

Towards Sustainable Flood Risk Management in the North-West Khyber
Pakhtunkhwa, Pakistan: A Flood Vulnerability Assessment Approach

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ABSTRACT

Vulnerability assessment is an important component of flood risk reduction. The north-west Khyber Pakhtunkhwa province of Pakistan is a highly vulnerable region to seasonal and flash floods. Due to changes of climate and socio-economic activities, flood vulnerability is increasing. The assessment of flood vulnerability in the area has received very little attention at district level, where the majority of the administrative decisions takes place. At local scale very few studies exist that are related to flood vulnerability. However, these studies have limitations while using an indicator-based approach. Hence the aims of this study are 1) to develop flood vulnerability indices in a transparent and reliable manner and 2) to assess the flood vulnerability of the area at two scales. A deductive approach is applied to build a composite indicator for flood vulnerability using a step-wise procedure. First, the flood vulnerability assessment was performed for the nine flood prone districts of Khyber Pakhtunkhwa, which were selected based on the reports of Provincial Disaster Management Authority and dataset availability. The methodology is downscaled to the community households' level by selecting the two main districts of Peshawar vale. Seven rural villages were randomly selected from these two districts after a thorough literature analysis and personal visits. Data were retrieved from various sources and especially from official publicly accessible portals that are best suited for assessing district level flood vulnerability and through a household survey for assessing local-scale flood vulnerability assessment. The findings of the study facilitate a vivid image of different districts and communities that might be situated in approximately similar geographical conditions with varying levels of flood vulnerability. Identifying the flood vulnerability profiles of these hotspots together with their underlying factors can help to take appropriate initiatives to reduce the existing flood risk. These analyses will facilitate the discussion about the development of sustainable flood risk management practices and will provide a background for extending the methodology to other flood-prone areas. However, there are several limitations in such kind of studies. From the current study it can be concluded that it is crucial to construct such an index of flood vulnerability that is not only intuitive to a variety of stakeholders, but also scientifically justified. It must be fairly simple in construction and comprehension to its technical and non-technical users to reduce the subjectivity issue, which is one of the main problems in the reliability of flood vulnerability indicators. Trying to apply such an approach at varying spatial scales can reduce time, resources and provide a common ground for faster comprehension, modification, and updating of flood vulnerability indices. Further, it enhances the transparency and reduces the gap between policy and sciences. Providing the flood vulnerability indices as an open tool to the end users for different experimentation is a strength and not a limitation. Vulnerability is closely related to sustainability since both are related to system or society's resilience to disturbance. A robust vulnerability assessment can support a sustainable flood risk management.

Keywords: Flood; Indicators; Khyber Pakhtunkhwa; Sustainable; Vulnerability

ZUSAMMENFASSUNG

Die Bewertung von Vulnerabilitäten ist ein wichtige Komponente zur Reduzierung des Hochwasserrisikos. Die nordwestliche Provinz Khyber Pakhtunkhwa in Pakistan ist sehr vulnerabel für saisonale Überschwemmungen und Sturzfluten. Angesichts des Klimawandels und der sozioökonomischen Dynamik in der Provinz, nimmt die Anfälligkeit für Überschwemmungen zu. Die wenig beachtete Bewertung der Anfälligkeit für Überschwemmungen findet in dem Gebiet auf Bezirksebene, in der die meisten Verwaltungsentscheidungen getroffen werden, statt. Auf lokaler Ebene existieren dazu nur sehr wenige Studien. Diese weisen Limitierungen auf, wenn sie einen auf Indikatoren basierenden Ansatz verwenden. Die Forschungsziele der Dissertation sind: 1) Die Entwicklung transparenter und zuverlässiger Anfälligkeitsindizes für Überschwemmungen und 2) die Bewertung der Anfälligkeit des Untersuchungsgebiets Khyber Pakhtunkhwa für Überschwemmungen. Für das Hochwasserrisikomanagement sind mehrere Interessengruppen zusammenzuführen, um die Anfälligkeit für Hochwasser mithilfe eines zusammengesetzten Indikators integrativ bestimmen zu können. Verwendet wird ein deduktiver Ansatz, um einen zusammengesetzten Indikator für die Anfälligkeit gegenüber Überschwemmungen zu erstellen. Die Bewertung der Anfälligkeit für Überschwemmungen wurde für neun hochwassergefährdete Teilräume durchgeführt, die für drei topographisch und klimatisch unterschiedlichen Bedingungen ausgewählt wurden. Für die beiden Hauptbezirke des Peshawar-Tals erfolgen die Berechnungen auf der Ebene der Haushalte in den Gemeinden. Sieben ländliche Dörfer wurden nach einer gründlichen Literaturrecherche und persönlichen Besuchen zufällig aus diesen beiden Hauptbezirken ausgewählt. Die Daten wurden insbesondere von offiziellen Portalen abgerufen. Die Ergebnisse der Studie geben ein differenziertes Bild von den verschiedenen Stadtteile und Gemeinden zu den Vulnerabilitäten. Die Vulnerabilitätsprofile von Hotspots für Überschwemmungen zusammen mit den zugrunde liegenden Faktoren können dazu beitragen, geeignete Initiativen zur Reduzierung des vorhandenen Hochwasserrisikos zu ergreifen und gleichzeitig zukünftige Strategien zur Reduzierung des Hochwasserrisikos zu planen. Die vorgenommenen Analysen werden die Entwicklung nachhaltiger Hochwasserrisikomanagementpraktiken für ausgewählte Distrikte und Gemeinden erleichtern. Der verwendete Ansatz ist mit verschiedenen Einschränkungen verbunden. Ein Merkmal der Vulnerabilität ist die dynamische Natur. Darüber hinaus gibt es Kompromisse bei der Gewährleistung der Robustheit. Aus den Ergebnissen kann geschlussfolgert werden, dass ein methodisch ausgewogener, einfach zu nutzender und zu interpretierender Ansatz das Subjektivitätsproblem mindern kann. Ein Ansatz in unterschiedlichen räumlichen Maßstäben kann Zeit und Ressourcen reduzieren und eine gemeinsame Grundlage für ein schnelleres Verständnis, eine schnellere Änderung und Aktualisierung der Vulnerabilitätsindizes für Überschwemmungen bieten. Darüber hinaus wird die Transparenz erhöht und die Kluft zwischen Politik und Wissenschaft verringert. Die Verwundbarkeit steht in engem Zusammenhang mit der Nachhaltigkeit. Eine solide Bewertung der Vulnerabilität kann zu einem nachhaltigen Hochwasserrisikomanagement beitragen.

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LIST OF ABBREVIATIONS

ADB- Asian Development Bank
ACFID: Australian Council for International Development
BBC- Bogardi/Birkmann (2004) and Cardona (1999/2001).
CORDIS-Community Research and Development Information Service
DHIS- District Health Information System
EPA- Environmental Protection Agency of government of Khyber Pakhtunkhwa
IDKP- Irrigation Department Government of Khyber Pakhtunkhwa
ICG- International Growth Centre
IHE- Institute of Water Education, Delft
INRM- Integrated Natural Resources Management
IS- Iyenger & Sudarshan
JRC- Joint Research Centre of the European Commission
KP- Khyber Pakhtunkhwa
KPBOS- Khyber Pakhtunkhwa Bureau of Statistics
MOVE- Methods for the Improvement of Vulnerability Assessment in Europe
NDMA- National Disaster Management Authority
OECD- Organisation for Economic Cooperation and Development
PBS- Pakistan Bureau of Statistics
PCA- Principal Component Analysis
PDMA- Provincial Disaster Management Authority
SUST- Sustainable
UN- United Nations
UNDRR- United Nations Office for Disaster Risk Reduction
UN- UN-HABITAT: United Nations Human Settlement Program
UNESCO- The United Nations Educational, Scientific and Cultural Organization
UNISDR- United Nations International Strategy for Disaster Reduction
WFP- World Food Program

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1 INTRODUCTION

1.1 BACKGROUND

Worldwide human population is vulnerable to natural disasters and environmental changes (Balica 2012). There is no doubt that the weather-related events are increasing dramatically both in frequency as well as in intensity (Kron 2014). Flooding is one of the major weather-related disasters that have affected almost every continent in the world (ibid). Floods caused 84% deaths in all disaster-related casualties from 2000 to 2005, while found responsible for 65% economic losses from 1992 to 2001 (ADB 2013, p.10). An estimate based on available information showed that floods accounted for 539,811 fatalities, 361,974 injuries and affected nearly 2.8 billion people around the globe from 1980 to 2009, although some reports suggest that this is an underestimation, particularly concerning injuries, and the people affected (Doocy et al. 2013). It has been observed that the beginning of this century has experienced several costliest (where losses exceed US\$ 8 billion) and deadliest (where death toll exceeds 1,500 people) flood disasters in different countries around the world (Kron, 2014).

There are several flood management strategies, and the vulnerability assessment is one of them (Nasiri et al. 2016). Defining vulnerability, however, is itself a challenging task. Fussel (2007) said that in common words it means “the capacity to be wounded.” It has been observed that the term “vulnerability” is a common word that a person can use or listen to, in his daily life without knowing its scientific background. The general synonym is “being susceptible to harm” is the first sentence that comes to mind. However, in the fields of natural disasters or flood management, the concept is much broader and can play a vital role in its management (Rezaee 2013, p.25). It has been also reported that the scientific use of the word “vulnerability” has its roots in geography and natural hazard research, but now it has become the central concept of other research fields, such as ecology, health, development, livelihood and climate change (Fussel 2007). Literature also indicated that vulnerability is one word with multiple meanings

(Ciurean et al. 2013, p.4) that is conceptualized in different terminologies in different fields of research (Fussel 2007) often to address similar problems (Brooks, 2003, p.2). Nevertheless, the dilemma does not seem to be resolved so far to compromise on a single universally accepted definition and evaluation. The definition and assessment of vulnerability in each specific context is therefore considered to be specific (Ciurean et al. 2013, p.4).

Indicators-based assessment has the central role in the vulnerability studies (Ciurean et al. 2013, p.13). However, indicator-based vulnerability assessment is “a hot potato.” The spatial scale of the system is foremost. Cutter et al. (2008) posits that contrasting views exists in literature about scale. Some argue that a large-scale assessment of vulnerability is appropriate as policies are developed mainly on a national level (Adger, et al. 2004 ; Adger 2006) and convincing policymakers for disasters mitigation or adaptation that may or may not happen (again) only for vulnerable people (local scale) is a challenging job compared to the benefits of general population(Vink, 2014; p.108). While others said the assessment of large-scale vulnerability is often concealed the heterogeneity that actually exists (Balica & Wright 2010). However, it is emphasized that the scale of the assessment needs to be consistent with the decision-making scale of the coordinating stakeholders (Schröter et al. 2005 and Cutter et al. 2000 in Frazier 2012). In addition, some saying that through the use of local information, it is possible to compare large scales in the perspective of hazard research (Cutter, et al. 2008). Whether one downscaling or aggregating, there is considerable agreement on those attributes, characteristics, and procedures that affect the prospective effect of the hazard or stress. An availability of resources, for instance, decreases the potential effect of a particular threat. However, the interpretation may change such as mean income or personal saving at an individual scale to gross domestic product or collective communal wealth etc. at large-scale (ibid). Fussel et al. (2006 in Frazier 2012), however, showed some reservation about “scale-based” approach as vulnerability

is highly dependent on external forces (stressors) while Green (2010) said that any action in one place will have positive or negative consequences somewhere else.

The other issue in indicator-based vulnerability assessment is the construction of composite indicators (in this research, flood vulnerability indices), that is full of challenges. It has been noted that not only composite indices, but also their construction steps are not exempted from criticism (Greco, et al. 2018). Keeping this uncertainty in mind, some authors proposed that vulnerability assessment is study-specific (Ciurean et al. 2013), discretionary (Roder, et al. 2017) and with inevitable analytical limitations and inconsistencies (Damm 2010, p.i). Highly sophisticated (statistical/empirical) approaches for the construction of composite indicators is also not desired, as it creates a hindrance for easier comprehension by its non-technical users or covered some statistical artifacts (Fekete, 2010, p. 96). Similarly, this issue is linked with the robustness of the developed methodology. For reliability composite indicators for vulnerability assessments should be made exclusively transparent, flexible and customizable to enable users to change their structural design, compile (substitute) indicators, weighting schemes, aggregated approaches and be easily understood by their non-technical users. (Baptista 2014, p.20).

1.1.1 Rationale

North-western Pakistan is a region where the population faces natural disasters and their impacts time and time again. It is asserted that flooding causes casualties every year and causes enormous material losses to the population, which is in any case poor (Etter et al. 2011, p.4). The remarkable attention received by flood risk management in the province following the 2010 super flood. Besides a huge material loss, it was reported that 1,156 persons out of 1,961 that died in last flooding was from the northern part of Pakistan (Atta-ur-Rahman & Khan, 2013). The physical land features, topographic variation and climatic setup are also contributing a major role in the flood exacerbation in the province. Proliferation the tributaries of major rivers creating flash floods in sparsely populated areas, whereas the main rivers constitute the catchment area

of densely populated places. In this context, it was reported that the northern (includes north-eastern) part along with the southern part of the province is highly prone to flash floods (Hashmi et al. 2012; PDMA 2017, p.3). Where seasonal river flooding occurs in the central part of the province (Qasim et al. 2015; Qasim et al. 2017; PDMA 2017, p.3) because of a well-marked monsoon season from July to mid-September (Hashmi et al. 2012; Atta-ur-Rahman & Khan, 2013). The role of climate change cannot be disregarded in the context of Khyber Pakhtunkhwa. The Environmental Protection Agency of the government of Khyber Pakhtunkhwa (EPA 2016, p.8) reported that the province is in the category of mid-latitude on global scale that is warned to extremes weather pattern by the IPCC fifth assessment report 2014 (AR5). Due to the warmer temperatures, the monsoon rainfall is predicted to rise and shift to a more north. Keeping this variation in mind, the province is more likely to be prone to the impacts of climate change regarding the glacial melting, a change in the hydrological cycle, the loss of biodiversity and change, the acceleration in extreme weather events and a variability or loss in crop production.

The flood disaster in the province is further aggravated by numerous socio-economic issues such as a high population, the high illiteracy rate, the lack of proper health facilities, the widespread poverty (Akhter et al. 2017; Qasim, et al. 2017), the encroachment in water ways (PDMA 2017, p.7; Atta-ur-Rahman & Khan 2013) and the unbridled economic activities in flood-prone areas that is highly dependent on natural resources and agriculture (Aslam 2012; Khan et al. 2016). It is reported that, among others, the lack of clear guideline, a weak coordination, the parallel decisions and the lack of data preservation are main administrative reasons for flood devastation (Sayed & González 2014; Zarmina et al. 2014). These issues definitely reduce the overall resilience of the system or society to cope with the negative impacts of flooding in the area. However, it is not possible to plan comprehensive flood risk reduction measures or to move towards sustainable development by discussing these problems in general without recognizing the exact hotspots and main drivers (Birkmann, 2007). It is believed

that vulnerability of an area is not only affecting by its physical location (Cutter et al. 2000) or extreme event magnitude but also by the fabric of a society (Cutter et al. 2003; Fekete, 2010, p.17). In view of these concerns and the growing need for a solution to the flood problem in the region, a clearer ' vulnerability snapshot ' of this complicated scenario is essential to facilitate policy action or dialog initiatives.

1.1.2 Research Questions

The study framing the research questions as;

- How to simplify the flood vulnerability assessment approach?
- How can sustainable flood risk management be practiced by assessing flood vulnerability in the study area?
- What are the main challenges in Khyber Pakhtunkhwa's local context by operationalizing indicator-based flood vulnerability at two different geographic scales?
- Is it possible to develop such an approach that is interdisciplinary in nature for variety of end users? And
- Is it possible to assess the reliability of the results through a non-sophisticated and easy-to-use method?

1.1.3 Research Objectives

Keeping in mind the above research questions, this study has the following specific objectives;

- To conceptualize and develop the flood vulnerability assessment approach in a fairly simple and easy to understand approach,
- To assess a district level flood vulnerability for selected flood prone districts of the province,

- To assess a community level flood vulnerability for riverine flooding in the central part of the province
- To build the composite flood vulnerability indexes in a detailed step-by-step approach that must be comparatively easy to build and understandable to non-technical users.
- To couple the results with non-sophisticated easy to use approach of methodological robustness, and
- To elaborate its application to help in the policy direction for sustainable flood risk management.

1.2 SIGNIFICANCE OF THE STUDY

The results of the research study are expected to be important for a variety of reasons. Firstly, it would demonstrate a detailed procedure for the development of flood vulnerability indices in the context of a multidisciplinary approach. Secondly, it would provide a “snapshot” of each vulnerable hotspot in the context of multifaceted flood vulnerabilities along its underlying contributors that will help to reduce the flood damages. Thirdly, it would help in the robust decisions making for prioritization of flood management activities using an appropriate methodological model. And fourthly, it would provide a good background and a source of information for the subsequent researchers to improve the understanding of multifaceted flood vulnerability.

1.3 THESIS OUTLINE

After reading the chapter one, there are seven more chapters. The workflow to understand the study structure is given in Figure 1, while the remaining chapters are;

Chapter 2: Conceptualization

The chapter deals with clarification of the process that can help in the development of the materials and methodology for the current study. Mainly the topics like flood risk,

general vulnerability, flood vulnerability and its quantification through composite indicators are discussed in this chapter.

