Flood Hazards Vulnerability And Risk Of Food Security In Bait Community Flood-Prone Areas Of Punjab Pakistan: In Sdgs Achievement Threat

Dilshad Ahmad (dilshad@ciitvehari.edu.pk)
COMSATS University Islamabad https://orcid.org/0000-0002-3991-805X

Salyha Zulfiqar Ali Shah
Bahauddin Zakariya University

Muhammad Afzal
Preston University - Islamabad Campus

Research Article

Keywords: Climate change, Flood hazards, Riverbank erosion, Food security, Punjab, Pakistan

Posted Date: March 10th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1337210/v1

Abstract

Food security is a global concern while economic growth, hunger eradication programs, raising agricultural productivity, and public policy measures have played a significant role in improving food security. However, to a great extent of Pakistan's population still experiencing poverty and hunger in their daily livelihood. Flood disasters have caused barricade agricultural production and interrupt livelihood routine matters so household-level food security is eventually affected by floods. This study investigated food security of rural flood-prone households of Punjab, Pakistan with a broader aspect in contrast to previous research work. Constructing the food security index composition of different IPCC and FAO factors with related dimensions of food security was used for the empirical estimation of this study. Composite food security index was developed through polychoric principal component analysis. To estimate the influence on the whole food security condition in the study area food security index was regressed on various independent variables. The finding of the study indicated as ¾ of the household respondents in the study area are confronted with the issue of food security with a changeable scale. Financing schemes, physical assets, and family type illustrated the positive influence on respondents' food security level whereas respondents suffering property losses owing to floods and having mostly status of female. Findings of the study suggested as integrated strategies necessitate adopting for well deal with issues of food security in the scenario of rising severity of flood disasters. In the scenario of Pakistan policymakers to deal with food insecurity tackled regarding flood hazards.

1. Introduction

In the global scenario, in a couple of decade's natural hazards specifically, the floods, landslides, drought, cyclones, and earthquakes, intensity and frequency have risen (Teo et al., 2018; Ahmad and Afzal, 2020; Week and Wizor, 2020; Elahi et al., 2021), due to increasing temperature and related climatic variability's (Tirivangasi, 2018; Eckstein et al., 2019; Hoq et al., 2021). Floods in contrast to other hazards considered most destructive and consecutive (Daniell et al., 2016; Ahmad et al., 2019; Houng et al., 2019) due to substantial involvement in human fatalities, economic losses, and social risks (Kreft et al., 2016; IPCC, 2017; Ahmad and Afzal, 2021). In 2017, throughout the world, almost 96 million populations were severely affected by natural hazards (Emergency Event Database, 2017; World Bank, 2021) in which more than 60% were affected by flood disasters (Huong et al., 2019; IPCC, 2021). During a couple of decades, rising severity and recurrence of floods have been estimated specifically in South East Asian and South Asian countries (Hirabayashi et al., 2013; Eckstein et al., 2019) where a few countries from Asian region such as Bangladesh, China, Pakistan and India declared the supermarkets of flood disasters (James and James, 2010; Mahmood and Babel, 2016; Teo et al., 2018). In the future, increasing intensity and severity of flood hazards are expected in the Asian region (Ahmad et al., 2019; IPCC, 2021) which consequently affects regional disparities regarding onset and distribution, causes to higher losses accumulating in nations inside the Asian region (Abbas et al., 2017; UNSCCC, 2021; Sam et al., 2021).

Pakistan has ranked the world's 5th most climate change natural disasters affected country because of facing frequent floods and is situated in the critical region of hazard-prone (Eckstein et al., 2019; IPCC, 2021). Erratic rain, monsoon rainfall expanding cycle, and glacier melting are some considerable factors linked to successive floods in interlinked rivers regarding downstream and upstream (Abid et al., 2015; Teo et al., 2019; Ahmad and Afzal, 2020). In natural hazards and particularly in flood disasters aspect, Pakistan during 1950 to 2014 repeatedly faced twenty-two serious flood hazards (Yaqub et al., 2015; Ali and Erenstein, 2017; Shah et al., 2017). The flood disaster of 2010 was the worst one that adversely affected 24 million population, destroyed two million cropped areas and the cumulative estimated cost was $10 billion (United Nations, 2011; Abbas et al., 2017; Ahmad et al., 2021). In the flood of 2011, recorded higher ever rainfall severely affected 2.7 million population of southern Balochistan and Sind, major 434 human fatalities, damaged 1.52 million homes and destroyed the crops of 6.79 million acres (PDMA Punjab, 2017). Heavy monsoon rains significantly affected 4.85 million populations of Sindh, Punjab, and Balochistan in 2012, destruction of 1.172 million cropped areas and 571human fatalities (PDMA Punjab, 2018). In 2013, heavy monsoon rains caused flash floods and

affected 1.5 million people, destructed cropped area of 1.6 million acres, and 234 human fatalities (BOS, 2016). Flash flooding in 2014 major rivers affected Gilgit-Baltistan, Kashmir and Punjab caused 350 human fatalities, vast destruction of homes, and cropped area (PDMA Punjab, 2019).

In developing countries, flood events increasing intensity and frequency causes many implications for the livelihood of the population regarding different aspects (Abbas et al., 2018; Sam et al., 2019). Increasing flood specifically in developing countries predicted severe repercussions for the survival of human beings by distressing availability and access of food, thus showing obstructions to attaining SDGs of UN, particularly the SDG-2 focused on endorsing sustainable agriculture, improving nutrition, attaining food security, and hunger eradication till 2030 (Banik, 2019). Food security is regarded as a worldwide human right (WHO, 2018) and achieving food security is the vital objective that can be attained through maintaining affordable health and a sustainable supply of food (Perez-Escamilla, 2017). In the global scenario, least-developed and developing countries are consecutively confronted with the major challenge of achieving food security and almost 820 million people do not have sufficient food for their hunger satisfaction (WHO, 2018). In Pakistan, the green revolution was introduced in 1960 with advanced inputs of high yield seed varieties, fertilizer, pesticides, tubewell, mechanization through tractor and other advanced technologies (Khan and Makki, 1980; Chaudhry, 1982; Khan, 1983) which caused to hyper increase in agricultural outputs, reduced income inequalities in rural areas consequently contributed in reducing poverty and food insecurity issue regardless of doubling the population of the country (Choudhry, 1994; Khan and Gul, 2013). Furthermore, multiple measures such as mostly five-year plans, public policies of hunger eradication, and rapid economic growth helped to fight food insecurity issue in the country (United Nations, 2018; GOP, 2019; Ahmad and Afzal, 2020). Despite all such feasible measures, in Pakistan currently, 12.9% population have a prevalence of undernourished (FAO, 2019) where 1.3% employed proportion earns less than $1.90 per day (ADB, 2021) and in the official scenario, 21.5% population lives below the poverty line with rural 27.6% and urban 10.7% population (Haroon, 2021). Currently, the extreme scenario of climate and its variations have increased the issue of food security of previously vulnerable peoples. Furthermore, climatic variations have increased the tendency of floods frequency which hindered the measures of reducing the issues of food security in Pakistan and alarming threat to attaining food security.

Food security is closely linked with climate change and the outcome of the food system (Arouri et al., 2015; Frelat et al., 2016; Choithani, 2020), climate-based natural disasters could push 122 million population particularly farmers into extreme poverty till 2030 (FAO, 2019; Thiede and Gray, 2020). In Pakistan, almost 63% rural population depend on natural resources for their livelihood (PBS, 2020) and recurrent flood hazards seriously menaced agricultural production and increased uncertainty of farmer livelihood (Ahmad and Afzal, 2021). Humans need food for their survival, the repercussion of flood disasters is terrible because of insufficient accessibility, constrained utilization, and reduced access to food (Abbas et al., 2018; Pingali et al., 2019). Household food security managing capabilities are reduced due to long-term exposure of floods and farmers consequently bond to switch their assets to handle flood risks (Hwalla et al., 2016; Kantor et al., 2017). In the global scenario, rural communities are particularly confronted with manifested effects of floods such as agricultural production reduction, diminishing employment, lowering purchasing power, rising health issues, higher and severe threats of poverty, malnutrition, food insecurity, and enhancing hunger.

