Flood hazards, human displacement and food insecurity in rural riverine areas of Punjab, Pakistan: policy implications

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Abstract
Rural communities inhabited on riverbank areas are frequently facing the ever-increasing psychological, social and economic distress due to negative effects of riverbank erosion. This study focused to investigate the impact of climate-based hazards particularly riverbank erosion on human displacement, food security and livelihood of rural riverine households and how vulnerable households act in response. The survey data of 398 households of erosion-prone riverbank area were collected, and group discussions connecting household heads from this area were also used for this study. In human displacement scenario of the last ten years due to riverbank erosion, almost 60% households lost their homestead once while 38% more than three times and forced to displaced. Empirical estimates of households' food security status indicated the value of Food Security Index 2.11, highlighting households face issue of food security all over the year. Food security issue of vulnerable households is highly related with migration because these households have insufficient employment chances, and coupled with limited or no farming land, they are highly prone to migration. In conclusion, this study estimated that riverbank erosion risk is a co-exist reason of population displacement, increasing rural environmental vulnerability and obstacles to psychological, cultural and socioeconomic development. Implications of local-based proper policy interventions such as developing advance research regarding infusion of agro-based technology packages for emerging Bait areas for developing resilience, human capital development, credit access and institution service are necessary for improving livelihood and food security of these riverbank erosion households. State-based institutions and local community mutually need to focus increasing forestry specifically in riverbank areas to save fertile land from riverbank erosion and reducing environmental pollution. Convalescing livelihood and food security for erosion riverbank households, more employment opportunity needs to provided, investing more in training and education programmes to promoting income-generating activities that subsequently will develop livelihood and food security of households.

Keywords Adaptation · Vulnerability · Resilience · Migration · Rural livelihood

Introduction

Floods, droughts, cyclones and storms are some major and consecutive disasters (Field et al. 2012; Ali and Rahut 2020;

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Alam et al. 2020) in couple of decades due to increased frequency of extreme climatic events in the world (Ahmad and Afzal 2020). These natural disasters are mostly influenced by choices of lifestyle, geographical locations and risk exposure (Teo et al. 2018) and have no limits of cultural, social, economic, political and geographical boundaries (Khan et al. 2013) of communities, countries and continents (Daniell et al. 2016; Ahmad et al. 2019). The world has faced severe human fatalities and economic costs, the reason of increasing severity and frequency of these natural disasters (Daniell et al. 2016; Ahmad and Afzal 2019). In the forthcoming era of 2050, human death is likely estimated at twofold due to these natural disasters (Wilkinson and Brenes 2014). Floods generally are the leading reason of losses among humans and mainly the source of economic and social risks (Doocy et al. 2013). In the forthcoming decades, riverine area households are

expected to face higher tendency of intense storms, rising sea level, increasing temperature, prolonged drought, water logging and consecutive and extreme flooding (IPCC 2019; Alam et al. 2020; Ahmad et al. 2020). Erosion scenario is highly associated with climate and catchment development and management of water resource, land use, geology and topography (Mirza 2003; World Bank 2019). Low vegetation cover, fast runoff and higher relief are expected some significant factors within increasing erosion rate naturally (Ali and De Boer 2010; World Bank 2019).

Flood hazards have adverse and severe penalty on economic activity, cultures, environment, livestock, infrastructure, property, human health and livelihood (Ali and Rahut 2020; Ahmad et al. 2020; Sarker et al. 2020a, b) rather than other natural hazards (Week and Wizor 2020). Climate experts in weather prediction perceive floods as the utmost challenge (Ali and Rahut 2020). Overflow of water body causes to overwhelm land formally known as flooding as overtopped the river banks, water stretch over flood plains (Week and Wizor 2020) and normally turn out to be hazards to society (Ali and De Boer 2010; World Bank 2019). Flood hazards are extreme one among metrological events (Ahmad et al. 2020) that generally occur in the areas characterized by high degree of rural enclaves or urbanization (World Bank 2019; Week and Wizor 2020). Annually, in global scenario, almost 20 million of people were negatively impacted, with almost 20,000 lives lost due to flood hazards and estimated to rise in the forthcoming era (Kellens et al. 2013). Inefficient and incompetent responses of adopted policies and inadequate non-structural and structural measures are major causes of loss of property and lives largely due to flood events (Mustafa and Wrathall 2011; Ali and Rahut 2020).

In hazards scenario, the phenomenon of flood hazards and human displacement is not new (Alam et al. 2020); recurrent floods ruin employment opportunities and increase vulnerability of rural riverbank population (Ahmad et al. 2020), and such frequent uncertainties cause riverbank erosion rural households to migrate permanently or temporary both externally and internally (Přívara and Přívarová 2019; Alam et al. 2020). In the world scenario, flood hazards cause enormous amount of losses of land, landlessness and displacement of population causing large number of population to become homeless (Islam and Rashid 2011; Das et al. 2011; Hossain et al. 2012; Rahman et al. 2019; Sarker et al. 2020a, b). Annually, throughout the world, owing to the reason of natural climates such as flood hazards, millions of rural families migrate from one region to another and face severity of livelihood, shelters and safety (Brouwer et al. 2007) with disasters of losses of homestead land, farmland and destroyed standing crops (Rahman and Gain 2020). To overcome the gap of food insecurity and income-consumption gap, restore lost assets in these flood-affected rural households (Islam and Rashid 2011; Das et al. 2011), and attain appropriate employment
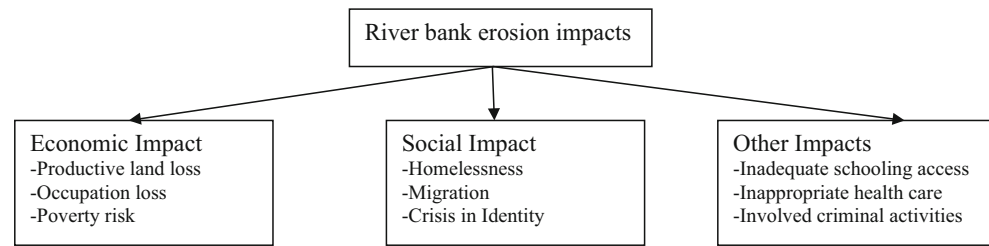
opportunities and schooling of their kids, migration to nearby developed or urban areas is preferred (Rahman et al. 2019).