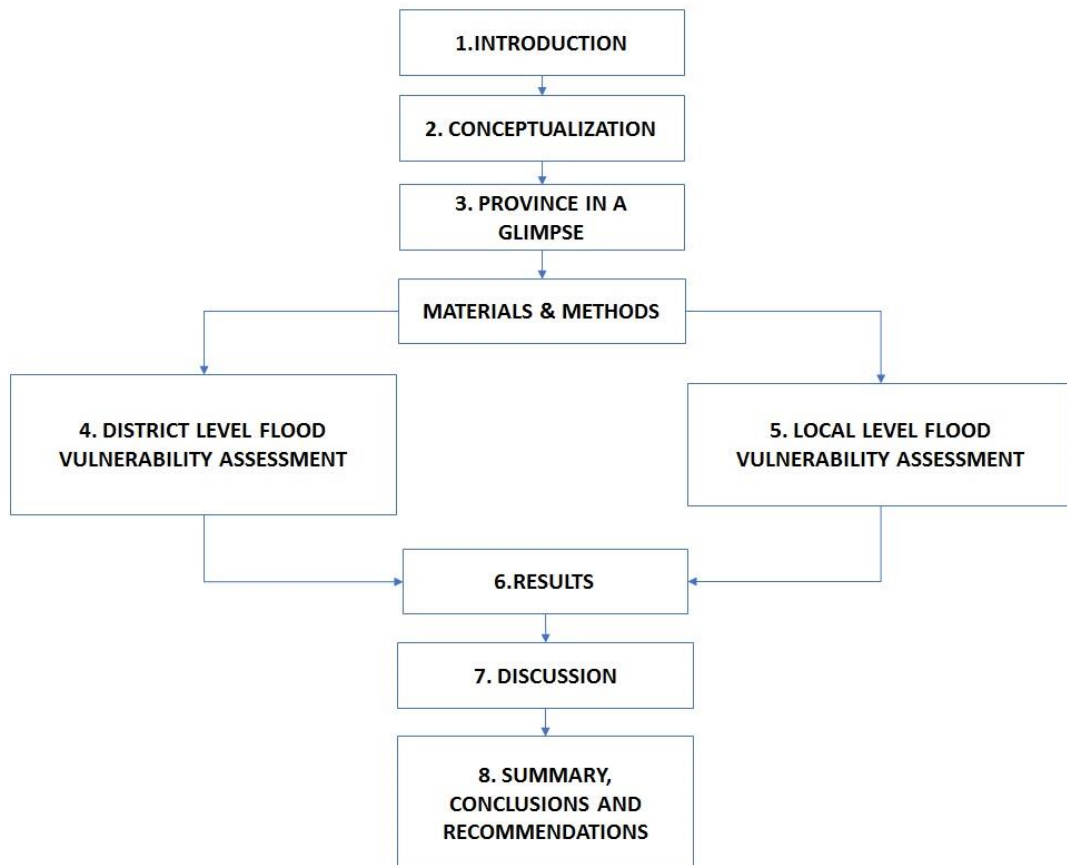


Figure 1: Workflow of the Current Study

Chapter 3: Province in a Glimpse

In this chapter the biophysical and socio-economic aspects of the province is discussed that will help the readers to get a general profile about the study area.

Chapter 4: District Level Flood Vulnerability Assessment

The “materials and methods” part of the study is divided into two main chapters. Chapter four is about the district or large-scale flood vulnerability assessment. This chapter explains the underlying methodology about the whole process from framing flood vulnerability concept to quantifying flood vulnerability indices.

Chapter 5: Local level Flood Vulnerability Assessment

In this chapter the materials and methodology that are employed for the quantification of flood vulnerability assessment at local or community households’ level is laid down.

Chapter 6: Results

This chapter is about to present the results that are derived through chapter 4 and 5 for two different scales flood vulnerability assessment. The results are presented in a fairly simple manner through graphs and tables.

Chapter 7: Discussion

This chapter has primarily two main parts as per two different kind of flood vulnerability assessment at two different scales. In the first part the district level flood vulnerability assessment is discussed in the light of earlier literature. While the second part deals with local level flood vulnerability assessment.

Chapter 8: Summary, Conclusions and Recommendations

This is the final chapter of the current study where all the contents of the study are rehashed in a detail step-wise procedure to elaborate that what has been done in the current study and what are the constraints that are faced in terms of limitations. The use of flood vulnerability assessment as a tool for sustainable flood risk management is also lightly discussed. The basic conclusions in the light of study results are extracted and some recommendations are laid down for future studies.

1.4 SUMMARY

The chapter started from the general discussion on the flood issue, which poses a serious threat to life and property worldwide by showing some statistics from a global

perspective. However, to manage or reduce the risk of flooding, it is necessary to formulate explicitly what is the element or variables that require policy action? The vulnerability assessment mainly used a vital tool for such purpose. Framing vulnerability, however, is primarily an interdisciplinary subject that is difficult to describe in a single universally accepted way that requires the investigator's clear explanation that he wants to portray. In connection with this, by using composite indicators, the flood vulnerability can be best represented. Due to various assumptions, however, the development of composite indicators is itself no less a “mountain to climb.” Mainly the resilience of the system or society that the researcher seeks to analyses can be related. Apparently, in this regard, Pakistan's north-west Khyber Pakhtunkhwa province is highly vulnerable to flash and seasonal flooding due to its hugely diverse topography, land features and climatic conditions. In addition, its socioeconomic circumstances and flood management measures further exacerbated the problems of flood disasters. The main aggravating factors, among others, are the lack of resources, high population growth, fragile economy, prevailing social structure, solely dependency on natural resources, relying exclusively on structural flood management measures, lack of advance warning systems, coordination between institutions and lack of data preservation. However, it is almost impossible to move towards sustainable flood risk management through general discourse without proper identification of the exact hotspots and the main factors that need priority. A robust assessment of flood vulnerability is thus needed to provide a common ground for this purpose to initiate appropriate debate among varying stakeholders or to implement flood risk management measures in the province. The current study tries to address this important issue.

2 CONCEPTUALIZATION

This chapter aims to conceptualize the notion of flood vulnerability assessment in an easy-to-understand process. It seems to be the most complicated portion of the study as there are endless issues that need a proper roadmap. 1) Flood, 2) vulnerability, and 3) assessment are three different concepts and “crux of the matter” that need to be linked to the objective of assessing flood vulnerability.

2.1 FLOOD

Jonkman & Kelman (2005) defined flood is the presence of water in such areas which are normally dry. While Rezaee (2013, p.27) enumerated several definitions of floods from various authors such as;

- “A significant rise of water level in a stream, lake, reservoir or coastal region (Centre for Research on the Epidemiology of Disasters (CRED) 2011)
- Water accumulation that is not submerged (Jakibicka, Phalkey et al. 2010)
- The result of runoff where runoff depends on the intensity and areal extent of the precipitation (Green, Parker et al. 2000).
- Floods are high-water stages where water overflows its natural or artificial banks onto normally dry land (Schmidt-Thomé 2006).
- A flood is a body of water which rises to overflow land which is not normally submerged (Ward 1978).”

Ali et al. (2016) defined flood in the specific context of meteorology that “meteorologically flood can be defined as situation over a region or place where that rainfall is mostly heavy and higher than the normal climatological mean value”. The current study will not differentiate between words “flood” and “flooding” both will mean the overflow of water from waterways to the areas that are normally dry.

Besides that, several authors classified flooding into different categories. The major types of floods are 1) river floods 2) flash floods 3) tidal floods 4) surface floods 5) groundwater flooding 6) sewer flooding 7) reservoir flooding 8) glacier lake outburst flood 9) back-up flood 10) seiche 11) mud-floods and so on (Rezaee, 2013,p.28; Sayers et al. 2013,p.22; Kron, 2014; Ali et al. 2016). These classifications are mainly based on the sources or causes of flood generation such as high and intense rainfall, high temperature that caused snow melts, earthquake to make tsunamis and technical failures like the breach of dams or embankments (Rezaee, 2013, p.28; Kron, 2014). However, Kron (2014) are in the view that primarily the floods are three types that are 1) river floods 2) flash floods and 3) storm surge. As he described these three kinds to hydro-metrological events where the other types of floods included, but not limited, the glacial lake outburst, dam breaks, back up flooding, most tsunamis etc. was mentioned as geophysical phenomena. In the context of this study, riverine flood and flash floods are quite common. Kron (2005) and Kron (2014) define these floods as;

2.1.1 River Flood

The river flood is also known as basin-wide flood. The main reason behind such flood is a heavy rainfall along with snowmelt (in some cases) that continues for long span of time often for days or weeks while covering basin area at large. Due to high water accumulation the soil retention capacity reached to zero where it cannot hold more water and the drainage system of the basin convey the excess water to main rivers. Although such kind of flood doesn't happen at once (normally) but as it moves downwards it can affect the whole basin, even of thousands square kilometers. The high-level water remains stagnant for long time that not only damaging property but also disrupting the routine lives for long time of span. In river floods water always arise from river channels and caused inundation. The sequence of inundation areas remains almost the same and different hot spot areas can be identified because of flood frequencies as well as intensity.

2.1.2 Flash Flood

Flash flood is also known as the off-plain flood that can practically happen anywhere. An intense rainfall of usually short span can trigger flash flood. Spatially it happened in small area due to thunderstorm and in large areas due to tropical storm. Another characteristic of a flash flood is that it can happen at once and remain for a few hours to a day or two. Due to its onset appearance it poses severe danger to human and property. In steep topography the water speed is super-fast with enormous potential for destruction while in flat areas it accumulates on the surface and filling depressions. Often flash floods are the sign of a riverine flood however, not always and it appears an individual event that is scattered randomly both spatially and temporally. Some time it appeared downstream in areas where there is no rainfall happened at all. The silent features of flash flood included its highly mechanical forces, erosive capacity and the transport of solids. In the case of current study area this type of flood is very common in the mountainous part of the province.

2.2 FLOOD MANAGEMENT

No clear indications exist to the author's knowledge in literature that has shown that the difference or similarity between "flood management" and "flood risk management." Ali et al. (2016) asserts from others that some time flood management encompasses the term "risk or risk assessment" and sometimes precludes. In the first scenario, flood management is regarded as the actions and decisions covering risk analysis, assessment and reduction. Whereas in the second case, it means the flood management actions or decisions that are based on the hydrological reliability of flood protection's design and standards. Banihabib & Laghabdoost-Arani, (2014) described the flood management process is the wide range of plans (might be they mean activities or measures) that helps to reduce the negative effects of flooding on human, environment and economy. They broadly divided the flood management into structural and non-structural measures. Nasiri et al. (2016) explained these terminologies from other authors such as;

- **Structural measures:** are those measure that consists of infrastructure development like dams, levees, dikes that modify the river flow through storing or confining; while
- **Non-structural measures:** are those measures that not diverting the river flow but mitigate the negative effects of the flood through proper education, awareness, social and economic measures, health measures, public participation etc. in short, all other human and natural activities rather than structural measures.

In this respect, Samuels (2006 in Nasiri et al. 2016) explained that “flood risk management” is a complete array of activities including: vulnerability assessment, emergency planning, developing structural measures and taking non-structural measures before flood disaster while taking rehabilitation and reconstruction after flooding. Flood risk management is therefore the collective activity of several experts such as hydrologists, hydraulic engineers, economists, social scientists, ecologists, and planners to reduce flood risks (Nasiri et al. 2016). Similarly, each of these disciplines have multiple techniques for assessing flood risk and vulnerability. Through flood risk and vulnerability assessment it may be possible to formulate context-specific policies and measures.

The paradigm has shifted from traditional flood risk management to sustainable flood risk management. Although literature often used the term "sustainable flood risk management," its clear definition is missing. It's usually linked to vulnerability. For instance, it has been linked to vulnerability by Hooijer, et al. (2004); Lumbroso et al. (2008) and Shajahan & Reja (2011). Birkmann (2006, p.48) said that while linking sustainability to risk reduction is crucial, in fact it is practically not easier. Sustainable development can, however, be viewed as a basic doctrine that reduces the magnitude, frequencies and effects of natural disasters by improving system resilience (Birkmann 2006, p.45). Nevertheless, Guillaumont (2015) explicitly mentioned that "vulnerability

is a handicap and the opposite of sustainable development." In this study sustainable flood risk management implies using a systematic flood vulnerability assessment approach to assist in the development of robust flood risk management.

2.3 FLOOD VULNERABILITY

Before describing what is meant by flood vulnerability, it is undeniably essential first to understand some complicated concepts and connotations.

2.3.1 Defining Vulnerability

In general, it is important to learn about "vulnerability" before understanding the assessment of flood vulnerability. Cambridge dictionary defining vulnerability is the status that is "capable of being easily hurt (physically, mentally and emotionally), influenced or attacked" (Cambridge Dictionary, n.d.). Several authors interpreted the roots of the word "vulnerability" in the case of disaster management or natural hazard research. For instance, McEntire et al. (2010) sheds light on the emergence of the term "vulnerability." They stated that scientists started to question the "naturalness" of the disasters in the mid-1970s. Several contributors to the "interpretation of calamity" include Hewitt (1983), provided that poverty is linked to disasters, and technocratic approaches that focus entirely on hazards are not likely to minimize the impact of disasters. Hewitt argued for pursuing policies that take social, economic and political realities into consideration. This led to the emergence of the rapidly expanding research agenda for vulnerability, led by Blaikie, et al. (1994) and several others. Whereas, Ciurean et al. (2013, p.6) argues that there were initially two perspectives that view vulnerability in 1) the perspective of technical or engineering sciences, and in 2) the perspective of social science. The former highlights hazard assessments and their impacts where the role of human systems in mediating the outcomes of hazard occurrences is downplayed or ignored. While the subsequent focuses on the human system and relies on ascertaining the ability of society to cope with, resist, respond and recover from the impact of a natural hazard (Blaikie 1994, *ibid*). Whereas, the

vulnerability viewpoint of technical sciences focuses primarily on physical elements, the perspective of social sciences takes into account various factors and parameters influencing vulnerability, such as physical, economic, social, environmental and institutional characteristics (UNISDR, 2014, *ibid.*). Birkmann (2006, p.13) and Adger (1999) also provide similar depictions. Other disciplines stress the need to take into consideration additional global factors such as globalization and climate change. Thus, the broader vulnerability assessment is in scope, the more it becomes interdisciplinary (Ciurean et al. 2013, p.6).

It is reported that the vulnerability can be mainly seen in three different perspectives that are 1) (bio) physical vulnerability, 2) social vulnerability and 3) integrated vulnerability (Rezaee, 2013, p.54). However, Fussel (2007) reported that although some authors discriminating between socio-economic (social) and bio-physical (natural) vulnerability, but there is no agreement on the meanings of these terms as some authors see one vulnerability as determinant to the other like in the study of Klein & Nicholls (1999) and Brooks (2003) while in contrast other thinks that the two types of vulnerability are independent of each other like in the study of Cutter, (1996). Mainly these studies used incompatible terminologies and none of them is such comprehensive to be integrated with others.

Due to the involvement of various areas of research and experts, including but not limited to, disaster management, climate change, development, economics, policy making, social sciences and health often using distinct terminology or vocabulary to address similar issues and factors (Fussel 2007; Brooks 2003, p.2). This issue makes it difficult and almost impossible to rely on single universally acceptable definitions of vulnerability (and associated terms) as different disciplines have developed their own definitions. Birkmann (2006, p.20) rightly posits that “we still face a paradox: we aim to assess vulnerability, but we cannot define vulnerability precisely”. Ciurean et al. (2013, p. 4) reported vulnerability is one term with multiple meanings and its definitions and assessments are context-specific for each research study. A large set of vulnerability

definitions are enlisted by several authors (see Taylor & Butterfield 2011; Rezaee 2013, pp.51-53; Ciurean et al. 2013, p. 7) where the interested readers can read.

2.3.2 Vulnerability as a Concept

In addition to the variability in definition, assessment and conceptualization, there is a somehow consensus on the basic characteristics of vulnerability. Adger (1999), Downing et al. (2005, p.3) and Vogel & O'Brien (2004) reported that vulnerability is multidimensional and differential, scale dependent and dynamic in nature. Birkmann (2006, p.13) posits that from multidimensional and differential, it means that vulnerability varies across physical space and between and within social groups while from scale dependent it means that it depends on the system of analysis such as individual, community, regional, system etc. And similarly, from dynamic, vulnerability means that vulnerability features and driving forces change over time and space. Further, Fussel (2007) argues that Liverman (1990) related vulnerability to resilience, marginality, susceptibility, adaptability, and risk though I (he) could easily add exposure, sensitivity, coping capacity, criticality, and robustness to his list. It is generally understood now, that vulnerability is the root cause of disaster (Lewis, 1999 in Balica 2012) and it is the risk context (Gabor & Griffith, 1980 in Balica 2012).

Birkmann (2006, pp.38-40) and Birkmann (2007) give an overview about the widening of the concept of vulnerability in the scientific community as shown in Figure 2. From innermost sphere, he posits that nearly there is consensus that view vulnerability as the “internal side of risk” that links vulnerability to the intrinsic characteristics of elements at risk as described by ISDR (2004), Cardona (2004, p.37), Wisner (2002, pp.12/7) and Thywissen (2006). While the second sphere define vulnerability as the likelihood of injury, death and other losses from a hazardous event (Wisner, 2002). This human-centered definition highlights the fact that the main vulnerability features are those conditions that raise and ascertain the potential for injury. Similarly, from third sphere, it is shown that vulnerability is also viewed from dualistic point of view where it was said that the concept of vulnerability encompasses the susceptibility (weakness or

negative characteristics) on the one hand and coping capacity (positive characteristics) on the other hand to describe the vulnerability of a system at risk that is somehow reported by Wisner (2000), and partially by Chamber (1989) and Bohle (2001). The fourth sphere shows that the concept has got wider from susceptibility and coping capacity to exposure, adaptive capacity and stresses by the discourse on vulnerability in the global climate changes community like Turner et al. (2003). Overall, the notion of vulnerability has been constantly expanded and extended to include a more holistic approach covering susceptibility, exposure, coping capacity and adaptive capacity, as well as various thematic areas such as physical, social, economic, environmental and institutional vulnerability.

