2015). These impacts may be presented through either a slow onset of climate/environmental changes affecting rural livelihoods,[1] or through extreme events such as (amongst others) droughts, floods, and heat waves (Dasgupta et al. 2014).

The adverse impacts of climate change on farm-based livelihoods are manifested through shifts in cropping seasons and a loss in agricultural productivity (IPCC 2014). This not only translates into loss of income, but also exacerbates food insecurity among the rural population. Especially vulnerable are those households who are engaged in subsistence farming. Furthermore, climate extremes resulting in widespread destruction have livelihood consequences that may resonate long after the event has passed. Through loss of lives,

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[1] Based on agriculture and ecosystems such as (amongst others) the natural trend of environmental degradation, population pressures and land use changes.

property and livelihoods, people lose their human, physical, natural and financial capital that has long-lasting repercussions on income and income-generating means (Gray and Mueller 2012; Ngwa et al. 2015). It is estimated that between 2000 and 2005 alone, natural disasters led to a loss of about 250 million livelihoods per year globally (Feron 2012, cited in Ngwa et al. 2015). The threats associated with climate change impacts may lock the already marginalised rural population in poverty traps as their livelihoods are exposed to additional risks, thereby perpetuating poverty, deprivation and livelihood insecurity (IPCC 2014; Ngwa et al. 2015).

In view of the enhanced vulnerability of semi-arid regions to climate change (IPCC 2014), this paper attempts to identify the key determinants of vulnerability in three semi-arid districts of Pakistan using an indicator-based approach. By providing a comparative vulnerability ranking for the selected districts, it also aims to encourage investment in adaptation strategies that are better suited to the needs of the population. This paper uses the IPCC-Livelihood Vulnerability Index for developing site-specific vulnerability scores that portray the unique aspects that determine districts' vulnerability to climate change.

1.1 Rural Economy in Semi-Arid Pakistan

Being primarily an agrarian country, 61% of the population of Pakistan lives in the rural areas and over 45% derives its income from agriculture (The World Bank 2015). However, Pakistan's economy is transforming from agrarian and rural to a more industrial- and service-based economy, leading to a declining share of agriculture in the Gross Domestic Product (GDP) (GoP 2016). Despite the staggering agricultural contribution to GDP, its importance cannot be denied in terms of the employment it generates. The rural livelihood profile of Pakistan shows that households' livelihood activities are somewhat diverse, but the prime source of income is mostly agriculture (Irfan 2007; Hamid and Afzal 2013).

Women's role in the rural economy is crucial, yet it goes largely unnoticed because of strong patriarchal norms (Samee et al. 2015). Rural women of all ages actively participate in agricultural production, livestock rearing and cottage industries. However, much of the work they perform is unpaid or underpaid and mostly ignored in public policy and development planning. Women are involved in farming during various stages such as seed bed preparation, weeding, and crop harvesting (Ishaq and Memon 2016), yet despite all their efforts, they are merely considered 'helpers' to their male family members and get little to no remuneration.

Pakistan, owing to its geographical location in arid and semi-arid zones,[2] is expected to witness high temperatures as impacts of climate change make themselves more evident (Arif 2007; Hussain 2010; Abid et al. 2016). Afzaal and Haroon (2009) postulated in their study that the rate of area-weighted annual temperature rise in Pakistan is speeding up. The rate of average annual temperature change was 0.2 °C between 1907 and 1945 per decade, which by 2007 had gone up to 0.53 °C per decade.[3] In a comprehensive assessment, Salik et al. (2015) explain future climate trends in Pakistan based on country-specific climate scenarios. Using RCP8.5[4] scenario, it was projected that during 2030–59, average annual temperature is expected to rise by 2 °C or slightly less in semi-arid regions (with base period 1970–1999), especially in the irrigated plains. Precipitation has the probability of declining in the monsoon belt, comprising the arid and semi-arid regions, however, uncertainty related to precipitation trends is high. Salik et al. (2015) project a decrease in average precipitation in the first half of the year (up to − 17%) and an increase in the second half of the year (up to + 12%). As agriculture is largely concentrated in the arid and semi-arid regions of Pakistan, these areas are the breadbasket of the country. In that sense, climate risks to these areas may affect the already discouraging state of food security in the country (Shah et al. 2005).

Semi-arid lands in Pakistan predominantly feature irrigated agriculture. However, in southern semi-arid districts of Pakistan such as D.G. Khan, agricultural farms are also irrigated through hill torrents (Dawn 2007). It is speculated that climate change would render river flows highly unpredictable due to increasingly early and rapid melting of glaciers. In some years, the increase in early melting of Hindu Kush Himalaya (HKH) glaciers will be coupled with monsoon period in the country, often leading to increased flooding in the rivers (Hasson et al. 2017). In other years, projections also show that delayed and decreased glacier melting may reduce river flows, thereby unfavourably affecting crop production (ibid.).

One fourth of the cultivable area of Pakistan suffers from wind and water erosion, salinity, inundation and water logging (Irfan 2007). Agricultural productivity, particularly for

[2] About 70% of Pakistan's geographic area can be characterised as semi-arid, receiving annual rainfall of about 250 mm (Alam 2000; Qaisrani 2015).

[3] The area-weighted anomaly has been calculated using 1961–1990 as base period.

[4] The RCP8.5 combines assumptions about high population and relatively slow income growth with modest rates of technological change and energy intensity improvements, leading in the long term to high energy demand and GHG emissions in absence of climate change policies. RCP8.5 thus corresponds to the pathway with the highest greenhouse gas emissions.

winter crops such as wheat, often suffers due to heat waves (Qin et al. 2014; Saeed et al. 2015). A study by the Asian Development Bank (2012) observes that subsequent impacts of climate change may adversely affect the production of cereal crops in Pakistan. With the River Indus being the lifeblood of semi-arid regions, alternate periods of droughts (1999–2012) and floods (2010 onwards) have immensely increased the vulnerability of livelihoods based on river flows (Asian Development Bank 2012). The changing patterns of monsoon rains increase the risk of flash-flooding in the hill-torrent zones of the country (Hussain 2010). As a result, extreme events have become more frequent and less predictable in the recent years (GoP 2013).

2 Literature Review

For any adaptation effort to be initiated in response to climate change impacts, vulnerability assessment is often the preliminary step. Fussel (2007) described three approaches to understand vulnerability of a system: (1) a risk-hazard approach that looks into the risk that a system experiences as a result of exposure to a particular hazard; (2) a social constructive approach that considers the socioeconomic dynamics which shape the ability of a system to respond to any shock; and (3) an integrated approach that combines the earlier two forms to integrate the hazard exposure as well as the socioeconomic capacity to respond to that hazard. These classifications are similar to the work of Turner et al. (2003) who classified vulnerability into three approaches: risk-hazard model, pressure and release model and an expanded vulnerability model. Exploring climate change-related vulnerability finds its relevance in the integrated approach (Fussel 2007; Adger 2006) or the expanded vulnerability model (Turner et al. 2003), both of which consider the synergies between the human and biophysical systems.

A number of vulnerability assessment frameworks have been utilised over the past decade that aspire to provide a metrics for quantifying vulnerability. Preston et al. (2011) gave a critical review of 45 vulnerability mapping studies through the context of (1) goals of assessment, (2) vulnerability framework used, (3) technical methodologies applied for assessing vulnerability and (4) users, beneficiaries and participants of the assessment activity. The review showed that a lack of consensus on the appropriate methodology and framework often leads to choice of methods based on ease of use rather than the effectiveness of the approach. According to the authors, the objective of conducting the vulnerability assessment directs the efficiency of the method used.

Although methods of vulnerability assessment may often be debated, studies focusing on vulnerability agree that exposure to risk, sensitivity to damage and the capacity to recover are essential elements of determining vulnerability (IPCC 2001; Cutter 2003; Adger et al. 2003; Hahn et al. 2009; Shah et al. 2013 etc.). In the context of sustainable livelihoods, vulnerability assessment is often undertaken through an indicator-based approach. Adger et al. (2003) used an indicator-based approach to understand how various factors interact to explain vulnerability significantly. As per the conceptual framework developed by the authors, vulnerability cannot be defined in terms of singular indicators nor it is static; rather different factors combine differently in a specific context to determine a system's vulnerability in a dynamic way.

Hahn et al. (2009) calculated livelihood vulnerability for two districts of Mozambique through two alternative methods: the Livelihood Vulnerability Index (LVI) and the IPCC–LVI. The authors used primary data collected at the household level. Both methods produced similar results related to the vulnerability status of the two districts. This methodology categorises incidence of natural disasters, climate variability, early warnings and monetary loss due to climate events under exposure; food, water and health conditions under sensitivity; and socio-demographic, livelihood strategies and social networks under adaptive capacity. The study provides a practical approach to identify factors that play a significant role in explaining the vulnerability of the areas. The ad hoc selection of indicators can be debated, but at the same time, such a context-based choice of indicators actually proves to be helpful in capturing the local aspects that determine the districts' vulnerability.

Hahn et al. (2009) have offered a replicable methodology which has been used by many researchers to determine vulnerability in different contexts (e.g. Pandey and Jha, 2012; Shah et al. 2013; Panthi et al. 2015, Adu et al. 2017, etc.). Pandey and Jha (2012) used the approach for two communities in rural India in the Lower Himalayan region and provided a comparative analysis of the strengths of rural mountainous livelihoods. The study found that owing to the similar ecological settings, the difference in exposure and sensitivity between the two regions was offset, portraying a somewhat similar picture of overall vulnerability. Similarly, Shah et al. (2013) employed the Livelihood Vulnerability Index for the case of two rural communities in wetlands of Trinidad and Tobago. Apart from providing a community comparison, the study also compared vulnerability scores on gender basis and found that female-headed households are more vulnerable as per the index, compared to male-headed households. Panthi et al. (2015) applied the methodology for the case of agro-livestock owners in three ecologically different districts in Nepal. Besides throwing light on the site-specific determinants of vulnerability, the study found that a lack of income and livelihood diversification opportunities is the prime causes of high vulnerability in all districts. Applying the same methodology for two communities in Ghana, Adu et al. (2017) identified that both regions had different determinants of vulnerability. While the Wenchi community's high vulnerability was due to high climate variability, high incidence of natural disasters and shortage of food and water (i.e. high exposure and sensitivity), low adaptive capacity in the Techiman region, primarily due to limited livelihood strategies, was the defining factor of vulnerability for this community.