Food security issues are mainly emerging in the current era due to severe effects of flood hazards which frequently occur due to consecutive climate change (Week and Wizor 2020). Inadequate supply of food, lack of access and purchasing power of food all relate to food insecurity phenomena (Abid et al. 2016; Ahmad et al. 2020). In spite of global food production gains, in the couple of decades, still almost 800 million people are estimated to be undernourished in the world (Nyarko and Kassai 2017). Extreme variability of rainfall, temperature, droughts and floods due to increased environmental intensity has increased the crisis of food security in household and national levels, more specifically in riverine areas of developing countries (Přívara and Přívarová 2019; Alam et al. 2020). Poor and low income households' food access is negatively affected due to higher food prices because of demand and supply gap of reduced crop productivity owing to flood hazards and increased food demand due to increasing population (Abbas et al. 2017; Ahmad et al. 2019).

People that inhabit near riverbank areas are mostly displaced due to erosion of riverbank and frequently face the crisis of losing previous identity, assets, means of living and homes (Das 2012; Das et al. 2019). Riverbank erosion and floods are two types of disasters (Alam et al. 2020); riverbank erosions have permanent losses of land scarcely to replace and long-lasting negative impacts on economy whereas floods show short-term losses of land, crops and houses with recovery afterward (Das et al. 2019; Přívara and Přívarová 2019). Riverbank erosion has multiple negative impacts on riverbank-inhabited population as loss of schooling, health, economic and social status (Alam et al. 2020). Social impact is first and foremost as due to land erosion in which people become homeless forcing them to migrate. With the reason of forced migration, migrated people undergo economic crisis such as loss of property and occupation most frequently at the risk of poverty and for a time caught up in criminal activities (Iqbal 2010). Access to inadequate medical and schooling facilities is a former issue of riverbank erosion (Ahmad et al. 2020) as people who migrate to new settled points for access of schooling of kids and medical treatment have to travel far areas (Das et al. 2019). Migrated population due to loss of occupation mostly faces economic crises (Alam et al. 2020) having no adequate money for essential needs such as shelter, food, schooling and medical (Abbas et al. 2017). Consequently, migrated population becomes unemployed, sick due to poor health and involved in criminal activities and losses their children schooling (Das 2012; Přívara and Přívarová 2019). These riverbank erosion impacts are indicated in Fig. 1.

In the world scenario, the Asian region is estimated to have 0.4% (Qamer et al. 2016) to 2% (Ahmed et al. 2015) the highest deforestation rate in the world, and such status increased the tendency of floods (Bradshaw et al. 2007) as

Fig. 1 Riverbank erosion impacts


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                          River bank erosion impacts

    Economic Impact              Social Impact              Other Impacts
    -Productive land loss        -Homelessness              -Inadequate schooling access
    -Occupation loss             -Migration                 -Inappropriate health care
    -Poverty risk                -Crisis in Identity        -Involved criminal activities
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consecutive and intense floods experienced in Pakistan during the current decade (Tariq and Van De Giesen 2012; NDMA 2014; Ahmad and Afzal 2019). In current couple of decades, in the region of Southeast Asia, the occurrence and potency of flooding have amplified and forecasted to boost up in the future (Krausmann and Mushtaq 2008; Hirabayashi et al. 2013; IPCC 2014). In South Asian countries, Pakistan is rigorously affected by floods, earthquake and drought in the last couple of decades (Abbas et al. 2017), reason of main fatalities of lives, crops, infrastructure and property resulting increase in the issue of food insecurity (PDMA 2014; UNDP 2019). Reducing riverbank erosion scenario in Pakistan widespread watershed projects have been implemented by the government (World Bank 2019); however, these are less effective due to covering limited portion of catchment area (WWF 2010). Pakistan has severe threats linked with alarming likelihood of melting Himalayan icecap, rising water stress, longstanding drought and augmented intensity and frequency of floods due to climate change (Bahadar et al. 2015; GOP 2019a, b). In the current climate change impacts of advanced hydrological models regarding different climatic zones across Asia, erosion riverbank and riverine households in Pakistan are largely denoted vulnerable to the impact of climate-induced hazards (Eregno et al. 2013; Hussain et al. 2016).

In developing countries, mostly riverbank erosion-affected households frequently face seasonal income-consumption gap resulting using the tool of migration to overcome this severity (Hussain et al. 2016; Mondal et al. 2015; Afifi 2011; Alam et al. 2020; Myers 2002; Khan et al. 2017). Pakistan is facing severe resourced-based economic losses of land, homesteads, crops, livestock and infrastructure due to erosion of riverbank hazards from consecutive floods rather than other natural hazards as earthquake, drought and storms (Ali and De Boer 2010; Ashraf and Shakir 2018; World Bank 2019). Households facing land and employment loss, food insecurity and social inequality due to erosion of riverbank hazards migrate permanently or temporarily (Afifi 2011; Islam 2018; WHO 2019) and search employment in neighbouring urban areas (Khan et al. 2017; Carling et al. 2018; Ahmad and Afzal 2020). Suitable likelihood of employment opportunities, improved schooling chances and affiliations to relatives and friends in urban areas are some other significant factors associated with rural migration in Pakistan (Akhtar 2011; Khan et al. 2017; Ashraf and Shakir 2018).

In the upcoming scenario, hazard severity under various hypotheses will encourage vulnerable households to undertake internal migration (Ercan and Younis 2009; Berman et al. 2015; Saleem Ashraf et al. 2017). Inappropriate policy measures due to misunderstanding regarding local-based issues of environmental hazards and application of adaptation and coping strategies not properly functioning need to be replaced with local-level effective and relevant policy measures (IPCC 2007; Alam 2016; Alam et al. 2017; Rahman and Gain 2020). Hazard-affected households' livelihood becomes more vulnerable due to climate change as indicated in the conceptual framework of the study in Fig. 2. Climate change causes abnormal flooding and subsequent riverbank erosion resulting in reduced household income due to losses of land, crops, livestock and homestead. Hazard-based households have reduced income causing marginal health expenses and lower schooling expenses, reducing food consumption and forcing household displacement resulting in households' status to be more vulnerable as indicated in Fig. 2.