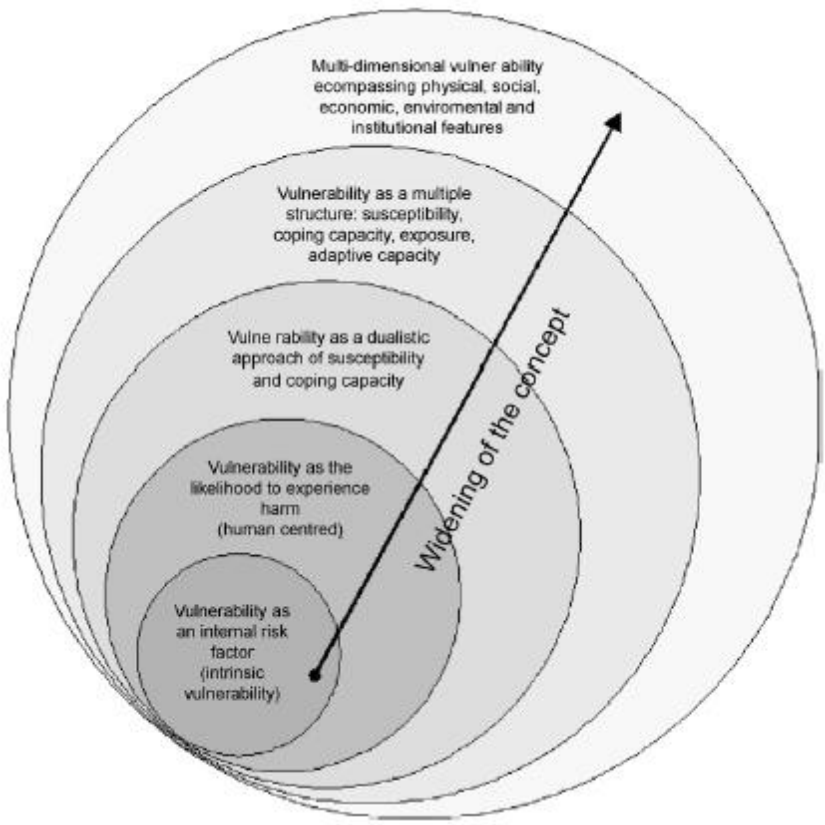


Figure 2: The Spheres of Vulnerability (source: Birkmann 2005 in Birkmann 2007)

Like the complexity of describing vulnerability, its assessment approach is also not very easy and straightforward. In each specific research, the definition and assessment of vulnerability is specific and must be transparent in that specific context (Crucian et al. 2013, p.4). Birkmann (2006, p.11) counted more than 25 methods, concepts and definitions to systemize vulnerability under different schools of thoughts. The detail of well-known and widely used conceptual models can be seen in very great detail in the studies of Birkmann (2006, pp. 18-39), Ciurean et al. (2013, pp. 8-11) and Rezaee (2013, pp.59-67). Relevant to this study, it is explained in later chapter (sec 4.2) to avoid repetitive discussion.

2.4 FLOOD VULNERABILITY ASSESSMENT

One of the main problems that need proper attention is the lack of vulnerability context that can be seen in almost all flood vulnerability assessment studies. From the context it means that researchers start with vulnerability directly and readers, newbies or non-technical readers don't understand what is the actual aim of vulnerability assessment? So, it is indispensable to start from the beginning that what is vulnerability and how did the investigator frame the concept? Either he thinks vulnerability is an element of risk and independent of hazard or not? Since, there is no consensus on the framing of these concepts so far.

Let start from general discourse that is risk and vulnerability are the “same piece of the puzzle”? The answer under the current study is, "No.". Dikmen et al. (2008) reported from several other authors that vulnerability is always confused with risk, but these are two fundamentally different terms. Vulnerability implies being prone to a dangerous situation whereas risk is the severity of the consequences. The vulnerability is distinct from risk and hence their methods of management are also different. Risk management includes both the probability and the consequences of risk, while vulnerability management used to describe system characteristics that can alter the potential for harm or vulnerability exists before the risk happens. Similarly, reducing vulnerability as a significant means of managing risk, however reducing risk has no

impact on vulnerability. In this sense, they give a very nice illustration that if material theft happens from a site, it will cause money loss. And if the material is insured, the owner will receive the compensation. Here insurance is the risk response, the risk is reduced or recompensed. But to reduce the vulnerability i.e. to avoid again theft of materials, it will need to increase the site security by building some secure storage. Balica et al. (2013) said that the flood is conceptualized by various authors as a hazard, risk and vulnerability. However, this is not the satisfying answer that needs further investigation.

2.5 SO, WHAT IS FLOOD VULNERABILITY ASSESSMENT?

What do we understand by looking at flood as a hazard, risk and vulnerability up to this point? Perhaps it would be not cleared. Therefore, without a clear explanation, framework and guidelines to conceptualize what the researcher will explain while assessing flood risk or vulnerability is not more than just "beating one's head against the wall." Fekete (2010, p.119) points out that without first knowing the vulnerability (connotation) there will be no risk reduction or adaptation possibilities.

Consequently, it is necessary to understand flood in terms of hazard, vulnerability and risk (Rezaee, 2013, p.41). In the scientific community, there are vast, complicated and competing definitions and ideas that addressed these terminologies in different perspectives and wordings. Interpreting the meanings of these terminologies without defining a disaster, however, can be useless. The United Nations Office for Disaster Risk Reduction (UNDRR 2017) define these terminologies with the aim of common understanding. The report defines disaster, hazard, risk and vulnerability in the following words;

- **Disaster:** “A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts.”

- **Hazard:** “A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.”
- **(disaster) Risk:** “The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure¹, vulnerability and capacity².”
- **Vulnerability:** “The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.”

Apart from a variety of conceptualization of disaster risk, the present study framing it is the function and product of a hazard and vulnerability (Wisner et al. 2004 in Muller et al. 2011; Agarwal & Blockley, 2007; Dikmen et al. 2008; Fekete 2010, p.30; UNISDR 2004 in Ciurean et al. 2013, p. 5; Ali et al. 2016; Nasiri et al. 2016). Akhter et al. (2017) reported that it is the “risk” that promotes the disaster management (flood management) into the disaster risk management (flood risk management). While, Kobayashi & Porter (2012, p.12) said that the idea and management of flood risk is at the core of the strategic flood management framework where they exclusively demonstrate the approach in the context of China. Following their approach (not framework, as their risk concept is different from the present study), it is now evident that the current study is speaking about "flood risk". Kron (2005) and Kron (2014) exclusively point out this issue that the word “risk” is grasped by different individuals in distinct ways. Whereas this plurality of uses may often have no consequence, the risk for scientific discussions should be defined in a clear and coherent sort of way.

¹ Exposure is the part of vulnerability framework in the current study

² The current study cannot differentiate between capacity and resilience, where resilience is also the part of vulnerability framework in the current study.

2.5.1 Methods for Flood Vulnerability Assessment

Dapeng Huang (2012 in Nasiri et al.2016) categorized flood vulnerability assessment into four types includes;

2.5.1.1 Indicators-based Assessment

This method is used in the case of available data to show the “logical image” of an area. The method is widely used and preferred by policy makers to prioritize certain actions. Different method exists for indices building that sometime face hardship in its construction method like weighting, normalization, standardization etc. and uncertainty is one of the main weakness in this kind of studies.

2.5.1.2 Vulnerability Curve Method

A fragility or empirical curve is developed between the flood risk and elements at risk in this method. The method is used for real damages analysis from well documented sources. As the method is based on real data so to take actual damages surveys need a lot of time and money. The weakness is that the method is not replicated to other areas as it is site-specific in nature.

2.5.1.3 Disaster Loss Data

This method requires actual damage data to predict future events and is one of the simplest among the four methods. The weakness of this method is the use of unevenly recorded data.

2.5.1.4 Modelling Method

The model simulation can also consider the characteristics of the hazard like flood depth, velocity, inundation area etc. The method needs detail topographic, hydrological and economic data. The intangible nature of economic loss and lack of enough data can cause irregularities in model results that raise questions in its validity (Balica et al. 2013).

However, in contrast to this discussion, Blaica et al. (2013) reported that indicator-based methods can be used for vulnerability assessment and computer modelling for risk

assessment. An indicators-based vulnerability assessment is relevant to the current study. Balica (2012) enumerates several well-known indicator-based vulnerability assessment approaches that are widely using in different parts of the world such as Environmental Vulnerability Index (Pratt et al. 2004); Social Vulnerability Index (Cutter et al. 2003) etc.

2.6 CONCEPTUALIZING THE WHOLE PROCESS

This discussion provides to conceptualise the structural design of the study, understanding the mutual relationship of hazard, vulnerability and risk and its assessment through indicator-based approach. Now its need to understand what is the meaning of "vulnerability assessment" in the current study? This definition can hardly be found to the author's knowledge in any natural disasters' studies. However, for vulnerability assessment, other disciplines, especially computer science or information technology, have a very sound and comprehensive definition. Vulnerability assessment is generally defined in the field of computer science or cyber security as the identification, quantification and prioritization or ranking of system's vulnerabilities (Altaf et al. 2015; Experts Exchange 2018).

Putting this concept to flood vulnerability assessment implies to identify the hotspots, quantify the flood vulnerability through composite indicators (as relative measures of these vulnerabilities) and to prioritize required actions to reduce these vulnerabilities. Now the concept is crystal cleared to move forward. All this discourse is summarized in Figure 3. The upper part of the figure shows that flood vulnerability is primarily conceptualized in three main pillars, but not isolated from each other. Where vulnerability and flood (risk) has the relationship in such a way that vulnerability is one of the components of flood risk and flood risk can be reduce through vulnerability assessment. The lower part means that its assessment can best be carried out by placing it within the general vulnerability assessment framework. The lower part of the diagram is further explained in chapter 4 (section 4.2.6).

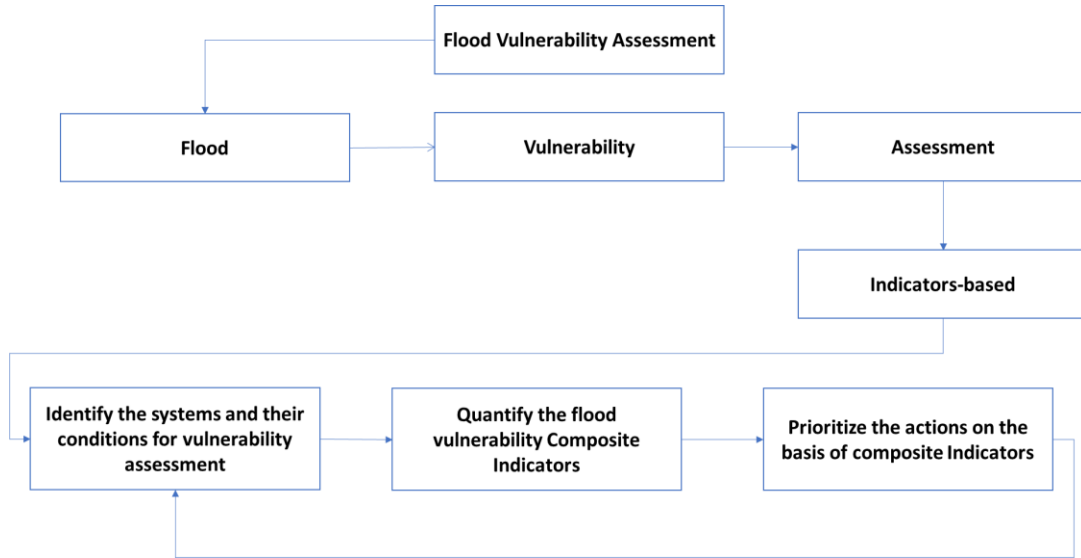


Figure 3: Conceptualization of the whole Procedure for Flood Vulnerability Assessment

2.7 INDICATOR BASED FLOOD VULNERABILITY ASSESSMENT

Assessment is the last facet of the title. Perhaps this is the major component or tool that can be used to simplify the flood vulnerability procedure. However, the indicator-based vulnerability assessment is not less complex than the other two parts. The detail is given in following sub-sections.

2.7.1 Indicators and Composite indicators

Hammond et al. (1995, p.1) pointed out that the term "indicator" dated back to the Latin word "indicare", which implies revealing or pointing out, disclosing or publicly disclosing, or estimating or pricing. Indicators transmit information about progress towards social goals such as sustainable development. But their function can be simpler: the clock on a hand, for example, indicates the time. As is generally understood, an indicator is something that gives an indication of an issue of higher significance or makes a trend or phenomenon perceivable that is not immediately perceptible. For example, a drop in barometric pressure may signal a coming storm. Thus, the

significance of an indicator extends beyond what is actually measured to a higher phenomenon of interest. Balica (2012) noted that an indicator is an intrinsic characteristic that quantitatively estimates the situation of the system and usually focuses on a small, easy to handle, substantial and convincing element of a system that can give the concept of a broader picture that plays a greater part in policy making. While Baptista (2014, p.1) described an indicator either as a directly or indirectly measure (proxy indicator) or an estimate used to define a feature of the system in question (e.g. population, geographic region, socio-economic sector, or a coupled human-environment system). Its values are derived from process information and can be of a qualitative or quantitative nature, such as child mortality and life expectancy, etc.

The composite indicator, on the other hand, is the aggregate of several individual indicators. OECD (2008, p.13) discoursed that “a composite indicator is created when individual indicators are compiled into a single index based on an underlying model. The composite indicator should preferably assess multifaceted concepts that cannot be apprehended by a single indicator e.g. sustainability”. Hammond et al. (1995, p.1) opined that matters and explicitly the process of communicating information to decision-makers and the public, are more accurately described as indices. Indicators give better information in a more quantitative form than words or pictures alone. Indicators provide information in a streamlined, simpler-to-understand format than complex statistics or other kinds of financial or scientific data and indicate a framework or set of assumptions that relate the indicators to more complicated phenomena. Even though indicators are commonly displayed in statistical or graphic form, they differ from statistics or primary data. However, indicators and highly aggregated indices top an information pyramid based on primary data obtained from data processing and analysis. The procedure from data to indexes can be seen in the "information pyramid" (Figure 4).

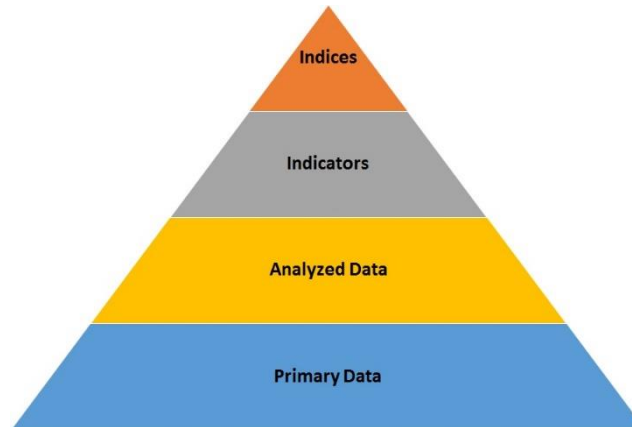


Figure 4: The Information Pyramid (redeveloped from Adriaanse 1994 in Rezaee 2013, p. 95; Hammond et al. 1995)

In current study the composite indicator will mean that it is the aggregate of several individual indicators to provide a summary statistic of a complicated and multifaceted phenomenon in a simple and meaningful form (Baptista, 2014, p.1) that will be useful for policy making (Balica, 2012) and for formulating measures, activities and defenses against flood disaster (Dinh et al. 2012). Munda & Saisana (2011) equated composite indicator with an “index.”

Index building and use are gaining sufficient importance in recent times due to the complicated issue and the involvement of multidimensional features in policy making. There are, however, some criticisms of both the development and use of composite indicators. For instance, some of the objections logged by Booysen (2002 in Moreira & Crespo 2017, p.141) are;

- Composite indicators always exclude one or more key components of the realm in question
- Individual components of the index may be quantified utilizing different variables (potentially better)

- Composite indicators may not reveal more than what is revealed by a single variable
- The selection process of variables may be arbitrary, politically or ideologically motivated, or simply determined by the availability and precision of data
- The data used in the composite indicators are sometimes incomplete and incomparable
- Often there is no clear justification for the selected weighting and aggregation practices, and
- Composite indicators may be devoid of practical significance if they do not provide particular policy guidance.

In contrary, there are elements that are in the favour of composite indicators. Bandura (2005, 2008, 2011 in Greco et al. 2018) mentioned that composite indicators had gained exceptional prominence in all fields of studies, even with all their obscure definitions. The number of their applications is constantly increasing at a rapid pace from social aspects to governance and the environment, and there are at least over 400 official indices available to measure or classify the social, economic, political or environmental aspects of a country. For instance, Greco et al. (2018) referenced Sharp (2004), Saltelli (2007) and Ray (2008) as stating that while the development of the Human Development Index was highly criticized, it still gained enormous attention and popularity. Saisana & Tarantola (2002, in OECD 2008, pp.13-14) listed some of the advantages of composite indicators in this respect, such as;

- Composite indicators refine multidimensional or complicated issues
- They are easier to interpret than a battery of separate indicators
- They can assess progress over time
- They reduce the size of indicators without losing the basic information.

- They have the ability to incorporate new information within its existing limit (may be authors means structure)
- They facilitate to communicate with common people (lay and illiterate), media and help in accountability, and
- They enable users to compare complex issues in a simple manner

Saisana et al. (2005 in OECD 2008, p.14) opined that it is difficult to imagine that the discussion about the use of composite indicators will ever be resolved. Official statisticians may tend to resent composite indicators, through which much work in data collection and processing is "wasted" or "concealed" behind a single number of questionable significance. And from the other side, the tendency of stakeholders and practitioners to summarize complicated and sometimes uncertain procedures (e.g. sustainability) into a single number seems equally irresistible. Greco et al. (2018) posits in this regard, as "their success and widespread use by global organisations, academics, the media, and policymakers around the world can be attributed to this irresistible characteristic."

Unfortunately, the construction of (vulnerability) composite indicators has several challenges. Nelitz et al. (2013, p.66) reported that techniques for developing aggregate or composite vulnerability indices are not technically complicated, though subjectivity is an issue. It is reported that there is no a single universally accepted method that can be used to construct composite indicators (Mazziotta & Pareto, 2013). Furthermore, personal judgment or subjectivity cannot be avoided (Damm, 2010, p.6) and its construction is almost discretionary (Roder et al. 2017). Booyesen (2000 in Greco et al. 2018) states that this is logical, because there are many phases in the development of composite indicators, and at the same time criticism could grow for each of them. The OCED's checklist (OECD, 2008, p.15) also proposed by Greco et al. (2018) is a common ground that can enhance the reliability and transparency of the composite indicators. Various fields of research include, but are not limited to, finance, economics,

sustainability, agriculture; geography and the environment have already adopted the method for reliable results.

The present study also adapted this technique to develop composite flood vulnerability indices for two primary reasons. First, to think "outside the box" by not to follow the readily available flood vulnerability framework's assessment method, as there are several schools of thought. And second, flood risk assessment is a combination of various stakeholders, from engineers to sociologists, economists, researchers and even the common mass, who need a commonality for easier understanding.

2.7.2 Construction of (Flood Vulnerability) Composite Indicators

The basic stages that can be used to develop composite indicators for (flood) vulnerability assessment are outlined in the following subsections. OECD (2008, pp. 15-16) recommend ten basic steps in the construction of composite indicators. It should be noted that each step has a number of options and merits and demerits that are largely dependent on the needs and expertise of the investigator, the availability of data, the structure of data and the compatibility of assumptions. Consequently, various researchers tailored these steps in different perspectives where some steps are not applicable, some overlaps and some are combined. However, the most frequently steps are given in following sub-sections.

