ASSESSING DYNAMICS OF RURAL-URBAN LINKAGES AND THEIR INFLUENCE ON RURAL VULNERABILITY TO EXTREME FLOOD EVENTS

CASE STUDY OF THREE RURAL FARMING COMMUNITIES IN PUNJAB, PAKISTAN

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Dedicated to my parents, wife, daughter and teachers

DECLARATION

I hereby declare that this doctoral dissertation is composed independently, and all the sources of information and material have properly acknowledged.

Ali Jamshed

Stuttgart, 15-03-2021

PREFACE

This dissertation is submitted in partial fulfilment of the requirements for obtaining the Ph.D. degree in Engineering (Doctor Ing.) at the University of Stuttgart, Germany. The research work described in this document was conducted and defended at the Institute of Spatial and Regional Planning (IREUS), Faculty of Civil and Environmental Engineering between April 2016 and January 2021 (see the timeline in Annex A) under the supervision of Prof. Dr.-Ing (habil) Joern Birkmann and Prof. Dr.-Ing Stefan Greiving. The research was funded by the Higher Education Commission of Pakistan (HEC) in cooperation with German Academic Exchange Services (DAAD) under "Faculty Development of MSc leading to PhD for Universities of Engineering, Science and Technology (UESTP)".

This dissertation is mainly based on the work published/accepted/in preparation to be published as research articles and a book chapter which include:

Publication 1 ***Journal Article:*** Jamshed, A., Birkmann, J., Feldmeyer, D., Rana, I.A., (2020) "A Conceptual Framework to Understand the Dynamics of Rural-Urban Linkages for Rural Flood Vulnerability". **Sustainability** 12 (7), 2894. DOI: https://doi .org/10.3390 /su1207289. Publisher: MDPI. (see Chapter 2)

Publication 2 ***Book Chapter:*** Jamshed, A., Birkmann, J., McMillan, J., Rana, I.A. and Lauer, H. (2020) "The Impact of Extreme Floods on Rural Communities: Evidence from Pakistan" in Leal, W.F., Nagy, G., Borga, M., Chavez, D. and Magnuszewski, A. (Eds.), **Climate Change, Hazards and Adaptation Options: Handling the impacts of a changing climate., Climate Change Management, 1st ed.**, Springer, Cham, 585-613. DOI: https://doi.org/10.1007/978-3-030-37425-9_30 Publisher: Springer. (see Chapter 4)

Publication 3 ***Journal Article:*** Jamshed, A., Birkmann, J., Joanna, M.M., Rana, I.A., Feldmeyer, D., Sauter, H (2021) "How do Rural-urban Linkages Change After an Extreme Flood Event? Empirical Evidence from Rural Communities in Pakistan" **Science of the Total Environment**, Vol 750C, 141462. DOI: https://doi.org/10.1016/j.scitotenv.2020.141462. Publisher: Elsevier. (see Chapter 4 and 5)

Publication 4 ***Journal Article:*** Jamshed, A., Birkmann, J., Rana, I.A., Joanna, M.M. (2020) "Relevance of City Size to the Vulnerability of Surrounding Rural Areas: An Empirical Study of Flooding in Pakistan" **International Journal of Disaster Risk Reduction**, Vol 48, 101601. DOI: https://doi.org/10.1016/j.ijdrr.2020.101601. Publisher: Elsevier. (see Chapter 6)

Publication 5 ***Journal Article:*** Jamshed, A., Birkmann, J., Rana, I.A., Feldmeyer, D. (2020) "The Effect of Spatial Proximity to Cities on Rural Vulnerability against Flooding: An Indicator Based Approach" **Ecological Indicators**, Vol 118, 106704.

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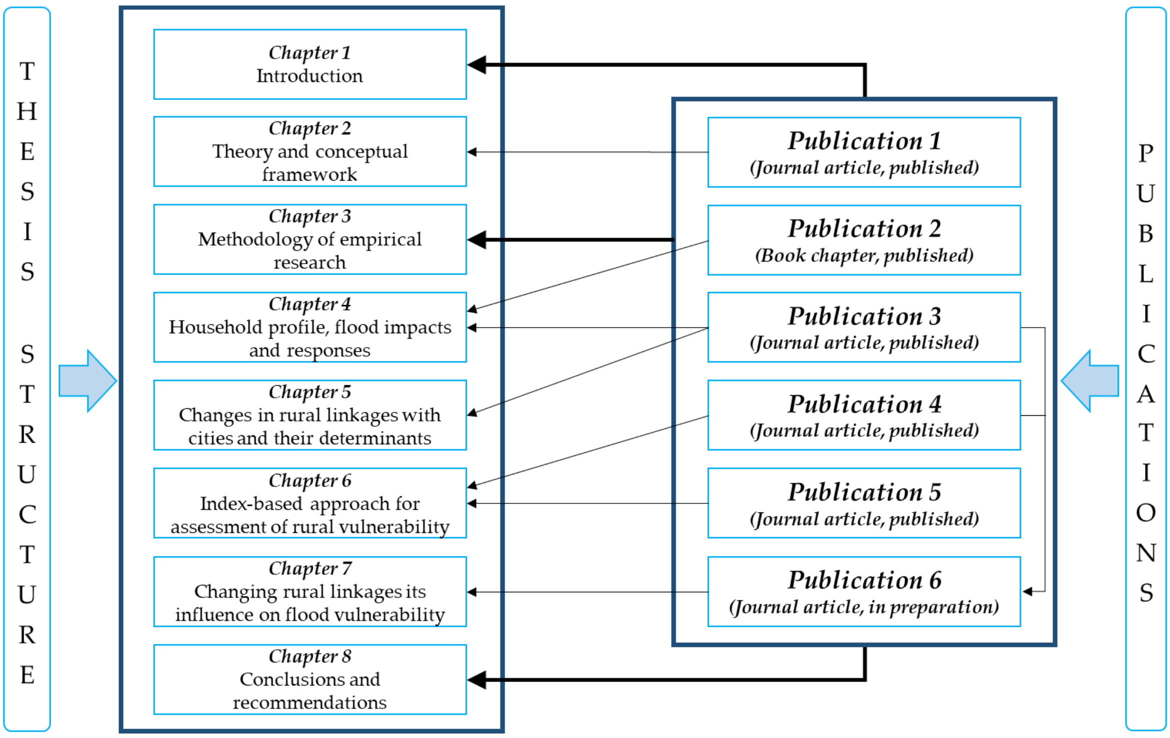
Publication 6 ***Journal Article (in preparation):*** Jamshed, A., Greiving, S. Birkmann, J., Rana, I.A., "Dynamics of Rural-Urban Linkages due to Flooding and Their Influence on Vulnerability: Case of Pakistan" to be submitted in **Science of the Total Environment.** Publisher: Elsevier. (see Chapter 7)

Research work already published/ in preparation to be published contribute to a different chapter of the thesis (see figure below). The introduction is based on the introduction section of all publications. Chapter 2 is based on publication 1, chapter 3 based on the methodology sections of all publications. Chapter 4 is based on publication 2 and 3. Chapter 5 is based on publication 3. Chapter 6 is based on publication 4 and 5. Chapter 7 is based on publication 6. Chapter 8 is based on the conclusion section of all the publications.



Ali Jamshed
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ABSTRACT

Although rural areas and cities are intrinsically linked, the vulnerability of rural households and communities to hazards or extreme weather and climatic events is often assessed without considering their relationships to cities. These linkages are important due to interdependencies between rural and urban areas for socio-economic and physical growth. Moreover, extreme events can lead to dramatic shifts in societal processes, disrupt rural-urban linkages, and affect rural vulnerability; these matters need to be investigated. Considering these gaps in knowledge, this study aims to conceptualise and understand rural vulnerability with respect to the dynamics of rural-urban linkages in the case of flooding, with a special focus on spatial factors like city size and proximity to the city.

To do so, a mixed methods approach was adopted in this research. Still, the present study is largely based on quantitative techniques. First, the current literature on rural-urban linkages, vulnerability and factors that influence them was critically reviewed, and a unified framework was proposed to connect the elements of rural-urban linkages and flood vulnerability. The framework was designed to examine changes in rural-urban linkages and the subsequent impact on rural vulnerability to flooding. For empirical research, three case studies (Darya Khan, Muzaffargarh, and Multan) were selected in the Punjab province of Pakistan. A multistage, mixed methods sampling approach was applied to derive 325 samples. Secondary data, observations and a focus group discussion deepened understanding of the topic. The household survey, using a structured questionnaire, was administered to collect information from the required sample, comprised of a flood-affected rural population surrounding three different-sized cities and at varied proximity. The data were analysed using descriptive statistics (frequency analysis, cross-tabulation) and inferential statistics (correlation, regression, chi-square, the Mann-Witney U test). Moreover, an index-based approach was developed to obtain the composite values of the three components of vulnerability: (1) exposure, (2) susceptibility and (3) capacity.

The findings show that flooding severely affects rural households both directly and indirectly. The ramifications have led to several changes among rural households; most notably, they have modified how they earn a living and their relationship with the nearest major city. Floods have shifted the flow of people, information, finances, goods, and services between rural and urban areas. The research indicates that rural-urban linkages are altered in that flooding both increases and decreases rural households' dependence on cities in different ways. These outcomes are largely driven by socio-economic, spatial, and flood-related factors.

In terms of vulnerability, first, the findings signal that rural populations surrounding smaller cities are less exposed, but more vulnerable, as compared to rural households that surround larger cities. This is because rural populations adjoining larger cities are better able to deal with flood hazards due to stronger linkages. Secondly, the results confirmed that distance to the city influences the vulnerability of surrounding farming households. Rural farming households located close to cities are less vulnerable, mainly due to a better transfer of services and facilities from cities, which has made such households more educated, informed, financially strong and more closely connected, with easier access to public and private institutions. Thus, city size and proximity to the city modify linkages that further impact the flood vulnerability of the rural population.

Lastly, changes in linkages made by rural households following a flood influence their overall vulnerability differently; increasing linkages with the city after a flood reduce their vulnerability, while decreasing linkages with the city exacerbate it. These changes in linkages are used to adapt to future floods and affect rural households' vulnerability both positively and negatively. Hence, the dynamics of linkages and rural households' exchanges with cities are crucial to reducing their vulnerability to future flood hazards. This study paves the way for regional planners and disaster managers to establish synergies between them for devising integrated flood management and development strategies that strengthen linkages, mitigate disparities and curtail vulnerability.

ZUSAMMENFASSUNG

Obwohl ländliche Gebiete und Städte eng miteinander verbunden sind, wird die Vulnerabilität ländlicher Haushalte und Gemeinden für Gefahren oder extreme Wetter- und Klimaereignisse häufig ohne Berücksichtigung ihrer Beziehung zu Städten bewertet. Diese Verflechtungen sind aufgrund der gegenseitigen Abhängigkeiten zwischen ländlichen und städtischen Gebieten für die sozioökonomische und physische Entwicklung wichtig. Darüber hinaus können Extremereignissezu dramatischen Veränderungen in gesellschaftlichen Prozessen führen, die Verbindungen zwischen Land und Stadt beeinträchtigen und ländliche Verwundbarkeiten betreffen, die untersucht werden müssen. In Anbetracht dieser Wissenslücken zielt diese Studie darauf ab, die ländliche Verwundbarkeit in Bezug auf die Dynamik der Verflechtungen zwischen Land und Stadt bei Überschwemmungen zu konzipieren und zu verstehen. Hierbei stehen räumliche Faktoren, wie die Größe der Stadt und die Nähe zur Stadt, im Vordergrund.

Zu diesem Zweck wurde ein Mixed-Method-Ansatz, mit einem starken Fokus auf quantitativen Methoden gewählt. Zunächst wurde die aktuelle Literatur zu urban-ruralen Verflechtungen, zur Vulnerabilität sowie zu Faktoren, die sie beeinflussen, kritisch überprüft. Es wird ein einheitlicher Rahmen vorgeschlagen, der die Elemente der Verflechtungen zwischen Land und Stadt und die der Anfälligkeit gegenüber Überschwemmungen miteinander verbindet. Der Rahmen dient dazu, Änderungen der urban-ruralen Verflechtungen und deren Einfluss auf die Vulnerabilität des ländlichen Raums bezüglich Überschwemmungen zu untersuchen. Für die empirischen Untersuchungen wurden drei Fallstudien (Darya Khan, Muzaffargarh und Multan) in der pakistanischen Provinz Punjab ausgewählt. Ein mehrstufiger Mixed-Method Stichprobenansatz wurde angewendet, um 325 Proben zu erhalten. Anhand von Sekundärdaten, Beobachtungen und Gruppendiskussionen aus der Haushaltsumfrage wird das Thema erfasst. Es wurde eine Haushaltsumfrage basierend auf einem strukturierten Fragebogen durchgeführt, um die erforderliche Stichprobe von der von Überschwemmungen betroffenen ländlichen Bevölkerung, die im Umfeld von drei

verschiedenen Städten unterschiedlicher Größe und Lage leben, zu sammeln. Die Daten wurden unter Anwendung deskriptiver Statistiken (Frequenzanalyse, Kreuztabelle) und Inferenzstatistiken (Korrelation, Regression, Chi-Quadrat, Mann-Witney-U-Test) analysiert. Darüber hinaus wurde ein indexbasierter Ansatz entwickelt, um die zusammengesetzten Werte der drei Komponenten der Vulnerabilität zu ermitteln, nämlich Exposition, Anfälligkeit und Kapazität.

Die Ergebnisse zeigen, dass ländliche Haushalte sowohl direkt als auch indirekt besonders schwer von Überschwemmungen betroffen sind. In Folge dieser Auswirkungen ist eine Reihe von Verhaltensänderungen bei ländlichen Haushalten zu beobachten – beispielsweise im Hinblick auf Einkommensquellen oder die alltäglichen Stadt-Land-Verflechtungen. Überschwemmungen führten zu einer grundlegenden Veränderung des Stadt-Land-Gefüges und den Beziehungen zwischen ländlichen und städtischen Gebieten im Hinblick auf den Strom von Menschen, Informationen, Finanzen, Waren und Dienstleistungen. Die Forschungsergebnisse verdeutlichen, dass sich die Verflechtungen zwischen städtischem und ländlichen Räum insofern verändert haben, als dass Überschwemmungen die Abhängigkeit der ländlichen Haushalte vom städtischen Gebiet auf unterschiedliche Weise sowohl erhöht als auch verringert hat. Diese Veränderungen sind weitestgehend auf sozioökonomische und räumliche Faktoren zurückzuführen sowie auf Faktoren, die in direktem Zusammenhang zur Überschwemmung stehen, wie der Verlust von landwirtschaftlichen Flächen.

Im Hinblick auf die Verwundbarkeit lassen sich zwei zentrale Ergebnisse festhalten. Erstens sind ländliche Haushalte in der Umgebung kleinerer Städte im Vergleich zu ländlichen Haushalten, die in der Umgebung größerer Städte leben, weniger exponiert, aber verwundbarer. Dies lässt sich dadurch erklären, dass ländliche Haushalte in unmittelbarer Nähe zu größeren Städten stärkere Stadt-Land Verflechtungen haben und daher besser in der Lage sind, mit Überschwemmungsgefahren umzugehen. Zweitens bestätigten die Ergebnisse, dass die Entfernung zu den Städten die Verwundbarkeit der umliegenden landwirtschaftlichen Haushalte beeinflusst. Ländliche Haushalte, die in der Nähe dieser Städte leben, waren weniger verwundbar, was hauptsächlich auf den besseren Transfer von Dienstleistungen und Einrichtungen aus den Städten zurückzuführen ist, wodurch sie besser ausgebildet, informiert und finanziell unabhängig sind und einen leichteren Zugang zu öffentlichen und privaten Institutionen haben. Abschließend lässt sich festhalten, dass die Stadtgröße und die Distanz ländlicher Haushalte zur Stadt das Beziehungsgeflecht zwischen Stadt und Land formen, welches wiederum die Verwundbarkeit ländlicher Haushalte beeinflusst.

Verhaltensänderungen von ländlichen Haushalten aufgrund der Überschwemmung beeinflussen die Vulnerabilität unterschiedlich. Eine Intensivierung der Stadt-Land-Verflechtung verringerte die allgemeine Vulnerabilität, während gleichzeitig eine Abnahme von Verbindungen diese erhöhte. Die Verhaltensänderungen dienen zur Bewältigung von negative Folgen und Anpassung an zukünftige Überschwemmungen und können die Vulnerabilität von ländlichen Haushalten sowohl positiv wie negativ beeinflussen. Daher ist die Veränderung der Stadt-Land-Verflechtung von entscheidender Bedeutung für die zukünftige Verletzlichkeit von ländlichen Haushalten. Diese Studie ebnet den Weg zur Schaffung von Synergien zwischen Regionalplanern und Katastrophenmanagern für das Hochwassermanagements und allgemeine Entwicklungsstrategien, die Verbindungen stärken, Ungleichheiten verringern und die Verwundbarkeit reduzieren.

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LIST OF ABBREVIATIONS

BBC	Bogardi, Birkmann and Cardona framework
BSP	Bureau of Statistics Punjab
CRI	Climate Risk Index
DFID	Department for International Development
DoIP	Directorate of Industries Punjab
EM-DAT	Emergency Events Database
FFC	Federal Flood Commission
FPS	Far Proximity Settlements
GDP	Gross Domestic Product
GoP	Government of Pakistan
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
Km	Kilometres
KPK	Khyber Pakhtunkhwa
MC	Municipal Corporation/Municipal Committees
MoF	Ministry of Finance
MOVE	Methods for the Improvement of Vulnerability Assessment in Europe
NDMA	National Disaster Management Authority
NPS	Near Proximity Settlements
NRSP	National Rural Support Program
PBS	Pakistan Bureau of Statistics
PDMA	Provincial Disaster Management Authority
PDS	Punjab Development Statistics
PKR	Pakistani Rupees
PMD	Pakistan Metrology Department
PRSP	Punjab Rural Support Program
SCARV	City Size and Rural Vulnerability framework
SDGs	Sustainable Development Goals
SFDRR	Sendai Framework for Disaster Risk Reduction
SPDI	Sustainable Policy Development Institute
UC	Union Council
UN-DESA	United Nations Department of Economic and Social Affairs
UNDRR	United Nation Office for Disaster Risk Reduction
UNFCCC	United Nation Framework Convention on Climate Change
UNHABITAT	United Nations Human Settlements Programme
VPN	Vulnerability Proximity Nexus framework
WASH	Water and Sanitation

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Chapter 1
Introduction

1.1 Background: *Flood hazards and vulnerability*

Extreme weather and climatic events, especially in the form of hydro-meteorological hazards, have wreaked havoc around the world. These events cause severe impacts, including fatalities, injuries and damage to homes and infrastructure, which disrupt the economy, infrastructure systems, people's sources of livelihood and societal services (Kirsch et al., 2012). A flood is one of the most damaging types of events and is likely to become more frequent (Willner et al., 2018). It is expected that climate change will further increase the intensity and magnitude of such events (Jongman et al., 2018). Different regions around the world are exposed to different kinds of floods, including fluvial or river-related floods, pluvial and flash floods, and coastal (i.e. due to storm surges) floods. Their destructive effects, both in rural and urban areas, have become a global issue.

Floods have resulted in widespread human, economic and physical losses. According to an estimate, flood events in the last two decades have caused economic losses of more than US$537 billion, affected 1.6 billion people, and taken more than 100,000 lives (EM-DAT, 2020). The aftermath is worse in low-income and developing countries in Asia, where the majority of people live in rural areas. In these regions, the flood impacts and resulting losses are projected to increase in the future (Winsemius et al., 2016; Willner et al., 2018). These increasing impacts and losses are not only due to an increase in the intensity and magnitude of flood hazards, but also the vulnerability of the socio-ecological system.

These systems' vulnerability[1] depends on location-specific social, economic, demographic, political, physical and environmental attributes (Greiving et al., 2006a;

[1] Vulnerability refers to characteristics and circumstances of people, their surroundings and systems, which makes them likely to be adversely affected by a hazard or climatic event. Vulnerability has several components and dimensions. In this research, vulnerability encompasses the aspects of exposure, susceptibility and capacity.

Birkmann et al., 2013; Jamshed et al., 2017) that make vulnerability spatially dynamic (i.e. vulnerability varies between regions, countries and counties, as well as between urban and rural areas) (Vogel et al., 2004; Cutter et al., 2008b; Greiving, 2013; Cutter et al., 2016; Feldmeyer et al., 2017). When comparing the vulnerability of rural and urban regions, rural regions are considered more vulnerable (Bird et al., 2002; Turpie et al., 2012). This higher vulnerability in rural areas is caused by lower human development, poor physical infrastructure, high dependence on agriculture with impoverished conditions, and little attention from public institutions (Kapucu et al., 2013; Dasgupta et al., 2014; Lazarte, 2017). Rural locales are also less prepared for (and have fewer mechanisms to adapt to) weather or climate-related events like floods (Steinberg, 2014; Cutter et al., 2016). Hence, rural areas are hotspots of high flood impacts, and are likely to continue to be in the future unless vulnerability is significantly reduced. In this regard, understanding vulnerability is imperative for informed decision-making that aims to reduce flood impacts.

A vulnerability assessment is important for designing flood risk reduction and adaptation measures, and is a vital step toward alleviating and managing flood risk over space and time. There is agreement on this in the different—but related—international discourses on disaster management, sustainable development and climate change adaptation (Birkmann, 2013b; IPCC, 2014b; Birkmann et al., 2020a). This can be seen in the Sendai Framework for Disaster Risk Reduction (SFDRR), in which Priority 1 calls for understanding disaster risk in all its dimensions, including vulnerability (UNDRR, 2015). In the United Nations' (UN) Sustainable Development Goals (SDGs), goals 11 and 13 call for safe and resilient human settlements by strengthening resilience and capacity (United Nations, 2018). The Paris Agreement on combatting climate change calls for climate change impact and vulnerability assessments of people, places and ecosystems to prioritise actions for reducing vulnerability (UNFCCC, 2015, pp. 9–10).

Much of the research on flood vulnerability assessment focuses either on the vulnerability of urban hubs/cities (Douglas et al., 2008; Adelekan, 2011; Balica et al., 2012; Welle et al., 2015b; Rana et al., 2018b) or rural areas (Mustafa, 1998; Brouwer et al., 2007; Armah et al., 2010; Schütte et al., 2012; Jamshed et al., 2019b; Sarker et al., 2019), but not on the relationship between the two. Although such studies have investigated different components (exposure, susceptibility and capacity to adapt) and dimensions (social, economic, physical, institutional, environmental and others) of vulnerability to flood events, they have not paid sufficient attention to the relationship between rural areas and cities/urban areas that can be affected due to flood events, and how it can influence vulnerability. In short, assessment of the vulnerability of rural areas and their residents in relation to the nearest city (on which rural households depend for various services and facilities) has been widely neglected.

1.2 Motivation: *Rural-urban linkages and rural vulnerability*

Over 90% of the world's rural population lives in less developed regions[2] (UN-DESA, 2018b). Rural settlements in these regions are usually undersupplied and underdeveloped (Srivastava et al., 2016). These settlements are going through socio-economic, demographic, environmental and governance changes due to interdependencies between rural and urban areas (Dasgupta et al., 2014). Rural populations depend on nearby cities as they provide employment, health, education, emergency services, markets and information to the rural population. Similarly, cities and their inhabitants depend on rural areas for labour, food and other ecological services (Gebre et al., 2019). These dependencies are often referred to as rural-urban linkages in the literature, and are explained in terms of the flow of people, finances/income, information, goods and services (Tacoli, 1998; Lynch, 2005). Spatial and regional development studies underscore that these linkages result in the social, economic and physical growth of rural regions (see for example Douglass, 1998, Bah et al., 2003, Tacoli, 2007). There is a need to consider rural-urban linkages not only from a spatial development perspective but also how they can be affected by floods or other hazards (Srivastava et al., 2012).

There is a consensus—but limited evidence—that the dependencies and linkages between rural and urban places may be affected by the repercussions of weather or climatic events

[2] Less developed regions comprise all regions of Africa, Asia (except Japan), Latin America and the Caribbean plus Melanesia, Micronesia and Polynesia.

like flooding (Dasgupta et al., 2014), which can considerably influence the vulnerability of rural communities. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) highlighted the need for improved understanding of rural-urban linkages and their management in the face of climate change and its impacts (Dasgupta et al., 2014, p. 645). UN-Habitat's *'New Urban Agenda'* has also called for integrated initiatives where disaster risk, climate change, and spatial and territorial planning should be harmonised. It has called for strengthening rural-urban linkages, especially in the face of hazards and disasters (UNHABITAT, 2016, 2017). Hence, examining changes in rural-urban linkages due to the impact of extreme events is a relevant area of research for understanding and reducing vulnerability and risk.

Research has shown that the impacts of extreme events, such as flooding, can cause both formal (by government agencies) and informal (by households, communities) changes in society (Birkmann et al., 2010), including organisational and legislative shifts, as well as modifications of housing structures and livelihood/farming practices or linkages between rural and urban areas (Douglass, 1998; Birkmann et al., 2010; Birkmann, 2011). These changes can influence vulnerability and hence communities' risk level (Jamshed et al., 2017). As such, it is important to explore how extreme events in rural locales alter livelihood practices, as well as rural linkages with cities, and how these changes influence rural households' vulnerability (see Figure 1.1).

In addition to the impacts of an extreme event, several other factors influence rural-urban linkages and vulnerability, especially in post-disaster situations (Douglass, 1998; Birkmann et al., 2013); these include the socio-economic, physical, environmental and spatial characteristics of society. Although the nature of the rural-urban linkages between a rural community and its nearest city—on which the rural community depends for multiple city-based services (e.g. markets, health and emergency services, institutions)—is determined by several factors, two spatial features are important in this regard: (1) the nearest city's proximity to the rural community and (2) city size (Jamshed et al., 2020b). These two elements can significantly influence the social, economic, physical and institutional attributes of rural-urban linkages, and thus the rural landscape surrounding the city (Berdegué et al., 2015; Abbay et al., 2016; Sharma, 2016; Rana et al., 2020c). Neither of these two factors (as reviewed by Jamshed et al., 2020b) has been given enough attention in previous studies on rural vulnerability, particularly in Pakistan (see Figure 1.1).

A large body of literature indicates that larger cities are less at-risk than smaller cities (Cross, 2001; Birkmann et al., 2016b; Handayani et al., 2017). Cross (2001) and Handayani et al. (2017) underscored that larger cities can have higher exposure to hazards or climatic events, and some parts of such cities can be more susceptible. However, large cities generally have greater social, economic, physical and institutional resources compared to smaller cities, which results in the varied overall vulnerability between these city types (Cross, 2001; Birkmann et al., 2016b; Handayani et al., 2017). Despite the substantial body of research on the vulnerability of cities of different sizes, the investigation of how city size influences the vulnerability of households in surrounding rural settlements has been largely neglected. There is a dearth of research on the relationship between the proximity of rural households and their settlements to a district's main city, as well as their vulnerability. Some research has shown that different human, natural, physical and financial factors differ with a community's proximity to the city; this affects the community's vulnerability to climate change (Pandey et al., 2012; Pandey et al., 2017). However, these studies only categorise rural settlements as near or far from the city, and do not provide any information on proximity criteria (e.g. distance). Moreover, these studies do not present information on the characteristics of cities and types of linkages.

Socio-economic and infrastructure conditions, as well as institutional coverage, can be significantly influenced by a household's proximity to the city and city size. In this way, rural households' vulnerability to floods can be affected by city size and proximity. These two factors can serve as baseline parameters in investigations of flood vulnerability, as they influence all other social, economic, institutional and infrastructure factors, as well as rural-urban linkages (Ferré et al., 2012; Abbay et al., 2016; Sharma, 2016; Rana et al., 2020c). Further, changes in rural linkages with cities following a flood event can impact rural households' vulnerability, as mentioned earlier. In this context, changes in linkages need to be connected with rural households' overall vulnerability in order to examine how the modification of various linkages could influence rural households' vulnerability to flooding (see Figure 1.1).

Despite the importance of rural-urban linkages for rural vulnerability, linkages and vulnerability have not yet been theoretically framed together. Several theoretical frameworks for vulnerability assessment have been developed for different scales (local, national, global), components (exposure, susceptibility/sensitivity, capacity), and dimensions (social, economic, physical, environmental, institutional) depending on the research field (Cutter, 1996; DFID, 1999; Cardona et al., 2000; Bohle, 2001; Turner et al., 2003; Wisner et al., 2004; Birkmann, 2006b; Füssel et al., 2006; Birkmann et al., 2013; IPCC, 2014b). However, none of the frameworks or assessment studies has adequately given attention to (and revealed) the effects of rural flooding or other rural hazards on the interactions/linkages between spatial units (rural and urban), or their influence on vulnerability. The factors and issues that characterise rural-urban linkages and vulnerability need to be outlined together and assessed jointly.

To address the above research gaps, rural vulnerability to flooding needs to be evaluated and filtered from the perspective of rural-urban linkages and spatial factors, which are closely related; for example, flood impacts can influence rural-urban linkages, but rural-urban linkages also affect impact typologies and other socio-economic and spatial conditions (see Figure 1.1).

The key proposition of this dissertation is:

> *Extreme flood events modify the linkages between rural and urban areas and hence the vulnerability of rural households. A rural settlement's proximity to a city and the size of that city are deciding factors in how these rural-urban linkages and rural households' vulnerability are altered.*

This thesis conceptualises the rural-urban linkages, vulnerability and associated factors into a framework that is operationalised using three case studies in Punjab, Pakistan.

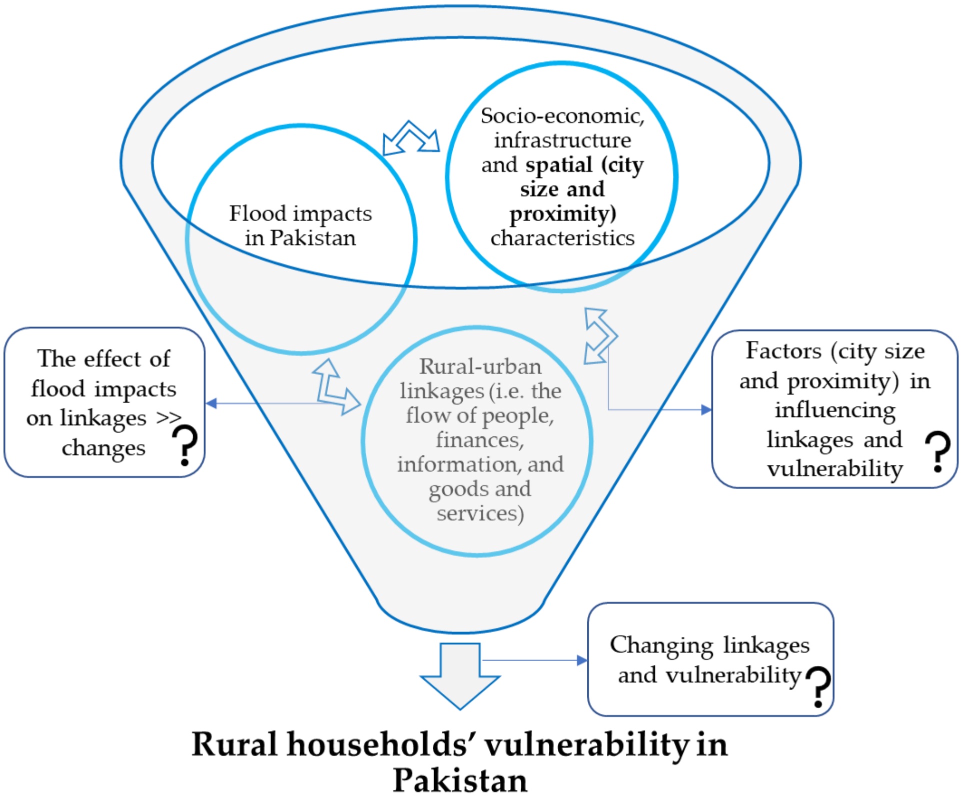

Figure 1.1. Gaps in examining rural flood vulnerability
(Own figure, 2020)

1.3 Pakistan and flooding

Pakistan is a nation in South Asia with an agro-industrial economy, a population of over 207 million, an average annual gross domestic product (GDP) growth rate of 5.5%, and is ranked at 150 on the Human Development Index (PBS, 2017; Jahan et al., 2018). The rural areas are crucial as they house more than 65% of the population and form the backbone of the country's agricultural economy (PBS, 2017; Mughal, 2019). Agriculture alone employs 43% of the total workforce and contributes about to 20% of national GDP (MoF, 2016) There is a high development disparity between the rural and urban regions (Rana et al., 2020c). Areas further away from primary cities are less developed, and conditions in rural areas are far more inferior than those in urban areas (Rana et al., 2017; Rana et al., 2020b). This situation has caused the rural population to depend heavily on cities for many facilities and services (e.g. markets to buy farm inputs and tools, basic health facilities, information services).

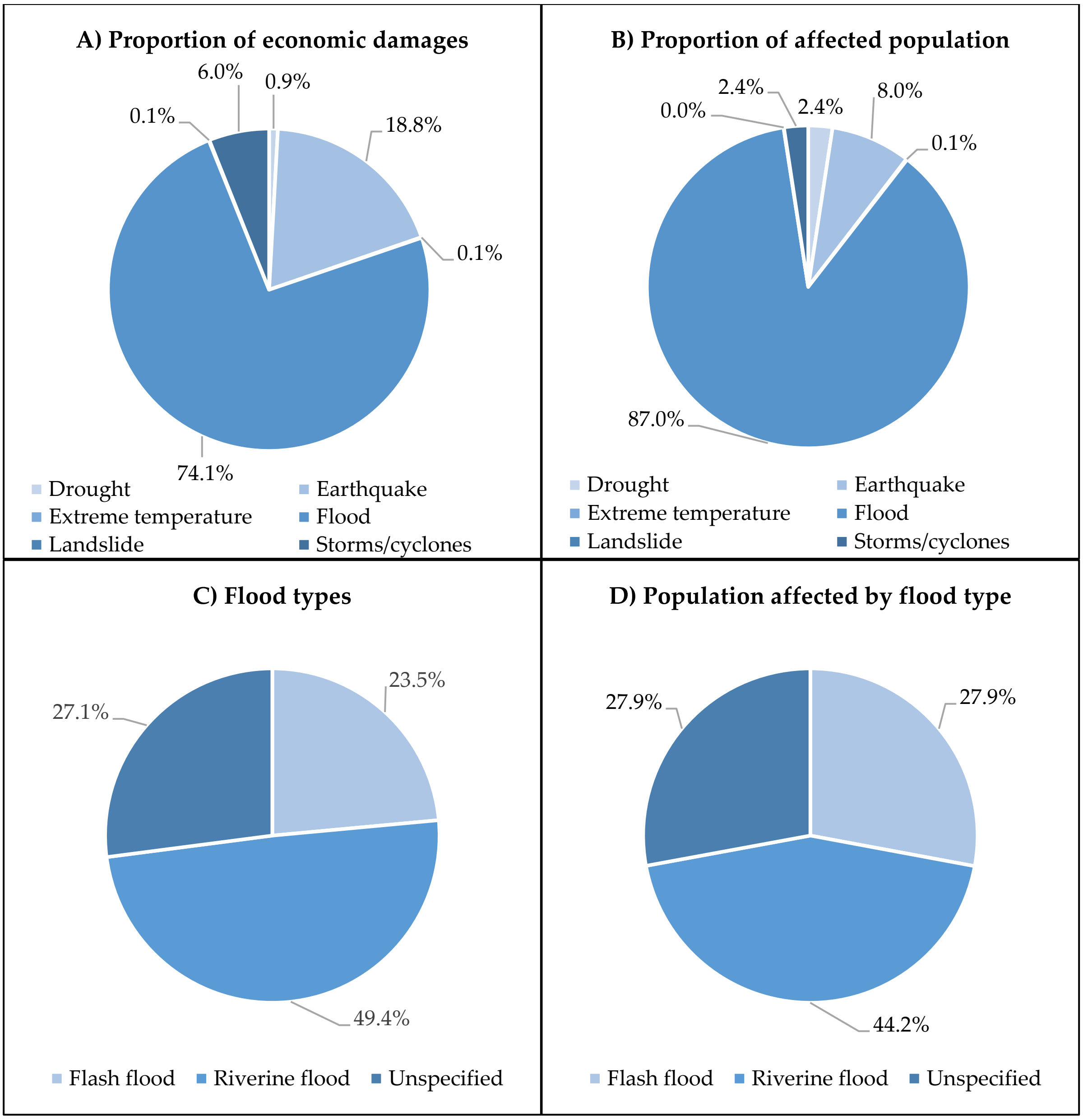

Figure 1.2. Hazard impacts between 1970-2017. (A) the proportion of economic damages; (B) the proportion of the population affected; (C) the proportion of flood events by type; (D) the proportion of the population affected by flood type.
(EM-DAT, 2017)

Pakistan is prone to numerous natural hazards, but flooding is the most common and devastating kind due to diverse climatic and hydrological conditions. Among all natural hazards between 1970 and 2017, floods caused 74% of economic damage (worth US$20 billion) and affected 87% of the population, as shown in Figure 1.2A&B (EM-DAT, 2017). According to Pakistan's National Disaster Management Authority (NDMA), 67 out of the country's 156 districts are at high flood risk. The frequency and intensity of floods have increased, and climate change is considered one of the main reasons (GoP, 2012).

According to the Climate Risk Index (CRI), Pakistan was the fifth most affected nation by climate change in 2020. The country's rank was first in 2010, third in 2011 and 2012, and sixth in 2013 (Kreft et al., 2016). Willner et al. (2018) found that Pakistan is already highly affected and will observe almost a doubling in high-end flood risk at the sub-national level within the next 25 years.

Pakistan can be divided into three major hydrological landscapes—the Indus Basin, the Kharan Basin, and the Makran coastal drainage area—with each one being prone to a different major flood type, specifically riverine, flash and coastal flooding, respectively (Tariq et al., 2012). Riverine floods account for almost 50% of all floods in Pakistan (see Figure 1.2C). Flooding in the Indus Basin has caused major economic and human losses; the proportion of affected people is also highest in this area (see Figure 1.2D). The Indus Basin is very fertile for agriculture and plays a major role in the country's economy; it is highly populated, and population pressure has led to development in floodplains, with no regard to the resulting increase in flood risk due to higher exposure. The government has spent a vast amount of money on structural engineering to counter flood risk, but these measures have been unable to prevent large-scale disastrous flood impacts in recent years (Tariq and van de Giesen, 2012).

Between 2010 and 2015, Pakistan faced five consecutive large-scale floods. The flooding of 2010 was extreme and left half of the nation paralyzed due to devastating ramifications for people, the economy and infrastructure (Solberg, 2010; Shah et al., 2020). Disastrous floods mainly affected rural areas and their inhabitants, while cities and industrial hubs remained relatively safe (Asgary et al., 2012). Aslam et al. (2017) and van der Schrier et al. (2018) revealed that a flood event like that of 2010 could occur again and may have even more severe socio-economic impacts, especially on the rural population. With the current situation and impending climate change, rural locales and the livelihoods of their residents are highly threatened (Abid et al., 2016a). Moreover, effects on infrastructure and rural households may have influenced linkages between rural and urban areas and hence vulnerability. It is important to note that existing disaster risk management and climate change adaptation policies and strategy documents (Government of Pakistan

GoP, 2012b, 2012a; Shahzad et al., 2018)—both at the national and provincial levels—do not acknowledge the impacts of climatic events or hazards on rural-urban linkages and their influence on people. Thus, a rigorous assessment of rural households' vulnerability, considering their linkages with cities, is critical to guide future policies, as well as for risk-informed decision-making.

1.4 Objectives and research questions

The limited consideration of rural-urban linkages in the evaluation of rural vulnerability to floods has been identified as a vital research gap. The overall goal of this research is *to examine the dynamics of rural linkages with cities due to flood impacts and their effects on rural households' vulnerability*. Based on multiple research gaps, the study's sub-objectives are:

Objective 1. To develop a framework to scrutinise households' changes and modifications of rural-urban linkages following a flood event in rural areas, as well as their effects on residents' vulnerability.

Objective 2. To investigate the impacts of flooding, as well as other socio-economic and physical factors, in shifting rural-urban linkages.

Objective 3. To determine the impact of city size and proximity on rural households' flood vulnerability, with a focus on rural-urban linkages.

Objective 4. To explore the influence of changing rural linkages with cities on rural households' flood vulnerability.

To achieve these goals, the following research questions (RQs) were developed.

RQ1. How can the theoretical perspectives on rural-urban linkages and vulnerability be framed together?

- How are rural-urban linkages defined, and how is vulnerability understood in different schools of thought?
- What are the driving factors of rural-urban linkages and flood vulnerability?

- In what ways can floods affect rural-urban linkages, and how can the impacts of flooding on these linkages be connected to rural households' vulnerability?

RQ2. How do the effects of flooding lead to changes in rural households and influence the linkages between these households and cities?

- What are the direct and indirect impacts of flood events on rural farming households in Pakistan?
- How do rural households change their housing structure, livelihood patterns and linkages with cities following an extreme flood event?
- Which drivers modify rural-urban linkages after flooding?
- How are changes in rural-urban linkages related to rural households' vulnerability?

RQ3. To what extent can city size and proximity to the city influence the vulnerability of surrounding rural settlements, keeping in mind the rural-urban linkages?

- How can rural vulnerability be operationalised in the context of city size and proximity to the city?
- How different are the vulnerability levels of rural households around cities of different sizes and at different proximities?
- Are rural-urban linkages relevant to rural households' vulnerability?

RQ4. How do changes in rural-urban linkages after a flood influence rural households' vulnerability to flooding?

- Are there any differences in the vulnerability of households that changed their linkages with cities compared to those that did not?
- To what extent do changes in linkages influence rural households' vulnerability?

1.5 Research approach

This study is primarily based on empirical research and predominantly uses a quantitative approach, while a qualitative approach is also employed for conceptual framing, as well as for empirical research (see Figure 1.3). The triangulation of both approaches is performed to support and test the validity of the findings. To answer the RQs, this study is divided into four parts: (1) a framework for the study; (2) the impacts of floods and resulting changes, including changes to rural-urban linkages; (3) the vulnerability assessment; and (4) the influence of changing linkages on overall flood vulnerability. Case studies were used to perform empirical research; they were carefully selected and encompass differences in economic functions and spatial characteristics. Data were collected by conducting face-to-face interviews using a questionnaire (these aspects are described more precisely in the methods section).

RQ1 sought to clarify different theoretical and conceptual perspectives on rural-urban linkages and vulnerability, and how they can be framed together under the umbrella of flood events and their influence. To do so, multiple literature sources (e.g. research articles, books, published reports, dissertations and newspaper articles) were scrutinised, and a conceptual framework was proposed (see Chapter 2). The conceptual framework provides the basis to answer further RQs.

RQ2 aimed to investigate the impacts of past flood events and the changes following a flood (Chapter 4 and Chapter 5), including shifts in livelihood and in rural-urban linkages. These were analysed using descriptive statistics. Further, inferential statistics were employed to examine the relationship between changes in livelihood and in rural-urban linkages. Factors that determine the modification of rural-urban linkages were also explored using inferential statistics. The findings were supported and validated by excerpts from responses to the household survey.

RQ3 intended to assess rural households' vulnerability considering city size and proximity parameters. This built on the findings from RQ2, which identified the importance of changes in rural-urban linkages and other relevant factors for investigating vulnerability. The findings highlight the importance of city size and distance to the city as parameters that influence rural-urban linkages and can be pertinent to assessing vulnerability. The research applied a composite indicator method for evaluating vulnerability, followed by inferential statistics to discern differences in the vulnerability of rural households living on the peripheries of different cities (using the criteria of city size and proximity).

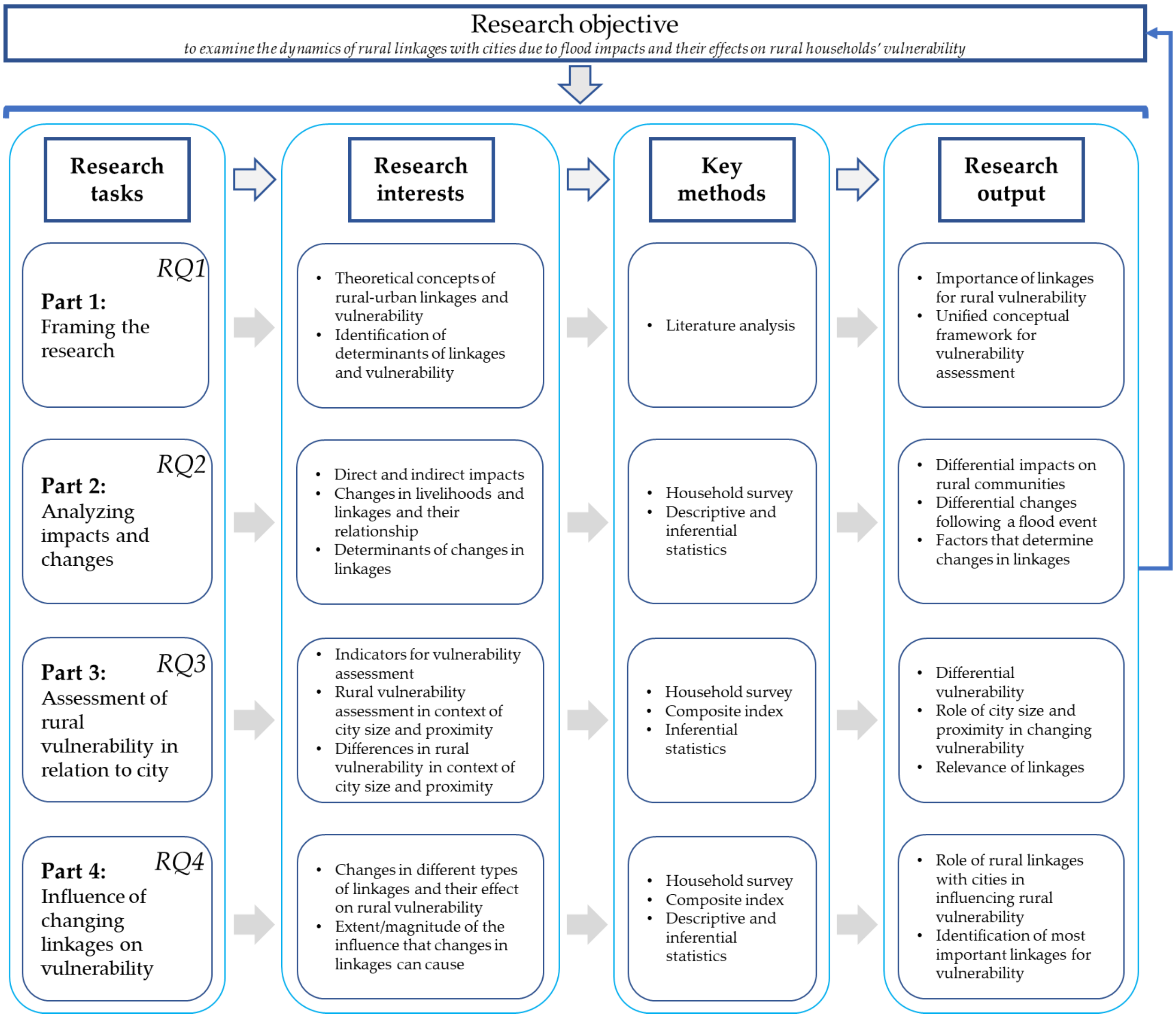

Figure 1.3. Overview of the research approach and research tasks (Own figure, 2020)

RQ4 aimed to combine the results of RQ2 and RQ3, and to study the influence of changing linkages on rural households' vulnerability. The findings suggest that shifting linkages can both increase and decrease rural households' vulnerability. This section is based on descriptive and inferential statistics.

1.6 Scope of the research

This research focuses on the local community and household levels, since investigations at the local level are often viewed as effective in capturing the complexity of interactions in coupled human-environmental systems (O'Brien et al., 2004). Rural households are the key focus of this research, as floods particularly affect rural communities in Pakistan. Three case studies were selected from the province of Punjab (i.e. Darya Khan, Muzaffargarh, and Multan). These case studies represent important research sites because the study areas have a history of flooding and different flood profiles (in terms of the number of flood events, risk level, etc.); in addition, the study areas are around cities of different sizes, with different demographic and socio-economic profiles.

Flood impacts can lead to both formal (carried by the public sector) and informal (carried by private sector; e.g. households, non-profit organisations [NGOs]) changes (Birkmann et al., 2010). This thesis focuses mainly on informal changes (adopted by households), and also refers to changes in linkages. Four central types of rural-urban linkages are studied, specifically the flow of (1) people, (2) information, (3) finances, and (4) goods and services. Vulnerability is explained as the function of exposure, susceptibility and the capacity to cope with and adapt to flood events (Birkmann et al., 2013). Although the flood impacts on rural households and the resulting changes in rural-urban linkages can also affect urban residents, the scope of this research is on affected rural households.

1.7 Organisation of the dissertation

The dissertation is divided into eight chapters. Chapter 1 outlines the background of flood events and their trend in low-income and developing countries; it describes the research gaps, objectives, questions and research approaches. Chapter 2 explains the theoretical context of rural-urban linkages and vulnerability, and develops a conceptual framework that guides the empirical part of the thesis. Chapter 3 provides the methodology; it elaborates on the selection of the case study areas, the sampling and data collection methods, and the different analytical approaches used to answer the various RQs. Chapters 4 through 7 present the findings. Chapter 4 details the respondents' socio-economic profiles, the impacts of flooding on the surveyed households, and their responses. Chapter 5 uses descriptive statistics to identify changes in linkages following a flood event; regression analysis was applied to determine the factors that result in changes in rural-urban linkages, and correlation analysis was performed to reveal the relationships between changes. Chapter 6 employs an index-based approach to assess vulnerability considering city size and proximity. The indicators were chosen and validated using selected statistical approaches. Chapter 7 uses the results of all the empirical chapters and analyses the influence of changes in linkages on rural households' vulnerability. Chapter 8 concludes the thesis and provides policy recommendations, as well as possible directions for future research.

Chapter 2

Theoretical and conceptual perspectives on rural-urban linkages and flood vulnerability and their framing

The parts of this chapter (including figures and tables) have already been published in a peer-reviewed journal 'Sustainability' (see the citation below)

Jamshed, A., Birkmann, J., Feldmeyer, D., Rana, I.A., (2020) "A Conceptual Framework to Understand the Dynamics of Rural-Urban Linkages for Rural Flood Vulnerability". Sustainability 12 (7), 2894. DOI: https://doi .org/10.3390 /su1207289. Publisher: MDPI.

One objective of this research was to develop a conceptual framework that could connect the elements of rural-urban linkages and vulnerability. The conceptual framework was crucial for the development of the methods, and highlighted relevant aspects to help design the empirical research and answer the research questions (RQs) (see Chapter 1, Section 1.5). This chapter presents a unified conceptual framework to assess how rural-urban linkages evolve in the aftermath of a flood event in rural areas, and how these influences rural residents' vulnerability. The RQs are: (a) How are rural-urban linkages defined, and how is vulnerability understood in different schools of thought? (b) What are the driving factors of rural-urban linkages and flood vulnerability? (c) In what ways can floods affect rural-urban linkages, and how can the impacts of flooding on these linkages be connected to rural households' vulnerability?

This chapter is based on an extensive literature review. A systematic scrutiny of peer-reviewed papers and books on the topic of vulnerability, regional development and rural-urban linkages was carried out in three steps. In the first step, theoretical studies on rural-urban linkages in the context of regional/rural planning and development were assessed. In the second step, conceptual frameworks of vulnerability and its assessment from the perspective of climate change and disaster risk research were shortlisted. Lastly, screening of empirical studies on flood hazards, vulnerability assessment, rural-urban linkages and rural development was performed. This literature analysis enabled connections to be made among various components and factors of rural-urban linkages and vulnerability in the context of flooding.

The framework incorporates theoretical views on vulnerability and rural-urban linkages. Moreover, factors that determine variations in vulnerability, as well as linkages, are discussed. Vulnerability is explained in terms of exposure, susceptibility and response capacity to flood events (Birkmann, 2013b; Greiving, 2013), whereas rural-urban linkages are defined as the flow of people, information, finances, and goods and services (Tacoli, 1998). Factors that influence vulnerability and linkages include social, economic, institutional, infrastructure, spatial and environmental aspects (Cutter, 1996; Douglass, 1998; Tacoli, 2003; Birkmann et al., 2013). In this thesis, rural-urban linkages, vulnerability components and their associated factors collectively define rural vulnerability to flooding. Moreover, the present study ascertained the dynamics of rural-urban linkages in flooding conditions and their role in influencing rural vulnerability. The framework and underlying theoretical discussion serve as a parent framework for conceptualising and empirically analysing specific questions within chapters 4, 5 and 6. The following sections provide definitions, concepts (as well as key elements) and components of rural-urban linkages and vulnerability.

2.1 Rural-urban linkages

2.1.1 Defining 'rural' and 'urban'

The distinction between rural and urban areas can be described by many criteria, but there is no general definition available. Rural and urban areas are defined based on one or a combination of demographic, economic, infrastructure and administrative factors (Rana et al., 2020c). Within these elements, population size and density, the predominant type of economic activity, conformity with legal and administrative status, as well as specific services and facilities, are prominent criteria to define rural and urban regions (UN-DESA, 2018a). However, definitions vary even more often when considering different parts of the world. In South Asian countries, areas within the boundaries of local administrative agencies (e.g. municipalities, councils, committees) are declared as urban (UN-DESA, 2018a). For example, in Pakistan, *"all localities which are either a metropolitan corporation, a* *municipal corporation, a municipal committee or a cantonment at the time of the census are treated as urban"* (Reza, 2013). Based on this, areas are divided into rural and urban Union Councils[3] (UCs) in Pakistan. Many African countries define 'urban' with respect to administrative, demographic and infrastructure characteristics, while in several Latin American nations, a population threshold of 2,000 or 2,500 is used to define urban areas (Tacoli, 1998). The term 'urban areas' is also frequently used to describe a city or a town. In this context, rural areas are considered the inverse of urban areas or cities (i.e. a residual or relative category) (Lerner et al., 2011). Consequently, low population and housing density, a high dependence on natural resources for one's livelihood, limited infrastructure, and social services can characterise rural places in low- and middle-income countries (Lerner et al., 2011). Although a dichotomy exists between the features of rural and urban areas, they are essentially related due to the dependence of resources and facilities that both areas provide to each other.