In Pakistan, most of the research studies related to flood hazards focused on the aspect of protection work and riverbank erosion (Khan and Ali 2003; Ashraf and Shakir 2018); inundation of hazard zones and riverbank erosion (Ali and De Boer 2010; Khan et al. 2017); causes, consequences and measures of protection to floods (Khan 2011; Yaqub et al. 2015); flood hazard perception and adaptation strategies (Ahmad and Afzal 2020; Ahmad et al. 2020); and hazard assessment and management (Hashmi et al. 2012; Tariq and Van De Giesen 2012; Bahadar et al. 2015). In some extent, few studies in Pakistan focused on the aspect of flood-induced vulnerability and health risks (Shah et al. 2020), flood hazard vulnerability and resilience (Ahmad and Afzal 2019) and flood hazard effect on poverty and food security (Ashraf and Shakir 2018; Ali and Rahut 2020) while the aspect of flood hazards, human displacement and food insecurity in rural riverine households is not properly discussed.

In this scenario, there is deficiency in detailed pragmatic study on how riverine vulnerable rural households react in climatic issues and riverbank erosion flood hazards to lessen insecurity of food and livelihood issues that frequently trigger intra-country migration and displacement. Sympathetic household reaction to hazards will make possible policymakers to plan suitable policies for protecting the livelihood of vulnerable farmers and food security (Ford et al. 2010; IPCC 2014). In addressing this research gap, the

Fig. 2 Conceptual framework of study

Sources; Uddin and Basak (2012)
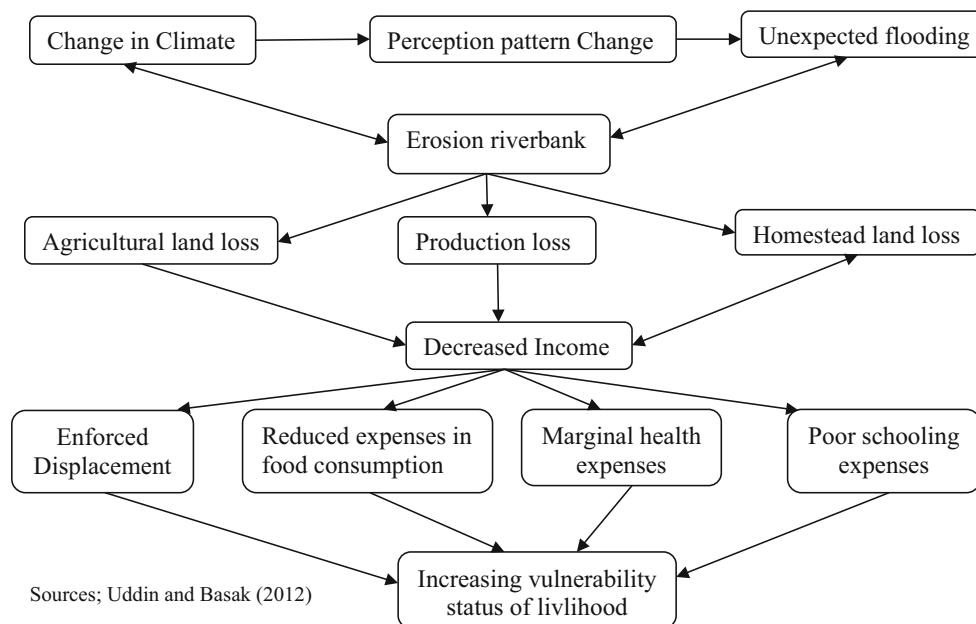
specific objective of this study is to assess association among flood hazards, human displacement and food insecurity related to viewpoint of adaptation of climate hazards in rural riverine households in Punjab, Pakistan. This study is categorized into four sections as introduction is explained in the first section, while materials and methods are discussed in the second section. The results and discussion are elaborated in the third section, and the last section highlights the conclusion and suggestion of the study.

Materials and methods

Study area

Punjab, the most populated province, sharing 53% of the population of the country, is enriched with fertile lands and properly recognized land of fiver rivers (GOP 2020) and thus selected for the study due to several considerable basis. Firstly, due to climate change and subsequent extreme and consecutive monsoon seasons, Punjab is highly vulnerable to flood hazards rather than tornadoes, earthquakes and droughts (PDMA 2014). Secondly, Punjab is facing the higher costs of property and human lives owing to urban, flash and riverine floods than other provinces (PDMA 2014). Thirdly, Punjab province faced major losses of properties, lives and infrastructure due to experiencing consecutive five floods from 2010 to 2015 in the current decade (Yaqub et al. 2015; NDMA 2016; Shah et al. 2017). Lastly, destructive and consecutive flooding is expected to increase in the future due to likely intense climate change as drought in winter and hail, stormy rainfall and increasing temperature in summers causing higher severity in the region.

Geographical features of study area

In Punjab province, the southern Punjab region is highly vulnerable to flood hazards and located among major rivers as indicated in the high-risk, flood-prone area (NDMA 2016; GOP 2019a, b) specifically selected for this study. In southern Punjab region, due to higher risk of flood-prone and severe riverbank erosion status, Muzaffargarh and Rajanpur districts (PDMA, Punjab 2014) were purposively selected as indicated in Fig. 3. The Muzaffargarh district administratively consists of four tehsils, Alipur, Muzaffargarh, Jatoi and Kot addu, with 93 union councils (GOP 2019a, b), covering the area of 8249 km^2 with a population of 4,322,009 (PBS 2017). This district faces higher severity of floods due to being located in the centre of two major rivers as in the western side the Indus River flows and in the eastern side the Chenab River flows (GOP 2018). Hot summer and mild winter are some major aspects of this arid climate in this region with average rainfall of 127 mm and highest temperature of 54 °C (129°F) and lowest temperature of 1 °C (30°F) (GOP 2019a, b). The Rajanpur district administratively consists of three tehsils Rojhan, Rajanpur and Jampur covering the area of 12,318 km^2 consisting 1,995,958 population size (PBS 2017). The district of Rajanpur with extreme and long summer is denoted with hot region and stuck strongly by severe flooding as it is located in the Indus river western bank (PBS 2017).