2.7.2.1 Conceptual Framework

Rosen (1991 in Saisana & Saltelli 2011) posits that in the computational sense of the term, the issues surrounding multifaceted measures may be put into perspective when one deems these measures as models. Models are inspired by the systems (natural, biological, social etc.) that one wants to understand. Developing a conceptual model or framework for vulnerability assessment is crucial as it will help to identify the underlying terminologies, goals, procedures and components that are required for the development of flood vulnerability indicators (Fekete 2010, p.28).

2.7.2.2 Indicators Selections and Data Treatment

This is actually the foundation of the composite indicator's construction. Indicators' selection in the current study is based on deductive approach. Adger et al. (2004, p.17) reported that in a deductive approach a theory or conceptual framework is used for the selection of indicators that best suit the relationship or phenomena to be measured. Simply put, it is the operationalization of a concept or testing hypothesis of the concept by gathering suitable data to explore the underlying relationship. Nevertheless, the inductive approach is primarily based on statistical and empirical generalizations. Niemeijer (2002 in Vincent 2004, p.9) said that deductive approach is a theory-driven method based on a theory or conceptual framework while inductive is a data-driven approach based on statistical procedures. It is reported that indicators selection should be based on conceptual framework (in deductive approach), availability of data, their usefulness and easily recollection (OECD 2008, p.15; Balica & Wright 2010; Saisana & Saltelli 2011).

There are varying opinions that classify these techniques into different perspectives. However, relevant to the current study it is simplified from Adger et al. (2004 pp.93-94) and Reckien (2018) as shown in Figure 5As stated above, the vulnerability composite indicators can be constructed primarily through two approaches: 1) deductive reasoning and 2) inductive reasoning. The current study is based on the first approach. Here the composite indicators can be developed either to aggregating all indicators into a single composite indicator by keeping in mind the functional relationship or by making sub-indices and then aggregating them to the final index i.e. hierarchical approach. Note that inductive reasoning is some time used for weighting purpose in deductive approach.

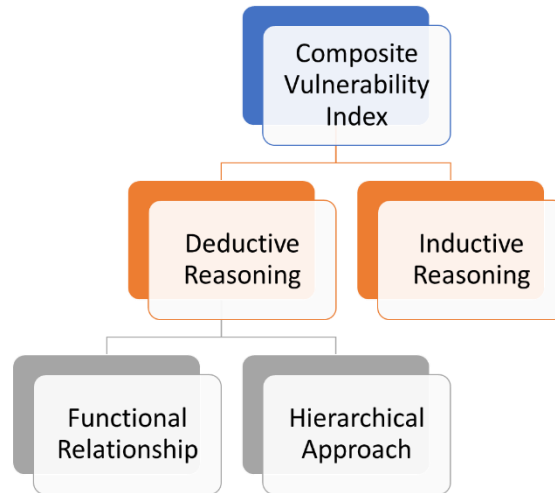


Figure 5: Methods for the development of Vulnerability Indices

The lack of some indicators or data in some regions is not uncommon in the development of composite indicators. In this regard, there are different options for substituting missing data (Saisana & Saltelli 2011). Rules also exist for the detection of outliers such as the combined use of skewness and kurtosis. However, some authors said that it will change the actual data structure that can create problem in data analysis and interpretation (Damm 2010 p. 137). The issue of double counting of the indicators is another important step to be considered in the formation of composite indicators in the case of additive aggregation without or equal weights. Indicators reduction (based on correlation) is actually a big dilemma in the development of composite indicators. OECD (2008, p.32) said that there will always be positive correlation among indicators while Merz et al. (2013) quoting Saisana & Tarantola (2002) that completely independent indicators cannot be selected if they measure same phenomena. Though it is desired to use independent indicators in additive aggregation still some authors considered this issue as “unrealistic” (OECD 2008 p.103). However, different views exist for the selection of certain indicators when they are highly correlated. It is generally adopted that if the two or more indicators representing same phenomena and there is highly correlation exists, then it is necessary to discard certain indicators using a

“rule of thumb”. For instance, if two indicators are logically correlated then the rule is applicable but if the correlated indicators represent different phenomena than the rule can be safely neglected (see Damm 2010, p.136). The cutoff value of Pearson’s correlation (r) for strong linear relationship as a “rule of thumb” was reported 0.65 in the study of Damm (2010, p.136), 0.70 in the study of Balica & Wright (2010) and 0.90 in the study of Hagenlocher et al. (2016). Commensurability is also required in case of comparison across the administrative units to bring indicators into comparable unit (Baptista 2014, p.16). For instance, if Region A has 40,000 women and Region B has 20,000, the comparison will be misleading as one does not know the proportion of women with respect to overall population. The conversion of these values into percentages with respect to the total population can therefore ensure reliable results.

2.7.2.3 Data Transformation

To avoid the adding up “oranges and apples” the data need to be transformed into a single scale (OECD 2008, p.27). Several methods exist for this purpose; however, when selecting the appropriate method, the data properties and objectives of the composite indicator should be taken into account by practitioners (Saisana & Saltelli 2011). Indices that employ deductive and hierarchical designs generally apply “Min-Max” normalization (min-max linear scaling) to convert values to a min-max scale (such as 0 to 1), whereas indices that use inductive designs tend to apply a z-score normalization technique that generates variables with a mean of zero and a standard deviation of one (Baptista 2014, p.16).

2.7.2.4 Weighing and Aggregation

Weights can have a substantial effect on the overall composite indicator (OECD 2008, p.31). Weights to indicators may be equal or differential. Equal weights are used in these cases, if there is insufficient understanding of causal relationships or a lack of consensus on the alternative. In any case, equal weighting does not mean “no weights,” but implies “equal weights” (OECD 2008, p.31; Baptista 2014, p.17). Whereas when weights are decided to be unequal or differential, three ways that are normative, data-

driven and hybrid are usually adapted (Decancq & Lugo 2013 in Baptista 2014, p.17). Normative approach consists on expert opinion, public opinion or stakeholders' consultation while data-driven means the weights are derived though some statistical or empirical means like principal component analysis (PCA), factor analysis, regression etc. (OECD 2008, p.32; Saisana & Saltelli 2011; Baptista 2014, p.17). However, Nelitz et al. (2013, p.67) argued that statistical methods are sometimes considered to be more scientifically defensible and less resource-intensive. The commonly used aggregation options are summation (linear aggregation), multiplication (geometric aggregation) and multi-criteria analysis. The most common technique for calculating the overall index is a simple averaging method while presumes equal weights to be assigned across all indicators. The inherent assumption being that all elements contribute equally to vulnerability (Nelitz et al. 2013, p.66). Compensability can be a weakness of additive aggregation if a low value in one indicator or dimension masks a high value in another (Tate 2012 in Baptista 2014, p.18).

2.7.2.5 Uncertainty and Sensitivity Analysis

OECD (2008, p. 117) related robustness tests (uncertainty and sensitivity analysis) with “X-ray” of the underlying phenomena i.e. the checking of assumptions made during the development of composite indicators. Literature shows that the methodological choices made during various stages of the composite index construction involve assumptions, subjectivity and uncertainties that should be identified, acknowledged and communicated across the quantitative procedure (Baptista 2014, p.6). It is also referred as robustness tests regarding uncertainty and sensitivity analysis. Greco et al. (2018) said that it is often seen that these two are handled independently, with the uncertainty analysis being the most common type of robustness check. They further added that analysis of uncertainty refers to variations observed in the final results (i.e., the composite index value) from a possibly different choice made in the inputs (i.e. the composite index stages). Whereas sensitivity analysis estimates how much variability of the overall output is attributed to these uncertainties. Different views exist in scientific

community about the use of robustness tests. Baptista (2014, p. 23) stated that the assessment of uncertainty and sensitivity is not optional but essential to guarantee transparency of the vulnerability assessment indices. In contrast, Saerwitz et al. (2000 in Nelitz et al. 2013, p.71) opined that a lack of certainty should not paralyze an investigator to perform vulnerability assessment and decision makers to use it for making decisions. The uses of highly sophisticated approaches that get dominant over logical cohesion (Maggino and Zumbo 2012 in Baptista 2014, p. 6) are also not desirable. There are several techniques that can be used for robustness tests. However, the “average shift in ranking” (OECD 2008 p.118; Merz et al. 2013; Hudrliková 2013) in comparisons to a reference is the easier one. Primarily robustness tests are conducted to understand the uncertainty caused by the inclusion and exclusion of certain indicators or factors, data rescaling, weighting and aggregation (OECD 2008, p.34), which can also assist to show the methodological prejudice.

2.8 SUMMARY

The aim of this chapter was to conceptualize the current study. Based on the title of flood vulnerability assessment, the chapter was analyzed into three main parts for this purpose. 1) Flood, 2) vulnerability, and 3) assessment are illustrated in a relatively simple manner and have been linked to the development of a framework for the present study.

First of all, a comprehensive study is needed to define "flood." In the scientific community, there is a complicated work that needs further research before proceeding to frame a flood vulnerability study. It has been found that most authors start their study without clarifying what they are going to define? Since, there are distinct implications to the word "flood." Several authors used it solely from the viewpoint of "hazard," whereas others used it from the viewpoint of "risk" and "vulnerability". This issue is related to flood management. Some authors regarded flood management from a hydrological perspective, i.e. flood level (stage) in the rivers to construct, monitor and maintain hydrological infrastructure, while others thought that it is the overall management

activities included risk reduction through adequate planning and development of policies i.e. flood risk. Similarly, there is no agreement on the implication of flood risk and vulnerability. Some believe that risk encompasses hazard, exposure, vulnerability and adaptive capacity, while others believe that hazard and vulnerability are risk components.

Second, there is no doubt that "vulnerability" is a very complex matter. This issue relates to the involvement of different areas of research, ranging from social sciences to natural, medical and managerial sciences. These disciplines have developed not only their own variants of vulnerability definitions, but also frameworks for assessment and methodological approaches. The issue is further complicated while using comparable terminologies with divergent meanings or vice-versa. Though flood risk management is a field where professionals from different sectors work together to develop flood risk mitigation policies and measures

Third, the vulnerability assessment on the basis of the problems mentioned. In the scientific community, the "assessment" of flood vulnerability is based primarily on indicators. However, the complexity of this "term" in any situation is not less than the "flood" and "vulnerability". The right approach is to develop an assessment method that is transparent and convenient to comprehend, not only for technical users, but also for non-technical and lay people.

In the present study, word flood stands for "flood risk". It is the product of "flood hazard" and "vulnerability of the system". Whereas the current study deals with the flood vulnerability. The current study framed flood vulnerability in the later chapter (Sec 4.2.1). In the current study, the flood vulnerability assessment is based on indicators. Again, however, there are different techniques for assessing flood vulnerability based on indicators. In the present study, a deductive reasoning is relevant while using the OECD guideline to create composite flood vulnerability indicators called the "flood vulnerability index". The OECD approach is the prevalent ground where the development of composite indicators can be realized via a step-wise procedure. Though

the approach is primarily using for the economic, technological and development-based performance's assessment of different countries. However, for other disciplines such as agriculture, sustainability, environment, etc., some authors have also adopted it. These issues are discussed in depth in this chapter to build on the concept of flood vulnerability assessment in this study.

3 THE PROVINCE IN A GLIMPSE

3.1 PAKISTAN AND KHYBER PAKHTUNKHWA

Pakistan is most commonly described as a cross-road country. Geographically, here's where minor Asia, Central Asia and the Indian subcontinent intersect. Inside the country, this turns into the geographical difference between the wide eastern Indus basin and the mountainous northern and western areas (van Steenbergen & Oliemans 1997, p.93). Pakistan is located approximately between 24-37° N latitudes and 62-75° E longitudes in South Asia, bordering India in the East, China in the North, Afghanistan in the Northwest, Iran in West and the Arabian Sea in South (Salma et al. 2010) with a total area of 803,940 square kilometres (Ahmad 1997). The country has four provinces (Khyber Pakhtunkhwa known as KP, Punjab, Sindh, and Baluchistan), the administrative Northern Areas (Gilgit-Baltistan, so called fifth province), Federal Administrative Tribal Area (FATA³) and the Federal Capital Territory (F.C.T) as shown in Figure 6. High mountain ranges consist of Himalayas and Karakoram with a small portion of the Hindukush in the north of the country. These three ranges are meeting in Pakistan. Most areas in central and southern Pakistan are arid, while the northern region of the country is humid, with the exception of the extreme northern mountains where it is dry (Salma et al. 2010; Qasim et al. 2014).

³ It is recently merged in Khyber Pakhtunkhwa

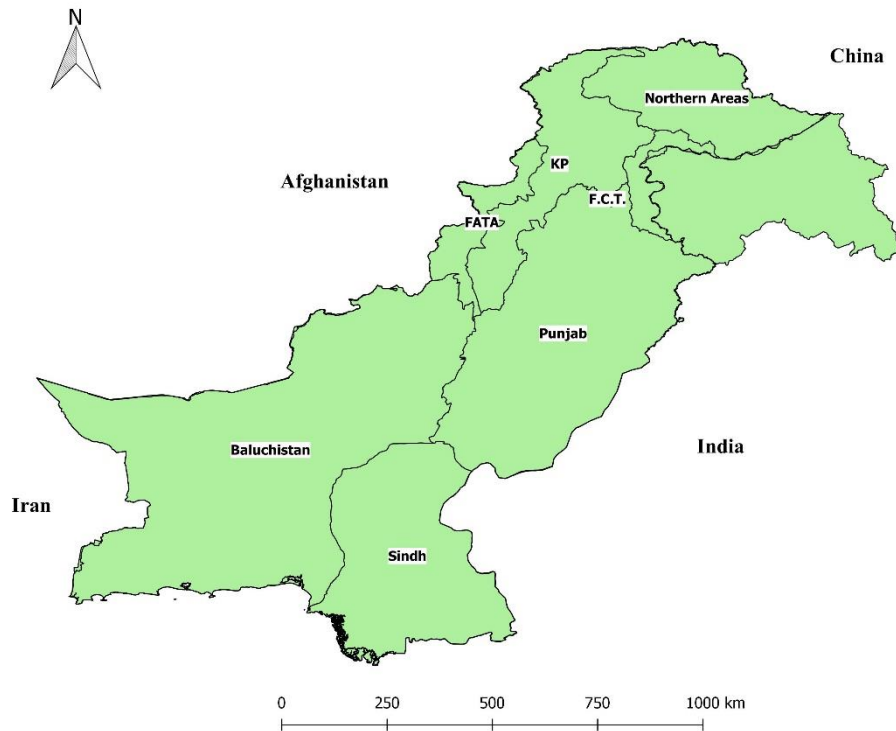


Figure 6: Map of Pakistan

The province of Khyber Pakhtunkhwa (Formerly called North-West-Frontier-Province) is situated between $31^{\circ}15'$ and $36^{\circ} 57'$ North latitude and $69^{\circ} 5'$ and $74^{\circ} 7'$ East longitude. Khyber Pakhtunkhwa is the smallest province of Pakistan, covering an area of $74,521 \text{ km}^2$ (Kruseman & Naqvi 1988, p.1; Aslam 2012; PDMA 2017, p. 3; Salim 2018, p.82) which is approximately 9.4% of the total area of Pakistan (PDMA 2017, p. 3). Khyber Pakhtunkhwa comprises the north-western part of Pakistan, neighbouring Afghanistan in the west, Gilgit-Baltistan in the northeast, semi-autonomous Azad Kashmir in the east, and the provinces of Punjab and Baluchistan in the southeast and southwest, respectively (Kienzler 2012, p.14).

3.1.1 Physical and Climatic Features

The topography of the province is pretty diverse (Figure 7). It includes large plains, vast deserts, low hills and high mountains. The province shares vast tracts of the ranges of the world-famous Karakoram, the Hindukush, and the Himalayan. The altitude ranges from 300 m in the south at Dera Ismail Khan (D.I. Khan) to 7690 m in Tirich Mir, the north's highest peak in the Hindukush range (Kruseman & Naqvi 1988 p.8; Kienzler 2012, pp.14-15; Salim 2018 p.82).

Extreme variations are existing in the climatic condition of the province that is controlled by geographic setup (Kruseman & Naqvi 1988, p.8; Atta-ur-Rahman & Khan 2013). Shams in 2006 (cited in Atta-ur-Rahman & Khan 2013) reported that the rainfall increases steadily as moving from south to north in the province. The province is situated at the tail end of the both rainy seasons i.e. the monsoon and the western disturbance from the east and west, respectively. The extreme north and south parts of the province fall in semi-arid to arid climate where little rainfall occur however the north-western part of the province is humid (Atta-Ur-Rahman & Khan 2013). The northern part of the country (Himalayan range) contributes nearly 72% of the mean annual flow in the Indus river system through it relatively higher annual rainfall (Tariq & van de Giesen 2012). The hottest district of Khyber Pakhtunkhwa, named D. I. Khan where the maximum temperature ranged from 46-50 degrees centigrade can be found in the south (Kruseman & Naqvi 1988, p.14) along the coldest region in the north where summers are temperate and winters are perpetual freezing (Atta-ur-Rahman & Khan 2013). 40% of the country's forests are in the province of Khyber Pakhtunkhwa. The province is comprised of 17%, 28%, 8% and 13% of forests, rangelands, agriculture and snow cover, respectively (Ahmad 2012 in EPA 2016, p. 5). In short, EPA (2016, p.4) opined that Khyber Pakhtunkhwa's northern region experiences exceptionally cold and snowy winters, with heavy rainfall and pleasant summers, while Khyber Pakhtunkhwa 's southern parts experience relatively less extreme winters, moderate rainfall and hotter summers.