2.1.2 Theories and concepts that correspond to rural-urban linkages

Many concepts describe these linkages; most of them have their roots in spatial and regional development theories that indicate how a city can influence the development of its surrounding rural settlements. Von Thünen's *model of agricultural land uses* suggests that land rent and transportation costs define the economic activities in a city's hinterland. Thus, specialisation of economic activities in rural areas is based on the distance to the central city (Thunen, 1826). Christaller's *central place theory* explains the distribution of central places (cities) of different sizes, on which their hinterland depends for various (central) services and facilities (Christaller, 1933). This theory implies that cities of different sizes can have varied linkages with the rural hinterland, depending on the types of goods and services, as well as spatial proximity to these services. Other models, like the *growth pole model* and the *core-periphery model*, infers that core areas/cities are the heart of economic activities, whereas periphery/rural locales deliver resources in the form of

[3] The Union Council (UC) is the lowest administrative unit in Pakistan's local administrative setup. Areas with administrative units (i.e. metropolitan/municipal or corporation/town committees in a given area) are termed 'urban'. Accordingly, the Bureau of Statistics in Punjab (BSP) designated UCs as both urban and rural.

labour and goods, among others (Perroux, 1955; Friedmann, 1966). Both theories depict a dominating core, whereas the periphery is dependent. This dependence is structured through the relations of exchange between the core and the periphery. The *virtuous circle model* presents how the flow of people, goods, information, and finances between rural and urban regions leads to the development of rural areas and their residents (Evans, 1992). The model includes the spatial dimension by stressing proximity to cities in providing income opportunities and services for the rural hinterland. The environmental notion of the *urban ecological footprint* suggests that cities need a larger space than their actual size, on which their inhabitants rely for food, natural resources and the absorption of carbon (Rees, 1992). This dependence on food and other natural resources is primarily fulfilled by rural areas, hence demonstrating another facet of rural-urban linkages. Despite their differences, all of these theories indicate that rural and urban areas are (intrinsically) linked. The dominant features in these theories are the size of and proximity to cores/cities for the linkages between rural settlements and cities. However, several other socio-economic, institutional, infrastructure, spatial and environmental factors affect these linkages.

2.1.3 Typologies of rural-urban linkages

The linkages between urban and rural areas can be categorised into four types, specifically the flow of (1) people, (2) information, (3) finances, and (4) goods and services (Lynch, 2005). There is a trade-off between rural and urban areas, as urban population depend on rural resources (food, labour and others), and urban services are vital for rural communities (Tacoli, 1998). These linkages are depicted in Figure 2.1. The ***flow of people*** indicates human mobility between rural and urban locales. Mobility takes several forms, such as temporary, permanent, circular migration and commuting (Tacoli, 2003). The ***flow of information*** represents information exchanges between rural and urban areas regarding population needs, job opportunities, market status, innovations, and new technologies for increased agricultural production, lifestyles and others (Srivastava et al., 2016). ***Financial flows*** can be classified under three types (1) formal, institutional; (2) informal and; (3) investments made by the government and aid agencies (Lynch, 2005, p.

164). First, formal flows include micro-credit schemes for economically active poor households from formal financial institutes, such as banks. Second, the informal exchange of finances involves remittance, taking loans from moneylenders, and landlords or relatives. Third, investments are made by urban-based government and aid agencies for the human and socio-economic growth of the rural population and the physical growth of rural areas (Lynch, 2005). Lastly, the transactions of ***goods and services*** are one of the most critical features of rural-urban linkages. Cities depend on rural resources; for example, agricultural products, water, and others (Gebre et al., 2019). Rural inhabitants purchase durable and non-durable goods for household use, as well as for expanding their livelihoods. Agriculture input, tools, building materials and household items are a few examples of goods needed by rural settlements (Douglass, 1998). In terms of services, urban areas often provide higher education, health and emergency services. Additionally, they offer rural households several off-farm opportunities for livelihood diversification (Tacoli, 2003).

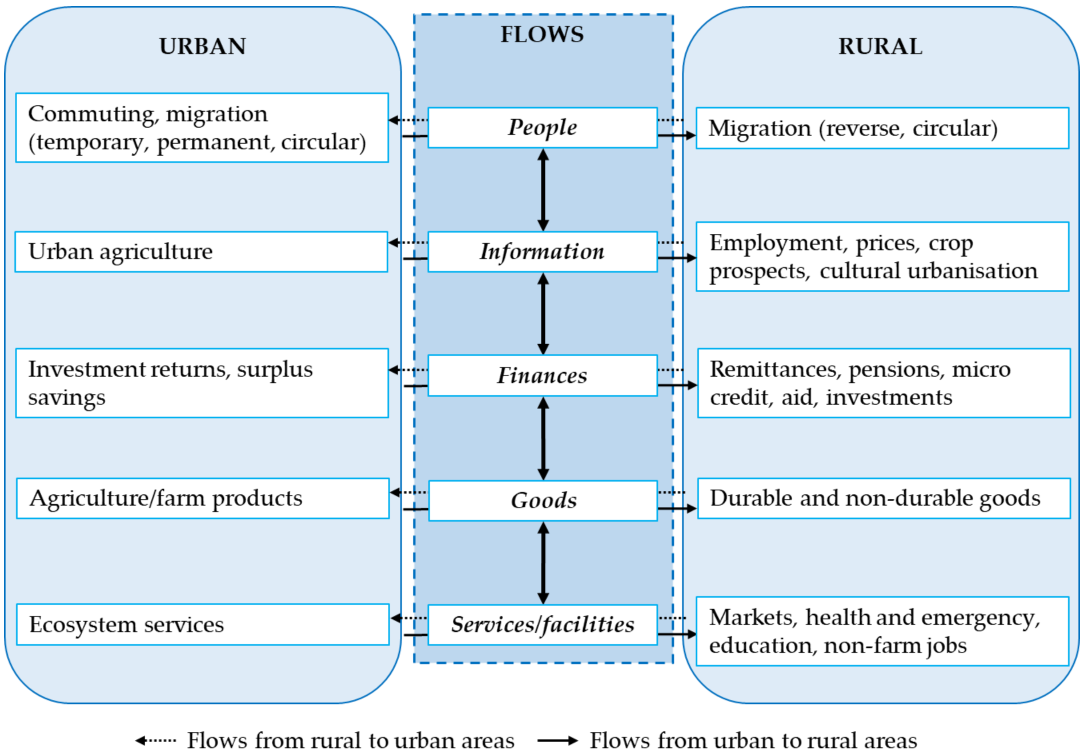

Figure 2.1. Linkages between rural and urban areas
(Own figure, 2020)

Such flows modify the social, economic and physical landscape in rural areas. However, these linkages differ from location to location, depending on the rural development efforts made to upgrade them. Rural-urban linkages are not autonomous, but rather overlap, and are closely interlinked. For example, migration flows toward cities are amplified by the increased flow of information to rural settlements based on employment prospects that augment the financial flows from cities. Similarly, off-farm livelihoods in cities result in remittances, which tend to be used to increase agricultural production, improve one's lifestyle, and send additional household members to urban hubs (Douglass, 1998; Tacoli, 2007). Moreover, better information services on market demand and trends increase the wellbeing of rural entrepreneurs (Mayer et al., 2016). These linkages, if properly understood, are important for framing development policies, and are vital for reducing poverty and social vulnerability.

2.2 Vulnerability

The term 'vulnerability' comes from the Latin word *vulnerare*, which means 'to wound'. In its most basic form, it indicates the fragility of living and non-living things (Luna, 2018). The concept has been widely used in the discourse of geographic development, poverty, human ecology, hazard and disaster risk reduction research, as well as climate change adaptation research (Birkmann, 2013b). Various fields have used this notion according to their applicability; therefore, the conceptual understanding of vulnerability has multiple schools of thought, contexts, dimensions and professions, which has resulted in numerous definitions and interpretations (Birkmann, 2013b). Human geography and human ecology have, in particular, theorised vulnerability to environmental change (Adger, 2006). In the field of disaster risk science, early perspectives on vulnerability were placed in the context of the physical resistance of engineering structures. Later, it was viewed as a characteristic of social and environmental systems (Cardona et al., 2012). The extensive use of these interpretations shows that vulnerability has become a critical concept in both disaster risk reduction and climate change adaptation research.

2.2.1 Definitions

Diverse definitions of vulnerability suggest different views of the concept, which may lead to specific priorities in assessments (Birkmann, 2013b). Table 2.1 presents a range of definitions from the angle of research on hazards and disasters, as well as on climate change.

Table 2.1. Development of vulnerability definitions from the context of hazard, disaster risk, environment, and climate change

Source	Definitions	Context
	Vulnerability is defined as	
Mitchell (1989)	"… the potential of loss"	Hazard and disaster risk
Cutter (1993)	"… the likelihood that an individual or group will be exposed to and adversely affected by a hazard"	Hazard and disaster risk
Blaikie et al. (1994)	"… the characteristic of person or group and their situation that influences their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard"	Hazard and disaster risk
Adger (1999)	"… the exposure of individuals or collective groups to livelihood stress as a result of the impacts of climate change and related climatic extremes"	Climate Change
Turner et al. (2003)	"… the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress stressor"	Both hazard/disaster risk and global environmental change
Adger (2006)	"… the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt"	Both hazard/disaster risk and climate change
Intergovernmental Panel on Climate Change IPCC (2007)	"… the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity".	Climate Change
United Nations Office of Disaster Risk Reduction UNDRR (2009)	"… the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard"	Hazard and disaster risk
Intergovernmental Panel on Climate Change IPCC (2014a)	"… the propensity and predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt"	Climate Change

There are several advancements in defining vulnerability over time. Vulnerability was once seen as possible losses from a hazard event and mainly focused on individuals. Later, it was defined in terms of the socio-economic characteristics of individuals, households and communities exposed to (and affected by) hazards or climate change. In the last two decades, the definition of vulnerability has become more system-oriented in that it considers human, social, economic, physical and environmental systems, as well as their characteristics, that make people or ecological systems likely to be adversely affected. Thus, coupled socio-ecological systems were placed at the centre of vulnerability analysis (Turner et al., 2003; Birkmann et al., 2013). These social, economic, physical and environmental systems refer to the thematic dimensions of vulnerability (Birkmann et al., 2013).

Overall, several studies have defined vulnerability as a function of exposure, susceptibility/sensitivity/fragility, and a lack of a system's capacity (see Table 2.1). Climate change research (Füssel et al., 2006; IPCC, 2007) has mostly centred on the impact-oriented perspective of vulnerability—regarding probability character, magnitude, and the rate of climate change and variation—which differs from the definition of the disaster risk reduction community (Birkmann, 2013b). IPCC Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) and Fifth Assessment Report (AR5) defined vulnerability in terms of susceptibility and a lack of capacity while considering exposure as a separate factor. Nonetheless, this study considers exposure, susceptibility and capacity to be components of vulnerability (see Figure 2.2).

2.2.2 Components

Exposure is the duration and extent of a system's interaction with a disturbance (Adger, 2006). Birkmann et al. (2013) explained it as *"the extent to which a unit of assessment falls within the geographical range of a hazard event"*. Exposure encompasses the physical features of society (infrastructure, buildings), economic systems (livelihoods), as well as human and social systems (people, cultures, values) that are spatially restricted to particular resources and practices that may also be exposed to (and affected by) a potential hazard (Greiving et al., 2006a; Birkmann et al., 2013). Exposure acts as a bridging concept between hazards and exposed systems. Exposure, as a component of vulnerability, is contested, and it is arguable whether it should be seen as part of risk (Costa et al., 2013). Some approaches consider it an integral part of vulnerability (Cutter, 1996; Turner et al., 2003; Birkmann, 2006a; Füssel et al., 2006; IPCC, 2007), while some approaches view it as a hybrid between vulnerability and hazards (Cardona et al., 2000; Birkmann et al., 2013). Others conceptualise exposure as a separate component alongside vulnerability (IPCC, 2012, 2014b). Cardona et al. (2012) and Birkmann (2013b) maintained that if human-environmental systems are not exposed to the effects of hazards or climate change, then it is insignificant to assess their susceptibility and hence overall vulnerability. This is because if vulnerability refers to conditions that intensify susceptibility and limit the capacity to deal with hazards, then it also depends on spatial and temporal dimensions, which can be referred to as the degree of exposure of human-environmental systems to hazards. In this way, a location's general exposure is essentially a component of hazards, while the degree of exposure of its elements (infrastructure, houses, people, farmland) falling within a hazard-prone area can be attributed to the spatial dimension of vulnerability (Birkmann, 2006a; Asare-Kyei et al., 2017). The degree of exposure can also be explained, in part, by losses and damages resulting from a hazard (Birkmann et al., 2008). This study considers the degree of exposed elements as a component of vulnerability.

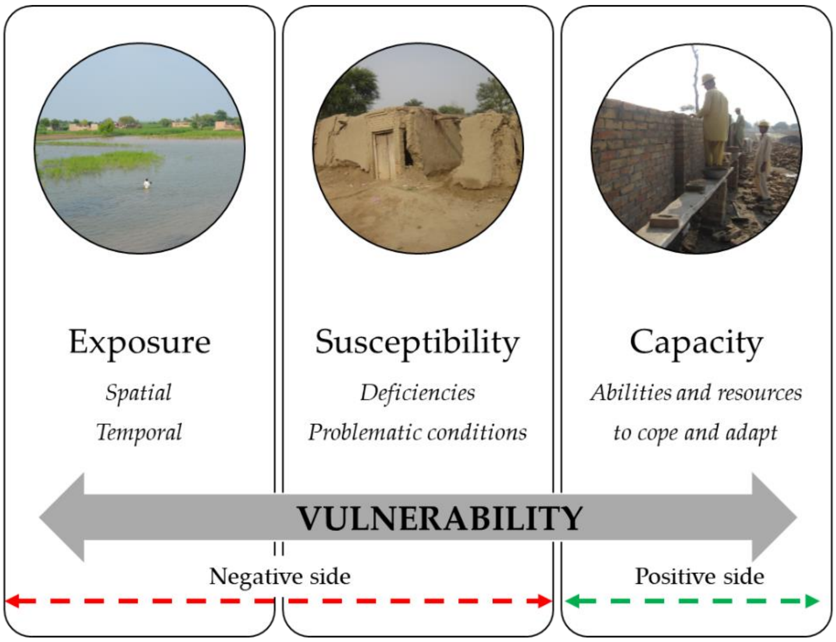

Figure 2.2. Components of vulnerability
(Own figure, 2020)

Susceptibility is one of the central elements that explain the degree of vulnerability of exposed elements. Susceptibility—also termed 'sensitivity' or 'fragility'—is the degree to which a system is modified or affected by hazard or climate variability (Adger, 2006; IPCC, 2014a); it is the predisposition of an element at risk of suffering harm (Birkmann et al., 2013). Susceptibility describes the characteristics and conditions of a system that mainly correspond to negative characteristics (i.e. a system's deficiencies and problematic conditions) (Birkmann, 2006b; Birkmann et al., 2008). These characteristics and conditions entail a system's social, economic, physical, institutional and environmental settings (Birkmann, 2013b). However, a community or system that is significantly exposed and susceptible to hazards does not necessarily have to be highly vulnerable, since the response capacity is also influencing its vulnerability. Engle (2011) asserted that capacity influences vulnerability by modulating exposure and susceptibility/sensitivity (see Figure 2.3). Notwithstanding, it is not necessarily true that higher capacity lowers exposure and susceptibility, since case studies indicate that higher capacity can affect one of the components, both, or neither (Kablan et al., 2017; Hamidi et al., 2020b).

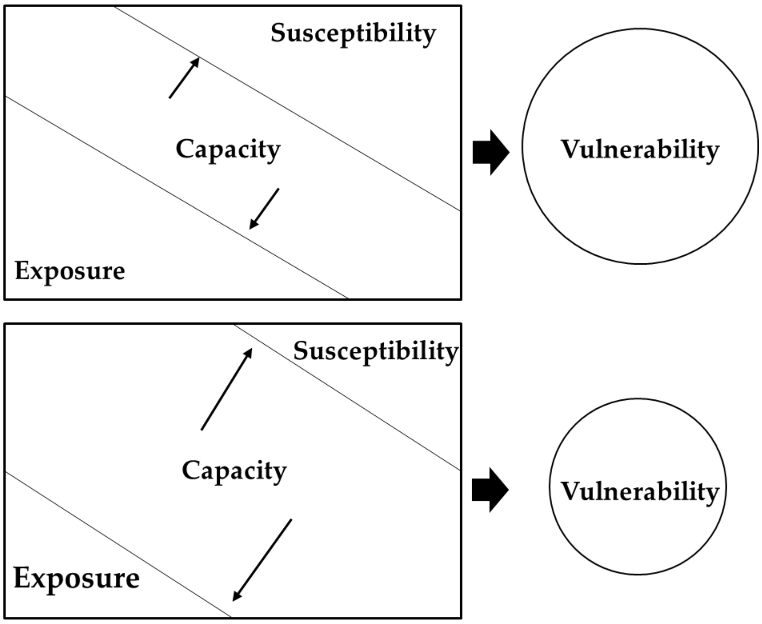

Figure 2.3. Role of the capacity component in influencing vulnerability.
(Engle, 2011)

Capacity is *"the combination of all the strengths, attributes and resources available within an organisation, community or society to manage and reduce disaster risks and strengthen resilience"* (UNDRR, 2017). The ability to respond is broadly categorised in the literature as a 'coping capacity' or 'adaptive capacity' (see Figure 2.2). Coping capacity refers to *"the ability of* *people, institutions, organisations, and systems, using available skills, values, beliefs, resources, and opportunities, to address, manage, and overcome adverse conditions in the short to medium term"* (IPCC, 2014a). It is the ability of a system or an area's inhabitants to adequately prepare and respond to a hazardous event (Greiving, 2013). Coping capacity is present in a community or system before a hazard impacts the system (Gallopín, 2006). On the other hand, adaptive capacity is the *"ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences"* (IPCC, 2014a). It is seen as a more long-term adjustment (Smit et al., 2006). Thus, adaptive capacity involves changing existing practices and behaviour in light of past hazardous events. Birkmann et al. (2010) found that the impact of a hazardous event leads to several formal and informal changes in society. Change is viewed as a response to minimise current and future impacts, and corresponds to the ability to adapt (see Figure 2.2). Change emphasises that societal shifts, in response to the impact of an event, influence a system's vulnerability.

2.2.3 Assessment frameworks

Different views and concepts of vulnerability resulted in the formulation of several theoretical models and frameworks (Jamshed et al., 2019b). Vulnerability assessment frameworks are used in research on development, disaster risk, and climate change adaptation (Table 2.2). These frameworks are crucial in terms of orientation for outlining problems, evolving different methods for measuring and assessing vulnerability, as well as to help establish appropriate indicators by focusing on the most relevant factors affecting vulnerability (Birkmann, 2013b). The existing frameworks can be categorised into three approaches: (a) biophysical, (b) socio-economic, and (c) integrated assessment (Brooks, 2003; Nazari et al., 2015). The biophysical approach considers site conditions, as well as the impact and associated losses of a hazard event, while the socio-economic approach views vulnerability as an internal state and structural factors, and the integrated assessment considers both approaches (Cutter et al., 2000; Nazari et al., 2015). The integrated assessment sometimes includes a hazard's character, duration and magnitude; this often shifts the focus of the assessment from vulnerability to risk (Birkmann, 2013b).

Table 2.2. Conceptual frameworks with respect to assessment approaches, conceptual understanding of vulnerability, applicability as per spatial scale and reflection on the interaction between spatial units

Name of framework	Assessment approach	Conceptualization of vulnerability	Vulnerability dimensions	Spatial scale	Interaction between spatial units i.e. rural and urban
Hazard of place model	Integrated	Combination of biophysical and social vulnerability	Social, Geographical	Local/ place	No
Sustainable livelihood framework (1999)	Socio-economic	Shocks, trends and seasonality which can be influenced by transforming structures	Human, Social, Financial, Physical, Natural	Local/ place	No
Holistic approach (2000)	Integrated	Function of exposure, susceptibility/fragility and ability to cope/recover	Social, Economic, Physical	Local to national	No
Vulnerability in the context of socio-ecological perspective (2003)	Integrated	Function of exposure, sensitivity and resilience	Coupled human and environment	Local to global	No
The pressure and release (PAR) model (2004)	Socio-economic	Explained by three progressive levels: root causes dynamic pressure and unsafe conditions	Physical environment, Local Economic, Social relation, Public action and institutions[1]	Local to global	No
BBC framework (2006b)	Integrated	Function of exposure, susceptibility, and coping capacity	Social, Economic, Environmental	Local/place	No
Second generation vulnerability assessment framework (2006)	Integrated	Function of exposure, sensitivity and adaptive capacity	Not specified	Local to global	No
Methods for the Improvement of Vulnerability Assessment in Europe (MOVE) framework (2013)	Integrated	Function of exposure, susceptibility and resilience	Physical, Ecological, Social Economic, Cultural Institutional	Local to global	No
Intergovernmental Panel on Climate Change vulnerability and risk framework (2014b)	Socio-economic	Consist of susceptibility and capacity to cope and adapt	Environment, Social, Economic[2]	Local to global	No

[1] As specified in the section that deals with "Unsafe Conditions". [2] As specified in IPCC SREX Report 2012".

Table 2.2 provides an evaluation of the most commonly used frameworks according to their assessment approach, conceptual understanding of vulnerability, applicability as per spatial scale, and reflection of the interactions between spatial units (rural and urban areas). Most of the frameworks are grounded in an integrated assessment approach and perceive exposure, susceptibility and capacity as constituents of vulnerability. Each framework considers different dimensions required to assess vulnerability. The sustainable livelihood framework was not primarily meant to be a vulnerability assessment framework, but its five livelihood assets provide a checklist that represents exposure, susceptibility and capacity to appraise vulnerability at the household level (Birkmann, 2006a). Frameworks like the 'hazard of a place model' and the Bogardi et al. (2004) and Cardona (2001) 'BBC' framework are specific, whereas others are relatively extensive and deal with different spatial levels. The hazard of place model considers geographical features, in addition to other elements, to assess the vulnerability of places (Cutter, 1996). Turner et al. (2003) identified human and environmental conditions at the centre of vulnerability. They highlighted aspects of exposure and various responses to hazards to assess vulnerability. The Methods for the Improvement of Vulnerability Assessment in Europe (MOVE) framework defines vulnerability in terms of exposure, susceptibility and a lack of resilience (which incorporates capacity); it also presents multiple dimensions (physical, ecological, social, economic, cultural and institutional), based on which the vulnerability of communities or households can be evaluated. Further, exposure is defined in both spatial and temporal terms (Birkmann et al., 2013).

All the frameworks refer to the characteristics of a particular community, spatial unit or system in a given place that is exposed to a natural hazard or climate change. These frameworks also draw attention to several elements and linkages (i.e. human and environmental factors) that potentially affect vulnerability. However, these frameworks do not adequately give attention to the roles of interactions and linkages between the two spatial systems (rural and urban), which can influence the degree of exposure, susceptibility and capacity of both spatial systems (or at least one that is prone to hazards); for example, how a city influences the vulnerability of surrounding flood-prone rural settlements since there are several demographic, social, economic, information, and infrastructure linkages between them, as defined in Section 2.1. These linkages are often neglected, both theoretically and practically. Thus, this study fills this gap in knowledge by proposing a framework exclusively for rural-urban linkages, and empirically tested it to explore and assess the effect of (changing) linkages on vulnerability (chapter 5 to 7).

2.3 Flood hazards, impacts, rural-urban linkages and rural vulnerability

This section defines flood events, their impacts and subsequent changes. This section also contains information on how various linkages between rural and urban areas can be affected/altered due to rural flooding, and how these linkages can influence households' vulnerability. In addition, this section details multiple factors that drive these linkages and flood vulnerability. The discussion helps one to understand and connect different factors and to frame the research.

2.3.1 Flood, impacts, losses/damages and changes

A flood, in Pakistan, is defined as *"a phenomenon of inundation by water coming from direct rainfall or river, drainage or other water bodies, such as lakes or seas due to overflowing from an ordinary boundary between land and water or water surging"* (NDMA, 2018b). The level of fluvial floods (high, medium or low) in Pakistan is defined in terms of the amount of water discharge into rivers or canals. Thus, flooding brings a huge amount of water from its natural or artificial boundaries onto land that is generally dry, and impacts the exposed elements of communities in a rural setting over a period of time (Hong et al., 2013). A natural or anthropogenic phenomenon, or a combination of both, can cause a flood.

A flood event can have social, economic, physical and environmental effects. Impacts are closely defined as the consequences of a damaging event; they can be positive or negative, as well as direct and indirect (Birkmann et al., 2010). This thesis looks at the negative, direct and indirect impacts of flooding; for example, effects on lives, livelihoods, ecosystems and infrastructure. Direct impacts refer to direct losses/damages, while indirect impacts entail the influence of direct outcomes in the socio-ecological system such as health, income, markets, transport, soil and water (Looney, 2012). Losses/damages are the manifestations of negative impacts (UNFCCC, 2012). The terms 'losses' and 'damages' are often used interchangeably or together in Pakistan (e.g. NDMA, 2018a) as well as internationally (e.g. Huq et al., 2013; James et al., 2014; Birkmann et al., 2015; PreventionWeb, 2015). Mechler et al. (2019) affirmed that 'losses and damages can be material (i.e. physical) or immaterial, as well as economic (measurable in financial or economic terms) and non-economic, with some overlap between these categories' (Mechler et al., 2019). Losses are irrevocable, while damages are alleviated or repaired (Huq et al., 2013). Moreover, losses are quantifiable measures (expressed in either monetary terms or counts), while 'damages' is a generic term that is not necessarily quantified. Losses are also explained as *"a measure (quantified or not) of the damage or destruction caused by a disaster"* (PreventionWeb, 2015). Considering the various perspectives and limited consensus on defining these terms, their differences and how they are considered in Pakistan, this thesis uses them interchangeably. Change is viewed as a response to minimise actual or anticipated impacts. Changes after an extreme event or disaster can affect the capabilities of a system, communities, households and individuals, and thus condition their vulnerability (Birkmann et al., 2010; Birkmann, 2011). These changes can be structural modifications, shifting livelihood patterns, behavioural changes, or altered linkages between rural and urban areas.

2.3.2 Rural-urban linkages in the context of floods events

This section explains how different flows/linkages between rural and urban areas can be affected in the case of flooding. Moreover, this section gives some ideas on how these linkages can help people to recover from the impacts of a flood event.

2.3.2.1 People

Flood events in rural areas affect the flow of people and can result in various mobility patterns both during and after a flood; these patterns include displacement, commuting and migration (Black et al., 2013; Warner et al., 2013; Guadagno, 2016). Populations in flood-prone rural areas move chiefly toward urban areas. Evacuation and displacement occur mostly in the direction of towns and cities, since relief activities and camps are concentrated in and around these place, such as in Pakistan (Guzder, 2010), Bangladesh (Mutton et al., 2004) and India (The Guardian, 2018). People also migrate to cities for short- and long-term employment in the aftermath of a flood event (Ferdous et al., 2019). Apart from displacement, all these movements are increasingly seen in the context of coping with and adapting to floods (McLeman et al., 2006; Tacoli, 2009; Srivastava et al., 2015). By contrast, short- and long-term migration is challenging to consider as a coping or adaptation measure due to expensive living conditions in cities, getting a reasonable job, good accommodations and the weakening of social cohesion, which may aggravate vulnerability (Suckall et al., 2015; Suckall et al., 2016). Thus, actual or potential flood events can alter the mobility patterns of rural households, which in turn affect their vulnerability.

2.3.2.2 Information

The flow of information can be crucial in shaping the vulnerability patterns of rural households. In the case of flooding, in Pakistan, information on flood warnings is disseminated from city institutions via TV, radio or local government institutes (Rahman et al., 2013; Shahzad et al., 2018). This can help rural households to prepare and evacuate before an event occurs. The resulting evacuation reduces the exposure of people and their assets (Hahn et al., 2009). Information delivery on getting financial aid, building shelter, food distribution, preventing disease and other post-flood welfare activities comes—in most circumstances—from cities (Engeler, 2010; Srivastava et al., 2016). Moreover, frequent access to information following an event on the weather forecast, new seeds and fertilisers, as well as improved agricultural practices, helps rural farmers to modify their cropping patterns and adapt accordingly (Abid et al., 2016a). In sum, the flow of information from cities can help rural households to reduce their exposure and susceptibility, and to increase their capacity before, during and after a flood.

2.3.2.3 Finance

Financial flows from cities to rural areas comprise an important aspect affected by floods and influence people's vulnerability. In the majority of cases, extreme events and disasters generate resource inflows to affected areas (Birkmann et al., 2010), especially in the form of finances. The distribution of financial aid is common to compensate for flood losses by government and donor agencies (Jamshed et al., 2019b). Remittances from rural migrants in cities are critical to sustaining rural households' livelihoods, and become imperative during and after a hazardous event in order to cope and adapt (Le De et al., 2015; Pairama et al., 2018). Moreover, increased credit demand from rural farmers following a flood may change financial flows. Hence, the occurrence of a flood event can stimulate financial flows from cities for the redevelopment of rural infrastructure, thereby helping households to recover from a flood event.

2.3.2.4 Goods and services

Cities provide various services and goods to the rural population that help them to cope, recover and adapt in case of a flood event. Cities often deliver emergency services for evacuation and relief in the face of a flood event, and provide avenues to diversify income of rural population (Cardona et al., 2012; Srivastava et al., 2015). In addition, cities provide numerous services like markets, health, institutions and livelihood opportunities that help rural households both during and after a flood (Abid et al., 2017; Rakib et al., 2017). In the aftermath of a flood, cities offer both durable and non-durable goods through markets and aid agencies; for example, materials for shelters and building homes, fertilisers, tools and technology, and food items that help rural households to revive their livelihoods (Arai, 2012; Zyck et al., 2015).

On the contrary, the impacts of flooding could hamper the flow of finances, information, and goods and services, and hence change rural households' dependence on cities. This may be due to impacts on infrastructure and economic systems following a flood event (Douglass, 1998). Therefore, the flows between rural and urban areas can affect vulnerability to flooding in both the short and long term. Moreover, the effects of flooding on rural agricultural production indirectly influence the urban population due to food shortages or inflation, and can impact urban vulnerability as well. Overall, linkages between rural and urban areas influence vulnerability in flood events. If a flood occurs, the frequency and direction of flows between rural and urban areas can vary in the form of changing mobility patterns, as well as both an increasing and decreasing flow of goods, information, and finances. However, diverse factors are involved that drive variation, both in linkages and flood vulnerability.

2.3.3 The driving factors of rural-urban linkages and flood vulnerability

The factors that drive variation in both *rural-urban linkages* and *flood vulnerability* are interwoven. In both fields, these are broadly divided into social, economic, infrastructure, institutional, spatial, and environmental factors (Douglass, 1998; Birkmann, 2013b), which were examined by analysing studies in developing countries, especially in Pakistan. Figure 2.4 demonstrates the factors that influence rural-urban linkages and rural households' vulnerability to flood events.

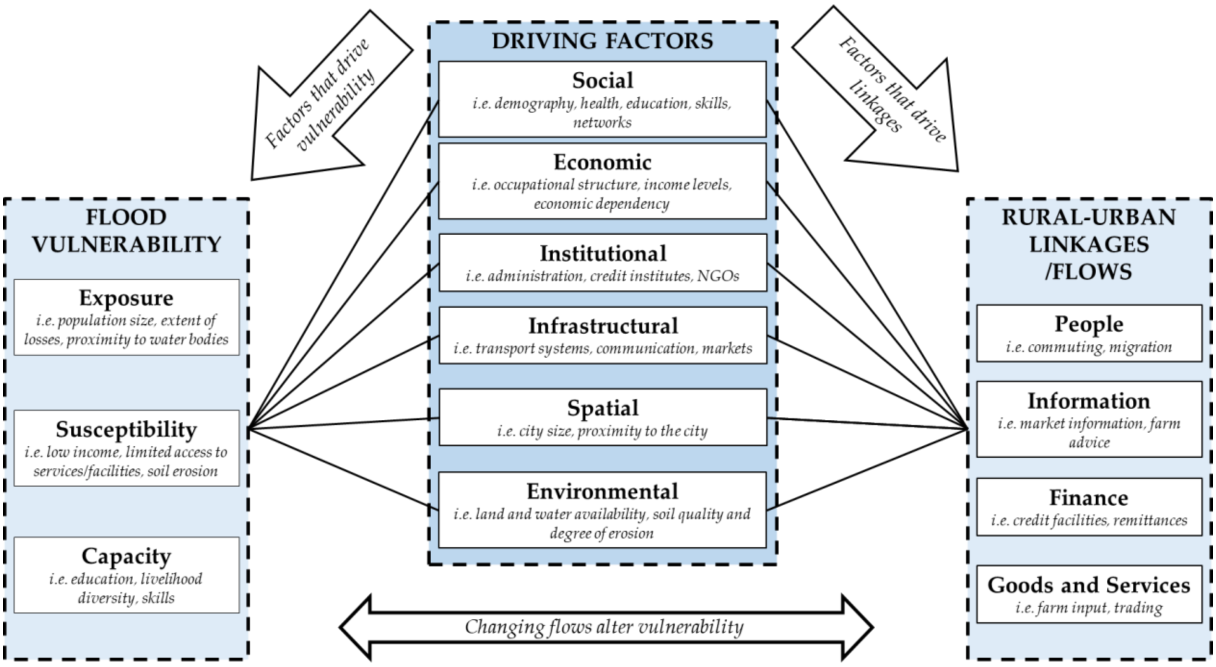

Figure 2.4. Interconnections of driving factors, rural-urban linkages, and flood vulnerability. (Own figure, 2020)

2.3.3.1 *Social factors*

Social factors encompass demography, health, education, skills and social networks. Demographic aspects (e.g. age, gender), health and education are likely to affect access to material assets such as tools, technology and knowledge of different market processes (Bah et al., 2003; Abid et al., 2015; Nazari et al., 2015). These demographic aspects also impact mobility patterns (Tacoli et al., 2010). The possession of different skills by the household head or other members helps to increase farm productivity. On the other hand, rural households' wellbeing depends on urban areas for the transfer of these skills by involving people in non-farm activities (Tacoli, 2007). Further, social networks are vital in terms of getting market and technology information (Maertens et al., 2013), migrating to cities (Mitra et al., 2009; Liu et al., 2012) and getting access to credit (Okten et al., 2004).

In the context of flood vulnerability, population density reflects the level of flood exposure. At the household level, household size indicates the level of exposure (Rana et al., 2016). Lianxiao et al. (2019) showed that the elderly and children are more susceptible to floods due to a lack of strength. Further, females are considered to be more susceptible (particularly in developing countries) due to limited social networks, as well as restricted access to information and other resources as a result of traditional and cultural norms (Azad et al., 2013). These gender-related factors are important for flood vulnerability in Pakistan (Mustafa, 1998). The health status of household members (e.g. physical and mental issues) also influences susceptibility, as it restricts mobility and requires special attention in the case of a flood event (Rana et al., 2016; Sorg et al., 2018). Educational level indicates one's capacity as an educated person, and that one is well-informed on flood issues and better understands flood warning systems (Paul et al., 2010; Shah et al., 2018). Skilled households can cope better with floods by using their abilities to diversify their livelihoods, as in Pakistan (Rana et al., 2018b; Jamshed et al., 2019b). Scheuer et al. (2011) asserted that social networks are useful in the face of a hazardous event to get information on warnings, to help move belongings and people to safety, and to access relief and aid items (Scheuer et al., 2011). Hence, social factors influence exposure, susceptibility and capacity, as well as flows between rural and urban areas (Figure 2.4).

2.3.3.2 Economic factors

Economic factors represent income level, occupational structures, the number of earning members in a household, access to land and resources, as well as the type of production in agriculture (Douglass, 1998; Bah et al., 2003). Income level affects the demand for urban goods, thus altering the interactions between rural and urban settlements (Evans, 1992; Tacoli, 2007). The occupation and type of production in which rural households are employed suggest their interactions with cities. For example, if a rural household is involved in dairy farming, then it can have more intense linkages with the city in terms of mobility in order to sell dairy products, getting price information, and buying tools and medicine for animals (compared to farm labourers). Inequality in income and resources can modify mobility patterns where people migrate seasonally or permanently to cities in order to increase their income (Tacoli, 2007).

In the flood vulnerability discourse, low-income households are seen as having limited financial ability to cope and adapt (Shah et al., 2017). For these households, it is challenging to fulfil their basic needs during and after a flood due to price inflation, as in Pakistan (Zyck et al., 2015). The susceptibility of households or communities also depends on the occupation in which they are employed. For instance, in Pakistan, farm wage labourers working in flood-prone areas are more susceptible, followed by farmers (Rana et al., 2018b). Jamshed et al. (2019b) revealed that flood events can destroy crops and other financial assets and economically affect these people. However, occupational diversity leads to multiple income sources, and hence increases capacity (Few, 2003; Motsholapheko et al., 2012). Bhattacharjee et al. (2018) maintained that vulnerability is also altered by the economic dependency ratio, whereby a higher number of earning members within a household expands the household's capacity. Thus, economic factors drive flows and vulnerability, as depicted in Figure 2.4.

2.3.3.3 Environmental factors

Environmental factors—such as the presence of river bodies, soil quality, the degree of erosion, water availability or other ecosystem services—affect rural linkages with an urban area. A high degree of erosion, poor availability of water, and bad soil quality can force people to seasonally or permanently migrate to cities (Bah et al., 2003). The occurrence of a flood affects natural factors such as soil and water quality, which influence the type of functions supported by rural areas (Douglass, 1998). A flood can degrade farmland and impact crop cultivation and productivity, whereas the degradation of water quality directly affects human and crop health (Paul et al., 2010; Gain et al., 2015; Jamshed et al., 2019b). Reduced crop productivity lowers the income of rural households engaged in farming and increases their vulnerability; it can also have ramifications for food availability in an urban area (Srivastava et al., 2016). Moreover, exposure increases for people living closer to river bodies, which are a source of flooding (Penning-Rowsell et al., 2005; Luu et al., 2018). As such, environmental factors affect both linkages and vulnerability to floods.

2.3.3.4 Institutional factors

Institutional factors refer to governance and institutional structures (Bah et al., 2003). Both public and private institutions are mainly based in cities, and are instrumental for the flow of numerous facilities and services (information, goods, finances) between rural areas and cities (Lynch, 2005). The presence of, and access to, local administrative departments, credit institutions, market cooperatives and private organisations in cities significantly alter the social, economic and physical development of surrounding rural settlements (Tacoli, 2003).

Institutional and governance factors are vital in determining flood vulnerability. Laws and regulations, as well as their enforcement by relevant institutes, restrict development in flood-prone areas and mitigate exposure (Greiving et al., 2006b; Greiving et al., 2012; Birkmann, 2013b). Rana et al. (2018b) found that in Pakistan, the timely dissemination of flood warnings from responsible institutes limits the exposure of people and their moveable assets to floods (Rana et al., 2018b). In the case of a flood event, both formal (e.g. government) and informal (e.g. local NGOs, donors, and political and religious groups) institutions manage emergency and recovery processes by carrying out evacuation operations, providing relief items and giving out compensation in the form of financial aid, building materials, seeds, fertilisers, and rebuilding rural infrastructure (Sam et al., 2017; Younus, 2017; Andrade et al., 2018; Jamshed et al., 2019b). Moreover, these institutions offer training to farmers on skill development for livelihood diversification, disaster awareness programs, extension services on changing cropping patterns, and information on the weather and new technologies in the aftermath of flood hazards (Arai, 2012; Abid et al., 2016a). Credit institutions provide loans and allow remittance flows during and after a flood event in order to support the revival of livelihoods. All these aspects alleviate exposure and susceptibility and increase capacity. However, all these activities depend on the types of institutions and their abilities that drive linkages, and thus the level of vulnerability.

2.3.3.5 Infrastructure factors

Infrastructure factors correspond to the state of the built environment and represent community infrastructure facilities, which are extremely imperative for flows like people, goods and information (Douglass, 1998; Braun, 2007). Infrastructure facilities include transport systems, telecommunications and electricity coverage, markets and production systems, health and education. Such infrastructure facilities are often referred to as critical infrastructures (CIs) (Greiving et al., 2016). In Pakistan, these are referred to as 'key infrastructure and lifelines' and defined as 'those facilities, structures and services whose disruption or destruction would seriously affect peoples' lives and livelihoods, including those whose functioning is crucial in a post-disaster situation' (Government of Pakistan GoP, 2012b). The availability and quality of these infrastructure facilities have a significant influence on the flow of people, finances, information and goods (Lynch, 2005; Satterthwaite et al., 2006; Cook, 2011; Akkoyunlu, 2015; Srivastava et al., 2016).

Infrastructure factors[4] are vital in influencing rural households' vulnerability to flood hazards. Limited access and damages to farm-market roads, sanitation facilities, the water supply, telecommunications and electricity services increase household vulnerability (Birkmann et al., 2008; Rakib et al., 2017). In South Asian and African countries, poor and/or damaged infrastructure restricts rural households' mobility, increases transportation costs, hinders rescue and relief operations, and deteriorates the information exchange between cities and rural areas (Bah et al., 2003; Jamshed et al., 2017; Jamshed et al., 2019b). In Bangladesh, damages to basic health centres and education facilities in villages increase rural households' susceptibility (Younus, 2017). The distance

[4] The vulnerability of CIs (measured by the built environment's exposure and susceptibility to hazards) and their criticality (defined by the importance of infrastructure, considering interdependencies between different CIs and cascading effects due to failure) determine a population's vulnerability to a particular hazard or climatic event (Birkmann et al. (2016c); Greiving et al. (2016)). However, this thesis does not assess the vulnerability or criticality of infrastructure facilities. Instead, it takes into account how existing infrastructure facilities, their access and conditions (also post-flood) can affect rural households' vulnerability.

to emergency facilities, health centres and paved roads are vital physical features that influence rural households' susceptibility to flooding (Abbas et al., 2014; Abid et al., 2015; Sam et al., 2017). Hence, the availability, accessibility and quality of infrastructure modify rural linkages with cities, as well as vulnerability.

2.3.3.6 Spatial factors

Rural-urban linkages differ depending on the spatial pattern of settlements (i.e. how the settlements are distributed over space) (Douglass, 1998). City size and a rural settlement's proximity to the city is important in this regard (Evans, 1992; Deichmann et al., 2009; Steinberg, 2014; Berdegué et al., 2015; Abbay et al., 2016). City size is not only determined by the population, but also by the size of its functional and economic diversity (Steinberg, 2014). Hsu (2012) and Romic (2018) argued that functional and economic diversity increases with size. City size influences the level and extent of services and facilities provided to rural areas, and determines their socio-economic and physical development (Schmitt et al., 2000; Rana et al., 2020c). Employment growth (Henry et al., 1999) and poverty rates (Ferré et al., 2012; Berdegué et al., 2015) in rural areas are influenced by the sizes of neighbouring cities. The physical proximity (in terms of distance) of rural settlements to a town or city is key to rural livelihood development, and also affects the various flows (Douglass, 1998; Tacoli, 2006; Abbay et al., 2016). The distance to the city could alter mobility and information patterns as well as the education, skills and income level of the rural population (Douglass, 1998; Fafchamps et al., 2003; Sharma, 2016). Rural households in close proximity to cities are often economically better off due to diversified livelihoods (Deichmann et al., 2009; Duvivier et al., 2013; Sharma, 2016). The access to infrastructure and communication facilities in rural areas, as well as their quality, are influenced by the distance of those rural areas to cities (Abbay et al., 2016; Sharma, 2016). Moreover, the distance to urban markets and paved roads influences the livelihood security of rural households (Ahmed et al., 2017).

Studies on the vulnerability of cities suggest that larger cities are often less vulnerable to hazards compared to small cities as they have more social, economic, physical and institutional resources to deal with hazards (Cross, 2001; Birkmann et al., 2016b; Fang et al., 2016; Handayani et al., 2017). In terms of rural households' distance to cities, Maddison (2007) and Abid et al. (2015) contended that farmers living in close proximity to markets are more able to adapt to climate change. Pandey et al. (2017), in their study of Himalayan communities in India, underscored that rural households living far away from district headquarters are more vulnerable to the impacts of a changing climate. Nonetheless, previous studies have widely neglected the flood vulnerability of rural settlements in relation to spatial factors (such as city size and proximity).

These above-mentioned factors determine the intensity of linkages and variability in vulnerability, and thus affect the wellbeing of rural households. These factors are mutually dependent; for example, in rural areas, city size and proximity (spatial factors) influence the level and quality of infrastructure facilities (infrastructure factors). Further, city size and distance are not only important in terms of infrastructure, but are also vital in modifying the socio-economic features of the surrounding rural population. Additionally, rural-urban linkages are directly related to flood vulnerability and changing linkages due to flood events, which can impact rural households' vulnerability, as outlined in preceding sections.

2.4 The conceptual framework

Against the backdrop of the discussion on the factors of flood vulnerability and urban-rural-linkages and the relationships between them, this thesis proposes a conceptual framework that connects the concepts of rural-urban linkages (backed by the work of Tacoli, 1998 and Douglass, 1998) and flood vulnerability (supported by the theoretical contributions of Cutter, 1996, Turner et al., 2003, and Birkmann et al., 2013). Figure 2.5 demonstrates the conceptual framework; its primary purpose is to help analyse how rural linkages with a neighbouring city influence/change with the occurrence of a flood event and how, in turn, this shapes rural households' vulnerability. Moreover, it can help to assess how diverse factors (especially spatial features: city size and proximity) affect linkages and vulnerability. The framework assists in answering RQ2, RQ3 and RQ4 (see Chapter 1, Section 1.4). The proposed framework consists of three segments: (1) rural-urban linkages, (2) flood vulnerability and (3) factors that affect both linkages and vulnerability.

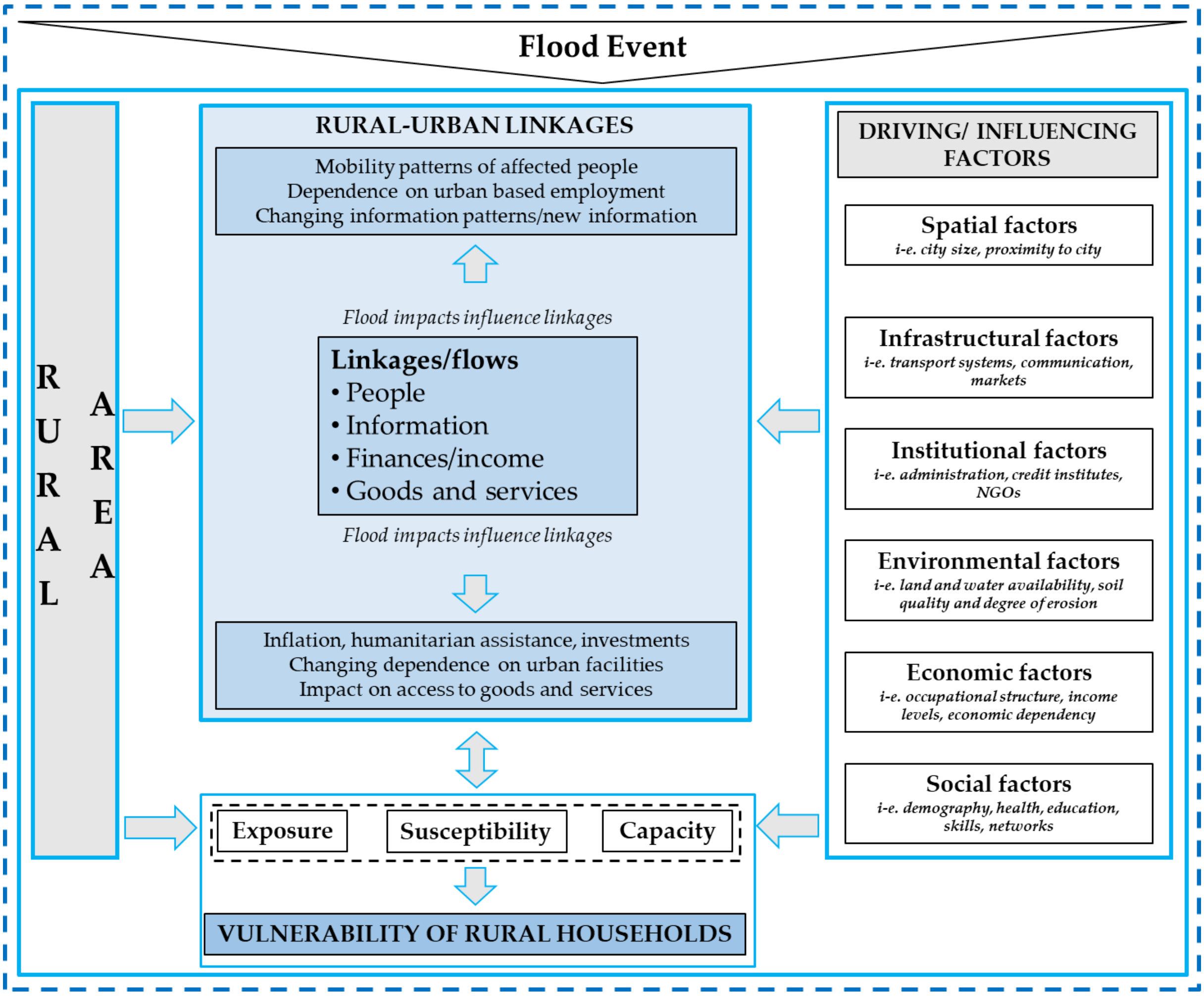

Figure 2.5. Conceptual framework demonstrating the dynamics of rural-urban linkages and its influence on rural flood vulnerability
(Own figure, 2020, and published in Jamshed et al., 2020b)

1. Within the rural-urban linkages discourse, rural areas are not seen as isolated entities, but are characterised by their relationship with their nearest urban hub. This relationship is represented by the flow of people, information, finances, and goods and services, which ties both areas and helps with development, particularly in relation to rural households and communities.
2. Flood vulnerability, as an integrated phenomenon, recognises vulnerability as having three components (i.e. exposure, susceptibility and capacity), which can be influenced depending on the type of linkage and the extent of flood impacts on

such linkages. In this thesis, 'exposed elements' are studied and defined in terms of the 'degree of exposure' (see Section 2.2.2). Apart from other factors, the degree of exposure is also explained by the extent of damages to houses and household assets, since the extent of past damages and losses is directly related to their location and position (spatial dimension) (Penning-Rowsell et al., 2005; Birkmann et al., 2008). 'Susceptibility' is defined as conditions of social, economic and infrastructure systems that make rural households more likely to get damaged. This includes conditions that are indirectly created due to flooding, which can have negative consequences for the community's socio-economic conditions. Capacity is the ability of rural households to address, manage, overcome and adjust to flood events; it includes both short- and long-term measures that help rural households to overcome adverse conditions and potential damage. These are considered to be response capacities. Exposure and susceptibility are seen as negative, whereas capacity is seen as the positive side of vulnerability.

3. Factors that drive or influence both rural-urban linkages and vulnerability include social (demography, health, education, skills, social networks), economic (income, occupation, resources, livelihood diversity), institutional (local administrations, public and private credit institutes, development organisations), infrastructure (roads, electricity, transport, telecommunications, markets, schools, health), spatial (city size and proximity), and environmental (water bodies, soil and water quality, erosion, flood proneness) aspects.

Figure 2.5 outlines how rural areas' socio-economic, physical and environmental features are prone to flooding. As shown in Figure 2.5, rural-urban linkages and the components of vulnerability (exposure, susceptibility and capacity) are influenced by multiple factors. These factors shape the internal characteristics of rural households as well as the direct behaviour and intensity of linkages, as presented in Section 2.3.3. The flow of people, information, finances, and goods and services also influences the exposure, susceptibility and capacity of rural households. In the case of a flood event in less developed regions, cities often provide information, multiple services, goods and finances to rural households; for example, flood warnings, evacuation and relief services and non-food items (see Section 2.3.2). These flows can alter the exposure, susceptibility and capacity of rural households.

Following the idea that impacts can lead to societal changes (Birkmann et al., 2010), the effects (both direct and indirect) of a flood event can modify specific rural-urban linkages that affect exposure, susceptibility and capacity (Figure 2.5). These changes can reflect the variation in mobility patterns for income diversification; more frequent access to (new) information on building construction; farming techniques; technology; increased financial flows in the form of aid, remittances, and credit for household recovery; and investments for the overall development of rural areas. For instance, in Sri Lanka and Indonesia, disaster awareness and preparedness training, microfinance, aid distribution and the provision of goods for livelihood revival (boats and fishing equipment) were central responses to the Indian Ocean Tsunami (Birkmann et al., 2010) that caused several behavioural and livelihood changes. On the other hand, long-term displacement, the destruction of infrastructure (leading to high transportation costs), and inflation can restrict different flows. In Pakistan, floods have interrupted supply lines and resulted in a shortage of grocery items in markets, and caused inflation, affecting poor rural flood victims (Zyck et al., 2015). In Nigeria, flooding badly affected feeder roads and restricted farmers' access to city markets due to high transportation costs, leading to a loss of income (Bah et al., 2003). Such flood impacts may also alter rural households' dependencies from cities to rural areas.