Sampling procedure, questionnaire and collection of data

In collecting data from hazard-prone riverbank erosion-affected rural households of Punjab province, this study used simple random sampling approach. Adequate expert

Fig. 3 Study districts of Punjab province, Pakistan
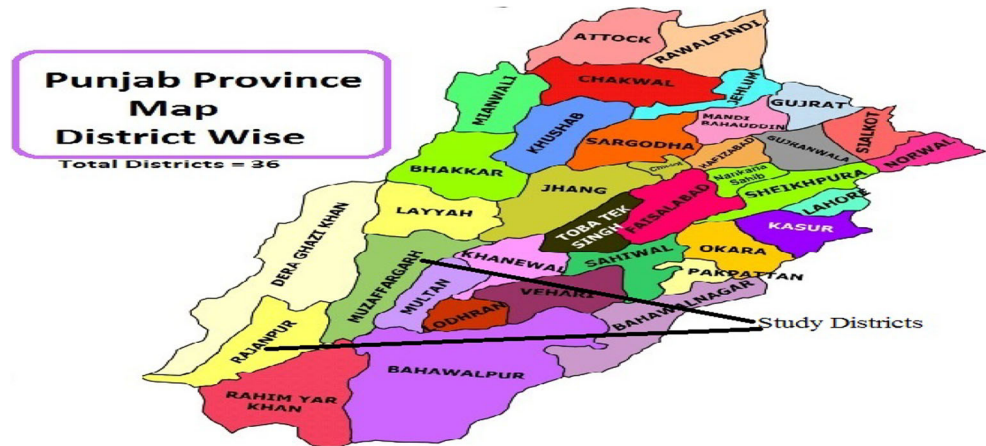
consultations, newspaper reports, literature justification and proper reports of NDMA and PDMA were significant sources in selection of erosion-affected riverbank study areas regarding erosion severity as districts, tehsils, union councils and villages. Respondents were chosen randomly from specified erosion-affected riverbank villages of the study area. The tehsil Alipur from the district of Muzaffargarh and the tehsil Rajanpur from the Rajanpur district were specifically selected due to most severely erosion-affected riverbank by the Indus River area in southern Punjab of Pakistan (PDMA 2017). The Indus River is the largest river of Pakistan and reported the most erosion-affected riverbank river in southern Punjab region of Pakistan (GOP 2019a, b; NDMA 2018). Eight erosion-affected riverine villages were appropriately selected according to information provided by local government and official land record holder (patwari) of the area.

In selected villages, the listed erosion-affected riverine households according to agriculture department were targeted for collection of data. In data collection procedure, households were basic unit while household head (male/female) is the major respondent of the study. This study used sampling method of Cochran (1977) to determine minimum sample required for study as indicated in Eq. (1). Household heads from each village were targeted and collected data of 398 respondents, and 5% of the population was considered adequate for cross-sectional data (Kotrlik and Higgins 2001). In selection of these households, random numeral table was created through a computer and used to the list chosen to these households. Enumerators completed the given respondent numbers from each village while respondent not willing to participate was replaced with others. In each village, a focus-group discussion including 8 to 13 of household heads was conducted to obtain views of different issues of food security, socioeconomic factors and climatic issues, and these judgements were applied for cross-validating the information attained from key information collected from the surveys. Eq. (1) indicated sample size as SS, Z

elaborated the confidence level as ($\pm$ 1.96 at 95%), choice of percentage picking pointed as p, expressed as decimal (0.5 used as sample size required), whereas precision value was denoted as e (0.07 = $\pm$ 7).

$$Sample\ size = \frac{Z^2(p)(1-p)}{e^2} \quad (1)$$

In data collection procedure, with direct interaction of respondent from February to May 2018, a well-developed questionnaire was used. To avoid ambiguity and to find out accuracy and adequacy of information, 20 respondents were pilot tested with the questionnaire prior to proper survey in the study area. The author himself and five trained enumerators started the survey and all relevant issues were clarified and corrected. Households' monthly basis status of food security self-reporting, socioeconomic status of household and adapted vulnerability mitigation strategies related to seasonal migration and income were significant information included in the questionnaire. To make sure of significant presentation, data percentages and mean were calculated through statistical analysis.

Flood hazard measures

Potential of flood so as to engage risk to property, health, life, functions and resources of floodplain was known as flood hazards that comprise the elements of incidence of probability, severity and speed of flooding onset (Linsley 1986; United Nations 2009). Hazard-specific characteristics and scales were prerequisites for measuring the severity of natural hazards as floods (Smith 2013; Rana and Routray 2018). In flood hazard risk, seven indicators as flood frequency inside house, in neighbourhood, flood height in resident ground floor, in local roads, flood duration, inundation likelihood and damages of previous floods were specified. These indicators were further categorized in classes according to responses and weights as flood hazard index used in the study (Rana and Routray 2018)

as given in Eq. (2) indicating the flood hazard weights (FHW) and *n* as numbers.

$$Flood\ hazards\ index = \sum_{i=1}^{7} FHWi/n \qquad (2)$$

Measures of human displacement due to flood hazards

In earlier studies, human displacement was more approximately measured with ratio formula as (DRI = VSI/CRSI) related to sub-components of VSI and CRSI while this ratio formula was involved in many difficulties of computational, outcome interpretation and policy recommendation (Esnard et al. 2011). In overcoming such drawbacks in measuring displacement ration formula, displacement risk index finally developed on many multiple dimension indices as community resilience sub-index (CRSI) and vulnerability sub-index (VSI) with flood exposure probability component as used in the study (Esnard et al. 2011). Vulnerability sub-index (VSI) consists of housing vulnerability (floods, built environment) and socioeconomic (schooling, age, income, housing, economic, ethnicity) indicators, whereas community resilience sub-index (CRSI) includes policy (institution resilience, state performance) and resiliency (emergency capacity, economic resilience) indicators to reduce displacement and vulnerability (Sarker et al. 2020a, b, c). Displacement risk index as used in different studies as applied in this study is indicated in Eq. (3)

$$DRI = \left(\frac{CRSI + VSI}{2}\right) *Probability \qquad (3)$$

In Eq. (3), the displaced risk index is indicated as DRI, community resilience sub-index elaborated as CRSI, while the vulnerability sub-index was highlighted as VSI.