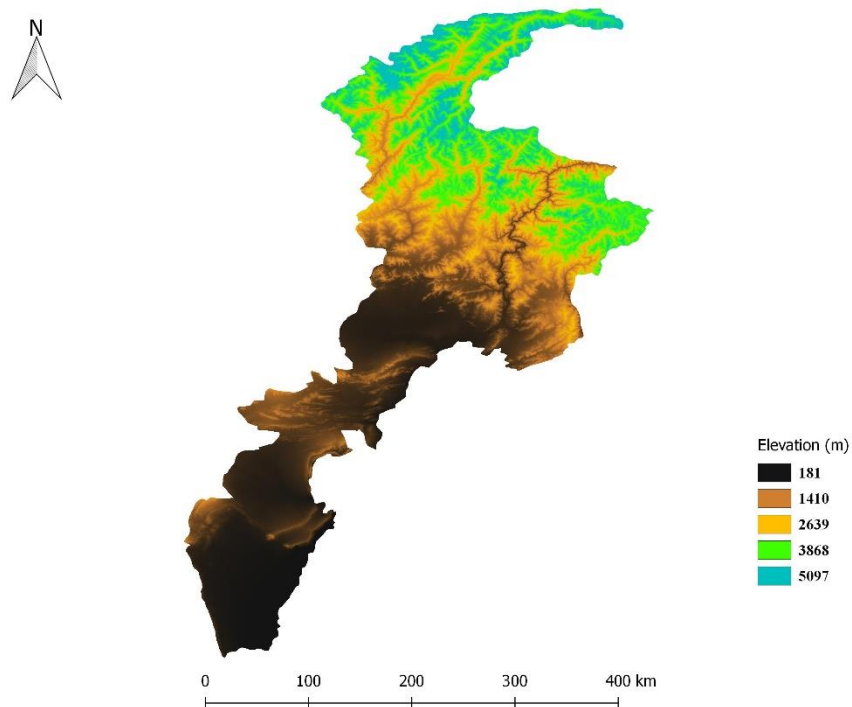


Figure 7: Elevation of Khyber Pakhtunkhwa from Mean Sea Level

3.1.2 Geological Setup and Hydrology

The province is located within the subduction zones of two continental platelets, the Eurasian and the Indian. The Indian plate continues to move north at around 40 mm per year (1.6 inches / year). As a result, seismic activity in the region is very high, leading to numerous earthquakes (Kienzler 2012, pp.15-16). Mainly the soil of northern and mountainous area is shallow loam while that of the plain area and south is loam (Khan et al. 2010). The Indus river originates from the Tibetan mountain range and flows down along the Khyber Pakhtunkhwa boundary in the Kohistan District in northern areas. Downwards near Tarbela (name of place) the Indus is dammed by the world's largest earth-fill dam. The reservoir's purpose is flood regulation and the production of power generation (Kruseman & Naqvi 1988, p.8). In Khyber

Pakhtunkhwa, Indus and Kabul are the two major river systems with several perennial and seasonal tributaries (PDMA 2017, p.3).

3.1.3 Demography and Social Setup

The official results of the national census described that the province has a population of 30.52 million. The rural-urban ratio is 81.2% and 18.8%, respectively. This total population comprised on 50.7% males and 49.1% females (PBS 2017). The Government of Khyber Pakhtunkhwa's Bureau of statistics report (KPBOS 2017a) was thoroughly analyzed to make a social synopsis of the province. The statistics given in the report (also on official webpage) is mainly based on old census, recent surveys and statistically derived data. Based on the reports, the literacy rate was found 54.1% in the province. The literacy ratio between male and female was found 72.1% and 36.8%, respectively. Similarly, this ratio was found 66.3% for urban area and 51.3% for rural area in the province. Literacy means here the ability to read and write. The infant mortality rate is 79 per 1,000 live births in the province. The province has 207 hospitals, 454 dispensaries and 56 health centers.

3.1.4 Economic Profile

IGC (2015, p.1) reported that the proportion of the population underneath the poverty line in Khyber Pakhtunkhwa at 39 percent is significantly higher than the national average. The province has a workforce of 6.60 million contributing 5.31 million males and 1.29 million females. Only 6.02 million people are employed in which 5.00 million are males and 1.09 are females. The unemployment rate is 7.73 percent where 5.84% are males and 15.50% are females. Agriculture is the main source of sustenance either directly or indirectly. It contributes approximately 24 per cent to Gross Domestic Product (GDP) and accounts for nearly half of the labor force employed. It remains the largest source of foreign-exchange earnings with its 60 contribution to exports (KPBOS, 2017a). However, Aslam (2012) reported that agriculture is the primary source of livelihood in Khyber Pakhtunkhwa, but it has a slender and fragile structure. Throughout the province, the major challenges faced by agricultural communities are land ownership

and the resulting fragmentation of land into small and unprofitable holdings, inadequate irrigation facilities, lack of relevant expertise, education and extension services, widespread poverty among farmers and insufficient credit facilities, gender segregation, costly farming inputs (quality seeds, fertilizers and pesticides), lack of field-to-market roads, low agricultural output prices and lack of agricultural industries. ICG (2015, pp.6-10) listed key sectors that can play vital roles in economic development such as construction and production, agriculture and livestock, mining and tourism. However, it also highlights the main challenges in this development, such as attracting investors, energy shortages, communication (roads, railways, etc.) development and law enforcement.

3.2 SUMMARY

A synopsis was developed in this chapter to address lightly the prevailing conditions in the area that make it the country's highly vulnerable part. Both natural and socio-economic conditions seem equally responsible for the vulnerable profile of the province that needs further exploration in order to identify the relative levels of varying hotspots and the contributing factors for appropriate measures.

4 A DISTRICT LEVEL FLOOD VULNERABILITY ASSESSMENT

4.1 STUDY AREA

The province has been defined by several authors based on different characteristics. However, for the convenience of understanding the study results, the current study divided the selected districts into three different parts, including the northern, central and southern parts (Figure 8). These districts are selected based on the Provincial Disaster Management Authority's reports and the availability of data set. The districts selected are;

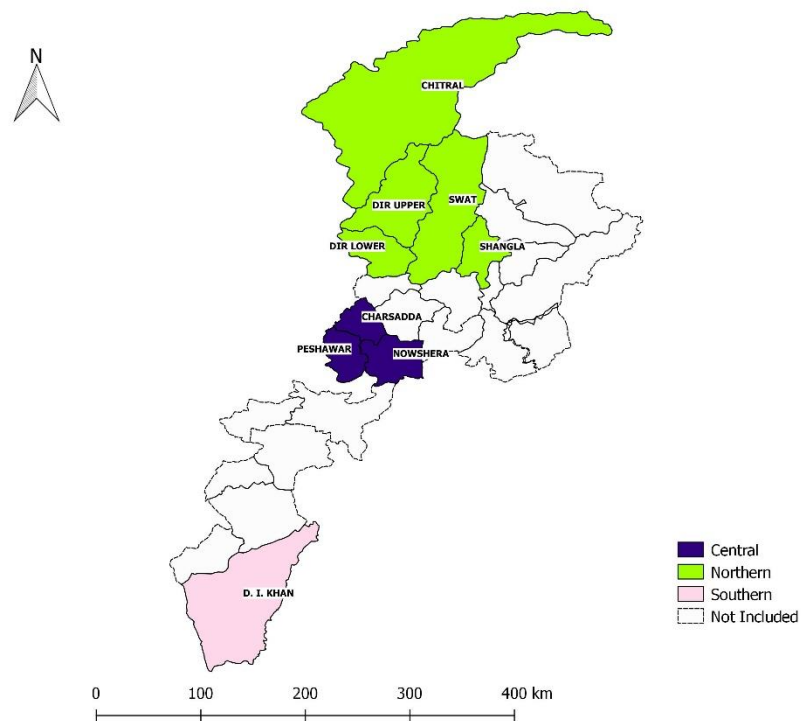


Figure 8: Selected Districts for Flood Vulnerability Assessment

- Chitral, Dir Upper, Dir Lower, Shangla and Swat: Geographically they situated in upstream northern mountainous part of the province.

- Charsadda, Nowshera and Peshawar: Geographically they are in the downstream central plain part of the province.
- D. I. Khan: Geographically it is also situated downstream in the southern plain part of the province.

Figure 9 shows the prevailing climate conditions in the selected districts in terms of mean annual maximum temperature, mean annual minimum temperature and annual rainfall (1982-2012). It can be seen that the temperature rises as one moves from north (left) to south (right). While on the other hand, annual precipitation rises as one moves from south (right) to north (left) with the exception of the extreme north, i.e. the district of Chitral. The variability in climatic parameters (temperature and precipitation) is due to the topographical variation and physical characteristics of the land as described in Chapter 3.



Figure 9: Climatic Conditions of the Selected Districts (based on Climate-Data.org 1982-2012)

4.2 THE CONSTRUCTION OF (FLOOD) VULNERABILITY INDEX

The flood vulnerability assessment through indicators-based approach is conducted through a step-wise procedure as shown in Figure 10.

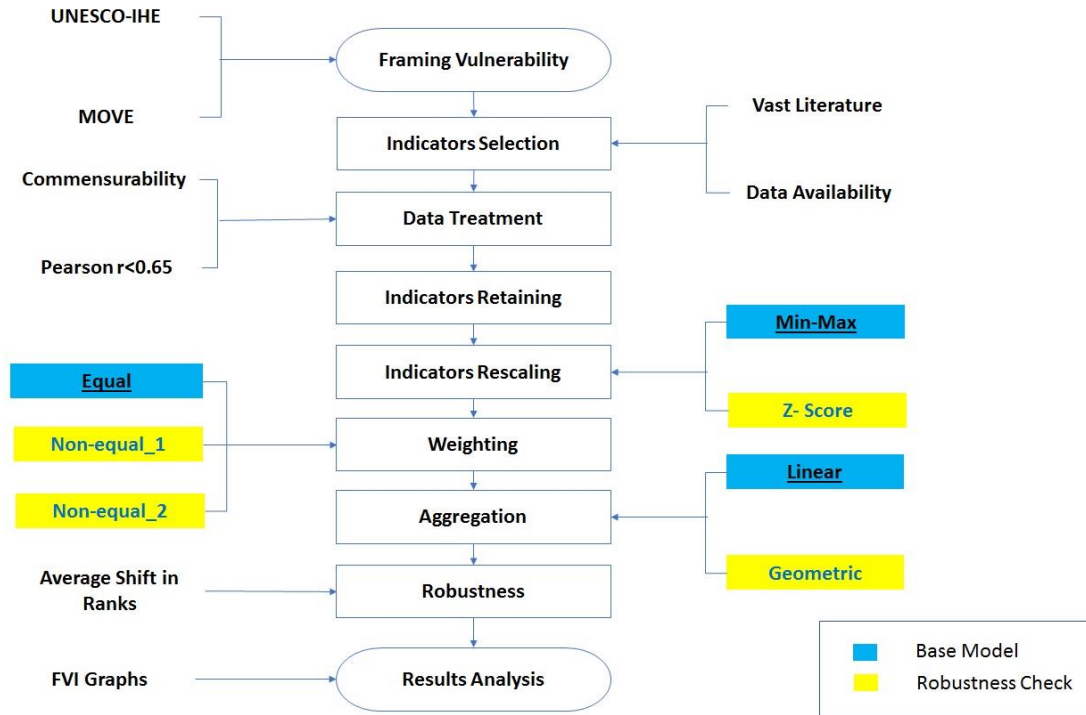


Figure 10: Flowchart for the Flood Vulnerability Assessment (based on OECD 2008 and modified from Hagenlocher et al., 2016)

4.2.1 Conceptual Framework(s)

Before framing the flood vulnerability concept for the current study, it is necessary to highlight the conceptual context. It was observed that several authors in different parts of the world have used different conceptual frameworks such as the BBC framework (Birkmann 2006, p.35), the SUST-vulnerability framework (Turner et al. 2003), the UNESCO-IHE flood vulnerability assessment framework (Balica et al. 2009) and the

MOVE vulnerability framework (Birkmann et al. 2013) for flood vulnerability assessment. The current study is primarily inspired by the last two frameworks. Therefore, it seeks to expand and criticize these approaches for developing flood vulnerability indices.

4.2.1.1 UNESCO-IHE Framework

The UNESCO-IHE (Balica et al. 2009) approach used the Van Beek (2006 in Balica et al. 2009) concept of a water resource system for assessing flood vulnerability. The concept described water resource system as a combination of interdependent three sub-systems, such as;

- The natural river sub-system (NRS): Where the physical, chemical and biological activities take place,
- The socio-economic sub-system (SES): That is comprised on social, economic and demographic conditions, and
- The administrative and institutional sub-system (AIS): That is bounded by legal, constitutional and political boundary.

These sub-systems are comprised on four components. The physical and environmental components belong to NRS while the social and economic belongs to SES as well as AIS (Figure 11).

In the view of UNESCO-IHE, the flood disaster can distress any (water resources) system in its four components includes social component, economic component, physical component and environmental component. The social component encompasses all the major issues related with human beings like deficiencies in mobility of individual with respect to gender, disabilities, age etc., as flood can cause damaging to the houses, communication, or even killing. The component also includes the administrative arrangements of the societies, consisting organizations and their respective level. The economic component encompasses all the economic related activities that are related to

income or income generation that are predisposed to be harmed. Numerous economic activities existed among them the agriculture; fisheries, industries etc. are very common.

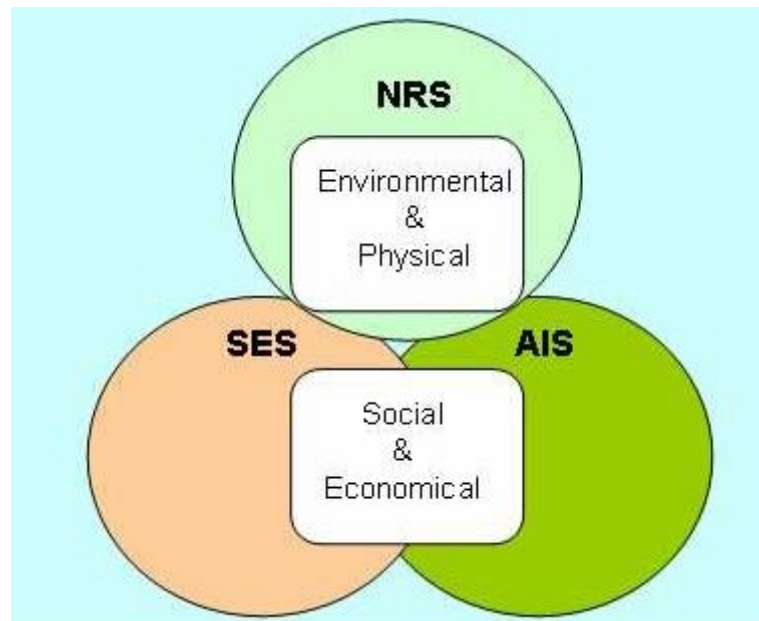


Figure 11: The Sub-systems and Components of a Water Resources System (source: <http://www.unesco-ihe-fvi.org/>)

The damaging of these sectors can influence the life and prosperity of the common mass. Lack of environmental awareness, in recent times can create even more disruption to ecosystem if flood water is highly polluted. Urbanization, deforestation and industrialization have enhanced environmental degradation. While the physical component includes the geo-morphological and climatic conditions of the system along with the physical infrastructure such as dike, levees etc. these conditions indicate the proneness of the physical component to floods of a certain area or region. The flood vulnerability of the mentioned components (as well as the system) can be quantified through the general vulnerability factors includes exposure, susceptibility and resilience. The framework used basin, sub-basin and urban areas as spatial units. The interested

readers can read in more detail in Balica & Wright (2010), Balica (2007), Balica et al. (2009), Balica et al. (2013), Balica et al. (2012) and the UNESCO-IHE flood vulnerability website.

4.2.1.2 MOVE Framework

The MOVE framework was developed primarily to construct a general, integrative and holistic framework for systemizing and assessing vulnerability, risk and adaptation, taking into account the perspectives of disaster risk management and climate change. The framework is based on the underlying factors that create vulnerability, including the exposure of society or a system to a hazard, the susceptibility of the exposed system or community and its resilience and adaptive capacity (Figure 12). Further, the framework also considers the multidimensionality of the system (social, economic, environmental, physical, institutional and cultural aspects) to assess the vulnerability (Birkmann, et al. 2013). Vulnerability is defined in this context, as the degree of sensitivity or fragility of elements, systems or communities, including their ability to cope with hazardous conditions (Kablan et al. 2017) that is the product of exposure, susceptibility and lack of resilience (Birkmann et al. 2013; Welle, et al. 2014). Kienberger et al. (2014) further added that the framework changed the "resilience" domain to "lack of resilience" while preserving the negative meaning of the word "vulnerability". Although the framework is for general vulnerability assessment, several authors in different parts of the world have effectively used it for the flood vulnerability assessment. For instance, Welle, et al. (2014) utilized the framework for Cologne (Germany), Kienberger & colleagues (2014) for Salzach River Basin (Austria), Kablan et al. (2017) for Cocody area (Ivory Coast) and Lianxiao & Morimoto (2019) for Tokyo (Japan). Some of them utilized the framework for social vulnerability only while others used it for several domains (economic, environmental etc.). In any domain vulnerability means the potential for damage or the conditions that facilitate damage (Umweltbundesamt, 2016). The framework is best suited for place-based intervention measures (Kienberger et al. 2014).