The shifts in linkages can be reported in two categories: (1) linkages that became stronger due to increased flows from cities to surrounding rural communities (i.e. rural households accessing services and facilities more frequently); (2) linkages that became weaker due to the source of flow changing to rural villages instead of from cities (i.e. households accessing services and facilities from the village that were previously acquired from the city). In this way, rural households' dependence on the city can be increased or decreased. Thus, flood impacts on social, economic, physical and natural conditions can alter the flow of people, information, finances, and goods and services, and in turn affect household vulnerability. Overall, flood vulnerability is the outcome of conditions already ingrained in rural society, as well as the modified conditions created by a flood event (both during and after) in the form of the dynamics of rural-urban linkages.

The proposed framework introduces a spatial dimension (city size and proximity) as a separate, new factor and an important geographical feature (for rural households' vulnerability) in this thesis. The framework stresses that city size and proximity are imperative in the discourse on the flood vulnerability of rural households and their relation to linkages (see Figures 2.4 and 2.5). Rural-urban linkages are highly influenced by these two factors. Theoretical concepts (e.g. the model of agricultural land use, central place theory, the core-periphery model and the virtuous circle model) highlight the importance of either city size or proximity (or both) for linkages and rural development. Both city size and proximity can substantially influence socio-economic and infrastructure conditions, as well as institutional coverage in the surrounding rural area. In this way, the rural population's vulnerability to floods can be influenced based on city size and proximity to the city. Moreover, these two factors are essential parameters in the investigation of flood vulnerability, as they affect all other social, economic, institutional and infrastructure factors, as well as rural-urban linkages.

2.5 Summary

This chapter presents a unified framework for the assessment of rural vulnerability to floods; it identifies rural areas not as secluded units, but rather as interlinked with cities through different flows that prior frameworks and studies did not sufficiently consider.

Using this framework, the investigation and information on how linkages can change in the case of a flood event, different interacting factors that shape linkages and their importance for the vulnerability of rural households and communities, can lead to better recommendations and a more targeted approach to rural development and vulnerability reduction. In this sense, the framework implies that rural linkages with a city are key (in addition to other factors) to variation in rural vulnerability.

The framework links the two previously disconnected discourses of rural vulnerability to floods and rural-urban linkages. Moreover, the framework can help to conceptualise further studies on this specific topic (e.g. flood impacts and changes in linkages, city size/proximity and vulnerability), as well as empirical research (see chapters 4, 5 and 6).

Chapter 3
The methodology for empirical research

The parts of this chapter (including figures and tables) have been published in a book and various journals (see Preface)

This chapter explains the research approach and methods adopted for answering RQ2, RQ3 and RQ4 (outlined in Chapter 1). The nature of the research is exploratory and comparative. It is exploratory in the sense that it aims to examine the impacts of floods, changes in livelihood strategies, modifications made to rural-urban linkages and their influence on vulnerability. It is comparative as it investigates the differences between the case studies, which in this thesis are Darya Khan, Muzaffargarh and Multan.

The research employed a mixed methods approach that combines qualitative and quantitative techniques. Triangulation was performed to test for the validity and complementarity of the empirical findings. However, a considerable proportion of the thesis is based on quantitative methods. The qualitative methods were employed to provide a foundation and support for the validation of the empirical quantitative results (triangulation). The research is grounded in extensive fieldwork that was mainly conducted in 2017 to collect qualitative and quantitative information from case studies.

Overall, the research design of consists of two aspects: qualitative and quantitative. The empirical study and the methods were guided by the conceptual framework. An overview of the empirical research (Part II) is provided in Figure 3.1.

The qualitative aspects involve secondary data collection, encompassing the academic literature, government reports and newspaper articles focusing on flood impacts, hazard and risk maps, vulnerability, as well as regional and rural development aspects. Moreover, (informal) conversations with officials of institutions, academics and local community elders were carried out. This was primarily done to choose the case study areas and to validate the results of the household survey.

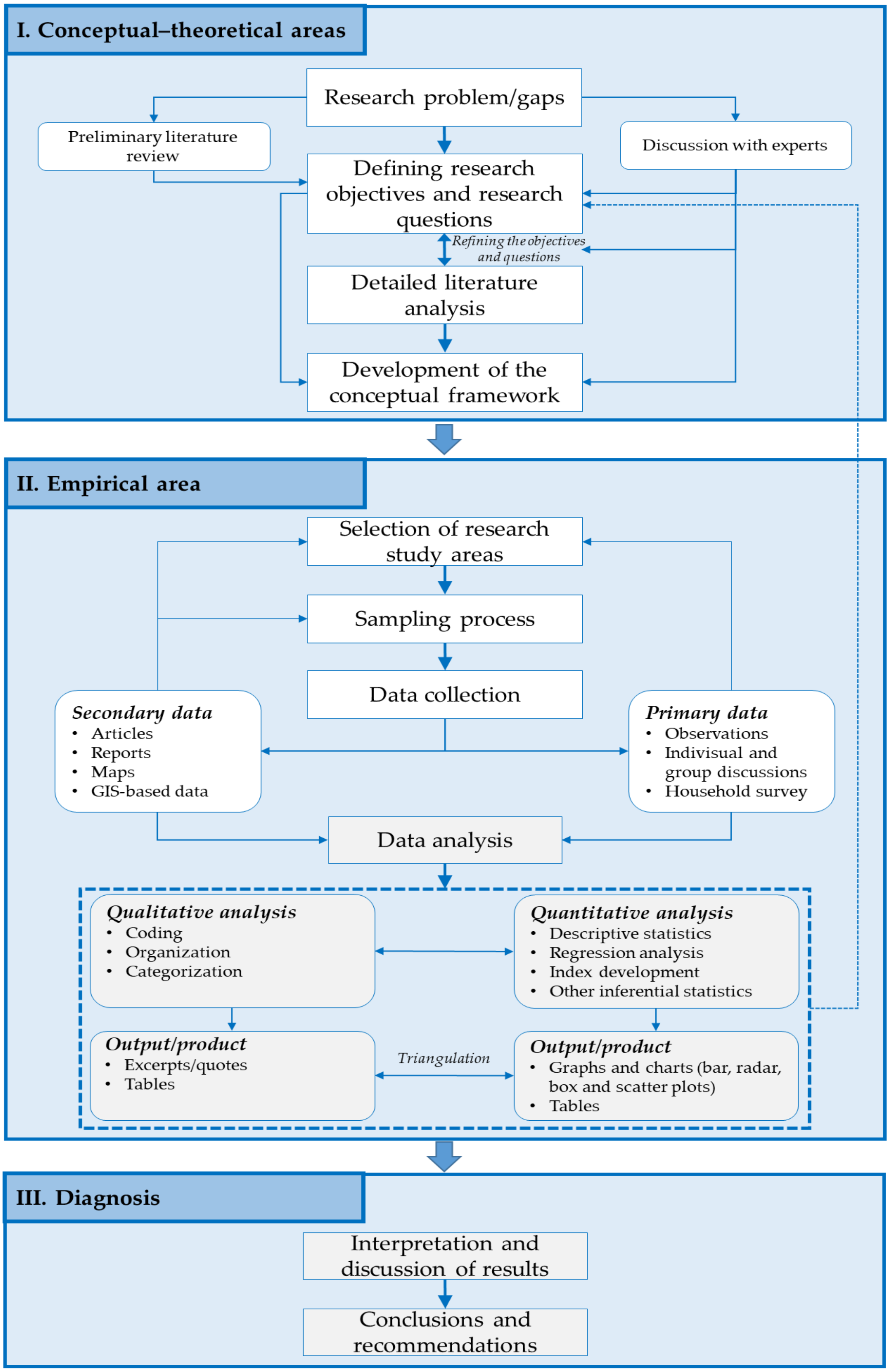

Figure 3.1. Research process
(Own figure, 2020)

The quantitative aspects are central to this research. A structured questionnaire was designed based on the preliminary results of the qualitative analysis. It was developed to collect data from 325 households in three flood-exposed communities (Darya Khan, Muzaffargarh and Multan) in the province of Punjab. Various statistical analyses were applied to examine the RQs. Questions related to flood impacts and changes in rural-urban linkages involved descriptive and inferential statistics, while vulnerability was assessed using an index-based approach.

This chapter is divided into five sections: (1) the selection of the case study areas (3.1); (2) the sampling process (3.2); (3) data collection (3.3); (4) data processing and analytical techniques (3.4); and (5) challenges faced while conducting the empirical research (3.5).

3.1 The selection of the case studies

Existing data on the research topic was rare to answer the RQs; therefore, empirical research in case study areas was needed. Careful selection of case studies leads to reliable outcomes, which can successfully answer queries (Yin, 2018). Hence, it is necessary to select areas that can provide sufficient in-depth information on the subject under investigation. The case studies were chosen based on a literature review of past flood disasters and flood impacts in Pakistan, judgements from experts, and time constraints. The province of Punjab was chosen for the study.

3.1.1 Punjab: A brief overview

Flood hazards, predominantly fluvial floods, are common throughout Pakistan, causing widespread socio-economic damage and loss of life. The province of Punjab is particularly affected by flooding and was selected as the focus of this research. In terms of the region, Punjab is the second largest province, located at 30°00′ North and 70°00′ East in a semi-arid lowland zone. It is the most populous province, accommodating about 53% of the country's population. According to the most recent census, the population of Punjab was 110 million, with approximately 36% of people living in urban areas (PBS, 2017; Rana, 2017). The literal meaning of Punjab is the 'land of the five rivers' consisting of the Indus, Jhelum, Chenab, Ravi and Sutlej. The world's largest irrigation network, in the Indus

Basin, makes Punjab one of the most fertile agricultural regions in Asia. Punjab makes up 57% of the nation's total cultivatable area, 53% of agricultural GDP, and comprises 74% of the country's total cereal production (BSP, 2017). This makes Punjab an important province in the national economy, which could be jeopardised by increasing flood risk and climatic changes (Hanif et al., 2010; Abid et al., 2015).

Table 3.1. Characteristic of flood events between 2010 and 2014 in Punjab

Characteristics	2010	2011	2012	2013	2014
Time	End of July	Beginning of August	Beginning of August	Middle of August	Beginning of September
Causes	Extreme rainfall in monsoon, snowmelt, dyke breach	Extreme rainfall in the monsoon	Extreme rainfall in the monsoon	Extreme rainfall in the monsoon	Extreme rainfall, snowmelt, transboundary water discharge, dyke breach
River bodies	Indus, Chenab, Kabul	Indus and Sutlej	Indus and Chenab	Chenab and small tributaries	Chenab, Jhelum, Ravi
Exposure					
Districts affected	12	7	7	13	15
Settlements affected	3000	335	1512	2946	3500
Population affected (thousand)	7000	26	887	634	3000
Area submerged (thousand acre)	3500	137	1491	746	3000
Loss and damages					
Deaths	112	4	60	109	284
House damaged (thousand)	400	1	26	20	100
Loss of crops (thousand acre)	7500	126	474	555	2400

(NDMA, 2010; Nadeem et al., 2014; NDMA, 2014; PDMA, 2014; Jamshed, 2015; Jamshed et al., 2019a)

Historically, Punjab has experienced numerous river floods in rural areas. However, the higher frequency of fluvial floods between 2010 and 2014 is seen as an impact of the changing climate, particularly the increased and more intense monsoon rainfall (Hussain et al., 2014). These recent flood events have displaced millions of people, destroyed thousands of homes, and harmed the agricultural base, as well as important social services (e.g. schools, basic health centres), transport networks, small businesses and an extensive irrigation system. According to one estimate, the flood of 2010 heavily impacted people's livelihoods by damaging standing crops on 7.5 million acres of land and destroying more than 40,000 small shops and 41 industrial units (NDMA, 2010; Jamshed et al., 2018). In 2014, 73% of farmers and 50% of daily wage labourers lost their livelihoods in flood-affected districts. Almost 750 schools were damaged, which hampered the schooling of children. Further, more than 50% of access roads were critically damaged (NDMA, 2014). Table 3.1 shows the characteristics of major flood events in Punjab. These flood impacts have serious repercussions, not only for the livelihoods of rural households, but also for urban settlements whose economy is closely linked with rural areas.

3.1.2 Specific study areas for empirical research

Punjab is divided into 36 administrative districts, which are further split into 145 sub-districts[5]. Many of these districts and sub-districts have been affected by floods in the past ten years and have varied risk profiles. For the selection of specific study areas within the province, three criteria were chalked out, keeping in view the scope and objectives of the research. These criteria included the following: (a) the study areas needed to have different flood profiles (e.g. number of flood events, level of flood risk); (b) the study areas needed to be around cities of various sizes, with different demographic and socio-economic profiles; and (c) the study areas needed to be at a certain distance from the city.

Against the aforementioned criteria, at first, districts with flood risk were identified based on the NDMA's flood risk map (see Annex B). Secondly, from this shortlist, cities of different sizes within a district were identified based on population size, as well as economic and functional diversity. This was done to check for variability in changes in rural-urban linkages, as well as vulnerability concerning different geographic entities. Data regarding socio-economic conditions, flood impacts and risk profiles were only available at the district level and not the sub-district level; therefore, these data were taken as the basis for choosing sub-districts as well. In addition to the secondary data for the selection of case studies, relevant academics, disaster management and local government officials were consulted to make sure that the rural areas/settlements surrounding the

[5] Sub-districts are locally known as *tehsils*.

selected cities were affected by floods. This process helped to narrow down the selection of a range of cities and surrounding rural settlements.

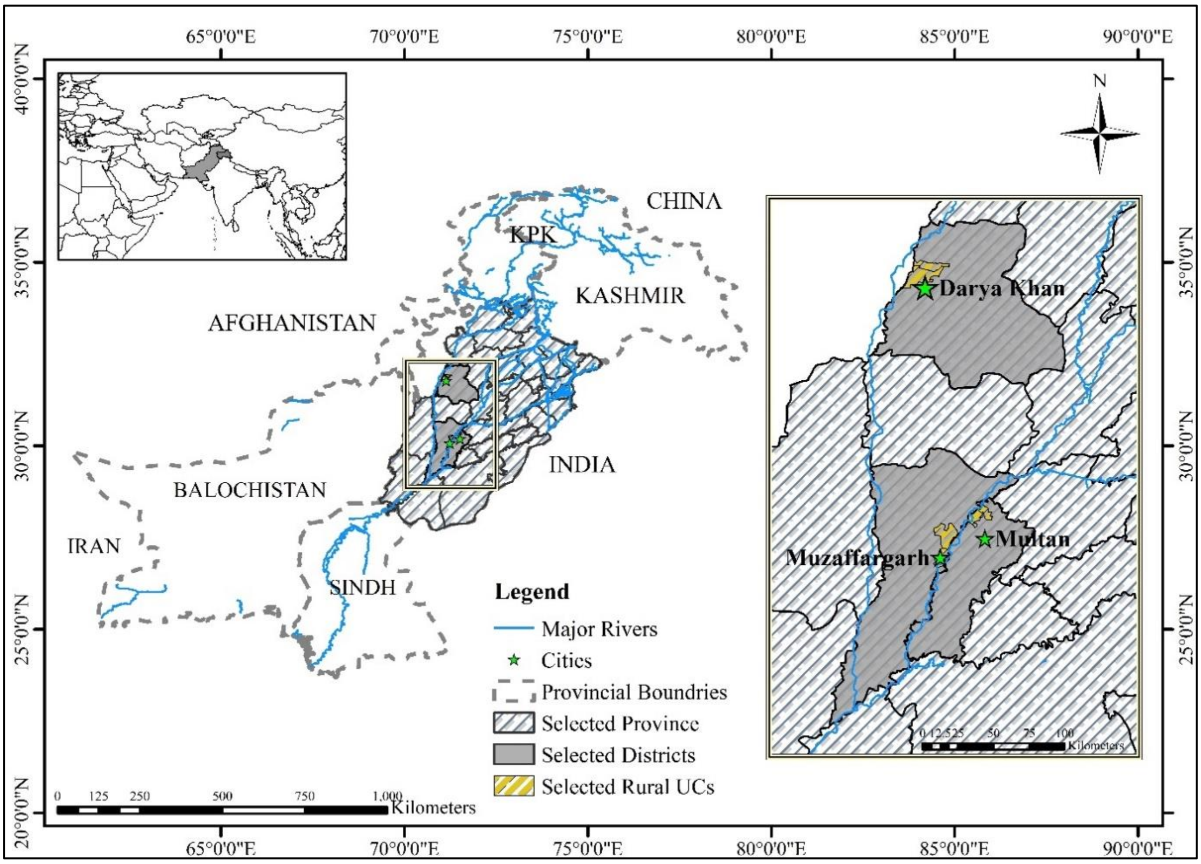

Figure 3.2. The figure showing the location of the case study areas.
(Own figure, 2020, already published as Jamshed et al., 2021)

Accordingly, the process resulted in the selection of three districts and their cities, namely Darya Khan (a small city in Bhakkar District), Muzaffargarh (a medium-sized city in Muzaffargarh District) and Multan (a large city in Multan District) (see Figure 3.2). Moreover, two rural UCs[6] per district were selected that have been affected by flood events in the last ten years and are located around the city (Section 3.1.3) provides a more detailed description of the case study areas and their locations). Lastly, several villages/rural settlements along the river in each UC were selected randomly, keeping in

[6] Mentioned earlier in this thesis, the Union Council (UC) is the lowest administrative unit in Pakistan's local administrative setup. Areas with administrative units (i.e. metropolitan/municipal or corporation/town committees in a given area) are termed 'urban'. Accordingly, the BSP designated UCs as both urban and rural.

view their spatial proximity to cities from the flood-affected rural settlements. The next section will outline how the distance of rural settlements from cities is defined.

3.1.2.1 Spatial proximity criteria

Spatial proximity is the physical distance between two spatial entities, which can be measured by a metric system (miles or kilometres) or using travel time (Balland, 2012). In this research, travel distance was measured in kilometres. There were three major issues that needed to be addressed in this regard. The first was to identify the point in each city from which the distance could be calculated. Initially, it was decided to use the central agricultural market in each city. However, the cities (around which the case study sites were chosen) were of different sizes, and the distances of the rural settlements to the central markets (grain/agricultural market) in each case study had a wide range. For example, the first flood-affected rural settlement from the market was between 25 km and 30 km in Multan, while in Darya Khan it was around 10 km. Thus, a comparison could not be drawn. Later, it was decided to take the distance of rural settlements to the boundary of each respective city, which resolved the problem and made the distances comparable (see Figure 3.2 to 3.5). Moreover, the peri-urban areas that had several businesses of interest for farmers were also within the boundary of the cities. Thus, this resolved the assumption that not all rural households go to central markets to buy goods and use services.

The second issue was to group the settlements according to proximity. Due to the absence of any criteria in Pakistan for defining settlements as near or far from a city, opinions were taken from experts, local government officials and communities. Considering this, rural settlements within a travel distance (the distance along the actual road network) of 10 km from the boundary of cities were deemed near proximity settlements (NPS), while those more than 10 km were labelled far proximity settlements (FPS). This proximity criterion has a resemblance to what was adopted by Abbay et al., 2016) in the context of rural development. However, discussion with experts showed that the split of 10 km (for defining a settlement that is 'near' or 'far') would call into question of the independence of the samples; for example, if the characteristics of a household 10 km from the city would be completely different than a household 10.5 km from the city. Therefore, a gap of 3 km to 4 km was given between settlements near and far from the city. Hence, households living close to the city were in the range of 5 km to 10 km, while those farthest away were in the range of 14 km to 25 km. Physical features (like rivers) and administrative boundaries, as well as other limitations, restricted the maximum distance to 25 km.

The third issue was the redundancy of routes that households use to travel to the city. In Darya Khan and Muzaffargarh, it was easy to identify the route, since there were mainly one or two paved roads near the settlements that led to the city. However, in Multan, it was slightly different, as more than two roads were going toward the city. Due to the absence/inaccessibility of data on the village road network at the time of the survey, one household from each village was asked about the usual route they took to go to the city and its rough distance. The majority of households identified one common route to go to the city with the best road conditions. This was considered for analysis. The distance was also calculated manually, using Google Earth from each rural settlement, along with the actual road network to the defined boundary of cities. This distance was applied to all households of the respective rural settlements.

3.1.3 The profile of the selected study areas

City size was an important parameter around which households from rural communities need to be surveyed. Considering this, Darya Khan, a small city in Bhakkar District, Muzaffargarh, a medium-sized city in Muzaffargarh District, and Multan, a large city in Multan District, were chosen. The following sections explain the geographic, demographic, socio-economic and flood profiles of these case studies, and Table 3.2 offers a concise comparison.

3.1.3.1 Darya Khan: Representative of a small city

The first case study was the rural area in the vicinity of Darya Khan in Bhakkar District. Bhakkar District is surrounded by Mianwali District in the north, the districts of Jhang and Khushab in the east, and Layyah District in the south. The western side of the district is fertile and there are irrigated plains along the Indus River, while most of the district lies in the desolated plains of the Thar desert in the east. Bhakkar District spreads across 8,153 km², which is divided into four sub-districts[7]: Bhakkar, Darya Khan, Kallur Kot, and Mankera, as well as 42 UCs, out of which 9 are defined as urban and 33 as rural (BSP, 2017). The district's total population is 1.65 million, with 84% comprising the rural population.

Table 3.2. Case study areas and key characteristics

Characteristics	Small city	Medium-sized city	Large city
Case study description			
Selected district	Bhakkar	Muzaffargarh	Multan
Selected sub-district studied	Darya Khan	Muzaffargarh	Multan
Main city of the sub-district	Darya Khan city	Muzaffargarh city	Multan city
Selected rural UCs for data collection	Angra Daggar and Panjgrain	Taliri and Muradabad	Boch Khusroabad and Lutefabad
Geography			
Location	31.62°N 71.06°E	30.20°N 71.05°E	30.05°N 71.40°E
Major nearby rivers	Indus	Indus & Chenab	Sutlej & Chenab
Population			
District population	1.65 Million	4.3 Million	4.7 Million
% of selected district's rural population	84%	87%	58%
% of selected sub-district's rural population	76%	86%	48%
Urban population sub-district	77 000	214 000	1 850 000
Population of the city	59 000	200 000	1 700 000
Socioeconomic characteristics			
Social progress index	0.18	0.22	0.35
Centrality functional index	0.11	0.26	0.36
Major economic sector	Agriculture	Agriculture and agriculture-based industries	Agriculture, industry, services, education, health and commerce
Impact of floods in rural areas of selected case studies between 2010 and 2014			
Displaced persons	67 000	1 800 000	300 000
Destroyed houses	12 000	184 000	3000
Affected settlements	65	1000	300
Damaged crops	28 000 acres	556 000 acres	200 000 acres

(Mayo, 2012; NDMA, 2014; BSP, 2017; The Urban Unit, 2018b; Jamshed et al., 2020d)

Darya Khan is representative of a small city, with almost 59,000[8] inhabitants. Darya Khan is also a sub-district headquarters; it was ranked 32nd on the Social Progress Index (SPI)[9]

[7] In Punjab, a sub-district is called a *tehsil* in the local administrative setup.
[8] The estimated population figures of the cities were extracted from BSP (2016). The figures represent the end of year population (i.e. 2016) and only indicate the population of the city, not the urban population of the entire sub-district.
[9] The SPI was calculated by The Urban Unit using 39 indicators from various social sectors, including dimensions like education, health, water and sanitation (WASH), gender and culture, and economics.

and 4th on the Urban Deprivation Index (UDI)[10] out of 36 (Jamal et al., 2003; The Urban Unit, 2018b). The Centrality Functional Index (CFI)[11] value is 0.11, which is low (Mayo, 2012). Around 60% of the population is employed in agriculture, 18% in industry and 22% in services, respectively (PBS, 2016). The district and sub-districts are predominantly characterised by agriculture as the main economic activity. Sugarcane, wheat and grams are the main crops in the region (DoIP, 2012).

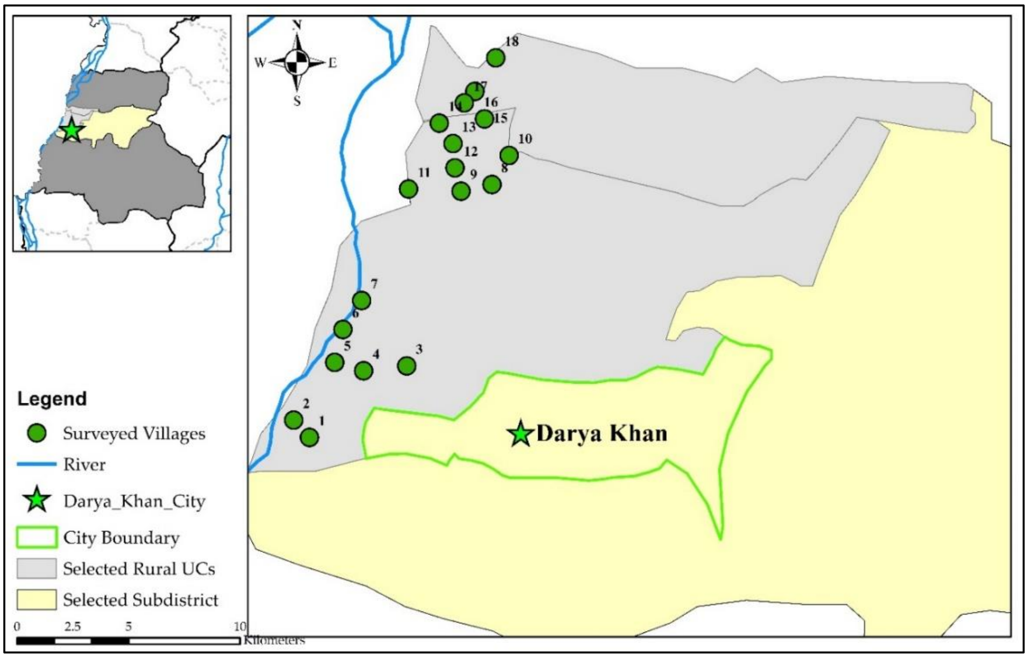

Figure 3.3. Location of surveyed villages in Darya Khan. The boundary of the city (in green) is defined by combining the boundary of all urban-UCs. The labels on green dots represent the identity code of the villages which are available in Annex B.
(Own figure, 2020)

During the summers, the Indus River causes flooding in the rural parts of the district and affects rural livelihoods. It is estimated that in the past 10 years, two flood events have displaced 67,000 people, destroyed almost 12,000 homes, affected several settlements, and damaged standing crops in an area of more than 28,000 acres (NDMA, 2010, 2014). Two flood-impacted rural UCs—Angra Daggar and Panjgran—in the city's hinterland were

[10] The UDI, calculated by Jamal et al. refers to deprivation in terms of housing conditions, quality of life, and utilities and services.
[11]Mayo (2012): The CFI is a multidimensional index based on the social, economic, infrastructure, market and industrial functions of places in Punjab.

selected from the sub-districts of Darya Khan. Within these UCs, 18 villages were surveyed (Figure 3.3). The green line in Figure 3.3 shows the city's boundary. Table 3.2 gives an overview of the study area's profile.

3.1.3.2 Muzaffargarh: Representative of a medium-sized city

The second case study was the rural area surrounding Muzaffargarh in Muzaffargarh District. The districts of Dera Ghazi Khan and Rajanpur lie to the west, and Multan District is located in the east of Muzaffargarh. The district is bounded by two major rivers. The Indus flows in the west and the Chenab in the east, making the district a *doab*[12]. A large part of the district consists of dunes and barren land (DoIP, 2012). The total geographical area of Muzaffargarh is 8,249 km^2, which is divided into four sub-districts (i.e. Muzaffargarh, Kot Addu, Alipur and Jataoi) and 93 UCs (13 urban and 80 rural). The district has 4.3 million people, 87% of whom are rural residents.

The city of Muzaffargarh—which is both a district and a sub-district headquarters—has a population of almost 0.2 million and is a medium-sized city. Out of 36, Muzaffargarh was ranked 29th on the SPI and 8th on the UDI (Jamal et al., 2003; The Urban Unit, 2018b). The CFI's value is 0.26 (Mayo, 2012). The city specialises in agro-industrial functions. Around 57% of the population is employed in agriculture, whereas 21% and 22% are employed in industry and services, respectively (PBS, 2016). Sugar, textiles, and cotton ginning are prominent industries (DoIP, 2012).

The two major rivers, the Indus and the Chenab, caused yearly large-scale flooding from 2010 to 2014. These disasters damaged over 225 thousand hectares of cropped area, affected over 1,000 villages, displaced more than 1.8 million people, and destroyed over 184 thousand homes (see Table 3.2). Thus, the rural part of the district has been massively impacted by flooding. The rural UCs of Taliri and Muradabad were selected from Muzaffargarh. Figure 3.4 shows the locations of the UCs, 20 selected villages, and the city's boundary, while Table 3.2 briefly describes Muzaffargarh.

[12] The land between two rivers is known as a *doab.*

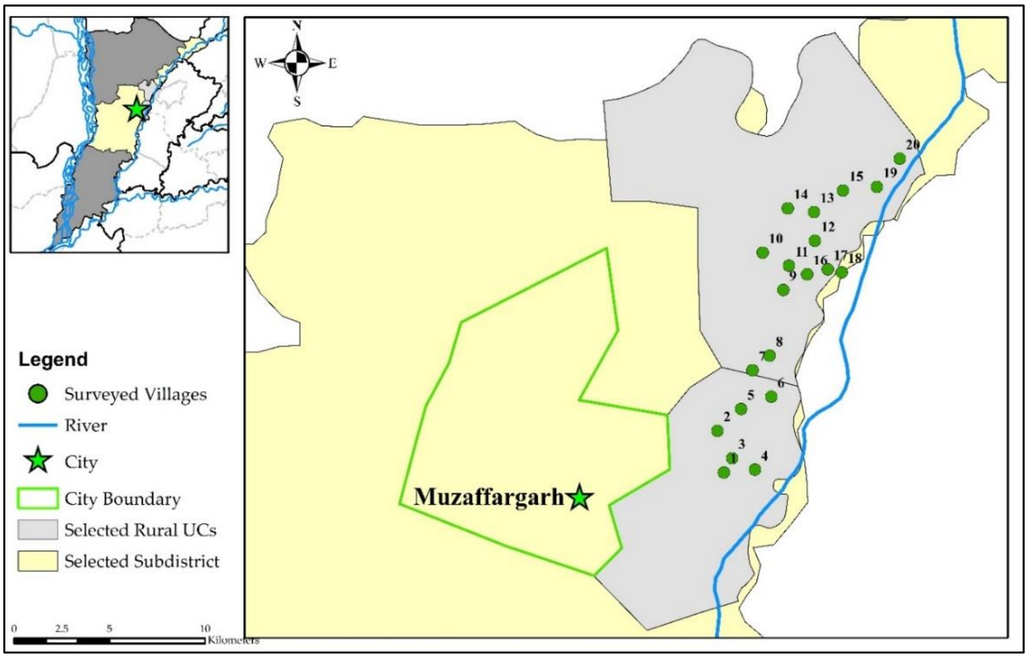

Figure 3.4. Location of surveyed villages in Muzaffargarh. The boundary of the city (in green) is defined by combining the boundary of all urban-UCs. The labels on green dots represent the identity code of the villages which are available in Annex B. (Own figure, 2020)

3.1.3.3 Multan: Representative of a large city

The third case study was the rural area around the city of Multan in Multan District, the heartland of southern Punjab; it is surrounded by Khanewal District in the north, Lodhran District in the east, and Bahawalpur District in the south. The river Sutlej in the south and the river Chenab in the west separate Multan District from Bahawalpur and Muzaffargarh, respectively. The district covers 3,720 km^2 and has a total of 129 UCs, out of which 65 are urban and 64 are rural (BSP, 2017). The district has 4.7 million people, 58% of whom are rural inhabitants.

The city of Multan has 1.7 million people and is considered to be large. Multan was ranked 14th and 22nd on the SPI and the UDI, respectively (Jamal et al., 2003; The Urban Unit, 2018b). The CFI's value is 0.36, which is sixth highest in Punjab when compared to other districts. Around 33% of the population works in agriculture, whereas the share of those employed in industry and services is 35% and 32%, respectively (PBS, 2016). Multan has mixed functions and serves as an exemplar in agriculture, industry, education, health and commerce, and various other sectors in southern Punjab (Ahsan et al., 2009). It provides multiple services to the surrounding rural population.

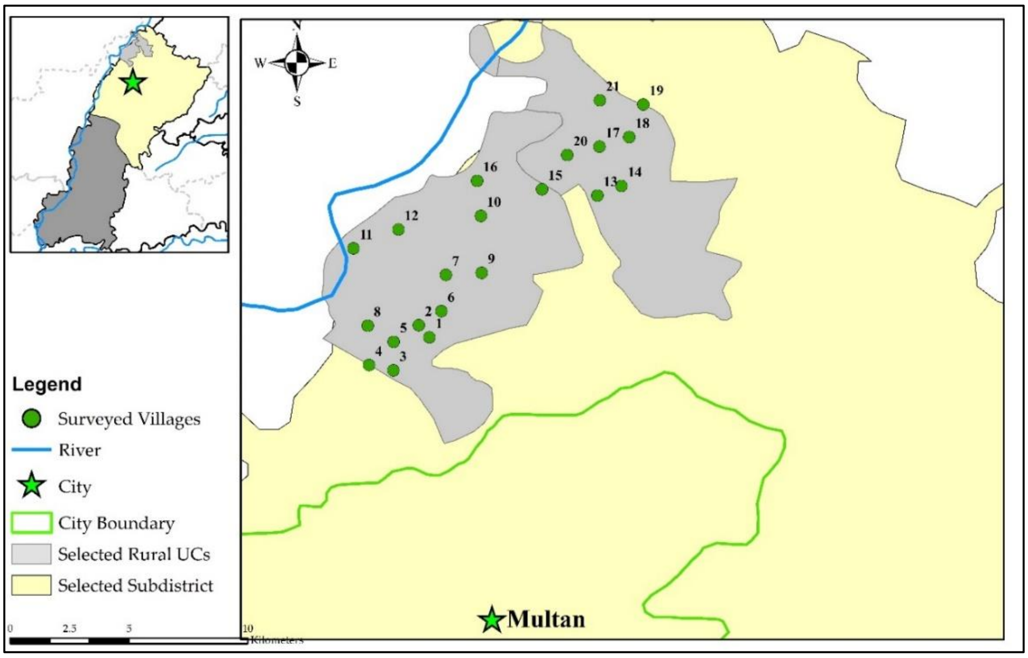

Figure 3.5. Location of surveyed villages in Multan. The boundary of the city (in green) is defined by combining the boundary of all urban-UCs. The labels on green dots represent the identity code of the villages which are available in Annex B.
(Own figure, 2020)

During the monsoon season, floods stemming from the Chenab River cause widespread socio-economic and physical losses in the district. Multiple flood events from 2010 to 2014 affected almost 300 settlements, destroyed over 3,000 homes, displaced 0.3 million people, and damaged 0.2 million acres of standing crops (see Table 3.2). Two rural UCs—Boch Khusroabad and Lutefabad—were selected for the survey; within these UCs, 21 rural settlements were surveyed (see Figure 3.5).

3.2 Sampling process

In empirical studies that involve different population groups and their vulnerability to deal with natural hazards and climate change, it is difficult to include the entire population in the research, given limited resources and time. Therefore, researchers choose a fraction of the population, a technique known as sampling (Onwuegbuzie et al., 2007). By examining the sample, the results can be generalised to the entire population, or to develop an understanding of the phenomenon happening in the sample population.

In this thesis, the sampling process consisted of three stages (see Figure 3.6) and utilised a mixed method sampling approach. This was done since the focus of the research was on flood-affected rural households, and the number of households impacted by flooding was unknown at the selected administrative level (i.e. the UC level) of the study area. Hence, it was possible to derive the sample at the aggregated level (i.e. the UC level). To select the size of the sample at the aggregated level, a probabilistic sampling method was employed. Secondly, proportionate sampling was adopted to distribute the calculated sample size according to the number of households in each UC. Later, the households affected by flooding were purposively chosen. Lastly, the samples were sorted and incomplete samples were eliminated.

3.2.1 Sample size calculation

To select the size of the sample at the aggregated level, the Cochran (1977) sampling technique was used to define the minimum sample size in light of the limitations discussed earlier. Equation 1 was used to determine the sample size. By assuming the confidence interval (CI, measured with Z) at 95% and an error value (e) at ±5%, a sample size of 384 households was obtained.

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

SS = sample size

Z = CI (±1.96 at 95% for this study)

p = percentage picking choice (expressed as a decimal and measured at 0.5 for the sample size needed to get the maximum value of the required sample size)

e = error value (0.05 = ±5% error was used to calculate the sample)

$$\mathrm{SS} = \frac{(1.96)^2(0.5)(1-0.5)}{(0.05)^2}$$

$$\mathrm{SS}=384$$

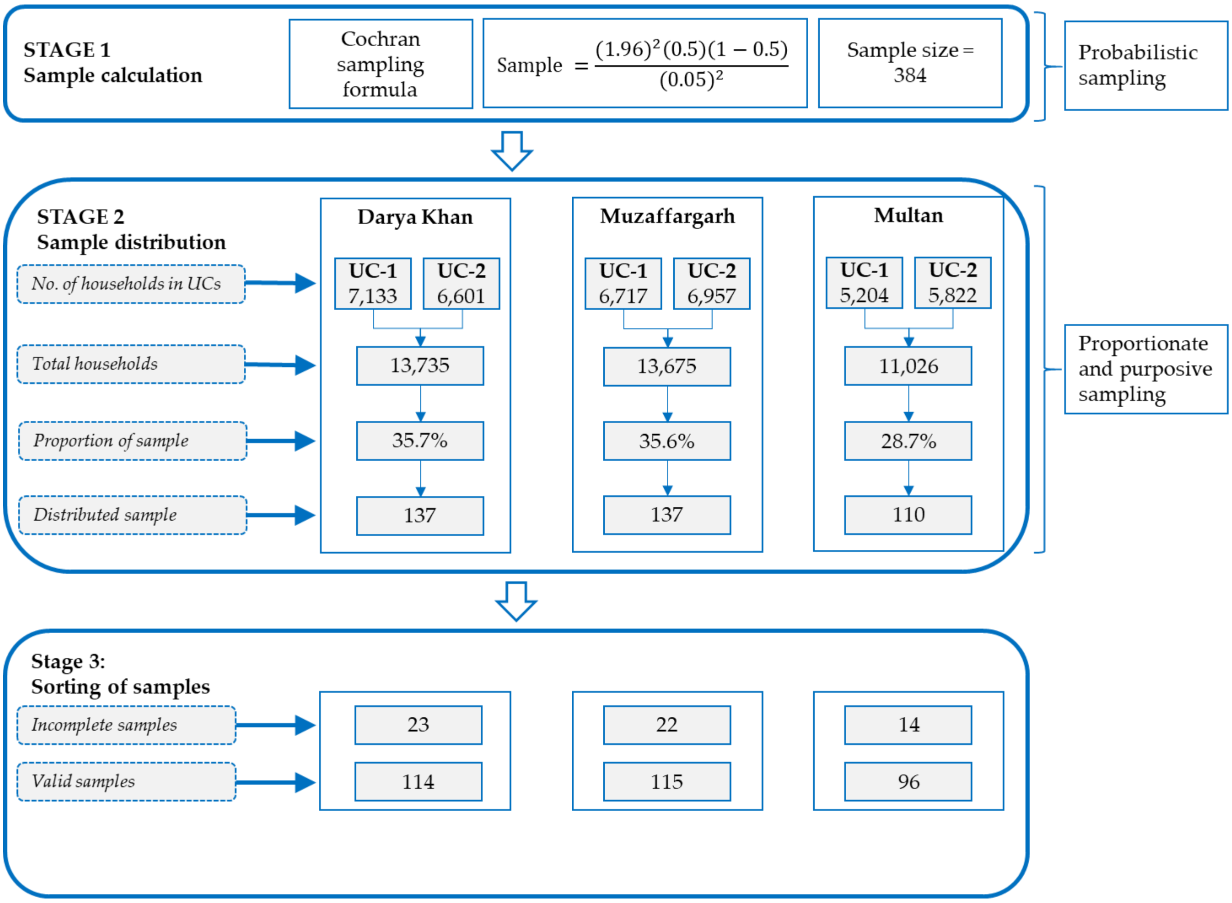

Figure 3.6. Sampling framework for the household survey (Own figure, already published as Jamshed et al., 2020d)

3.2.2 Sample distribution

To distribute the sample size, the number of households was calculated from the populations of the respective UCs. The calculation resulted in 13,735 households in Darya Khan, 13,675 in Muzaffargarh and 11,026 in Multan being identified. The sample size was proportioned according to the number of households in the UCs of each district, which came out to be 35.7% in Darya Khan, 35.6% in Muzaffargarh and 28.7% in Multan. This proportionate sampling resulted in 137 samples being collected from the flood-affected communities of Darya Khan and Muzaffargarh each, and 110 samples to be gathered from Multan. Figure 3.6 outlines the sample distribution process, while Annex B provides the overall calculations and distributions of the sample.

3.2.3 Sorting of the samples

The third and final stage of the sampling process involved sorting out the collected samples. This was done to identify incomplete samples, as well as samples with a large number of missing values. Sorting led to the identification of 23 incomplete samples from Darya Khan, 22 from Muzaffargarh and 14 from Multan. These samples were eliminated, and the final sample was 325 households. This resulted in 114 samples from Darya Khan, 115 from Muzaffargarh and 96 from Multan (see Figure 3.6).

3.3 Data collection

This research utilised both secondary and primary data, but the main focus was on primary data. Data collection started in mid-January 2017 and lasted until the end of March 2017. Some missing information was also collected in January of 2018 and 2019.

3.3.1 Secondary data

Secondary data from reliable sources are important to support and facilitate the findings of a research project (Sahu, 2013a). In this thesis, secondary data sources include journal articles, books, newspaper articles, theses, reports of international governmental and non-governmental institutions, and flood maps. The literature analysis (particularly the academic literature) helped to provide a theoretical foundation for the research (as discussed in Chapter 2) and to develop and refine the RQs (see Figure 3.1). Moreover, the literature on rural-urban linkages and flood vulnerability led to defining specific variables and indicators for the investigation, and provided a framework for questionnaire development. Further, government reports and other Pakistan-specific literature was crucial to understanding the local development and flood hazard context. The secondary information also helped to validate the findings of the empirical research. Most of the secondary data were available on the Internet, while some data (particularly related to GIS for preparing maps) were collected from relevant institutions.

3.3.2 Primary data

Primary data entails exploring ground realities in order to better grasp issues related to flooding and rural-urban linkages. In this research, primary data involved a questionnaire-based household survey (from 325 households), field observations, and a focus group discussion. However, a large proportion of the research was based on information gathered from household interviews.

3.3.2.1 Observations

Field observation is a vital method of primary data collection (Sahu, 2013a, p. 64), which includes acquiring information about entities of interest; these can be people, places, and infrastructure elements. In this research, field observation gave insights into the conditions of community buildings, infrastructure, changes in community livelihoods, infrastructure, and rural market centres. These observations also provided an understanding of people's use of the mode of transport for going to cities and the route they chose, as well as market sizes in different case study areas. The observations were recorded through field notes and photographs.

3.3.2.2 Individual and group discussions

Discussions were carried out with officials from public and private institutions, academics, and local community elders. The research topic was addressed in informal conversations with officials of public/private institutions and academics by posing questions related to the research (see Figure 3.7A). The discussions revealed that the topic needs empirical investigation, especially in the context of Pakistan, as it has rarely been examined, and insights into changing rural-urban linkages can deepen understanding of rural vulnerability. Moreover, the discussions helped to define the study's scope, and to identify related aspects that can be scrutinised. Thus, these discussions aided in the development of the questionnaire for the household survey.

The discussion with local government and provincial disaster management officials helped to pinpoint pertinent case study sites where the study could be conducted (as indicated in Section 3.1). Informal group discussions (mainly based on the questions in the household questionnaire) were also held with the participants of the household survey in small groups of 2 to 5 individuals (see Figure 3.7B) to gain more in-depth knowledge on how flood events and their impacts affect rural households' linkages with cities (e.g. mobility patterns, access to goods, and other services). These discussions were recorded in the form of statements from different group members.

A **B**

Figure 3.7. Individual and group discussion, (A) shows the discussion with an official of the Punjab Rural Support Program (B) shows the discussion with community members in Multan
(Field survey, 2017)

3.3.2.3 Questionnaire-based household survey

The questionnaire-based household survey was key to answering the RQs. Household surveys can be performed through telephone interviews, by mail or face-to-face (Sahu, 2013a). The face-to-face interview was the most appropriate method in the case study regions to carry out the household survey and gather reliable data. Therefore, face-to-face interviews using a structured questionnaire were used. Other methods were not suitable, as rural areas were the primary target, where most residents have no access to the Internet or telephones. Moreover, the literacy rate is very low. Information on the contact details and locations of flood-affected households was not available, which made paper-based, face-to-face interviews the best option for gathering household data.

3.3.2.3.1 Questionnaire preparation

A structured questionnaire was prepared, keeping in mind the study's objectives and RQs. The questionnaire was divided into different sections encompassing the study area's profile; households' socio-economic and demographic attributes; their hazard profiles and past flood impacts; the influence of flood events on one's livelihood, goods and services; and flood response measures conducted by households and government.

Different types of close-ended and open-ended questions were incorporated into the questionnaire, providing both quantitative and qualitative information. However, most questions refer to quantitative details (the questionnaire is provided in Annex C). The types of questions included in the survey were: (a) demographic survey questions; (b) multiple choice questions related to households' socio-economic conditions; (c) questions with a rating scale (between 0 and 10); (d) questions on the Likert scale (*strongly disagree* to *strongly agree*) (e) dichotomous ('Yes' or 'No') questions; and (f) open-ended questions to capture views, experiences, and recommendations in relation to the household.

3.3.2.3.2 Conducting the household survey

Once the questionnaire was prepared, a pre-test was carried out in February 2017 to validate and streamline the complete questionnaire. Pre-testing also gave an idea of the time required to complete each questionnaire, respondents' behaviour, as well as field conditions (especially the issue of proximity to cities[13] and cultural aspects). The pre-test helped to add a few more relevant questions.

Enumerators were recruited to assist the author in administering the final survey. Students from the Department of City and Regional Planning at the University of Engineering and Technology (UET) in Lahore were contacted to provide their services as enumerators. Those who were hired already had the experience of collecting field data using a questionnaire, spoke the local language, and originated from the study area's districts or were familiar with the cultural setting. They were briefed on the study's objectives and the questionnaire in a training session before going out to conduct field research.

The household survey was launched at the beginning of March 2017 under the author's supervision. It was decided to spend one week in each district. Field data collection was initiated in Darya Khan, followed by Muzaffargarh and Multan. At the start of the survey, verbal consent was obtained from the respondents, and they were informed about the study's purpose and potential outcomes. It was critical to inform households about the

[13] Issues related to proximity to the city are discussed in Section 3.1.2.1.

study's purpose to avoid false information, since many rural households think that surveys are conducted by aid organisations. Hence, these households sometimes provide false information regarding their socio-economic conditions and flood damage profile in order to receive aid. Moreover, local government offices in each sub-district were asked to provide one official to travel with the survey team to avoid any communication problems with the targeted communities. The average time to complete the questionnaire was around 45 minutes; in one day, around 25 to 30 households were surveyed. Figure 3.8 shows the enumerators collecting data from the respondents.

Figure 3.8. Enumerators collecting data from respondents (A) Darya Khan; (B) Multan (Field survey, 2017)

3.4 Data processing and analysis

The data gathered from primary sources needed to be processed, which required sorting and editing, data entry, cleaning, coding, classification and arrangement before proceeding to analysis (Sahu, 2013b, p. 75). In this research, the data were processed and analysed both qualitatively and quantitatively, considering the objectives and RQs. The quantitative analysis involved several analytical approaches to answer the respective RQs. The following sections outline the process of qualitative and quantitative analysis.

3.4.1 Qualitative analysis

Data collected from secondary sources, observations, and the focus group discussions from the household survey were examined qualitatively. Many tools are available for qualitative analysis, especially for coding purposes (Skjott Linneberg et al., 2019).

However, considering the limited qualitative information available, the data were coded and organised manually. The variables and indicators from secondary data were systematised into different categories, guided by the conceptual framework (see Chapter 2). These variables were later entered into tables, with columns of explanation and references to relevant literature (see Section 3.4.2.3, Table 3.3). The photographs retrieved from the field were organised with respect to the case studies and assigned to the relevant categories (e.g. mobility or markets). Similarly, excerpts from the focus group discussions and household individuals were sorted and edited, and placed in the pertinent categories. The qualitative analysis helped to define the proper variables and indicators to be studied, to select the case studies, and to better understand the reasons for changing rural-urban linkages and conditions in rural settlements, as well as their relevance for rural households' vulnerability to flooding.

3.4.2 Quantitative analysis

Quantitative analysis was the main part of this research and carried out using the Statistical Package for Social Science (SPSS) and Microsoft Excel; Stata and R played also a role. Data were initially processed by sorting the questionnaires. Incomplete questionnaires and those with a large number of missing values were eliminated (see also Section 3.2.3). Afterward, the data were entered into SPSS and organised with respect to the case studies. Relevant data were classified and coded according to the requirements of the different analysis methods. The results are presented as bar and column graphs, radar charts, box plots, scatter plots and cross tables. A brief description of the different analytical approaches used in the research is provided below.

3.4.2.1 Descriptive statistics

Descriptive statistics were used to examine the respondents' socio-economic profiles, the impacts of past flood events on rural households, the responses from aid and government organisations, and the subsequent changes adopted by households (chapters 4 and 5). These changes refer to structural shifts in houses, livelihood practices and multiple linkages with cities. Frequency tables, cross-tabulation, and relevant mean values were scrutinised for the households in each case study, as well as for the entire sample.

3.4.2.2 Regression analysis

Regression analysis was conducted to identify the factors that determine why households opt for changes in different flows that constitute rural-urban linkages (Chapter 5). Another purpose was to investigate if flood-related factors have also resulted in changes in rural linkages with cities. Based on the conceptual framework (see chapters 2 and 5), eight different regression models were calculated. Four models describe how the linkages were altered in that rural households became more dependent on cities, such as the flow of people (changing mobility patterns), finances/income (frequent access to credit and dependence on remittances), information (frequent access to information; i.e. markets, or weather, water and farm information), and goods (frequent access to farm input). The rest of the four models describe how the linkages were transformed in that rural households consequently became less dependent on cities and sourced their goods, information, finances and market/trading services from rural villages.

3.4.2.2.1 Explanation of the regression model

In this research, binary logistic regression was used to establish the factors that influence linkages/flows, as the dependent variable has a binary/dichotomous nature. The binary/dichotomous variable took two values; 1 was assigned if a household changed its linkages/flows (people, information, income, and goods and services) with the city after a flood; otherwise, 0 was assigned. The binary logistic model is written as the following (Equation 2):

$$Y_{ik} = \alpha + \sum X_k \beta_k + \varepsilon_{Y_{ik}} \qquad \text{Equation 2}$$

Y_{ik} is the dichotomous dependent variable, whereby k denotes the changes in linkages adopted by ith household. X_k refers to the vector of explanatory variables (e.g. the value of family income) used in the study, which affected rural households' decision to change particular linkages with cities. The symbol β_k represents the vector of the coefficient of binary regression to be estimated, and $\varepsilon_{Y_{ik}}$ is the error term (Abid et al., 2015).

Marginal effects and elasticities were also calculated since the estimated coefficient of binary logistic regression β_k only indicated the direction of the effect of explanatory variables and their statistical significance. This implies that a positive coefficient β_k represents the explanatory variable X_k, which increases the possibility that certain linkages/flows would be altered by households after a flood. Nevertheless, the coefficient β_k does not quantify a household's probability of changing certain linkages/flows when there is a shift in the explanatory variable. Thus, the magnitude of the effect of a change in the explanatory variable on the dependent variable provides useful information, which can be represented by either the marginal effect or partial elasticities (Abid et al., 2015). The marginal effect explains the impact of a unit change in the explanatory variable on the dependent variable, while elasticity defines the probability of percentage change in the dependent variable in response to a 1% increase in the explanatory variable. The marginal effect is an informative measure and easy to interpret for binary/dummy variables (Jann, 2013). Therefore, the marginal effect was used to interpret the dummy variables, and elasticity was employed to interpret the continuous variables.

3.4.2.2.2 Description of variables included in the regression models

The explanatory variables were chosen based on the conceptual framework and relevant literature (see Douglass, 1998; Joarder et al., 2013; Abbay et al., 2016; Jamshed et al., 2020b for details). Discussions with academics were also carried out to select relevant variables for measuring the influence of specific linkages. The explanatory variables represented household internal factors; that is, socio-economic characteristics (the age and educational level of the household head, network ties in the city, farming as a primary occupation, the number of earning members, family monthly income, ownership of any means of transport, ownership of farmland), as well as external factors like spatial aspects (distance to the city) and factors related to flood events and their impacts (the number of floods experienced in past ten years, losses of/damages to household assets, increased prices of goods and services after a flood, high transportation costs, farmland degradation, and crop productivity). These flood-related variables were chosen to confirm if flood impacts essentially influence/change rural linkages with the city. The literature suggests that households do not necessarily make not just one, but rather multiple changes (Douglass, 1998). Moreover, the selected explanatory variables (that influence the changes in rural-urban linkage/flows) differ depending on the type of flow. Therefore, some variables were dropped from the model for a certain type of flow after speaking with experts. The list of variables used in each model is documented in Annex D.