In the general scenario of flood vulnerability of households, food security is considered a robust indicator. Consequential deluges of floods have severe implications regarding food security, as they terrorize access, availability, utilization, and stability of food (Vervoort et al., 2014; Abbas et al., 2018). Food security is the function of access, availability, utilization, and stability of food whereas SDG-2 broadly covers the outcomes of these four dimensions (FAO, 2019; ADB, 2021). Floods impact on food security and significance of such four dimensions fluctuates over time, across regions and most important related to the country on the whole socioeconomic conditions. Punjab province is formally known land of the fertile area of five rivers Ravi, Sutlej, Jehlum, Indus, and Chenab (BOS Punjab, 2020). In Pakistan, Indus and Chenab are major rivers of the country (PBS, 2020) which causes frequent floods destructions in the summer season due to extreme

erratic rains and extreme snow melting because of intense climate change variations (PMD, 2019; Ahmad and Afzal, 2021). In natural flowing progression, such rivers are scattered in various impermanent inland waterways while crossing in the course of various areas as impermanent islands are frequently engendered in the river areas. In the southern Punjab region, such impermanent islands in the rivers identified as Bait areas in the local language Saraiki. Farming communities specifically populated adjacent to these river areas mostly inhabited and carry out their farming in such islands and cultivate these areas of Bait. All such areas of Bait are under direct fire of rivers in flooding seasons. In the scenario of rainy seasons and floods, such Bait communities have to face the destruction of crops, infrastructure, human fatalities losses, livestock losses, and damages of shelters. Indus and Chenab rivers side by side flowing has increased the flood hazards vulnerability of the Southern Punjab region (PDMA Punjab, 2019). The frequent scenario of floods severely affected Bait farmers' livelihood and harshly increased food security issues in contrast to rest of region farmers the reason of insufficient flood hazards mitigation measures. Insufficient allocation of resources about measures to hazards mitigation, lack of awareness and communication and partial function of hazards institutions are some significant factors related to higher vulnerability in Bait areas of southern Punjab.

In literate, the aspect of household food security is discussed in a narrow and myopic framework particularly in developing countries. Some significant studies focused household level various aspects of food expenditures, food consumption, and nutrition security (Li and Yu, 2010; Carletto et al., 2013; Alexandri et al., 2015). Nutritional security and consumption of food aspect were discussed in different studies regarding the limited dimension at the informative level as availability of food whereas ignoring other dimensions which are most critical for household-level food security status (Leroy et al., 2015; Sseguya et al., 2018; Green et al., 2020; Kogo et al., 2020). Furthermore, in scenario of flood-prone communities household-level food security aspect generally elaborated in a few studies (Di Falco and Bulte, 2011; Ajaero, 2017; Balana et al., 2020; Alhassan, 2020) whereas no study particularly focused on FAO illustrated all damnations of food security linkage with the vulnerability of climate change specifically in Pakistan according to the best knowledge of authors.

Hence, it is a prerequisite to the application of an unrestrained approach for estimating household level food security through including these food access, availability, utilization, and stability four dimensions of food security. For food security to widen the concept it is necessary to extensive research of relevant linkage among the set of structure factors such as land access, production, ownership of assets, health, malnutrition, and availability of water. In addition, food security in recurrent floods and climate change has foremost significant for adaptation to farmers and policy decisions. In the aspect of inadequate information flood risks, mitigation programmers and adaptation policies cannot be effectively formulated. In such background, food security investigation by very fact and actually regarding the dimensions of access, availability, utilization, and stability has turn into dominant to make possible to considerate of central elements significantly affecting the food security of households in flood hazards areas. Furthermore, such an approach is comprehensive in nature because it combines food security FAO dimensions and climate change IPCC dimensions and is thus positioned to provide appropriate policy-related and empirical insights. In this scenario according to the research gap mentioned above and using a comprehensive approach, this study focused on these specific objectives firstly considering food security four dimensions examine the status of food security in flood Bait communities of Punjab Pakistan. Secondly, establish the association in vulnerability indicators of climate change and food security in flood-prone Bait communities of Punjab Pakistan. This study is classified into five sections as introduction indicated in section first, the second section elaborated conceptual framework while material and method discussed in the third section. Results and discussion illustrated in section four and last section highlighted conclusion and suggestions.

[1]Intergovernmental Panel of Climate Change

[2]United Nations Security Council and Climate Change

[3]Provincial Disaster Management Authority

[4]Bureau of Statistics

[5]World Health Organization

[6]Government of Pakistan

[7]Food and Agriculture Organization

[8]Asian Development Bank

[9]Pakistan Bureau of Statistics

[10]Pakistan Metrological Department

[11]Temporary islands are usually generated within the area of the river in the local language Saraiki is formally known as *Bait*

2. Study Based Conceptual Framework

In previous research scenario, some significant studies particularly discussed the changeable levels of dimensions in most frameworks of food security whereas a significant food security framework was developed particularly focusing on linking pathways of agriculture to food security outcomes (Kanter et al., 2015; Garrett et al., 2017; Sassi, 2018). The mechanism linked the outcomes of agriculture and food security more appropriately and directly suggested by a pathway in these frameworks (Renzaho and Mellor, 2010). Most food security frameworks addressed the perspective of developed countries in the context of political, cultural, and social regarding occurring these outcomes. The significance of this framework in contrast to other frameworks is as it confined the modulation variation of food security regarding various cultures such as in conventional communities food security severity is estimated in terms of hunger among adults in contrast to children. In particular, these frameworks are based on the food security aspect of FAO while not properly related to the IPCC concept to climate change vulnerability. This study used the food security FAO approach linking with various climate change dimensions of IPCC. Food security (family base) at the household level for the description of cultural variations was used to capture the food shortage. In nature, this approach is comprehensive and hence to be found to present an improved policy linked and empirical approach.

[Figure 1]

This research work suggests an advanced framework in flood and food security research through associating the food security dimensions (FAO) with climate change dimensions (IPCC) as illustrated in figure 1. Household-level strong indicator regarding the overall vulnerability of flood, food security implies the capability to take up any unanticipated occurrence including sickness, unemployment, and sufferers of earning (Shah and Dulal, 2015). In different dimensions of food security, the food availability dimension is concerned with the suitable and adequate quantity of food available to households throughout the year by import or domestic resources (Swaminathan and Bhavani, 2013). Food access indicates the scenario in which all community members have sufficient earnings to attain the appropriate quality of food substance composing the healthful diet for healthily life form. The food access dimension has unified functions of different institutional, social, physical, and policy-based environments that settle on effective utilization and access of resources for making certain food security goals among households. Access to ample diet, health care, clean water, and sanitation for understanding a state of dietary wellbeing is known as the dimension of food utilization as such dimension is more particularly related to the implication of non-food inputs in a scenario of food security. Food stability

is mostly portrayed as a household having a higher risk of losing access to earning means permanently or temporarily requires making certain consumption of adequate food. Losing access to earning means jointly or solely spearheaded by income shocks inadequate resources for sufficient consumption or both (Shah and Dulal, 2015). Food stability includes the capability to secure the food security dimensions such as food access, availability, and utilization in due course (Hwalla et al., 2016).

The scenario of vulnerability is particularly and relatively based on a system or person. Systems vulnerability delineates the state of affairs differentiate a group or person that weights their capability to predict fatal events cope, mitigate and recover from the impact of such disaster after its onset (Adger, 1999; Blaikie and Muldavin, 2014). Vulnerability is formally known as the function of exposure, susceptibility, and adaptive capacity. Adaptive capacity is the system as the proportion of resources to utilize preference and approaches of risk management to get ready for, restrain or evade, and recover from the effects of exposure to natural disasters. Exposure indicates the presence of people's livelihoods, environmental services, infrastructure, and capital resources (social, economic, cultural) in areas that could be fully and partially ramshackle (Aleksandrova et al., 2014). Susceptibility is illustrated as the tendency of a person or system to be negatively impacted by experiencing or change in climate disasters (Birkman et al., 2013). Household-level adoption of vulnerability functions causes food security declines in the dimension of sensitivity as it is extremely susceptible to the least type of natural hazards. More particularly the adaptive capacity of the household is constituted by physical, economical, and social characteristics. Climate change and flood constitute exposure dimension that affects households.

3. Material And Methods

3.1 Selection of study area

Khyber Pakhtunkhwa, Sindh, Punjab, and Balochistan are four provinces of Pakistan while because of some considerable factors Punjab is more preferably chosen for this study. Firstly, Punjab favored because of major share 53% in agricultural GDP, most populated 52.95% and covering the 26% area of the country (BOS, Punjab 2019; PBS, 2021). Secondly, this province in contrast to other provinces faces higher severity of flood disasters owing to the successive flowing of the major five rivers of the country throughout the fertile lands of Punjab (PDMA Punjab, 2019). Thirdly, in the province the region of southern Punjab is particularly focused for study, consecutive facing flood disasters due to located at the eastern and western bank of largest and major Indus river (NDMA, 2019; GOP, 2020). Fourthly, in the southern Punjab region, Bait communities were particularly focused because these communities mostly inhabited temporary islands owing to Indus river distributive riverine channels and mostly engaged in farming activities. Bait communities specifically focused on this study because consecutive flood disasters enhance their farming vulnerability. Lastly, among seven higher flood risk Bait communities districts, three higher flood risk Bait community districts Dera Ghazi Khan, Rajanpur, and Muzaffargarh according to their severity to flood risk were chosen for the study as indicated in figure 2.