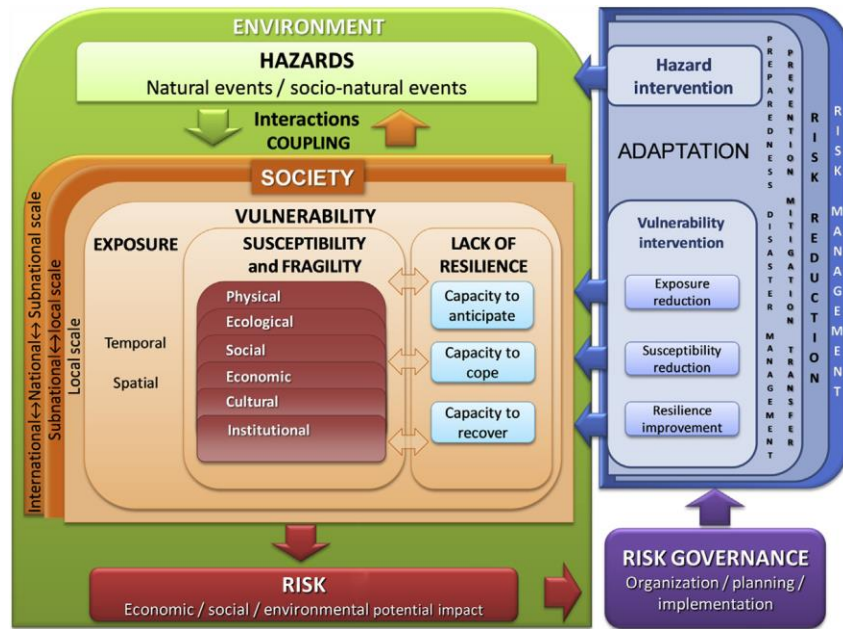


Figure 12: Schematic Diagram of MOVE Framework (source: Birkmann et al. 2013 in Welle et al. 2014)

4.2.2 Flood Vulnerability Assessment Method

There is no doubt that the current research uses the above-mentioned frameworks to frame the concept of flood vulnerability. Perhaps the UNESCO- IHE flood vulnerability index is the most prevalent method using for flood vulnerability assessment. However, there are some issues that need to be addressed. It is quite evident that the vulnerability of a system, place, community etc. is multidimensional that can be influenced by multiple aspects at the same time involves, but not limited to, social, economic, environmental and physical that are hard to distinguish in a tidy manner (Birkmann & Wisner 2006, p.15). It can also demonstrate some different views by examining the Van Beek (2006) water resource system model (Figure 13). To the knowledge of the author, the model said that the water resources system is obviously composed of three sub-systems (as stated previously). The SES takes resources from

NRS and consequently leaving negative impacts. To regularize both these sub-systems, there is AIS that can regularize the NRS through infrastructures and SES by different policies and legislations. Of course it belongs to human-being but from analytical point of view it is kept separate. Coming to the components, there is no indication that these components are either belonging to one sub-system or to other. Limiting physical and environmental components to NRS makes no sense that is contradicted to their own statements i.e. three interdependent sub-systems. If physical is only limiting to dikes, levees or river morphology than what about built environment i.e. houses, roads, drainage etc.? How Urbanization, deforestation, industrialization and human awareness come to natural river sub-system? Generally speaking, these (economic, social and physical, etc.) are the dimensions of the human-environmental system composed of several features conceived by indefinite authors in disaster risk context (see McEntire et al. 2010; Kron 2014). This issue can create the question of data availability and redundancy. Is it possible that indicators used for such component-wise indices will be available everywhere? And if they do, won't they be redundant? Further, by establishing spatial scales such as basin, sub-basin and urban might create hindrance for universal applicability, as countries like Pakistan use administrative units for policy making and implementation. No doubt that framing flood vulnerability concept, providing much great detail for subsequent researchers and the availability of indicators list cannot be underestimated, though similar indicators are often replicated in different components (see <http://www.unesco-ihe-fvi.org/>). In brief, they might have different ideas but, in general, flood vulnerability indices without a pool of indicators (i.e. in data scarce situations) and scale relevance, the methods is difficult to apply in such conditions.

The MOVE vulnerability framework is quite straightforward in this respect. There is no specific method for measuring vulnerability indices; no list of indicators is provided and there are no limitations on the spatial and temporal scales. Simply put, it gives the investigator the liberty to use the framework based about the need for study, accessibility of data and scale.

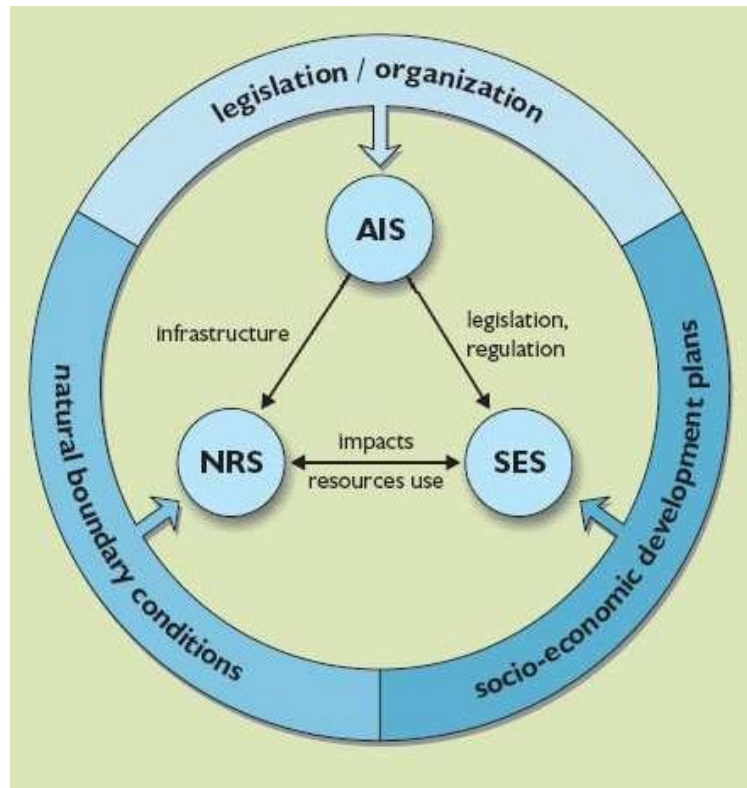


Figure 13: Water Resource System's Sub-systems and its interactions (Source: <http://www.unesco-ihe-fvi.org/>)

So, the assessment method for flood vulnerability indices is not based on UNESCO-IHE approach, as one of the goals of this study is to "think outside of the box" by developing flood vulnerability indices for a broad spectrum of stakeholders. As Nelitz et al. (2013, p.66) posits that, "the challenge is that the end result must be accepted and satisfactory to a multitude of stakeholders, including decision-makers, stakeholders, development planners and practitioners equally". The construction of flood vulnerability indices in the current study is following a widely acceptable and practicing approach of the OECD (2008) that can be considered a common ground for variety of stakeholders. The same or almost similar approaches can be found in unlimited studies (e.g. Hudrliková 2013; Talukder et al. 2017; Hagenlocher et al. 2016) and adopted by

different fields of studies for vulnerability assessment or other requirements. Note that the “Handbook on Constructing Composite Indicators” is jointly prepared by OECD and JRC. The publications and reports of the JRC, therefore, are almost following similar method.

4.2.2.1 Vulnerability Factors

What are the meanings of vulnerability factors, i.e. exposure, susceptibility and (lack of) resilience, and what are their mutual relationships? It is highly debated. The present study is not intended to revise the complexity of these terminologies and their relationship to vulnerability assessment. However, briefly there are no implications that either resilience is or is not an integral part of vulnerability. And does resilience belong either to adaptive capacity or vice versa? In this respect, Cutter et al. (2008) argues that different schools of thought have different connotations about these terms (see Cutter et al., 2008). Similar situation is also related with term “exposure.” In some frameworks it is kept independent from hazard while some think it is a hazard-dependent phenomenon.

Both the mentioned frameworks defined these terms in fairly similar ways. The UNESCO-IHE defined exposure is “the predisposition of a system to be disrupted by a flooding event due to its location in the same area of influence”. While susceptibility is “the elements exposed within the system, which influence the probabilities of being harmed at times of hazardous floods”. And resilience is “the capacity of a system to endure any perturbation, like floods, maintaining significant levels of efficiency in its social, economic, environmental and physical components” (<http://www.unesco-ihe-fvi.org/>). While the MOVE framework elaborated the three vulnerability factors such as that exposure is “the extent to which an area that is subject to an assessment falls within the geographical range of a hazard event”. Similarly, susceptibility means “the predisposition of the elements at risk (social and ecological) to suffer harm, resulting from the levels of fragility of settlements, disadvantageous conditions and relative weaknesses” (Birkmann et al. 2013; Kablan et al. 2017). The lack of resilience is defined as, “the limitation of access and mobilization of the resources of human settlements and

their institutions and the inability to adapt and respond to the absorption of socio-ecological and economic impacts." Resilience includes the capacity to anticipate, cope with and recover "(CORDIS 2013).

Regarding the above debate, in the current study, flood vulnerability implies the circumstances of the system which facilitates damage (CORDIS 2013; Umweltbundesamt 2016) under certain conditions of exposure, susceptibility (Balica & Wright, 2010) and lack of resilience (Birkmann et al., 2013).

4.2.3 Selection of Indicators and Data Treatment

The next step in the construction of composite indicators is the selection of suitable indicators that best match the phenomenon to be evaluated. Indicators are selected through comprehensive literature and availability of data, while keeping in mind the criteria for good indicators.

4.2.3.1 Indicators Explanation

Literature shows that population density increases exposure to flooding (Balica & Wright 2010; Holand et al. 2011; Hiremath & Shiyani 2013; Kablan et al. 2017). Since it is difficult for the dense population to evacuate easily and thus increase the potential to cause harm. The places where more people live in flood-prone areas tend to be highly exposed to flooding as compared to areas where relatively fewer people live in flood-prone areas (Messner & Meyer, 2005; Balica & Wright 2010). Flood prone union councils (small administrative units) with respect to total union councils of a given district are used as a proxy indicator. Houses situated on low elevated areas are considered in high exposure category (Villordon 2014, p.106; Kablan et al. 2017). Altitude above sea level is used as proxy for this indicator. This indicator can best be used in local flood vulnerability where the relative height of the houses can be identified. There are, however, some reservations about this indicator. It is said that the flood can cause high damage in a flat area where the water can stay for a long time, and that high speed in a narrower (mountainous) valley can also cause high damage (Kron 2014). In

the context of the study area, the central and southern districts are mainly plain, while the northern regions are mountainous. This will be checked against other indicators for the final list of indicators.

Women are considered in the highly vulnerable category compared to the men because of less mobility, care and income, which make it difficult to deal with and recover easily from disasters (Cutter et al. 2003; Dwyer et al. 2004; Kablan et al. 2017). In regions where maternal mortality rates (Goodman, 2016) or child mortality rates are higher (Balica & Wright 2010), the flood vulnerability is also higher by proposing a socio-economic disadvantaged area. The proportion of children to household members in an economically active age group is one of the limiting factors in satisfying daily household requirements (e.g. food), is a significant indicator (WFP & Colleagues 2009) for flood vulnerability assessment. It is assumed that the larger the area dependency ratio, the more likely the higher the flood vulnerability. In terms of showing a socio-economically poor region, it is also believed that the lack of basic human requirements, such as access to improved drinking water and sanitation, will increase flood vulnerability by increasing the likelihood of epidemics and drinking water scarcity (McCluskey, 2001; See et al. 2017). Literature also demonstrated that the unemployed are more likely to have problems with natural hazards and to recover from them (Dwyer et al. 2004; Cutter et al. 2008; Holand et al. 2011; Kuhlicke et al. 2011). Residential property affects the potential losses and recovery (Cutter et al. 2003; Dwyer et al. 2004; Muller et al. 2011). The greater proportion of Kacha houses in the area (where low-quality materials are used in house construction) indicates low resilience and higher physical vulnerability to flooding (Rafiq & Blaschke 2012; Shah et al. 2013). Agricultural land is used as a proxy for vulnerable occupations. As hypothesized by Cutter et al. (2003), some occupations, such as agriculture, fisheries, etc., are highly susceptible than others. It has been observed that the potential for harm to agricultural land induced by heavy flooding is higher than its productivity, which is more likely to

have an effect on agriculture-related people who use land as a source of food and income (Rafiq & Blaschke, 2012).

Literature has shown that education can improve comprehension, awareness and resilience against flood disaster (Muller et al. 2011; Kuhlicke et al. 2011). While access to the lifeline lowers vulnerability (Jonkman & Kelman, 2005; Jonkman et al. 2009; Rafiq & Blaschke, 2012). The number of hospitals is used as proxy indicator in the current study. The indicator determines the capacity per district of public healthcare facilities. It has a significant impact on the ability of a region to deal with emergency response during disaster events (Rafiq & Blaschke 2012). The higher evacuation routes in terms of asphalt roads (Balica & Wright 2010) imply the less complicated evacuation process (Holand et al. 2011), which can affect the vulnerability. Besides the function as a flood barrier to reduce the velocity of runoff and erosion (Rafiq & Blaschke 2012), vegetation can act as a buffer zone for water decontamination (Zanetti, et al. 2016). Thus, the potential for harm to less forested areas will increase, implying that the community's coping ability will greatly reduce (Ortwin 2006 in Rafiq & Blaschke 2012). The forest area per district is calculated through the land utilization data with respect to overall reported area per district. Income enhances the capacity to cope and recover from a disaster easily (Cutter et al. 2003; Dwyer et al. 2004; Holand et al. 2011). It is mainly assumed that households with higher incomes or resources are less vulnerable than those with lower incomes or resources. Finally, it is also observed that flood management/protection measures in terms of structural interventions can reduce flood vulnerability (Balica & Wright 2010; Qasim et al. 2015). The higher the region's flood control measures, the less likely the vulnerability to flooding. The numbers of completed flood management projects are used as a proxy indicator. Note that indicators are resilience indicators in real sense that values are reversed to make it lack of resilience.

Proxy indicators are used in case where actual indicators are not available as suggested by Baptista (2014, p.1). Before proceeding to the next step, commensurability was confirmed (Table 1). It was simply developed by transforming the datasets into

percentages (if given in different units or not comparable in given form) for the districts concerned (Appendix A1). Descriptive statistics can help to understand data that can also aid in data normalization, weight selection while correlation analysis can help to reduce double counting. Damm (2010, p.136) used the threshold of Pearson $r = 0.65$ to be followed in this study.

Table 1: Flood Vulnerability Indicators

Factors	Abbreviation- Indicators (unit)	Data Source
Exposure	PD- Population density (persons/ Km ²)	Calculated (PBS 2017)
	FPA- Flood prone area (%)	Calculated (PDMA 2017)
	AASL- Altitude Above Sea Level (m)	Climate-data.org
Susceptibility	WMN- Women gender (%)	Calculated (PBS 2017)
	MMR- Maternal mortality rate (per population)	DHIS 2017
	CMR- Child mortality rate (per 1,000 live birth)	DHIS 2017
	DPR- Dependency ratio (%)	WFP & Colleagues 2009
	LAIW- Lack of access to improved drinking water (%)	WFP & Colleagues 2009
	LAIS- Lack of access to improved sanitation (%)	WFP & Colleagues 2009
	UNE- Unemployment (%)	Calculated (KPBOs 2017a)
	KH- Kacha houses (%)	WFP & Colleagues 2009
	AGL- Agricultural land (%)	KPBOs 2017a
Lack of Resilience	LR- Literacy rate (%)	KPBOs 2017a
	NH- Numbers of hospitals (per districts)	KPBOs 2017a

ASR- Length of asphalt roads (km/km ²)	KPBOS 2017b
FC- Forest cover (%)	Calculated (KPBOS 2017a)
MMHI- Mean monthly household income (US\$)	WFP & Colleagues 2009
FMM- Flood management measures (number)	IDKP, 2017

Calculated (): Calculated from the source given in bracket

4.2.4 Data Transformation

The general minimum-maximum method is used for data rescaling (Iyenger & Sudarshan 1982; Hudrliková, 2013; Chakraborty & Joshi 2014; Kissi et al. 2015; Kablan et al. 2017). The indicators that are directly related with vulnerability were transformed through Eq. 1;

$$X_i = \frac{X_a - X_{Min}}{X_{Max} - X_{Min}} \quad (\text{Eq.1})$$

While the indicators that have inverse relationship with vulnerability, were rescaled through Eq.2;

$$X_i = \frac{X_{Max} - X_a}{X_{Max} - X_{Min}} \quad (\text{Eq.2})$$

Where X_i means the normalized value, X_a is the actual value, X_{Max} is the maximum value and X_{Min} is the minimum value for an indicator i (1,2,3...n) across the selected districts.

4.2.5 Weighting Scheme

No weights are allocated to the indicators for the construction of composite indicators in this case to avoid the subjectivity issue in the first instance. Note that

indicators will only have equal weights with respect to sub-indices and sub-indices for the final flood vulnerability index.

4.2.6 Aggregation

The additive arithmetic function in terms of non-weighted averages is used for aggregation of the indicators into its respective sub-indices (factors) using Eq.3 (Booyesen 2002 and Tate 2012 in Talukder et al. 2017);

$$SI = \frac{\sum_{i=1}^n X_i}{n} \quad (\text{Eq.3})$$

Where, SI stands for sub-indices exposure (SIE), susceptibility (SIS) and lack of resilience (SILoR) factors for n numbers of indicators in each factor. While, the overall flood vulnerability composite indicators (FVI) is calculated through Eq.4 (modified from Lee & Choi, 2018);

$$FVI = \frac{1}{3} (SIE + SIS + SLoR) \quad (\text{Eq.4})$$

This is the simplest approach that is frequently used in the scientific community for composite indices, where the normalized indicators are simply averaged through additive function. It is renamed “MMNA” in this study. Here “MM” means that the indicators are normalized through “min-max” method, “N” means that “no” weights are assigned to indicators, and “A” implies that the aggregation is based on “additive” function. This is the base model, where it is assumed that its construction, interpretation, and comprehension are extremely simple. Thus, flood vulnerability index is the function of its three sub-indices as given in Figure 14.