3.4.2.2.3 Evaluation of models

In order to test the models for their significance and precision of their prediction, three different methods were used to evaluate each one: (1) the global null hypothesis technique, (2) Nagelkerke pseudo-R^2, and (3) the classification table. Firstly, a global null hypothesis technique based on the chi-square statistic was adopted, which assumed that all the coefficients of binary regression were equal to zero against at least one coefficient that was not zero. Peng et al. (2002), Abid et al. (2015) and Iqbal et al. (2016) found this method to be the same as the F-test in linear regression. This chi-square test includes all explanatory variables and checks if the model is a good fit. In addition, $\text{Nagelkerke pseudo} - R^2$ was calculated, which indicates the proportion of variance in the dependent variable due to the explanatory variables used in the model. Moreover, the classification table method was employed to gauge the extent to which the present study's model could precisely predict the dependent variables (i.e. changes in rural linkages with cities). This method gives the outcome in percentage form by comparing the predicted scores of observations (grounded in explanatory variables in the model) with actual responses given in the data (Hosmer et al., 2000).

3.4.2.3 The composite index development

Composite indices are widely applied in multiple fields of research (e.g. society, the economy, the environment) to understand intangible issues (OECD, 2008). Indices help in measuring and assessing the progress of countries and various entities on sustainability, human development, poverty, livelihood, vulnerability and risk (OECD, 2008; Becker et al., 2017; United Nations, 2018). A composite index combines multi-dimensional indicators to reduce the complexity of an entire system by summarising data in a simplified way, and provides a single metric for better understanding a complex phenomenon (Tate, 2012; Birkmann, 2013a; Feldmeyer et al., 2019; Feldmeyer et al., 2021). Since vulnerability is a multi-dimensional phenomenon that involves critical intangible factors, various approaches can capture these factors (Birkmann, 2013a). In the context of flood vulnerability assessment, an indicator-based approach can also be important, as it allows one to compare different case studies. In addition, it provides more precise results compared to other methods (Nasiri et al., 2016). In this research, an index-based approach was used to measure flood vulnerability and to explore differences (among case studies) in terms of city size and proximity to cities. The index was developed in six different steps (see Figure 3.9) and is briefly explained in the following sections.

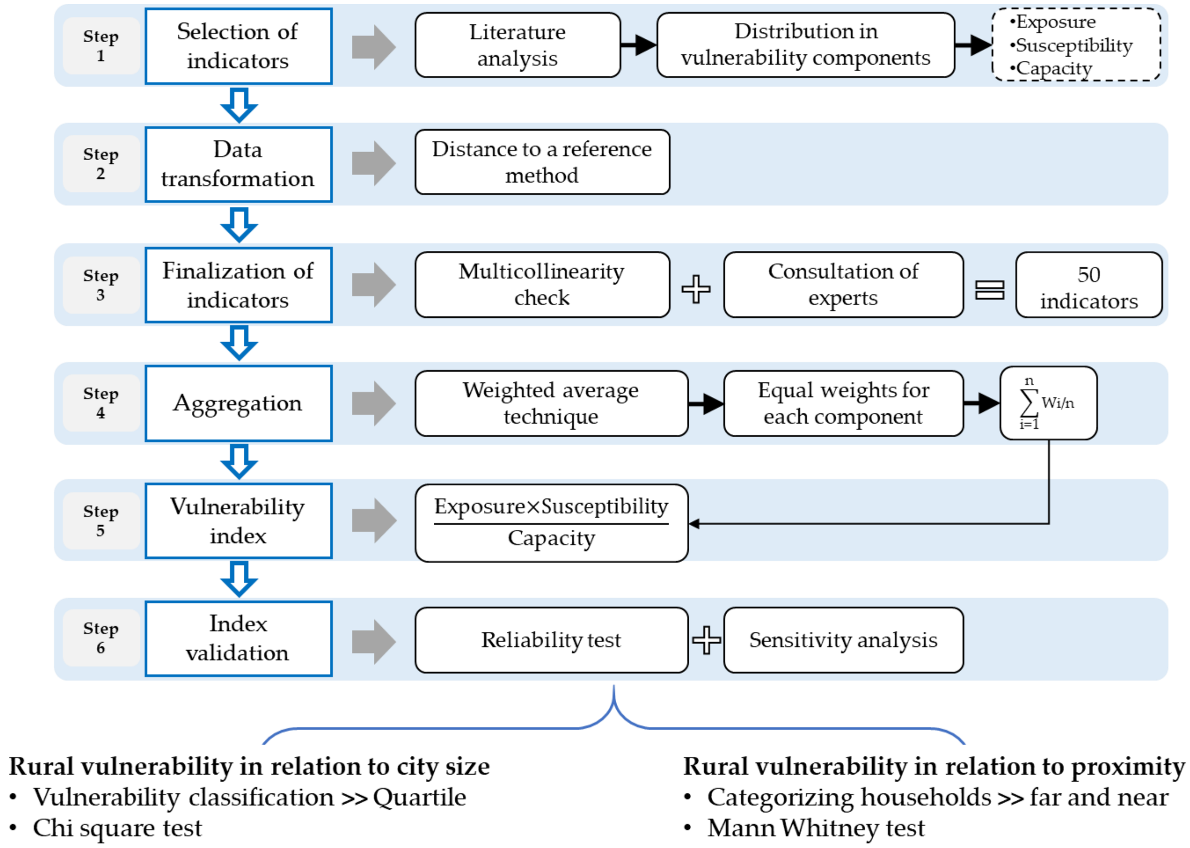

Figure 3.9. Steps to construct a vulnerability index for rural households affected by floods in Pakistan
(Own figure, 2020)

3.4.2.3.1 Data transformation

Although household data were mostly measured on a nominal or categorical scale (i.e. already classified), other household data for different indicators were also classified. The values of classified data were transformed between 0 and 1 to standardise the data using the 'distance to reference measure' method, whereby a mathematical/coded value (as assigned by the researcher) of categorical/nominal data for a particular case is divided by the reference (maximum) value of the same data (see OECD, 2008, Romanescu et al., 2018). This methodology has been adopted by several studies to investigate vulnerability (e.g. Abbas et al. 2014, Gain et al. 2015, Giupponi et al., 2015, Rana et al. 2018a, Romanescu et al., 2018 and Jamshed et al. 2019b). Depending on the classification of each indicator, the transformed values were divided equally between 0 and 1 using the technique mentioned before, where 0 represented the lowest value, and 1 was the highest. The dichotomous indicators were scored as 0 and 1. The multiple-choice questions, with three options, were scored as 1, 0.66 and 0.33 (and in some cases, based on the indicator's nature); the three-option questions were scored 1, 0.5 and 0 (e.g. the extent of damages to a home with the options being 'total', 'partial' and 'no damage'). Indicators with four classes were scored as 1, 0.75, 0.5 and 0.25, whereas indicators with five classes were scored as 1, 0.8, 0.6, 0.4 and 0.2. These transformed values were named as (standardised) scores (see Table 3.3).

3.4.2.3.2 Indicator selection

The indicators were developed and selected based on theoretical and empirical literature backed by the study's objectives. The indicators were chosen for exposure, susceptibility, and the response capacity components of vulnerability (see Table 3.3). To minimise the redundancy of indicators, a correlation analysis was performed. Cutter et al. (2014), Welle et al. (2015a) and Sorg et al. (2018) asserted that if two indicators show a high correlation, then one can be removed. The suggested threshold used to eliminate highly correlated variables can either be 0.7 or 0.8 (Burton, 2015; Shi et al., 2019). In this study, the threshold of the correlation coefficient was kept at 0.8. The finalisation of indicators also involved incorporating suggestions from experts regarding the importance of indicators for gauging vulnerability in the context of Pakistan, and determining if the indicator belonged to exposure, susceptibility or capacity. Accordingly, some indicators were removed, some were maintained, and a few were merged. In addition, sensitivity and reliability tests were used for an additional justification of the statistical relevance of the indicators and their selection.

Table 3.3. Classification, standardized scores and explanation of vulnerability indicators with respective components (exposure, susceptibility and capacity)

Sr#	Indicators	Classes	Scores	Explanation	References
EXPOSURE					
1	E1: Size of the household	> 10 5 to 10 < 5	1 0.66 0.33	Large household size indicates that a higher number of people are exposed to flood hazard	Willroth et al. (2011); Maleki et al. (2018)
2	E2: Households that did not get any early flood warning in the last event	Yes No	1 0	Households are more exposed to flood if they did not receive any flood warning	Penning-Rowsell et al. (2005); Hahn et al. (2009); Rana et al. (2016); Rana et al. (2020a)
3	E3: Experienced flood exposure over the last ten years	>=4 3 2 1	1 0.75 0.5 0.25	Households are more exposed if they have faced more flooding events in the past	Messner et al. (2006); Ahsan et al. (2014); Salik et al. (2015); Panthi et al. (2016); Hamidi et al. (2020a)
4	E4: Number of times the house flooded in the past ten years	>=4 3 2 1	1 0.75 0.5 0.25	Houses are more physically exposed if they have been flooded frequently in the past	Cutter et al. (2000); Kappes et al. (2012); Jamshed et al. (2020d)
5	E5: Distance of house to the water body (river, stream)	<=1 km 2 km 3 km >3 km	1 0.75 0.5 0.25	Households living in proximity to river/stream are more exposed to flooding	Penning-Rowsell et al. (2005); Messner et al. (2006); Bohensky et al. (2014); Phung et al. (2016); Luu et al. (2018); Imran et al. (2019); Hamidi et al. (2020a)
6	E6: The extent of loss/damage to the house and households' possessions (last worst flood event)	Total Partial No damage/loss	1 0.5 0	High degree of loss and damage to housing structure and households' personal belongings shows a higher exposure to floods	Birkmann et al. (2008); Younus (2017); Sam et al. (2017); Weisser et al. (2020)
7	E7: The extent of loss/damage to harvested crops/stockpiled grains (last worst flood event)	Total Partial No damage/loss	1 0.5 0	Higher the degree of loss and damage to harvested crops and stockpiled grains, the higher the exposure of the financial capitals will be	Younus (2017); Jamshed et al. (2017)
8	E8: The extent of damage to standing crops (last worst flood event)	Total Partial No damage/loss	1 0.5 0	High degree of loss and damage to standing crops indicates that crop farms are more exposed	Gain et al. (2015) Younus (2017); Qaisrani et al. (2018); Jamshed et al. (2019b)

SUSCEPTIBILITY					
9	S1: Household members with physical or intellect handicap	Yes No	1 0	Family unit having individual(s) with a physical disability or mental illness are more susceptible in a flood event	Hahn et al. (2009); Panthi et al. (2016); Sorg et al. (2018)
10	S2: Physical dependency ratio (dependents to total household size)	> 0.75 0.50 to 0.75 0.25 to 0.50 < 0.25	1 0.75 0.5 0.25	Younger adults are less susceptible compared to older people and children	Cutter et al. (2003); Hahn et al. (2009); Scheuer et al. (2011); Sorg et al. (2018); Lianxiao et al. (2019)
11	S3: Female to male ratio	>2 1 to 2 <1	1 0.66 0.33	Females are more susceptible due to their limited physical strength, social network and access to information resulted from traditional and cultural norms	Mustafa (1998); Yoon (2012); Jamshed et al. (2020b)
12	S4: Family type	Nuclear Joint	1 0.5	Nuclear families[14] are more susceptible to floods due to their limited societal resource and support compared to joint family	Rana et al. (2016); Ali et al. (2017); Jamshed et al. (2019b)
13	S5: Household's level of understanding of early warning system	Very low Low Moderate High Very high	1 0.8 0.6 0.4 0.2	Households that understand the early warning signs and signals are less susceptible to floods	Ahsan et al. (2014); Rana et al. (2016); (2018a)
14	S6: Time duration that household spent away from the village due to flood	>60 days 46-60 days 31-45 days 15-30 days <15 days	1 0.8 0.6 0.4 0.2	Long term displacement makes households more susceptible due to various social, financial and psychological complications	Mosel et al. (2013); Maria Pinto et al. (2014); Jamshed et al. (2020d)
15	S7: Household income (average per month)	<10,000 10,000 to 19,999 20,000 to 29,999 30,000 to 39,999 >=40,000	1 0.8 0.6 0.4 0.2	Low-income households are more susceptible to floods	Cutter et al. (2003); Shah et al. (2018); Hamidi et al. (2020b)
16	S8: Primary source of income	Daily wage labourers Farming (crop and livestock) Commerce and trade Government/ pension/ remittance	1 0.75 0.5 0.25	Daily wagers and farmers are most susceptible to floods	Cutter et al. (2003); Rana et al. (2018a); Hamidi et al. (2020b)

[14] Nuclear families are those consisting of parents and their children

17	S9: Households experiencing price inflation of goods	Yes	1	Increase in prices of necessities and other goods after flood makes households economically weak	Rashid (2000); Del Ninno et al. (2003) Skjeflo (2013); Jamshed et al. (2020d)
		No	0		
18	S10: Type of the house (construction material)	Mud house	1	Mud houses are more susceptible to flood compared to pecca	McElwee et al. (2017); Jamshed et al. (2019b); Hamidi et al. (2020b)
		Semi-pecca	0.66		
		Pecca	0.33		
19	S11: Limited access to improved sanitation facilities	Yes	1	Households are more vulnerable if they have restricted access to improved sanitation	Islam et al. (2013); Ahsan et al. (2014); Imran et al. (2019)
		No	0		
20	S12: Household without ownership of any means of transportation	No means	1	Households without any transportation means can hinder evacuation in case of a flood event	McElwee et al. (2017); Rana et al. (2018b)
		Have means	0		
21	S13: Level of access to telecommunication services (mobile, TV, internet)	Low	1	Limited access to communication facilities can hamper information exchange and affect susceptibility	Birkmann et al. (2008); Panthi et al. (2016); Qaisrani et al. (2018)
		Medium	0.66		
		High	0.33		
22	S14: Distance to the nearest health facility	>15 km	1	Proximity to a health facility can help in providing quick medical aids and make households less vulnerable	Mustafa (1998); Abbas et al. (2014); Sam et al. (2017)
		10 to15 km	0.75		
		5 to 10 km	0.5		
		<5 km	0.25		
23	S15: Distance to a paved road	>=4 km	1	Large distance to a paved road can restrict rescue, relief and evacuation operations as well as hamper access to market services	Abid et al. (2015); Ahmed et al. (2017); Jamshed et al. (2020d)
		3 km	0.75		
		2 km	0.5		
		<=1 km	0.25		
24	S16: Distance to nearest emergency services	>25 km	1	Distant emergency (rescue) services require more time to reach the affected location	Alexander (2002); Zhao et al. (2015)
		10 to 25 km	0.66		
		<=10 km	0.33		
25	S17: Poor quality of access roads	1= Extremely poor; 0 = Extremely good	1	Poor condition of access roads can affect the mobility of people and all other communications through road	Letsie et al. (2015); Flower et al. (2017); Jamshed et al. (2019b)
			0		
26	S18: Absence of basic goods of daily use in the nearby market during and after the flood	Unavailable	1	Absence of goods of daily usage in the local market affects the vulnerability of households	Del Ninno et al. (2003); Dewan (2015)
		Available	0		
27	S19: Inadequate availability of water for farming	Yes	1	Deficiency of water can reduce the farm output and affects the income of households.	Sam et al. (2017); Abid et al. (2016a); Ullah et al. (2017)
		No	0		

28	S20: Absence of safe drinking water	More than a month	1	Long term unavailability of safe drinking water after flood makes households more susceptible	Islam et al. (2013); Abid et al. (2016a); Qaisrani et al. (2018); Jamshed et al. (2019b)
		One month	0.66		
		Less than a month	0.33		
CAPACITY					
29	C1: Household head's education	University/ college	1	Household heads with education can easily access and understand information, are better equipped to communicate in case of emergency/ crisis and are more able to shift to different livelihoods	Eakin et al. (2008); Hahn et al. (2009); Paul et al. (2010); Handayani et al. (2017)
		Secondary School	0.75		
		Primary School	0.5		
		Illiterate	0.25		
30	C2: Household having members with multiple skills	Yes	1	Households with different skills can enable them to seek multiple sources/diversified income	Nhuan et al. (2016); Serrat (2016); Jamshed et al. (2019b)
		No	0		
31	C3: Household having relatives/friends living in the city	Yes	1	Households which have someone in nearby urban areas can give them refuge in a flooding event	Hahn et al. (2009); Boon (2014); Rana et al. (2016)
		No	0		
32	C4: Household with members having moved to cities for employment	2	1	Members of the household who have migrated to urban centres for employment after the flood can help in recovery. This multilocality of household is also seen as risk-sharing and livelihood strategy	Tacoli (2009); Dick et al. (2012); Aslam (2015); Bhattacharjee et al. (2018); Bernzen et al. (2019)
		1	0.66		
		0	0.33		
33	C5: Household with good relations with neighbours	Good relationship	1	Households with good relationships with neighbours can help each other in case of a flood event	Boon (2014); Serrat (2016); Shah et al. (2018)
		Not good relationship	0		
34	C6: Household living in the community (years)	<10 years	0.25	Households residing in a community can form stronger ties and have local knowledge	Cutter et al. (2003); Rana et al. (2018a)
		10 to 20 years	0.5		
		21 to 30 years	0.75		
		> 30 years	1		
35	C7: Household accessing the market, weather and water-related information more frequently	Yes	1	Households that frequently assess market, weather and water related information specifically during monsoon season (to manage to cultivation/harvesting) have more capacity	Abid et al. (2015); Abid et al. (2016b); Jamshed et al. (2020c)
		No	0		

36	C8: Household accessing agriculture extension services[15] more frequently	Yes	1	Households accessing agricultural extension services more often have higher capacities to protect their farmland and crops against floods	Abid et al. (2015); Abid et al. (2016b); Jamshed et al. (2020d)
		No	0		
37	C9: Household accessing agriculture or other credit more frequently	Yes	1	Households that access agriculture credit or other financial loans more often can rapidly recover their losses	Abid et al. (2015); Abid et al. (2016b); Jamshed et al. (2020d)
		No	0		
38	C10: Participation of any household's member in flood awareness seminars and training	Yes	1	Households that have attended flood training and awareness programs can develop adaptive/coping capacities	Mishra et al. (2010); Rana et al. (2018a)
		No	0		
39	C11: Economic dependency ratio (number of earning members to the household size)	>0.75	1	Households with higher economic dependency ratio can secure/save more financial earnings	Nhuan et al. (2016); Bhattacharjee et al. (2018); Jamshed et al. (2020d)
		0.50 to 0.75	0.75		
		0.50 to 0.25	0.5		
		<0.25	0.25		
40	C12: Household with more than one income source	Yes	1	Households with more than one source of income can increase their financial capacities	Eakin et al. (2008); Panthi et al. (2016); Jamshed et al. (2019b)
		No	0		
41	C13: Household with members employed outside the community (in number)	>=2	1	Households with members employed outside the flood-prone area can have a safe and sustainable source of income	Hahn et al. (2009); Pandey et al. (2012); Rana et al. (2018b)
		1	0.5		
		0	0		
42	C14: Household with the provision of financial aid against flood losses	Yes	1	Households with financial assistance from government/donor agencies can help in their recovery	Birkmann et al. (2008); Sam et al. (2017); Pandey et al. (2017); Jamshed et al. (2017)
		No	0		
43	C15: Household with savings	Yes	1	Savings can increase the capacity of the household to recover from a flooding event	Cutter et al. (2008a) Serrat (2016); Bhattacharjee et al. (2018)
		No	0		
44	C16: Household with the provision of basic amenities for relief and recovery	Yes	1	Households that get support from the public and private organization during and after a flood can help them to cope with the flood	Mustafa (2003); Arai (2012); Jamshed et al. (2017)
		No	0		

[15] Agriculture extension services offers knowledge based on scientific research and technical advices on agriculture to farmers to support agriculture production (Oakley et al. (1985)

45	C17: Rural development/ support programs by the government in the community	Yes No	1 0	Frequent rural development programs can increase the capacity of flood-affected rural victims	Brooks et al. (2005); Jamshed et al. (2020d)
46	C18: Household that have higher platform/plinth level than ground level	Yes No	1 0	Households that have raised the platform of the house are physically less vulnerable to future floods	Shah et al. (2017); Bhattacharjee et al. (2018)
47	C19: Household owning farmland	>10 5 to 10 acres <5 acres	1 0.66 0.33	Households that own larger farms have a higher capacity to deal with flooding events	Eakin et al. (2008); Ullah et al. (2016); Bhattacharjee et al. (2018)
48	C20: Household changing the variety of crops after a flood	Yes No	1 0	Households that change crop variety and plant crops which can mature before the flooding season have a higher capacity to secure their livelihood	Abid et al. (2016a); Ullah et al. (2017) Bhattacharjee et al. (2018)
49	C21: Household changing plantation/ sowing date of crops	Yes No	1 0	Households changing the planting dates due to the fear of flooding have more capacity	Abid et al. (2016a); Ullah et al. (2017); Pandey et al. (2017) Bhattacharjee et al. (2018)
50	C22: Household adopting crop diversification methods	Yes No	1 0	Households that are adopting crop diversification method have more capacity	Abid et al. (2016a); Pandey et al. (2017); Bhattacharjee et al. (2018); Jamshed et al. (2020c)

The selected indicators represent different components of vulnerability at the household level, and help to assess vulnerability following a flood. In this study, degree of exposure also consisted of the extent of losses/damages of assets, which is associated with their position and location (Penning-Rowsell et al., 2005; Birkmann et al., 2008). These aspects represent the spatial dimension and were therefore associated with the degree of exposure. Households that do not receive flood warnings were included as an indicator of exposure, since flood warnings affect people's location and hence their evacuation. For example, a warning can result in people moving themselves and their major assets to safer locations; thus, the degree of exposure can be reduced (Penning-Rowsell et al., 2005). Exposure also includes the number of past flood exposures experienced by households. As described in Chapter 2, an area's general exposure can be related to hazards

(Birkmann, 2006b, p. 38), but within that specified area, people and homes (exposed elements) are differently exposed to floods; this is represented by the degree of exposure. As such, past flood experiences embody the extent of exposure. Moreover, this assessment is different than evaluating risk, as it does not include an assessment of hazards (e.g. flow velocity, sedimentation load, and inundation depth and duration, as well as their probabilities).

3.4.2.3.3 Index calculation and composition

This study used a weighted average index technique (using equal weights for each component of vulnerability) to calculate the index values. Equal weighting increases transferability and transparency, and allows for easier communication with stakeholders and decision-makers (Cutter et al., 2010; Birkmann et al., 2016a; Karagiorgos et al., 2016; Sorg et al., 2018). Further, factor analysis justifies equal weighting of vulnerability components, since factor loadings of exposure, susceptibility and capacity were 0.919, 0.872 and -0.866, respectively, which did not reveal a significant difference. The magnitude of differences between these values was similar to previous research that justified equal weighting using the same approach (e.g. Welle et al., 2015a; Sorg et al., 2018). The composite index values for exposure (EI), susceptibility (SI) and capacity (CI) were calculated using Equation 3. Each vulnerability component was calculated for each case study, which represents rural settlements and their inhabitants in the city's hinterland. The vulnerability was determined using Equation 4, which is a widely used equation for flood vulnerability indices (Balica et al., 2009; Dinh et al., 2012; Rana et al., 2016, 2018a; Shah et al., 2018; Nasiri et al., 2019; Hamidi et al., 2020b; Hamidi et al., 2020a). An example of the index calculation is provided in Annex D.

$$\text{Composite Index} = (W_1+W_2+W_3+ \ldots W_n)/n = \sum_{i=1}^{n} Wi/n \qquad \text{Equation 3}$$

where W_1 to W_n are respective standardised scores/values of indicators, and n is the number of indicators used to compute the composite index.

$$\text{Vulnerability index (VI)} = \frac{\sum_{i=8}^{n} EIWi/n \times \sum_{i=20}^{n} SIWi/n}{\sum_{i=22}^{n} CIWi/n} \qquad \text{Equation 4}$$

where

EI is the exposure index
SI is the susceptibility index
CI is the capacity index

3.4.2.3.4 Index validation

Reliability analysis that measures the internal consistency of composite indicators was carried out to establish if the selected indicators were appropriate to describe vulnerability. Cronbach's alpha (c-alpha) is an accepted method to gauge the internal consistency of composite indicators (OECD, 2008, p. 72). A c-alpha value higher than 0.6 is recommended depending on the discipline (OECD, 2008; Cutter et al., 2014; Sorg et al., 2018). Additionally, a sensitivity analysis was performed to analyse which indicators (the input factors) would have significant, little, or no impact on overall vulnerability (the output factor). Thus, sensitivity analysis increases the confidence in the composite vulnerability index. Global sensitivity analysis was used as it takes into account the uncertainty of every single indicator (see Welle et al., 2015a; Feldmeyer et al., 2020). The analysis was conducted in *RStudio* using the *sens* function in *tgp package*.

3.4.2.4 Other inferential statistics

Other statistical analyses were performed, particularly on index values (see Figure 3.9). In order to examine the flood vulnerability level of the rural population around cities of different sizes, the index values were classified into quartiles. The values in the first quartile (*Q1*), second quartile (*Q2*), third quartile (*Q3*), and fourth quartile (*Q4*) represent the low, moderate, high, and very high levels of vulnerability. In addition, Pearson's chi-square test (Sahu, 2013b) was applied to clarify if a difference in the level of rural vulnerability in relation to cities of different sizes was significant or not (Chapter 6). As for studying the effect of distance to the city on the rural population's vulnerability, the index values were divided into two groups for each case study (rural settlements), depending on the distance to the city, such as being close to or far from it. The vulnerability of villages (settlements) near the city and far from the city was also scrutinised. The Mann-Whitney U test (Sahu, 2013b, p. 164) was employed to determine how significant the difference would be between the vulnerability of two proximity groups. Further, correlation analysis (OECD, 2008, p. 81) was performed to understand the relationship between distance to the city and the level of rural vulnerability to flood hazards (Chapter 6). In addition, correlation analysis between structural-livelihood modifications and changes in linkages was carried out to establish if shifts in rural-urban linkages were indicative of other changes (Chapter 7). The outcomes are presented in graphs, diagrams, maps and tables.

3.5 Challenges and limitations

- *Language and cultural barriers*

Language and the cultural setting were key barriers for conducting the survey at all three case study sites. The members of the target population spoke Saraiki and were culturally conservative, which means that Saraiki-speaking enumerators (both male and female) had to collect household information from male and female respondents. To ensure female participation in the household survey, female students were also shortlisted as enumerators. However, considering the cultural aspects and the problem of travelling and accommodation, female enumerators were reluctant to participate in data collection. Accordingly, only male enumerators were hired. In the absence of female enumerators, the survey could not be administered to female-headed households, since local customs and traditions do not allow females to interact with male enumerators. However, this did not significantly influence the results, as the proportion of female-headed households in Punjab is only between 7% and 8%, which could be even less in rural areas (BSP, 2016).

- *Problems related to participation in the survey*

A major challenge was to convince households to participate in the survey. Some households were reluctant to participate after they were informed that this study was being conducted for academic purposes and not for any aid distribution. The presence of an official from the local government helped to resolve such issues.

- *The timing of conducting a household survey*

Since it was harvest time for crops during the time of the survey, the majority of the respondents were busy harvesting (Figure 3.10). Considering their work schedule, the length and time for responding to the questions were rather long. Therefore, many respondents left before answering all questions. This issue was not anticipated before going into the field.

Figure 3.10. Farmers harvesting crops during the time of the survey
(Field survey, 2017)

- *Accessibility issues*

Accessibility to flood-affected rural settlements was another challenge. Most of the questionnaires from the flood-affected villages with close proximity to the city were easily gathered, since these villages were accessible by car. However, conducting interviews in villages in remote areas was challenging due to the dispersed nature of the settlements and a lack of proper transportation routes; the author and the enumerators had to travel several kilometres by motorbike, as well as on foot.

Chapter 4
The respondents' socio-economic profiles, flood impacts and responses

The parts of this chapter (including figures and tables) have been published in a book and a journal (see the citation below):

Jamshed, A., Birkmann, J., McMillan, J., Rana, I.A. and Lauer, H. (2020) "The Impact of Extreme Floods on Rural Communities: Evidence from Pakistan" in Leal, W.F., Nagy, G., Borga, M., Chavez, D. and Magnuszewski, A. (Eds.), Climate Change, Hazards and Adaptation Options: Handling the impacts of a changing climate., Climate Change Management, 1st ed., Springer, Cham, 585-613. DOI: https://doi.org/10.1007/978-3-030-37425-9_30. Publisher: Springer.

Jamshed, A., Birkmann, J., Joanna, M.M., Rana, I.A., Feldmeyer, D., Sauter, H (2021) "How do Rural-urban Linkages Change After an Extreme Flood Event? Empirical Evidence from Rural Communities in Pakistan" Science of the Total Environment, Vol 750C, 141462. DOI: https://doi.org/10.1016/j.scitotenv.2020.141462. Publisher: Elsevier

It was vital to grasp the background information on the respondents' socio-economic conditions (age, household size, income etc.), impacts of flooding, and how households respond to such impacts, since these are key factors that influence rural households' linkages with cities, as well as their vulnerability to flooding (as described in Chapter 2).

Extreme flood events in Pakistan have had severe impacts in rural areas, especially on populations living along rivers. Floods have destroyed homes, crops, farmland and community infrastructure, as indicated in chapters 1 and 3. Such ramifications, both direct and indirect, can lead to several changes in society (Chapter 2). Changes after extreme events or disasters can affect the capabilities of communities, households and individuals, and thus condition vulnerability (Birkmann et al., 2010; Birkmann, 2011).

Against this backdrop, this chapter provides information on the socio-economic characteristics of the households that took part in the study. It also explains the impact of floods and their subsequent responses (in the form of changes to structural and livelihood strategies). This chapter answers two important RQs: (a) What are the direct and indirect impacts of flood events on rural farming households in Pakistan? and (b) How do rural households respond to the effects of an extreme flood event?

This chapter is based on empirical research conducted in the three selected study sites in Punjab: Darya Khan, Muzaffargarh and Multan (see Chapter 3). Using descriptive statistics, a comparison was made between case studies concerning the respondents' socio-economic attributes, flood impacts and the structural-livelihood changes they adopted following a flood. The analysis showed similarities and differences of the effects on the capacities of different households in the case study areas.

The chapter is divided into four sections. The first examines the respondents' demographics and socio-economic characteristics. The second part presents a comprehensive analysis of flood damages, followed by an interpretation. The third section describes public and private organisations' responses to flooding, as well as changes carried out by households in terms of livelihood strategies. The last section summarises the findings and their discussion. Overall, the chapter provides important insights into households' socio-economic status, the impacts of flooding and responses to those impacts.

4.1 The socio-economic profiles of the surveyed households

This section sheds light on the diverse demographic, social and economic aspects of the surveyed households. These features include the age of the household head, the male-to-female ratio within the household, household size, family type, education, income, housing conditions and farmland ownership. It is vital to examine all of these elements in rural-urban linkages and to determine rural vulnerability to flooding.

4.1.1 Age of the household head and gender ratio

Age is one of the most critical factors, as it shapes views and ideas about several things, including the decision to migrate, local knowledge (which also relies on traditional farming and construction methods), and the dependency ratio. Household heads are the decision-makers in the family, and the age of the household head can be important in this regard. Male members were the head of the household in all case studies. More than 50%

of households in all case studies were headed by members aged between 36 and 65 years old. A small difference was observed among case studies in terms of the average age of household heads. According to Table 4.1, the mean age of the household head was 46 years in Darya Khan, 48 years in Muzaffargarh and 49 years in Multan. The male-to-female ratio differed by study area; the mean ratio was highest in Multan (1.38), followed by Muzaffargarh (1.26) and Darya Khan (1.19). Only 36% of households in Darya Khan, 32% in Muzaffargarh, and 23% are Multan had more females than males. Overall, the number of males was higher than females in the surveyed rural households.

Table 4.1. The table shows the age of household head and male to female ratio in surveyed villages

Variables	**Classes**	**Darya Khan (N=114)**		**Muzaffargarh (N=115)**		**Multan (N=96)**		**Overall (N=325)**	
		Freq.	%	Freq.	%	Freq.	%	Freq.	%
Age of household head	<20	2	1.8	4	3.5	5	5.2	11	3.4
	20 to 35	25	21.9	21	18.3	11	11.5	57	17.5
	36 to 50	45	39.5	33	28.7	29	30.2	107	32.9
	51 to 65	23	20.2	30	26.1	32	33.3	85	26.2
	>65	19	16.7	27	23.5	19	19.8	65	20.0
	Total	114	100.0	115	100.0	96	100.0	325	100.0
	Mean	46.08		48.41		49.21		47.83	
	Std. Dev.	14.103		15.314		14.556		14.689	
Male to female ratio	<1	41	36.0	37	32.20	22	22.90	100	30.8
	1 to 2	57	50.0	57	49.60	56	58.30	170	52.3
	> 2	16	14.0	21	18.30	18	18.80	55	16.9
	Total	114	100.0	115	100.00	96	100.00	325	100.0
	Mean	1.19		1.26		1.38		1.27	
	Std. Dev.	0.614		0.683		0.792		0.697	

(Household survey, 2017)

4.1.2 Household size and family type

Regarding household size, rural households were characterised by large family size (i.e. often more than eight people). In all case study areas, more than 65% of the respondents had a household size between 5 and 10 members. Small household sizes (less than 5 people) comprised 5.3% in Darya Khan, 10.4% in Muzaffargarh and 6.3% in Multan (see Table 4.2). Family type indicates the mutual understanding and togetherness of household members. The predominant family type was nuclear in all case study areas. Joint family structures (i.e. 2 to 3 families living together) were found in 39% of households in Darya Khan, 43% in Muzaffargarh, and 38% in Multan (see Table 4.2). Joint families were found to have more strength in numbers and to have wider access to societal resources (Rana et al., 2018b).

Table 4.2. Differences among case studies concerning household size and family type in surveyed villages

Variable	Classes	Darya Khan (N=114)		Muzaffargarh (N=115)		Multan (N=96)		Overall (N=325)	
		Freq.	%	Freq.	%	Freq.	%	Freq.	%
Household size	>10	32	28.1	28	24.3	27	28.1	87	26.8
	5 to 10	76	66.7	75	65.2	63	65.6	214	65.8
	<5	6	5.3	12	10.4	6	6.3	24	7.4
	Mean	8.80		8.40		8.44		8.55	
	Std. Dev.	3.243		3.581		3.270		3.369	
Family type	Nuclear	70	61.4	66	57.4	60	62.5	196	60.3
	Joint	44	38.6	49	42.6	36	37.5	129	39.7

(Household survey, 2017)

4.1.3 Education attainment

Educational qualifications were categorised as per Pakistan's education system. The situation of educational attainment in Table 4.3 demonstrates that educational attainment differed among households significantly.

Table 4.3. Education attainment status of households in surveyed villages

Variable	Classes	Darya Khan (N=114)		Muzaffargarh (N=115)		Multan (N=96)		Overall (N=325)	
		Freq.	%	Freq.	%	Freq.	%	Freq.	%
Education attainment	Illiterate	77	67.5	66	57.4	38	39.6	181	55.7
	Primary	22	19.3	21	18.3	34	35.4	77	23.7
	Secondary	11	9.6	23	20.0	16	16.7	50	15.4
	College and above	4	3.6	5	4.3	8	8.4	17	5.3

(Household survey, 2017)

A large proportion of households did not receive any kind of education in all case study areas. The level of education was lowest in the rural settlements of Darya Khan, where 68% of respondents had received no education. In Muzaffargarh, 43% of the surveyed rural households had received some kind of education. Educational levels were highest among the rural households of Multan, with 60% of households having attained education. Most of the households that attained education had received primary or secondary level education. The highest educational attainment among rural households in Multan can be related to better education facilities of different levels compared to other districts, and might also be influenced due to the fact that Multan is a large city.

4.1.4 Primary income source and household income

Sources of income were categorised into wage labour, farming, commerce/trade, remittances and government (see Table 4.4). The primary source of income in all study areas was farming; more than 70% of rural households were involved in crop or livestock farming. Non-farming sources of income included services, labour and remittances. Among non-farming income sources, remittances were the most significant in Muzaffargarh (15%), whereas labour was more common in Multan (10%). However, households with a non-farming primary income source were involved in farming as a secondary or tertiary source of income. This suggests that some households have multiple sources of income.

Table 4.4. Primary income sources and family income of households in surveyed villages

Variables	Classifications	Darya Khan (N=114)		Muzaffargarh (N=115)		Multan (N=96)		Overall (N=325)	
		Freq.	%	Freq.	%	Freq.	%	Freq.	%
Primary source of income	Government	4	3.5	4	3.5	6	6.2	14	4.3
	Remittance	6	5.3	17	14.8	5	5.2	28	8.6
	Commerce/trade	10	8.8	2	1.7	1	1.04	13	4
	Farming	88	77.2	84	73.0	74	77.1	246	75.7
	Wage laborer	6	5.3	8	6.9	10	10.4	24	7.4
Family income (in PKR)[16]	<10000	17	14.9	24	20.9	13	13.5	54	16.6
	10000-19999	52	45.6	50	43.5	35	36.5	137	42.2
	20000-29999	24	21.1	20	17.4	26	27.1	70	21.5
	30000-39999	9	7.9	6	5.2	9	9.4	24	7.4
	>39999	12	10.5	15	13.0	13	13.5	40	12.3
	Mean	18100.88		19017.39		21802.08		19518.46	
	Std.Dev	10502.461		13600.169		14725.288		13018.018	

(Household survey, 2017)

The results regarding income level revealed that monthly household income varied significantly among the rural households of the selected study sites (see Table 4.4). More than 60% of households in Darya Khan and Muzaffargarh belonged to the lower income group (i.e. below PKR 20,000) compared to 50% in Multan. Overall, the mean monthly

[16] 1 US dollar is Pakistani Rupees (PKR) 139 in March 2019

income was lowest in Darya Khan (PKR 18,100), followed by Muzaffargarh (PKR 19,000) and was highest in Multan (PKR 22,000). Thus, the economic situation of rural households was better in Multan than the other two case study regions.

4.1.5 House type and ownership of farmland

Table 4.5 presents information on housing conditions and land ownership, which relate to the aspects of susceptibility and capacity. Regarding housing conditions, the majority of residents live in semi-adobe or adobe houses in Darya Khan (72%), Muzaffargarh (77%) and Multan (58%). Nevertheless, the situation was slightly better in Multan, where almost 42% of people live in pucca houses (made from reinforced materials; i.e. burnt bricks and concrete). In the context of the ownership of farmland, a large number of households owned agricultural land, while only 6.2% were landless among all case studies. However, the size of land varied among the case studies. In Muzaffargarh, around 65% were small landholders (owning 1 to 5 acres of farmland), while in Darya Khan and Multan, 46% and 44% were small landholders, respectively. In Darya Khan, large landholders (more than 10 acres) comprised the highest proportion (19.3%) compared to the other two case studies. A significantly higher number of rural households in Darya Khan was reported to be landless.

Table 4.5. Housing conditions and agriculture land ownership status of households

Variables	Classes	Darya Khan (N=114)		Muzaffargarh (N=115)		Multan (N=96)		Overall (N=325)	
		Freq.	%	Freq.	%	Freq.	%	Freq.	%
House condition	Katcha	22	19.3	20	17.4	13	13.5	55	16.9
	Semi Pecca	60	52.6	68	59.1	43	44.8	171	52.6
	Pecca	32	28.1	27	23.5	40	41.7	99	30.5
Ownership of agriculture land	Landless	13	11.4	2	1.7	5	5.2	20	6.2
	1-5 acres	52	45.6	74	64.3	42	43.8	168	51.7
	6 to 10 acres	27	23.7	26	22.6	41	42.7	94	28.9
	> 10 acres	22	19.3	13	11.3	8	8.3	43	13.2

(Household survey, 2017)

4.2 The impacts of flooding on the surveyed households

This section provides an assessment of flood impacts on rural households in the three case study areas. First, the number of floods experienced and their impacts on the households in the last ten years were examined. Thereafter, direct and indirect effects experienced by households in the most recent, worst flood event were analysed.

4.2.1 The impacts of flooding: 2007 – 2017

Flooding had varied outcomes for the residents in the case study areas (see Figure 4.1). Around 73% of households experienced more than one flood event between 2007 and 2017 (inclusive). Rural households in Multan experienced the greatest incidence of floods. More than 80% of the households interviewed experienced more than four flood events in a ten-year period (2007–2017). In Muzaffargarh, 57% of households experienced more than four floods, whereas in Darya Khan, 76% experienced only one flood event.

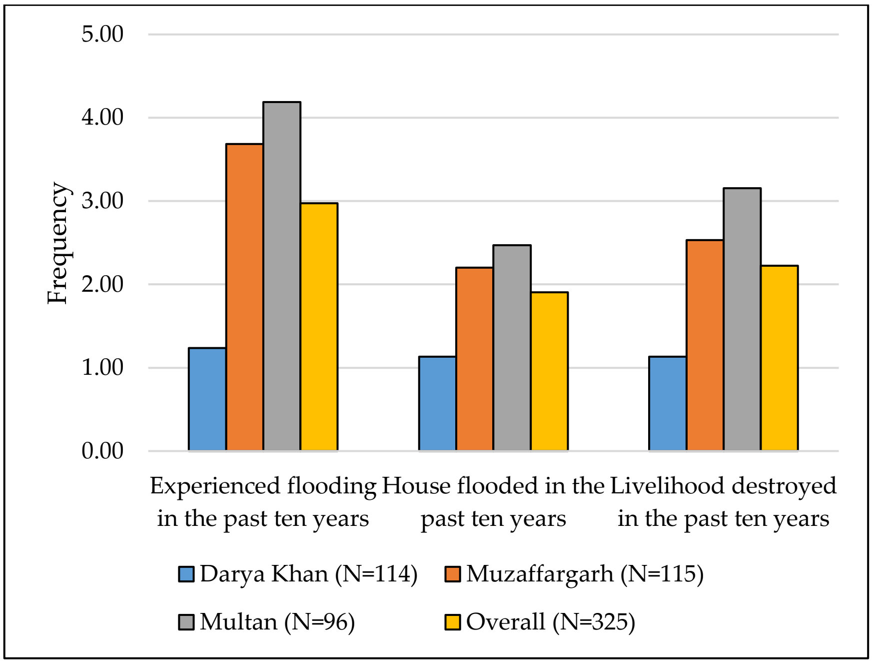

Figure 4.1. The average number of floods experienced by households between 2007 and 2017, the number of times flood reached inside the house and the number of times livelihood destroyed by flooding between 2007 and 2017.
(Household survey, 2017)

Houses were inundated once in Darya Khan and more than twice in Muzaffargarh and Multan. Flood events in the last ten years have also heavily affected rural livelihoods. These consequences include losses of, and damages to, crops, tools, livestock and shops. On average, livelihood assets have been destroyed once in the past ten years in Darya Khan, 2.5 times in Muzaffargarh and 3.2 times in Multan. The results of the household survey imply that all households and their livelihoods have been exposed to flood hazards.

4.2.2 The impacts of the most recent, worst flood event

The households were adversely impacted in all three case studies by the most recent extreme flood event. In Darya Khan, all households reported that the 2010 flood event was the worst, whereas in Muzaffargarh and Multan, some households reported 2014 as the worst flood event. Flood events have affected rural households both directly (e.g. damages of assets) and indirectly (e.g. disruption of access to a market).

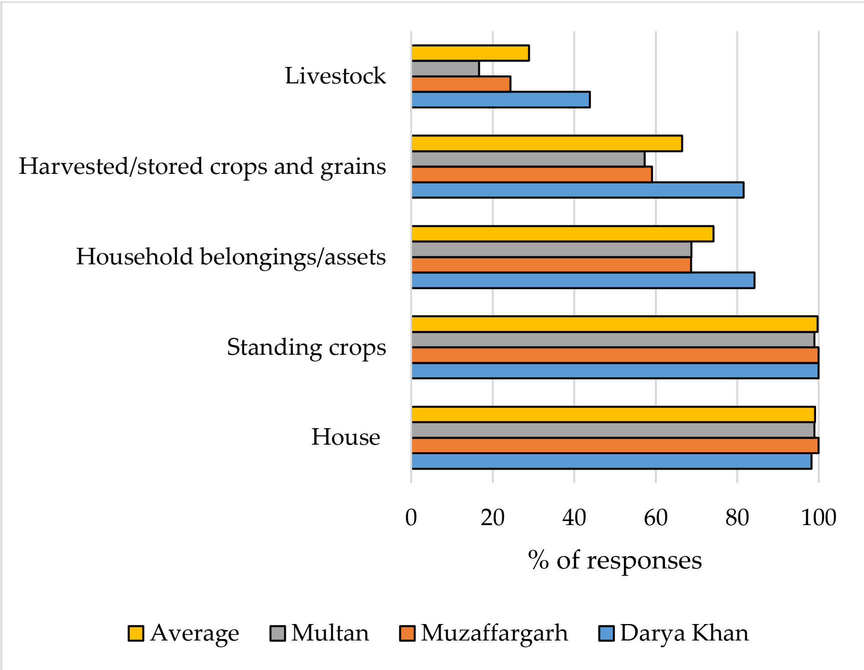

Figure 4.2. Comparison of direct impacts of the extreme flood event in case study areas (Own figure, 2020 already published as Jamshed et al., 2021)

In terms of direct impacts, flooding has caused severe losses/damages to housing structures, households' belongings, harvested crops, standing crops and livestock. Moreover, floods have displaced the population for longer durations. Figure 4.2 shows that damages to housing structure and standing crops were highest among all case study areas, where almost all respondents reported that their homes and standing crops were completely or partially destroyed by a flood. The damage to, and loss of, household belongings and assets were highest in Darya Khan, where 84% of respondents completely or partially lost their belongings/assets. This proportion was 69% both for Muzaffargarh and Multan, where the majority experienced partial damages to household assets. The case with the losses/damages of harvested crops/stored grains kept for sale or household consumption was similar. The proportion of this loss was 82% in Darya Khan, 59% in Muzaffargarh and 57% in Multan. Most households experienced a partial loss of harvested or stored crops. In terms of the loss of livestock, the majority of households in Muzaffargarh (75%) and Multan (83%) did not experience any losses, whereas 44% of households in Darya Khan experienced a (partial) loss of livestock.

In addition, flooding caused massive displacement in all three case study areas. Almost 76% of households in Darya Khan, 71% in Muzaffargarh and 79% in Multan, respectively, were displaced for more than a month due to major floods (see Table 4.6). This indicates the severity of an extreme flood event where water remained in the area for more than a month, and in some places for more than two months. Even though floods quickly receded in some places (Darya Khan), people were unable to return due to a lack of access. Affected and displaced households took refuge upon flood dykes, in relief camps and with relatives and friends (see Annex E). In Darya Khan and Multan, most of the people went to relief camps, as well as relatives and friends in nearby villages and cities. In Muzaffargarh, many flood-affected households stayed on flood dykes and relief camps in the nearby city (see Annex E). This signals the strength of the social ties of flood-affected households with their relatives and friends, who helped them for the duration of the flood event.

Table 4.6. Duration of households' displacement due to the last worst flood event

Duration of displacement	**Darya Khan (N=114)**		**Muzaffargarh (N=115)**		**Multan (N=96)**		**Overall (N=325)**	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Not displaced	1	0.9	3	2.6	6	6.3	10	3.1
<15 days	3	2.6	4	3.5	0	0.0	7	2.2
15-30 days	23	20.2	26	22.6	14	14.6	63	19.4
31-45 days	12	10.5	17	14.8	20	20.8	49	15.1
46-60 days	35	30.7	23	20.0	40	41.7	98	30.2
>60 days	40	35.1	42	36.5	16	16.7	98	30.2

(Household survey, 2017)

Flooding indirectly affects transportation costs to cities, the market prices of goods and farm inputs (e.g. fertilisers, seeds, groceries), agricultural land, water availability and crop productivity (see Figure 4.3). Households in Darya Khan and Muzaffargarh (95%) and Multan (78%) experienced an increase in transportation costs to cities after flooding. There were many households, especially in Darya Khan (68.4%) and Muzaffargarh (75.7%), that reported an increase in the prices of goods and farm inputs after a flood event. Extreme flooding also resulted in farmland degradation. In Darya Khan, 2.6% of households reported that their farm was degraded because of floods, while 43% of households reported the same problem in Muzaffargarh and Multan. In Darya Khan, limited agricultural land degradation was due to upstream locations and dykes that did not overflow. Thus, the water did not stay longer there, as in Muzaffargarh and Multan. An inadequate supply of water for farming and drinking purposes was also reported by some households. Around 17% of households in Darya Khan, 22% in Muzaffargarh and 23% in Multan, respectively, experienced an inadequate supply of water after flooding due to severe damage to the water supply infrastructure. Households in Muzaffargarh (77.4%), Darya Khan (62%) and Multan (45%) also reported a decrease in crop production after floods. Reduced crop productivity can be affected by one or more direct and indirect impacts. Overall, the survey results underscored that negative flood impacts are particularly high in Darya Khan and Muzaffargarh as compared to Multan.

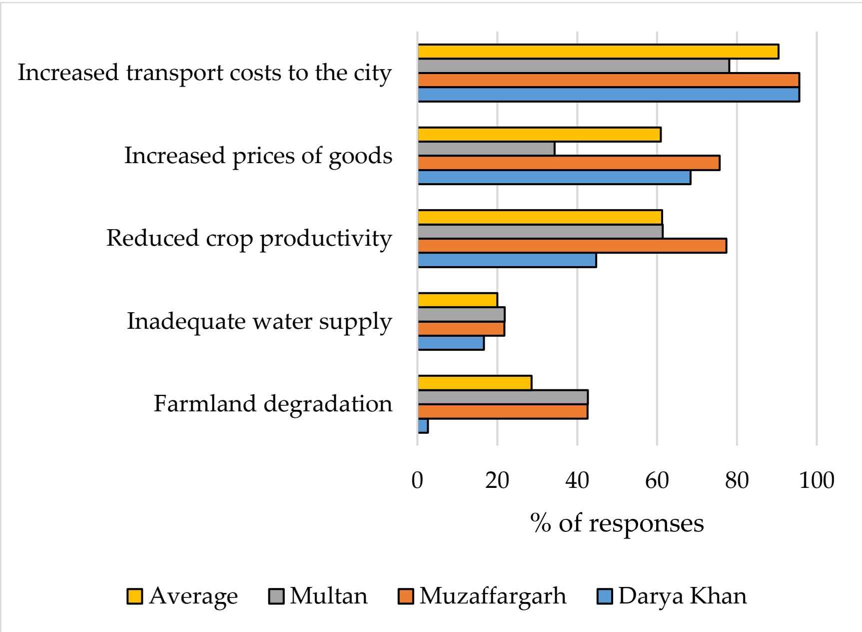

Figure 4.3. Comparison of indirect impacts of the extreme flood event in case study areas (Own figure, 2020 already published as Jamshed et al., 2021)

In sum, flood events have had various direct and indirect impacts on households in the selected case study areas. Rural flooding severely impacts housing structures, standing crops, household belongings and other assets. Most damages are associated with immovable assets like houses and standing crops. Indirect flood impacts, in the form of price inflation and reduced farmland productivity, have further aggravated the situation. Damage to road infrastructure was observed, which increased the cost of transportation services. In Darya Khan and Muzaffargarh, the availability of limited transportation options also resulted in its high cost. Zyck et al. (2015) also ascribed higher transportation costs to an increase in demand for transportation services after a flood by affected households, as well as aid organisations. Increasing demand for household goods and farm inputs after a flood, as well as a shortage of goods due to damaged supply routes, caused price inflation, especially in Muzaffargarh and Darya Khan. Zyck et al. (2015) maintained that this increase in the prices of goods and services was also due to illegal profiteering by traders in the city. The low proportion of price inflation in Multan was because of large markets with significant stocks, as well as unaffected supply routes. In addition, flood events have damaged the farms of rural households due to the deposition of sand or stagnant floodwater for a longer period. Floods damaged water infrastructure (e.g. hand pumps, tube wells and water channels), which led to low quantities of water being available for use for household and farm purposes. These findings are supported by other studies (e.g. Jamshed et al., 2017 and Ullah et al., 2019). Direct and indirect flood impacts were severe and had significant social and economic effects on rural households, thus prompting several changes in the community (see Section 4.3.2 for structural and livelihood changes, and Chapter 5 for changes in rural linkages with cities).

4.3 Response to flooding in rural areas of Pakistan

4.3.1 Immediate responses from the government and donors

Both government and non-governmental relief organisations respond during and after a flood to provide relief to victims. The household survey revealed that these organisations first offer support for basic needs like food and non-food items[17], which helps in the recovery of losses/damages by providing victims with financial aid, building materials, seeds and fertiliser. More than 90% of households in Darya Khan, 87% in Muzaffargarh and 80% in Multan received at least one kind of support from relief or donor organisations. Food items for relief and financial aid, building materials, and seeds/fertilisers were widely distributed (see Figure 4.4).