Such index-based analyses have certain precedence over other methodologies that rely on secondary data as they are better designed to provide a localised viewpoint, giving context-based insight for local needs and adaptation responses required. As vulnerability is a socially constructed subject (Hinkel 2011), studies based on primary data collection or those employing a mix of primary and secondary data are better posited to provide insight on socially determined drivers of vulnerability. This paper aspires to identify the determinants of livelihood vulnerability in three semi-arid districts of Pakistan and also aims to compare the scores to encourage investments on issue-oriented adaptation strategies.

3 Methods

The Third Assessment Report of the IPCC (2001) defines climate change vulnerability as:

> The degree to which a system is susceptible to, or unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

In its most simple form, vulnerability is the tendency to be adversely affected (Kelly and Adger 2000; IPCC 2001; Fussel 2007; Opiyo et al. 2014). Since the primary aim of this study is to understand vulnerability as an outcome, rather than as a factor that shapes an outcome (i.e. risk) (IPCC 2014), we consider vulnerability of a system within three components:

1. Exposure to a risk or a hazard.
2. Sensitivity to that risk or hazard.
3. Capacity to respond to that hazard either by coping, recovering or adapting from the situation (IPCC 2001; Smit and Wandel 2006; Reed et al. 2013).

These drivers of vulnerability differ according to geographic location, economic situation, socio-political scenarios, psychological conditions, infrastructural development, institutional capacities as well as individual characteristics such as gender, age, health, and education (Zarafshani et al. 2016).

This research applies the IPCC Livelihood Vulnerability Index to study the risks imposed by climate-related extreme events on agricultural households in semi-arid regions. The IPCC Livelihood Vulnerability Index offers a tested technique that has the ability to identify the determinants of vulnerability and at the same time possessing the capacity to compare scores among different units (Adu et al. 2017). It also allows contextualising the choice of indicators to the local scenario. The power of providing household level analysis is also a positive feature of this methodology (Adu et al. 2017). We take guidance from work done by Hahn et al. (2009) and Panthi et al. (2015) and apply it to the specific context of semi-arid regions of Pakistan.

4 Computational Method

For computing the IPCC-Livelihood Vulnerability Index, we have categorised components of socio-demographic profile, livelihoods, health, social networks, food, water and natural disasters and climate variability into aspects exposure, sensitivity and adaptive capacity (Hahn et al. 2009; Adu et al. 2017). The data used in the computation of subcomponents have been measured at different scales, so it is essential to rescale/normalise data before measuring vulnerability index (Hahn et al. 2009). For this purpose, the min–max normalisation technique (Patro and Sahu 2015) has been applied using the following formula:

$$\text{Index}_{\text{sd}} = \frac{S_{\text{d}} - S_{\min}}{S_{\max} - S_{\min}}.$$

Here S_{d} is defined as the original value of a variable, and $S_{\min}$ and $S_{\max}$ reflect the minimum and maximum values of that variable, respectively.

In addition, to determine the internal validity of the identified variables, Chronbach's Alpha Test was applied. With the test score of 0.675, it is drawn that the included variables are internally consistent.[5] The balance weighted average approach was, then, applied (Beccari 2016) which provided equal weighted index for each sub-component.

Following the normalisation of variables, method of aggregation was employed to find out the values of exposure, sensitivity and adaptive capacities using the following equation:

$$\text{CF}_{\text{d}} = \frac{\sum_{i=1}^{n} w_{\text{Pi}} P_{\text{di}}}{\sum_{i=1}^{n} w_{\text{pi}}}.$$

[5] Co-efficient values close to 0.70 or higher represent internal consistency (Babin and Zikmund 2015).

Here, CF_d is defined as the contributor factor such as exposure, sensitivity and adaptive capacity for each of the districts. The major components of each of the contributing factor are expressed by P_{di}, weights of the components are expressed by w_{pi} and n reflects the number of major component in each of the contributing factors. All individual indicators were equally weighted. Using equal weights for constructing composite indices is the most popular method (Beccari 2016). Different weights for each proxy variable leave room for subjective value judgment as experts and researchers may give different value to variables (Hudrlikova 2013). A weighted average was obtained for each of the major components as per the above equation. Following that, IPCC–LVI formula, given below, was applied to combine the weighted averages to obtain scores for each of the districts (Deressa et al. 2008). IPCC–LVI ranges from 0 (least vulnerable) to 1 (most vulnerable). The computations were conducted on the software titled Statistical Package for Social Sciences (SPSS).

$$\text{IPCC} - \text{LVI} = (\text{Exposure} + \text{Sensitivity}) - \text{Adaptive Capacity}.$$

To test the significance of difference in the values of indicators, we applied sample t-test to the indicators comprising the index for all possible pairs of the three study sites (Adu et al. 2017; Salik et al. 2017). Majority of the indicators show significance difference among the indicators between the three sites. Table 5 in "Appendix" shows the p values of the differences in indicators between the sites.

This study presents a holistic picture of rural agricultural households' vulnerability to climate change and climate extremes in three semi-arid sites of Pakistan. The research adopts a case study approach for each site to define its vulnerability in terms of exposure, sensitivity and adaptive capacity, while also throwing light on the adaptation strategies available to the farmers. Table 1 presents the selection of indicators for these three components and provides their criteria for justification:

4.1 Study Sites and Data Collection

With respect to the focus on semi-arid regions in Pakistan, the study areas include two districts of Punjab (Faisalabad and D.G. Khan) and one district of Khyber Pakhtunkhwa (KP) (Mardan).[6] Figure 1 shows the map of Pakistan with the study sites highlighted. Union Councils within the district were purposely selected that had witnessed climate extreme events in the past:

1. UC 108 Rattar Chattar, Faisalabad.
2. UC 28 Kala, D.G Khan.
3. UC 34 Bala Garhi, Mardan.

These UCs were identified in consultation with subject expert stakeholders as well as by drawing on the knowledge of locals.

4.1.1 Faisalabad

Located in Central Punjab, District Faisalabad has a comparatively thriving economy compared to the other two study sites. More than half (52.2%) of the district's population resides in the rural areas (PBS 2018). Drawing on the descriptive facts from the survey, 64% of respondents in Faisalabad had diversified incomes. About 66% of the households were headed by individuals with at least secondary level education. Wheat is commonly grown as a winter crop, cultivated by more than 90% of the respondents. During the summer season, sugarcane is the most popularly grown crop, often in combination with cotton or fodder. Farmers primarily cultivate winter and summer crops for the sale of products, while saving some portions of wheat for household consumption. In 10% households, women were actively involved in labour force activities. Working women in Faisalabad district were mostly salaried, engaged in government jobs (such as village school or local health clinic) as well as private jobs (including work as domestic help).

4.1.2 Khan

Located in South Punjab, the semi-arid district of D.G. Khan hosts 80.9% of its population in rural areas (PBS 2018). A descriptive analysis from the survey depicts that even though 80% of the respondents rely on more than one source of income, agriculture is still the lifeline of their livelihoods. Wheat is the most popular winter crop grown in the district (harvested by 94% of the respondents) which is often coupled with sugarcane as a secondary crop. In summers, cotton is the most commonly harvested crop (grown by 68% of respondents) which is often grown in combination with rice and fodder. About 30% of the households surveyed had at least one female member active in the labour force. Majority of these women were involved in agriculture, i.e. managing livestock or helping their male household members in farming activities.

4.1.3 Mardan

Mardan is located in the Khyber Pakhtunkhwa (KP) province of Pakistan. Majority population (81.5%) resides in rural areas (PBS 2018). As much as 82% of the households surveyed showed income flows from more than one stream, while the prime occupation remained agriculture. Most households had one or more members working as

[6] For more details about site selection, refer to Salik et al. (2017).

Table 1 Indicators for IPCC Livelihood Vulnerability Index

Indicators and subcomponents	Explanation	Source of data	Functional relationship	References
Exposure				
Climate extremes/disaster	Average number of climate extreme events in the last 10 years (derived from the total number of climate disasters reported by the households in the past 10 years)	Household survey	More frequent events lead to higher exposure	Panthi et al. (2015) Hahn et al. (2009) Salik et al. (2015)
Temperature variability	Monthly variability in average temperature	Pakistan Meteorological Department	Increase in temperature variability increases the risk to crop yield	Porter and Semenov (2005) Salik et al. (2015)
Hot months	Number of extreme hot months with average monthly temperature above 30 °C	Pakistan Meteorological Department	Higher the frequency, higher will be the exposure	Salik et al. (2015)
Precipitation variability	Monthly variability in average precipitation	Pakistan Meteorological Department	Increase in the variability of precipitation increases the risk to crop yield	Porter and Semenov (2005) Salik et al. (2015)
Extreme dry months	Number of extreme dry months explained as the months during spring season having precipitation < 5 mm and in summer precipitation = 0 mm	Pakistan Meteorological Department	Higher the frequency of dry months higher will be risk of drought/water shortage which leads to enhanced exposure	Salik et al. (2015)
Monetary loss	Average monetary loss in PKR incurred due to last extreme event	Household survey	Higher the loss, greater will be the exposure to climate change impacts	IPCC. (2001)
Crop failure	Percentage of households that experienced complete crop failure due to last climate extreme	Household survey	Higher the crop loss, greater will be the exposure to climate change impacts	Powell and Reinhard, 2016
Physical damage to human body	Percentage of households with an injury or death as a result of extreme event (used to assess the physical impact of any disaster on human body)	Household survey	More injuries or death reflect higher exposure to climate change impacts	Hahn et al. (2009)
Sensitivity				
Source of irrigation	Percentage of households that do not have access to canal water	Household survey	Higher sensitivity because of lower access to diverse fresh water resources for irrigation	Zachariadis (2016)
Access to water	Percentage of households that do not have access to good quality drinking water	Household survey	Limited access to good-quality drinking water implies higher sensitivity	Salik et al. (2015)
Physical disability	Percentage of households with a physically disabled member	Household survey	More disabled persons in the household lead to higher sensitivity	Panthi et al. (2015)
Cost on health issues	Average health-related cost per (in PKR) month for the household	Household survey	Higher cost implies higher sensitivity	Hutton and Menne (2014)
Professional skills	Percentage of households that do not have any skill other than farming	Household survey	This is to assess the occupational diversity of the households Less diverse the skills, higher will be the sensitivity	Hahn et al. (2009)