[Figure 2]

3.2 Geographical feathers of the study area

Dera Ghazi Khan covers the area of 11,294 km^2, 2.87 million population, administratively categorized in four tehsils Taunsa, Kot Chhutta, Dera Ghazi Khan, and DE-Excluded Area Dera Ghazi Khan, and consists of 98 union councils (GOP, 2017; BOS Punjab, 2019). Dera Ghazi Khan is classified as a low socio-economic status district based on the scenario of the provincial social progress index, the reason of low social, cultural, and economic dimensions (BOS Punjab, 2018). Frequent variation in climatic scenario of the district is estimated with extremely hot summer and mild winter with minimum -1°C and maximum 51°C temperature and an average rainfall of 104mm (PMD, 2019). The critical location of the district is the reason for extreme hazards to this region as the eastern side located on the bank of the Indus river

causes riverine flood and the western side Koh-Suleman mountain range causes flash floods during erratic rain season (NDMA, 2018; PDMA Punjab, 2019). During a couple of decades, this district faced erratic rain and frequent floods which caused human fatalities, losses of livestock, destruction of crops and infrastructure (BOS Punjab, 2020).

Administratively district Muzaffargarh consists of four tehsils Kot Addu, Jatoi, Muzaffargarh, and Alipur, with 4.3 million populations, an area of 8249 km^2, and ninety-three (93) union councils (GOP, 2017; PBS, 2021). Muzaffargarh is regarded as a highly vulnerable district to frequent flood disasters and is situated in a critical geographical location surrounded by two major rivers eastern side of Chenab river flows and the western side Indus river flows (PDMA, Punjab 2018; BOS Punjab, 2019). In climatic scenarios various considerable feathers related to this area such as 127mm average rainfall, lowest 1°C, and highest 54°C temperature summer season relatively hot while mild winter season (PMD, 2020). In the last two decades, Muzaffargarh faced consecutive floods and erratic rainfall which caused major losses of livestock, crops, human fatalities, and destruction of infrastructure (PDMA, Punjab 2018). This district is also categorized as low socioeconomic in the province the reason of lower social, economic, and cultural dimensions and lower social progress index (BOS Punjab, 2020).

Rajanpur district is administratively categorized into three tehsils Rojhan, Rajanpur, and Jampur, 69 union councils with an area of 12318 km^2 and a population of 1.99 million (GOP, 2017; PBS, 2020). In climatic scenario district Rajanpur with mild winter, long and hot summer season with lowest 1°C and highest 52°C temperature and having an average rainfall of 119mm (PMD, 2019). Rajanpur higher vulnerable due to flood hazards with the critical geographical scenario as located on the western bank of the Indus river (GOP, 2019). Erratic rains and riverbank erosion of the Indus river caused consecutive flooding in rural areas of the district causes to extreme destruction of infrastructures, human fatalities, losses of livestock and crops (PDMA Punjab, 2018). The reason for lower social, economic, and cultural dimensions and lower social progress index this district is categorized as the low socioeconomic area in the province (GOP, 2019).

3.3 Sampling method and data collection

In this study, a multistage sampling method was employed for the collection of data firstly, due to the higher destruction and vulnerability of floods, Punjab was among four provinces chosen for the study (NDMA, 2018). Secondly, the region of southern Punjab and particularly the Bait communities specifically preferred in this study due to frequent floods and higher vulnerability (BOS Punjab, 2019). Thirdly, three riverine Bait communities districts (Dera Ghazi Khan, Rajanpur, Muzaffargarh) among seven Bait communities districts are preferably chosen for the study owing to their higher severity of flood hazards (PDMA Punjab, 2019) as indicated in figure 3. Fourthly, based on higher flood vulnerability two tehsils from every district and two union councils from tehsils were chosen according to information provided by the agriculture officer, land record local officer (patwari) and DDMA. Lastly, according to vulnerability and destruction of flood hazards two villages of Bait communities from each union council were chosen and sixteen respondents were randomly selected and were interviewed from each village.

[Figure 3]

In the procedure of data collection, major respondents were household heads (male/female) and households illustrated as the basic unit in the study area. The sampling method of Cochran (1977) as shown in equation (1) specifically applied for obtaining the minimum data in this study. Heads of households were particularly focused on data collection of 384 household respondents where 5% population elaborated the adequate for study sample (Kotrlik and Higgins, 2001). SS illustrated the sample size in equation 1 where Z(±1.96 at 95%) indicated confidence interval for point picking, p choices percentage, (0.5 used required size of sample) explained decimal and e(0.07 = ± 7) elaborated precision value.

$$SS = \frac{Z^2(p)(1-p)}{e^2} (1)$$

Respondents in the study area were directly connected, a well-developed and pre-tested questionnaire was applied for data collection from September to November 2019. For accuracy and adequacy of information, furthermore evading vagueness questionnaire was applied for the pilot study and through 24 respondents pre-tested before starting the appropriate survey. The author himself and six trained enumerators clarified and corrected all related matters about questionnaires before beginning the data collection procedure in the study area. Respondents in the study area were properly informed concerning the use and purpose of data collection, respondents who refused to contribute their information were substituted to other respondents.

3.3.1 Food security index (FSI)

Regarding different individuals, communities, regions, and nations various status of food security was estimated (Arouri et al., 2015). Food security is more preferably measured by a few methods such as HFIAS and FAO for estimation of household expenditure and income survey, per capita calories available at the national stage, and individual basis dietary intake measurement. Furthermore, no single approach is capable to address all dimensions of food security in the given period, in the same scenario no organization or institute has the mandate or capability to monitor or assess food security taking into consideration all of its different level dimensions (Carletto et al., 2013).

A household level food security was measured by adopting the developed food security index (Sam et al., 2021), and a systematic method was used in its construction which is the combination of composite indices (Antony and Rao, 2007; Mutabazi et al., 2015). The food security index is based on a weighted index which elaborated a single composite indicator with the combination of various four dimensions and eleven key indicators in this food security index as indicated in Table 1. Household family farm dependency for food consumption, the sufficiency of food, and the food expenditure of households are significant indicators of household food availability. Individual household holding livestock, PDS access and farmland area included in dimensions of food access. Crop diversification, food supplies instability, and reduction in yield are illustrated as dimensions of food stability. Household-level potable water accessing issues and malnutrition problems highlight the dimensions of food utilization.

Table 1
Food security index used variables in its construction

Food security FAO dimensions	Food security indicators	Indicators explanation	Sources of indicators
Availability of food	Household expenditure on food	Per month household average food expenditure in PKRs	Paul et al., (2014)
	Sufficient food all over the year	Household having sufficient food for consumption all over dummy variable =1 otherwise = 0	Pangaribowo et al., (2013)
	Family farm dependency for food	Household having family farm dependency for food production dummy =1 otherwise =0	Food and Agriculture Organization (2013)
Access of food	Cultivated land area	Cultivated total land area in acres	Frelat et al., (2016)
	Access of public distribution system	Household depending on public distribution system for items of subsidized food dummy variable =1 otherwise =0	Food and Agriculture Organization (2006)
	Holding livestock	Available total number of livestock in the household	Valdivia, (2001)
Stability of food	Loss of crop yield	Household facing loss of crop and yield due to flood dummy variable =1 otherwise=0	Savary et al., (2012)
	Food supply instability	Household facing food supply instability from shop or market due to idiosyncratic or covariate shocks dummy variable =1 otherwise=0	Devereux, (2007)
	Index of crop diversification	Inverse of number of edible crops cultivated by households +1	Wani et al., (2012)
Utilization of food	Problems of water access	Household facing issue regarding in access of irrigated or potable water dummy variable =1 otherwise=0	Sinyolo et al., (2014)
	Issues of malnutrition	Household facing issue of malnutrition dummy variable =1 otherwise=0	Pangaribowo et al., (2013)

[Table 1]

In estimating the food security indicators procedure of acquiring weighting objectives Principal Component Analysis (PCA) method was used. Some discrete indicators were also estimated in the food security index such as whether water access households have some issues. Discrete variables usage causes to violation of PCA assumption of Gaussian distributional and led to biased findings consequently. In such a scenario, polychoric PCA was used to overcome the issue of assumption violation. The calculation of the food security index is performed in equation form in 2 and 3, afterward the estimation of polychoric PCA.

$$PC_{mn} = \sum {}_{l}f^{l}_{n}\left(X^{l}_{m}\right) (2)$$

In equation (2) n illustrated nth household respondents whereas m indicated mth components regarding the PC_{mn}. In the same way f^{l}_{n} the nth components is factor loading for nth indicator whereas the $X^{l}_{m,}$ highlighting the factors of mth households respondents.

$$FSS_m = \sum {}_n V_n \left(PC_{mn} \right) (3)$$

Equation (3) has elaborated the FSS_m as composite mth household respondents food security score whereas nth principal components variance as V_n. Food security score (FSS) is employed in equation (4) for developing the Food Security Index (FSI) which ranges from scale 0 to 1.

$$FSI_n = \frac{FSS_m - FSS_{min}}{FSS_{max} - FSS_{min}} (4)$$

In equation (4) mth household's respondent's food security index is indicated as $FSI_{m,}$ whereas the sample maximum Food Security Score value is denoted as $FSS_{maximum,}$ and $FSS_{minimum}$ illustrated the minimum Food Security Score of the sample of the study area.