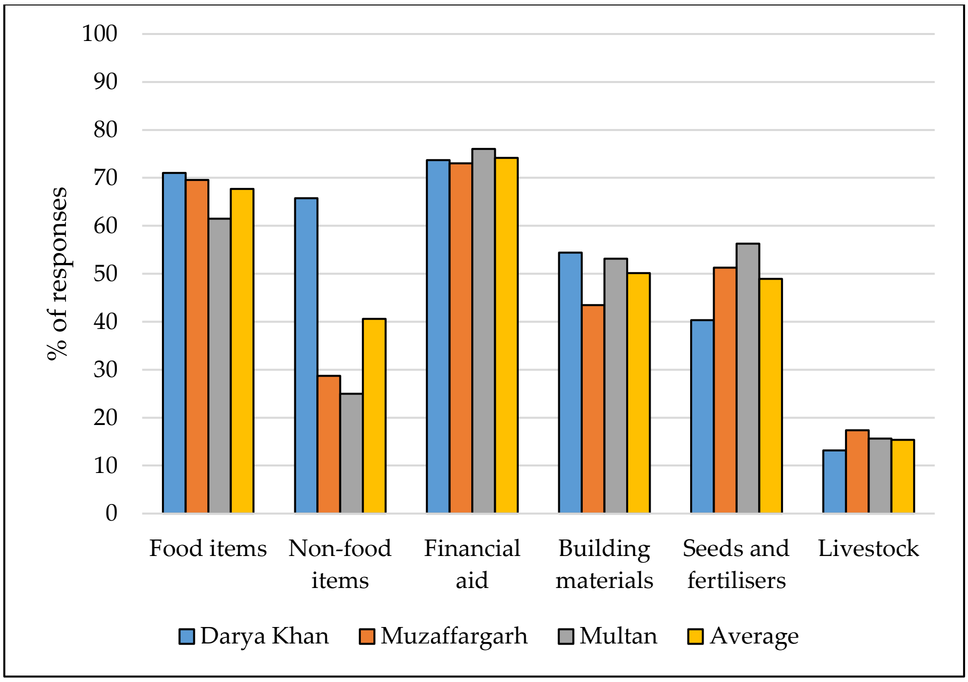

Figure 4.4. Percentage of households that got multiple relief and recovery items during and after the flood
(Household survey, 2017)

Households in Darya Khan received more support in terms of food items, non-food items and building materials, which could be associated with the extent of losses/damages to household assets (see Section 4.2.2). Households in Multan received more support in terms of financial aid and farm inputs. This may be because the city of Multan's district administration has more financial resources, and is home to several agricultural organisations and fertiliser industries that have helped local flood-affected households (Ahsan et al., 2009). However, the extent of relief and recovery support differs among the

[17] Non-food items 'include essential household items such as mattresses, blankets, plastic sheets, containers for water, cooking utensils and hygiene kits' (UNHCR (2016).

case study areas, especially for the provision of non-food items, building materials and seeds/fertilisers for cropping.

4.3.2 Changes to structures and livelihood practices

Extreme flooding led many rural residents to modify the structures of their homes, as well as their livelihood practices (see Figure 4.5). In terms of structural modifications, 61% of households in Darya Khan, and 74% in Muzaffargarh and Multan each, modified their housing structures, either regarding changes in the construction materials of a home, or increasing the height of the plot. Some households opted for both structural types of modifications. Around 50% of households in Darya Khan and Muzaffargarh, and 62.5% of households in Multan, changed the construction materials of their homes in order to better withstand future floods. Similarly, 25%, 47% and 48% of households in Darya Khan, Muzaffargarh and Multan, respectively, have raised the platforms of their reconstructed homes (between 2 and 4 meters). A lower proportion of households adopting this measure in Darya Khan can be attributed to limited financial ability and knowledge.

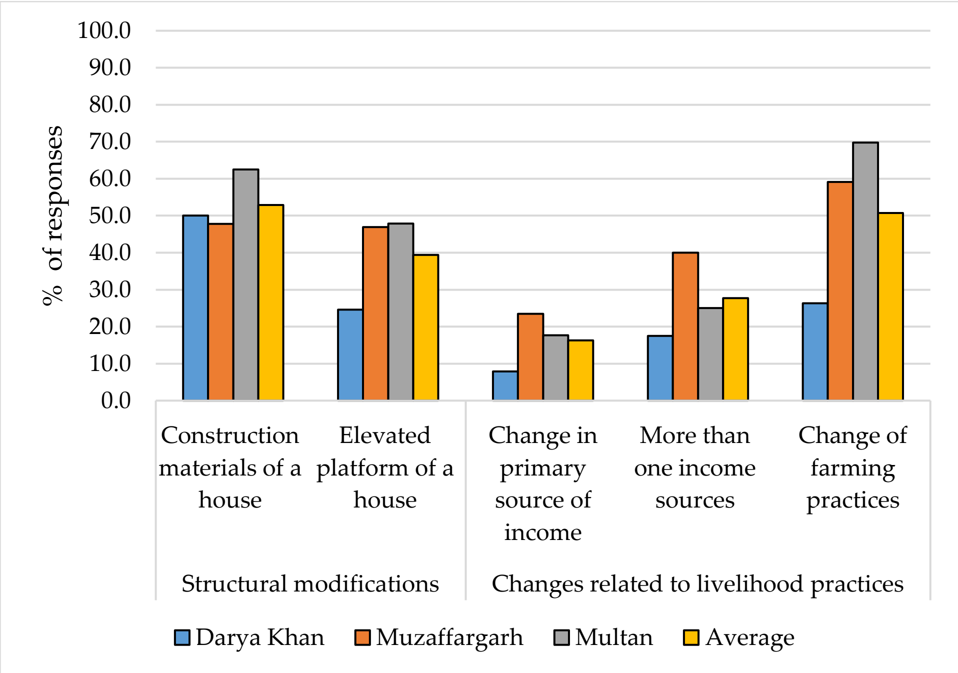

Figure 4.5. Structural and livelihood changes following the flood event in case study areas (Household survey, 2017)

Devastating flood events also resulted in changing livelihood practices in the form of shifts in primary occupation (16.3%), adopting multiple income sources[18] (28%), and changes in farming practices (51%). The highest changes in primary occupation and adopting multiple sources of income were noticed in Muzaffargarh, followed by Multan. The majority of people who work in farming adopted other occupations after a flood, such as labourers or working in commerce. In addition, following a flood, there was an increase in the number of households that were diversifying their incomes by engaging in daily wage jobs or commerce. The diversification of income was also associated with households' migration patterns.

One of the main changes in livelihood practices was the influence on farming practices. Almost all of the households surveyed were involved in farming as a primary, secondary or tertiary occupation, and some households had changed farming practices since experiencing flooding. In Darya Khan, 26.3% of households, in Muzaffargarh, 59.1% and in Multan, 69.8% altered their farming practices. Households opted to change the type of crop as well as variety. Major changes were seen in Muzaffargarh and Multan, where 44% and 46% of households, respectively, had grown multiple crops. In addition to traditional crops, farmers were growing vegetables, which have a shorter maturity period and can be harvested before the flood season. However, the use of this adaptation option remained limited, especially in Darya Khan, where only 11% diversified their crops. A significant number of farmers in Muzaffargarh and Multan shifted the plantation and sowing dates of crops to take into account the potential of future flooding. Households started growing the same crops (e.g. sugarcane, wheat, rice, maize and cotton), but with different varieties, which can be sown late in the monsoon period and grow more quickly. Overall, Multan has the highest proportion of changing all types of cropping pattern adaptations (see Annex E for different farming practices).

Overall, structural and livelihood changes were highest in Multan and Muzaffargarh. The lower proportion of households adopting these changes in Darya Khan could be because

[18] Multiple sources of income indicate that a household is involved in more than one occupation for income earning purposes, such as farming and wage labour or farming and commerce.

of: (a) lower income and educational levels; (b) limited opportunities provided in the nearest city and other neighbouring rural settlements for income diversification; (c) smaller and less specialised markets that provide information and material resources for changing cropping patterns; and (d) the perception that large floods will not hit this area again (as reported by several households). In contrast, farm degradation (due to sand deposits and waterlogging) and reduced crop productivity were higher in Muzaffargarh and Multan, which might have influenced higher livelihood changes.

To summarise, in response to these adverse flood impacts, households modified structures and adopted more livelihood options. The majority of households previously had mud homes, which are structurally more vulnerable to flooding and were severely damaged. Following flooding, households changed the construction materials that they used to rebuild their homes, using burnt clay or concrete bricks. The height of extreme flooding also influenced households' decision to elevate the ground floor of their homes. These structural shifts increased rural households' resilience to future flood events (Shah et al., 2017; Ahmad et al., 2020). Immense direct and direct impacts caused farmers to adopt other occupations; for instance, working as labourers or in commerce. Extreme devastation of crops also led farmers to alter agricultural practices by changing the crop variety, type and plantation date, as well as by diversifying their crops. These livelihood adjustments are important strategies to improve the capacity to cope with and adapt to future floods (Ayeb-Karlsson et al., 2016; Ullah et al., 2019). Thus, these changes can be instrumental in reducing future vulnerability.

4.4 Summary

The analysis of households' socio-economic characteristics, the impacts of flooding, and the subsequent changes adopted provide interesting insights. Socio-economic attributes (such as educational attainment status and income level) were different between the case study areas, while some traits were quite similar, such as household size and family type. Key differences were noticed in terms of education and income level in Multan, where many households were more educated and had higher income levels compared to households in the other case study areas. In terms of impacts, housing structures and crops were massively damaged in all case study areas, while indirect damages were highest in Darya Khan and Muzaffargarh. The duration of population displacement was different in all case studies. A longer duration of inundation in villages, limited access in returning to one's home, the destruction of housing structures, and the provision of adequate facilities in relief camps resulted in longer periods of population displacement. Thus, both direct and indirect damages highly affected the livelihoods of rural households.

There were differences in study areas regarding the distribution of aid and relief items. On the one hand, these differences can be attributed to the level of damage experienced by households, and on the other hand, to the focus of non-governmental relief and donor organisations on particular settlements. In the aftermath of flooding, structural and livelihood changes were undertaken by rural households. These changes were highest in Multan, especially regarding structural modifications and shifts in farming practices. These households were living around large cities and therefore characterised by higher educational and income levels, as well as better access to services (within urban centres). Hence, more rural households in Multan opted for changes after extreme floods.

Overall, the assessment of rural households' socio-economic situation shows that households living in settlements near a large city were better off compared to those near medium and small cities (Muzaffargarh and Darya Khan). In this context, Darya Khan was more deprived in terms of socio-economic characteristics compared to Muzaffargarh and Multan, as depicted in Table 3.2 and Section 4.1. The findings from this chapter provide the basis for the analysis in the next chapters (chapters 5, 6 and 7), which deal with the assessment of rural-urban linkages and their changes after flooding, and of rural households' vulnerability.

Chapter 5

Changes in rural linkages with cities and their determinants

The parts of this chapter (including figures and tables) have been published in 'Science of the Total Environment' (see the citation below):

Jamshed, A., Birkmann, J., Joanna, M.M., Rana, I.A., Feldmeyer, D., Sauter, H (2021) "How do Rural-urban Linkages Change After an Extreme Flood Event? Empirical Evidence from Rural Communities in Pakistan" Science of the Total Environment, Vol 750C, 141462. DOI: https://doi.org/10.1016/j.scitotenv.2020.141462. Publisher: Elsevier.

The ramifications of flood events or other climate-related hazards can modify the linkages between rural and urban areas (Srivastava et al., 2012; Dasgupta et al., 2014). This chapter uses an empirical approach to investigate the impact of flood events on rural households and the resulting changes to rural-urban linkages. Further, the chapter examines the factors that determine these changes or influence in rural-urban linkages.

Analysed changes in linkages are differentiated into two categories (explained in Chapter 2). First, linkages are scrutinised that became stronger after flooding due to increased flows from cities to surrounding rural communities (i.e. households accessing services and facilities more frequently). Second, linkages are studied that became weaker due to the source of flow shifting to rural villages instead of from cities (i.e. households accessing services and facilities from the village that were previously acquired from the city).

Based on RQ2, mentioned in Chapter 1, this chapter attempts to answer three questions: (a) How do rural-urban linkages change for rural households following a flood event? (b) Which drivers modify rural-urban linkages after flooding? (c) How are changes in rural-urban linkages related to rural households' vulnerability?

To answer these questions, the chapter is structured into five sections. The first one explains the conceptual framework, which is specific for this chapter and was extracted from the core framework (see Chapter 2). The second section briefly explains the methods (see Chapter 3, Section 3.4 for details). Descriptive and inferential statistics are applied to study particular linkages, and excerpts from households are used to validate them. The third section describes the results, which suggest that rural households opt for several changes in their linkages with cities. The findings show that rural households' dependence on the city both increases and decreases in different ways. The results also highlighted that not only impacts, but other social, economic and physical factors propel these changes. The fourth section encompasses the discussion and an interpretation of the outcomes. The last section contains a summary of this chapter.

5.1 Conceptual framework

An additional conceptual framework was developed to investigate changes in rural linkages with cities at the community level, which is based on the parent framework provided in Chapter 2 (see Figure 5.1). The parent framework defines how flood impacts can influence linkages and which factors are crucial in altering linkages. The conceptual framework (in Figure 5.1) indicates that flood events can have social, economic, physical and environmental effects (Chapter 2). In this research, direct impacts are those related to losses and damages of household livelihood (see Section 2.3.1), such as housing structure, standing and harvested crops, and belongings. Indirect impacts involve effects on farmland/soil, water availability, crop productivity and price inflation (see details in Chapter 4).

Direct and indirect flood impacts might influence rural-urban linkages by changing different types of flows between cities and surrounding rural areas (Chapter 2). For example, mobility patterns can shift as people living in rural areas start to migrate (for the short or long term) or commute to cities for additional income to recover their losses from a flood. Rural households might also access credit more often and receive more remittances from household members living in the city. Farmers might begin to access more market information (new varieties of seeds and fertilisers, technology, input-output prices), weather and water information (in summers and during the monsoon season), as well as farm advisory information (for the application and use of new methods regarding crop and livestock farming)—particularly from cities—as a way to adapt to changing conditions. Thus, rural households might alter the way they access this information. Rural households might also access farm inputs (fertilisers, seeds, and other farm items) more often to make their land fertile and get more output to recover losses.

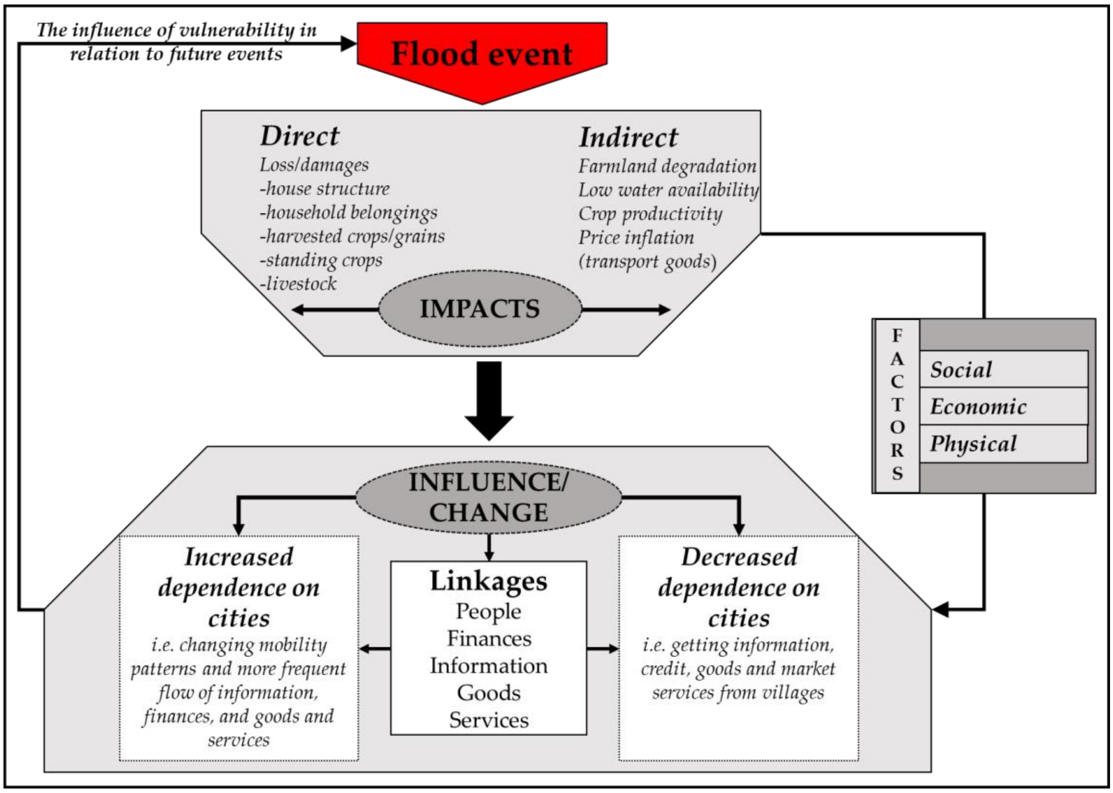

Figure 5.1. The conceptual framework of the study
(Own figure, 2020 based on Birkmann et al., 2010 and Jamshed et al., 2020b, already published in Jamshed et al., 2021)

Further, flood impacts might also affect household access to these facilities and services in that they can become less dependent on cities and take services from the village. In this context, this thesis investigated if households change the location of accessing goods and services (i.e. from the village to the city or vice versa). Thus, a flood can increase dependence on cities or decrease it. In this research, these aspects are termed (a) increased dependence on cities, and (b) decreased dependence on cities (see Figure 5.1). In addition to flood impacts, other critical factors that could lead to changes in rural linkages with cities after an extreme event are the household members' traits including age, educational level, social networks, income, type of primary occupation and material assets (internal factors), as well as the household's proximity to the city, urban markets or other services (external factors). Thus, not only direct and indirect flood impacts, but also multiple social, economic and physical factors play a role in changing flows between rural and urban areas, as well as stimulating other changes after an extreme event. These shifts refer primarily to households' response capacity to cope and adapt (Jamshed et al., 2017); as such, they can have substantial relevance for rural households' overall vulnerability.

5.2 Analytical approach

Two analytical methods were used to answer the RQs. First, descriptive statistics were employed to establish the impacts of extreme flood events on rural households and the changes in multiple linkages/flows with cities that households adopted following a flood event. Secondly, binary logistic regression was performed to identify the factors that affect rural-urban linkages. Based on the conceptual framework of this chapter, eight different regression models were calculated. Four models describe how the linkages changed in that rural households became more dependent on cities. The rest of the four models describe how the linkages changed in that rural households became less dependent on cities and sourced their goods, information, financial and market/trading services from villages after a flood event (see Chapter 3, Section 3.4.2.2 for details on the regression model). The excerpts from the qualitative analysis were also used to discuss the results. This triangulation supported and validated the outcomes.

5.3 Results

This section presents the findings and their interpretation. First, a comparison of case studies in terms of changes in different flows following a flood event is shown (Section 5.3.1). Thereafter, the results from the regression analysis are explained and discussed (Section 5.3.2).

5.3.1 Changes in rural-urban linkages

5.3.1.1 Increased dependence on cities: More frequent flows

The flow of people from the village to the city increased, primarily for income-earning purposes, following a flood event. The results show an increase in the number of households that sent at least one (additional) member to work in the city after a flood. In total, the mobility pattern of 28.3% of households changed after a flood. The changes in mobility varied slightly across three study areas. Around 31% of households in Darya

Khan, 29% in Muzaffargarh and 25% in Multan had members working in the city after a flood event (see Figure 5.2). Three different mobility patterns of household members were identified; these include commuting, as well as short-term and long-term migration (see Annex E). Thus, people's mobility patterns were altered after extreme flooding.

The flow of finances/income between rural settlements and cities was modified after extreme flooding. Financial/income flows were changed for 18% of households in Darya Khan, 33% in Muzaffargarh and 30.2% in Multan (Figure 5.2). Such flows include remittances sent to affected households from their members or relatives in the city, as well as frequent access to credit services for the revival of farming. Some households opted for more frequent access to credit, while others opted for both remittances and credit (see Annex E). Thus, in the form of increased dependence of remittances (even though by a limited number of households) and frequent credit access, the flow of income and finances from the city was intensified after extreme flooding.

The flow of information was also influenced due to extreme flooding. Changes in the flow of information (in terms of accessing information more frequently) were highest in Multan (71%), followed by Muzaffargarh (58%) and Darya Khan (39%). Information flowed in the form of market information, weather and water-related information, and farm advice (see Annex E). Less frequent access to information was observed in Darya Khan compared to the other two case study areas (see Figure 5.2). Thus, farmers were accessing various streams of information more frequently from diverse sources in the city in order to protect their livelihoods.

The flow of goods was studied in terms of frequent access to agricultural input by rural households after a flood. The findings revealed that 34.2% of households in Darya Khan were accessing agricultural goods more often after a flood. Figure 5.2 shows that Muzaffargarh had the highest number of households that were accessing agricultural input more frequently (67%), followed by Multan (56%). This might be due to the greater damage to farmland by floods and reduced crop productivity in these two cases compared to Darya Khan.

Overall, after a flood event, households intensified their interactions with the city in terms of commuting and migration (28%), accessing credit (27%), acquiring information (55%) and getting farm goods (52%) (see Figure 5.2). Changes in the flow of information and goods were highest, especially in Muzaffargarh and Multan. In general, the dependence of some rural households on cities increased after a flood.

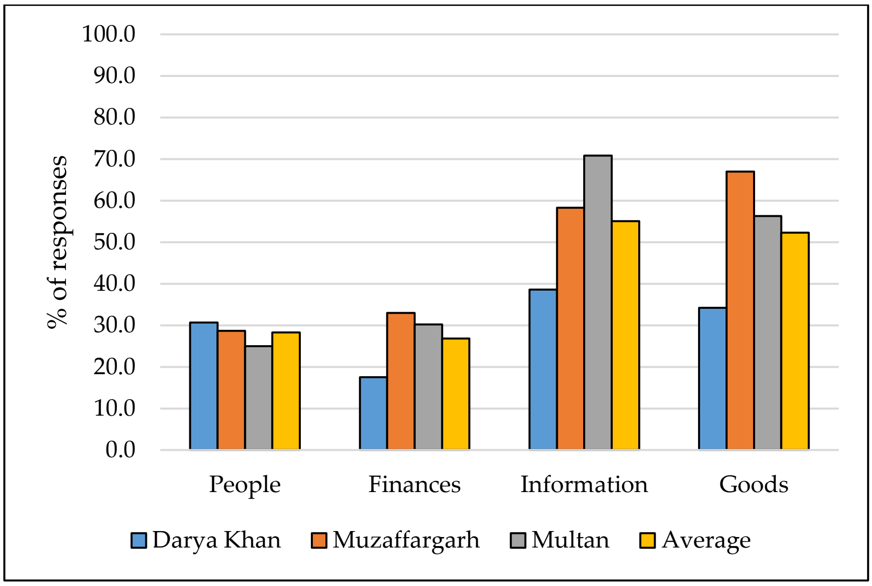

Figure 5.2. Percentage of responses that indicated an increased frequency of the different types of flows after the flood, which shows a strengthening of rural-urban linkages (Own figure, 2020, already published in Jamshed et al., 2021)

5.3.1.2 Decreased dependence on cities: Change in the location of flows

Flows between rural and urban areas were also affected in that many rural households were getting facilities and services from the rural village after a flood that were previously acquired from the city. The results imply that several households obtain different facilities and services from local rural markets/shops after a flood (Figure 5.3).

The flow of finances (in terms of credit) was affected in that 10% of households in Darya Khan, and 25% of households in Muzaffargarh and Multan, each started to get these services from the village following a flood event (see Figure 5.3). Overall, around 20% of households were acquiring credit from rural settlements after a flood that was previously obtained in the city. Thus, access to financial services from cities (for some households) was reduced, particularly in Muzaffargarh and Multan.

The flow of information was also modified since some households started to get information, especially farm advice, from rural areas. Around 8% of households in Darya Khan, 32% in Muzaffargarh and 28% in Multan were getting information from their village (that was obtained from the city before the flood) after the flood (Figure 5.3). Hence, the dependence of some rural households on cities for accessing information was reduced, predominantly in Muzaffargarh.

Concerning *the flow of goods*, the outcomes show that all case studies had a nearly similar number of households that were getting goods (farm inputs) from cities before a flood. However, after a flood, they were acquiring those goods from rural centres/shops. The percentage of such households was 32%, 32% and 31% in Darya Khan, Muzaffargarh and Multan, respectively (see Figure 5.3).

In terms of *market/trading services*—specifically when households sell their farm outputs/products—there were changes in location of accessing these services; they were previously derived from cities, and are now sourced from villages. Some households began to acquire these services from rural areas after flooding. The results outlined that around 23% of households in Darya Khan, 32.2% in Muzaffargarh and 32.3% in Multan started to sell their farm products in village shops/markets (Figure 5.3).

Overall, 19.7% of the participants acquired credit services, 22.5% obtained information, 32.6% of households acquired farm inputs, and 29% used market/trading services from their rural areas that they had previously obtained from cities (Figure 5.3). Changes in getting facilities and services from the city to the village varied slightly among the case study areas. Muzaffargarh had the highest number of households that started taking all of the abovementioned goods and services from their rural area after a flood.

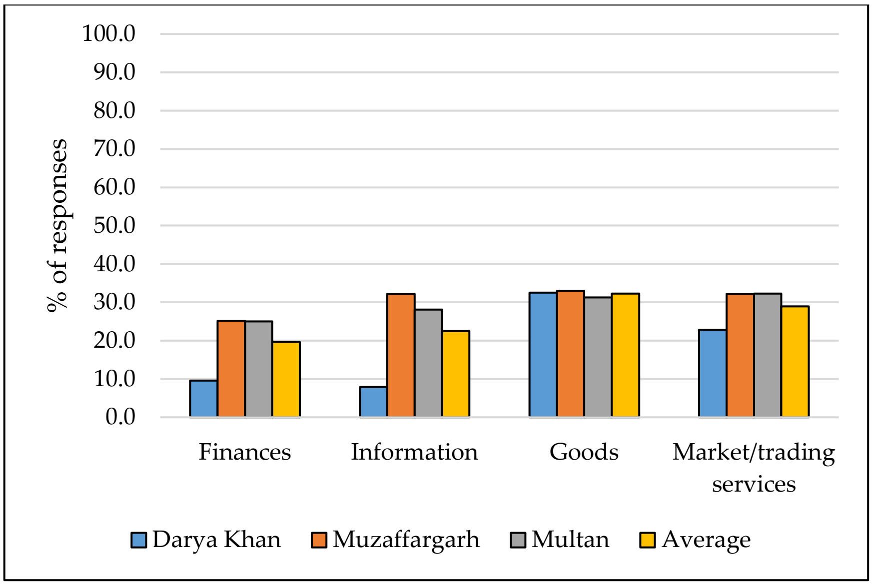

Figure 5.3. Percentage of households acquiring facilities and services from the rural village after the flood event that were previously acquiring them from the city (Own figure, 2020, already published in Jamshed et al., 2021)

5.3.1.3 Comparing more frequent flows and changes in the location of flows

It is also important to examine if the households that were frequently accessing finances (credit), information, and goods were similar or different to those that started to get these services from the village after a flood. Out of households that obtained information and goods more frequently, very few of them started to get these services from the village. Likewise, of rural households that were accessing credit more frequently after a flood, 6% of them started to get credit from the village, rather than the city (see Annex E). Nevertheless, most households that changed the location (from city to village) after flooding were different from those that were frequently accessing those services. This could be due to a different factor (flood impact, socio-economic, physical) that affects the linkages between rural areas and cities, as defined in the conceptual framework. The next section examines the factors and determinants that influence changes in the rural linkages/flows with cities.

5.3.2 Factors influencing changes in rural-urban linkages

5.3.2.1 Descriptive statistics of the explanatory variables

The variables used in each model are provided in Chapter 3 (Section 3.4.2.2.2), as well as in Annex D. Descriptive statistics of the explanatory variables suggest that the surveyed households had diverse socio-economic profiles (see Table 5.1). The age of the household head ranged between 17 and 73 years, with an average age of around 48 years. There was a high proportion of households that were illiterate, and the mean value of years of schooling was 3.5 years. More than 50% of households had network ties in cities, and 76% were involved in farming as their primary source of income. All of the other households were involved in farming as their secondary or tertiary source of income. Moreover, 79% of households owned a mode of transport in the form of an animal cart, motorbike or tractor. The average amount of farmland owned by households was 6.2 acres (2.5 hectares). Monthly family income ranged from as low as PKR 3,000 to as high as PKR 70,000, whereas the average income is around PKR 19,500. The results imply that the surveyed households belong to different social and economic groups. Moreover, the households in the three case study areas had different socio-economic profiles, where Multan was better off, followed by Muzaffargarh.

5.3.2.2 The evaluation of binary logistic regression models

All eight models (as mentioned in Chapter 3, Section 3.4.2.2) performed satisfactorily. Table 5.2 gives the value of χ^2, degree of freedom and p-value. We can see that χ^2 values were positive, and p-values were less than 0.01, which means that all the models have significant goodness of fit. The R^2 values in the models ranged from 0.20 to 0.60, which also indicates that all models have a good fit for their selected variables. In addition, the percentage of correctness for all models is above 74%, which indicates that all models have significant goodness of fit (as suggested by Abid et al. (2015) and Iqbal et al. (2016)). In sum, chi-square statistics, R-square and the classification table signalled that all eight models selected for the study have a good fit, and can accurately estimate the factors that influence change in linkages between rural and urban areas.

Table 5.1. Description of explanatory variables selected for different linkages

Explanatory variables	Min	Max	Mean	SD*	Variable type
Age of household head (in years)	17	73	47.83	14.69	Continuous
Education (in years)	0	16	3.54	4.50	Continuous
Social network ties in the city	0	1	0.54	0.50	Dummy takes the value 1 if a household has network ties in the city otherwise it takes 0
Farming as a primary source of income	0	1	0.76	0.43	Dummy takes the value 1 if the primary source of income is farming otherwise it takes 0
Number of earning members	1	7	2.25	1.17	Continuous
Average monthly income of the household (in Pakistani Rupees PKR[19])	3000	70000	19518.46	13018.02	Continuous
Ownership of mode of transport	0	1	0.79	0.41	Dummy takes of value 1 if any transport mode is owned otherwise it takes the value
Ownership/size of farmland (in acres)	0	20	6.24	4.30	Continuous
Distance to the city (in kilometres)	5	25	13.11	6.70	Continuous
Number of times exposed by flood in the last ten years	1	5	2.98	1.55	Continuous
Damage/loss to household assets	0	1	0.74	0.44	Dummy takes value 1 if house experience complete or partial damages/loss otherwise it takes value 0
High prices of inputs/goods after the flood	0	1	0.61	0.49	Dummy takes value 1 if household experience high prices of inputs and goods otherwise it takes value 0
High transportation cost after the flood	0	1	0.90	0.29	Dummy takes value 1 if household experience high transportation cost otherwise it takes value 1
Farmland degradation due to flood	0	1	0.29	0.45	Dummy takes value 1 if household experience degradation of farmland otherwise it takes value 0
Reduced crop productivity after the flood	0	1	0.61	0.48	Dummy takes value 1 if household experience reduces crop productivity otherwise it takes value 0

*SD is Standard Deviation

(based on household survey 2017, already published in Jamshed et al., 2021)

[19] 1 US dollar is 160 Pakistani Rupees (PKR) in May 2020

Table 5.2. Testing hypothesis for accuracy and significance of the model

Linkages /Flows	Models	Chi-square (χ^2)	Degree of freedom	p-value	Nagelkerke pseudo-R-square	Model Correctness (%)
Increased dependence on cities: More frequent/increased flows						
People	Changes in mobility pattern	88.51	15	0.00	0.34	78.8
Financial	Frequent access to farm credit/dependence on remittance	54.65	15	0.00	0.23	75.1
Information	Frequent access to market information	108.50	13	0.000	0.38	74.2
Goods	Frequent access and use of farm inputs	133.95	15	0.00	0.45	75.4
Reduced dependence on cities: Change in location of flows						
Financial	Accessing credit from village	59.51	11	0.00	0.27	80.3
Information	Accessing information from village	153.41	11	0.00	0.57	86.2
Goods	Accessing farm input from village	145.92	11	0.00	0.50	80.9
Services	Taking market/trading services for selling crops from village	174.72	11	0.00	0.59	84.6

(Own analysis, 2020, already published in Jamshed et al., 2021)

5.3.2.3 *Increased dependence on cities: More frequent flows*

The flow of people represents changes in the mobility patterns (commuting and/or migration) of rural households between rural areas and cities, depending on multiple factors (see Figure 5.4 and Table 5.3). Age, farming as a primary occupation, and ownership of farmland had a negative and significant coefficient. The number of earning members, the losses/damages of household assets, increased prices of goods and services after flooding, and farmland degradation had a positive and significant coefficient (Figure 5.4). The elasticity scores in Table 5.3 suggest that a 1% increase in average age and farmland area would reduce the probability of migrating or commuting by 0.6%. A 1% increase in the number of earning members would increase the probability of mobility to the city by 1.3%. The marginal effect[20] revealed that the probability of changing mobility patterns would be reduced by 14% if the households were to rely on farming as a primary

[20] The marginal effect explains the magnitude of the effect of a change in the explanatory variable on the dependent variable (see Section 3.4.2.2.1 for details).

occupation. In terms of flood impacts, the marginal effect suggests that losses/damages of household assets and an increase in the prices of goods and farming inputs would increase the probability of changing mobility patterns by 11.2% and 9%, respectively. The degradation of farmland, due to extreme flooding, would increase the likelihood of mobility to the city by 8%. Thus, both socio-economic aspects and flood impacts influence people's mobility to cities after a flood.

The flow of finances/income represents frequent access to credit and remittances by rural households, mainly from cities. Frequent access to credit was negatively significant for farming as a primary occupation, ownership of farmland, distance to the city and the high transport costs for going to the city after a flood. The regression coefficient was positive and significant for the number of times households were exposed to flooding (see Figure 5.4). The elasticity score signalled that a 1% increase in farmland ownership and distance to the city would reduce the probability of frequently accessing credit and remittances by 0.71% and 0.42%, respectively (Table 5.3). An increase in the number of floods would heighten the intensity of financial flow(s) by 2.7%. Similarly, the marginal effect suggests that the increase in the cost of transport would reduce access to financial flows from cities by 15%.

The flow of information represents market, weather and water-related information and farm advisory announcements. Regression analysis suggests that changes in information patterns are influenced by age, education, income, distance to the city, the number of floods experienced, farmland degradation and lower crop production (Table 5.3). The age of the household head and distance to the city had a negative coefficient with changes in the flow of information, while education and income had a positive, significant coefficient. This implies that more educated and higher-income households, as well as those that live closer to the city, access information from different sources in the city more often. In terms of flood-related variables, the number of flood events, farmland damage, and reduced crop production experienced by households had a positive, significant coefficient for frequent access to information (Figure 5.4 and Table 5.3). This signals that households that have experienced more flood events in the past and faced negative impacts on farmland and crop production access information more frequently.

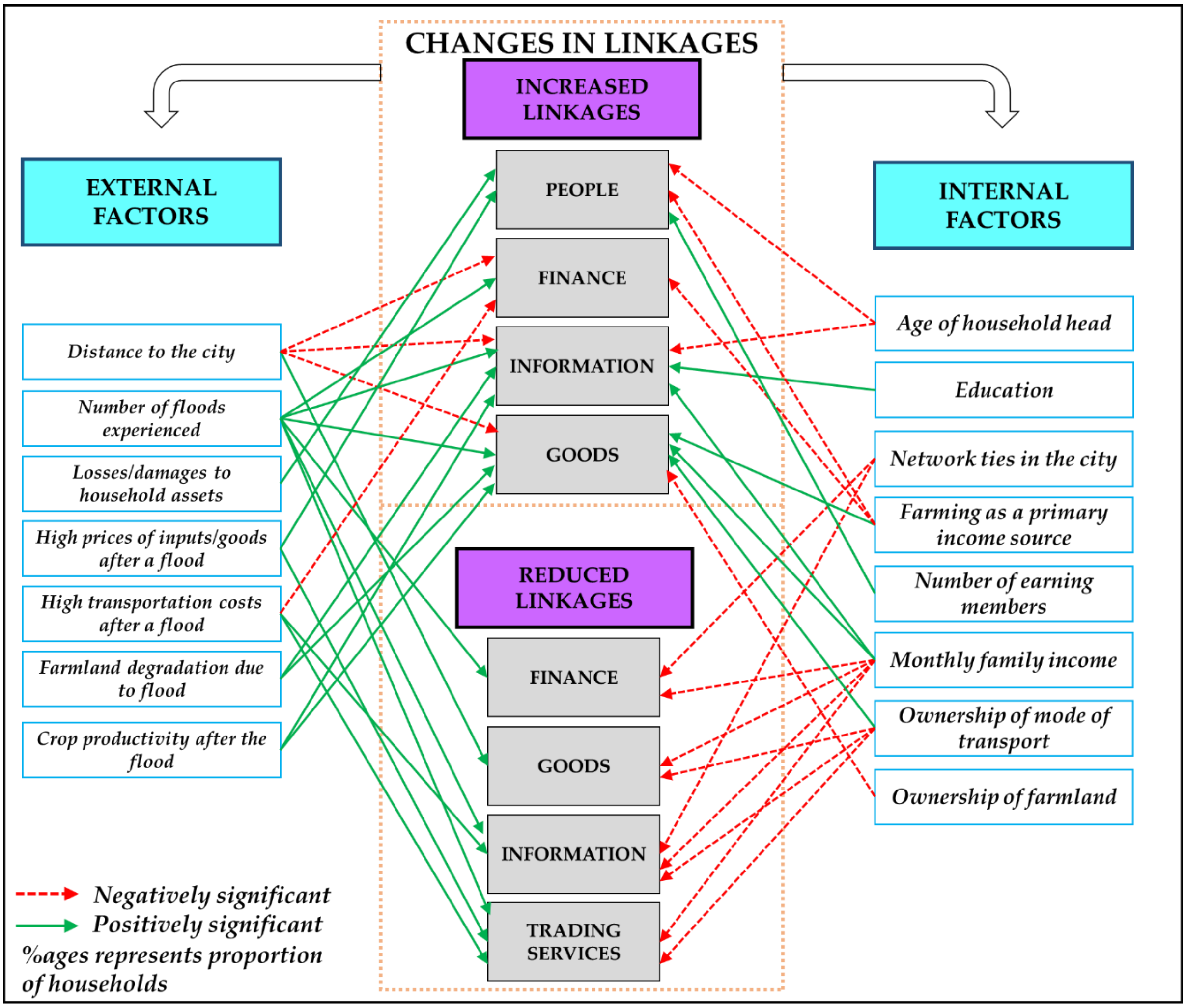

Figure 5.4. Factors that determine changes in rural linkages with cities (Own figure, 2020, already published in Jamshed et al., 2021)

The elasticities in Table 5.3 show that a 1% increase in the age of the household head and distance to the city would reduce the probability of frequently accessing information by 0.34% and 0.57%, respectively. A 1% increase in the schooling of the household head and family income would increase the likelihood of accessing market or other information by 0.13% and 0.50%, respectively. Flooding also affects access to information. The marginal effect indicated that if the number of flood events were to increase by one unit, the probability that households would access market and weather/water information, as well as advisory services more often, would increase by 3.2% (Table 5.3). The marginal effect further showed that high transportation costs would reduce the likelihood of more frequent access to information by 6.9%. Moreover, if farmers were to experience farm damages and reduced crop productivity after a flood, then the likelihood that they would access information more often would increase by 17.2% and 13.2%, respectively.

The flow of goods represents frequent access to farm inputs after a flood. The results indicated that frequent access to farm input can be determined by primary occupation, monthly household income, ownership of mode of transport, farmland ownership, distance to the city, number of flood events experienced in the past, farmland degradation and reduced crop production (Table 5.3). Farming as a primary income source, monthly income and ownership of transport mode had a positive, significant coefficient, while farmland ownership and distance to the city had a negative, significant coefficient with the more frequent flow of goods from the city. All flood-related explanatory variables had positive coefficients, but were significant for the number of flood events, farmland degradation, and reduced crop productivity (Figure 5.4).

The marginal effect in Table 5.3 suggests that the probability of getting farm inputs more often would increase by 24% if a household were involved in farming, and by 13% if a household were to own a mode of transport. The elasticity scores highlighted that a 1% increase in family income, land ownership and distance to the city would increase the flow of farm inputs by 0.54%, 0.40% and 0.25%, respectively. In terms of flood-related variables, an increase in the number of flood events experienced by a household would increase the probability of the frequent flow of goods by 2.9%. For an increase in farmland degradation and a drop in crop production, the probable increase in the flow of goods (farm inputs) from the city would be 30% and 29%, respectively (see Table 5.3). Hence, the economic and physical characteristics of households, as well as flood impacts, influence changes in the flow of goods.

5.3.2.4 Decreased dependence on cities: Change in the location of flows

The flow of finances was also affected in that households started to get credit services from villages instead of cities. Getting financial services from the village after a flood was influenced by network ties in the city and monthly family income, which had a negative, significant coefficient, while the number of flood events experienced had a positive, significant coefficient (see Figure 5.4). The marginal effect in Table 5.3 underscored that with an increase in network ties in the city, the probability of getting credit services from the village would diminish by 10.3%. A 1% increase in income would lower the likelihood of using farm credit services from the city by 1.4%. Moreover, an increase in flood events would increase the probability of accessing credit from the village by 4.9%. There are other factors involved that slightly affect the flow of finances, such as a lack of education and ownership of a mode of transport, as well as increased transportation costs.

The flow of information was changed from the city to the village for some households. Similar to financial flow, the flow of information was influenced by network ties, family income, and ownership of mode of transport, which had negative, significant coefficients. In the context of flooding, the number of flood events and high transportation costs after a flood had a positive, significant coefficient, thus increasing the flow of information toward the village (see Figure 5.4). The marginal effect in Table 5.3 suggests that having a social network in cities and ownership of a mode of transport would decrease the dependence on villages for information by 8.3% and 7.6%, respectively. The elasticity values showed that a 1% increase in family income would reduce access to information from villages by 3.8%. In terms of flooding, an increase in the number of floods and transportation costs would increase a rural household's dependence on the village for accessing information by 7.7% and 24%, respectively.

The flow of goods (agricultural/farm inputs) shifted in that the villages became the source of goods, rather than the cities (i.e. the majority of farmers had previously purchased goods from cities, but after a flood, they obtained their goods from rural areas). The factors that propelled these changes were family income and ownership of mode of transport, which had a negative, significant coefficient, while the distance to the city had a positive, significant coefficient (Figure 5.4). Education and network ties had a negative coefficient but were insignificant (Table 5.3). All flood-related explanatory variables had positive coefficients, but were of minor importance. The elasticity scores indicated that a 1% increase in household income would reduce the likelihood of taking farm inputs from the village by 2.3%, while an increase in distance to the city would increase the probability of taking farm inputs from the village by 0.6%. The marginal effect revealed that ownership of a mode of transport would decrease the dependence of buying farm inputs from the village market by 26.7% (see Table 5.3).

Market/trading services were normally accessed in cities by rural households for selling their farm products. After a flood, several households were selling their products in villages. Factors that influenced this change included household income and ownership of a mode of transport, which had a negative, significant regression coefficient. Moreover, all flood-related explanatory variables (such as the number of floods experienced, high prices of goods after a flood, and high transportation costs after a flood) had positive, significant coefficients (see Figure 5.4). The elasticity scores demonstrated that a 1% increase in household income would reduce the likelihood of using market/trading services from the village by 3.8%. The marginal effect suggests that ownership of a mode of transport would likely decrease dependence on the village market and trading services by 23.1%. An increase in flood events and transportation costs would increase the probability of accessing marketing/trading services from the village by 3.8% and 17.6%, respectively (Table 5.3).

5.4 Discussion

The analysis of changes in rural linkages with cities, as well as their determinants, provided important insight into how rural households respond to an extreme flood event regarding changes in mobility patterns toward cities and accessing services and information. The results suggest that an extreme flood event has consequences for rural households in terms of their linkages with cities. The surveyed households had social and economic heterogeneity, which corresponds to how they were impacted by flooding, as well as to the numerous changes they adopted in response to flood events.

Table 5.3. Coefficient estimates for binary logistic regression, marginal effect and elasticity for changes in a different type of linkages after the extreme flood event

Explanatory variables	Coefficients	Increased dependence on cities				Reduced dependence on cities			
		People	Finance	Information	Goods	Finance	Information	Goods	Services
Age of household head (in years)	*β*	-0.017***	-0.001	-0.016***	-0.004	0.013	-0.021	-0.014	0.005
	ME	-0.003	0.000	-0.003	-0.001	0.002	-0.002	-0.002	0.001
	EL	-0.590	-0.019	-0.344	-0.083	0.482	-0.771	-0.459	0.178
Education (in years)	*β*	-0.044	0.011	0.122*	0.013	-0.002	0.006	-0.019	0.006
	ME	-0.007	0.002	0.021	0.002	0.000	0.001	-0.002	0.001
	EL	-0.115	0.029	0.128	0.021	-0.005	0.018	-0.048	0.017
Network ties in the city	*β*	-0.144	0.197	0.318	0.059	-0.792**	-0.887**	-0.383	-0.262
	ME	-0.021	0.032	0.056	0.009	-0.103	-0.083	-0.050	-0.028
	EL	-0.050	0.071	0.062	0.014	-0.375	-0.420	-0.163	-0.114
Farming as a primary source of income	*β*	-0.939*	-0.882*	0.341	1.506*	-0.124	-0.116	0.495	-0.353
	ME	-0.140	-0.143	0.060	0.241	-0.016	-0.011	0.065	-0.037
	EL	-0.566	-0.532	0.123	0.528	-0.073	-0.064	0.227	-0.176
Number of earning members	*β*	0.901*	0.164	n/a	0.188	n/a	n/a	n/a	n/a
	ME	0.134	0.027	n/a	0.030	n/a	n/a	n/a	n/a
	EL	1.262	0.257	n/a	0.190	n/a	n/a	n/a	n/a
Monthly family income (in PKR)	*β*	0.000	0.000	0.000*	0.000*	-0.000**	-0.000*	-0.000*	-0.000*
	ME	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	EL	0.337	0.387	0.481	0.538	-1.440	-3.780	-2.246	-3.735
Ownership of mode of transport	*β*	0.561	0.107	-0.193	0.810**	-0.269	-0.814**	-2.028*	-2.191*
	ME	0.083	0.017	-0.034	0.130	-0.035	-0.076	-0.267	-0.231
	EL	0.300	0.060	-0.065	0.289	-0.179	-0.546	-1.273	-1.443
Ownership of farmland (in acres)	*β*	-0.135**	-0.153*	-0.027	-0.140**	-0.024	0.035	0.103	0.066
	ME	-0.020	-0.025	-0.005	-0.022	-0.003	0.003	0.013	0.007
	EL	-0.590	-0.708	-0.060	-0.399	-0.131	0.187	0.505	0.343
Distance to the city (in kilometers)	*β*	0.001	-0.042***	-0.085*	-0.037***	-0.033	-0.003	0.074*	0.022
	ME	0.000	-0.007	-0.015	-0.006	-0.004	0.000	0.010	0.002
	EL	0.007	-0.419	-0.573	-0.246	-0.340	-0.031	0.597	0.187
Number of times exposed by flood in the last ten years	*β*	0.123	0.167***	0.181***	0.182***	0.381*	0.824*	0.013	0.356*
	ME	0.018	0.027	0.032	0.029	0.049	0.077	0.002	0.038
	EL	0.267	0.345	0.215	0.219	0.865	1.730	0.025	0.707
Damage/loss to household assets	*β*	0.756**	0.416	-0.054	0.253	n/a	n/a	n/a	n/a
	ME	0.112	0.068	-0.009	0.040	n/a	n/a	n/a	n/a
	EL	0.398	0.225	-0.019	0.093	n/a	n/a	n/a	n/a
High prices of inputs/goods after the flood	*β*	0.606**	0.204	n/a	0.188	-0.214	-0.323	0.352	0.934*
	ME	0.090	0.033	n/a	0.030	-0.028	-0.030	0.046	0.099
	EL	0.250	0.090	n/a	0.054	-0.107	-0.158	0.152	0.437
High transportation cost after the flood	*β*	0.11	-0.914**	-0.392	0.428	0.376	2.574*	0.221	1.664**
	ME	0.016	-0.149	-0.069	0.069	0.049	0.241	0.029	0.176
	EL	0.071	-0.625	-0.165	0.187	0.272	1.767	0.133	1.050
Farmland degradation due to flood	*β*	0.537	0.522	0.984*	1.880*	n/a	n/a	n/a	n/a
	ME	0.080	0.085	0.172	0.301	n/a	n/a	n/a	n/a
	EL	0.097	0.087	0.061	0.064	n/a	n/a	n/a	n/a
Crop productivity after the flood	*β*	0.161	0.444	0.752*	1.827*	n/a	n/a	n/a	n/a
	ME	0.024	0.072	0.132	0.292	n/a	n/a	n/a	n/a
	EL	0.070	0.184	0.173	0.337	n/a	n/a	n/a	n/a
Constant		-2.486	-0.662	-0.570	-4.620	-0.901	1.443	1.96	0.674
Observations		325	325	325	325	325	325	325	325

Significant at *1%, **5% and ***10%

β = Regression coefficient; ME = Marginal Effect coefficient; EL = Elasticity coefficient, ***n/a = not applicable***

5.4.1 The flow of people: Changing mobility patterns

Extreme flood events and their impacts trigger changes in the flow of people. In this thesis, flooding affected rural households' traditional sources of income generation so severely that changes in commuting and short-term labour migration were visible. The results suggest that losses of households' material assets, degradation of farmland, and increasing prices of goods and farm input contribute to the decision to migrate or commute to the city. Having a younger head of household, a higher number of earning members in the family, and a primary occupation other than farming are also factors that meant these households were likely to commute or migrate to the city. Joarder et al. (2013) and Bernzen et al. (2019) also found that loss of livelihood assets and households' socio-economic characteristics were important determinants in the decision to change mobility patterns after flooding. Thus, both flood impacts and household attributes influence the flow of rural people to cities, as reported by the following household:

> *I was working as a daily wage labourer; I also farm on my small piece of land. However, everything was flooded, destroyed and lost; even our beds and utensils. There was no work on farms after the flood. Therefore, I decided to go to the city and started working there as a construction labourer. This helped me to buy food and other things for our house. Members of many other families also started to work in the city after the flood. (Respondent 281, Multan, 19 km from the city)*

5.4.2 The flow of finances: Credit and remittances

The findings show that the financial flow from the city to rural areas increased. Remittances from household members residing in cities was an important income source for some households, especially for those severely affected by floods. Remittances in the face of an extreme event or disaster can be a vital coping strategy to recover losses (Armah et al., 2010; Le De et al., 2015). The following quote shows how an increase in a household's dependence on remittances as a source of family income emerged after flooding, and was essential for coping and adaptation:

> *My son started to work in a large city after the flood; he brought in a lot of money to revive the farm and buy necessary household things. Later, he sent more*

money than usual and more often, so that we could rebuild our house. (Respondent 4, Darya Khan, 6 km from the city)

In addition, farming households took out credit more often, both from public and private credit institutes in cities, to revive their farmland after flooding. Access to credit can reduce farming households' vulnerability (Jamshidi et al., 2019). However, not all rural households have the same access to credit, and those that are unable to pay it back might reduce their future capacity to cope and adapt. The empirical outcomes show that rural households that live close to the city can easily and more frequently access credit services. Moreover, more severe flood damages, especially to farmland, lead to households to take out credit more often than usual, as specified by a rural household:

My farming mainly depends on credit. After harvesting, I pay back what I take from credit institutions. The flood destroyed the crops, damaged the farmland and reduced the soil productivity. Therefore, I had to buy several things and I needed the money. Thus, I took out credit several times from public institutes, as well as from private creditors. (Respondent 264, Multan, 9 km from the city)

Several farmers who previously got credit from the city started to get it out from the village. The regression analysis suggests these farmers belonging to low-income households that do not own any mode of transport, have a very limited social network in the city and experience high transportation costs due to damaged road infrastructure. Thus, poor socio-economic and infrastructure conditions deteriorated by flood impacts can restrict rural households' access to credit from the city. Two farmers explained this situation:

We usually take out credit from private creditors in the city. The flood caused a lot of losses and we could not pay back what we previously took. Now, if we take credit services from them, they ask us to mortgage land and crops. Thus, either we do not take out credit and buy things from what we have, or we ask some friend or relative in the village to give us money. (Respondent 110, Darya Khan, 15 km from the city)

5.4.3 The flow of information: Access to support

The flow of information also changes and intensifies after floods. In this study, rural households started to access various types of information more often, primarily from the city. The majority of rural households in the case study region do not have access to television or radio services. Further, information on local weather and the release of water from dams and barrages (particularly during the monsoon season) is not communicated via television, but via rather by word of mouth. This means that most households depend on institutions and organisations in cities, such as government farm advisory programmes. However, not all households have to go to the city for farm extension and advisories, as NGOs offer such services in some villages. While the frequency of advisory programmes did not increase, households accessed available information more often. Abid et al. (2019) showed that information on markets, weather/water and farm advice enables rural farmers to make better plans for their farm-based livelihoods. Two households stated the following:

> *NGOs came to our village. They provided information on different techniques for sowing crops and also informed us about changing our crop variety. They also taught us reconstruction techniques for the houses. They have a temporary office in the city; we go there to get more information, as well as some goods needed for farming. It is good for us. (Respondents 127 & 128, Muzaffargarh, 6 km from the city)*

The results indicate that farmers are likely to request more information if they experience a greater number of floods, greater farm damages and a significant reduction in crop productivity. In addition, information is more accessible to those who are younger, more educated, have social ties in the city, higher incomes, and live closer to the city. On the contrary, some farmers started accessing information from the village after flooding, mostly those with limited social ties, lower incomes and high costs of transportation to the city. This was also demonstrated by Abbay et al. (2016). Thus, flood impacts can prompt more frequent access to information from cities and a change in the location from which information is accessed. In this regard, socio-economic and spatial aspects are critical factors that influence these changes. In this respect, one household explained his situation:

> *Agricultural extension/advisory services are only attainable for rich people or people who have a good relationship with institutions. If extension workers come to the village, they do not come to our area (as our household is remote, with*

access roads in poor condition). Who cares for the poor? (Respondent 279, Multan, 19 km from the city)

5.4.4 The flow of goods and services: Farm input and markets

The results illustrated that many rural households increase their use of farm inputs purchased from cities in order to revive their agriculture-based livelihoods. People employ agricultural inputs (fertilisers and seeds) in large quantities to make their land fertile and derive more outputs to recover losses. The regression analysis signalled that households were likely to use farm inputs more frequently if they experienced farm degradation or reduced crop productivity after a flood. Moreover, farmers with higher economic status with social ties in the city and who live in closer proximity to the city were able to get and use farm inputs more frequently. Consequently, rural-urban linkages, in terms of getting farm goods and services, can intensify after a flood, but socio-economic and spatial factors also play a vital role in shaping such linkages and opportunities.