Table 1 (continued)

Indicators and subcomponents	Explanation	Source of data	Functional relationship	References
Type of house	Percentage of households that have a house made of temporary material	Household survey	Houses made of concrete are more resistant to extreme events that leads to lower sensitivity	Brooks and Adger (2006)
Average crop diversity index (range 0–1)	The inverse of (the number of crops grown by the households + 1), e.g.: a household that grows sugar cane, rice, wheat and maize will have crop diversity index = 1/(4 + 1) = 0.20	Household survey	More crop diversity, higher will be adaptive capacity	Hahn et al. (2009) Zarafshani et al. (2016)
Adaptive capacity				
Dependency ratio	Ratio of the population above or below the of age of 15–64	Household survey	Higher the age dependency ratio, lower will be the adaptive capacity	Barr et al. (2010) Panthi et al. (2015)
Education	Percentage of household heads who have secondary and above level of education	Household survey	More education of household heads, higher will be the adaptive capacity	Connolly-Boutin and Smit (2015).
Income diversification	Percentage of households who have more than one source of income	Household survey	Income diversification increases adaptive capacity	Panthi et al. (2015)
Access to media/information	Percentage of households having access to phone, internet and TV	Household survey	Communication media helps to enhance awareness of hazards and preparedness which ultimately contributes to adaptive capacity	Panthi et al. (2015)
Social networking	Percentage of households who are actively involved in local politics, social relief work, local level associations and have a strong social circle	Household survey	Social networking enhances adaptive capacity by providing support in the form of physical help, information and experience sharing, etc.	Hahn et al. (2009)
Savings	Percentage of households who have savings of any kind	Household survey	More savings enhance the capacity of the household to adjust more quickly to any shock and stressor	Cutter et al. (2008)

Table 1 (continued)

Indicators and subcomponents	Explanation	Source of data	Functional relationship	References
Government-initiated disaster management plans	Percentage of households have awareness about or have access to government-initiated climate disaster management plans	Household survey	Awareness of and access to these services help in improving adaptive capacity	Hahn et al. (2009)
Use of remittances for investment	Percentage of households willing to invest their remittances on agriculture	Household survey	Investments in agriculture will raise the adaptive capacity of farming households	Scheffran et al. (2011)
Purpose of agriculture production	Percentage of households that use agriculture production for sale of product	Household survey	Commercial agriculture reflects agriculture as a source of income which contributes to adaptive capacity	Adger et al. (2003)

daily wage labourer in the non-farm sector. Only 18% of the household heads had education up to secondary school level or higher. Like the other two districts, the most commonly grown winter crop is wheat, while in summer cultivating maize is popular, sometimes in combination with rice. The main purpose of farming both summer and winter crops is for household consumption. Although female members of households in Mardan were better educated than women in D.G. Khan, none of them were actively participating in labour force activities.

The household survey intended to reflect on farmers' perceptions and experiences related to climate change, agricultural risks they are exposed to, coping mechanisms, livelihood strategies and adaptation options being used. Data were collected during December 2016 and January 2017. The research sample constituted agricultural households, i.e. those households whose primary source of income is from the agriculture sector. In each district, 50 rural households were interviewed, regardless of their land ownership status. The respondents were household heads chosen randomly among the agricultural households in the villages and consent was taken from them by giving a brief introduction regarding the purpose of the survey. As the target respondents were household heads, the survey team mostly came across male respondents. However, females were involved through qualitative in-depth interviews to understand their lifestyle in the villages.

Secondary data were also used for estimating climate indicators. The study used average monthly data for temperature and precipitation for the time period 1961–2014 obtained from Pakistan Meteorological Department (PMD). Faisalabad and D.G. Khan districts have meteorological stations. However, due to the absence of any meteorological station in Mardan, data from the nearest meteorological station of Risalpur were used, which is at a distance of 17 km from Mardan.

Key Informant Interviews (KIIs) were conducted with experts and government officials in district development and agriculture departments. The purpose of conducting these KIIs was to develop an understanding of the departments' initiatives in addressing climate change, agriculture and migration concerns, as well as the challenges they face. In total, nine KIIs were conducted.

5 Results

5.1 Livelihood Vulnerability Index

Results of IPCC–LVI show varying levels of vulnerability experienced by farmers in the three study sites (Table 2). Figure 2 shows the vulnerability triangle for the three study sites. Detailed results of the subcomponents of the

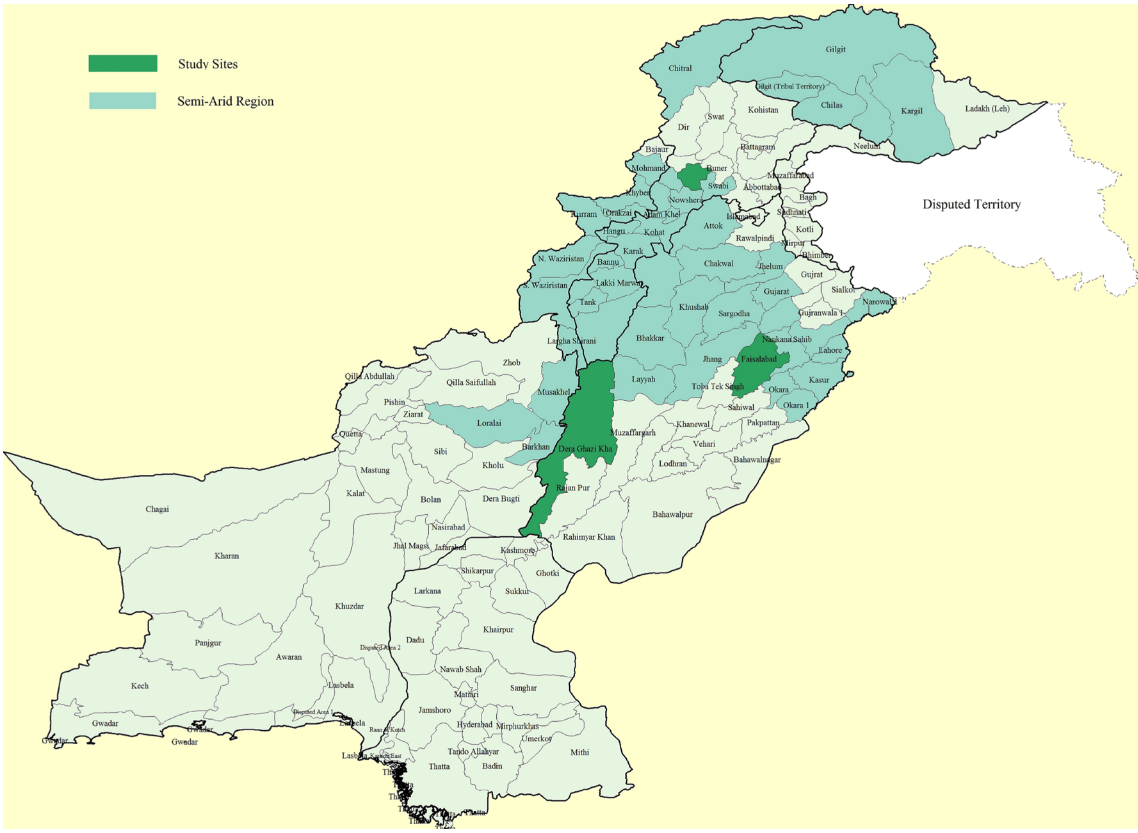

Fig. 1 Map of Pakistan with study sites. Source: Authors' own

Table 2 IPCC–LVI scores for Faisalabad, D.G. Khan and Mardan. Source: Authors' own

IPCC–LVI	Faisalabad	D.G. Khan	Mardan
Exposure	0.336	0.406	0.251
Sensitivity	0.382	0.412	0.274
Adaptive Capacity	0.699	0.504	0.467
IPCC–LVI	0.019	0.314	0.058

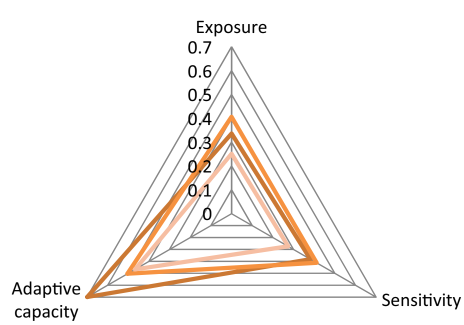

Fig. 2 Vulnerability triangle based on IPCC–LVI. Source: Authors' own

IPCC–LVI for each of the study site are given in Table 4 in Appendix. The Index entails components reflecting the farmers' exposure to climate risks, their sensitivity to climate impacts and their levels of adaptive capacity that reflects their abilities to cope with climate shocks.

A composite score shows that D.G. Khan has the highest livelihood vulnerability (0.314), followed by Mardan (0.058). Faisalabad is the least vulnerable of the three districts with a score of 0.019. D.G. Khan shows the highest levels of exposure and sensitivity, and is better than Mardan in terms of adaptive capacity. Despite being more exposed and sensitive to climate change than Mardan, Faisalabad has comparatively higher scores of adaptive capacity that decreases its overall livelihood vulnerability.

The prime factor leading to D.G. Khan's higher sensitivity is the highest incidence of complete crop failure. All farmers who participated in the survey lost their standing crops during the floods of 2010 and 2011. In comparison, in both Faisalabad and Mardan, 70% of farmers experienced complete crop failure. D.G. Khan's higher exposure is also a result of higher number of extreme hot months that it experiences compared to the other two districts. The district has endured longer and more frequent dry spells which add to its higher exposure. The Index shows that loss in monetary terms was also highest in D.G. Khan as a result of climate extreme events. Higher exposure of both, Faisalabad and D.G. Khan, is also explained by the higher level of variability in precipitation and temperature that may reflect more intense impacts of climate change in these areas.