Measuring household food security

The method of calorie intake (Feleke et al. 2005), measures of food security self-assessment (Headey and Ecker 2013) and score of food consumption and index of coping strategies are indicated as various significant measures to estimating food security household level. Adequate food-acquiring ability required for family members considered a house food secured while it does not highlight individual members as nutritionally food secured (Pinstrup-Andersen 2009). Food security index (FSI) was employed in measuring the status of rural households food security during the year if every one of household member of family be able to pay for to obtain food thrice a day (secured) or not (insecure) (Kazal et al. 2010; Chatterjee et al. 2012; Alam 2016). In national and global scenarios, multiple researches indicated various approaches of measurement and

provided dissimilar estimates regarding food security and insecurity (Haysom and Tawodzera 2018). As captivating to description according to local perspective as derived food security index (FSI) used in the study (Alam et al. 2020) also employed in this study.

Scarce, inadequate and adequate status on food security questionnaire of three Likert scale was developed for the response of respondents of the study area. Food secured was considered the scenario as family households attain day meal without lacking any worries indicating adequate response. Acquiring calories and appropriate nutrition thrice time a day according to proposed healthy and active life as household bother no worry of difficulty was denoted as food secure as adequate. Households attaining food twice a day as sometime thrice a day while bother difficulty in attaining required recommended calories and thrice a day of meals indicated as food inadequate. Households only able to have one time meal in a day while bother in attaining required calories intake and food twice a day were denoted as the food scarce. In the given scale on monthly basis, the required questions were responded by household heads in no or yes, and scores were produced according to Eq. (4). The related values of scale as scarce, inadequate and adequate were specified the values of 1, 2 and 3 correspondingly for developing FSI index (Kazal et al. 2010). The structure of FSI is as follows:

$$FSI_i = \frac{X1F1 + X2F2 + \dots\dots\dots XnFn}{N} \qquad (4)$$

Respondents' total numbers specified for *i*th food security status were denoted as *X*, food security *i*th status was given scale values indicated as *Fi*, while total sample size was highlighted as *N* in Eq. (4). Food security measurement is basic and easy to recognize and facilitates policy makers to be aware of the month in which household countenance has more food shortage for devising the policy-based involvement. Food shortage scenario diverges diagonally the months in households while not similar all through the year. To make possible, knowledgeable policy interference of food security index is considered on monthly basis.

Results and discussion

Socioeconomic characteristics of study area

In developing possible policy involvement to improving livelihood and food security of the vulnerable households, appropriate provision of social demographic information is essential. In hazards impacts on socio-demographic status of households in the study area as explained in the last ten years due to river bank erosion, almost 61% of the households lose their homestead once while 39% more than three times. Average

schooling years in the study area is below five years (2.91 years), while 31% have no schooling. Inadequate road infrastructure, being far away and limited schools are major constraints regarding deficient schooling facilities, causing more than 22% of the households not sending their children to school. In the last 10 years, due to erosion of river bank, the study area has lost dozens of markets, many roads, 18 religious institutions (masjid schools) and 23 formal schooling institutions as information given by the respondents. Loss of agricultural income and employment opportunities has been reported to be more than 96% of the households according to the respondents of the study area. Selling agricultural products to local market farmers incurs high transportation cost due to poor infrastructure of transport and roads facilities causing issues in participation of off-farm activities and traders' visits. In assistance and advices of rural development, market and agriculture, 67% of the households have no access to extension services. In the study area, average family size is 6.93; in households that lost their homestead, 51% of them have no safe drinking water facility, 23% no access of sanitary latrine and those having own tubewell face the issue of higher arsenic contamination. Households have a distance of 1 or 1.5 km to safe water access, 59% no electricity and 43% no health facility access due to loss of 5 public hospitals in erosion of river bank.

Farming status changes caused by riverbank erosion

Farming community of erosion river bank area over the years has faced major losses of land caused by the changes in farming status regarding their ownership as indicated in Table 1.

Average farm size in Pakistan is 6.4 acres (FAO 2010), and almost 29% of the households in the study area were indicated as landless. In the last ten years, due to erosion of river bank, of 44 large farm size households, 19%, 37%, 32% and 12% are categorized as medium, small, marginal, and landless farming status, respectively, while of 154 medium farm size households, 26%, 33%, 25% and 16% are grouped as medium, small, marginal and landless farming status, respectively.

Out of 134 small farm size households have now become 17%, 48% and 35% small, marginal and landless farming status, respectively, while out of 45 marginal farm size households, 23% and 77% were grouped as marginal and landless farming size status, respectively, in the study area. In the last ten years, 29% farming households of the study area have dropped in the landless farming group. Farming is indicated as the major source of livelihood in the study area, whereas changing farming size status to marginal and small farming community has been affected worse, but medium and large farmers were more severely badly affected due to erosion of river bank. Farming community severity in changed farming size status due to erosion river bank causes the major issue of food security.