> *I had massive damages to my farm; almost all other farmers [were also affected]. [The flooding] affected the quality of soil as well. I had to use a lot of fertilisers to make the soil fertile, and used a lot of seeds to increase crop productivity. For this, I travelled several times to the city to get the inputs. (Respondent 247, Multan, 8 km from the city)*

In terms of obtaining goods and services, there was a shift from cities to villages in all case study areas. The empirical results revealed that low-income households in particular—which tend to not own a mode of transport, have limited social network ties in the city, and live in remote villages—are more likely to access goods and services from the village after a flood, rather than go to the city. In terms of flood impacts, rural households that have experienced more floods in the past, high transportation costs, and price inflation of goods/inputs in city markets after flooding cause increased dependence on the village shop and centres. However, the marginal effect and elasticity scores indicate that each factor contributes to changing the flow of goods and services differently (Table 5.3). In sum, the combination of flood impacts and socio-economic and spatial features affect rural households' dependence on cities for goods and services. One of the interviewed households explained the following:

> *In the market, all people were looting from us. The prices of inputs and goods became higher after the flood. This affected poor people who could not afford inputs for such prices. Therefore, we buy inputs and sell outputs here in the village shops. (Respondent 206, Muzaffargarh, 24 km from the city)*

5.4.5 The main differences between the case studies

The quantitative analysis revealed differences among the case studies in terms of flood impacts and changes in different types of rural-urban linkages. These differences can also be associated (among other factors) with the size of the city around which rural settlements are located and on which rural households depend for facilities and services. The rural hinterland of larger cities has better access to services, facilities, infrastructure and institutions than smaller cities (Rana et al., 2020c), which means they are affected by flood impacts differently. Multan, as a major city, has higher functional and market diversity, more administrative capacity, and good infrastructure facilities than the other case study cities (Jamal et al., 2003; Mayo, 2012; The Urban Unit, 2018b). Indirect flood impacts—especially the price inflation of goods and transport—were less severe in Multan because of better roads and the city's greater institutional ability to rebuild and control prices. There were also fewer changes in mobility in Multan. Multan is characterised by mixed functions that offer more opportunities for income diversification with better transport facilities; thus, rural residents commute rather than migrating to the city. Similarly, Multan has bigger and more specialised markets, as well as larger public and private institutions, which provide better services for reviving livelihoods after extreme events (as indicated in Chapter 3). Therefore, in rural areas around Multan, households made more changes in agricultural practices and accessed more information and credit services. Hence, city size seems to affect the intensity and direction of changes in rural-urban linkages. These changes in linkages can influence rural households' vulnerability.

5.4.6 The impact of changes in rural-urban linkages on vulnerability

Changes in rural-urban linkages after a flood can influence households' vulnerability since these linkages particularly affect rural households' response capacity to recover and adapt to future floods, therefore reducing vulnerability (Birkmann et al., 2010; Jamshed et al., 2020c). Shifts in rural-urban linkages can also decrease vulnerability to future flood events.

Many of the strategies used to cope with and adapt to flood impacts can either increase or decrease vulnerability depending on the circumstances. On the one hand, migration to cities for employment can provide an additional source of income for rural households and mitigate vulnerability; on the other hand, expensive accommodation in the city, difficult living conditions, dangerous working conditions, and social isolation can increase vulnerability (Ayeb-Karlsson et al., 2016). Improved access to formal and informal credit institutions can help in the recovery of livelihoods, but can add pressure in the case of crop failure or lower productivity, which makes it difficult for rural households to pay back their debts. Likewise, changing the source of goods and services from the city to the village can result in cost and time savings by reducing travel to the city, but can restrict farmers' access to new market trends and processes (Abbay et al., 2016). It can also have repercussions for the urban market due to reduced rural dependence. Thus, these shifts in rural-urban linkages can have positive and negative outcomes for rural households' medium- and long-term vulnerability.

5.5 Summary

Extreme flooding influences the linkages between rural and urban areas, and can manifest the changes in these linkages. The conceptual framework—based on the parent framework in Chapter 2—was developed, operationalised and validated for systematising different impact dimensions and changes within rural-urban linkages in the context of large floods. The findings revealed several factors associated with changes in rural-urban linkages. Flood impacts play a role in influencing specific types of rural-urban linkages, but certain socio-economic and other physical factors also affect these linkages differently. The magnitude of influence of the explanatory factors on linkages also differed, as depicted by the marginal effect and elasticity scores.

The socio-economic and spatial characteristics of households accessing finances, information and goods from the city were different from the traits of households obtaining them from the village after a flood. Increased dependence on cities (in terms of more frequent flows of finances, information and goods) was associated with higher educational levels, more income, extensive social networks in the city and close proximity to the city. Conversely, those with lower educational levels, less income, fewer social ties to the city, and those who live further from the city relied more on facilities and services from the village after a flood.

In contrast, high transportation costs restricted households' access to credit, information, and goods and services from the city after a flood, which was not the case for those who did not experience this cost inflation. Rural households living in remote rural settlements are disadvantaged in terms of socio-economic and infrastructure facilities and services (Abbay et al., 2016; Sharma, 2016). Flooding further deteriorated the situation for remote rural households, as it increased their dependence on rural areas for facilities and services, and restricted their access to cities. Hence, an increased dependence on cities is a coping strategy for rural households living close to the city. This was not a viable strategy for households living more remotely (and which often have lower family incomes and a higher number of farmers with small landholdings), whose strategy was to depend more on facilities and services from rural areas. Tacoli (2003) identified similar barriers that affect rural linkages with cities. In this context, distance to the city can be a important factor that influences rural-urban linkages aside from flood impacts (Chapter 2, section 2.3.3.6). However, both changes - a higher interaction of rural households with the city or vice versa a lower interaction with the city – can influence the vulnerability to flooding in different ways.

Overall, this chapter has empirically verified that rural-urban linkages were influenced by flood impacts as well as by socioeconomic and spatial factors. Among others, the size of the city and distance is found to be important in changing the linkages of flood-affected households with cities. These changes can also influence vulnerability. The next chapter (Chapter 6) assesses the vulnerability of rural households considering city size and proximity to the city as well as changes in linkages. The results from this chapter (Chapter 5) are used in Chapter 7 to examine the influence of changing linkages on the overall vulnerability of rural households.

Chapter 6

Index-based assessment of the linkages between the size of the city, proximity to the city and rural flood vulnerability

The parts of this chapter (including tables and figures) have been published in 'International Journal of Disaster Risk Reduction' and 'Ecological Indicators' (see the citations below):

Jamshed, A., Birkmann, J., Rana, I.A., Joanna, M.M. (2020) "Relevance of City Size to the Vulnerability of Surrounding Rural Areas: An Empirical Study of Flooding in Pakistan" International Journal of Disaster Risk Reduction, Vol 48, 101601. DOI: https://doi.org/10.1016/j.ijdrr.2020.101601. Publisher: Elsevier.

Jamshed, A., Birkmann, J., Rana, I.A., Feldmeyer, D. (2020) "The Effect of Spatial Proximity to Cities on Rural Vulnerability against Flooding: An Indicator Based Approach" Ecological Indicators, Vol 118, 106704. DOI: https://doi.org/10.1016/j.ecolind.2020.106704. Publisher: Elsevier.

The theoretical-conceptual discussion of rural-urban linkages (see chapters 2 and 5) underscored that rural linkages with cities, as well as the socio-economic and physical characteristics of rural settlements and their inhabitants, are influenced by city size and proximity[21]. Chapter 2 highlighted that a city's size affects its vulnerability; the impact of city size on rural vulnerability has not yet received sufficient attention in research. Moreover, research on the effect of proximity to cities on rural vulnerability is limited and does not provide information on proximity criteria (Chapter 2).

Chapter 4 exhibited that socio-economic factors, flood impacts and structural-livelihood changes differ among rural households in the hinterlands of different city sizes. Moreover, changes in linkages were differentiated by city size and proximity to the city (Chapter 5). Thus, linkages are influenced by city size and proximity, which can also influence the rural households' vulnerability to flood hazards. As such, these linkages will be

[21] Spatial proximity is defined as travel distance to the city (see Chapter 3, Section 3.1.2.1 for details).

considered in the assessment of rural households' vulnerability in the hinterlands of different city sizes at varied proximity.

Vulnerability was assessed based on its three components: (1) exposure, (2) susceptibility and (3) capacity (see Chapter 2 and Table 3.3 in Chapter 3). This chapter answers the questions: (a) How can rural vulnerability be operationalised in the context of city size and proximity to the city?, (b) How different are the vulnerability levels of rural households around cities of different sizes and at different proximities?, and (c) Are rural-urban linkages relevant to rural households' vulnerability?

This chapter is divided into four sections. The first part explores how rural households' vulnerability is conceptualised (taking into account the framework presented Chapter 2) with respect to city size and proximity to the city. The second section explains the methods used for the index-based approach and inferential statistics. The third part discusses the results of the vulnerability assessment with regard to city size and proximity. The fourth section concludes the chapter.

6.1 Conceptual frameworks

This chapter employed a multidisciplinary perspective by integrating concepts of spatial and regional development into the notion of vulnerability to hazards, as outlined in Chapter 2. Two frameworks to conceptualise 'city size and rural vulnerability' (SCARV) and 'vulnerability and proximity nexus' (VPN) were extracted from the parent framework on rural-urban linkages and vulnerability in Chapter 2. The frameworks also consider some aspects of central place theory.

In terms of SCARV, central place theory suggests that central places (predominantly cities) of different sizes provide various goods and services to their inhabitants and those living in the surrounding hinterland. Small cities provide low-order goods and services, while large cities provide more specialised and diverse goods and services to their residents and peripheral areas. In this context, different types and levels of services and facilities that cities provide to their rural areas depend on city size. Dependency is represented by different linkages/flows between rural areas and cities (chapters 2 and 5).

In terms of VPN, central place theory implies that the quantity of central goods consumed declines along with increased distance from the central place due to transport costs (Christaller, 1933). The concept is translated in a way that not only considers transport costs, but also other socio-economic and physical factors that vary with distance from central places and affect linkages (in the form of services and facilities) with cities in the context of major floods (chapters 2 and 5).

6.1.1 City size and rural vulnerability (SCARV)

The SCARV framework (in Figure 6.1) depicts hazard-prone rural hinterlands and their nearest central places, which are cities of three different sizes. Cities and their rural hinterlands have social and in part immaterial (people, information), economic (finances, remittances, investments) and physical linkages (goods, services, infrastructure) to each other. The framework argues that large cities have more intense linkages with their rural hinterlands, followed by medium and small cities. The strength and intensities of linkages in the form of the flow of goods, services, finances, people or information are acknowledged in the framework[22]. Moreover, the framework includes less and more specialised facilities and services that may affect rural vulnerability[23]. Large cities provide higher-order and more specialised services to their rural hinterlands in the form of economic diversity, better service delivery and greater institutional capacity, as well as large, innovative and diverse markets compared to medium and small cities (see the arrow above the circles). Considering this, rural households in the hinterlands of small cities are assumed to have limited access to socio-economic opportunities provided by their nearby city. Thus, the framework signals that rural hinterlands of small cities have less access to coping and adaptive capacities that can be provided by cities. Thus, these rural areas and their inhabitants are characterised in general by a higher level of vulnerability than those around larger cities. Rural households' degree of exposure varies with respect to city size; for example, information on flood warnings and losses/damages

[22] The black double arrow indicates linkages; the thickness of the arrow represents the intensity of these linkages.

[23] Plus (+) and minus (-) signs on either side of the double arrow denote more specialised and less specialised services/facilities, respectively.

to moveable items can be influenced by city size, as small cities have limited resources to disseminate flood warnings in a timely manner and to evacuate people and their belongings.

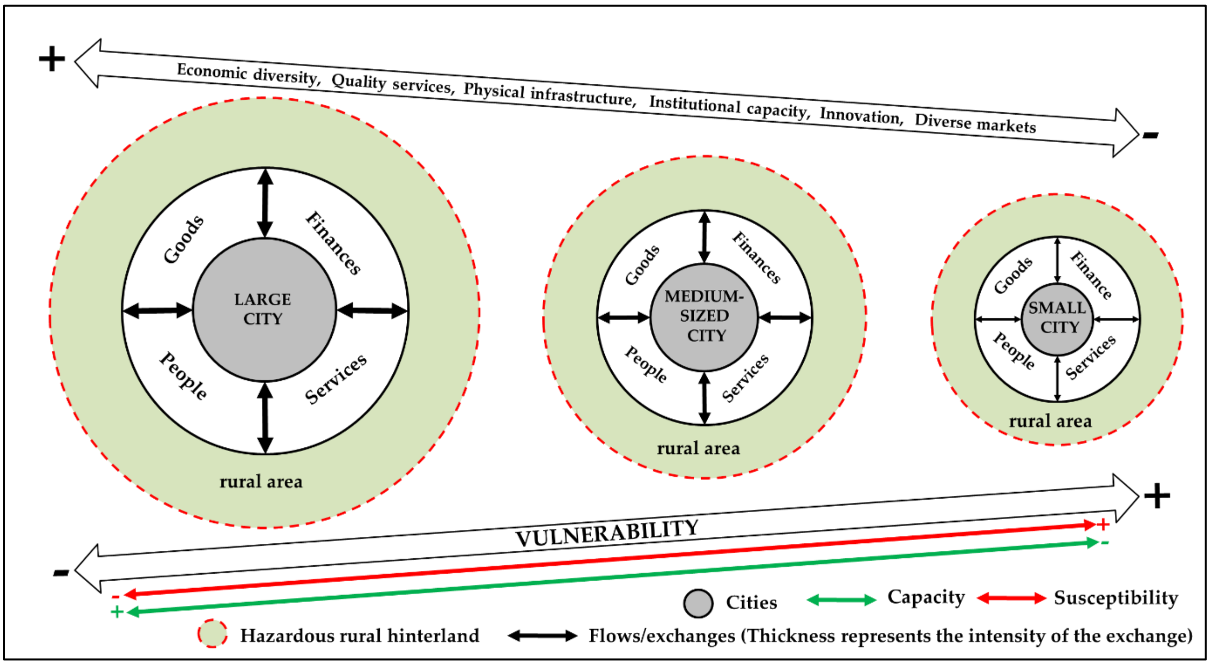

Figure 6.1. City Size and Rural Vulnerability (SCARV) framework
(Own figure_2020, already published in Jamshed et al., 2020d)

6.1.2 The vulnerability proximity nexus (VPN) framework

This research conceptualises rural households vulnerability as a spatially dynamic phenomenon, even at the local level, and as dependent on spatial proximity to the city. Figure 6.2 demonstrates a hypothetical space with a city and its surrounding rural settlements. The city transfers numerous functions and services to rural settlements and their residents, even in the event of a hazard or crisis, which can help to sustain and improve livelihood security. These services include social facilities (information, emergency, relief items, health care), economic services in the form of markets to sell one's harvest and buy agricultural inputs, jobs and credit facilities (which are presented in the form of exchanges and transfers). The rural space is shown as being exposed to flooding[24],

[24] In the context of Pakistan, rural areas are exposed to fluvial flooding (chapters 1 and 3), while cities are protected by dykes. Hence, in this framework, only rural areas are considered as prone to fluvial floods.

while settlements in the space and the households living in those settlements have diverse socio-economic, infrastructure, spatial and environmental features. The proximity gradient reveals the distance from the city: the darker the colour, the greater the distance. In this context, the components of vulnerability are both positively and negatively related to distance. The exposure and susceptibility of households living in rural settlements are positively tied to an increase in distance, whereas capacity has a negative relation. Although the degree of exposure is mainly associated with proximity to the hazard source and other geographical features of the area, distance to the city can still play a role in influencing exposure, as outlined in Section 6.1.1. Susceptibility, a characteristic of households living in rural settlements, makes them vulnerable and is positively influenced by proximity to the city. Capacity is negatively influenced, since households living in rural settlements closer to the city often have easier access to its services and facilities. Moreover, in any calamity, households living in rural settlements near the city usually benefit. Overall, this concept assumes that rural vulnerability deepens with increasing distance from the city.

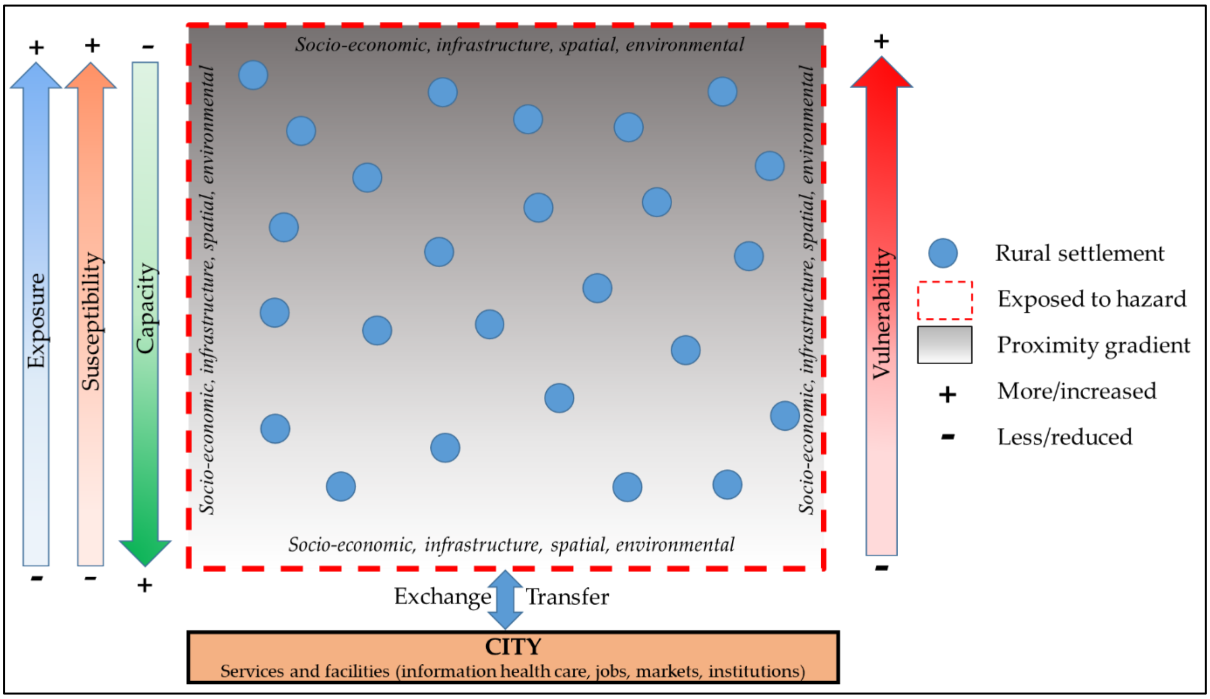

Figure 6.2. Vulnerability-Proximity Nexus Framework (VPN)
(Own figure_2020, already published in Jamshed et al., 2020a)

6.2 Analytical approach

An index-based approach was used in this chapter to measure flood vulnerability and to explore differences (among the case studies) in terms of city size and proximity to the city. The details on the method and steps for the development of the index were discussed in Chapter 3 (Section 3.4.2.3). The six steps employed to build the index were: (1) the selection of indicators, (2) data transformation, (3) the finalisation of relevant indicators, (4) aggregation, (5) calculating vulnerability, and (6) index validation using a reliability test and sensitivity analysis (see Figure 3.9). To examine the relevance of city size for rural vulnerability, the index values were categorised according to four quartiles, which represent four different levels of rural vulnerability, as well as its components. Pearson's chi-square was performed to investigate if the levels of rural households' vulnerability differed significantly among the selected case study areas (that represent the rural zone around cities of different sizes). The results are represented using boxplots and tables. In terms of investigating the effect of proximity to the city on rural vulnerability, two proximity groups with regard to distance to the city were classified as NPS and FPS (mentioned earlier). In addition, the Mann-Witney U test and correlation analysis were performed. The results are shown using a spider diagram and tables (see Chapter 3, Section 3.4.2.4).

6.3 Results and discussion

This section outlines the study's findings, accompanied by a discussion. The results from the analysis, used to validate the vulnerability index, are described in Section 6.3.1. Section 6.3.2 explains the flood vulnerability index, including its components for measuring human vulnerability to flooding in the hinterlands of different city sizes. This analysis is followed by a vulnerability assessment of rural households with respect to proximity to the city (Section 6.3.2). These methods allowed for exploring the relationship between different city sizes and proximity to the city and rural vulnerability to flooding in Pakistan.

6.3.1 Index validation

The index was validated in order to check its quality and to ensure if the indicators (included in the index) represented the vulnerability phenomenon satisfactorily. Cronbach's alpha and sensitivity analysis were performed (see Chapter 3, Section 3.4.2.3.4)., The alpha value for all indicators was 0.76 and was acceptable for the composite index (OECD, 2008; Cutter et al., 2014). The results of the sensitivity analysis in Figure 6.3 show three graphs; in graph A, the x-axis depicts the original input scales between -0.5 and 0.5, and the y-axis portrays the variance of the indicators.

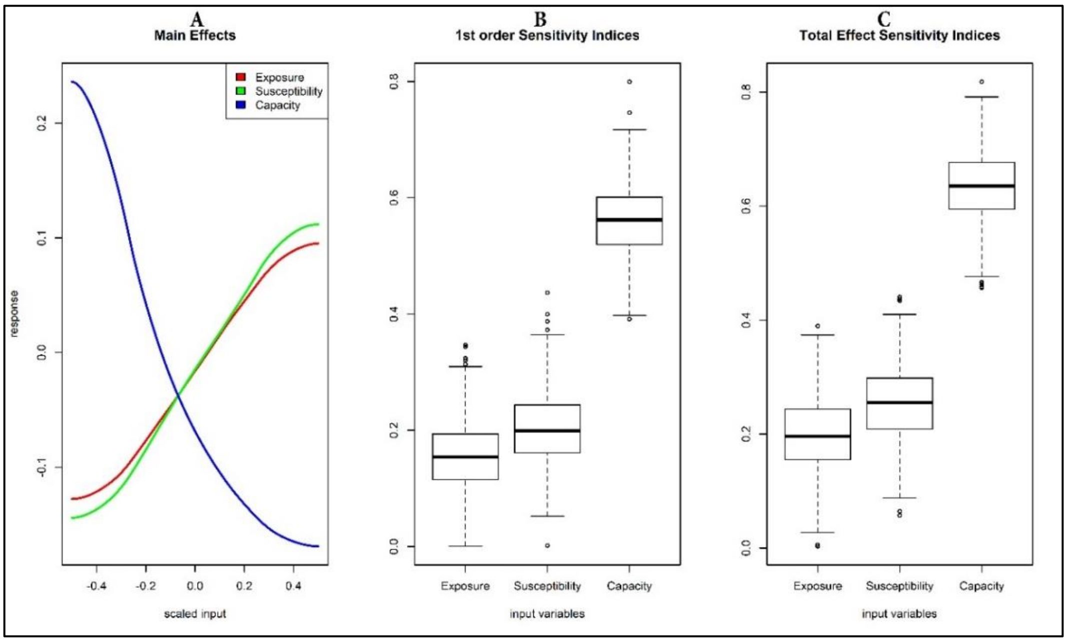

Figure 6.3. Sensitivity analysis of exposure, susceptibility, and capacity indicators (Own figure, 2020, already published as Jamshed et al., 2020d)

The curves represent the degree of impact of the input factors on the output factor. The steeper the curve, the greater the impact. Graphs B and C show box plots, which denote how precisely the indicators influenced the vulnerability index. A smaller box means that the influence was more precise. The bold horizontal line in the box plots signals the median. The upper whiskers show the minimum and maximum values and indicate the influence of the indicators (in each vulnerability component) on the overall vulnerability index. Graph C demonstrates how the indicators in each vulnerability component influenced or interacted if there was a change in one indicator. This provides information about the relevance of the indicators. For example, when the total effect sensitivity index of the indicators was zero, these indicators were exchangeable, whereas when the indicators had a median higher than zero, they were meaningful indicators and influenced the overall index. The sensitivity analysis suggests that all the indicators in the exposure, susceptibility and capacity components had a significant impact on the vulnerability index and are thus are important to consider.

6.3.2 City size and rural vulnerability

6.3.2.1 Exposure

The degree of exposure is a vital element of vulnerability and encompasses aspects such as experience with exposure, the extent of damages experienced, and spatial proximity to the hazard source (see chapters 2 and 3). The results showed differences in the degree of exposure between individual households in each case study area, as well as between the study areas themselves. The household exposure index values ranged from 0.35 to 0.83 in Darya Khan, 0.39 to 0.81 in Muzaffargarh and 0.46 to 0.80 in Multan. The boxplots in Figure 6.4A highlight that 75% of the exposure index values were above 0.49 in Darya Khan, 0.55 in Muzaffargarh, and 0.61 in Multan, suggesting that rural households in Multan are relatively more exposed to floods compared to the other two case study areas. The mean exposure values were 0.52, 0.62 and 0.65 in Darya Khan, Muzaffargarh and Multan, respectively. A significant difference in the level of exposure was observed among the selected study sites ($\chi 2$=53.299; p-value=0.000). In Darya Khan, only 28% of households were very highly exposed to floods; in Muzaffargarh and Multan, 50% and 68% of households, respectively, were highly exposed (see Table 6.1). Thus, Multan seems to be an area where more households have been exposed to floods and damages.

Overall, the high degree of exposure in Muzaffargarh and Multan was primarily due to the households having been exposed to floods more often between 2007 and 2017. On average, households in Darya Khan experienced flood exposure once, while households in Muzaffargarh and Multan experienced it four times. Similarly, housing structures were flooded more often in Multan and Muzaffargarh (on average 2 times) as compared to Darya Khan (on average only once) in the same time period (see Chapter 4, Section 4.2.1). Proximity to the river—the main source of flooding—is another factor that can increase exposure. In Darya Khan, 48% of households lived within 2 km of the river, whereas this proportion was 75% and 78% in Muzaffargarh and Multan, respectively. In Darya Khan, only three factors primarily influenced exposure: (1) not receiving a flood warning; (2) the extent of damages to houses; and (3) a loss of personal belongings in the most recent, worst flood event. A large proportion of households (12%) did not receive any kind of flood warning in the most recent, worst flood event (in 2010) in Darya Khan compared to Muzaffargarh (8%), whereas in Multan, all households received a flood warning. Similarly, damages to household assets were highest in Darya Khan and lowest in Multan (Chapter 4, Section 4.2.2).

Overall, experiences with flood exposure, flooding inside one's home, and distance to the river resulted in high exposure in the rural hinterlands of medium and large cities. Less damage to housing structures and personal belongings can be attributed to a better housing situation and timely evacuation of rural households living around large cities. In addition, better dissemination of early warnings can be linked to better institutional and organisational abilities within large cities. Experts have reported that the presence and activities of state institutions are much higher in Multan compared to Muzaffargarh and Darya Khan. This has also been supported by other studies (Mayo, 2012; The Urban Unit, 2018a). These aspects could result in timely warnings and evacuations, leading to fewer damages to the movable assets of rural households. Even though the flow of information on a flood event is better in rural settlements surrounding large and medium-sized cities, exposure is still high due to a high number of flood events in these rural settlements.

6.3.2.2 Susceptibility

Susceptibility is assessed based on households' diverse socio-economic and physical features. The index value of susceptibility varied from 0.36 to 0.84 in Darya Khan, 0.36 to 0.78 in Muzaffargarh and 0.31 to 0.71 in Multan. Figure 6.4B shows that 75% of susceptibility values were above 0.50, 0.47 and 0.43 in Darya Khan, Muzaffargarh, and Multan, respectively. The mean susceptibility values were 0.56 for Darya Khan, 0.54 for Muzaffargarh and 0.50 for Multan (Table 6.1). Pearson's chi-square test revealed a significant difference in the level of susceptibility among the selected rural case studies

($\chi 2$=24.331; p-value=0.000). The level of susceptibility was different within each study area as well. In Darya Khan, 29% and Muzaffargarh 22% of households were highly susceptible to flooding, whereas in Multan, this proportion was only 11.5% (see Table 6.1). Thus, there is a significant difference both within households in one location (case study area) as well as between locations.

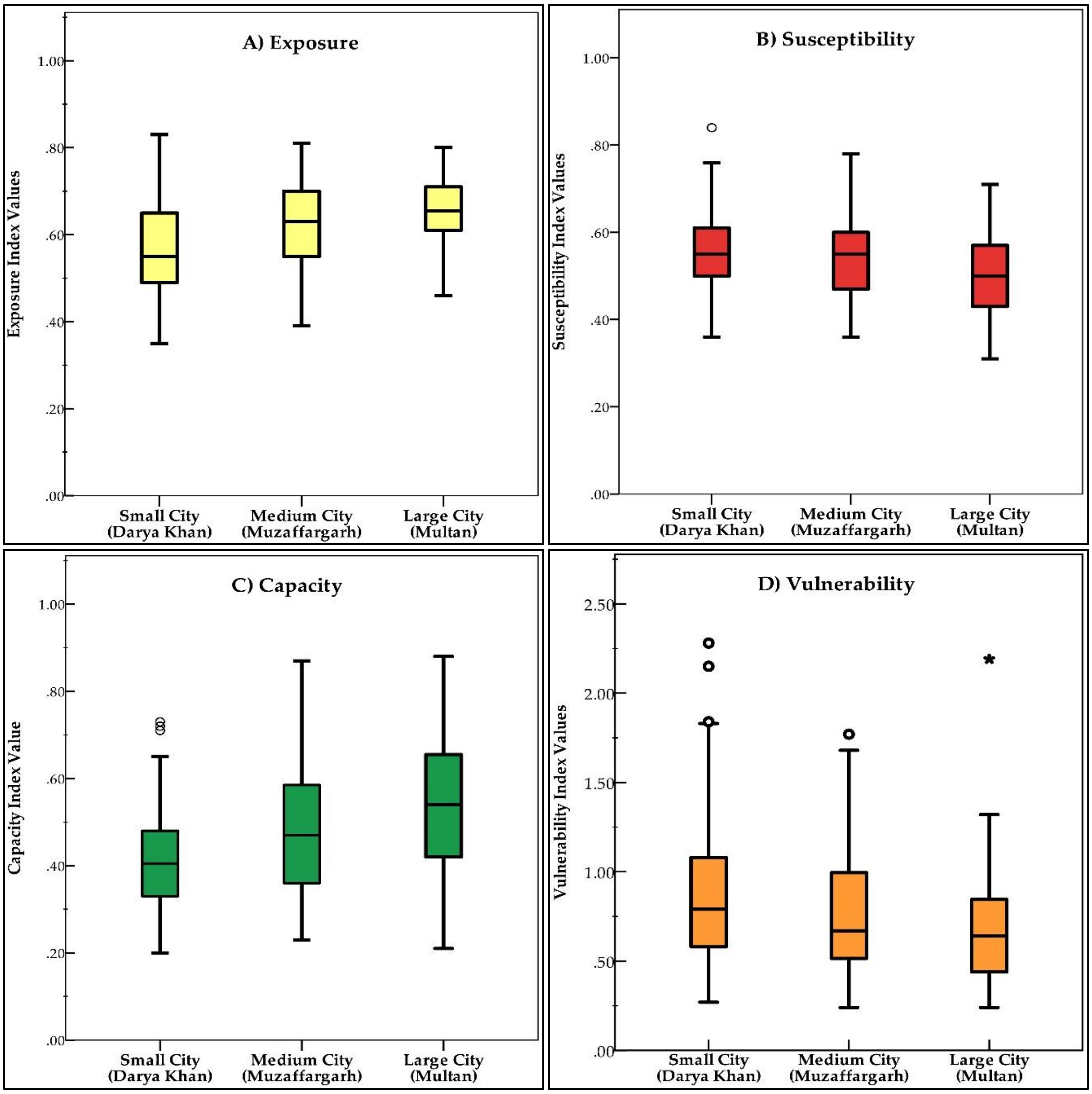

Figure 6.4. The boxplot shows A) Exposure, B) Susceptibility, C) Capacity, and D) Vulnerability of rural households surrounding cities of various sizes. The number of circles (°) over whiskers represents the number of mild outliers and asterisks (*) show the extreme outliers.
(Own analysis, 2020 and already published as Jamshed et al., 2020d)

The lower susceptibility level in Multan can be attributed to several factors. Rural households in Multan (65%) had a better understanding of the early warning system compared to households in Muzaffargarh (50%) and Darya Khan (37%). Households in Darya Khan and Muzaffargarh had lower income levels compared to those of Multan (Chapter 4, section 4.1.4), which also means that their financial assets to cope were different. The construction materials of the homes were much better in Multan, where only 14% of houses are built from mud compared to Muzaffargarh (17%) and Darya Khan (19%). Similarly, 82% of households in Multan, 69% in Muzaffargarh and 62% in Darya Khan, respectively, had access to improved sanitation. In Multan, households had better access to telecommunication services compared to other areas, and rural households in Multan lived in close proximity to paved roads. The quality of access roads in rural settlements was the best in Multan, followed by Muzaffargarh and Darya Khan. Flood-affected rural households, especially in Muzaffargarh, stated that basic goods (food and non-food items) were not available in local markets both during and after flood events. They further reported that it was difficult for them to buy basic consumables at regular prices after a flood, as markets in local cities were selling them at almost double the rate due to shortages. Zyck et al. (2015) also identified issues of price inflation in the province of Sindh. Further, households in Darya Khan explicitly expressed this situation. The shortage of goods and price inflation were less observed in Multan as compared to the other two study areas (Chapter 4, Section 4.2.2).

Overall, rural populations surrounding large cities are less susceptible than those surrounding medium and small cities. The results underscore that a better social, economic, and physical development context—such as a higher level of income, good quality housing, and good road infrastructure—makes households less susceptible to floods in various ways. Jamal et al. (2003) and Mayo (2012) found that Multan District is better off in diverse socio-economic and infrastructure-based ways compared to Muzaffargarh and Darya Khan. Further, that the survey results indicate that floods in the rural hinterlands of larger cities do not significantly influence the prices of essential products in such cities compared to what was reported by rural households in the hinterlands of small and medium cities. Based on the empirical findings of the household survey, it is safe to conclude that rural households around small and medium cities are more susceptible compared to rural households around larger cities. This is in part also due to the less intense linkages and limited socio-economic and physical resources of small and medium cities in their own rural hinterlands.

Table 6.1. Degree of exposure, susceptibility, capacity, and vulnerability rural households living around small, medium and large cities.

Level	Small city (Darya Khan) N = 114		Medium-sized city (Muzaffargarh) N = 115		Large city (Multan) N = 96		Pearson Chi-Square Test	
	Freq	%	Freq	%	Freq	%	χ2 Value	P value
Exposure level								
Low Q1 (0.00 to 0.53)	51	44.7	22	19.1	9	9.4	53.299	0.000
Moderate Q2 (0.53 to 0.61)	31	27.2	35	30.4	22	22.9		
High Q3 (0.61 to 0.68)	24	21.1	25	21.7	32	33.3		
Very High Q4 (0.68 to 0.83)	8	7.0	33	28.7	33	34.4		
Total	114	100.0	115	100.0	96	100.0		
Mean	0.56		0.62		0.65			
Std. Dev.	0.093		0.095		0.075			
Susceptibility level								
Low Q1 (0.00 to 0.47)	20	17.5	30	26.1	35	36.5	24.331	0.000
Moderate Q2 (0.47 to 0.54)	33	28.9	21	18.3	32	33.3		
High Q3 (0.54 to 0.60)	28	24.6	39	33.9	18	18.8		
Very High Q4 (0.60 to 0.84)	33	28.9	25	21.7	11	11.5		
Total	114	100.0	115	100.0	96	100.0		
Mean	0.56		0.54		0.50			
Std. Dev.	0.088		0.091		0.089			
Capacity level								
Low Q1 (0.00 to 0.36)	46	40.4	30	26.1	15	15.6	40.367	0.000
Moderate Q2 (0.36 to 0.45)	35	30.7	25	21.7	20	20.8		
High Q3 (0.45 to 0.58)	25	21.9	31	27.0	22	22.9		
Very High Q4 (0.58 to 0.88)	8	7.0	29	25.2	39	40.6		
Total	114	100.0	115	100.0	96	100.0		
Mean	0.41		0.49		0.54			
Std. Dev.	0.116		0.161		0.154			
Vulnerability level								
Low Q1 (0.00 to 0.52)	19	16.7	28	24.3	31	32.3	12.816	0.046
Moderate Q2 (0.52 to 0.68)	27	23.7	33	28.7	25	26.0		
High Q3 (0.68 to 0.98)	33	28.9	23	20.0	25	26.0		
Very High Q4 (0.98 to 2.28)	35	30.7	31	27.0	15	15.6		
Total	114	100.0	115	100.0	96	100.0		
Mean	0.86		0.78		0.68			
Std. Dev.	0.402		0.366		0.315			

(Own analysis, 2020, already published as Jamshed et al., 2020d)

6.3.2.3 Capacity

Capacity refers to the numerous abilities households possess that allow them to deal with flood events in the short, medium and long term. The results revealed significant variation in households' capacity both within and between the different case studies. The capacity index values varied from 0.20 to 0.73 in Darya Khan, 0.23 to 0.87 in Muzaffargarh and 0.21 to 0.88 in Multan. The box plot shows that 75% of the capacity index values were above 0.33 in Darya Khan, 0.36 in Muzaffargarh and 0.42 in Multan (see Figure 6.4C). The average value was 0.41, 0.49, and 0.54 for Darya Khan, Muzaffargarh and Multan, respectively. A significant difference was observed in the level of capacity of the case study areas ($\chi2$=40.367; p-value=0.000). According to Table 6.1, a large proportion of households in Darya Khan had low capacity (40%), and only 7% had very high capacity to deal with flooding and the subsequent impacts. In Muzaffargarh, 26% had low capacity and 25% of households had very high capacity, while in Multan, only 16% of households had low capacity to deal with floods, and 41% had the very high capacity, based on the index applied.

Interestingly, the difference between the case studies was very high. Almost all capacity indicators favoured Multan. In Darya Khan and Muzaffargarh, households were characterised by lower educational levels and more limited in multiple skills compared to Multan. The economic dependency ratio in Multan was also higher due to a greater number of earning members per household and more diverse sources of livelihood. A greater number of rural households in Multan had savings compared to the other two case study areas. In response to flood events, rural households in Multan received higher financial aid from donor and government aid programmes, followed by Darya Khan and Muzaffargarh. Participation in disaster awareness and training programmes was significantly higher in Multan. Moreover, rural development programmes in the form of physical infrastructure reconstruction (roads, electricity, irrigation, etc.) were reported in Multan (index value: 0.66), followed by Muzaffargarh (0.50) and Darya Khan (0.14). In terms of improving the capacity to secure one's livelihood against floods, households undertook several adaptation measures, including improvements in the access of weather information, agricultural extension and credit services, changing cropping patterns, and migration to cities for income diversification (chapters 4 and 5). Except for migration, all other capacity measures were highly utilised by households in Multan, followed by Muzaffargarh and Darya Khan. The lower migration rates from rural to urban areas in Multan were most likely due to better transportation infrastructure, which allows for daily commuting to the city, rather than temporarily migrating for income generation (Chapter 5).

Overall, the indicators and index results showed that the flood-prone rural hinterlands of large cities had a greater capacity to deal with floods compared to the other two case studies. These settlements and their residents were usually better off, not only in terms of the socio-economic situation, but also in terms of infrastructure and institutional structures. The SPI and functional centrality index also ranked Multan higher than Muzaffargarh and Multan (Chapter 3, Table 3.2). It seems that large cities influence their hinterlands regarding financial and institutional resources before, during and after a flood crisis. More disaster awareness programmes, development initiatives, and coverage of financial aid indicate that the rural populations near large cities are more prosperous than rural populations around small cities, and might also receive higher visibility for getting support. Large cities like Multan have bigger and more specialised markets that allow rural inhabitants to access services to adapt their livelihoods, which permitted people in Multan to modify their cropping patterns by changing crop varieties and plantation dates, as well as by diversifying their crops (Chapter 4, Section 4.3). The rural households of Multan also found it easier to access different credit services with less strict conditions compared to Darya Khan and Muzaffargarh. Jamal et al. (2003) and Mohey-ud-din (2018) noted that Darya Khan and Muzaffargarh are highly deprived in terms of urban services and facilities compared to Multan. Hence, support from cities for rural areas to access services and facilities can have a significant influence. Hence, large cities can influence the capacity of the households in their rural hinterlands to adapt to flood hazards compared to medium and small cities. Such capacity is also largely affected by rural-urban linkages.

6.3.2.4 *Vulnerability*

Given the sizes of nearby cities, the analysis of rural vulnerability to flood hazards provided interesting results. The findings showed little difference between the maximum and minimum value of vulnerability among the case studies. However, the mean value differed significantly. The index value of vulnerability varied between 0.27 and 2.28 in Darya Khan, 0.24 and 1.77 in Muzaffargarh, and 0.24 and 2.19 in Multan. However, Figure 6.4D illustrates that 75% of the vulnerability index values were above 0.58, 0.52 and 0.44 in Darya Khan, Muzaffargarh and Multan, respectively. The mean index value of vulnerability was 0.86 for Darya Khan, 0.78 for Muzaffargarh and 0.68 for Multan. The difference between the levels of vulnerability of households in rural areas around the three cities was significant ($\chi 2=12.816$; p-value=0.05). The proportion of vulnerable rural households was highest in Darya Khan, where almost 60% was highly vulnerable, whereas in Muzaffargarh and Multan, this fraction was 47% and 41%, respectively (see Table 6.1). These outcomes imply that rural populations surrounding large cities are less vulnerable despite being highly exposed to floods, followed by those surrounding medium and small cities. In this thesis, households in rural areas around large cities (such as Multan) exhibited a lower susceptibility and higher capacity to cope and adapt, which resulted in an overall lower vulnerability. These results also underscore the importance of rural-urban interactions for rural households' vulnerability.

6.3.3 Proximity to the city and rural vulnerability

The analysis and results differentiated between two proximity groups—NPS and FPS, mentioned earlier—(see Chapter 3, Section 3.1.2.1 for details on proximity groups). The lower index values (toward 0) represent a low level of exposure, susceptibility, capacity and vulnerability while higher values (toward 1) represent a high level of exposure, susceptibility, capacity and vulnerability. Thus, high capacity scores denote a positive aspect, while lower scores indicate negative aspects.

6.3.3.1 *Exposure*

Regarding the degree of exposure (of NPS versus VPS), a slight difference was noted for rural households living near to and far from Muzaffargarh and Multan (see Figure 6.5, A to D). In Darya Khan, the mean exposure score for NPS was 0.54, and for FPS it was 0.58. In Muzaffargarh, NPS was slightly less exposed, with a score of 0.61 compared to FPS, which had a mean index value of 0.63. In Multan, the exposure of both NPS and FPS was relatively similar, with index scores of 0.64 and 0.65, respectively. Overall, the exposure of NPS was slightly lower (0.60) compared to FPS (0.62). Multan demonstrated a higher exposure for both NPS and FPS, whereas Darya Khan had a lower exposure. In Muzaffargarh and Multan, exposure to flood hazards did not differ by proximity to cities.

In NPS, a greater number of individuals were exposed due to bigger family size in Muzaffargarh and Multan. Although a large family size is a kind of social capital in terms of a wider network, it also results in a larger number of people exposed. Households living in FPS in Darya Khan and Muzaffargarh did not receive flood warnings during the most recent flood event. This implies that FPS are less likely to receive flood warnings, which were mainly disseminated in areas closer to cities. Exposure to past flood events and the subsequent losses were other important factors that determined the degree of exposure in all settlements. These causal factors were also identified by Sam et al. (2017) and Jamshed et al. (2019b) in India and Pakistan, respectively. Compared to Darya Khan, households in Muzaffargarh and Multan experienced more floods in both NPS and FPS. In FPS, higher losses were reported for crops/grains stored for sale and household use. Households reported that they did not have enough time to move their crops and grains to a safer place; hence, their financial capital was more exposed. Moreover, losses of personal belongings were significantly high, especially in remote settlements. Rural populations living near cities also live close to flood dykes and evacuation points where they can transfer their household belongings, and therefore experience fewer losses compared to FPS. In addition, the results suggest that rural households in NPS and FPS are relatively equally exposed when considering immovable assets like homes, farmland and standing crops (physical and natural capital). Hence, proximity to a city might not affect the exposure of immovable assets. However, the vulnerability assessment framework used also signals that access to information services and evacuation points can influence the degree of exposure.

6.3.3.2 Susceptibility

In terms of susceptibility, the results revealed different index values, but similar patterns, between all three case studies (see Figure 6.5, A to D). The mean index values for NPS were 0.53, 0.58 and 0.48 for Darya Khan, Muzaffargarh and Multan, respectively. The index scores for FPS in Darya Khan and Muzaffargarh were the highest and similar (i.e. 0.58, while Multan had a score of 0.53). The composite susceptibility score for all case studies was 0.51 for NPS and 0.56 for FPS. The susceptibility index values were higher for Darya Khan and Muzaffargarh and lower for Multan. Generally, settlements closer to cities were less susceptible to flood hazards, whereas settlements far from cities were more susceptible.

Susceptibility is explained by numerous demographic, socio-economic, physical, and environmental features, and increases the vulnerability and predisposition to be adversely affected by a flood. The level of understanding of flood warning signs was much higher among households living in NPS. In Multan and Muzaffargarh, especially, FPS have lower income levels, making them more susceptible to flood hazards. Most of the houses, particularly in FPS in Darya Khan and Muzaffargarh, were built from mud, which is extremely susceptible to flood hazards, causing people to experience severe damages to mud houses in the past (Kirsch et al., 2012; Jamshed et al., 2019). In FPS, limited access to communication facilities, longer distances to paved roads and emergency services, long-term disruption of basic infrastructure services (electricity, transport), as well as poor road quality are central in increasing rural households' susceptibility. However, the situation was much better in Multan for both NPS and FPS, possibly due to better roads and other service deliveries. Moreover, sufficient water availability for farming purposes was lacking in FPS, and thus increased the susceptibility of rural households to flooding. Hence, the livelihood of households living in remote rural settlements seems to be less secure compared to those living closer to a city. Bah et al. (2003) also underscored that the disruption of infrastructure facilities and damages to roads caused livelihood insecurity among remote rural households.

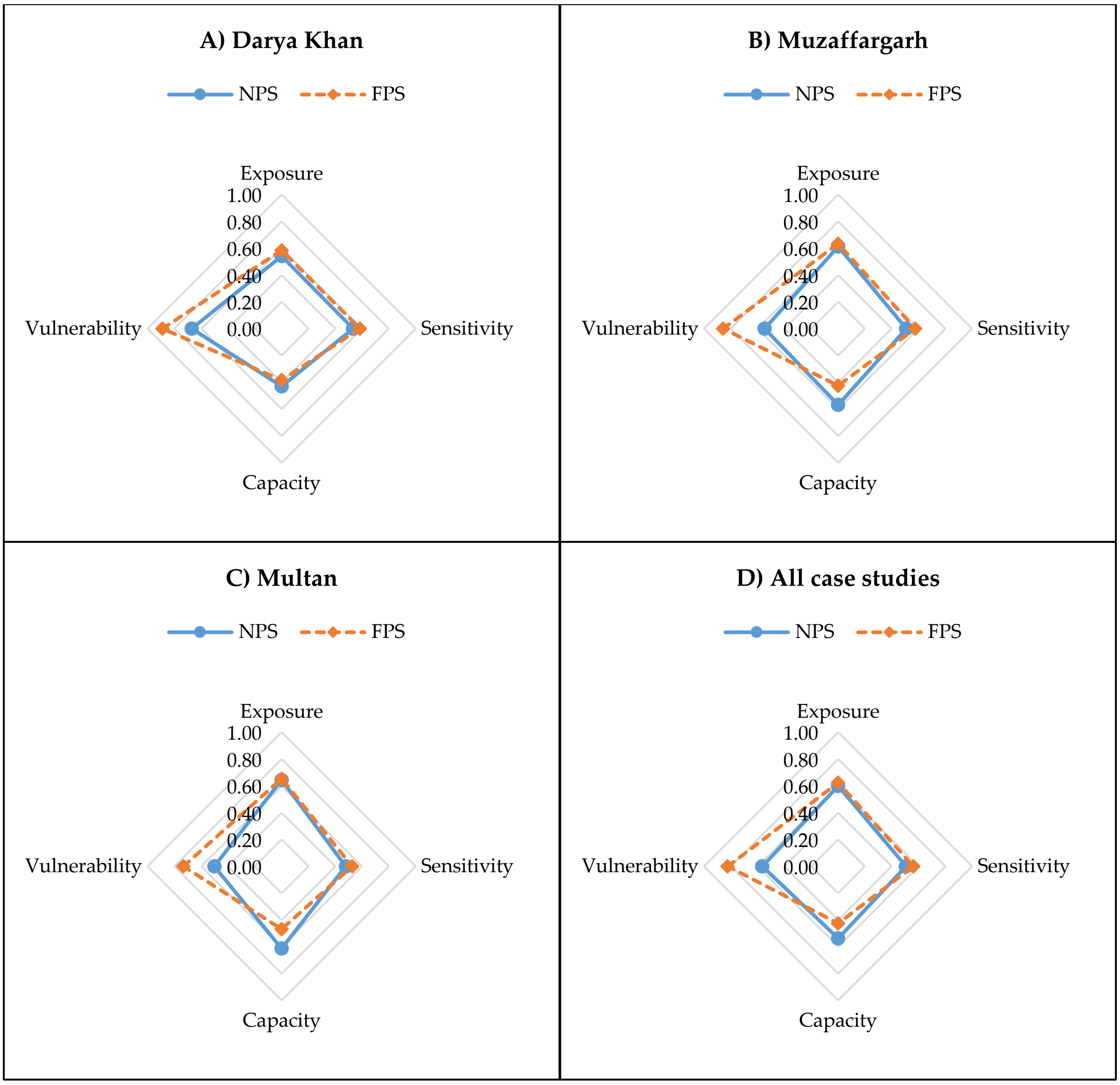

Figure 6.5. A-D showing exposure, susceptibility, capacity, and vulnerability of each case study area. 0 represents the lowest value and 1 represents the highest value in each case. (Own figures, 2020, already published Jamshed et al., 2020a)

6.3.3.3 *Capacity*

Capacity varied significantly, both in terms of study area and distance to the city (see Figure 6.5, A through D). The mean index value in Darya Khan was 0.43 for NPS and 0.38 for FPS, whereas in Muzaffargarh it was 0.57 for NPS and 0.43 for FPS. In Multan, the index scores were 0.61 and 0.47 for NPS and FPS, respectively. The capacity scores for all case studies were 0.54 for NPS and 0.43 for FPS. Overall, based on the index calculation, the NPS generally had a greater capacity to cope with and adapt to floods compared to FPS in all three case study areas.

The capacity to deal with flooding was lower in all FPS in all case studies. Higher illiteracy and a lack of skills among households of FPS in Darya Khan and Muzaffargarh significantly influenced the capacity to deal with floods. In Multan, higher accessibility to market and weather forecast information was noticed in NPS. In FPS, very few households have participated in disaster training and awareness programmes. Further, restricted access to agricultural extension services after flooding in Darya Khan and Muzaffargarh hampered capacity building and increased existing capacity deficits. This points to the fact that institutional resources, among other issues, were more concentrated in NPS.

In all case studies, multiple earning members, livelihood diversification, and financial aid by institutions were vital forms of capital and crucial capacity measures in NPS against flood hazards. Living closer to the city increases rural households' chance of livelihood diversification (Fafchamps et al., 2005; Khatiwada et al., 2017), lowers the probability of them being poor (Diao et al., 2019), and increases their wellbeing. As such, rural households in NPS had less vulnerability. Households living in NPS in Multan and Muzaffargarh also accessed agricultural credit more frequently. Moreover, physical capital (like the provision of relief goods and other aid against flood losses, as well as changing building materials and raising the platforms of homes to deal with future floods) was mostly concentrated in NPS. In NPS, particularly in Multan, the local government started various programmes to develop rural infrastructure (roads, sanitation, and irrigation), which may reduce future vulnerability. In NPS in Multan, households changed their cropping patterns in the form of altering crop variety and crop plantation dates. Further, rural households in NPS in Muzaffargarh and Multan highly adopted crop diversification as a capacity measure. This suggests that households living in NPS, in general, are better informed due to market proximity, have more access to agricultural extension services, and are hence likely to adapt their cropping patterns accordingly. These findings are also supported by other studies (e.g. Abid et al., 2015 and Ullah et al., 2019).

6.3.3.4 Vulnerability

Overall, vulnerability for NPS was 0.67, 0.55, and 0.50 for Darya Khan, Muzaffargarh, and Multan, respectively. In terms of FPS, the overall vulnerability was 0.89 for Darya Khan, 0.86 for Muzaffargarh and 0.73 for Multan. Regarding the vulnerability scores for the entire case study area, for NPS it was 0.56 and for FPS it was 0.82 (see Figure 6.5, A through D). Moreover, as seen in Figure 6.6, 9 villages were categorised as high to very highly vulnerable in Darya Khan, and 8 of those villages belong to FPS. In Muzaffargarh, 10 surveyed villages were in the category of high and very high vulnerability; only one of the villages belonged to the NPS group (Figure 6.7). Similarly, in Multan, 11 surveyed villages were in the category of low to medium vulnerability; only three of them belonged to FPS (Figure 6.8). Thus, the spatial analysis indicated that FPS are more vulnerable to flooding in all three case study areas.