Similarly, D.G. Khan has the highest score for sensitivity (0.412) to climate change impacts, followed by Faisalabad (0.382) and then Mardan (0.274). More people in D.G. Khan (96%) do not have access to canal water for irrigating their agricultural lands compared to Faisalabad and Mardan. This percentage is generally low in Mardan, with only 16% farmers without access to canal water, while the remaining 84% irrigate their crops through a canal. The type of housing structure also shapes the sensitivity of households to climate impacts. In D.G. Khan, about 50% households reside in mud or thatch houses, leading to their greater susceptibility to destruction during extreme events. Faisalabad ranks second in terms of sensitivity owing to a high percentage of people who do not have access to safe drinking water and fewer people with diversified professional skills, i.e. skills other than farming. Proper access to canal water lowers Mardan's sensitivity to climate change and related events.

In terms of adaptive capacity, Faisalabad (0.699) scores far better than the other two districts (0.504 for D.G. Khan and 0.467 for Mardan). Faisalabad's higher adaptive capacity is primarily due to more educated household heads. Additionally, Faisalabad also boasts better connectivity as more than 70% households have access to information and communication technology. The district also demonstrates higher saving patterns with more than 80% households having savings of some kind compared to D.G. Khan and Mardan where approximately 60% households have savings. Mardan has the lowest adaptive capacity among the three districts. The two main features that shape this low adaptive capacity are the strikingly low level of awareness about government-initiated plans for disaster risk management and low reliance on agriculture for income-generating purposes.

5.2 Farmers' Vulnerability Experiences

This study inquired about farmers' perceptions regarding climate change and climate variability. This reflects their understanding of the changes that are taking place and the expected impacts these changes might have on their livelihoods. Figure 3 shows the common changes that farmers have observed in the climate of their respective locations. A common observation in all three locations was that temperatures are rising and rainfalls are declining. In Punjab districts (Faisalabad and D.G. Khan), a considerable percentage of farmers (approximately 21%) perceived changes in the number of hot and cold days.

Average annual temperature trends drawn from station data from the respective study sites are available for the years 1961–2012 (Figs. 4, 5, 6). While the graphs do not reflect clear upward trends in the temperature, wide fluctuations in the average annual temperature are observed for all three study sites. Longer term trends may be better able to demonstrate changes in annual temperatures. IPCC (2014)

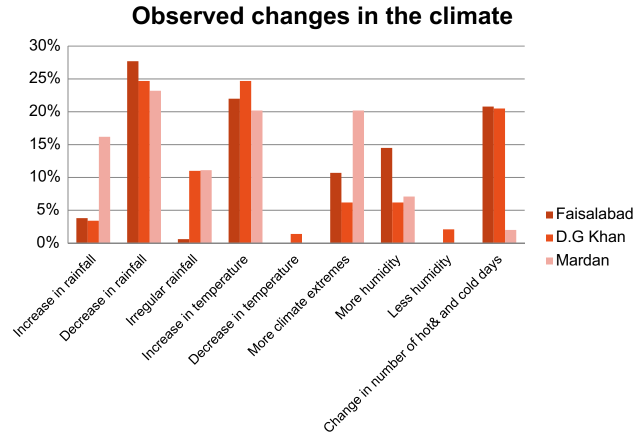

Fig. 3 Farmers' perceptions on climate change. Source: Author's own

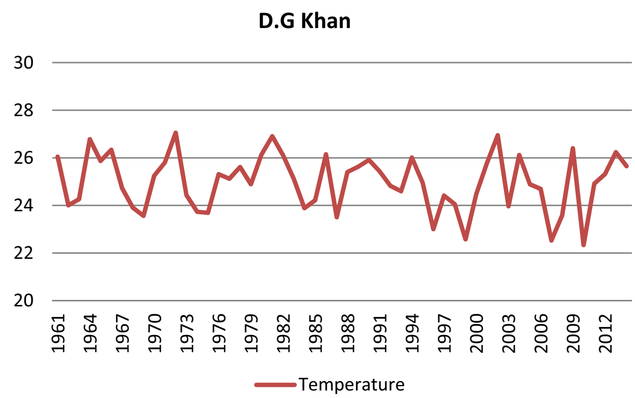

Fig. 4 Average annual temperature over time in D.G. Khan (1961–2012)

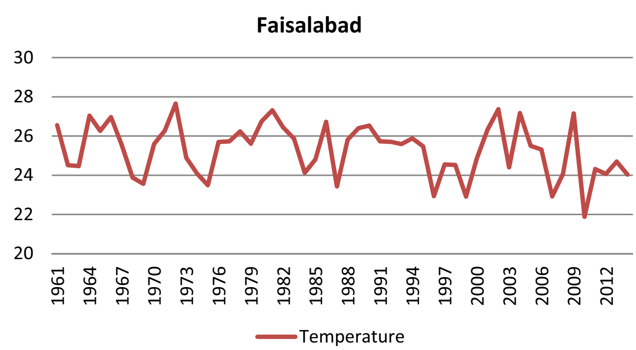

Fig. 5 Average annual temperature over time in Faisalabad (1961–2012)

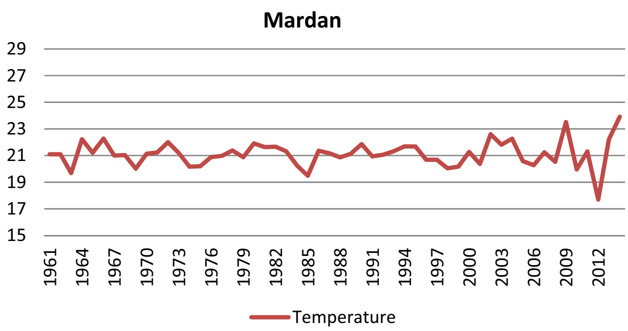

Fig. 6 Average annual temperature over time in Mardan (1961–2012). Source: Pakistan Meteorological Department

projections for semi-arid areas also predict temperature rises over the next century.

The most common source of climate information among the farmers varied in all three regions. In Faisalabad, the most common source was media through which 43% people obtained information related to climate change. This included information such as rising temperatures, rainfall predictions and warnings related to climate extremes. In D.G. Khan, 40% people relied on their social networks for climate information, while in Mardan, 66% people perceived changes in the environment through their own personal experiences. This reflects that while households in all three districts are aware of changes in the climate, the quality and accuracy of such information may vary depending upon the source of information.

In Faisalabad, shortage of water due to infrequent rains emerged as the most severe climate-related issue, which is also closely tied to intense heat waves over the past 10 years. Resultantly, as many as 80% respondents reported a decline in crop productivity and in some cases complete crop failure. Spread of contaminated water was also cited as a major issue, and 44% farmers reported that they experienced disease or death of livestock, 53% experienced loss of working hours, and thereby, decline in income following a climate extreme event. During the last climate event, about 40% farmers incurred financial losses of less than PKR 50,000 (USD 500), and about 22% suffered from losses between PKR 50,000 and 100,000 (USD 500–1000). Approximately 16% farmers even bore monetary losses amounting PKR 400,000 (USD 4000) and above.

In D.G. Khan, floods, including flash-floods and riverine floods, were ranked as extreme events with the most severe impacts on farmers' livelihoods. About 96% people reported complete crop failure as the severest climate impact that makes them vulnerable. Similarly, 60% experienced decline in crop productivity as a result of extreme heat, water shortage and climate-related disasters. Health hazards and injuries, and infrastructural damages were also common issues faced by 60% and more than 80% farmers, respectively, due to flood water. About 77% farmers also lost their stock of food and fodder as a result of floods. The last flood in D.G. Khan inflicted losses of over PKR 400,000 (USD 4000) to 36% of the respondents.

Torrential rains in Mardan have led to flash and riverine floods affecting the district severely. Hailstorms in the district have also led to heavy losses for the farmers. About 83% farmers faced complete crop failure due to floods, and 63% farmers were severely affected due to disease or death of livestock. Rising temperatures were regarded as one of the important factors leading to livestock diseases. As a result of supply shortage and difficulty in access, 63% complained that food stocks in the village markets declined. Heavy rains also damaged the stock of food and fodder for about 67% of households. These statistics indicate the inter-linkages between climate extreme events and potential rise in food insecurity. Furthermore, 60% of the respondents incurred monetary losses under PKR 50,000 (USD 500), while 30% had to bear losses from PKR 50,0000 to PKR 100,000 (USD 500–1000).

5.3 Adaptation Strategies for Farmers

With the rise of climate change risks, farmers have developed diverse measures to reduce their livelihood risks and vulnerabilities. In case of sudden extreme events, farmers use certain coping strategies to manage the losses and damage faced. As per the survey, borrowing money from friends and family is the most common strategy used in all three sites in the wake of any kind of disaster. In addition, other factors such as socioeconomic status, education, and institutional support also shape the choice of a coping measure (Coulibaly et al. 2015).

In D.G. Khan, 88% of respondents claimed being displaced from their settlements for some time as a result of a climate extreme event (mostly floods), reflecting their high susceptibility to such events. As an emergency coping mechanism, many farmers (26%) tend to sell their livestock for getting ready-cash to fulfil their immediate needs. About 11.2% of farmers reported that in such hard times, they rely on government-provided support in the shape of relief initiatives to sustain themselves. Furthermore, to compensate for the loss in agricultural production, farmers reported increasing their use of inputs such as fertilisers and pesticides (51%) and diversifying their crop production (28%). About 11% also reported increasing the use of labour and technological input in efforts to increase production. In fact, it was observed that in about 4% households, women were more involved in labour activities after the massive floods of 2010.

In Faisalabad, the most common response to cope with climate extremes (after borrowing money from family and friends) is selling livestock (16%) and other assets such as jewellery and motorbike (10%). Many farmers complained that in such difficult times, they have to sell their livestock at cheaper rates to have enough to feed themselves. On the other hand, to manage the losses being incurred due to the slow onset climate changes—rising temperatures, erratic rainfall, declining soil fertility—farmers tend to intensify their use of inputs such as fertilisers and pesticides (42.7%). Diversifying crop production is the second most common measure, while 18% farmers reported that members of their households have migrated to other locations as a means of diversifying their income sources. About 14% farmers reported introducing an alternative mode of irrigation to compensate for water shortage.