Estimates of flood hazard measures

Flood hazard components are denoted as the interesting estimates according to Eq. (2) which ranged from 0.28 to 0.98 for the district of Muzaffargarh and 0.24 to 0.89 for the district of Rajanpur with flood hazard average value of 0.71 and 0.65, respectively. These index values elaborated the higher severity of flood hazards in both Muzaffargarh and Rajanpur, while

Table 1 Farming status changes caused by riverbank erosion

Ownership of land (in acres) (1 acre = 0.405 ha)	Household numbers 10 years ago (%)	In the current scenario 2018 household no	Farm category scenario change in %
Farms in large size (above 50 acres)	44 (11.05%)	Farm category medium	19
		Farm category small	37
		Farm category marginal	32
		Landless farmers	12
Farms in medium size (12.5–25 acres)	154 (38.69%)	Farm category medium	26
		Farm category small	33
		Farm category marginal	25
		Landless farmers	16
Farms in small size (5–12.5 acres)	134 (33.67%)	Farm category small	17
		Farm category marginal	48
		Landless farmers	35
Farms in marginal size (less than 5 acres)	45 (11.31%)	Farm category marginal	23
		Landless farmers	77
Landless	21 (5.28%)	–	29

Sources: survey-collected data

Table 2 Flood hazard assessment of flood-prone households

Level	Muzaffargarh		Rajanpur		Pearson's χ^2	
	Frequency	Percentage	Frequency	Percentage	Value	P value
Very low Q1 (0.00–0.26)	19	9.54	28	14.07	74.896	0.001*
Low Q2 (0.26–0.33)	33	16.58	43	21.61		
Moderate Q3 (0.33–0.40)	49	24.63	52	26.13		
High Q4 (higher than 0.40)	98	49.25	76	38.19		
Total	199	100	199	100		

*At significance level of 1%

it is more severe in Muzaffargarh indicating 49% households were living in higher disaster prone area rather than Rajanpur wherein 38% households were in disaster-prone areas as indicated in Table 2. Higher severity of Muzaffargarh district is due to the district sandwiched in both Chenab and Indus rivers, so both of these rivers severely and ruthlessly damage frequently in each season whereas the Indus river flows in the eastern side of Rajanpur and causes destruction almost in each season. Such scenario of higher flood hazard severity and index values was the focus of these districts for study.

Food shortages, coping strategies and adaptation measures in the study area

Household food security level was severely affected due to major issues of climate change and erosion of river bank. The value of food security index ranges from 1 (least food secure (scarce)), 2 (insufficient food secure (inadequate)), to 3 (food secure (adequate)). In the study area, the estimated value of food security index is 2.11 indicating as regarding to food-secure households having hardships/inability to cope with food desires all over the year. Households of the study area are able to frequently deal with food for their family member two times a day with large diversity in overseeing food security index all over the years. Higher food insecurity

is experienced in six months (June to November) in the study area owing to rainy season and reduced non-farming and farming activities, and higher severity of erosion riverbank was also experienced in these days as indicated in Fig. 4. According to cultural basis in the study area, in food access to family members, there is no equal treatment as men are mostly focused priority due to more income earner and higher waged. Families with educated women and having way in to income sources indicated equivalent access of household food whereas older women who are illiterate, out of government social safety programmes and no significant income source are more vulnerable in the community.

Hazard effects were attempted to lessen by households of the study area in the course of using non-agricultural (activities with income and production capability such as disposing off livestock and assets) and agricultural adjustments (different methods to make better production of crops such as advanced crop varieties). Farming community-owned production of food supply is only adequate to feed few months to their own family members, so market for purchasing food and other necessities is frequently dependent, which is significantly influenced by their income earning capability. Inadequate employment opportunities cause limited earning capacities to the income of the study area households. Medium farmers frequently face food shortage due to inadequate income and

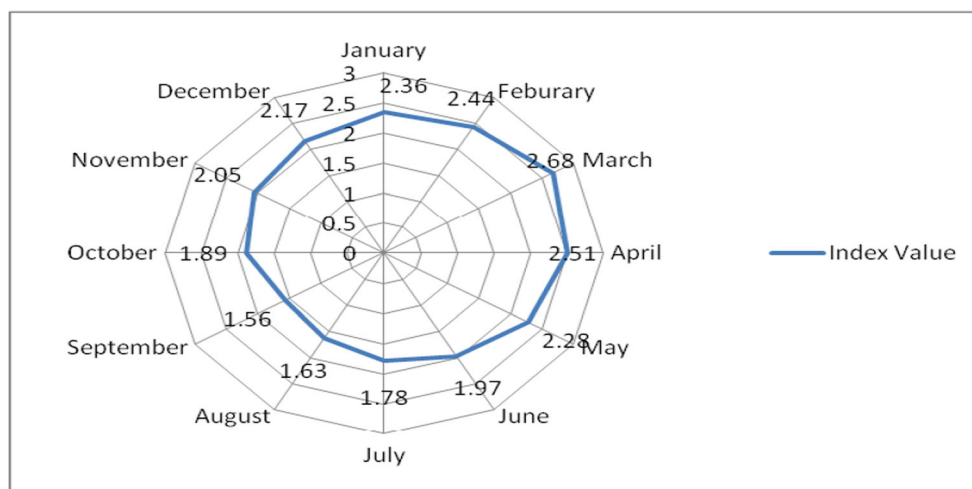**Fig. 4** Household status of food security throughout the year of study areas

Table 3 Study area closed to food shortages, coping strategies and adaptation measures

Coping strategies	Respondent response percentage[a]	Categories of farm			
		Medium-sized farms	Small-sized farms	Marginal-sized farms	Landless
Food consumption reducing	79	Y	Y	Y	Y
Neighbouring location or city migration	58	N	Y	Y	Y
Assets selling for food	54	N	Y	Y	Y
Expenditure reducing	41	Y	Y	Y	Y
Casual labour dependency for food	34	N	Y	Y	Y
Borrow money for food access	29	Y	Y	Y	Y
Credit used for food purchase	23	N	Y	Y	Y

Adaptation strategies	Respondent response percentage[a]	Farm categories			
		Medium-sized farms	Small-sized farms	Marginal-sized farms	Landless
Rearing duck, poultry and livestock	97	Y	Y	Y	Y
Sowing advance crop varieties	88	Y	Y	Y	N
Planting timing variation	81	Y	Y	Y	N
Vegetable cultivation	75	Y	Y	Y	N
Oil seed and spice cultivation	63	Y	Y	Y	N
Gardening at home	55	N	Y	Y	Y
Plantation of forestry	49	Y	Y	Y	N
Income sources from off-farm activities	23	N	Y	Y	Y

[a] The reason of multiple options % does not add up to 100

Y, for yes as using coping strategies and adaptation; N, for no as not using coping strategies and adaptation

production and not selling their assets to migrate to urban areas and purchase other necessities and food on credit.