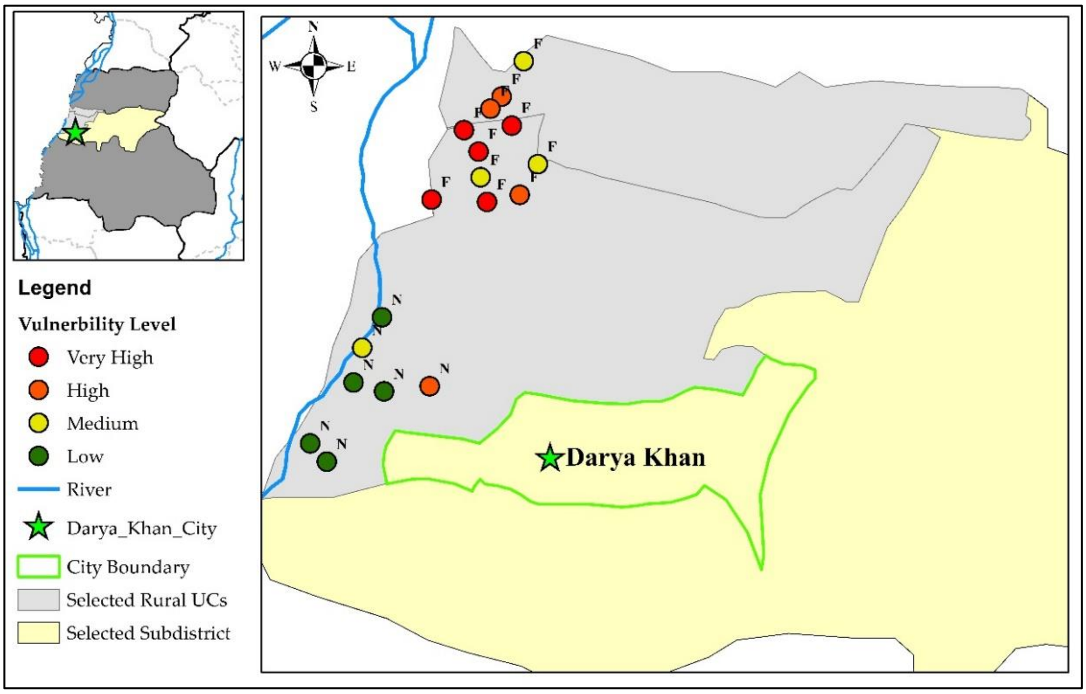

Figure 6.6. Comparison of flood vulnerability level of villages near (represented by 'N') and far (represented by 'F') from the Darya Khan city.
(Own figure, 2020)

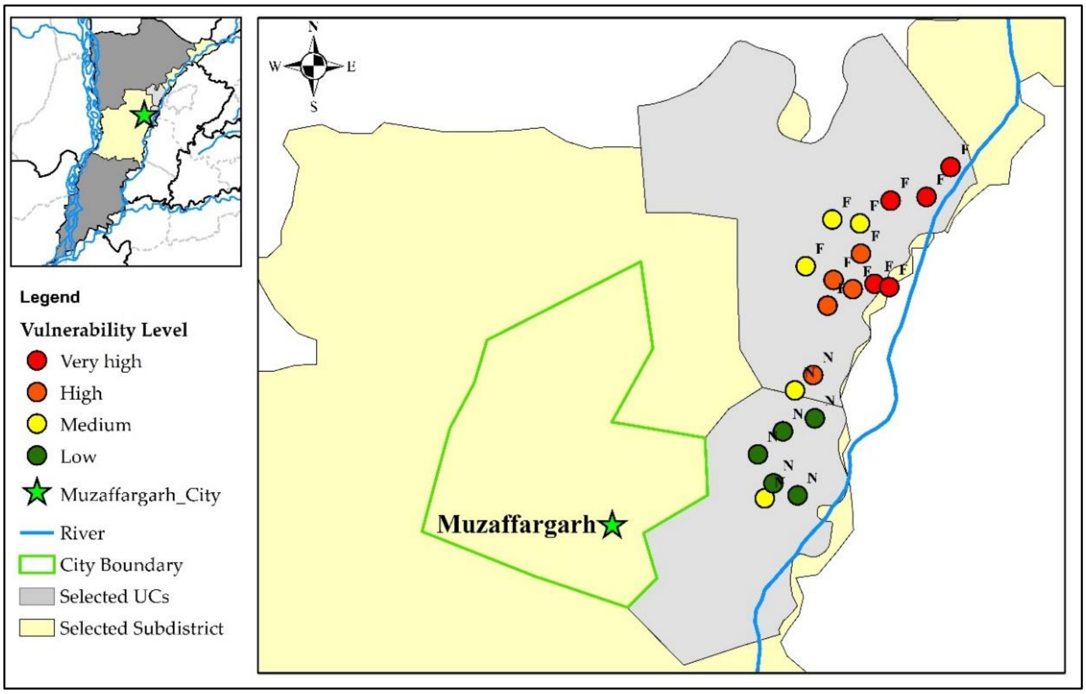

Figure 6.7. Comparison of flood vulnerability level of villages near (represented by 'N') and far (represented by 'F') from the Muzaffargarh city.
(Own figure, 2020)

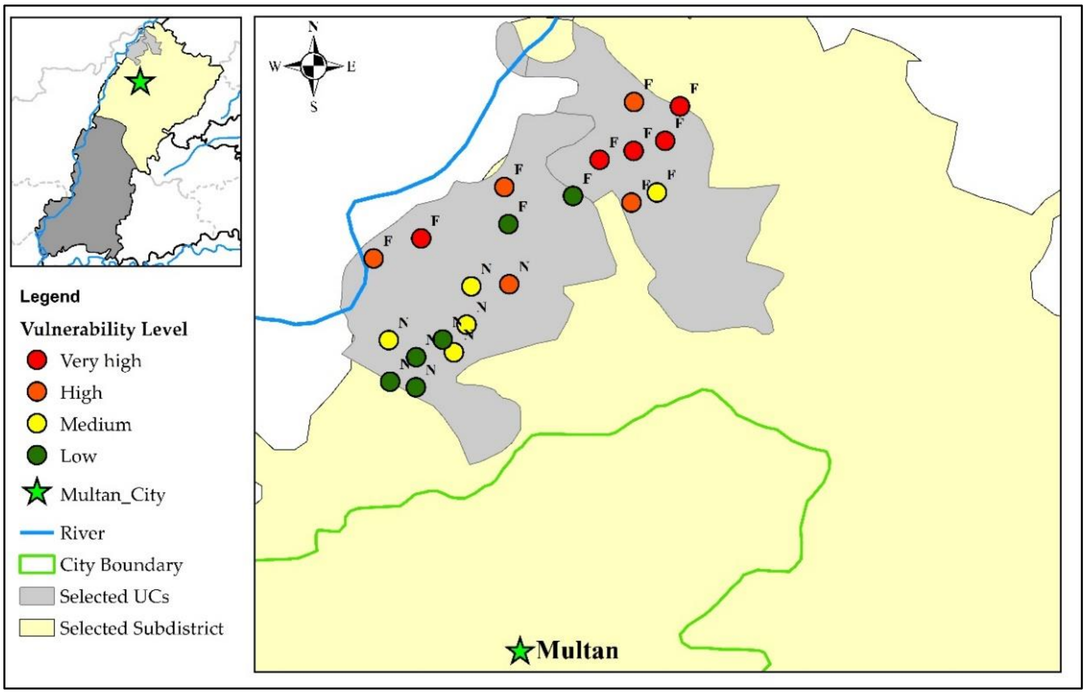

Figure 6.8. Comparison of flood vulnerability level of villages near (represented by 'N') and far (represented by 'F') from the Multan city.
(Own figure, 2020)

Overall, to check whether the difference of vulnerability between NPS and FPS was statistically significant, the Mann-Whitney U test was performed. The Mann-Witney U test (Table 6.2) revealed a significant difference of exposure, susceptibility and capacity between the NPS and FPS. The test outcome suggests that NPS are less exposed and susceptible, and have a greater capacity to deal with floods compared to FPS.

Table 6.2. Mann-Whitney U test for proximity groups of holistic vulnerability

Tests	Exposure	Susceptibility	Capacity	Vulnerability
Mann-Whitney U	11117.0	8887.0	7957.5	7120.0
Significance level (*p*)	0.014	0.000	0.000	0.000
Grouping Variable: Proximity to a city (1= NPS; 2 = FPS)				

6.3.3.5 Rural vulnerability vis-à-vis distance to the city

In order to check the relationship between distance to the city and vulnerability, as well as to confirm the findings of the index, Pearson's correlation analysis was performed between the absolute distance and index values of vulnerability (Figure 6.9 and Table 6.3). The findings displayed a significant correlation between rural households' distance to the city (Darya Khan, Muzaffargarh and Multan) and their vulnerability (and its components) to flooding (see Table 6.3).

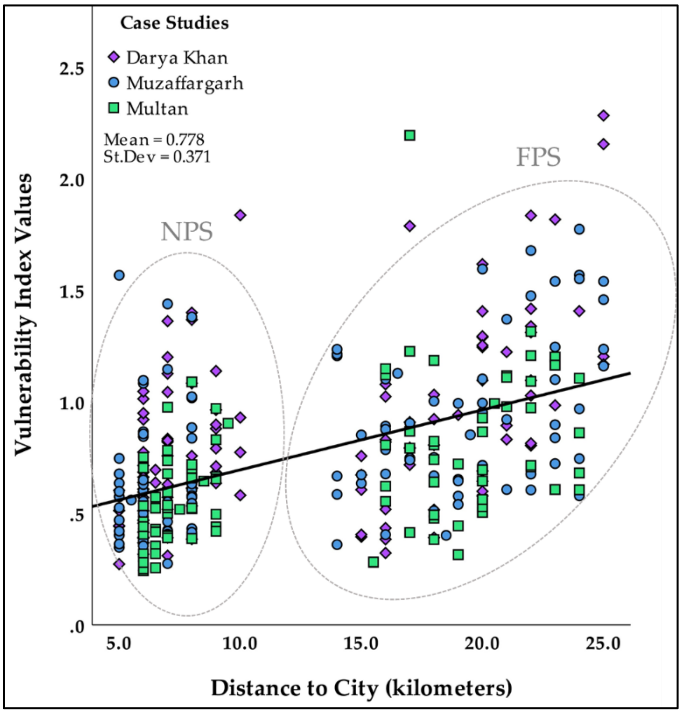

Figure 6.9. Figure showing the scatterplots between distance and vulnerability (Own analysis, 2020)

In all case study areas, exposure (except for Multan) and susceptibility were positively related, and capacity was negatively related to distance to the city. The extent of the correlation coefficient varied among the case studies for vulnerability and its components. In the context of vulnerability, the highest correlation coefficient was found for Muzaffargarh (r=0.514; *p*=0.01), followed by Darya Khan (r=0.506; *p*=0.01) and Multan (r=0.484; *p*=0.01). In general, exposure (r=0.261; *p*=0.01) and susceptibility (r=0.406; p=0.01) were positively and significantly correlated, whereas capacity was negatively correlated (r= -0.374; *p*=0.01) with distance to the city. Figure 6.9 depicts an increasing level of vulnerability with the increase in distance (see also figures 6.6, 6.7 and 6.8). This was because areas settlements far from cities had limited access to information, higher illiteracy rates, restricted access to local institutions for agricultural extension, low incomes, limited earning opportunities, and an unavailability of basic physical infrastructure. Thus, distance to the city is a crucial parameter that indirectly influences rural vulnerability (and its components) to floods.

Table 6.3. Correlation between rural households' distance to cities and their vulnerability

Rural vulnerability	Darya Khan	Muzaffargarh	Multan	All case studies
Exposure	0.416**	0.221*	0.127	0.261**
Susceptibility	0.450**	0.434**	0.394**	0.406**
Capacity	-0.276**	-0.460**	-0.484**	-0.374**
Vulnerability	0.506**	0.514**	0.484**	0.485**

** Significant at the 0.05 level*
*** Significant at the 0.01 level*

6.3.4 The relevance of city size, proximity to cities and rural-urban linkages for rural flood vulnerability

This research argues that cities' characteristics could influence the vulnerability (and its components) of households living in rural areas around different cities. The impact of cities on rural vulnerability is especially determined by different interactions that materialise within rural-urban linkages. Hence, rural-urban linkages are vital factors affecting reduced rural vulnerability, as the livelihoods of rural households depend on urban services (e.g. markets, information, technology, connectivity, etc.) (Belliveau et al., 2006). The results suggest that rural linkages with cities do not significantly influence exposure. The only aspect of exposure that is impacted by the city is the dissemination of flood warnings. The flow of information can mitigate the exposure of people and their moveable capital. However, these flows differ by city size and proximity. There are clear differences between rural households living in the vicinity of differently sized cities and in proximity to their respective city in terms of susceptibility and the capacity to deal with floods. Rural households living around large cities and those living near cities are better off in terms of social, economic, physical and institutional capacity compared to those living in small cities and far from cities.

In the event of a flood, households living closer to cities (especially large ones) have a greater level of accessibility to rescue, relief and other services. The study also found that flood events can intensify rural linkages with cities in terms of accessing credit, market information, agricultural extension services, and new technologies. For example, the flow and use of market information and agricultural extension programmes were more frequent in settlements close to the city and around large cities, which helped farmers to recover and diversify their cropping patterns after a flood. Hence, there are more intense socio-economic, infrastructure and institutional linkages between rural areas and large cities, as well as rural areas near cities, which makes them less vulnerable.

6.4 Summary

The analysis of rural vulnerability offers some valuable insights into the effect of city size and its spatial proximity on rural vulnerability to floods. The SCARV and VPN frameworks were operationalised, and the findings verified the theoretical-conceptual framework, which connects rural vulnerability to questions of rural-urban linkages.

Rural vulnerability and its components varied when considering city size and proximity to cities. In terms of city size, rural populations surrounding large cities were less susceptible and had more capacity. As for proximity to the city, the results revealed that areas close to cities were less exposed and susceptible to flood hazards, whereas areas far from cities had limited capacity to cope with and adapt to floods. This difference of vulnerability among the case studies and between proximity groups occurred not only due to the differential socio-economic, geographic, infrastructure and institutional characteristics of each case study, but also because of diverse and dynamic rural-urban linkages. In this context, the analysis signalled that Multan, as a large city, might have a stronger and broader influence on the rural hinterland (by offering multiple and diverse functions as well as higher-order services) compared to the influence of small and medium cities (Chapter 3 and section 6.3.2).

Overall, a city's size and the distance from it influence the intensity of linkages and the development disparity of surrounding rural areas, and in turn, households' vulnerability to flooding. The next chapter examines how changing linkages following a flood (Chapter 5) impacts rural households' overall vulnerability (Chapter 6).

Chapter 7
Changing rural linkages with cities and their influence on flood vulnerability

This chapter combines the results of previous empirical research chapters (chapters 4, 5 and 6) and explores the influence of changing linkages on rural households' overall flood vulnerability. The preceding chapters have shown that among other issues, flood impacts can lead to structural-livelihood modifications and shifts in rural linkages with cities, which can further affect rural vulnerability. These changes and vulnerability vary by city sizes and distance to the city. The changes in linkages (in the form of increased and reduced dependence on cities) are also linked to people's strategies to cope with and adapt to the impacts of flooding (Chapter 5). However, these changes may again influence overall flood vulnerability, which is investigated in this chapter.

The key question considered in this chapter is *'How do changes in rural-urban linkages after a flood event influence rural households' vulnerability to flooding'?* Based on this, secondary questions were probed: (a) Are there any differences in the vulnerability of households that changed their linkages with cities compared to those that did not? and (b) To what extent do changes in linkages influence rural households' vulnerability?

The chapter is divided into three sections. Section 1 briefly explains the analytical approach. Section 2 provides the results and discussion, which indicate that changing linkages have a differential effect on vulnerability. The third section summarises the key findings.

7.1 Analytical approach

This section outlines the descriptive statistics developed and used to analyse the effects of changing linkages on vulnerability. Initially, using descriptive statistics, box plots were drawn; later, the mean values of vulnerability were compared for households with changing linkages in the form of increased and reduced dependence on cities. The values of vulnerability represent the index values (as calculated in Chapter 6), whereby lower index values signal lower vulnerability and higher values denote greater vulnerability.

7.2 Results and discussion

The first sub-section (7.2.1) delineates how increased dependence on cities after a flood affects rural households' vulnerability. The second sub-section (7.2.2) explains how vulnerability differs if households decrease their dependence on cities and shift toward the use of facilities and services from rural areas. The third section investigates the extent of influence on rural households' vulnerability due to changing rural-urban linkages.

7.2.1 Increased dependence on cities and flood vulnerability

In this thesis, households increased their dependence on cities if they had more frequent or intense flows with cities in terms of the increased mobility of people (migration or commuting) to cities, more frequent information and financial flows, as well as the flow of goods (see Chapter 5). A brief description of the change in each flow is provided below.

The increased flow of people is represented by long- and short-term migration, as well as by commuting (Chapter 5). The results revealed that households with members that were migrating or commuting to cities after a flood were among the households classified as less vulnerable (33% had a low vulnerability level) compared to others (21% had a low vulnerability level), with a mean vulnerability score of 0.65 and 0.83, respectively (see Figure 7.1A and Table 7.1). Thus, increasing the flow of people is linked to a lower vulnerability level among rural households.

Changes in financial flows denote frequent access to credit and increased dependence on remittances following a flood event (Chapter 5). Figure 7.1B shows that in all case study areas, vulnerability was lower for households that altered financial flows compared to those who did not do so. Out of households that were able to access credit more often, only 8% were very highly vulnerable, compared to 31% of households that were not able to access credit. The average value of vulnerability was 0.84 among households that did not modify any financial flows, and 0.62 for those who changed financial flows, particularly in terms of being able to access credit (see Table 7.1).

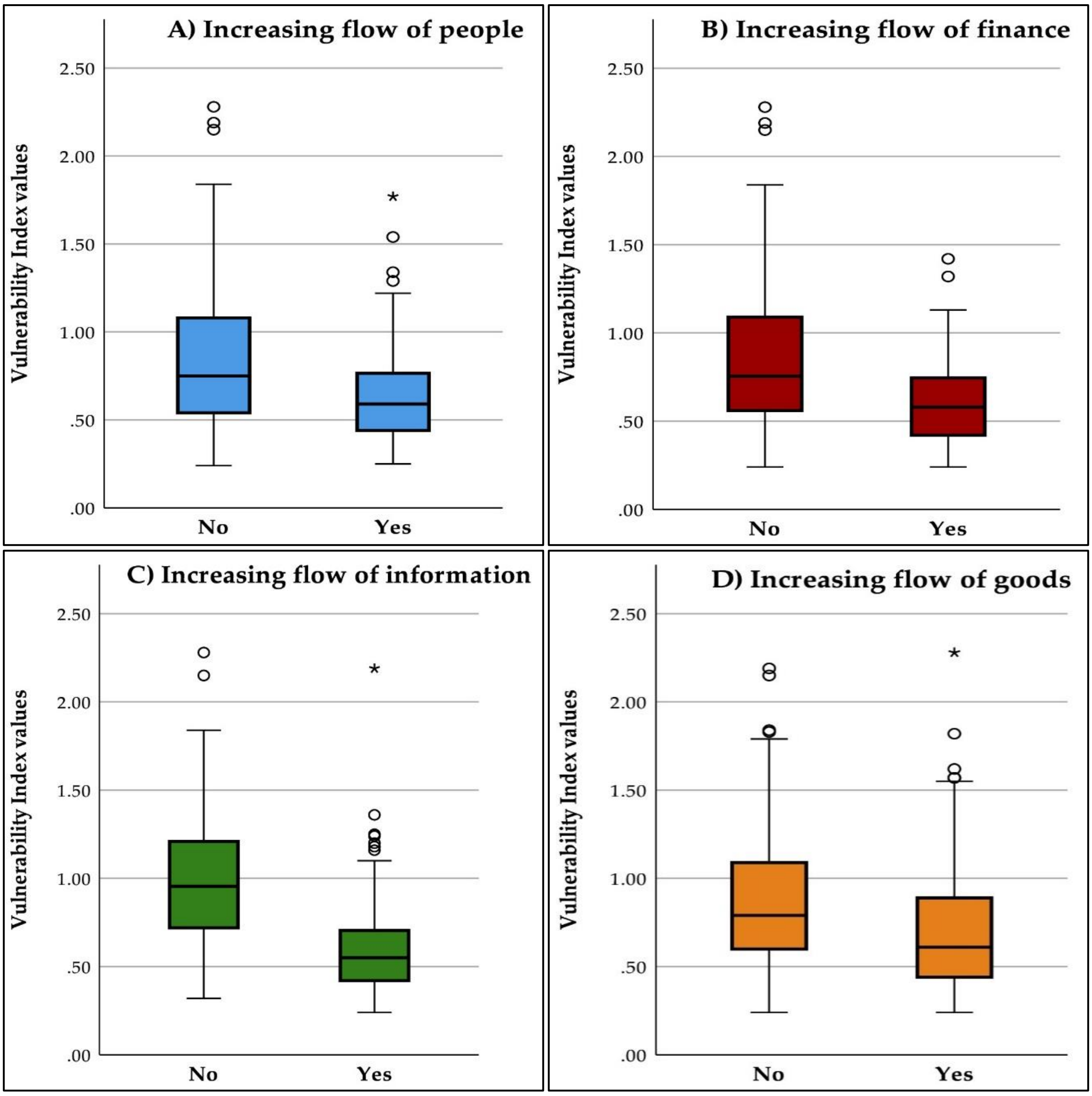

Figure 7.1. Box plot showing the difference between the vulnerability of households with and without increased dependence on cities after the flood event A) Flow of people, B) Flow of finance, C) Flow of information, D) Flow of goods. The number of circles (°) over whiskers represents the number of mild outliers and asterisks (*) show the extreme outliers. (Own figures, 2020)

In terms of the flow of information, the findings in Figure 7.1C underscore that households that were accessing information more frequently were generally less vulnerable. Around 77% of households that did not access information frequently were classified as highly vulnerable. The average value of vulnerability for households accessing information more frequently was 0.6, and 1.0 for households without any changes in information flows (see Table 7.1). Hence, improved access to information (the increased flow of information) can be help to reduce vulnerability.

Table 7.1. Comparison of vulnerability level of households that intensify their linkages (flow of people, finance, information, goods) with cities after the flood

Vulnerability level	People		Finance/income		Information		Goods	
	No (N=233)	*Yes (N=92)*	*No (N= 238)*	*Yes (N=87)*	*No (N=146)*	*Yes (N=179)*	*No (N=155)*	*Yes (N=170)*
Low (Q1)	20.6%	32.6%	19.3%	36.8%	4.1%	40.2%	14.2%	32.9%
Moderate (Q2)	22.3%	35.9%	23.9%	32.2%	18.5%	32.4%	26.5%	25.9%
High (Q3)	26.6%	20.7%	25.6%	23.0%	31.5%	19.6%	29.0%	21.2%
Very High (Q4)	30.5%	10.9%	31.1%	8.0%	45.9%	7.8%	30.3%	20.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Min	0.24	0.25	0.24	0.24	0.32	0.24	0.24	0.24
Max	2.28	1.77	2.28	1.42	2.28	2.19	2.19	2.28
Mean	0.83	0.65	0.84	0.62	1.00	0.60	0.85	0.72
Std. Dev.	0.390	0.281	0.392	0.246	0.368	0.260	0.376	0.355

Households were accessing goods (agricultural inputs) more frequently after a flood (Chapter 5). Figure 7.1D indicates that households that were accessing agricultural inputs from cities more frequently after a flood tended to be less vulnerable. Around 40% of households were classified as highly vulnerable that were getting goods more often compared to 60% of households (classified as highly vulnerable) that were not acquiring goods as frequently. The average vulnerability value was 0.72 for households accessing goods frequently after a flood, compared to 0.85 for other households (see Table 7.1).

Overall, the outcomes highlighted that households that were intensifying linkages with cities after a flood were among those classified as less vulnerable. In terms of an increasing flow of people, households with members that moved to cities after a flood for employment purposes can support the family in reviving their livelihood activities through their added and extra income sources (see the correlation between changes in livelihood and changes in linkages in Annex G). Besides using income to revive livelihoods, households also used their income to reconstruct their homes, as well as to buy food and other household goods that would enhance their capacity against future flood events. A respondent described this situation as the following:

> *We have experienced massive damages to household assets. Our shop—which was the main source of income—and crops were destroyed. The prices of goods, fertilisers and seeds became extremely high after the flood, and we could not afford [them], as we had nothing left. Therefore, we decided to send one*

household member to Multan to work there. He sends us money, which helped us to revive our livelihood. (Respondent 176, Muzaffargarh, 16 km from the city)

This shows that linkages to a city and its job markets or services can help to support affected (nearby) rural households. Tacoli (2009) also found that mobility to cities is an adaptation strategy to deal with extreme events, whereby affected households diversify their income and can help revive and innovate their farm-based livelihoods. Black et al. (2011) contended that the ability to move (migrate or commute to a city) reduces vulnerability, which depends on socio-economic and physical characteristics (as discussed in Chapter 5).

In the context of increased financial flow, households that access farm credit more often or other financial loans can recover their losses more rapidly compared to other households. Acquiring more credit and loans (both from formal and informal institutions) and increasing the flow of remittances resulted in people reviving their farms and rebuilding their homes (Annex G). Abid et al. (2020) also concluded that accessing farm credit more often would lead to increasing financial capacity following a disaster, and help to implement farm adaptation measures for rural households. Remittances in the face of disaster mitigate the vulnerability of affected people (Le De et al., 2015). Similarly, households that frequently access information and farm inputs can adjust their agricultural practices (e.g. changing crop variety, crop type, diversification of crops) accordingly, as indicated in Annex G. A respondent explained this situation:

The flood was very devastating. The government released water from barrages and canals without informing us, which damaged our crops. I have experienced enough losses. Now, I have started to access information on weather and water from relevant organisations during the monsoon season. I am not the only one who is doing it; several other villagers are also doing it. (Respondent 254, Multan, 7 km from the city)

Such adaptation measures can help rural households to protect their income sources from the imminent threat of flooding (Abid et al., 2015; Fahad et al., 2018). Shifts in flows and rural-urban linkages can also lead to several structural and farm adjustments, which alleviate households' vulnerability to future floods. In general, the findings of empirical research suggest that these increased linkages with cities for numerous facilities and services after a flood diminish households' overall vulnerability.

7.2.2 Decreased dependence on cities and flood vulnerability

Some households also reduced their linkages with cities following a flood. Thus, these rural households started to obtain various facilities and services from rural areas. The vulnerability of such households was generally higher compared to those that were more dependent on cities.

In terms of financial flows, households that started to get finances (farm credit or loans) from the village after a flood were more vulnerable (average vulnerability score: 0.87) compared to those who were able to access financial services from the city (average vulnerability score: 0.76), as shown in Figure 7.2A. Only 11% of households that were accessing credit from their respective villages fell in the low vulnerability category, compared to 27% that were accessing credit from the city (see Table 7.2).

In terms of information, households accessing information from rural areas were mostly among households that were more vulnerable compared to those accessing information from cities (see Figure 7.2B). Around 36% of households that were getting information from villages were classified as highly vulnerable, compared to 22% of households (in the same vulnerability category) that were accessing information from cities. The average vulnerability score for households accessing information from villages was 0.95, while it was 0.73 otherwise (see Table 7.2).

Households that were accessing goods (farm inputs) from the village after a flood were more vulnerable compared to those getting them from the city (see Figure 7.2C). Out of households that accessed agricultural inputs from villages, only 6% were in the low vulnerability category. Similarly, the mean vulnerability score for households getting goods from the village was 1.0, compared to 0.67 otherwise (see Table 7.2).

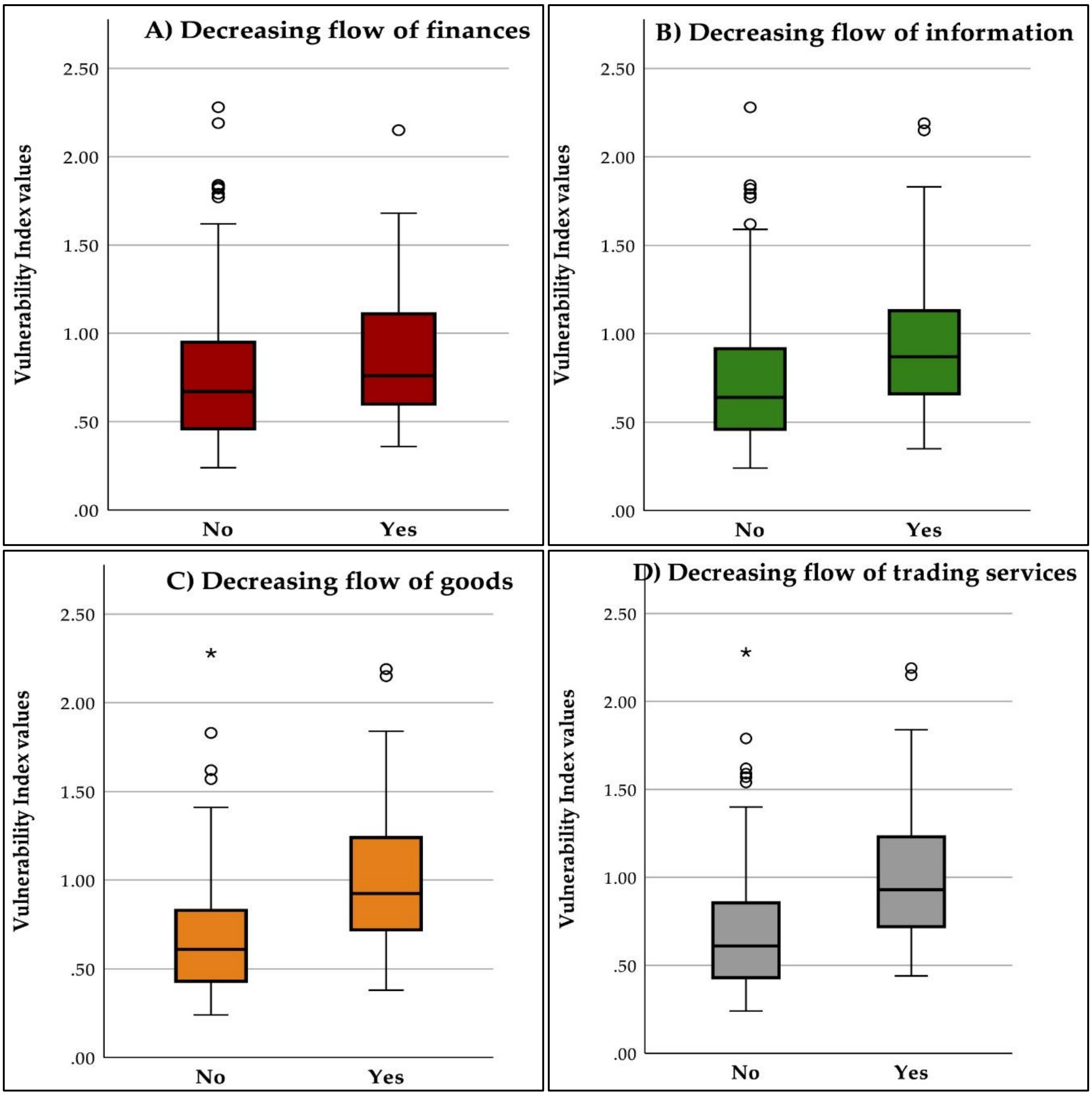

Figure 7.2. Box plot showing the difference between the vulnerability of households with and without reduced dependence on cities after the flood event A) Flow of finance, B) Flow of information, C) Flow of goods, D) Market and trading services. The number of circles (°) over whiskers represents the number of mild outliers and asterisks (*) show the extreme outliers.
(Own figures, 2020)

Concerning market/trading services, some households started to sell their farm products in village shops/centres after a flood. In general, households doing this also had a higher overall vulnerability score (see Figure 7.2D). Only 4% of these households were classified as having low vulnerability, while 32% of those selling their farm outputs in cities were classified as having low vulnerability. The average vulnerability scores were 0.68 and 1.01 for households selling their farm products in cities and villages, respectively.

Table 7.2. Comparison of vulnerability level of households that reduce their dependence on cities (in terms of finance, information, goods, services) after the flood

Vulnerability level	Finance		Information		Goods		Trading services	
	No (N=261)	*Yes (N=64)*	*No (N= 252)*	*Yes (N=73)*	*No (N=219)*	*Yes (N=106)*	*No (N=231)*	*Yes (N=94)*
Low (Q1)	27.1%	11.1%	29.0%	6.8%	32.9%	5.7%	32.0%	4.3%
Moderate (Q2)	26.0%	27.0%	26.2%	26.0%	28.8%	20.8%	28.6%	20.2%
High (Q3)	23.7%	30.2%	23.0%	31.5%	21.9%	31.1%	22.5%	30.9%
Very High (Q4)	23.3%	31.7%	21.8%	35.6%	16.4%	42.5%	16.9%	44.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Min	0.24	0.36	0.24	0.35	0.24	0.38	0.24	0.44
Max	2.28	2.15	2.28	2.19	2.28	2.19	2.28	2.19
Mean	0.76	0.87	0.73	0.95	0.67	1.00	0.68	1.01
Std. Dev.	0.374	0.351	0.353	0.384	0.308	0.385	0.320	0.383

Households opted to access services and facilities from village centres in order to cope with the impacts of floods (i.e. the price inflation of goods and transportation). The results revealed that households getting services from villages/rural areas were generally characterised by a higher level of vulnerability, as well as socio-economically and spatially disadvantaged (e.g. low-income, less educated, lacking social ties, and living in remote rural settlements) (see Chapter 5).

Moreover, households getting finances, goods, information and services from the village were less able to modify their housing structure or change their agricultural practices. Correlation analysis suggested that households taking facilities and services from villages had a negative correlation with structural livelihood changes (see Annex G). The reasons included the following:

(1) Losing their link with cities provided households with limited opportunities to use new products and advanced (higher-order and better) goods that are not typically provided by village shops/traders. Farmers were less informed about market prices in villages.

(2) These households were less educated and had lower incomes (see also Chapter 5). Hence, materialising information (provided by NGOs/local centres) to modify agricultural patterns and housing structures may be more difficult for them. These factors can also restrict access to formal credit, and might constitute an additional barrier in

implementing mitigation and adaptation strategies (see also Abid et al., 2015, Shah et al., 2017; E. Saqib et al., 2018).

(3) Lastly, such households were more dependent on informal credit services, which are normally small in terms of amount, with non-binding conditions; they therefore faced more constraints to recover compared to households that accessed credit in a city. Consequently, this did not add significantly to rural households' welfare and thus increased their vulnerability. One household explained:

> *After the flood, it was very difficult to get credit, especially for poor people like us. The banks or private people do not want to give us credit, as they know we are poor people—we already lost everything—and that if another flood came, we would not be able to return their money. In this case, the only option is to get a small amount of money from a village resident whom you know very well. (Respondent 219, Muzaffargarh, 20 km from the city)*

Some rural households' reduced interactions with the city might not only be due to a voluntary decision, but might also show that access to services within the city (or of institutions in the city) is constrained, especially for those who are already poor and more vulnerable households. Hence, fewer interactions can increase rural households' future vulnerability.

7.3 Summary

Past flood events in Pakistan have significantly altered the relationships of rural households with cities (on which they depend). This has also affected rural households' vulnerability; the level of vulnerability might also influence changes within the rural-urban linkages of different households both during and after flooding. Overall, the shifts in linkages both increased and decreased rural households' vulnerability.

Stronger linkages with cities related to people, information, finances and goods generally further diminished vulnerability. For example, increased linkages with cities allowed households to modify/diversify their livelihood patterns and to increase their coping and adaptive capacity for future flood events. However, stronger linkages could have consequences for households if access to cities were to be totally disconnected for longer periods. On the other hand, decreased linkages with cities increased rural households' vulnerability. For instance, reduced linkages to cities can hamper households' access to services and facilities (e.g. material and non-material assets) that are necessary for adapting to future floods. These differences in linkages can be attributed to households' socio-economic and/or spatial characteristics and flood exposure.

Although changes in all flows influenced vulnerability, the frequent flow of information from cities, as well as getting goods and trading services from village centres, were more important, as these changes significantly affect vulnerability both positively and negatively. Flood events and their impacts, together with other socio-economic and physical factors, resulted in various types of changes in rural households' linkages with cities. Linkages with cities are, for example, vital for the coping with and adapting to floods, and play a vital role in modifying households' vulnerability, both positively and negatively.

Chapter 8
Conclusions and recommendations

The purpose of this research was to investigate the impacts of flood events on rural households and their linkages with cities, as well as how changing linkages with cities can affect rural households' vulnerability. To address these issues and the respective RQs, a conceptual framework that links human vulnerability to flooding and rural-urban linkages was developed. Further, empirical research was carried out in three flood-affected rural communities in Punjab, Pakistan. Analysis and discussion of the findings revealed that rural linkages with cities were indeed affected due to flood impacts and influenced the vulnerability of rural households, which were differentiated by city size and proximity to the city.

The conclusions are summarised in this chapter according to four key themes: (a) a conceptual framing of rural-urban linkages and vulnerability; (b) flood impacts, changes in rural linkages with cities following flood events and their determinants; (c) the vulnerability assessment of rural households considering city size and proximity in the context of rural-urban linkages; and (d) the influence of changing linkages on rural vulnerability to flooding. In addition, this chapter outlines theoretical, practical and empirical contributions and implications based on the findings. Finally, the study's limitations and paths for future research are discussed.

8.1 Conclusions

This research presented an enhanced framework for the vulnerability assessment of rural households by considering the importance of rural-urban linkages in influencing flood vulnerability (Objective 1). A thorough review of impacts, changes and vulnerability (including its components and conceptual frameworks), as well as an examination of the terms 'rural' and 'urban', their interaction theories and typologies of linkages, were conducted. Theories and conceptual frameworks helped to identify factors that usually influence rural-urban linkages and flood vulnerability. The review suggests that rural-urban linkages and their dynamics, due to flood impacts, could affect the vulnerability of flood-prone rural households. Thus, understanding and assessing rural vulnerability to floods requires an improved knowledge of relationships with urban areas. Vulnerability should not only be defined by rural households' internal characteristics, but also by considering the evolving rural-urban interactions that result from flood impacts (Chapter 2, Section 2.4). This matter has not been given adequate attention in previous conceptual frameworks in the literature on disaster risk reduction and climate change adaptation. In this way, rural-urban linkages may provide an opportunity to mitigate rural households' vulnerability.

Overall, the proposed framework highlighted the multi-dimensional, differential, and dynamic nature of vulnerability and rural-urban linkages in the context of floods. It underscored the interactions between vulnerability and linkages, as well as the driving forces that shape the overall flood vulnerability of rural households. Further, the role of city size and proximity to the city was identified as an important research gap that is widely neglected in the discourse on flood vulnerability, and which could be imperative for deeper understanding of rural vulnerability. The framework was flexible enough to conceptualise other specific topics of the research (e.g. changes in rural-urban linkages, city size, rural vulnerability to flooding, spatial proximity to the city, rural vulnerability to flooding). These (additional) sub-frameworks were operationalised, and the empirical findings confirmed the theoretical arguments made in those frameworks.

The empirical research revealed that extreme flood events have devastating direct and indirect impacts on rural households, which lead to multiple changes in rural society. Extreme flooding also changes the relationship and dependencies between rural and urban areas (Objective 2). According to the quantitative empirical outcomes of the household survey, floods severely impact housing structure, crops, and other personal assets of households, and indirectly affect rural households regarding inflation, farmland degradation, and reduced crop productivity (Chapter 4, Section 4.2). The major types of changes in terms of coping and adaptation measures conducted by households were: physical changes to their homes, particularly by shifting from traditional building construction practices to more flood-resilient construction materials; and substantial changes in their livelihood practices to make them more diverse (e.g. by obtaining multiple sources of income or by altering agricultural practices through the diversification of cropping patterns) (Chapter 4, Section 4.3).

The findings of the empirical research further indicated that the impacts of extreme flood events and human responses thereafter interact with the modifications of rural households' linkages with cities in two ways (Chapter 5, Section 5.3.1). First, flood impacts on rural households can increase their linkages with cities through the more frequent flow of facilities and services. Second, flood impacts can limit linkages with cities as households acquire facilities and services from the village. The flows of people (for income diversification), information (more information on markets, weather and agricultural extensions), finances (credit) and goods (farm inputs) between rural and urban areas increase in response to the losses/damages of rural households' diverse physical and financial assets. These flows from cities to rural areas can be hampered after flood events due to the price inflation of goods and farm inputs, as well as damaged roads, which result in higher transportation costs. As such, rural households' dependence on cities can increase and decrease at the same time (Objective 2).

These differences in changing linkages were influenced by households' internal attributes and external factors like city size, proximity to the city, and the extent of flood impacts. The importance and effect of these factors for changing linkages were examined using inferential statistics. In this regard, regression analysis and its post estimations (the marginal effect and elasticity scores) showed that there are several possible ways in which the flows can shift due to socio-economic, physical and flood-related factors (Objective 2). Factors that influenced rural-urban linkages in the context of flood events included age, social networks, income, distance to the city, direct flood impacts, household losses due to flooding, transportation costs, farmland degradation and crop productivity (Chapter 5, Section 5.3.2). Households confirmed these findings with qualitative information as well. In short, rural-urban linkages are affected by flood impacts, as well as by socio-economic and spatial factors independent of flood events. Understanding changes that occurred as a result of extreme flooding is crucial in order to capture the dynamics of rural households' vulnerability to future floods.

Rural households' vulnerability was assessed with a set of indicators, an index, and factors that allowed for consideration of their relationship with cities. City size and proximity to the city were key parameters, as these two aspects also affect socio-economic and physical conditions, as well as linkages (Chapter 2, Section 2.3.3.6). The index-based approach (used in this research) highlighted a spatial disparity associated with city size in the capacity to deal with floods, which has resulted in the varied vulnerability of the surrounding rural populations (Objective 3). Rural households around small and medium-sized cities were less exposed to floods, but more susceptible and vulnerable than those around large cities due to a limited capacity to cope with floods (Chapter 6, Section 6.3.2). This study found that greater capacity is due to larger cities having more economic diversity, better service delivery and more innovative markets, as well as greater institutional ability, which reinforce linkages with surrounding rural settlements and their inhabitants, especially in times of crisis. These linkages not only help to alleviate rural households' vulnerability, which depends on hazards and non-hazards alike, but also contribute to the overall development (via improved access to information and services) of rural areas.

The VPN revealed the importance of distance to a city in rural vulnerability to hazards. The findings confirmed that rural vulnerability to floods is, among other issues, influenced by distance to the city. Thus, linking those issues in the conceptual framework was appropriate. Different components of vulnerability react differently, whereby exposure and susceptibility are positively related, and capacity is negatively related, to distance to the city. The case study analysis detected differences between the index values, implying the much-localised and dependent nature of vulnerability, especially for the aspects of susceptibility and capacity; socio-economic and physical features significantly differed with respect to distance to the city within each case study (Objective 3). There was a prominent difference between NPS and FPS in terms of the ability to cope with and adapt to flood hazards (Chapter 6, Section 6.3.3). Settlements closer to the city were better able to handle floods (and vice versa). The primary reason for this was stronger linkages (better and quick delivery of facilities and services) between cities and rural households living closer to those cities. These results underscore the relevance of distance and rural-urban linkages in the vulnerability of Pakistan's flood-prone communities.

In short, the intensity of rural-urban linkages and the levels of exposure, susceptibility and capacity of rural households to deal with floods also depend on city size and proximity. Cities of different sizes, as well as rural areas, have diverse social, economic, infrastructure and institutional characteristics that affect linkages and the vulnerability of households in the surrounding rural areas, at varied proximity to those cities (Objective 3). However, the changes households make in rural-urban linkages influence their overall vulnerability differently. In general, extreme flood events in the past and their numerous ramifications in rural settlements shifted linkages in a way that both increased and decreased dependence on cities. Both types of changes influenced vulnerability differently (Chapter 7, Section 7.1). A rise in linkages with the city after a flood often reduces a rural household's vulnerability, while decreased linkages with the city usually increases a rural household's vulnerability for future flood events (Objective 4).

The socio-economic and physical features of both communities were different as well. Moreover, rural households' increased dependence on cities for myriad services/facilities can also have consequences when access to cities is completely disrupted (in the future for a long period of time). In general, the outcomes signal that rural settlements' linkages and exchanges with cities are crucial in mitigating their vulnerability to flood hazards.

To summarise, the magnitude of the changes (both livelihood and linkages) differed between the case study areas. A higher degree of flood exposure induced more changes among rural households in Multan compared to the other case study areas. Multan's larger size led to frequent information access, and allowed for a more enhanced/diverse quality of services for its rural inhabitants. This helped people to better adapt to future flood hazards (e.g. by altering their livelihood strategies). Multan's rural households conducted most adaptation measures. Multan is also a large city with the highest centrality function; thus, the range of services the city provides to the surrounding rural region is a central factor that influences rural households' ability to change and adapt in the aftermath of flood events. Interestingly, in this thesis, the relationship between rural areas and cities shifted after flooding. Although the flow of services and facilities from urban to rural areas was often hampered after a flood event due to damaged roads, the flow of people, information and goods became stronger. Generally, the findings indicate that people alter their livelihoods following extreme events due to lessons learned. Households undertake structural and livelihood modification, as well as change the relationship between rural areas and cities, thereby influencing rural households' vulnerability. However, these shifts are also influenced by households' socio-economic conditions and the extent of flood impacts. Thus, extreme flood events seem to trigger changes in learning and help people to initiate alterations in flood-exposed rural communities. This empirical work underscores that a deeper understanding of rural-urban linkages for rural vulnerability to flooding is helpful, and suggests that rural linkages with cities are changing and not always increasing, which depends on households' internal characteristics and spatial factors (city size and proximity). These lessons and transformations are imperative for rural households to enhance their capacity to adapt to future flood hazards, and hence reduce their vulnerability.

8.2 Implications and recommendations for policy and practice

The research reveals the significance of the dynamics of rural-urban linkages in the aftermath of extreme events, as well as the socio-economic, spatial and flood-relevant aspects that affect these linkages. Further, it underscores how the dynamics of rural linkages with cities influence rural vulnerability. Based on the findings, specific recommendations can be derived and formulated.

I. Acknowledging rural-urban linkages interferes with risk management

Increased migration/commutes to the city and greater flows of information, finances and income can help rural households to secure their livelihoods after a flood by investing in resources for housing, income diversification, and altering their farming practices. At the same time, households that have stronger linkages with cities after a flood can have ramifications if they entirely disconnect from cities for longer periods due to the impacts of future flood events. Households' increased dependence on rural areas for certain facilities and services can increase vulnerability, especially if such facilities and services are limited. This suggests that rural linkages with cities, if carefully managed, can be important tools to mitigate vulnerability and increase capacity. In this context, acknowledging and strengthening rural-urban linkages in the face of flood hazards should be a priority in future risk management. Some strategies that could boost the positive influence of rural-urban linkages in alleviating rural vulnerability include efficient information delivery mechanisms, the creation of both urban and rural-based livelihood diversification opportunities, ensuring safe working and living conditions with adequate salaries for rural migrant workers, opportunities for building networks with the public and private sectors, strict control of prices, and the circulation of goods and services (both during and after a crisis), as well as rapid infrastructure reconstruction and providing alternative access to the nearest cities.

II. Giving remote rural communities more attention

The research highlighted that households living in the hinterlands of small and medium-sized cities (specifically in remote rural settlements) had less intensive linkages with cities and were often more vulnerable. These rural settlements are characterised by low literacy and incomes, limited social networks, inadequate infrastructure facilities, less diverse livelihoods, limited modifications of farm practices, and were highly affected by floods (especially regarding indirect impacts). Hence, special education and awareness programmes, both for innovation in livelihoods as well as flood preparedness, are required. In this context, the governmental agriculture advisory department can update the content for advisory services (by including market and weather trends) and the annual calendar with more frequent field visits. Farm-to-market roads need to be built or repaired to ensure that access to markets can be secured in times of flooding. In light of changing linkages due to flood events (in terms of households' greater dependence on rural areas as a strategy to cope and adapt), rural market centres also need more attention to facilitate their connection with urban market centres. This could help rural centres to be better informed about market trends and new farming technologies and methods. Thus, these actions could support successful second-order coping and adaptation strategies (see Birkmann, 2011) to mitigate vulnerability.

III. Improve the capacities of small and medium-sized cities

The study points to the important role that cities play in influencing rural vulnerability in that the city provides support to rural households when they are coping with flooding and during the adaptation process. Thus, cities' ability need to be developed alongside that of flood-prone rural areas. More concretely, capacity needs to be improved in terms of health and emergency services, storage capacity for food and non-food items to control shortages of goods and control prices, an increased and active presence of public and private credit institutes, and increments in financial budgets, as well as technical ability. Small and medium-sized cities should be focused on and strengthened, as these cities have limited economic, institutional and infrastructure resources; however, at the same time, they should be given opportunities to build and strengthen their capacity since they are easier to manage compared to large or megacities (Birkmann et al., 2016b). As such, the appropriate distribution of economic and physical resources—keeping in mind population growth and the associated demand for resources—by the national and provincial governments is required to curtail disparities in the capacity of small and medium-sized cities.

IV. Shift to multidisciplinary, collaborative strategic planning and design approach

It is critical to note that there is no one-size-fits-all strategy for reducing rural vulnerability, given the dynamics of both rural-urban linkages and vulnerability, as well as various factors such as city size and proximity. The study advocates for using city size, proximity, and rural-urban interdependencies to assess rural vulnerability. Further, a shift is needed from conventional rural flood risk reduction measures to more multidisciplinary, collaborative strategic planning and design that also considers the role of rural-urban linkages. Therefore, alleviating vulnerability requires an integrated and strategic planning process where disaster managers, rural and regional planners, human geographers, economists, researchers, policymakers, and communities work together to prioritise areas of intervention, and to develop effective policies and disaster risk reduction strategies based on socio-economic and landscape characteristics and development patterns.

In short, in contrast to disaster event-oriented measures (e.g. rescue), new risk management approaches need to be connected to rural and spatial development. Plans and strategies for managing these linkages in flood situations can provide avenues for adaptation and reducing vulnerability. Thus, the research calls for a focus on rural areas and their populations (which are prone to the effects of hazards, disasters, and climate change) for the purpose of intervention, as well as on the cities on which they depend and are tied to. Action is required in both rural and urban areas (by establishing synergies) to strengthen linkages and their ability by improving socio-economic, infrastructure, institutional and environmental conditions (which could provide feedback that helps to diminish future vulnerability).

8.3 Research contributions

This research contains both theoretical and practical contributions. The key scientific contribution is the enhanced understanding of flood vulnerability, which integrates spatial development concepts (rural-urban linkages) with flood vulnerability. Further, the research provides valuable information from a theoretical and practical angle.

Theoretical frameworks on vulnerability assessment have not paid enough attention to linkages between rural and urban areas, including how these linkages can shift due to hazardous events (chapters 1 and 2). This research endorses that rural-urban linkages must be incorporated into vulnerability assessments of rural households and communities, and provides a novel conceptual framework accordingly. Adding dimensions of rural-urban linkages into existing rural vulnerability frameworks shows that these interchanges are especially important for understanding response capacity within the recovery process, which influences future vulnerability. The framework is useful for application at the local level; it provides new, multiple, broad aspects for investigation, and can hence be applied in any flood-affected rural zone by using its context-specific information (as applied in the three flood-affected areas in this research). Moreover, the framework is not limited to flooding (even though the discussion revolves around flood hazards) and can be a vade mecum for other hazards, considering their character and scope of impact. Consequently, this research contributes to the evolving literature on disaster risk reduction and climate change adaptation by offering a framework that underscores rural-urban linkages in connection with rural vulnerability.

This study delivers solid empirical contributions to rural vulnerability research. First, the empirical research on rural vulnerability to flooding in this new framing of rural-urban linkages confirms the importance of (changing) flows from rural areas to cities (and vice versa) for capacity within the recovery process, as well as the overall vulnerability of rural households. The empirical research also highlights the role of cities, which can serve as counterparts in reducing rural vulnerability in Pakistan. In this context, the role of city size, proximity to the city, and linkages between rural and urban areas in affecting rural vulnerability were investigated; these aspects have not been sufficiently addressed in previous studies. Therefore, this research is significant in terms of identifying the dynamics of livelihood strategies and rural linkages with cities due to flooding and its repercussions. The research revealed several factors that drive changes in rural linkages with cities and influence vulnerability. Moreover, the findings imply that rural vulnerability is also affected by city size and proximity. The study indicated that changes in linkages, as well as city size and distance to the city, need to be included as elements in the assessment of vulnerability.

This research involved a combination of different analytical methods (e.g. descriptive statistics, regression analysis, correlation analysis, a composite index) to investigate shifts in rural-urban linkages and their influence on vulnerability. The study delivered an analytical approach to operationalise vulnerability in terms of city size and distance to the city. The proposed methodology can also be applied to other types of hazards and disasters in other locales by streamlining indicators and variables according to location-specific socio-economic, physical and hazard features. The triangulation of different methods and data was also important for identifying the intensity and strength of rural-urban linkages and their dynamics in the context of extreme flood events.