Similar to the other two districts, farmers in Mardan who have experienced climate extreme events cope with disastrous impacts by borrowing money from their friends and relatives (39.2%), selling livestock (17.6%) and other assets such as motorbike, jewellery and property (9.5%). About 12.2% also reported reducing their consumption levels in response to the difficult situation. With regards to long-term adaptation strategies, increasing the use of inputs was the most common (40.6%), followed by diversification of crop production (29.7%), similar to the trend in other sites. About 19% farmers also reported that as agriculture becomes less profitable due to climate change impacts, they migrate from the villages in search of economic opportunities elsewhere for diversifying their livelihoods, while 12.5% reported shifting to other sources of incomes while staying in the villages.

In D.G. Khan about 6.1% farmers in the survey reported that they do not use any adaptation measure against adverse climate impacts and 50% shared that they do not see the need to adapt. They explained that even if they use any adaptive measures, they all go to waste when floods hit and wash away all their crops, damage their settlements and result in death of family members and livestock. Given the situation that climate impacts continue to rise in frequency and intensity, only 28% farmers responded that they would consider shifting away from agriculture to another source of income. On investigating further, it was found that farmers in D.G. Khan believe that they have no means to shift to another livelihood source and agriculture is the only activity that they are familiar with. Nevertheless, those who would choose to switch to another livelihood reported they would work as daily wage labour.

In Faisalabad, 6.7% farmers revealed that they are not doing anything to adapt to climate change impacts for their agricultural livelihoods. Amongst them, 57% reported that they do not have the required skills or knowledge about the kind of strategies to use, while 29% responded that they cannot afford to use adaptive measures as they are expensive. About 48% expressed their interest in shifting to another livelihood source with high preferences for attaining a salaried job or starting their own small business (that includes establishing a small shop or providing transport services).

In comparison with the other locations, the percentage of farmers who do not make any efforts to adapt to climate change was highest in Mardan (14%). Approximately 69% of the farmers who do not opt for adaptive measures also responded that they do not find it useful to take up adaptation measures. Most of them were of the view that adaptation strategies are not effective when a disaster hits and if they invest in adaptation, then they have to bear greater losses. In response to the scenario if adverse climate impacts continue to increase, 64% farmers reported that they would prefer to shift away from agriculture to other means of earning incomes. Most farmers voiced their preference of investing in their own small start-up if they have to move away from agriculture.

Government-provided facilities were reported more in districts of Punjab, whereas in Mardan, people reported that there were no government-initiated facilities available for climate adaptation. In Faisalabad, 35% people reported that they had access to government-provided early warning systems and 23% reported that they received trainings on how to adapt to changing climatic scenario. In D.G. Khan, 37% farmers stated that they had received some subsidy, credit or insurance from the government owing to the district's repeated exposure to floods. About 35% also reported that the government has provided them with new crop varieties that are more resistant to climate change impacts. Table 3 provides an overview of the government facilities provided in the study sites based on KIIs with the Agriculture Extension Departments of the respective districts.

To summarise, it has been found that in semi-arid regions of Pakistan, the most common methods of adapting agricultural livelihoods to climate impacts are intensifying the use of agricultural inputs such as pesticides and fertilisers, and diversifying crop varieties. These results are consistent with the earlier findings of Khan et al. (2011). In addition, migration is a common adaptation response to climate impacts, yet its incidence varies for different locations. Climate extremes over time generally tend to weaken income generation from agriculture, in response to which many households decide to send a family member to the city to seek economic opportunities (Salik et al. 2015). In contrast, high costs of adaptation and lack of information on how best to adapt to certain climate impacts came out as the main impediments for those farmers who do not take any adaptive measures for their livelihoods (Ali and Erenstein 2017).

Table 3 Salient features of agricultural support provided by District Office of Agricultural Extension. Source: Authors' own based on KIIs

Faisalabad	D.G. Khan	Mardan
Training of farmers on cropping practices and usage of pesticides (after lab testing)	Provision of new seed varieties to major farmers (large landholders are willing to take risk. If new varieties give good results, small farmers are also encouraged to try new seeds)	Awareness raising through publication of agricultural newsletter (*Zarat Nama*), electronic messages, trainings, seminars, and field work
Provision of new seed varieties to 191 villages in the district	Soil sampling of land to advise what to grow due to changing soil quality	Provision of door-to-door consultancies to farmers regarding crop productivity, fertilisers, price/marketing schemes
Provision of farm implements/agricultural tools (4-5 per UC)	Implementation of Punjab Kisaan Package (interest-free loan scheme)	Provision of new wheat seeds at subsidised rates
Provision of 4000 vegetable toolkits for kitchen gardening with a subsidy of PKR 50 per packet	Registration of farmers for E-credit that provides small farmers (with up to 5 acres of land) with loan of up to PKR 25,000 per acre.	Provision of early warning systems (However, the agriculture officer reported a lack of capacity to provide trainings on flood adaptation mechanisms)

6 Discussion

6.1 Climate Change, Extreme Events and Agricultural Vulnerability

As defined in the methodology section, livelihood vulnerability to climate change is not merely a function of exposure to climate impacts. It is defined by a number of pre-existing factors—poverty levels, education, awareness, and livelihood diversification—all of which shape the sensitivity and adaptive capacity of a household (Abid et al. 2016). As concluded by Abid et al. (2016), this research reflects that each study site has varying associated factors that determine the level of livelihood vulnerability experienced by farmers. A striking finding is that rural livelihood vulnerability can be caused by a lack of adaptive capacity, despite its exposure and sensitivity to climate change impacts being lower. This is reflected by Mardan's vulnerability score that is higher than Faisalabad district despite its exposure and sensitivity being lower than both D.G. Khan and Faisalabad. This implies that high exposure and sensitivity to climate risks can be offset by a stronger adaptive capacity, rendering the population better positioned to counterweigh the negative effects (Hahn et al. 2009; Adu et al. 2017).

According to the findings, the most pronounced impact of climate disasters that defines the exposure of livelihoods is complete crop failure. As observed in the study sites, climate extreme events such as hydrological disasters (rain storm, floods and drought-like conditions) and heat waves have caused instability in agriculture-based livelihoods through complete crop failure. Floods and torrential rains wash away the standing crop, while intense heat impacts the rate of evapotranspiration and soil moisture, often resulting in decline in crop production (Rasul et al. 2012). This is particularly alarming as the increasing magnitude and intensity of such events erode the livelihoods of small landholders (Rasul et al. 2012). Their agricultural assets such as crops, seeds, and soil fertility are depleted, thus amplifying their vulnerabilities. In addition, as small farmers mainly fulfil their household food requirements from farms, loss of crops may worsen food insecurity (Wilkinson and Peters 2015).

On a macro-scale, increasing incidents of crop failures resulting from climate extremes can have detrimental impacts on national food and fibre production and affect the whole agricultural value chain. Considering that Pakistan's industrial sector is largely agro-based, this may even result in setbacks for the industrial sector (Wilkinson and Peters 2015; FAO 2015). Recurring floods and prolonged droughts not only depreciate peoples' livelihood-earning capabilities, they also hamper the government's development efforts and poverty reduction initiatives (Looney 2012). This may push vulnerable communities into perpetual states of deprivation.

Results indicate that sensitivity of agricultural livelihoods is highly dependent upon the source of water for irrigation, making those who do not have reliable irrigation sources more vulnerable (Salik et al. 2015; Zachariadis 2016). This is particularly important when the agricultural dependency on water is high but infrastructure is either poor or inaccessible to marginalised farmers (Panthi et al. 2015). In terms of sensitivity of livelihoods to climate change impacts, human capital plays a fundamental role, especially if taken in terms of health. Health issues decrease the working capacities of labour and result in reduced number of working days (Hahn et al. 2009). Respondents (males and females) in all three sites were dissatisfied with the health facilities available at the village level. They reported that the dispensaries and/or the basic health units available in the villages were not equipped with sufficient medicines. In addition, the availability of doctors in the facilities was also irregular, which often forced them to travel long distances to the next towns or district capital to consult a doctor or purchase medicines. While this issue was raised by both men and women, the latter seemed to be more concerned about the deficit in health provisions in their areas. This reflects concern for their children and family members suffering from diseases that can be prevented if health facilities are adequately available.

Sensitivity to climate vulnerability is also defined by the skill diversity of the population (Hahn et al. 2009; Shah et al. 2013). This study assumed that households that possess skills and capacities in addition to farming are less vulnerable to climate change impacts as they can easily use these additional skills to be absorbed in another profession in case climate change renders farming more and more susceptible (Hahn et al. 2009). This is also reflected in the study wherein many households in all three sites were concerned about not having any skill other than farming in case they decide to migrate to the cities.

As mentioned, higher adaptive capacity of a population may balance out the high exposure and sensitivity to climate change. Factors that contribute to higher adaptive capacity included education of household head, access to information and communication technologies and strong social networks (Hahn et al. 2009; Connolly-Boutin and Smit 2015; Panthi et al. 2015). Higher education level reflects higher ability to receive, interpret and comprehend risks and hazards, thus, it positively impacts adaptive capacity (Byrne 2014). As the household head is responsible for making the final household level decisions, his/her education level determines the capacity of the household to anticipate risks and respond to them through changes in livelihood strategies (Panthi et al. 2015).

The population of Faisalabad had more access to information and communication technologies than D.G. Khan and Mardan, reflecting its higher ability to obtain information quicker in case of any climatic or non-climatic risks. Greater dissemination of weather and climate news in Faisalabad could be because of the presence of the Regional Agrometeorological Centre in the city, along with the Ayub Agriculture Research Centre[7] in the city. The proximity of source of information and the greater integration of communication technologies reflect higher adaptive capacity in Faisalabad.