3.3.2 Beta regression empirical model

Food Security Score as the dependent variable of the model consists of the factors that determine food security of Bait flood-prone rural households which is the function of economic, social, demographic, flood, and physical factors. These economic, social, demographic, flood, and physical are major factors that are the combination of 18 sub-factors. Sub-factors denoted as independent variables of the model indicated the expected sign of coefficient estimated as illustrated in Table 2. Equation (5) elaborated the model of the study as indicated below

Table 2
Illustration of major factors and sub factors applied in the regression analysis

Major factors	Sub factors	Types of variables	Explanation of factors	Sign of factors
Demographic factors	Type of family	Dummy variable	Household living in joint family =1 otherwise=0	(+)
	Household head	Dummy variable	Female is household head =1 otherwise =0	(-)
	Age of household head	Continuous variable	Household head age in years	(+)
	Mother literate	Dummy variable	Female or mother related to cooking literate =1 otherwise=0	(+)
	Social caste	Dummy variable	Members of family belong to backward cast socially =1 otherwise =0	(-)
Social factors	Access of school	Dummy variable	Household having access of school=1 otherwise=0	(+)
	Informal money lenders access	Dummy variable	Household having access of money lenders =1 otherwise=0	(-)
	Money borrowing from kin	Dummy variable	During crisis money borrowed from kin =1 otherwise=0	(+)
Economic factors	Benazir Income Support programme (BISP) Pakistan	Dummy variable	Members of household joined BISP =1 otherwise=0	(+)
	Household migration	Dummy variable	Household having at least one member migrated =1 otherwise=0	(+)
	Access of bank	Dummy variable	Household having access of bank=1 otherwise=0	(+)
Physical factors	Structure of housing	Dummy variable	Household having permanent house=1 otherwise=0	(+)
	Household durable assets	Continuous variable	Household having total number of durable assets	(+)
Floods factors	Property losses	Dummy variable	Households faced losses of property (durable assets, house, livestock) during the flood period of 2010 to 2015 =1 otherwise =0	(-)
	Facing stress	Dummy variable	Household facing stress due to flood =1 otherwise =0	(-)
	Rainfall average variation	Dummy variable	Household reported any variation in average rainfall during 2010 to 2015=1 otherwise=0	(-)
	Environmental deterioration affects on income earning	Dummy variable	Household income affected due to environmental deterioration of climate change and floods=1 otherwise=0	(-)

$$FSS_m = \propto + \beta_i X_{im} + u_m (5)$$

In equation (5), mth household's composite food security score is indicated as FSS_m whereas sub-factors variables under exposure and adaptive capacity dimensions explained as X_{im} and respective coefficients are denoted as β_i. The food

security index considers a continuous variable with an interval (0, 1) in this model and correlated to added variables in the structure of regression. Hence, the beta regression model employed in this study is a replacement for normal regression because this model basis on the distribution of beta density in terms of parameters and mean (Ferrari et al., 2004). In this study, Maximum likelihood (ML) was employed to estimate the parameters of the model and in the STATA benefit package used for model implementation. Average marginal effects were estimated by employing margin commands. Direct interpretation of the Average Marginal Effect can be estimated, unlike the estimated coefficient. In the scenario of continuous variable Average Marginal Effect would be incidental as an added unit of increase in the variable increasing the score of food security by coefficient level. In the status of the dummy variable more caution need for interoperation where percentage changes in inferred regarding the coefficient form of 0 and 1.

[Table 2]

[12]Gross Domestic Product

[13]National Disaster Management Authority

[14]District Disaster Management Authority

[15]Household Food Insecurity Access Scale

[16] Public Distribution System

4. Results And Discussion

The food security index replicates the selection of food security dimensions which proceeds through the preliminary stage of performing polychoric PCA regarding dataset of eleven indicators. Eigenvalue criterion considers the base for factors selection as those factors having eigenvalues value greater than one were preferably selected for the study. Four components C1, C2, C3, and C4 were preferably selected based on this criterion which indicated the total variance of 78.89%. Component first (C1) and second (C2), having the eigenvalues 3.971 and 1.83 highlighting the variance 34.68% and 17.49% whereas the component third (C3) and fourth (C4) having eigenvalues 1.36 and 1.09 and illustrated the variance 12.53% and 10.12%. In Table 3, estimates of polychoric PCA are illustrated in which framework of PCA indicated the correlation in component and indicators is known factor loading and discloses the details shared by components and indicators (Mutabazi et al., 2015). Each indicator variance proportion illustrated through the component is indicated via loading square (Abdi and Williams, 2010) in which each indicator's highest loading factor was applied for Food Security Score construction as elaborated in equation 2.

Table 3
Polychoric Principal Component analysis

Dimension of food security	Food security indicators	Components*			
		Component 1	Component 2	Component 3	Components 4
Availability of food	Household expenditure on food	-0.054	0.781	-0.124	0.187
	Sufficient food all over the year	0.003	0.793	0.156	-0.171
	Family farm dependency for food	0.879	0.068	-0.113	0.002
Access of food	Cultivated land area	0.698	0.049	0.241	0.337
	Access of public distribution system	-0.287	0.151	0.598	0.003
	Holding livestock	0.299	0.327	-0.286	-0.184
Stability of food	Loss of crop yield	0.894	-0.039	-0.143	-0.047
	Food supply instability	-0.011	-0.048	0.006	0.899
	Index of crop diversification	-0.893	0.016	0.114	0.187
Utilization of food	Problems of water access	0.887	0.021	-0.127	0.004
	Issues of malnutrition	0.069	-0.138	0.784	0.017

* showing the uppermost component loading

[Table 3]

Area of agricultural land, losses of crop yield, diversification of crops, issues of water access, and family farm food dependency indicators have the uppermost loading related to component 1. In component 2, the maximum loading factor was estimated regarding the indicators numbers of livestock, sufficient food for all over the year, and household monthly food expenditure. In the scenario of component 3, the highest loading factor was estimated about the issue of malnutrition and public distribution system whereas the highest factor loading was found related to the indicator of food supply instability in component 4. Even though, information related hidden association in different variables presented by PCA and this method focused with the leading purpose to produce weights for the formation of Food Security Index for this research work (Sam et al., 2018). Households were categorized into four quantiles according to the range of food security index as households with most food secured indicated 1 while 0 for least food security status. In the study area, 16% of households were categorized in the first quantile (0-0.25), 49% and 31% households in second (0.251-0.50) and third quantile (0.51-0.75) whereas 4% households in the last quantile (0.751-1).

Social, demographic, physical, economic, and flood factors' impact on rural household food security was investigated with the estimation of beta regression model coefficients and calculated variables average marginal effect as depicted in Table 4. The marginal effect demonstrates whereby each independent variable alteration confirmed changes in outcomes which are purposes of probability itself and estimates the predictable alteration in the probability of exacting preference being completed concerning to a unit vary in independent variable due to mean (Green, 2000). Multiple demographic characteristics affect household food security in which family type and demographic profile are the most prominent demographic sub-factors which significantly and positively affect the food security of rural households.

Particularly in rural areas of Pakistan joint family system is the common practice where family members work together, live together, and share family expanses so such a joint family system regarding various household issues is used as a shock-absorbing approach (Kamo, 2000). Family elderly members consider the decision-making body of the household where each household has more than one earning family member which all significantly contribute to the household's overall economic scenario. Households more prefer to increase food expanses regarding the enhancement of economic status. Landholding and assets ownership are kept joint in the joint family system causing fragmentation avoiding in landholding of the family. Landholding fragmentation may cause to leading absolute termination of agriculture or reduce agricultural products output which will eventually generate issues of food security for rural areas households.