The research is pivotal from a practical perspective, as there has been limited research on rural flood vulnerability in Pakistan (e.g. Mustafa, 1998; Shah et al., 2018; Hamidi et al., 2020a) and no research that considers the impacts of flooding on rural linkages with cities and their relevance for vulnerability. Therefore, this research may increase awareness among disaster managers, regional planners, and policymakers at the local and regional levels regarding the complex and dynamic nature of vulnerability in Pakistan. Future risk management strategies, for example, should acknowledge the interactions between rural areas and cities, and should hence have a spatial design that allows for this integration. The indicator-based approach and regression analysis can help practitioners and decision-makers to pinpoint the areas that need the most attention, thereby permitting better planning of flood management measures and the efficient allocation of resources in order to reduce future flood vulnerability.

In addition, this research contributes to realising Priority 1 of the SFDRR on understanding disaster risk (through grasping vulnerability dynamics in the context of rural-urban linkages) (UNISDR, 2015). The study can sufficiently inform the implementation of SDGs 11 and 13 by suggesting the importance of various social, economic, and physical linkages in mitigating the vulnerability of the marginalised and remote rural populations (United Nations, 2018). Moreover, this research can guide the implementation plans of the New Urban Agenda (UNHABITAT, 2016, 2017) by forging ties between regional planning, rural development, and hazard vulnerability reduction, as well as by strengthening rural-urban linkages to build resilient settlements.

In sum, this thesis contributes to recent research activities concerning rural flood vulnerability in five aspects. First, this study has outlined crucial research gaps in the field of vulnerability and implies paths for future research. Second, it developed a novel conceptual framework to investigate vulnerability in terms of linkages between two spatial units (rural and urban areas). Third, the research empirically validated that flood impacts bring about several changes (including linkages) that can influence vulnerability, and highlights the significance of cities (including size and proximity) and their relationship with rural areas regarding the vulnerability of rural populations. Fourth, it has increased the knowledge of changes in livelihood strategies and linkages, as well as flood vulnerability in the case study areas. Lastly, it provides critical information for the implementation of international frameworks and agreements such as the Sendai Framework (UNISDR, 2015), the Paris Agreement (UNFCCC, 2015), the SDGs (United Nations, 2018), and the New Urban Agenda (UNHABITAT, 2016).

8.4 Limitations of the research

Conducting research in a developing country, especially in remote rural places, posed specific challenges and limitations. The household survey was administered to male household heads; female-headed households could not be included in the sample due to social and cultural norms (Chapter 3, Section 3.5). Therefore, it was not possible to pay attention to gender-specific issues in terms of changes in linkages and vulnerability analysis. As for the data, questions that represent rural linkages with cities (particularly those related to the livelihood activities of rural households) had to be limited in number due to time and financial constraints. Thus, the analysis was focused on selected linkages.

Due to some missing values and incomplete questionnaires (as indicated in Chapter 3, Section 3.5), the sample size became relatively small, even though 325 households were completely interviewed during household survey. This restricted the number of explanatory variables in the regression analysis. Moreover, due to inaccessible digital data on village routes at the time the survey was carried out, the study used proximity for travel distance, along with road networks, and only observed distances along 1 to 2 common routes used by rural households. Thus, the research was unable to fully address the matter of the redundancy of routes in travelling to the city.

Overall, the research is spatially explicit, as it concentrated on a few rural communities in southern Punjab. These communities are affected by riverine floods and have varied socio-economic and physical characteristics. Hence, the findings can be applied in areas with similar profiles. Therefore, the empirical findings cannot be directly generalised and applied to other places with different socio-economic contexts, types of floods and impacts. Nevertheless, this thesis has provided an entry point to identify diverse changes and their influence on flood vulnerability, which can be further investigated to find more concrete evidence by adapting variables and indicators for other cases. In addition, the role of rural-urban linkages (in the context of rural households' vulnerability to floods) is an issue for inhabitants in other rural parts of Pakistan, and most likely for numerous developing nations and countries in transition.

8.5 Future research

This thesis has provided a foundation for deeper investigation into the complex dynamics of linkages and other livelihood activities resulting from extreme flooding. Several other topics are revealed within this study that can be explored in the future.

Future investigations might consider the impact of other hazards on rural-urban linkages since other hazards (e.g. droughts or extreme temperatures) might not affect physical infrastructure in the same way as flooding. Therefore, changes in the type of linkage, as well as the subsequent vulnerability, may differ significantly. A more detailed assessment of each kind of flow and different factors (especially in terms of reducing rural dependency on cities in relation to goods and services) is required to understand the interlinkages and complexities involved. In this context, the criticality (since it takes into account the interdependencies of CI and the cascading effect of the failure of one infrastructure) of different infrastructures can be examined to better grasp the possible shifts in rural-urban linkages and their influence, even outside the exposed region. Additionally, more diverse linkages can be studied at the local, regional, and national levels when conducting research in regions with different hazard profiles.

Another vital area of future research includes scrutinising the effect of changing rural-urban linkages on cities and their markets, since the impact of a hazard in one place can influence the vulnerability of households in other non-affected areas (Eakin et al., 2009).

In this context, new research could investigate the influence of changing rural-urban linkages, especially on small agriculture-related businesses in cities. Zyck et al. (2015) also maintained that long-term aid provision to rural households reduces their dependence on urban markets, which affects the livelihood of small business holders in cities. Thus, the effects of flood relief measures by donor aid agencies on altering rural households' dependence on cities could be a relevant area of future research.

Another direction could be a focus on the use of qualitative methods (e.g. expert interviews, focus group discussions, and participatory rapid appraisals) to grasp additional knowledge on causal linkages and the root causes of vulnerability and other changes. The temporal dimension would be a pertinent sphere of future research, especially in terms of changing linkages. In this regard, both participatory and quantitative scenarios (Birkmann et al., 2020b) could be examined to understand the future dynamics of linkages and vulnerability. Additionally, further research could also on female-headed rural households affected by flooding since such households are marginalised due to limited mobility, access to resources, social networks, information, relief and aid distribution programmes, as well as often experiences greater losses (Mustafa, 1998; Rakib et al., 2017; Raza, 2017), which result in differential linkages and vulnerability.

More in-depth research is needed to confirm the dynamics of rural vulnerability (in the context of city size and distance to the city) in a broader spatial scope. The methodology applied in this study can be enhanced and modified in the future by using other statistical approaches and weight allocation methods. In addition, the issue of redundancy in travel routes could be addressed by using a more comprehensive methodology and employing geospatial techniques to judge the travel behaviour, route and mode choices of rural households for going to cities. Overall, within this research, a clear link between rural-urban linkages and human vulnerability to flooding (considering spatial factors like city size and proximity) has been established for rural communities in Pakistan.

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Annexures

Annex A

Timesheet

Activities	2016			2017				2018				2019				2020				2021
	Apr-Jun	Jul-Sept	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sept	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sept	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sept	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sept	Oct-Dec	Jan-Mar
Initial selection of research topic and writing proposal	■																			
Review and modification of topic	■	■																		
Literature analysis	■	■	■	■			■	■							■					
Refining proposal and research objectives and questions			■																	
Research methodology, its refinement, and finalization			■	■			■													
Data collection (trip to Pakistan)				■	■		■	■				■			■					
Organization/Reorganization of data					■	■	■													
Data analysis and interpretation							■	■	■	■	■	■				■				
Thesis writing									■	■	■	■	■			■	■			
Journal articles (writing and publication)														■	■	■	■	■		
Compilation, review, and improvements																		■	■	
Thesis Defence (preparation and oral exam)																			■	■
Thesis printing and publication																				■

Annex B

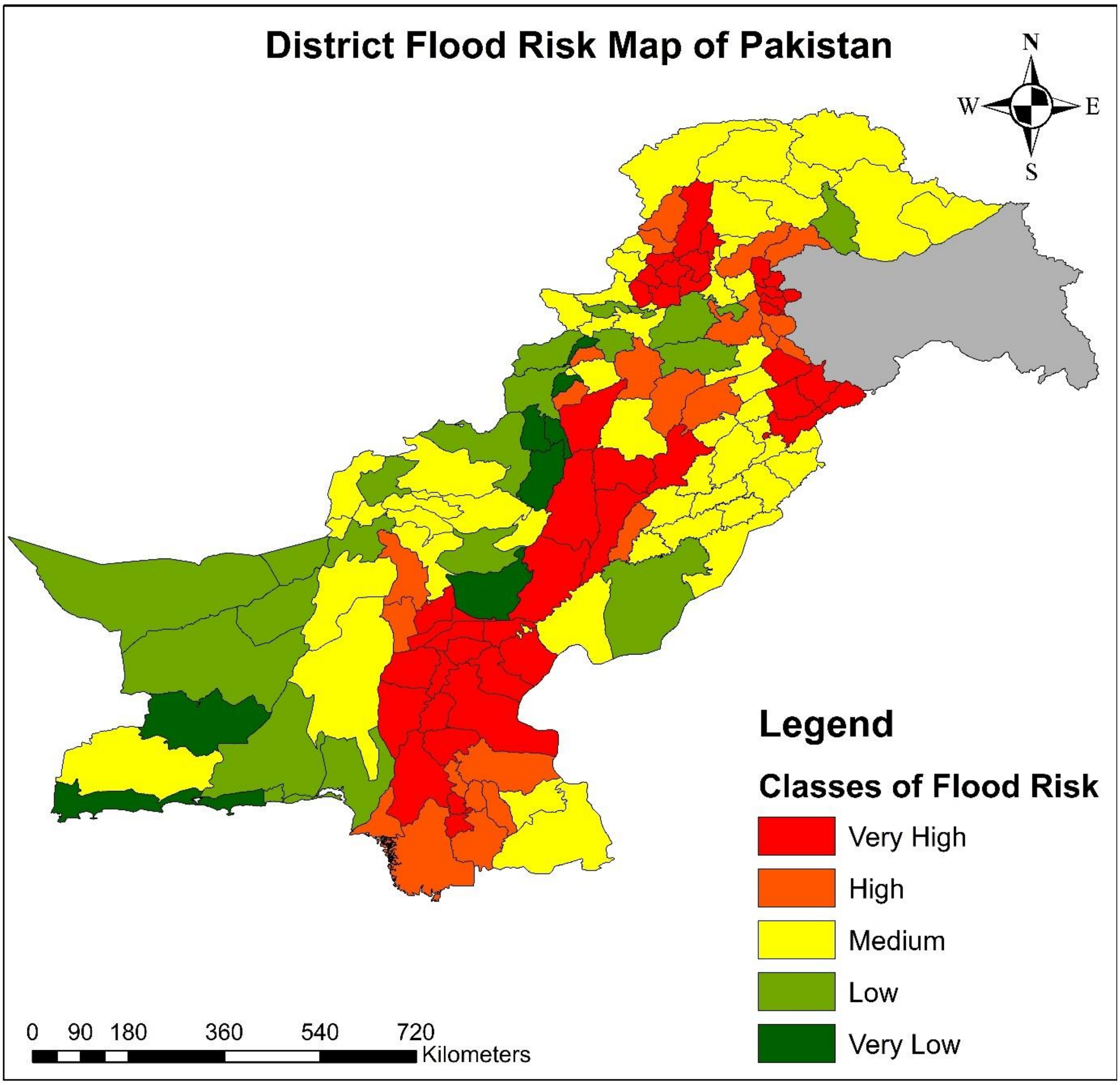

Figure A.1: Flood risk map of Pakistan.

Table A.1. The distance of different villages from their respective cities.

DARYA KHAN		
Union Councils (UCs)	Village Code	Distance (km)
Angra Daggar	1	5
	2	6
	3	6
	4	7
	5	8

	6	9
	7	10
	8	15
	9	16
	10	17
	11	18
	12	19
	13	20
	14	21
	15	22
Panjgran	16	23
	17	24
	18	25
MUZAFFARGARH		
Union Councils (UCs)	**Village Code**	**Distance (km)**
Taliri	1	5
	2	5
	3	5.5
	4	6
	5	6
	6	7
Muradabad	7	7
	8	8
	9	14
	10	15
	11	16
	12	17
	13	18
	14	19
	15	20
	16	21
	17	22
	18	23
	19	24
	20	25
MULTAN		
Union Councils (UCs)	**Village Code**	**Distance (km)**
Boch Khusro Abad	1	6
	2	6.5
	3	6
	4	7
	5	7

	6	8
	7	8.5
	8	9
	9	9.5
	10	15.5
	11	16
	12	17
	15	19
	16	20
Lutefabad	13	18
	14	18
	17	21
	18	22
	19	22
	20	23
	21	24

Table A.2. Sample size calculation

Case studies	Population		Average household size	Number of households		Total households	Proportion of households	Sample collected	Sorting of samples		Sample with respect to proximity groups	
	UC1	UC2		UC1	UC2				Incomplete samples	Valid samples	Household surveyed in settlements near to cities	Household surveyed in settlements far from cities
Darya Khan (Angra Dagar and Panjgran)	44226	40928	6.2	7133	6601	13735	35.73%	137	23	114	61	53
Muzaffargarh (Talairi and Muradabad)	44333	45919	6.6	6717	6957	13675	35.58%	137	22	115	55	60
Multan (Boch Khusroabad and Lutefabad)	31224	34930	6.0	5204	5822	11026	28.69%	110	14	96	48	48
Total	119783	121777		19054	19380	38435	100.00%	384	59	325	164	161

Annex C

Questionnaire for household survey

Date of interview: ___________________ **Questionnaire No:** ___________________

1 AREA PROFILE

Name of interviewer		**District name**	
Tehsil name		**UC number/name**	
Village name		**Mouza name**	

2 RESPONDENT PROFILE

2.1	**Name of respondent**	
2.2	**Are you the head of household**	[ ]1= Yes; [ ]2= No
2.3	**Age of household head**	
2.4	**Education of household head**	[ ]1= Illiterate; [ ]2= Primary school; [ ]3= Secondary school; [ ]4= College; [ ]5= University degree

3 HOUSEHOLD INFORMATION

3.1 Type of family [ ]1= Nucleus; [ ]2= Joint
3.2 How big is your household? [ ] No. of male members; [ ] No. of female members; [ ] Male members under age 15; [ ] Female members under age 15; [ ] Male members over age 65; [ ] Female members over age 65
3.3 Members with a physical/mental disability or chronic illness? [ ] No. of male members; [ ] No. of female members; [ ]= No One
3.4 Number of school-going members? [ ] Male(s); [ ] Female(s)
3.5 Number of literate members [ ] Male(s); [ ] Female(s)
3.6 Highest education in your household? [ ]1= Primary school; [ ]2= Secondary school; [ ]3= College; [ ]4= Technical college; [ ]5= University
3.7 Number of earning members in your household considering their workplace. [ ] In the village; [ ] In the city
3.8 Other skills among the household members? [ ]= Electrician; [ ]= Carpenter; [ ] = Bee keeper; [ ]=Mat maker; [ ]= Dairy; [ ]= Mason; [ ]= Plumbing; [ ]= Mechanic; [ ]= Computer; [ ]= Others; [ ]= None
3.9 Type of house [ ]1= Katcha; [ ]2= Semi-pecca; [ ]3= Pecca;
3.10 Ownership status of the house [ ]1= Owned; [ ]2= Rented; [ ]3= Relatives; [ ]4= Other (specify)
3.11 Do you have sanitation facilities in your house? [ ]1= Yes; [ ]2= No
3.12 Since when you are living in this house/settlement? [ ]1= <10yrs; [ ]2= 10-20yrs; [ ]3= 21-30yrs; [ ]4= 31-40yrs; [ ]5= >40yrs
3.13 Do you have good relationships with the neighbours? [ ]1= Yes; [ ]2= No
3.14 Do you have any close friends or relatives living in the city? [ ]1= Yes; [ ]2= No

3.15 Which transport mode you usually use to go to the city? [ ]1= Bicycle; [ ]2= Donkey/horse cart; [ ]3= Motorbike; [ ]4= Car; [ ]5= Tractor; [ ]6= Public transport; [ ]7= Walking	
3.16 Ownership of means of telecommunication (select multiple options if more than one) [ ]1= Mobile; [ ]2= Television; [ ]3= Internet; [ ]4= None of them	
3.17 Distance to (in km): Pecca road:_________, River:__________, Basic health center:__________, Rescue Facility: __________	
3.18 How much farmland do you own (in acres)?	
3.19 Roughly, how much is the total income (in PKR) of all the earning members?	

3.20 What is the main source of your income? (rank 1-3, 1=primary, 2=secondary, 3=tertiary)	**Before flood**	**After flood**
	[ ]1= Farming [ ]2= Daily Wage labourers [ ]3= Commerce (shop keeping) [ ]4= Remittances [ ]5= Pension [ ]6= Government job [ ]7= Other (specify)	[ ]1= Farming [ ]2= Daily Wage labourers [ ]3= Commerce (shop keeping) [ ]4= Remittances [ ]5= Pension [ ]6= Government job [ ]7= Other (specify)

3.21 How much do you agree: "Flood events have a major role in affecting income level" [ ]1= Strongly agree; [ ]2= Agree; [ ]3= Neutral; [ ]4= Disagree; [ ]5= Strongly disagree	

4 FLOOD PROFILE

4.1 How many times have you experienced flooding in the last 10 years?	
4.2 How many times your house affected by the flood in the last 10 years?	
4.3 How many times your livelihood disrupted by the flood in the last 10 years?	
4.4 To what extent do you agree with the statement: "Your area/settlement is highly exposed to flood" [ ]1= Strongly agree; [ ]2= Agree; [ ]3= Neutral; [ ]4= Disagree; [ ]5= Strongly disagree	
4.5 Which were the worst flood event(s)? Specify year(s)___________________________________	
Note: In the next sections, for the questions related to flooding, consider the last worst flood event you have experienced: **Flood event (year):**	

5 FLOOD IMPACTS IN THE LAST FLOOD WORST FLOOD EVENT

5.1 How long various services disrupted in your settlement?					
Transport system	Less than a week	2-3 weeks	1 month	More than a month	No
Electricity	Less than a week	2-3 weeks	1 month	More than a month	No
Drinking water	Less than a week	2-3 weeks	1 month	More than a month	No
School	Less than a week	2-3 weeks	1 month	More than a month	No
Health facilities	Less than a week	2-3 weeks	1 month	More than a month	No
Other:	Less than a week	2-3 weeks	1 month	More than a month	No

5.2 Damage/loss characteristic in last worst flood event	1= Total	2= Partial	3= No damage/loss	99= Not applicable
House				
Household belongings				
Means of transport				
Means of telecommunication				
Standing crops				
Harvested/stored crops				
Business (shop/vending cart)				
Livestock				

5.3 Were you displaced during the last worst flood events? [ ]1= Yes; [ ]2= No

If yes, where did you go during the flood events?
[ ]1= Flood dike; [ ]2= Relief camps near city; [ ]3= Relatives/friends in other village;
[ ]4= Relatives/friends in city; [ ]5= Other (specify)________________________

5.3.1 The time period of displacement
[ ]1= <15days; [ ]2= 15-30days; [ ]3= 31-45days; [ ]4= 46-60days; [ ]5= >60days

5.3.2 How beneficial was the displacement in the city or another village?

In terms of access to:	Extremely beneficial	Beneficial	Moderate	Least beneficial	Not at all beneficial
Food/drinking water					
Sanitation facilities					
Information					
Temporary jobs					

5.4 Did you notice an increase in the price of goods after the flood?
[ ]1= Yes; [ ]2= No

5.5 Were food items/goods easily available in local market centres?
[ ]1= Yes; [ ]2= No

5.6 Did you experience farmland degradation after the flood?
[ ]1= Yes; [ ]2= No

5.7 Did you experience lack of water for farming after the flood?
[ ]1= Yes; [ ]2= No

5.8 Rate the transportation cost for going to the city
[ ]1= Very high; [ ]2= High; [ ]3= Moderate; [ ]4= Low; [ ]5= Very low

5.9 How would you rate the quality of road infrastructure after the flood?

0	1	2	3	4	5	6	7	8	9	10

5.10 How would you rate the crop production after the floods? On a scale between 0 *(could not harvest and cultivate crops)* and 10 *(production increased)*

0	1	2	3	4	5	6	7	8	9	10

6 FLOOD WARNING AND RESPONSE

6.1 Before the flood event, did you receive the flood warning? [ ]1= Yes; [ ]2= No

If Yes, what was the medium of the flood warning?
[ ]1= Announcement on vehicles by govt; [ ]2= Announcement on media; [ ]3= Announcement in local mosques; [ ]4= Social contacts-on mobile; [ ]5= Social contacts-face to face

6.2 To what extent do you agree with the statement: "I was fully prepared before the flood event and evacuated immediately after warning or flood occurred" [ ]1= Strongly agree; [ ]2= Agree; [ ]3= Neutral; [ ]4= Disagree; [ ]5= Strongly disagree	
6.3 Which agencies were most involved in the flood response? ***Rank them***	[ ]= Local/provincial government; [ ]= Religious organizations; [ ]= Local NGOs; [ ]= International NGOs; [ ]= Pakistan Army; [ ]= Community Based Organizations; [ ]= Others ____________
6.4 Does any institute provide support to recover your losses? [ ]1= Yes; [ ]2= No	
6.4.1 What type of support you get? ***Tick multiple options if necessary*** [ ]1= Financial aid; [ ]2= Provision of food items; [ ]3= Provision of non-food items; [ ]4= Building material; [ ]5= Seeds and fertilizers; [ ]6= Livestock; [ ]7= Job in reconstruction activities; [ ]8= Provision of vending carts; [ ]9= Skill development; [ ]10= Other (specify):	
6.4.2 **To what extent do you agree with the statement:** ***"after the flood government is giving more attention to flood affected areas"*** [ ]1= Strongly agree; [ ]2= Agree; [ ]3= Neutral; [ ]4= Disagree; [ ]5= Strongly disagree	
6.4.3 Are there more rural development programs than before the flood? [ ]1= Yes; [ ]2= No	
If yes, name the development programs e-g. roads, dykes, agriculture extension etc.	
6.4.4 How important are rural development programs in increasing your wellbeing? [ ]1= Very important; [ ]2= Important; [ ]3= Moderate; [ ]4= Not important; [ ]5= Don't know	

7 HOUSEHOLD-LEVEL CAPACITY MEASURES/CHANGES IN RESPONSE TO FLOOD EVENTS

7.1 Measures	**Yes**	**No**
Change construction material of house		
Raise platform of house		
Change crop variety		
Change crop type		
Change planting dates		
Diversifying the crops		
Frequent access to market information after flood		
Frequent access to weather forecast after flood		
Frequent access to agriculture extension services after flood		
Frequent access to agriculture credit after flood		
More agriculture inputs (fertilizers, seeds etc.) after the floods		
Savings		
Disaster awareness and training program		
Insurance of assets/crops after the flood		

7.2 Migration (only households with earning members in the city)		
7.2.1 Number of family members working in the city.	Before flood	After flood
7.2.2 Which city they were migrated to?		
7.2.3 What is the pattern of mobility after the flood? [ ]1=Permanent; [ ]2=Temporary; [ ]3=Commuting		
7.2.4 Do the migrant family members send you the money? [ ]1= Yes; [ ]2= No		

7.2.5 How much is the share of this income?	

7.2.6 How did the migration of family members affect the local rural livelihood/income due to labour shortage or burden of activities on remaining members?
[ ]1= Highly affected; [ ]2= Moderate; [ ]3= Low affected; [ ]4= Very low; [ ]5= Do not affected

7.2.7 How would you rate the remittances from migrant members in recovering from flood losses and becoming more resilient? On a scale between 0 ***(Not important at all, we could not recover losses)*** **and 10** ***(Very important; we recovered many losses from remittance money)***

0	1	2	3	4	5	6	7	8	9	10

8 CHANGING LINKAGES: LOCATION OF SERVICES AND FACILITIES

8.1 How important are local towns/cities in providing goods and services during and after the flood?
[ ]1= Very important; [ ]2= Important; [ ]3= Moderate; [ ]4= Not important; [ ]5= Don't know

8.2 Which services do you target in the village and city before and after the flood? *Tick the options*

Services	Before flood		After flood		No access
	Village	City	Village	City	
Agriculture inputs					
Information/extension services					
Processed goods (food and non-food items)					
Traders/markets					
Credit services					
Health					
Education					
Others (specify): __________					

8.3 How would you rate the local town in terms of services and facilities provision after the flood? On a scale between 0 ***(least specialized, services became worse)*** **and 10** ***(highly specialized, much better services)***

0	1	2	3	4	5	6	7	8	9	10

8.4 To what extent do you agree with the statement: "considering the flood events, larger cities provide more and better services, facilities, than local towns"
[ ]1= Strongly agree; [ ]2= Agree; [ ]3= Neutral; [ ]4= Disagree; [ ]5= Strongly disagree

8.5 How different are services in large cities compared to the local towns?

8.6 To what extent do you agree with the statement: "I am selling my farm produce/products to traders at much better rate after the flood"
[ ]1= Strongly agree; [ ]2= Agree; [ ]3= Neutral; [ ]4= Disagree; [ ]5= Strongly disagree

8.7 How do you see the conditions of credit and loan schemes after the flood?	**Formal institutions**	**Informal institutions**
	[ ]1= Highly strict [ ]2= Strict [ ]3= Moderate [ ]4= Flexible [ ]5= Very flexible	[ ]1= Highly strict [ ]2= Strict [ ]3= Moderate [ ]4= Flexible [ ]5= Very flexible

9 FUTURE FLOODS AND RURAL-URBAN LINKAGES

9.1 **How much do you agree with the statement:** ***"It is more likely that flood will hit this area in future"***
[ ]1= Strongly agree; [ ]2= Agree; [ ]3= Neutral; [ ]4= Disagree; [ ]5= Strongly disagree

9.2 How much do you agree with the statement: ***"Past flood experience will help in dealing with flood"*** [ ]1= Strongly agree; [ ]2= Agree; [ ]3= Neutral; [ ]4= Disagree; [ ]5= Strongly disagree										
9.3 Do you think that you are more informed and prepared after the flood event? On a scale between 0 *(Not informed, we do not know what to do in case of flood)* **and 10** *(very much informed, we recognize warnings and know evacuation routes)*										
0	1	2	3	4	5	6	7	8	9	10
9.4 How likely is that you will get a job in the city after you would have to move there? On a scale between 0 *(Not likely, local do not offer good jobs)* **and 10** *(Very likely, it is easy to get)*										
0	1	2	3	4	5	6	7	8	9	10
9.5 How would you rate your financials situation for migration and recovering losses in response to future events? On a scale between 0 *(No resources)* **and 10** *(Have resources, savings, insurance, etc.)*										
0	1	2	3	4	5	6	7	8	9	10
9.6 Do you think you will become less dependent on cities if rural areas provided with basic infrastructure and services? On a scale between 0 *(No at all, it might increase due to better transport)* **and 10** *(Yes, our dependence will reduce significantly)*										
0	1	2	3	4	5	6	7	8	9	10

9.7 Overall, which factors may restrict your access to cities?	[ ]= Lack of social contacts [ ]= Poor road infrastructure [ ]= Expansive transportation [ ]= Trade/market associations biasedness and monopoly [ ]= Government restrictions for entering markets [ ]= Personal economic conditions [ ]= Poor information dissemination system [ ]= Other (specify):
In your opinion, what should be done to increase your resilience?	
Any suggestion, recommendation or other problems?	

Annex D

Table A.3. Explanatory variables used in different models

Explanatory variables	Increased dependence on cities				Reduced dependence on cities			
	People	Finances	Information	Goods	Finances	Information	Goods	Services
Age of household head (in years)	x	x	x	x	x	x	x	x
Education (in years)	x	x	x	x	x	x	x	x
Social network ties in the city	x	x	x	x	x	x	x	x
Farming as a primary source of income	x	x	x	x	x	x	x	x
Number of earning members	x	x		x				
Average monthly income of the household (in Pakistani Rupees PKR)	x	x	x	x	x	x	x	x
Ownership of mode of transport	x	x	x	x	x	x	x	x
Ownership of farmland (in acres)	x	x	x	x	x	x	x	x
Distance to the city (in kilometres)	x	x	x	x	x	x	x	x
Number of times exposed by flood in the last ten years	x	x	x	x	x	x	x	x
Damage/loss to household assets	x	x	x	x				
High prices of inputs/goods after the flood	x	x		x	x	x	x	x
High transportation cost after the flood	x	x	x	x	x	x	x	x
Farmland degradation due to flood	x	x	x	x				
Reduced crop productivity after the flood	x	x	x	x				

Example of weight and index calculation

Using these weights, original datasets were standardized for computation of composite index using Equation (1) and (2) as provided below as well as in the manuscript.

Composite Index = $(W_1+W_2+W_3+ \ldots W_n)/n$

$= \sum_{i=1}^{n} Wi/n$ (Equation 3)

Where,

W_1 to W_n are respective weights assigned to indicators, and

n is the number of indicators used for computing the composite index.

Vulnerability Index (VI) = $\frac{\sum_{i=8}^{n} EIWi/n \times \sum_{i=20}^{n} SIWi/n}{\sum_{i=22}^{n} CIWi/n}$ (Equation 4)

Where,

EI is the Exposure index

SI is the Susceptibility index

CI is the Capacity index

Exposure has eight indicators each has some weight:

Exposure Index (EI) = $\sum_{i=8}^{n}(E1 + E2 + E3 + E4 + E5 + E6 + E7 + E8)/n$

EI = $\sum_{i=8}^{n} (1+1+0.25+0.25+0.25+1+0.5+1)/8$

EI = 0.66

Susceptibility has twenty indicators each has some weight:

Susceptibility Index (SI) = $\sum_{i=20}^{n}(S1 + S2 + S3 + S4 + S5 + S6 + S7 + S8 + S9 + S10 + S11 + S12 + S13 + S14 + S15 + S16 + S17 + S18 + S19 + S20)/n$

SI = $\sum_{i=20}^{n}(0 + 0.5 + 0.33 + 0.5 + 0.6 + 0.4 + 0.8 + 0.75 + 1 + 0.66 + 1 + 0 + 0.66 + 0.25 + 0.5 + 1 + 0.4 + 0 + 1 + 1)/20$

SI = 0.57

Capacity has twenty-two indicators each has some:

Capacity Index (CI)= $\sum_{i=22}^{n}(C1 + C2 + C3 + C4 + C5 + CS6 + C7 + C8 + C9 + C10 + C11 + CS12 + C13 + C14 + C15 + C16 + C17 + C18 + C19 + C20 + C21 + C22)/n$

CI = $\sum_{i=22}^{n}(0.2 + 5 + 1 + 0 + 0.66 + 1 + 0.75 + 0 + 1 + 0 + 0 + 0.5 + 1 + 1 + 1 + 0 + 1 + 1 + 1 + 0.66 + 0 + 1 + 0)/22$

CI = 0.58

Vulnerability is calculated using formula Vulnerability Index= $\frac{E \times S}{C}$

Vulnerability Index (VI) = $\frac{\sum_{i=8}^{n} EIWi/n \times \sum_{i=20}^{n} SIWi/n}{\sum_{i=22}^{n} CIWi/n}$

VI = $\frac{0.66 \times 0.57}{0.58}$

VI = 0.65

Annex E

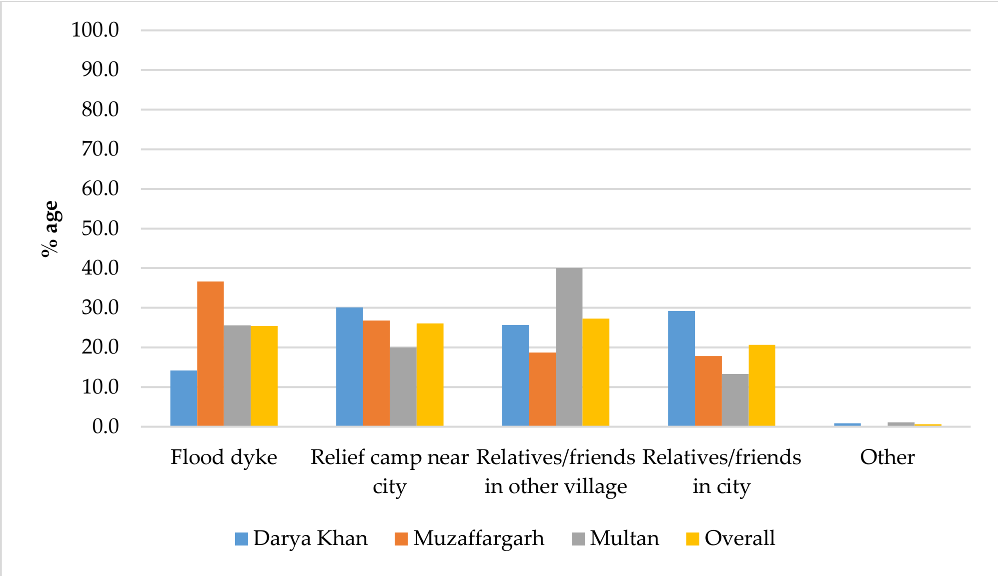

Figure A.2. Locations where households lived during the duration of the flood

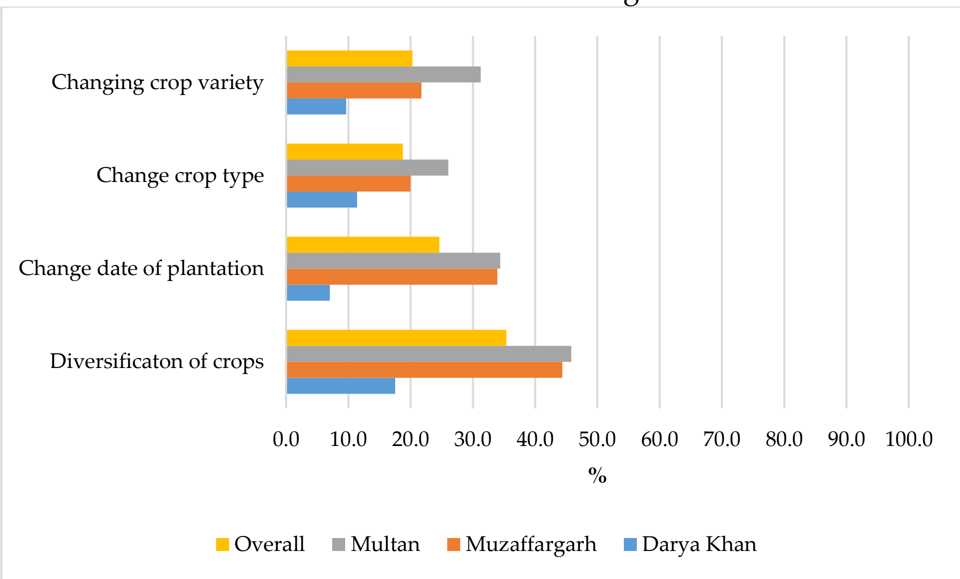

Figure A.3. Changes in farming practices in order to adapt to future flood events

Table A.4. Changes in mobility pattern, access to information, finance/income and flow of goods and services after the extreme flood event

Linkages/ flows		**Darya Khan (%)**	**Muzaffargarh (%)**	**Multan (%)**	**Overall (%)**
People	Long term migration	7.9	1.7	1.0	3.7
	Short term migration	12.3	16.5	8.3	12.6
	Commuting	9.6	10.4	16.7	12.0
Information	Frequent access to market information	17.5	33.0	51.0	32.9
	Frequent access to weather and water information	21.9	47.8	56.3	41.2
	Frequent access to farm advisory	25.4	33.0	51.0	35.7

Finance/ income	More remittance flows	5.3	16.5	6.3	9.5
	Frequent access to farm credit	13.2	18.3	25.0	18.5

Table A.5. Cross-tabulation of households that were frequently accessing facilities and services with those households getting these facilities and services from the village after the floods

Frequent flows		**Change of location of relevant facilities and services**		**Total**
		No	**Yes**	
More frequent access to the information after the flood	**No**	50.2%	14.2%	64.3%
	Yes	27.4%	8.3%	35.7%
	Total	77.5%	22.5%	100.0%
More frequent access to finance (farm credit) after the flood	**No**	68.0%	13.5%	81.5%
	Yes	12.6%	5.8%	18.5%
	Total	80.6%	19.4%	100.0%
More frequent access to goods (farm inputs) after the flood	**No**	23.1%	24.6%	47.7%
	Yes	44.3%	8.0%	52.3%
	Total	67.4%	32.6%	100.0%

Annex F

Table A.6. Correlation Matrix

EI	Exposure Index
SI	Susceptibility Index
CI	Capacity Index
VI	Vulnerability Index

	E1	E2	E3	E4	E5	E6	E7	E8	EI	S1	S2	S3	S4	S5	S6	S7
E1	1															
E2	-0.035	1														
E3	-0.021	-.219**	1													
E4	0.022	-.176**	.726**	1												
E5	-0.035	-.125*	.374**	.218**	1											
E6	-.110*	0.034	-0.082	-0.065	0.083	1										
E7	-0.026	0.103	-.266**	-.193**	-0.017	.210**	1									
E8	0.055	0.045	-0.020	-0.019	-0.005	0.036	0.075	1								
EI	.176**	.219**	.506**	.482**	.521**	.392**	.422**	.201**	1							
S1	.115*	-0.035	.121*	0.089	.129*	-0.038	0.008	-0.066	.118*	1						
S2	.246**	0.071	0.103	.110*	0.045	0.036	0.046	-0.046	.200**	.131*	1					
S3	-.242**	-0.064	0.037	0.019	-0.061	-0.013	-0.077	-0.032	-.127*	-0.029	-.122*	1				
S4	-.664**	0.037	-0.014	-0.050	0.094	.178**	0.080	-0.011	-0.043	-.132*	-.130*	.133*	1			
S5	-0.080	.287**	-.287**	-.244**	-0.064	.129*	.189**	0.089	0.015	-0.098	-0.083	-0.076	0.078	1		
S6	0.084	-.114*	-0.002	0.079	0.012	0.081	0.036	-0.018	0.047	0.020	-0.045	-0.063	-0.042	-.193**	1	
S7	-.386**	.113*	-0.022	-0.079	.123*	.180**	.122*	-0.087	0.060	-0.033	-0.087	-0.012	.483**	.131*	-0.099	1
S8	-.176**	0.021	-0.011	0.004	0.041	0.100	0.083	-0.028	0.045	0.083	-0.072	-0.048	.174**	.120*	-0.018	.329**
S9	0.052	0.081	-.174**	-0.109	-.138*	-0.014	.116*	-0.009	-0.057	-0.063	-0.036	0.004	-0.083	0.013	0.039	0.001
S10	-.294**	.126*	-0.029	-.120*	.131*	.247**	.216**	-0.054	.148**	-0.082	-0.027	-0.021	.358**	.169**	-0.042	.601**
S11	-.141*	0.000	-0.104	-0.053	0.049	0.098	.127*	-0.089	0.004	0.025	-0.054	0.002	.190**	0.090	0.002	.463**
S12	-.224**	0.084	0.098	0.043	.176**	.136*	-0.008	-0.059	.118*	-0.003	-0.063	0.073	.237**	0.096	-0.044	.342**
S13	-.242**	0.014	0.006	-0.026	.125*	.148**	0.062	-0.023	0.058	0.014	-.120*	0.047	.272**	0.073	-0.063	.577**
S14	-0.016	-0.041	-0.076	-.139*	.496**	.228**	.168**	0.027	.239**	0.023	0.005	-.115*	0.103	.125*	-0.088	.169**
S15	-0.060	0.073	-.189**	-.231**	.364**	0.089	.252**	-0.044	.135*	0.038	-0.034	-.175**	0.073	.210**	0.016	.254**
S16	-0.037	.130*	-.580**	-.505**	0.006	.224**	.282**	-0.006	-.135*	-0.016	-0.046	-.124*	0.106	.236**	-0.032	.123*
S17	-0.068	0.096	-0.067	-0.028	0.075	0.008	0.097	0.017	0.058	0.022	-.116*	0.026	0.038	0.080	.130*	0.021
S18	-0.038	-0.001	0.091	.114*	-0.054	-0.062	0.056	-0.040	0.043	-0.101	0.024	0.039	0.030	-0.057	-0.053	0.052
S19	0.005	0.035	0.028	-0.015	-0.008	-0.028	-0.033	0.044	-0.004	0.035	-0.010	-0.101	0.075	0.050	-.113*	.113*
S20	0.026	-0.012	.316**	.278**	.198**	-0.098	-0.059	0.104	.233**	0.018	-0.042	-0.045	-0.062	-0.025	-0.035	-0.083
SI	-.307**	.134*	-.130*	-.135*	.207**	.221**	.260**	-0.068	.137*	0.101	-0.018	0.051	.416**	.263**	0.034	.655**
C1	0.073	-0.011	.138*	0.054	0.100	0.020	-0.091	0.059	0.091	0.015	0.028	0.057	-0.038	-0.069	-.116*	-.164**
C2	.251**	-.112*	0.055	.125*	-.153**	-0.076	-0.085	0.044	-0.029	-0.010	.121*	0.046	-.249**	-.170**	.139*	-.371**
C3	.196**	-0.065	0.010	0.022	-0.035	-0.062	-0.032	-0.004	-0.012	-0.018	0.072	0.099	-.181**	-0.072	0.058	-.291**
C4	.216**	0.073	-0.054	0.018	-0.029	0.003	-0.017	0.007	0.046	0.073	0.015	0.068	-.160**	-0.011	0.031	-.206**
C5	-0.026	-0.096	0.056	0.027	0.074	0.045	-0.014	-0.015	0.027	0.027	-0.024	-0.019	0.053	-0.081	0.018	.114*
C6	0.083	0.071	0.106	0.056	0.085	-0.033	-0.055	.134*	.115*	0.096	-0.001	0.045	-0.086	-0.068	0.072	-.185**
C7	0.099	-.130*	.278**	.222**	0.016	-.153**	-.146**	0.066	0.051	0.035	-0.005	0.013	-.165**	-0.091	0.015	-.299**
C8	.147**	-.112*	.153**	.133*	-0.032	-.112*	-0.068	-0.002	0.019	0.011	0.008	-0.076	-.196**	-0.087	-0.072	-.262**
C9	-0.027	0.015	.120*	0.047	0.094	0.007	0.025	0.002	.111*	0.015	0.046	0.017	0.052	-0.063	-0.007	0.056
C10	0.091	-0.043	.250**	.263**	-0.001	-0.064	-.125*	-0.036	0.099	0.017	0.089	-0.055	-0.084	-0.079	-0.081	-.138*
C11	-0.037	-0.090	0.077	.119*	-0.004	-0.081	-0.074	0.001	-0.039	0.062	-.174**	.199**	-0.033	-0.008	0.076	-.239**
C12	0.106	-0.043	-0.069	-0.062	0.002	-0.039	0.018	-0.048	-0.045	0.000	-0.061	0.004	-0.062	-0.057	0.030	-.159**
C13	.413**	-0.017	0.031	0.081	0.004	-0.087	-0.004	0.083	.114*	0.051	0.072	0.041	-.348**	-0.101	.158**	-.436**
C14	0.067	-0.102	-0.008	0.048	-0.035	-0.006	0.040	0.105	0.010	-0.021	-0.058	0.025	-0.091	-0.036	0.012	0.020
C15	.195**	-.129*	0.088	.153**	-0.102	-.194**	-.151**	0.023	-0.083	-0.005	0.022	0.068	-.291**	-0.102	.114*	-.596**
C16	0.047	-0.002	-.148**	-0.055	0.004	0.012	0.035	.117*	-0.029	-0.037	-.138*	-0.021	-0.055	0.020	0.100	0.003
C17	.109*	-0.073	.354**	.255**	0.069	-0.075	-0.015	0.077	.221**	0.047	.122*	0.090	-0.089	-.211**	0.008	-.139*
C18	.163**	-.131*	.308**	.423**	-0.046	-0.044	-0.073	0.040	.183**	.134*	0.083	-0.078	-.183**	-.132*	.140*	-.263**
C19	.323**	-.173**	-0.044	0.031	-.178**	-0.106	-0.034	0.070	-0.091	-0.034	0.020	-0.050	-.398**	-.120*	0.063	-.671**
C20	0.072	-0.084	.172**	.186**	0.032	-0.052	-0.073	0.008	0.072	.121*	0.038	0.000	-0.059	-0.012	-0.081	-.111*
C21	.150**	-0.052	.259**	.245**	0.072	-.134*	-0.083	0.024	.137*	0.030	0.008	-0.021	-.223**	-0.079	-0.006	-.323**
C22	0.104	-0.084	.242**	.216**	-0.009	-0.085	-.139*	-0.004	0.058	-0.060	0.018	0.007	-.129*	-.112*	-0.047	-.258**
CI	.317**	-.168**	.309**	.334**	-0.019	-.169**	-.140*	0.083	.125*	0.054	0.059	0.039	-.351**	-.205**	0.067	-.559**
VI	-.241**	.254**	-0.062	-0.102	.291**	.313**	.319**	0.012	.330**	0.038	0.069	-0.054	.317**	.238**	0.004	.567**

	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	SI
S8	1													
S9	-0.013	1												
S10	.167**	-0.030	1											
S11	.110*	-0.026	.439**	1										
S12	.163**	-0.093	.304**	.163**	1									
S13	.284**	0.025	.382**	.378**	.367**	1								
S14	0.077	-0.068	.244**	.149**	.124*	.127*	1							
S15	0.048	0.080	.227**	.147**	.190**	.179**	.414**	1						
S16	0.068	-0.044	.164**	.135*	-0.023	0.104	.571**	.465**	1					
S17	-0.063	0.044	.116*	0.012	0.015	0.058	0.097	.211**	0.080	1				
S18	-0.004	.328**	0.036	0.031	0.061	0.019	-0.102	-0.081	-.262**	0.034	1			
S19	0.057	0.006	0.032	0.017	0.079	-0.015	0.014	-0.021	0.061	-0.098	0.020	1		
S20	0.032	-0.027	-0.103	-0.065	0.105	-0.086	.148**	-.158**	-.244**	-0.026	-0.003	0.079	1	
SI	.326**	.306**	.583**	.546**	.498**	.538**	.383**	.444**	.296**	.203**	.308**	.266**	-0.004	1
C1	-.132*	0.077	-.141*	-.472**	-0.028	-0.087	0.006	-0.067	-.130*	-0.078	0.018	-0.014	0.048	-.210**
C2	-.215**	0.069	-.231**	-.209**	-.118*	-.263**	-.207**	-.161**	-.110*	-0.073	0.021	-0.067	-0.038	-.290**
C3	-.236**	-0.005	-.141*	-0.103	-.222**	-.293**	-.161**	-0.052	-0.102	-0.062	-0.066	-.117*	-0.085	-.295**
C4	-.164**	0.106	-0.077	0.018	-.159**	-.110*	-0.056	-0.031	-0.041	0.045	0.029	-0.080	-0.029	-0.092
C5	0.056	0.055	0.076	-0.009	0.050	0.045	0.058	-0.041	-0.056	-0.016	0.069	-0.032	0.057	0.063
C6	-0.054	0.109	-0.051	0.010	-0.095	-0.083	0.046	-0.085	-.127*	0.012	0.001	-0.023	.120*	-0.043
C7	-0.105	-0.076	-.264**	-.252**	-0.077	-.220**	-.228**	-.298**	-.356**	-0.080	0.035	0.043	0.107	-.333**
C8	-0.084	-0.048	-.201**	-.196**	-.120*	-.216**	-.130*	-.145**	-.151**	-0.098	0.015	.173**	-0.025	-.260**
C9	-0.003	0.014	-0.043	-0.066	0.001	-0.021	-0.059	-0.017	-0.089	-.129*	0.092	0.035	-.109*	-0.018
C10	-0.047	-0.074	-0.056	-0.079	-0.034	-0.012	-0.096	-.151**	-.187**	-0.017	-0.052	0.040	0.050	-.168**
C11	-0.069	-0.073	-0.057	-0.086	0.009	-.138*	-0.071	-0.089	-0.061	0.032	0.003	0.075	0.041	-0.086
C12	-0.089	0.079	-0.077	-.125*	-.116*	-0.085	-0.075	-0.017	-0.035	0.009	0.096	-0.100	-0.055	-.119*
C13	-.319**	0.035	-.278**	-.151**	-.222**	-.274**	-.129*	-.111*	-.128*	0.013	-0.019	-0.080	-0.024	-.322**
C14	.130*	-0.055	-0.098	-0.007	0.049	0.036	-.130*	-0.104	-.136*	-0.086	0.047	0.032	-0.001	-0.054
C15	-.196**	-0.061	-.401**	-.263**	-.215**	-.326**	-.200**	-.233**	-.159**	0.017	-0.003	-.149**	0.066	-.447**
C16	0.062	0.026	-.145**	0.035	0.057	0.034	-0.028	0.048	-0.012	-0.045	-0.012	0.023	-0.007	0.008
C17	-0.061	-0.049	-.116*	-.175**	0.048	-0.002	-.213**	-.228**	-.311**	-.113*	0.045	-0.003	0.091	-.187**
C18	-0.060	0.000	-.191**	-.130*	-.157**	-.197**	-.180**	-.148**	-.251**	-0.014	0.028	-0.041	0.062	-.235**
C19	-.128*	0.028	-.494**	-.402**	-.263**	-.384**	-.228**	-.178**	-.115*	-0.089	-0.043	-.120*	-0.034	-.542**
C20	0.048	-0.035	-0.101	-0.089	-0.038	-.118*	-.112*	-.141*	-.174**	-.161**	0.030	.130*	0.041	-.109*
C21	-.160**	-0.069	-.234**	-.194**	-.122*	-.230**	-.185**	-.207**	-.315**	0.017	0.048	0.071	.140*	-.299**
C22	-.164**	0.034	-.206**	-.274**	-0.082	-.264**	-.182**	-.192**	-.280**	-0.027	0.051	.148**	0.071	-.265**
CI	-.229**	-0.018	-.413**	-.365**	-.209**	-.377**	-.324**	-.323**	-.406**	-.117*	0.046	0.010	0.057	-.511**
VI	.241**	.117*	.499**	.482**	.360**	.442**	.453**	.437**	.314**	.163**	0.071	0.072	0.061	.734**

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	CI	VI
C1	1																							
C2	.145**	1																						
C3	0.099	.211**	1																					
C4	-0.047	.149**	.133*	1																				
C5	0.074	-0.075	-0.026	-0.008	1																			
C6	-0.022	0.031	.124*	.176**	0.093	1																		
C7	.261**	.240**	.234**	0.031	-0.100	0.050	1																	
C8	.166**	.227**	.158**	0.068	-0.062	-0.045	.480**	1																
C9	0.054	0.089	-0.023	0.002	-0.036	-0.050	.185**	.267**	1															
C10	0.095	0.044	0.065	0.024	0.046	0.063	.114*	.126*	0.056	1														
C11	-0.023	.151**	.142*	.323**	-0.011	.178**	.131*	0.108	0.013	0.022	1													
C12	0.048	0.104	.187**	.183**	0.088	0.038	0.021	-0.032	-.141*	0.028	.153**	1												
C13	0.091	.288**	.289**	.672**	-0.018	.125*	.183**	.188**	0.057	0.086	.398**	.236**	1											
C14	0.046	0.059	-0.074	-0.021	0.017	-0.098	.131*	0.102	0.104	-0.027	-0.011	0.001	0.046	1										
C15	0.101	.377**	.246**	0.088	-0.066	.132*	.256**	.195**	-0.047	.126*	.214**	.123*	.262**	-0.019	1									
C16	-0.040	-0.055	-0.051	.150**	0.062	-0.050	0.060	0.005	0.060	-.111*	0.103	-0.011	0.104	.635**	-0.007	1								
C17	0.066	.110*	0.095	0.017	0.082	.129*	.196**	0.097	.183**	0.095	0.102	-0.038	.121*	.173**	0.099	0.090	1							
C18	-0.033	.213**	0.036	0.060	-0.054	0.088	.171**	.149**	.129*	.185**	0.098	-0.031	.171**	-0.028	.243**	-.139*	0.095	1						
C19	0.088	.250**	.225**	0.037	0.059	0.046	.260**	.174**	-0.065	0.049	.123*	0.102	.208**	0.040	.415**	0.013	.132*	.162**	1					
C20	.157**	.127*	.121*	-0.068	0.049	-0.033	.388**	.454**	.169**	0.075	0.066	0.041	0.025	0.088	0.104	0.003	.114*	.110*	.144**	1				
C21	.281**	.223**	.135*	0.068	-0.020	0.076	.509**	.439**	.201**	0.096	.119*	0.017	.235**	0.044	.221**	0.018	.239**	.183**	.193**	.297**	1			
C22	.262**	.222**	0.095	0.009	-0.064	0.035	.507**	.583**	.225**	.116*	0.082	-0.012	.143*	0.080	.164**	0.001	.148**	.160**	.180**	.270**	.388**	1		
CI	.309**	.507**	.408**	.254**	0.009	.175**	.677**	.623**	.319**	.281**	.326**	.177**	.504**	.280**	.506**	.183**	.413**	.386**	.417**	.465**	.610**	.591**	1	
VI	-.265**	-.422**	-.352**	-.213**	0.051	-0.090	-.559**	-.449**	-.185**	-.186**	-.296**	-.250**	-.388**	-.244**	-.481**	-.143**	-.279**	-.245**	-.489**	-.295**	-.416**	-.453**	-.780**	1

Annex G

Table A.7. Correlation between structural-livelihood modifications and changes in linkages

Linkages/flows		Structural changes in house	Change in the primary source of income	Multiple income sources	Agricultural practices
INCREASED DEPENDENCE ON CITIES	People	0.049	.359**	.359**	0.004
	Finance/income	0.102	.343**	.343**	.192**
	Information	.162**	0.074	0.074	.657**
	Goods	0.017	0.047	0.047	.243**
REDUCED DEPENDENCE ON CITIES	Finance/income	0.028	-0.047	-0.047	-0.023
	Information	-0.041	-.114*	-.114*	0.043
	Goods	-.133*	-.232**	-.232**	-.116*
	Services	-.163**	-.167**	-.167**	-.173**

** Significant at the 0.05 level*
*** Significant at the 0.01 level*

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