Similarly, social capital is an important pillar in defining adaptive capacity of a household (Salik et al. 2015; Qaisrani 2015). Kinship, relationships and strong community networks can act as a support system at times of distress and can also reflect stronger flow of information and news (Scheffran et al. 2011). Strength of social network is also useful in climate information dissemination, as is reflected by statistics from D.G. Khan where majority of people rely on disaster or climate updates from their networks through a phone call or message. People with strong social networks have been observed to survive calamities and rebuild their lives with the help social capital (family ties, relatives, and community networks) faster than those whose social ties are weak (Adger et al. 2003). D.G. Khan, with the lowest score in the social network indicator, has lower adaptive capacity compared to Faisalabad. This indicates that community members are less integrated in terms of reliance on each other for support during times of need (Adger 2001).

It was assumed that higher rates of female labour force participation would reflect less vulnerability (Muthoni and Wangui 2013). However, the impacts on vulnerability are structured by the type of labour force activity that women are involved in. For instance, by comparing the cases of Faisalabad and D.G. Khan, it can be concluded that higher labour force participation of women in agricultural activities in D.G. Khan actually enhances the overall vulnerability of the community due to higher dependence on natural resources (Samee et al. 2015; Batool and Saeed 2017). On the other hand, involvement in activities that are not too natural resource intensive reduces their vulnerability. Women in D.G. Khan were generally more involved in livestock management, crop sowing, weeding and harvesting, water management, collecting wood and biofuel. In Faisalabad, women were more involved in service sector and in education and health sectors or serving as domestic helpers in private homes.

While labour force participation is higher, women generally are less involved in decision-making processes and have limited access to information and facilities (Samee et al. 2015). Education levels of women in D.G. Khan are also lower than those in the other two districts. In contrast, though fewer women were economically active in Faisalabad, they were more educated and involved in government or private sector jobs. This reflects weaker impact of climate change on their livelihood activities, thus, their lesser vulnerability. In Mardan, despite higher education levels of women compared to D.G. Khan, women did not partake in any income-generating activities given the culture and norms of the village.

6.2 Adapting Agriculture to Climate Change and Climate Extremes

In light of the above vulnerability scenario, identification of the most suitable adaptation measures is pivotal to determine the pathways to resilient economic development in semi-arid regions. This research finds that most farmers are already adjusting their livelihoods to climate impacts. These adjustments include short-term, distress responses known as coping strategies as well as long-term modifications in their livelihood activities that can reduce their risk to climate impacts in the future (Khan et al. 2011; Ullah et al. 2018).

In the wake of a climate shock, farmers tend to adopt distress measures such as borrowing from friends and family, selling livestock and other assets or reducing household

[7] Pakistan Meteorological Department http://namc.pmd.gov.pk/ramc-faisalabad.php.

consumption. These measures are generally meant to buffer for the immediate adverse impacts (Smith et al. 2000). Such responses, in fact, reduce farmers' future capacity to invest and render their livelihoods more insecure (Boansi et al. 2017). In this study, the most popular modes of climate adaptation are increasing use of farm inputs such as pesticides and fertilisers and using more improved (heat-resistant or drought tolerant) crop varieties, in addition to various site-specific measures such as shifting to other livelihoods, migrating for work, and introducing other modes of irrigation (Khan et al. 2011). As numerous climate change impacts manifest themselves on populations, people often adopt multiple strategies to offset future risk. For example, in D.G. Khan, farmers are exposed to recurring floods as well as intense heat waves. In such a scenario, opting one strategy may not ensure security of livelihoods in a sustainable manner. Using a mix of heat- and flood-tolerant crop varieties and getting crop insurance may benefit the farmers more in times of oscillating weather and climate conditions (Boansi et al. 2017).

Institutional support is also pivotal in shaping farmers' adaptive capacity (Hahn et al. 2009). This can be drawn from the case of Mardan, where despite low exposure and low sensitivity to climate change and extreme events, underlying low levels of adaptive capacity has affected its livelihood vulnerability adversely. A major factor behind low adaptive capacity is the lack of government support to the community. Although the District Office of Agriculture in Mardan claims to provide agricultural extension services in the district, yet the community surveyed was not receiving any government support to help them buffer against climate manifestations. In contrast, communities in Faisalabad and D.G. Khan were receiving government support in the shape of training and awareness sessions, early warnings, provision of new crop varieties, and access to insurance, subsidies and credit. The district agricultural department of D.G. Khan was appreciated for the soil sampling they conducted for agricultural land and held awareness-raising sessions on what to grow on the soil with respect to the changing soil quality. The district administration was also said to be active in disseminating early warnings in case of riverine floods through the police and announcements in mosques. Communities were cognizant of the positive impacts of these services provided to them, but demanded enhanced government support in terms of subsidy on purchase of inputs. They admitted receiving information about new and improved seeds to withstand changing climatic conditions, but complained that those new seeds were not affordable for the small farmers. In Mardan, farmers expressed their need of loan and credit to support agricultural activities.

This study found that farmers prefer to opt for off-farm activities as a means of diversification. Their preferences vary according to the site, including strategies such as attaining a salaried job, doing non-farm wage labour or starting a small business. However, all respondents mentioned that the prospects of diversifying livelihoods were low in their villages. About 20% households reported using migration as a strategy to offset the loss of income as a result of a climate crisis. This differs from the usual phenomenon of displacement when families are uprooted from their homes to settle in other locations as a result of a disaster (Ferris, 2014). Migration of one or more family members reflects a planned response to a shock in income. However, it was also observed that migration is often considered as a last resort when other strategies fail. For agriculture-based households, when natural resources are pressurised due to factors such as climate change, migration often becomes the last logical option when alternative economic opportunities are limited (Penning-Rowsell et al. 2013; Arsenault et al. 2015).

Besides the farmers who are taking adaptation measures, there were also some who were not taking any action to adapt to climate change. It was observed that lack of employing an adaptive strategy stems from two main reasons: lack of financial resources to introduce a change in practices and a lack of awareness of the effectiveness of an adaptation strategy. Generally, farmers who did not adapt, especially those in D.G. Khan and Faisalabad, perceived that it is unfruitful to invest in agricultural adaptation as climate extremes erode all their efforts. This implies that these farmers may not have enough information regarding the usefulness of adaptation strategies that can withstand extreme events. Abid et al. (2015) also came to the conclusion that usually farmers are unaware of the type of adaptation needed and, therefore, believe that adaptation will be ineffective in their case. While some farmers admitted receiving government-provided training as mentioned earlier, this finding indicates that some proportion of farmers are not receiving relevant trainings in the context of climate disasters. This highlights the need of the local and district government emphasising more on trainings and awareness sessions about adaptation practices and ensuring that these trainings are imparted to all farmers, especially targeting areas that are hard-hit by climate extremes. Affordability of applying adaptation strategies is another facet that constrains farmers from using the most effective methods. High-input prices, high prices of new weather-resistant crop varieties, low penetration of credit facilities and widespread poverty in rural areas also restrict farmers' capacities to invest in adaptation practices (Abid et al. 2015).

7 Conclusion and Policy Recommendations

This study uses the IPCC livelihood vulnerability approach to understand the important causal factors behind exposure, sensitivity and adaptive capacity of various rural semi-arid regions in Pakistan that explain farmers' livelihood vulnerability to climate change. According to this study's IPCC–LVI ranking-based results, D.G. Khan appears as the most vulnerable district, Mardan as the second most vulnerable, while Faisalabad as the least vulnerable among the three districts in Pakistan. An important finding is that (a lack of) adaptive capacity plays quite an important role in shaping households' livelihood vulnerability on any given degree of exposure and sensitivity.

As agricultural livelihoods become increasingly vulnerable to climate change impacts and risks, farmers resort to various strategies to offset the ill impacts on their earnings. Besides, distress coping strategies adopted to respond to climate extremes, farmers also employ certain long-term adaptive measures to compensate for their depreciating livelihoods. In addition to increasing farm inputs and diversifying crop varieties, rural households also consider diversifying their livelihoods through out-migration. Rural economies need people-centric development to build climate resilience, i.e. growth that diminishes poverty and reduces deprivation. Livelihood vulnerability of farmers can be offset by reducing climate sensitivity and enhancing their adaptive capacity to climate change impacts. In light of this study, it is clear that livelihood resilience of rural agricultural households not only needs policy attention for strengthening of the agriculture sector, but also facilitation in diversifying livelihood activities.

An important cause of sensitivity to climate change in rural semi-arid areas of Pakistan is the variability and uncertainty of irrigation water supply for agricultural purposes. This variability might also be caused due to weak and deteriorating irrigation infrastructure. The disruption in water supply can be reduced by adopting innovative irrigation and water-saving/harvesting techniques, and a more effective role of the irrigation department with enhanced interactions with farmers.

As climate-related (extreme) events become more evident and severe, it is increasingly essential to rely on rural youth (including men and women) for coping with these risks, and adapting their livelihoods to climate change. This can be done by improving their capacity to understand vulnerable aspects of rural livelihoods, ability to effectively use new scientific information as well as local knowledge to anticipate and combat climate change risks and stressors such as floods, droughts, and heat waves. Similarly, rural labour also needs to have better and updated skills through trainings so that they are able to choose alternative (non-farm) opportunities which are less or not vulnerable to climate change.

Due to women's active involvement in agricultural activities, especially in D.G. Khan, their vulnerability to climate change is high. To encourage their participation in non-farm activities, local governments must create opportunities for them to access well-paid work in villages, such as supporting women-owned cottage industries by providing them trainings and access to credit and markets. Women should also be formally integrated in the value chains and efforts must be undertaken to reduce the wage gap between men and women.

This study found that climate-resilient seed varieties currently available to small farmers are quite expensive, especially for small farmers. In this regard, agricultural extension services need to provide subsidised crop varieties for farmers at affordable prices, control the spread of pests and diseases, and ensure proper storage of farm outputs. Furthermore, agricultural extension services need to broaden their reach, especially in KP, where people are still not receiving government services, and are thus, unaware of the many positive, livelihood enhancing schemes offered by the provincial government.