Table 4
Different sub factors impact on household food security

Food security major factors	Food security sub factors	Coefficients of Beta regression	Marginal effect
Demographic factors	Type of family	0.389***(0.091)	0.087*** (0.019)
	Household head	-0.274***(0.112)	-0.058*** (0.021)
	Age of household head	0.008**(0.003)	0.003** (0.001)
	Mother literate	0.176(0.158)	0.043(0.039)
	Social caste	0.024(0.071)	0.006(0.018)
Social factors	Access of school	0.159***(0.073)	0.041** (0.017)
	Informal money lenders access	0.029(0.081)	0.009(0.023)
	Money borrowing from kin	-0.089(0.077)	-0.019(0.016)
Economic factors	Benazir Income Support programme (BISP) Pakistan	0.274**(0.091)	0.498** (0.017)
	Household migration	0.499**(104)	0.123*** (0.022)
	Access of bank	-0.127(0.121)	-0.031(0.029)
Physical factors	Structure of housing	0.113(0.091)	-0.034(0.031)
	Household durable assets	0.249***(0.038)	0.054*** (0.006)
Floods factors	Property losses	-0.187**(0.079)	-0.049** (0.021)
	Facing stress	-0.017(0.081)	-0.004(0.019)
	Rainfall average variation	0.091(0.083)	0.026(0.021)
	Environmental deterioration affects on income earning	0.083(0.077)	0.023(0.021)
	Constant	-1.983***(0.287)	
	Ln-phi	2.734***(0.097)	
Parenthesis shows the standard error values, ***show1percent level of significance **shows 5percent level of significance			

[Table 4]

Household head status considerably influences rural households' food security. Estimates of the study illustrated the significant and negative influence on the household head in rural areas' food security. In the study area, the majority of household heads (79%) are male and limited numbers (21%) of household heads are females where females become household heads because of male head migration, disruption, family conflicts, and male death (Kassie et al., 2014). Households of female-headed were facing higher issues of food security rather than households of male-headed because of children responsibilities, maintenance of the household, mobility restrictions, ownership of limited land, labor

markets wage disparities, and levels of lower literacy. Household food security is notably influenced by the age of the household head because more significant decisions related to family are made by the household head. Increased household head age presumed to she or he could acquire more knowledge regarding the higher experience of farming practices, the physical environment, and social interactions. Aged household heads are considered higher risk-averse and with increasing age more probably to be food secure (Muche et al., 2014).

In a crisis scenario, institutional networks, social connections, and communal integration are reflected considerable actors in mounting food security at the household level. Estimates indicated the positive and significant coefficient of school access variable reflecting as household-level increasing in-school access considerably develop household-level food security condition. Household-level overall food security is not directly connected to school while it faculties in developing children food security those are attending schools. In 2011, the Punjab government introduced the policy for Free Lunch for primary schooling which was instigated to develop nutrition for school-going children (GOP, 2011). This scheme makes available at no cost cooked lunches to school children which sequentially facilitated poor children be regular to school presence and become healthy. Those children related to the disadvantageous segment of society and having no sufficient access to food may possible to have adequate intake.

In Pakistan, Benazir Income Support Programme (BISP) was launched in July 2008 (GOP, 2009) and estimate of the study indicated a positive and significant correlation between BISP and food security reflecting as increasing BISP financial assistance will be more feasible for food security particularly rural households (PBS, 2019). BISP in Pakistan was launched with the particular objective of poverty reduction with unconditional cash transfer which will ultimately increase the purchasing power of deserved population (GOP, 2020) and leads to improve household level food security. In this study, a positive and significant association was estimated regarding migration and food security of households. Households' majority depends on agriculture for their livelihood which is so risky to consider such a single source for earning because this area is highly prone to flood hazards. Households through performing small business practices, migrating nearby states or cities, and participating in daily labor activities are diversifying their incomes. In most of the developing countries, migration has become a significant aspect in strategies of livelihood because remittances are optimistically joined to welfare to the household of migrant-sending (Choithani, 2017). The major share of poor household income is spent on food whereas through sending back home the remittances by migrants have an optimistic straight effect on households' income (Naylor and Falcon, 2010; Zezza et al., 2011). The income status of a household is considered one of the significant sources for influencing hunger and food security where increasing income status directly declines hunger because some basic food items (preferred food, oil, salt) are neither bartered nor domestically produced so the required cash amount for purchasing (Silvestri et al., 2015; FAO, 2019).

In a food security scenario, there is a considerable role of household assets which significantly develop the ability of households to withstand unanticipated changes. The managing capability of households related to issues of food security depends on their various assets access (Ellis and Manda, 2011). Selling durable assets is major and common practice among poor rural populations in severe climatic hazards (McKernan et al., 2018). Households mostly purchase durable assets in sound financial era (wealthy periods) and financial crisis (negative income shocks) for purchasing necessities of life sell these durable assets. In such a scenario these durable assets perform the role of instrument for safeguarding food security of households in extreme climatic conditions so presumption can be generated as households food secure those having more physical assets. The findings of the study reflected the significant and positive effect of rural households' food security and durable assets. Household assets considered their resources stocks which can easily indirectly or directly convert for survival means (Mckernan et al., 2018; Silvestri et al., 2015). Increasing various durable assets is the element of food security that enhances a household’s capacity regarding the issue of seasonal food security and sudden economic shocks as such durable assets are highly liquid for cash conversion (Renzaho and Mellor, 2010).

In the scenario of rural population food security, floods have some considerable implications about different indirect or direct effects. Livestock losses, destruction of standing food crops, shelters, and damages of grain storage are some direct effects of floods on food security whereas indirect effects of floods on food security are domestic violence's, social unrest, compromised health, and reducing purchasing power (Shoufias, 2003; Brouwer et al., 2007). In study areas, recurrent floods almost every year mostly continue to a couple of weeks cause severe losses of lives, livestock, crops destruction, and property. Estimates of the study in the above subsections reported indirect losses of flood vulnerability and floods in the scenario of food security in the region of these study areas but reflected directly effect of flood on food security status related to respondents has its implication. In Table 4 the findings of the study indicated as property losses owing to flood events onsets considerably destabilized household status of food security. Property losses because of leading floods distressed food security situation appear to have an indirect effect on the other hand property losses integrated losses of crops, livestock, and grain stored with durable assets with having a direct and strong bearing on the regional food security. The marginal effect of such a variable was significant and complemented the role of loss in property on regional food security conditions. More particularly as indicated that increase in 1% probability of property loss owing to flood reduced status of food security 5%. Furthermore, stress owing to floods had an anticipated earlier sign, illustrating the negative association with household status of food security however the correlation was non-significant statistically. Related variables such as deterioration in environment income-earning and average rainfall variation owing to the incidence of the flood were illustrated to have a non-significant or diminutive impact on the food security status of the household. These results have investigated the effect floods have on food security by disturbing or destroying household inventories and assets basis. In the scenario of property loss, a significant variable indicated floods rising impact on household-level consumption of food, food availability, and comprised based nutrition uptake. In the major factors group of the flood, other variables are not as significant in affecting the food security of people because of the lower or equal to 5% marginal effect. In such consideration, the rising vulnerability of flood leads to rising losses of property which significantly affects food security levels in the population. These findings have multiple implications such as conditionally protecting assets of households which will facilities as mitigation in severe scenarios of disaster on multiple bases. There may be another measure such as adopting the insurance mechanism, particularly in flood-prone areas to safeguard the durable assets of households.

5. Conclusion And Suggestions

Human livelihood ordinary activities such as economic performance, health care, water access, agricultural production, and human livelihood are severely affected by flood disasters which consequently raises the issues of household food security. Nutritional security, patterns of food consumption, and food expenditures aspects are more particularly focused in many studies whereas limited work directly contributed related to factors of nutritional security and food consumption. This study used a composite index to investigate food security with focusing on components that influence the pattern of food consumption, food expenditure, and nutritional security. Southern Punjab region of Punjab province, Pakistan is more preferably focused for study due to subsistence agricultural dependency, less developed area in the region, and high-risk flood-prone area in the province. This region has higher severity of flood disasters due to frequent floods, lower socioeconomic status in the region, and facing higher dimensions of hunger and poverty. Estimates of the study justified as the majority of rural flood-affected households are facing issues of food security. Such conditions need the implication of intervention policies to reduce future risks of rising levels of food insecurity owing to intensified frequent floods. This study also examined the factors that affect household food security and calculated each significant variable average marginal effect. Findings of the study elaborated physical assets, education, BISP, and structure of joint family positively and significantly affect food security.