Food consumption reduction (79%), migration to other neighbouring or urban areas (58%), assets by selling for foods (54%) and expenditure reduction (41%) are some common significant coping approaches used by farming community in the study area as indicated in Table 3. These coping strategies have some severe outcomes; food consumption reduction in long-term badly affects their wellbeing and health causing them to be unhealthy and misfit for non-farm work and farm activities eventually turning into burden on society. Selling poultry and livestock indicated as assets as selling is major source of household income also has harmful effects on future food security and sustainability of households. In poor farming community of developing countries like Pakistan selling assets during time of adversity (flood, drought, erosion of riverbank) is indicated as a common practice (Paul 1998; Mondal et al. 2015; Alam 2018).

In suitable consideration of climate hazard household response, it is more proper to address both coping and adaptation strategies altogether (Berman et al. 2015; Ahmad et al. 2020). There is significant role of coping strategies in forming future adaptation strategies. The study area has shown in spite of evident problems households' reaction to other natural hazards and erosion riverbank in the course of adaption a range of adaptation strategies. Rearing duck, poultry and livestock (97%), sowing advance crop varieties (88%), planting timing variation (81%) and vegetable cultivation (75%) are some significant adaptation strategies adopted by households in the study area as indicated in Table 3. Off-farm work (23%) and rearing duck, poultry and livestock (97%) are major adaptation measures of landless and marginal farmers for diversifying their income sources. Oil seeds and spices (63%) are cultivated in recently formed *Bait* study area which remains fallow previously due to inadequate access of these suitable crop varieties for such land. To make sure sustainable and effective use of remaining available land, almost (55%) landless and small farmers' households are mostly focusing homestead gardening as indicated in the consecutive source of income and nutrition supply chain for households (Monirul Alam et al. 2018; Alam et al. 2018a, b; Sarker et al. 2019). Encouraging households to adopting these strategies through developing skills and providing advance technologies, NGOs and government institutions can play significant role (Alam et al. 2017, 2020). Landless and small farmers have used few adaptation measures due to inadequate technologies and resources because of limited access of extension services and credit as experienced in the study area. Encouraging adaptation process and making sure household institutional access in these areas, government involvement through appropriate policy measures is mandatory.

In the scenario according to land categorized food security of household specifying a changing status of food insecurity

regarding to different groups was practiced all over the year. In the study area, in the total of 48 medium farmers, 13 (27%) farmers were considered food insecure while 35 (73%) farmers were denoted with status of food secure (adequate food three times a day) all over the year as indicated in Fig. 5. In total of 90 small farmers, 70 (78%) were in the status of food insecure (including 29% scarce and 49% inadequate) while 20 (22%) were in the adequate food access in all over the year. Out of 127 marginal farmers, 24 (19%) farmers were considered food secure while 103 (81%) were denoted as food insecure (34% scarce and 47% inadequate) all through the year. In the total of 133 landless farmers, 16 (12%) were considered food secure while 117 (88%) (including 43% food scarce and 45% inadequate) indicated as food insecure during the year as shown in Fig. 5.

Causes of rapid migration in the study area

In the study area, farmers use migration as major coping mechanism as reaction to overcoming food shortage issue. Unemployment (91%), inadequate income (87%), insufficient crop production regarding consumption (74%), scarcity of land (68%) and inadequate financial resources for expenses (65%) are significantly associated with food insecurity and prompt as major factors of migration in the study area as indicated in Table 4. Hazard push and pull with appropriate employment opportunities (58%) also prompt migration as justified in the studies of Penning-Rowsell et al. (2013), Martin et al. (2017), Alam et al. (2017), and Alam et al. (2020). In the study area, higher tendency of migration was indicated in wage labourers and marginal farmers due to limited employment opportunities and inadequate or no cultivated land. Dropping the households in the landless category due to erosion of riverbank as justified regarding that in Table 1 whereas with higher tendency of migration was denoted among households having schooling less than primary and aged 18 to 47 years.

Farmer households with no or insufficient cultivated land not capable to feed their families migrate to neighbouring urban big cities or district areas for alternate livelihood and involve themselves in informal activities as wage labours, domestic labours and construction employment for a few months to secure their feed. Migration commonly increases in rainy season when employment in the area is deficient while when generating some scope of non-farming and farming employment, migrated households return to their homes (Alam 2016; Islam 2018).

Significant aspects of the households of seasonal migrant

Limited employment and crop production in rainy season due to mostly land of Bait area in riverine water cause diversifying livelihood strategies and encourage riverbank household to migrate often permanently while mostly seasonally. Seasonal migration receives significant proportion as 41% in the households were farm labours with annual income as indicated in Table 5. Substantial income proportion of small (24%) and marginal (35%) farmers' households is earned during migration season which facilitates farmers in returning their debts and improving food security status (Khandker et al. 2012; Etzold et al. 2014; Alam et al. 2020). Impacts of climatic hazards and erosion of riverbank motivate households to out-migrate and increase their food insecurity, so for vulnerable households, migration is complementary for food security.