Currently, the potential of migration as a resilience-enhancing adaptation strategy is not recognised in development plans. Policies facilitating planned migration could support improved climate adaptation for migrant families, and mitigate their risk of displacement. Since migration is an important response/adaptation strategy, the national and sub-national governments should mainstream migration and climate change adaptation into National Adaptation Plans (NAPs) and sub-national integrated development plans (Local Adaptation Plans of Action—LAPAs).

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Compliance with Ethical Standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Appendix

See Tables 4 and 5.

Table 4 IPCC–LVI scores for each study site

Indicators and subcomponents	Explanation	Faisalabad	D.G Khan	Mardan
Exposure				
Climate extremes/disaster	Average number of frequent climate extreme events in the last 10 years (based on survey)	0.129	0.142	0.172
Temperature variability	Monthly variability in temperature	0.232	0.248	0.158
Hot months	Number of extreme hot months with temperature above 30 °C	0.519	0.607	0.463
Precipitation variability	Monthly variability in total precipitation	0.209	0.220	0.171
Extreme dry months	Number of extreme dry months explained as the month during spring season having precipitation < 5 mm and in summer precipitation = 0 mm	0.667	0.722	0.315
Monetary loss	Average monetary loss incurred due to last extreme event	0.055	0.111	0.012
Crop failure	Percentage of households facing complete crop failure due to climate extreme	0.700	1.000	0.700
Physical damage to human body	Percentage of household with an injury or death as a result of natural disaster (used to assess the physical impact of any disaster on human body)	0.180	0.200	0.020
	Average	0.336	0.406	0.251
Sensitivity				
Source of irrigation	Percentage of households that do not have access to canal water	0.600	0.960	0.160
Access to water	Percentage of households not having access to good-quality drinking water	0.360	0.020	0.000
Physical disability	Prevalence of any permanent disability in the household	0.100	0.100	0.120
Cost on health issues	Average health-related cost per month for the household	0.119	0.085	0.137
Professional skills	Percentage of households not having any skill other than farming	0.700	0.420	0.440
Type of house	Percentage of households having house made of temporary material	0.020	0.500	0.320
Average crop diversity index (range 0–1)	The inverse of (the number of crops grown by the households + 1), e.g.: a household that grows sugar cane, rice, wheat and maize will have crop diversity index = 1/(4 + 1) = 0.20	0.778	0.798	0.738
	Average	0.382	0.412	0.274
Adaptive capacity				
Dependency ratio	Ratio of the population 0–14 and 65 and above years of age over the population between 15 and 64 years of age	0.530	-0.154	0.333
Education	Percentage of household heads who have secondary and above level of education	0.660	0.160	0.180
Income diversification	Percentage of households who have more than one source of income	0.640	0.800	0.820
Access to media/information	Percentage of households having access to phone, Internet and TV	0.713	0.353	0.433
Social networking	Percentage of households who are actively involved in: local politics, social relief work, local level associations and have a strong friendship circle	0.730	0.595	0.680
Savings	Percentage of households who have savings of any kind	0.840	0.600	0.680
Government-initiated disaster management plans	Percentage of households aware about or have access to government-initiated climate disaster management plans	0.52	0.52	0
Use of remittances for investment	Percentage of households willing to invest their remittances on agriculture	0.740	0.740	0.857
Purpose of agriculture production	Percentage of households that use agriculture production for sale of products	0.92	0.92	0.22
	Average	0.699	0.504	0.467
IPCC–LVI	(Exposure + sensitivity) − adaptive	0.019	0.314	0.058

Table 5 Testing significance of indicators among the three study sites

Indicators and subcomponents	Explanation	Faisalabad D.G Khan	Faisalabad Mardan	D.G khan Mardan
Exposure		(p value 0.000 < 0.05)		
Climate extremes/disaster	Average number of frequent climate extreme events in the last 10 years (based on survey)	0.489	0.034**	0.132
Temperature variability	Monthly variability in temperature	0.534	0.291	0.768
Hot months	Number of extreme hot months with temperature above 30 °C	0.044**	0.271	0.005**
Precipitation variability	Monthly variability in total precipitation	0.002**	0.000*	0.000*
Extreme dry months	Number of extreme dry months explained as the month during spring season having precipitation < 5 mm and in summer precipitation = 0 mm	0.342	0.000*	0.000*
Monetary loss	Average monetary loss incurred due to last extreme event	0.019**	0.000*	0.000*
Crop failure	Percentage of households facing complete crop failure due to climate extreme	0.000*	1.000	0.000*
Physical damage to human body	Percentage of household with an injury or death as a result of natural disaster (used to assess the physical impact of any disaster on human body)	0.801	0.007**	0.004**
Sensitivity				
Source of irrigation	Percentage of households that do not have access to canal water	0.000*	1.000	0.000*
Access to water	Percentage of households not having access to good-quality drinking water	0.001**	0.001**	0.320
Physical disability	Prevalence of any permanent disability in the household	0.801	0.007**	0.004**
Cost on health issues	Average health-related cost per month for the household	0.156	0.563	0.044**
Professional skills	Percentage of households not having any skill other than farming	0.004**	0.008**	0.842
Type of house	Percentage of households having house made of temporary material	0.001*	0.001*	0.068***
Average crop diversity index (range 0–1)	The inverse of (the number of crops grown by the households + 1), e.g.: a household that grows sugar cane, rice, wheat and maize will have crop diversity index = 1/(4 + 1) = 0.20	0.058***	0.001*	0.001*
Adaptive capacity				
Dependency ratio	Ratio of the population 0–14 and 65 and above years of age over the population between 15 and 64 years of age	0.000*	0.006**	0.000*
Education	Percentage of household heads who have secondary and above level of education	0.000*	0.000*	0.000*
Income diversification	Percentage of households who have more than one source of income	0.076***	0.043**	0.801
Access to media/information	Percentage of households having access to phone, Internet and TV	0.011**	0.022**	0.752
Social networking	Percentage of households who are actively involved in local politics, social relief work, local level associations and have a strong friendship circle	0.080***	0.042**	0.699
Savings	Percentage of households who have savings of any kind	0.007**	0.062***	0.410

Table 5 (continued)

Indicators and subcomponents	Explanation	Faisalabad D.G Khan	Faisalabad Mardan	D.G khan Mardan
Government-initiated disaster management plans	Percentage of households aware about or have access to government-initiated climate disaster management plans	1.000	0.001*	0.001*
Use of remittances for investment	Percentage of households willing to invest their remittances on agriculture	1.000	0.149	0.150
Purpose of agriculture production	Percentage of households that use agriculture production for sale of products	1.000	0.001*	0.001*

References

Abid M, Scheffran J, Schneider UA, Ashfaq M (2015) Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan. Earth Syst Dyn 6:225–243

Abid M, Schilling J, Scheffran J, Zulfiqar F (2016) Climate change vulnerability, adaptation and risk perceptions at farm level in Punjab, Pakistan. Sci Total Environ 547:447–460

ADB (2012) Addressing climate change and migration in Asia and the Pacific. Asian Development Bank, Manila

Adger WN (2001) Social capital and climate change. Tyndall Centre for Climate Change Research. Working Paper No. 8

Adger WN (2006) Vulnerability. Glob Environ Change 16(3):268–281

Adger WN, Huq S, Brown K, Conwoy D, Hulme M (2003) Adaptation to climate change in the developing world. Prog Dev Stud 3(3):179–195

Adu DT, Kuworno JKM, Anim-Somuah H, Sasaki N (2017) Application of livelihood vulnerability index in assessing smallholder maize farming households' vulnerability to climate change in Brong-Ahafo Region of Ghana. Kasetart J Soc Sci 39:22–32

Afzaal M, Haroon MA (2009) Interdecadel oscillations and the warming trend in the area—weighted annual mean temperature of Pakistan. Pak J Meteorol 6(13):13–19

Ali A, Erenstein O (2017) Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. Clim Risk Manag 16:183–194

Arif M (2007) Livelihood rights of peasants and rural workers. South Asia Partnership-Pakistan, Lahore

Arsenault MP, Azam MN, Ahmad S (2015) Riverbank erosion and migration in Bangladesh's Char Lands. In: Mallick B, Etzold B (eds) Environment, migration and adaptation: evidence and politics of climate change in Bangladesh. AH Development Publishing House, Dhaka

Babin BJ, Zikmund WG (2015) Exploring marketing research. Cengage Learn 24:322

Batool S, Saeed F (2017) Mapping the cotton value chain in Pakistan: a preliminary assessment for identification of climate vulnerabilities and pathways to adaptation. Pathways to Resilience in Semi-arid Economies (PRISE) and Sustainable Development Policy Institute (SDPI), Islamabad

Barr R, Fankhauser S, Hamilton K (2010) Adaptation investments: a resource allocation framework. Mitig Adapt Strat Glob Change 15(8):843–858

Beccari B (2016) A comparative analysis of disaster risk, vulnerability and resilience composite indicators [Online]. PLOS Current Disasters 1. http://currents.plos.org/disasters/article/a-comparative-analysis-of-disaster-risk-vulnerability-and-resilience-composite-indicators/. Accessed 20 Feb 2018

Belliveau S, Bradshaw B, Smit B, Reid S, Ramsey D, Tarleton M, Sawyer B (2006) Farm-level adaptation to multiple risks: climate change and other concerns. Occasional Paper no. 27. University of Guelph, Canada

Boansi D, Tambo JA, Müller M (2017) Analysis of farmers' adaptation to weather extremes in West African Sudan Savanna. [Online] https://doi.org/10.1016/j.wace.2017.03.001. Accessed 8 June 2017

Byrne TR (2014) Household adaptive capacity and current vulnerability to future climate change in rural Nicaragua. Department of Geography, University of Lethbridge, Alberta

Connolly-Boutin L, Smit B (2015) Climate change, food security, and livelihoods in Sub-Saharan Africa. Reg Environ Change 16(2):385–399

Coulibaly JY, Gbetibou GA, Kudhlande G, Sileshi GW, Beedy TL (2015) Responding to crop failure: understanding farmers' coping strategies in Southern Malawi. Sustainability 7:1620–1636

Cutter SL (2003) The vulnerability of science and the science of vulnerability. Ann Assoc Am Geogr 93(1):1–12

Cutter SL, Barnes L, Berry M, Burton C, Evans E, Tate E, Webb J (2008) A place-based model for understanding community resilience to natural disasters. Global Environ Change 18(4):598–606

Dasgupta P, Morton JF, Dodman D, Karapinar B, Meza F, Riverra-Ferre MG (2014) Rural areas. In: Field CB, Barros VR, Dokken DJ, Mach KJ (eds) Climate change 2014: impacts, adaptation and vulnerability, part A: global and sectoral aspects, contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 613–657

Dawn (2007) Sustainable agriculture in rain-fed areas.Dawn News [Online]. https://www.dawn.com/news/257612. Accessed 31 May 2017

Deressa T, Hassan RM, Ringler C (2008) Measuring Ethiopian farmers' vulnerability to climate change across regional states. IFPRI Discussion Paper 806. International Food Policy Research Institute, Washington, D.C.