Households having social support and alternative employment indicated food security in the study area. Generating additional employment opportunities by developing an agro-based industrial structure through public-private cooperation

in feasible financing policy measures in local flood-prone areas will ultimately boost food security. In addition, non-agricultural employment opportunities need to promote in these local areas because, in the failure of agriculture income due to hazards, it will alternative source of their earning and livelihood. Food security is indirectly or directly affected due to household vulnerability to flood hazards. Assurance plan of food security and schemes of flood disaster management of local community assisted in flood era need to implemented and developed. In various stakeholders, need to carry out systematic changes particularly in government institutions and financial sectors, mainly participating in welfare administration and social protection to reduce the influence of temporal and spatial severity. In high-risk, flood-prone, and least developing regions issues of food security are substantial so it is essential to concentrate on base level indicators that direct to food security. In contrast to previous studies, this study used the broader aspect of food security by including all dimensions of FAO and incorporating climate change dimensions of IPCC regarding flood hazards in flood-prone areas. Nevertheless, such type of region base studies more particularly in developing countries need to conduct for finding out the issues of food security and suggesting the appropriate and feasible policy measures to coping increasing food security issues in these regions.

Declarations

Ethical Approval
Ethical approval taken from the COMSATS University Vehari campus, ethical approval committee

Consent to Participate

Not applicable

Consent to Publish
Not applicable

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

Funding
This study has no funding from any institution or any donor agency.

Competing Interests

The authors declare that they have no competing interest.

Availability of data and materials

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

References

1. Abbas G, Ahmad S, Ahmad A, Nasim W, Fatima Z, Hussain S, Hoogenboom G (2017) Quantification of the impacts of climate change and crop management on the phenology of maize-based cropping system in Punjab, Pakistan. Agric For Meteorol 247:42–55
2. Abbas N, Wasimi S, Al-Ansari N, Sultana N (2018) Water resources problems of Iraq: Climate change adaptation and mitigation.Journal of Environmental Hydrology, *26*

3. Abdi H, Williams LJ (2010) Principal component analysis. Wiley interdisciplinary reviews: computational statistics 2(4):433–459
4. Abid M, Scheffran J, Schneider UA, Ashfaq MJESD (2015) Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan. Earth Sys Dyn 6(1):225–243
5. Adger WN (1999) Social vulnerability to climate change and extremes in coastal Vietnam. World Dev 27(2):249–269
6. Ahmad D, Afzal M (2020) Climate change adaptation impact on cash crop productivity and income in Punjab province of Pakistan. Environ Sci Pollut Res 27:30767–30777
7. Ahmad D, Afzal M (2021) Flood hazards and livelihood vulnerability of flood-prone farm-dependent Bait households in Punjab, Pakistan.Environmental Science and Pollution Research,1–21
8. Ahmad D, Afzal M (2021) Flood hazards, human displacement and food insecurity in rural riverine areas of Punjab, Pakistan: policy implications. Environ Sci Pollut Res 28(8):10125–10139
9. Ahmad D, Afzal M, Rauf A (2019) Analysis of wheat farmers' risk perceptions and attitudes: evidence from Punjab, Pakistan. Nat Hazards 95(3):845–861
10. Ahmad D, Afzal M, Rauf A (2021) Flood hazards adaptation strategies: a gender-based disaggregated analysis of farm-dependent Bait community in Punjab, Pakistan. Environ Dev Sustain 23(1):865–886
11. Ajaero CK (2017) A gender perspective on the impact of the flood on the food security of households in rural communities of Anambra State, Nigeria. Food Secur 9(4):685–695
12. Aleksandrova M, Lamers JP, Martius C, Tischbein B (2014) Rural vulnerability to environmental change in the irrigated lowlands of Central Asia and options for policy-makers: A review. Environ Sci Policy 41:77–88
13. Alexandri C, Luca L, Kevorchian C (2015) Subsistence economy and food security–the case of rural households from Romania. Procedia Econ Finance 22:672–680
14. Alhassan H (2020) Farm households' flood adaptation practices, resilience and food security in the Upper East Region,Ghana. Heliyon, 6(6), e04167
15. Ali A, Erenstein O (2017) Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. Clim Risk Manage 16:183–194
16. Antony GM, Rao KV (2007) A composite index to explain variations in poverty, health, nutritional status and standard of living: Use of multivariate statistical methods. Public Health 121(8):578–587
17. Arouri M, Nguyen C, Youssef AB (2015) Natural disasters, household welfare, and resilience: evidence from rural Vietnam. World Dev 70:59–77
18. Asian Development Bank (2021) Asian Development Outlook, 2021, Financing a Green and Inclusive Recovery Metro Manila, Philippines https://www.adb.org/sites/default/files/publication/692111/ado2021-highlights.pdf
19. Balana BB, Bizimana JC, Richardson JW, Lefore N, Adimassu Z, Herbst BK (2020) Economic and food security effects of small-scale irrigation technologies in northern Ghana. Water Resour Econ 29:100141
20. Banik D (2019) Achieving food security in a sustainable development era
21. Birkman RW, Elizondo F, Wadlington PL (2013) The Birkman method technical manual.Houston, TX: Birkman International, *3*
22. Blaikie P, Muldavin J (2014) Environmental justice? The story of two projects. Geoforum 54:226–229
23. Board of Statistics (BOS) Punjab (2018)Agriculture Information Marketing Services (AIMS) Lahore, Punjab, Pakistan
24. Board of Statistics (BOS) Punjab (2019)Agriculture Information Marketing Services (AIMS) Lahore, Punjab, Pakistan
25. Board of Statistics (BOS) Punjab (2020)Agriculture Information Marketing Services (AIMS) Lahore, Punjab, Pakistan
26. Brouwer R, Akter S, Brander L, Haque E (2007) Socioeconomic vulnerability and adaptation to environmental risk: a case study of climate change and flooding in Bangladesh. Risk Analysis: An International Journal 27(2):313–326

27. Carletto C, Zezza A, Banerjee R (2013) Towards the better measurement of household food security: Harmonizing indicators and the role of household surveys. Global food security 2(1):30–40
28. Chaudhry MG (1982) Green Revolution and redistribution of rural incomes: Pakistan's experience.The Pakistan Development Review,173–205
29. Chaudhry MG (1994) Transformation of agriculture, food self-sufficiency and prospects for surpluses: The case of South Asia. Contemp South Asia 3(1):37–52
30. Choithani C (2017) Understanding the linkages between migration and household food security in India. Geographical Res 55(2):192–205
31. Choithani C (2020) Gendered livelihoods: Migrating men, left-behind women, and household food security in India. Gend Place Cult 27(10):1373–1394
32. Cochran WG (1977) Double sampling. In: Cochran WG (ed) Sampling techniques, 3rd edn. Wiley, New York, pp 327–358. https://doi.org/10.1201/9780429296284
33. Daniell H, Lin CS, Yu M, Chang WJ (2016) Chloroplast genomes: diversity, evolution, and applications in genetic engineering. Genome Biol 17(1):1–29
34. Di Falco S, Bulte E (2011) A dark side of social capital? Kinship, consumption, and savings. J Dev Stud 47(8):1128–1151
35. Dilshad A, Muhammad A (2020) Flood hazards and factors influencing household flood perception and mitigation strategies in Pakistan. Environ Sci Pollut Res Int 27(13):15375–15387
36. Eckstein D, Künzel V, Schäfer L, Winges M (2019) Global climate risk index 2020. *Bonn: Germanwatch*
37. Elahi E, Khalid Z, Tauni MZ, Zhang H, Lirong X (2021) Extreme weather events risk to crop-production and the adaptation of innovative management strategies to mitigate the risk: A retrospective survey of rural Punjab, Pakistan. *Technovation*, 102255
38. Ellis F, Manda E (2012) Seasonal food crises and policy responses: A narrative account of three food security crises in Malawi. World Dev 40(7):1407–1417
39. Emergency Event Database (2017) The International Disaster Database, Emergency Event Database (EE-DAT), 2017
40. FAO (2019) Agriculture and Climate Change: Challenges and Opportunities at global and local level collaboration on climate-smart agriculture, Food, and Agriculture Organization of United Nations Rome https://www.fao.org/3/CA3204EN/ca3204en.pdf
41. Ferrari S, Cribari-Neto F (2004) Beta regression for modeling rates and proportions. J Applied Statistics 31(7):799–815
42. Frelat R, Lopez-Ridaura S, Giller KE, Herrero M, Douxchamps S, Djurfeldt AA, van Wijk MT (2016) Drivers of household food availability in sub-Saharan Africa based on big data from small farms. *Proceedings of the National Academy of Sciences*, *113*(2), 458-463
43. Garrett RD, Gardner TA, Morello TF, Marchand S, Barlow J, de Blas DE, Parry L (2017) Explaining the persistence of low income and environmentally degrading land uses in the Brazilian Amazon.Ecology and Society, *22*(3)
44. GOP (2011) Right to Free and Compulsory Education in Pakistan; Enforcement of Article 25-A of the Constitution of Pakistan. https://schools.punjab.gov.pk/system/files/RighttoFreeandCompulsoryEducationinPakistanBackgroundpaper_0.pdf
45. Government of Pakistan (GOP) (2009) Economic Survey of Pakistan (2008-09) Ministry of Finance. Finance division Islamabad, Government of Pakistan
46. Government of Pakistan (GOP) (2017) 6th Household and Population Survey. Ministry of Finance, Finance division Islamabad, Government of Pakistan