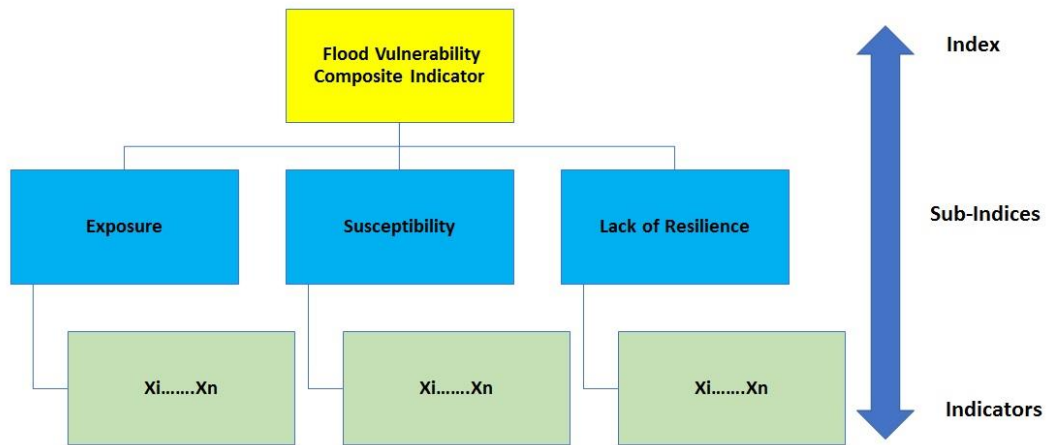


Figure 14: Construction of Flood Vulnerability Index (based on Hammond et al. 1995; OECD 2008; Birkmann et al., 2013; UNECE 2017)

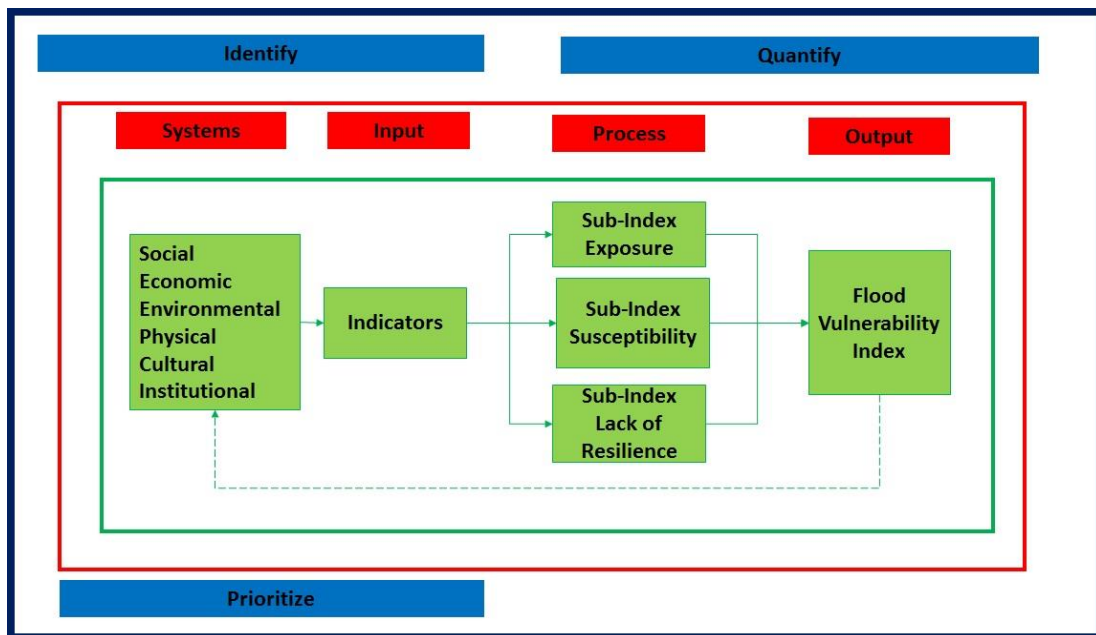


Figure 15: Flood Vulnerability Assessment (based on general vulnerability assessment framework; Birkmann et al., 2013; Lee & Choi 2018)

Figure 14 summaries the flood vulnerability composite indicator that is constructed through hierarchical approach by aggregating the individual normalised indicators to the exposure, susceptibility and lack of resilience sub-indices. While, Figure 15 is the summarized version for the whole process developed through different approaches. The outermost box (blue) laid out the three main phases of general vulnerability assessment framework; the second box (red) put the process into a model (systems, input, process and output) while the most inner box (green) summarized the whole procedure of the outer two boxes.

4.2.7 Robustness Tests

Various types of robustness check can be found in different flood vulnerability studies. For instance, Damm (2010, pp.143-148) set out different tests include methodological soundness (different rescaling, weighting and aggregation), correlation between indicators and flood vulnerability composite indicators, variation in indicators and their effects on overall composite indicators and distribution of probability for some ordinal indicators in a few districts. Similarly, Rezaee (2013, p. 268) used three methods for this purpose, including correlation analysis, PCA and some assumptions (such as omission of certain indices, variation and varying weighting).

In the present study, almost all of these methods overlap as the correlation is performed for indicator selection and the PCA is adapted for weighting purposes. It cannot make sense to correlate individual indicators with the overall flood vulnerability index as the composite indicators are developed through a hierarchical approach rather than a functional relationship where linear strength may indicate the impacts of individual indicators on final results. Similarly, the contribution of indicators in the respective indices (see results) may show how much the indicator contributes to the overall value of the index (i.e. the impacts of excluding certain variables can be readily understood). Therefore, the only issue in this study is not the handling of data for skewness and completely independent indicators; robustness tests are therefore necessary to conduct only in relation to comprehend the impact of different data

rescaling, weighting and aggregation (Nardo et al. 2005 in Talukder et al. 2017) on the overall results. The current study thus adopted a very straightforward and robust approach of “average shift in ranking” (discussed in the next section) that will even be understood by non-statisticians. For this purpose, the flood vulnerability indices are constructed through following ways;

4.2.7.1 Alternative Data Rescaling

The second technique used in the current study is z-score. This type of data rescaling is generally used because it converts all indicators to a common scale with an average of zero and a standard deviation of one that avoids aggregation distortion. However, attention is needed in the case of exceptional behaviour of certain indicators (OECD 2008, p. 28). Furthermore, the data range of the standardized indicators will not remain the same with the new set of positive and negative values (Damm 2010, p.138). In this method, the mean is subtracted from the actual value and divided by the standard deviation of the indicator across the selected districts as implied in Eq.5;

$$X_i = \frac{X_a - \bar{X}}{\sigma} \quad (\text{Eq.5})$$

Where, \bar{X} stand for the mean values and σ for the standard deviation.

4.2.7.2 Alternative Weights

The current study is using a data-driven technique for the weights of indicators. The main advantage of the data-driven approach is to address issues of subjectivity and equal weighting (Damm, 2010, p.144). Principal component analysis or factor analysis is commonly used for that purpose. However, these methods have some issues such as that it is not desirable in the case of small number of indicators and composite based on deductive reasoning (using a conceptual framework) whereby the indicators do not align

to the components of the conceptual framework (Damm, 2010, p.144). In addition, Mishra (2008 in Mazziotta & Pareto, n.d.) argues that these approaches obviously lose significant indicators as they are heavily based on highly correlated indicators while neglecting others. Nevertheless, the current study uses this only for the purpose of weighting rather than for the construction of composite indicators. Varimax rotation with a value greater than 1 approach (Kaiser criterion) is used (Roder, et al. 2017). The weights are calculated using Eq.6 (Nicoletti et al. 2000 in OECD 2008, p. 90; Damm 2010, p.145);

$$W_i = \frac{\text{Square of Factors Loadings}}{\text{Total Variance of the Rotated Square Loadings}} \quad (\text{Eq.6})$$

The second approach used in current study is known as the Iyenger & Sudarshan’s method (1982). Previously, this approach has been used by different authors for different types of vulnerability assessment. In this approach, the weights are assumed to vary inversely as the variance over the regions in the respective indicators of vulnerability (Bhattacharjee & Wang, 2011; Hiremath & Shiyani, 2013; Kissi et al. 2015; Kablan et al. 2017). It is also reported that calculating weights through this approach “would ensure that large variation in any one of the indicators would not unduly dominate the contribution of the rest of the indicators and distort inter-regional comparisons” (Bhattacharjee & Wang, 2011; Hiremath & Shiyani, 2013; Kissi et al. 2015). The weights for each indicator i across the selected districts are calculated through Eq.7;

$$W_i = K / \sqrt{\text{Var } X_i} \quad (\text{Eq.7})$$

Where $\sum_{i=1}^n W_i = 1$ and $0 \leq W_i \leq 1$ and K is the normalized constant that is calculated using Eq.8;

$$K = \left[\sum_{i=1}^n 1 / \sqrt{\text{Var } X_i} \right]^{-1} \quad (\text{Eq.8})$$

4.2.7.3 Alternative Aggregation

The weighted sub-indices are calculated through Eq.9, by putting the weights derived for each indicator using Eq.6 and 7 such as (OECD 2008; Chakraborty & Joshi 2014; Kabalan et al. 2017; Lee & Choi 2018);

$$SI = \sum_{i=1}^n W_i X_i \quad (\text{Eq.9})$$

The weighted sub-indices are aggregated as an overall flood vulnerability index using Eq. 4.

As the additive (linear) aggregation is fully compensated where the low value in one indicator can be re-compensated by other indicators' sufficiently high values, which are sometimes not desirable. Whereas the multiplicative aggregation (geomean) is partially compensated (Hudrliková 2013). However, due to the normalization method, one was added to all indicators as geometric function is strictly applicable in positive data (Water and Waste Digest, 2001). The factor wise (sub-indices) aggregation was done through Eq.10 (Nardo et al. 2005 in Talukder et al. 2017);

$$SI = \prod_{i=1}^n X_i^{\frac{1}{n}} \quad (\text{Eq.10})$$

While the overall flood vulnerability indices are calculated through Eq.11 (modified from Lee & Choi, 2018);

$$FVI = (SIE \times SIS \times SILoR)^{1/3} \quad (\text{Eq.11})$$

Based on above techniques four (4) different procedures are used to construct composite indicators for flood vulnerability assessment;

- Data normalized through Min-Max approach with weights calculated through Iyenger & Sudarshan's method and aggregated through additive function (MMISA)
- Data normalized through Min-Max approach with PCA extracted weights and aggregated through additive function (MMPCA)
- Data rescaled through Z-score approach, with no weights to indicators and aggregated through additive function (ZSNA), and
- Data normalized through Min-Max approach, with no weights to indicators and aggregated through geometric function (MMNG)

All the above process for various types of flood vulnerability indices are summarised in Table 2.

Table 2: Different Methodological approaches for Flood Vulnerability Indices

Model	Data Rescaling	Weighting	Aggregation
MMNA (Base Model)	Min-Max (Eq.1 & 2)	No Weights	Additive Arithmetic (Eq. 3 & 4)
MMISA	Min-Max (Eq.1 & 2)	Iyengar & Sudarshan Weights (Eq. 7 & 8)	Additive Arithmetic (Eq. 9 & 4)
MMPCA	Min-Max (Eq.1 & 2)	PCA Weights (Eq. 6)	Additive Arithmetic (Eq. 9 & 4)
ZSNA	Z- Score (Eq. 5)	No Weights	Additive Arithmetic (Eq. 3 & 4)
MMNG	Min-Max (Eq.1 & 2)	No Weights	Geometric (Eq.10 & 11)

(): Equations used in calculation

The OECD (2008) approach (Eq.12) used by Hudrliková (2013) is adapted in current study where the results stability and reliability is ascertained by the average absolute shift in ranking from median ranking (\bar{R}_s). The lower value near to zero will indicate the more similar ranking to median ranking. It was reported that median ranking is perceived to be the most accurate ranking in comparison to other approaches that are largely influenced by data issues, such as highly correlated indicators, presence of extreme values, etc. (Hudrliková 2013). Spearman correlation is also used for such purposes in earlier studies (see Talukder et al. 2017). The higher correlation coefficient between the MR and other methodological approaches will indicate the most similar and stable ranking.

$$\bar{R}_s = \frac{1}{M} \sum_{Y=1}^M |Y_{Med} - Y_{SM}| \quad (\text{Eq.12})$$

Where \bar{R}_S stands for average shift in ranking, Y_{Med} for median rank and Y_{SM} for the rank derived through different selected methods for a given district Y across the selected districts ($i= 1,2,3\dots M$).

Analysis of sensitivity by including/excluding certain indicators in not performed. Firstly, it is not feasible to draw so many rankings and secondly, the flood vulnerability composite indicators are based on a hierarchical approach (where exposure, susceptibility and lack of resilience sub-indices were developed) that reduces the influence of individual indicators on final flood vulnerability indices.

5 LOCAL SCALE VULNERABILITY ASSESSMENT

5.1 RATIONALE

The most significant job before gathering data through a questionnaire survey is to research sites and to check the response to the survey. As mentioned in the previous chapter, several provincial districts are vulnerable to flooding. This research, however, seeks to explore only the Peshawar valley, the central part of the province, which is prone to riverine seasonal flooding. For this study, Districts Nowshera and Charsadda are selected that were irreparably damaged in previous floods. There is a plethora of studies (Khan & Mohmand 2011; Khan et al. 2013a; Khan et al. 2013b; Qasim, et al. 2015; Qasim, et al. 2016; Farish et al. 2017; Qasim et al. 2017; Khan et al. 2016; Akhter et al. 2017) in this part of the province, which is probably the only most vulnerable part of the province facing the issue of seasonal flooding quite often.. However, only a few studies can be found that assessed flood vulnerability or resilience while using an indicator-based approach.

Qasim, et al. (2016) conducted community-based flood resilience study in this part of the province. Indicators have been selected on the basis of comprehensive literature. A proportion based survey was conducted through random sampling from 280 houses in districts Charsadda, Peshawar, and Nowshera. For the construction of composite indicators, a subjective weighting approach was used. They concluded that community-based resilience across all three districts is very low. Similarly, Qasim et al. (2017) conducted flood vulnerability assessment in Districts of Charsadda, Peshawar and Nowshera and applied almost the same methodology as given in Qaim et al. (2016). Not surprisingly, the results are the same and same is concluded that all the districts have very higher vulnerability. These studies, though, provide a good background in terms of data collection and survey approach as well as providing a hint for the formulation of certain site-specific indicators. However, the use of logically related indicators, allocating subjective weights to indicators and leaving a gap for physical

surroundings needs further investigation. This part of the study will also cover these aspects of flood vulnerability assessment approach.

Some steps in the assessment of local scale flood vulnerability are similar to those in the case of district level flood vulnerability, but some of the steps are context-specific. The detailed approach for local scale flood vulnerability assessment is shown in Figure 16.

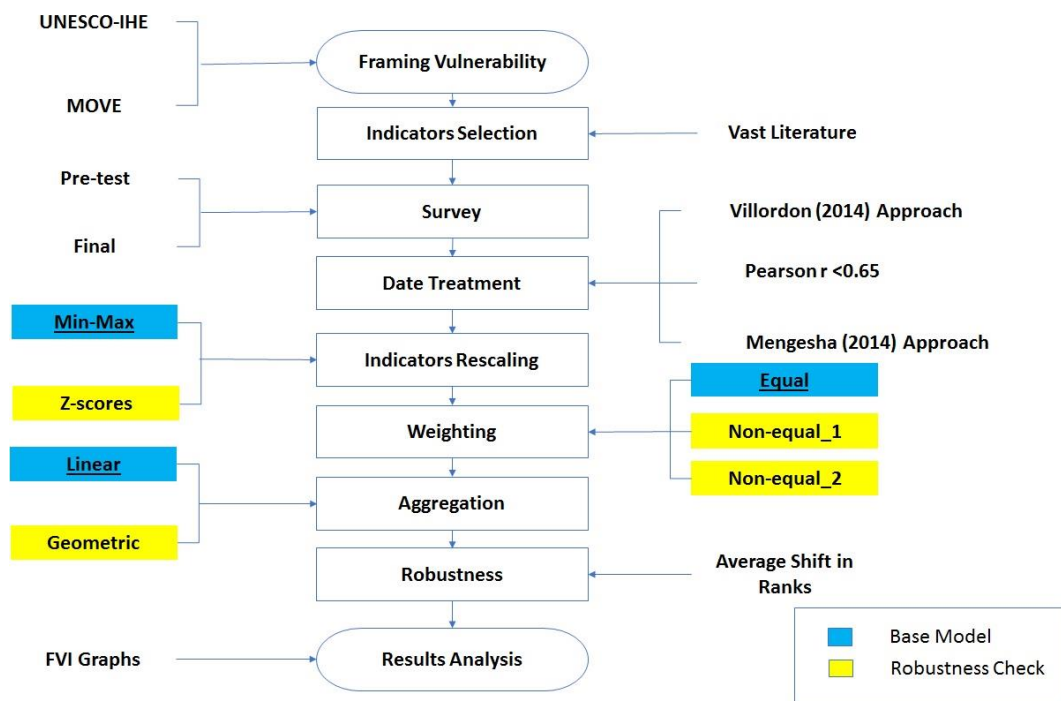


Figure 16: Flowchart for the Local Level Flood Vulnerability Assessment (based on OECD 2008 and modified from Hagenlocher et al. 2016)

5.1.1 Framing Flood Vulnerability

As stated earlier, the current study conceptualizes flood vulnerability using the UNESCO-IHE approach (Balica et al. 2009) and the MOVE vulnerability framework (Birkmann et al. 2013).

5.1.2 Indicators Selection

Indicators are selected on the basis of earlier studies conducted either for social vulnerability to natural hazards or exclusively for flood vulnerability assessment in different parts of the world. However, relevancy to the local context is top priority. The selected indicators are explained in detail in next part (Sec.5.2.3.3) of the current chapter.

5.1.3 Survey

This part of the study included several related steps, such as selection of the study area, checking the suitability of the questionnaire in the local context (pre-testing), data collection approach, limitations, etc. All of these steps are briefly discussed as follows;

5.1.3.1 Selection of Study Area

The two central districts of Peshawar Vale include Charsadda and Nowshera, also known as the catchment of the River Kabul and the River Swat, are the research areas of the current study (Figure 17). The location is quite flat compared to the surrounding areas. The majority of the population relies on agriculture because of its fertile soil (Aslam 2012). One of the main difficulties in research site selection is the use of two overlapping governmental classification for administrative⁴ purpose. The novel concept is the "Union Council" based on electoral boundaries rather than the previous "Patwari Circles" that is based on revenue perspective, which may often overlap different union councils (RisePak, 2006, p.7). Patwari (the term used for revenue officer) Circles are primarily used as a unit for system analysis, since the census is mainly based on Patwari Circles (Amin 2008, p.252). However, the Provincial Disaster Management Authority's reports (PDMA 2011-2017) have used union councils with certain statistics such as the population of those union councils, which can help to

⁴ The country has multi-tier administrative system. The lowest administrative unit is the ' union council ' in the electoral context and the ' patwari circle ' in the revenue context. Its boundaries, however, are different some time. Each of these units is made up of several villages. In order to prevent this complexity, this study exclusively used villages as analytical units.

estimate the sample size. Aside from this complication, the present study used villages solely as analytical systems where some villages may belong to one Union Council or Patwari Circle. Following the Provincial Disaster Management Authority’s reports and other research literatures, it was found that almost all villages that are situated in the river Swat and Kabul’s catchment had been previously damaged by 2010 flood. It was not practically possible, however, to include all these villages. Personal visits were therefore made to contact local people in order to pick the final villages and to check the appropriateness of the questionnaire. Note that urban areas are not part of this study such as the cities of Nowshera and Charsadda, although they are also located on the banks of the rivers, but have a fairly good resource availability and infrastructure. Haji Zai (HZI), Sukkar (SKR), Agra (AGR), Dheri Zardad (DZD), Banda Shaikh Ismail (BSI), Muhib Banda (MB) and Pashtun Garhi (PGI) are selected villages (also referred to as communities in this study). The former four fall into the administrative jurisdiction of Charsadda district, while the later three fall into Nowshera district (Figure 18). However, It should be noted that villages often exist in a geographically scattered form where there is little to no communication between inhabitants or settlements of the same village (RisePak 2006, p.7; Amin 2008, p.253).