Seasonal migration within the country in the background of seasonal deprivation mitigating regarding Pakistan is discussed in this study. In overcoming food anxiety for vulnerable communities, specifically in month of food insecure, particular food policy intervention from the government is required while existing policies are having minimal role. Households of riverine are more vulnerable to food insecurity which causes complementary migration; the effective role of

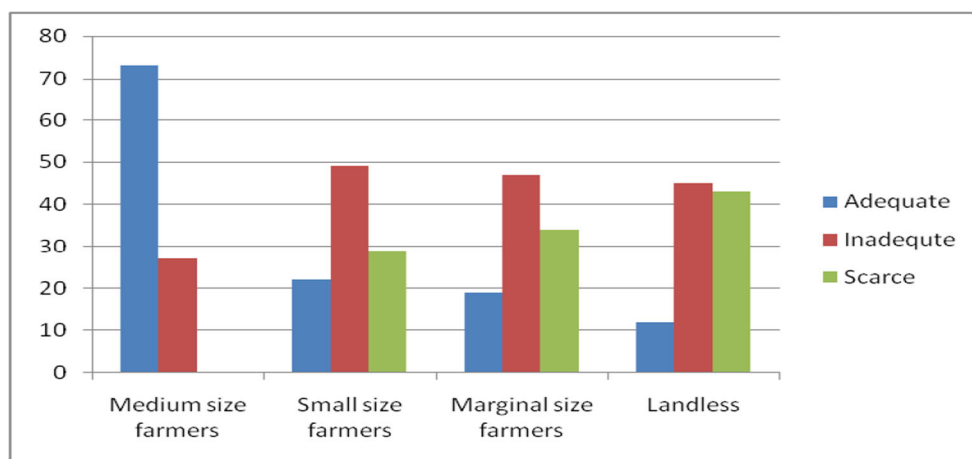**Fig. 5** Land-categorized household farmer food security status all over the years

Table 4 Causes of rapid migration in the study area

Major causes	Percentage responses[a]	Categories on farm basis		
		Farm size small	Farm size marginal	Landless
Unemployment	91	Y	Y	Y
Inadequate income	87	Y	Y	Y
Inadequate production of crop regarding household consumption	74	Y	Y	N
Scarcity of land for farming/cultivation	68	Y	Y	Y
Inadequate financial resources for purchasing needs	65	Y	Y	Y
More and appropriate employment opportunities in urban areas	58	Y	Y	Y

[a] The reasons of multiple options % not added up to 100

NGOs and government institutions through training better prepares workers for labour market providing information of employment opportunities which can make migration less costly and more efficient. Employing unskilled agricultural worker in the study area in agro-based industries needs to be promoted through proper government intervention policies. In the scenario of local conditions, infusion of advanced technologies, high value-added crops and advanced, improved crop varieties accelerates adaptation procedure specifically in emerging *Bait* areas. In erosion-prone riverbank areas, environmental condition considers rearing ducks, livestock and poultry more suitable to branch out strategies of livelihood which need to be encouraged through credit provision and technical assistance from proper NGOs and government intervention policy measures rather than crop production. Homestead gardening is another adaptation strategy for

households of the study area, which must be encouraged through providing adequate training and access of advance technologies. Improving land management practices, agronomics and production techniques regarding climate change issues and extension of service access for appropriate information need to be enhanced in these poor resources used area for speeding up of adopting adaptation strategies. These measures will significantly develop livelihood and getting better food security status of riverine households across Pakistan. In promoting and supporting policymakers in turn to sustainable and effective actions, local-level sympathetic adaptation strategies play crucial role. In the scenario of the field survey experience, marginal and small farmers have inadequate access of extension services and credit that squeezes capability of farmers in obtaining technologies and resources for adaptation procedure. Ensuring extension service and credit access throughout the riverbank and riverine areas, appropriate government intervention policies are required.

Estimates of displaced risk index of study area

Displacement risk index (DRI) validation was estimated by using regression analysis flood exposure, VSI and CRSI as independent variables whereas the DRI is considered as dependent variable. Estimates indicated as model were highly statistically significantly the reason of F-statistics value (F-

Table 5 Significant aspects of households of seasonal migrant

Significant indicators of migrants	Indicator-related comments
Households experience of migration (numbers)	49%
Farming grouping wise migration	
Household of small farm size	21%
Household of marginal farm size	28%
Labour of farms	51%
Migrants gender wise	
Male gender	83%
Female gender	17%
Educational-level range (illiterate to 10 years schooling)	Average 3.1 years
Migrant age range	Average 25.78 years
Migrants income status (percentage of total income)	
Households of small farm	24
Households of marginal farm	35
Labour of farms	41

Table 6 Displacement risk index regression estimates and analysis

	Unstandardized coefficients		T statistics	Significance
	Coefficient	Standard error		
Intercept	− 18.43	4.78	− 3.97	0.000
CRSI	0.31	0.09	4.34	0.003
VSI	0.38	0.06	8.41	0.001
Probability	489.27	18.97	31.73	0.001

statistics, 387.14, and probability value, 0.001). In this model, variance was explained as 87% with the adjusted $R = 86.93$. In Table 6, the coefficient and intercept of three regressions statistically highly significant indicating displacement risk index can be predicted logically well.

Conclusions

Pakistan is considered among the mainly vulnerable countries of the world owing to recurrent environmental changes such as abnormal rainfall, consecutive intense floods and frequent riverbank erosion and drought. The Southern Punjab region of Pakistan is one of the major vulnerable riverbank erosion areas of the country because of the flowing largest Indus River of the country. Riverbank erosion unfavourably influences the inhabited population livelihood culturally, psychologically, economically and socially. Riverbank erosion displaces a large number of population in each flooding season. Inhabitants of riverbank areas lose their tangible properties, forests, livestock, agricultural land and habitats. Riverbank population due to riverbank erosion is displaced, builds new settlement and commonly faces the issues of psychological stress, economic crisis and food insecurity. Consequently, such scenario causes vulnerability socially and environmentally in all senses. Poor and marginalized people of riverbank erosion areas face socioeconomic vulnerability and lose their assets throughout riverbank erosion era. Earlier than weakening conditions to further than control it is far above the ground time to hold essential action to make sure sustainable livelihood management of affected riverbank population and control or minimize riverbank erosion.

Policy implications

In sustainable and effective actions regarding promoting and supporting appropriate strategies, policymakers need to be familiar of local-based issues and native feasible adaptation strategies.

Firstly, saving farmland from river erosion-concerned state authorities must focus to construction of embankment in current riverbank erosion areas. Secondly, private sector, local civil society and non-governmental organizations should mutually take appropriate measures to overcome deforestation. Thirdly, urgent-basis policy measures for rehabilitation and relief programmes such as providing shelter, nutrition, medical, schooling and interest-free loans for migrated population need to be implemented. Lastly, involving local government and institutions in providing disaster preparedness training to the inhabitants of riverbank erosion is a must.

Compliance with ethical standards

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