47. Government of Pakistan (GOP) (2019) Economic Survey of Pakistan (2018-19) Ministry of Finance. Finance division Islamabad, Government of Pakistan
48. Government of Pakistan (GOP) (2020) Economic Survey of Pakistan (2019-20) Ministry of Finance. Finance division Islamabad, Government of Pakistan
49. Green A, Nemecek T, Chaudhary A, Mathys A (2020) Assessing nutritional, health, and environmental sustainability dimensions of agri-food production. Global Food Security 26:100406
50. Green M (2000) " How long does it take to stop?" Methodological analysis of driver perception-brake times. Transp Hum factors 2(3):195–216
51. Haroon M, Al-Saadi AA, Iqbal MA (2021) Comparative Exposure Assessment of Potential Health Risks through the Consumption of Vegetables Irrigated by Freshwater/Wastewater: Gujranwala, Pakistan. Chemical Research in Toxicology
52. Hirabayashi Y, Mahendran R, Koirala S, Konoshima L, Yamazaki D, Watanabe S, Kanae S (2013) Global flood risk under climate change. Nat Clim change 3(9):816–821
53. Hoq MS, Raha SK, Hossain MI (2021) Livelihood vulnerability to flood hazard: Understanding from the flood-prone haor ecosystem of Bangladesh. Environ Manage 67(3):532–552
54. Huong NTL, Yao S, Fahad S (2019) Assessing household livelihood vulnerability to climate change: The case of Northwest Vietnam. Hum Ecol Risk Assessment: Int J 25(5):1157–1175
55. Hwalla N, El Labban S, Bahn RA (2016) Nutrition security is an integral component of food security. Front life Sci 9(3):167–172
56. IPCC, Stockhause M, Lautenschlager M (2017) 2017, April. CMIP6 citation services and the data services of the IPCC Data Distribution Centre for AR6. In EGU General Assembly Conference Abstracts (Vol. 19, p. 4325)
57. IPCC (2020) Climate Change and Land Summary for Policymakers Intergovernmental Panel for Climate Change https://www.ipcc.ch/site/assets/uploads/sites/4/2020/02/SPM_Updated-Jan20.pdf
58. James SJ, James CJFRI (2010) The food cold chain and climate change. Food Res Int 43(7):1944–1956
59. Kamo Y (2000) Racial and ethnic differences in extended family households. Sociol Perspect 43(2):211–229
60. Kanter R, Walls HL, Tak M, Roberts F, Waage J (2015) A conceptual framework for understanding the impacts of agriculture and food system policies on nutrition and health. Food Secur 7(4):767–777
61. KANTOR C, McLEAN E, KANTOR M (2017) Climate change influences agriculture and the water-energy-food nexus in central and eastern European countries. Notulae Scientia Biologicae 9(4):449–459
62. Kassie M, Jaleta M, Mattei A (2014) Evaluating the impact of improved maize varieties on food security in Rural Tanzania: Evidence from a continuous treatment approach. Food Secur 6(2):217–230
63. Khan MH (1983) " Green Revolution and Redistribution of Rural Incomes: Pakistan's Experience"—A Comment.The Pakistan Development Review,47–56
64. Khan MH, Maki DR (1980) Relative efficiency by farm size and the green revolution in Pakistan.The Pakistan Development Review,51–64
65. Khan MZ, Gul H (2013) Impact of Green Revaluationn Variables on Agriculture Productivity in Pakistan. Sarhad J Agric 29(3):455–460
66. Kogo BK, Kumar L, Koech R (2021) Climate change and variability in Kenya: a review of impacts on agriculture and food security. Environ Dev Sustain 23(1):23–43
67. Kotrlik JWKJW, Higgins CCHCC (2001) Organizational research: Determining the appropriate sample size in survey research. Inform Technol Learn Perform J 19(1):43

68. Kreft S, Eckstein D, Dorsch L, Fischer L (2016) Global climate risk index 2016. Who suffers most from extreme weather events? Weather-related Loss Events in 2014 and 1995 to 2014. German Watch, Bonn, 32 pp. *Online]*: https://germanwatch. *org/en/download/13503. pdf [Accessed 20 April 2016]*
69. Leroy JL, Ruel M, Frongillo EA, Harris J, Ballard TJ (2015) Measuring the food access dimension of food security: a critical review and mapping of indicators. FoodNutr Bull 36(2):167–195
70. Li Y, Yu W (2010) Households food security in poverty-stricken regions: Evidence from western rural China. Agric Agric Sci Proc 1:386–395
71. Mahmood R, Jia S, Babel MS (2016) Potential impacts of climate change on water resources in the Kunhar River Basin, Pakistan. Water 8(1):23
72. McKernan SM, Ratcliffe C, Iceland J (2018) Policy Efforts to Reduce Material Hardship for Low-Income Families. Urban Institute, Washington DC
73. Muche M, Endalew B, Koricho T (2014) Determinants of household food security among Southwest Ethiopia rural households. Food Sci Technol 2(7):93–100
74. Mutabazi KD, Amjath-Babu TS, Sieber S (2015) Influence of livelihood resources on adaptive strategies to enhance climatic resilience of farm households in Morogoro, Tanzania: an indicator-based analysis. Reg Envriron Chang 15(7):1259–1268
75. Naylor RL, Falcon WP (2010) Food security in an era of economic volatility. Popul Dev Rev 36(4):693–723
76. NDMA Pakistan (2018) Annual Report 2018, National Disaster Management Authority Pakistan. http://web.ndma.gov.pk/
77. NDMA P (2019) Annual report 2019, National disaster management authority Pakistan
78. Pakistan Bureau of Statistics (PBS) (2020) Economic Survey of Pakistan (2019-20) Ministry of Finance. Finance division Islamabad, Government of Pakistan
79. Pakistan Bureau of Statistics (PBS) (2021) Economic Survey of Pakistan (2020-21) Ministry of Finance. Finance division Islamabad, Government of Pakistan
80. Punjab PDMA (2018) Punjab Disaster Response plan report 2018. Provincial Disaster Management Authority, Government of Pakistan
81. Punjab PDMA (2019) Punjab Disaster Response plan report 2019. Provincial Disaster Management Authority, Government of Pakistan
82. PDMA (2017) Punjab Disaster Response plan report 2017. Provincial Disaster Management Authority, Government of Pakistan
83. Pérez-Escamilla R (2017) Food security and the 2015–2030 sustainable development goals: From human to planetary health: Perspectives and opinions.Current developments in nutrition, 1(7), e000513
84. Pingali P, Aiyar A, Abraham M, Rahman A (2019) Managing climate change risks in food systems. Transforming Food Systems for a Rising India. Palgrave Macmillan, Cham, pp 241–275
85. PMD (2019) Monthly weather report, 2019, National weather forecasting center Pakistan Meteorological Department (PMD) Islamabad, Government of Pakistan. https://www.pmd.gov.pk/en/achievements2019.php
86. Renzaho AM, Mellor D (2010) Food security measurement in cultural pluralism: Missing the point or conceptual misunderstanding? Nutrition 26(1):1–9
87. Sam AS, Abbas A, Padmaja SS, Sathyan AR, Vijayan D, Kächele H, Müller K (2021) Flood vulnerability and food security in eastern India: A threat to the achievement of the Sustainable Development Goals.International Journal of Disaster Risk Reduction,102589
88. Sam DB, Sajjan NN, Babu RV, Srinivasan M (2018) Divide and grow: Capturing huge diversity in crowd images with incrementally growing CNN. In *Proceedings of the IEEE conference on computer vision and pattern*

recognition(pp. 3618-3626)