FAO (2015) Pakistan and FAO: Partnering to Improve Food Security and Livelihoods. Food and Agriculture Organisation of the United Nations, Islamabad

Feron D (2012) Monsoon floods in Assam India. Europa [Online]. http://ec.europa.eu/echo/index_en.htm. Accessed 6 June 2017

Ferris E (2014) Changing times: the international response to internal displacement in colombia. Brookings-LSE project on internal displacement. The Brookings Institution, Washington, D.C.

Fussel HM (2007) Vulnerability: a generally applicable conceptual framework for CC research. Glob Environ Change 17:155–167

GoP (2013) National disaster risk reduction policy. Ministry of Climate Change and National Disaster Management Authority, Government of Pakistan, Pakistan

GoP (2016) Pakistan economic survey 2015–16. Ministry of Finance, Government of Pakistan, Pakistan

Gray CL, Mueller V (2012) Natural disasters and population mobility in Bangladesh. In: Proceedings of the National Academy of Sciences of the United States of America (PNAS), 109(16). University of California, Los Angeles

Hahn MB, Riederer AM, Foster SO (2009) The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change—a case study in Mozambique. Glob Environ Change 19:74–88

Hamid YA, Afzal J (2013) Gender, water and climate change: the case of Pakistan. Global Water Partnership, Pakistan Water Partnership-South Asia, Islamabad

Hasson S, Bohner J, Lucarini V (2017) Prevailing climatic trends and run-off response from Hindukush-Karakoram-Himalaya, Upper Indus Basin. Earth Syst Dyn 8:337–355

Hinkel J (2011) "Indicators of vulnerability and adaptive capacity": towards a clarification of the science–policy interface. Global Environ Change 21(1):198–208

Hudrlikova L (2013) Composite indicators as a useful tool for international comparison: the Europe 2020 example. Prague Econ Pap 22(4):459–473

Hussain S (2010) Food security and climate change assessment in Pakistan. Special Program on Food Security and Climate Change, Oxfam Novib

Hutton G, Menne B (2014) Economic evidence on the health impacts of climate change in Europe. Environ Health Insights 8:43–52

IPCC (2001) Climate change 2001: impacts, adaptation, and vulnerability—contribution of working group II to the third assessment report of the intergovernmental panel on climate change. In: McCarthy JJ, Canziani OF, Leary NA, Doken DJ, White KS (eds) Cambridge University Press, Cambridge

IPCC (2014) Climate change 2014: impacts, adaptation, and vulnerability. In: Field CB, Barros VR, Dokken DJ, Mach KI, Mastrandrea MD, Bilir TE (eds) Summaries, frequently asked questions, and cross-chapter boxes. A working group II contribution to the fifth assessment report of the intergovernmental panel on climate change. World Meteorological Organisation, Geneva

Irfan M (2007) Poverty and natural resource management in Pakistan. Pak Dev Rev 4(46):691–708

Ishaq W, Memon SQ (2016) Roles of women in agriculture: a case study of rural Lahore, Pakistan. J Rural Dev Agric 1(1):1–11

Kelly PM, Adger WN (2000) Theory and practice in assessing vulnerability to climate change and facilitating adaptation. Clim Change 47(4):325–352

Khan MA, Hussain A, Mehmood I, Hassan S (2011) Vulnerability to climate change: adaptation strategies and layers of resilience in semi-arid zones of Pakistan. Pak J Agric Res 24(1–4):65–74

Looney R (2012) Economic impacts of the floods in Pakistan. Contemp South Asia 20(2):225–241

Muthoni J, Wangui E (2013) Women and climate change: strategies for adaptive capacity in Mwanga District, Tanzania. Afr Geogr Rev 32(1):59–71

Ngwa KA, Ndoh MI, Balgah RA, Fomunyam RT (2015) Natural disasters, vulnerability and livelihood security in rural Cameroon. Int Rev Basic Appl Sci 3(9):108–121

Opiyo FE, Wasonga OV, Nyangito MM (2014) Measuring household vulnerability to climate-induced stresses in Pastoral Rangelands of Kenya: implications for resilience programming, research, policy and practice. Springer, Pastoralism

Pandey R, Jha SK (2012) Climate vulnerability index—measure of climate change vulnerability to communities: a case of rural Lower Himalaya, India. Mitig Adapt Strategy Glob Change 17:487–506. https://doi.org/10.1007/s11027-011-9338-2

Panthi J, Aryal S, Dahal P, Bhandari P, Krakauer NY, Pandey VP (2015) Livelihood vulnerability approach to assessing climate change impacts on mixed agro-livestock smallholders around the Gandaki River Basin in Nepal. Reg Environ Change 16(4):1121–1132

Patro S, Sahu KK (2015) Normalization: a pre-processing stage [Online]. Cornell University Library. Available from: https://arxiv.org/abs/1503.06462. Accessed 12 Feb 2018

Penning-Rowsell E, Sultana P, Thompson PM (2013) The 'Last Resort'? Population movement in response to climate-related hazards in Bangladesh. Environ Sci Policy 27s:s44–s59

Porter JR, Semenov MA (2005) Crop responses to climatic variation. Philos Trans R Soc Lond B Biol Sci 360(1463):2021–2035

Powell JP, Reinhard S (2016) Measuring the effects of extreme weather events on yields. Weather Clim Extremes 12:69–79

Preston BL, Emma Y, Westaway RM (2011) Putting vulnerability to climate change on the map: a review of approaches, benefits, and risks. Sustain Sci 6(2):177–202

Qaisrani A (2015) Connecting the dots: linking climate change resilience to human capital. Pathways to resilience in semi-arid economies. Sustainable Development Policy Institute, Islamabad

Qin D, Plattner GK, Tignor M, Allen SK, Boschung J, Nauels A et al (2014) Climate change 2013: the physical science basis. In: Stocker T (ed) Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge

Rasul G, Afzal M, Zahid M, Bukhari AA (2012) Climate change in Pakistan: focus on Sindh Province. Pakistan Meteorological Department, Islamabad

Reed MS, Podesta G, Fazey I, Geeson N, Hessel R, Hubacek K (2013) Combining analytical frameworks to assess livelihood vulnerability to climate change and analyze adaptation options. Ecol Econ 94:66–77

Saeed F, Salik KM, Ishfaq S (2015) Climate change and heat waves: rural to urban migration in Pakistan. A silent looming crisis. Environment and Climate Change Unit, Sustainable Development Policy Institute, Islamabad

Salik KM, Jahangir S, Zahdi WZ, Hasson S (2015) Climate change vulnerability and adaptation options for the coastal communities of Pakistan. Ocean Coast Manag 115:61–73

Salik KM, Qaisrani A, Umar MA, Ali SM (2017) Migration futures in Asia and Africa: economic opportunities and distributional effects—the case of Pakistan. Pathways to Resilience in Semi-arid Economies (PRISE) Report. Sustainable Development Policy Institute, Islamabad

Samee D, Nosheen F, Khan HN, Khowaja IA, Jamali K, Paracha PI et al (2015) Women in agriculture in Pakistan. Food and Agriculture Organisation of the United Nations, Islamabad

Scheffran J, Marmer E, Sow P (2011) Migration as contribution to resilience and innovation in climate adaptation: social network and co-development in Northwest Africa. Appl Geogr 33:119–127

Shah H, Khan MA, Akmal N, Sharif M (2005) Livelihood assets and livelihood strategies of small farmers in salt range: a case study of Pind Dadan Khan, District Jhelum, Pakistan. Pak J Agric Sci 42:1–2

Shah KU, Dulal HB, Johnson CA, Baptiste AK (2013) Understanding livelihood vulnerability to climate change: applying the liveliood vulnerability index in Trinidad and Tobago. Geoforum 47:125–137

Skoufias E, Essama-Nssah B, Katayama R (2011) Too little, too late: welfare impacts of rainfall shocks in Rural Indonesia. Policy Research Working Paper 5615. The World Bank, Washington, D.C.

Smit B, Wandel J (2006) Adaptation, adaptive capacity and vulnerability. Glob Environ Change Hum Policy Dimens 16:282–292

Smith B, Burton I, Klein RJ, Wandel J (2000) An anatomy of adaptation to climate change and variability. Clim Change 45:223–251

The World Bank (2015) World development indicators: Pakistan. The World Bank, D.C.

Turner BL 2nd, Kasperson RE, Matson PA, McCarthy JJ, Corell RW, Christensen L et al (2003) A framework for vulnerability analysis in sustainability science. Proc Natl Acad Sci USA 100(14):8074–8079

Ullah W, Nihei T, Nafees M, Zaman R, Ali M (2018) Understanding climate change vulnerability, adaptation and risk perceptions at household level in Khyber Pakhtunkhwa, Pakistan. Int J Clim Change Strat Manag 10(3):359–378

Wilkinson E, Peters K (2015) Climate extremes and resilient poverty reduction: development designed with uncertainty in mind. Overseas Development Institute, London

Zachariadis T (2016) Climate change in Cyprus: review of impacts and outline of an adaptation strategy. Cyprus University of Technology, Springer. https://doi.org/10.1007/978-3-319-29688-3

Zarafshani K, Sharafi L, Azadi H, Passel SV (2016) Vulnerability assessment models to drought: toward a conceptual framework. Sustainability 8(588):1–21