89. Sam TT, Khoi DN, Thao NTT, Nhi PTT, Quan NT, Hoan NX, Nguyen VT (2019) Impact of climate change on meteorological, hydrological and agricultural droughts in the Lower Mekong River Basin: a case study of the Srepok Basin, Vietnam. Water and Environment Journal 33(4):547–559
90. Sassi M (2018) Conceptual Frameworks for the Analysis of Food Security. Understanding Food Insecurity. Springer, Cham, pp 31–49
91. Shah KU, Dulal HB (2015) Household capacity to adapt to climate change and implications for food security in Trinidad and Tobago. Reg Envriron Chang 15(7):1379–1391
92. Shah P, Mallory ML, Ando AW, Guntenspergen GR (2017) Fine-resolution conservation planning with limited climate-change information. Conserv Biol 31(2):278–289
93. Silvestri S, Sabine D, Patti K, Wiebke F, Maren R, Ianetta M, Cristina RM (2015) Households and food security: lessons from food secure households in East Africa. Agric Food Secur 4(1):1–15
94. Skoufias E (2003) Economic crises and natural disasters: Coping strategies and policy implications. World Dev 31(7):1087–1102
95. Sseguya H, Mazur RE, Flora CB (2018) Social capital dimensions in household food security interventions: implications for rural Uganda. Agric Hum Values 35(1):117–129
96. Swaminathan MS, Bhavani RV (2013) Food production & availability-Essential prerequisites for sustainable food security. Indian J Med Res 138(3):383
97. Teo HC, Lechner AM, Walton GW, Chan FKS, Cheshmehzangi A, Tan-Mullins M, Campos-Arceiz A (2019) Environmental impacts of infrastructure development under the belt and road initiative. Environments 6(6):72
98. Teo M, Goonetilleke A, Ahankoob A, Deilami K, Lawie M (2018) Disaster awareness and information-seeking behavior among residents from low socio-economic backgrounds. Int J disaster risk Reduct 31:1121–1131
99. Thiede BC, Gray C (2020) Climate exposures and child undernutrition: Evidence from Indonesia. Soc Sci Med 265:113298
100. Tirivangasi HM (2018) Regional disaster risk management strategies for food security: Probing Southern African Development Community channels for influencing national policy. JÃ mbá: Journal of Disaster Risk Studies 10(1):1–7
101. United Nations (2011) Pakistan floods: one year on 2011. A Report by the United Nations Pakistan, Islamabad
102. United Nations (2018) United Nation Framework Convention on Climate Change Annual Report 2018https://unfccc.int/sites/default/files/resource/UN-Climate-Change-Annual-Report-2018.pdf
103. UNSCCC (2021) United Nations Security Council and Climate Change Research Report 2021, https://www.securitycouncilreport.org/atf/cf/%7B65BFCF9B-6D27-4E9C-8CD3-CF6E4FF96FF9%7D/climate_security_2021.pdf
104. Vervoort JM, Thornton PK, Kristjanson P, Förch W, Ericksen PJ, Kok K, Jost C (2014) Challenges to scenario-guided adaptive action on food security under climate change. Glob Environ Change 28:383–394
105. Week DA, Wizor CH (2020) Effects of flood on food security, livelihood and socio-economic characteristics in the flood-prone areas of the core Niger Delta, Nigeria.Asian Journal of Geographical Research,1–17
106. World Bank (2021) Climate Risk Country Profile: Pakistan (2021); The World Bank Group and Asian Development Bank https://climateknowledgeportal.worldbank.org/sites/default/files/2021-05/15078-WB_Pakistan%20Country%20Profile-WEB.pdf
107. World Health Organization (2018) The state of food security and nutrition in the world 2018: building climate resilience for food security and nutrition. Food & Agriculture Org

108. Yaqub M, Beytullah EREN, Doğan E (2015) Flood causes, consequences, and protection measures in Pakistan. Disaster Sci Eng 1(1):8–16
109. Zezza A, Carletto C, Davis B, Winters P (2011) Assessing the impact of migration on food and nutrition security. Food Policy 36(1):1–6

Figures

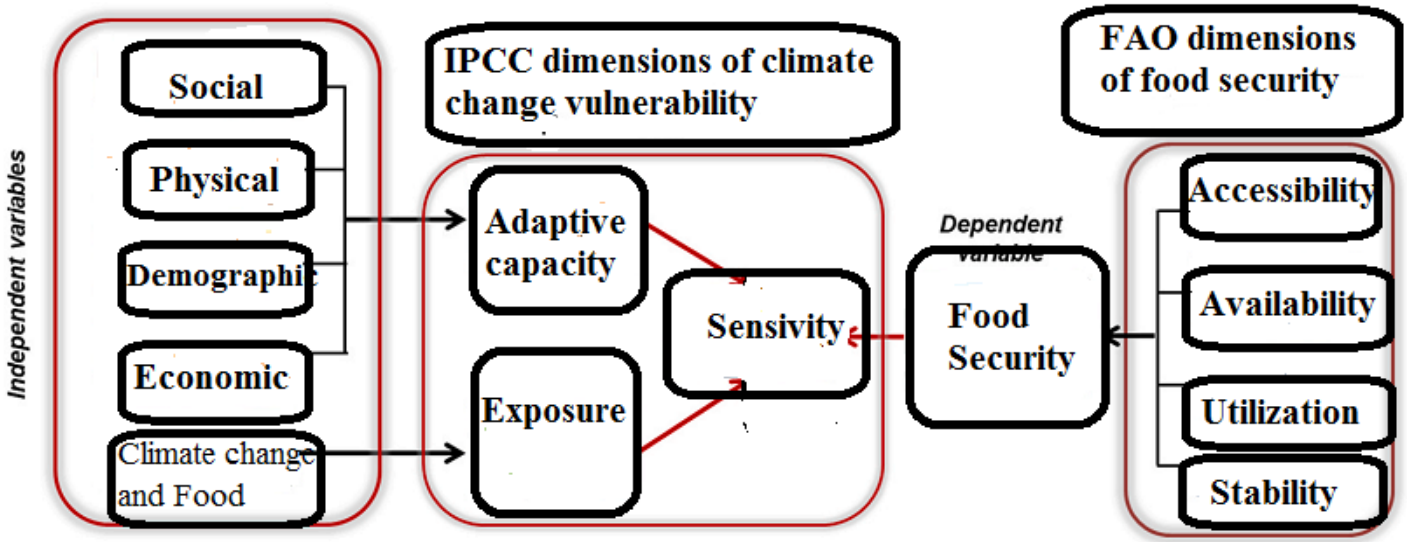

Figure 1

Theoretical framework with FAO and IPCC dimensions

Figure 2

Study districts of Punjab pakistan

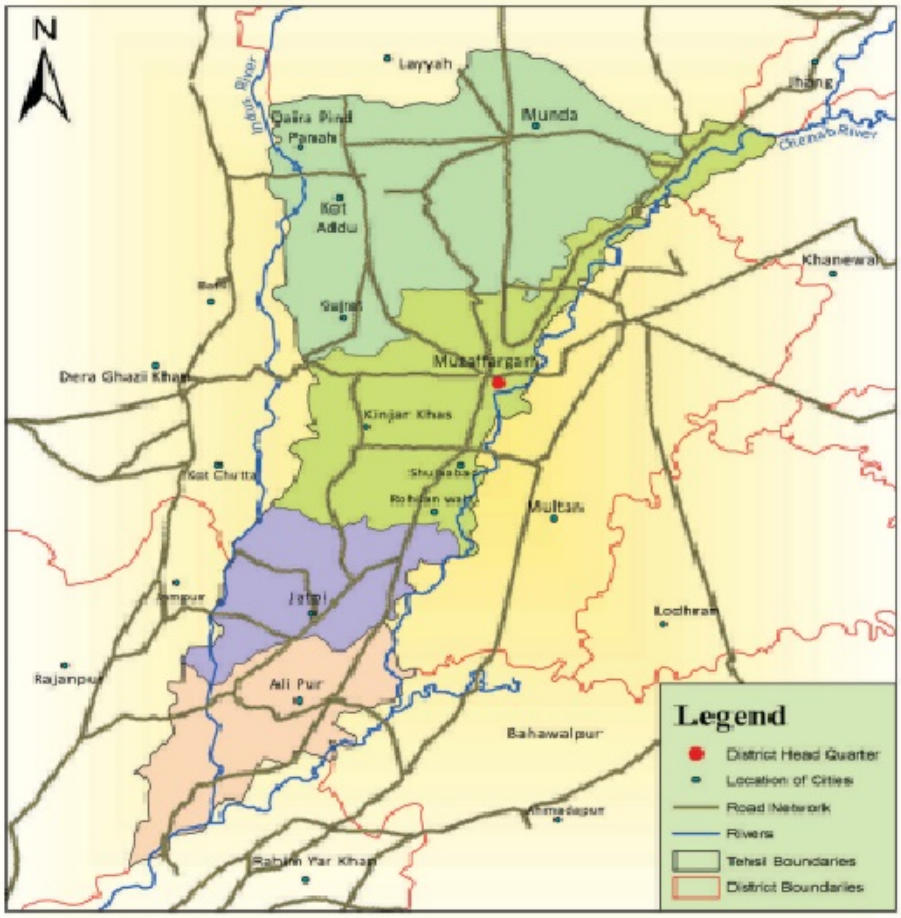

Figure 3

Map of three study districts Muzaffargarh, Dera Ghazi Khan and Rajanpur showing surrounding rivers