5.1.3.2 Sample Size and Data Collection

The sample size was calculated using the Slovin’s approach (in Villordon 2014, p.106). The sampling was based on the report of the Provincial Disaster Management Authority (PDMA 2014), with a total population of 146,137. By keeping the margin of error value 5%, the desired sample size is achieved, that was divided proportionally in selected villages⁵ as given in Table 3;

Table 3: Sample Size for the Selected Settlements

HZI	AGR	SKR	DZD	BSI	MB	PGI
56	56	67	62	51	51	57

⁵ The union council data is applied here, as there is no data exists to be used exclusively for the selected villages.

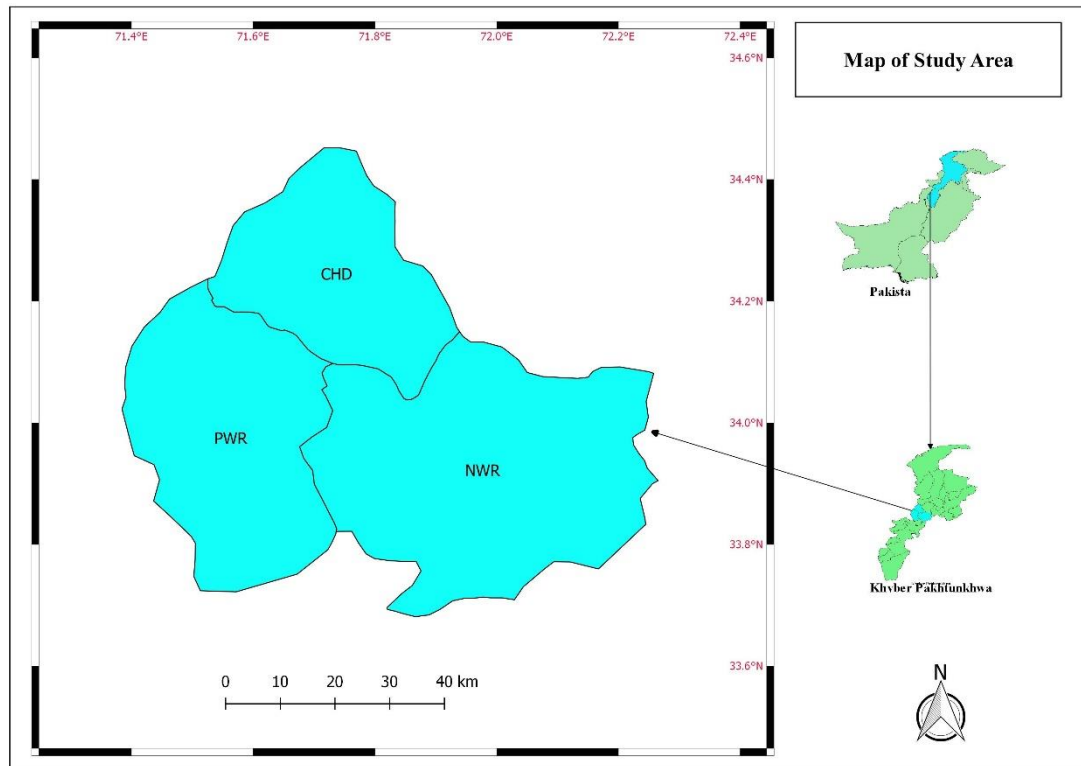


Figure 17: Map of Peshawar Vale

The study pursued the Villordon (2014, p.253) questionnaire as a model to be followed. A pre-test was done to know its soundness and applicability. However, due to some irrelevancies such as flood insurance, drilling, the presence of shelters houses, building codes, etc. that do not exist in the area, the second part of the questionnaire was found to be almost non-applicable in the context of the study area. It was also found that there is no notion of household resilience in the region towards floods. This phenomenon is consistent with earlier studies. Qasim et al. (2015) and Qasim et al. (2016) noted that certain beliefs and poverty also play a role in the lack of resilience among community households in the study area, while UN-HABITAT (2013, p.13) argued that people's lack of awareness is a major factor. However, the response ratio was found satisfactory. So, only the first portion of the mentioned questionnaire (Appendix

B1) was retained for final survey that was modified (to suit) in the local context of study area and explained in the next section.

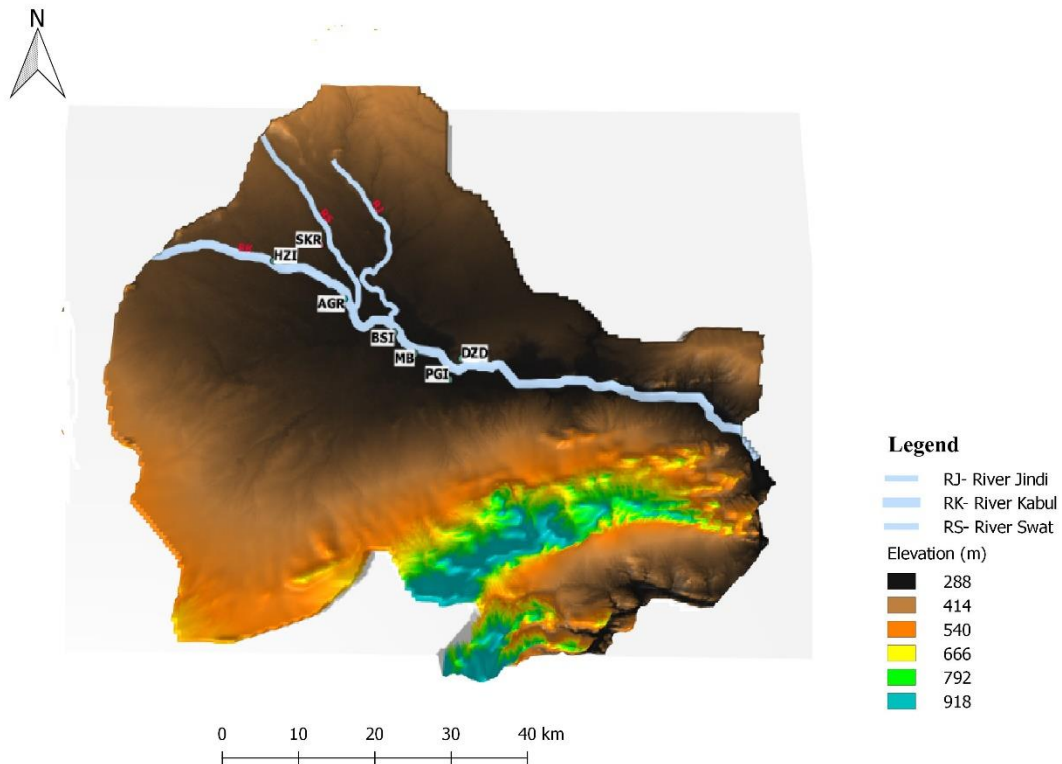


Figure 18: Map of the Research Site

5.1.3.3 Indicators Explanation

The list of selected indicators with respect to vulnerability factors is showed in Table 4. The houses near the river channel are reported to be more probable to be highly exposed (Villordon & Gourbesville, 2014, Qasim et al. 2015). Those houses are considered in flood prone area that are approximately within 2 km (where the water had reached in the last flooding) to river channel as contrast to 1 Km reported by Qasim et al. (2015). As literature indicated that these two districts were the badly hit zones in last

super flooding (ACFID 2011) where almost all the villages were badly damaged by flood water (Saeed & Attaullah, 2014). It is also reported that houses built above ground or street level have less flood exposure (Muller et al. 2011; Villordon & Gourbesville, 2014). The larger a household's members, the more probably it will be highly vulnerable due to high dependency, low accessibility of resources and hurdles in safe evacuation (Cutter et al, 2003; Holand et al. 2011; Muller et al. 2011; Qasim et al. 2015). The threshold was kept 8 people per household to simplify this indicator. Qasim et al. (2015) study indicated that there are 8.66 members in the average household. The house type also shows the degree of vulnerability to flooding. Houses made of low-quality materials have been revealed to be more probable to be highly vulnerable (Cutter et al, 2003; Qasim et al. 2016). Khyber Pakhtunkhwa's Bureau of Statistics (KPBOS 2017) showed that Kacha (made of mud or other low-quality materials), semi-Kacha (developed with kiln bricks and plastered with mud) and Pacca (kiln bricks with cements or high-quality materials) are primarily three kinds of buildings in the region. Except the last, the earlier two are considered Kacha houses that are highly vulnerable to flooding. Certain occupations are more vulnerable to flood than others (Cutter et al. 2003). In the current study, occupation is tied with employment to avoid ambiguous answers. Households that depends solely on agriculture or livestock and related occupation or daily wages (general labor) are considered more vulnerable than households that have permanent jobs (government or private), own business or profession (not related with agriculture, livestock or related). The more income sources a household has, the more likely it will be resilient to flooding as income and wealth boost the ability to recover readily (Cutter et al, 2003; Holand et al. 2011). Different connotations exist in scientific community about "multiple income sources". Some authors using it for diversified sources while other think it in the sense of family members who are working. The current study used it in the later sense. Similar assumption is applied to the household's average monthly income. The average monthly household income limit is greater than 20,000 in the current study. Studies have also shown that open waste disposal has caused high flood vulnerability by blocking drains and raising environmental pollution that can induce and

spread diseases (Pelling, 1997; Villordon & Gourbesville, 2014). Likewise, living in or close to degraded land increases a household's vulnerability to flooding (Villordon & Gourbesville, 2014) as it will not only affect the built environment but also indicated the disadvantaged conditions for residents who relying on agriculture or natural resources. Studies have also shown that communication penetration rate can influence flood vulnerability (Balica & Wright 2010). The current study includes community households who have access to advanced communication sources (TV / Radio, mobile phone, etc.) in a resilient category compared to those who rely on loudspeaker, siren or other traditional approach for flood warning and awareness. Since it may help to save lives, but it is difficult to manage property and livestock. The presence of asphalt or paved routes (Balica & Wright 2010) can influence a household vulnerability to safely evacuate. The increased level of literacy increases the resilience to flooding in two respects. In the first place, it improves the socio-economic status and, in the second place, it improves the capacity to understand and acquire timely awareness (Cutter et al. 2003; Fekete, 2010; Muller, et al. 2011; Qasim et al. 2015). In a previous study, Qasim et al. (2015) used ten years of formal education to be regarded as literate. Similar approach was also adopted by the present study. The presence of flood protection measures (retention walls, gabion walls, etc.) in the vicinity (Qasim et al. 2016), inability of access to healthcare facilities (Holand et al. 2011; Hagenlocher et al. 2013) and participation in any flood awareness or related program (Villordon & Gourbesville, 2014; Qasim et al. 2016) are regarded as resilience to flood vulnerability. It was found that life-style is mainly based on joint -family where the dependent concept is not really applicable, as almost each household has children or aged persons. Additionally, females are (predominantly) dependent on their family men (father, parents, siblings or husbands). These results are consistent with Qasim et al. (2015) and Ahmad & Khan (2017). Variability in shifting to a safe place, lack of drinking water and toilet facilities was noticed to be negligible. The social-environment of the questionnaire included cooperating with each other in hard time, social connection with neighbors and relatives etc. These are cultural tenets in the context of study area, where no variation has been

observed in responses. These issues can be helpful in scaled-based index that is not applicable for the current approach. So, they are not included in the preliminary list of indicators. Hazard related issues (e.g. flood frequency, depth of water, etc.) are also not included as the framework used in the current study is independent of hazards.

Table 4: Indicators for Local Level Flood Vulnerability Assessment

Abbreviation	Indicators	Vulnerability Factors
HFPA	Houses in flood prone area	Exposure
HNESL	Houses not elevated from street or ground level	
HHS	Households size	
KH	Households living in Kacha houses	Susceptibility
VO	Households relying on vulnerable occupation	
SOI	Households with one source of income	
MMHI	Households with less mean monthly income	
OWD	Households practicing open waste disposal	
LINDL	Households living in or near degraded land	
WCS	Households without advanced communication sources	Lack of Resilience
LASR	Houses that lack asphalt/paved routes	
LEH	Households with less educated heads	
LFMM	Households in areas that lack flood management/protection measures	
LAMF	Households that lack ability to medical facilities	
LPFT	Households that lack to participate in flood management training	

5.1.3.4 Data Collection Approach

Qasim et al. (2015) methodology for field data collection has been adopted as best suited in the area of study. The author personally administered and collected a small portion of the sampling between Sep, 2017 and Oct, 2017, while a major part of the data was collected through hired enumerators. Like Qasim et al. (2015), the current study also considered only male respondents to be target audiences. There are cultural constraints where women cannot take part in such studies. Before conducting the field study, all ethical concerns (social and religious) are taken into consideration. Respondents were told that this survey is being performed solely for educational purposes and the completion of the questionnaire is entirely voluntary. Household's head was the main person to be interviewed, where another household elder was interviewed in his absence. The data was collected by random sampling and the questionnaires were filled in person. The average time required to complete a questionnaire is roughly 25-30 minutes.

5.1.3.5 Limitations of the Study

The study was planned to involve government or local government representatives in the assessment of community flood vulnerability. However, it has been found that most of them have little or no influence on policy or strategy development at the root level. UN-HABITAT (2013, p.3) stated that local government has no role to play or does not support any disaster reduction as the top-down approach is adopted in the area. It was therefore not included, as it will not make any significant contribution.

5.1.4 Data Treatment

In previous community-based flood vulnerability or resilience assessment studies (e.g. Villordon 2014; Villordon & Gourbesville 2014, Qasim et al. 2017), a relatively easy method (primarily Balica & Wright 2010) is adopted using a general vulnerability equation. For instance, if a village has 50 per cent exposure, 100 per cent susceptibility and 50 per cent resilience, then that village's flood vulnerability will be 100 per cent regarding the general vulnerability equation (i.e. $(\text{exposure} \times \text{susceptibility}) / \text{resilience}$).

This approach is simple and easy to use. There are, however, some issues with this approach. First, most indicators are definitely redundant at local level, as reported by Birkmann (2007). Second, such an approach hardly facilitates the development of flood vulnerability indices using different weighting, rescaling and aggregation approaches. As these issues can have a significant impact on the results of the flood vulnerability. Therefore, the current study uses the Mengesha's methodology (2014) to address this issue. This means that the response for each indicator in each selected village has been recorded in percentages, as in the Villordon study (2014). Values of indicators (percentage of responses) were then arranged across selected villages. Pearson correlation analysis was conducted to identify highly correlated indicators. And the final list of indicators was rescaled as performed by Mengesha (2014). However, the current study used different approaches for rescaling.

5.1.5 Indices Construction

The same approach is used for the local level flood vulnerability assessment as used for the district level flood vulnerability assessment. However, the data were rescaled using a single formula (Eq.1) in case of "min-max" rescaling approach, as the responses were recorded in a "lack of resilience" format that does not entail reversing their values as in the case of district level flood vulnerability.

5.2 SUMMARY

In this part of the dissertation, a detailed summary of the community-based flood vulnerability assessment is presented in the north-western province of Khyber Pakhtunkhwa, Pakistan. Two central districts that were severely damaged in the last flood were finally selected on the basis of extensive literature from earlier PDMA reports, as well as a number of published and unpublished scientific studies. These studies addressed aspects related to floods such as climate change, health effects, gender studies, water quality, hazard zoning, etc. However, only a few were found appropriate for the quantitative assessment of flood vulnerability in the selected area relevant to the

present study. These studies, however, presented the results of the flood vulnerability in a generalized form (at district level) instead of identifying the exact hotspots that need further investigation. As far as methodological issues are concerned, these studies used a set of indicators without checking their linear relationship, used subjective weights for indicators and did not perform robustness tests that could indicate the stability of the flood vulnerability index and to consider other alternatives approaches. This study attempted to fill these gaps by conducting a detailed flood vulnerability assessment to highlight the most vulnerable hotspots in the area, along with robustness tests, to determine whether or not the findings are stable in relation to other methodological assumptions.

5.3 DATA ANALYSIS TOOLS AND INTERPRETATION

In the current study, different tools are used. QGIS version 2.18 (QGIS Development Team 2018) is used to create maps. The DIVA portal (diva-gis.org) and the Japan Aerospace Exploration Agency portal (Japan Aerospace Exploration Agency 1997) are used for spatial data. For statistical analysis, JASP version 9.2 (JASP Team 2018), Jamovi project (2019) and PAST (Hammer et al. 2001) are used. The correlation “ellipse” can be regard for strong linear relationship with narrower in size and straight in (slope) position. Column graphs are developed that rank districts and communities from low (left) vulnerable to high (right). The OECD (2008), Heltberg & Bonch-Osmolovskiy (2010) and Hagenlocher et al. (2016) approaches have been used to analyze the contribution of indicators. Stacked charts are generally used for index disaggregation; however, they are a bit complicated for a large number of comparative units as each column can serve as an independent chart in stacked graphs where confusion arises, as some indicators have shown quite low value across comparative units (districts or communities) but greater contribution in each column. So, the current study uses colored matrix instead of stacked charts. These colored plots can give the final user an "instant idea" that is the relative proportions of the respective indicators in the respective sub-indices and sub-indices of the final flood vulnerability index. The indicators or sub-

indices are plotted on the X-axis while the districts or communities are plotted on the Y-axis that can be read from highly (bottom) vulnerable to low (top).

6 RESULTS

6.1 DISTRICT LEVEL FLOOD VULNERABILITY ASSESSMENT

The data were processed using the Pearson correlation matrix to identify highly correlated indicators (Figure 19). It was noticed that some indicators were highly correlated with others that were based entirely on general understanding. DPR, WMN, LAIW and CMR were found to be highly correlated. Intuitively, all these are linked to one another, so the DPR is retained, while the remaining three are discarded as a DPR in some sense more attributed to all these indicators. UNE was found to be highly correlated with KH, as individuals with constant sources of revenue are usually assumed to live in decent houses most probably. It was thus excluded from the final list of indicators. There is also a strong correlation between NH and PD, which means that health facilities are provided on the basis of population size. It was therefore discarded from the final list of indicators. AASL was found to be highly correlated with a number of indicators such as LAIW, UNE, FC and FMM. If the social relationship is ignored such that unemployment in mountainous areas is higher than in plain areas, it cannot be ignored that forests are primarily found in mountainous districts of the province. So, it was discarded from final list of indicators. It will also generate confusion if plain areas are deemed highly vulnerable compared to mountainous areas or vice versa because flood damage depends on the type of flood hazard. For final flood vulnerability assessment, twelve indicators are retained with clear policy implications (Table 5). Although data is skewed, no further data is treated before normalization as it will change the real data structure, generate hurdles in interpretation and can suppress the presence of extreme values.

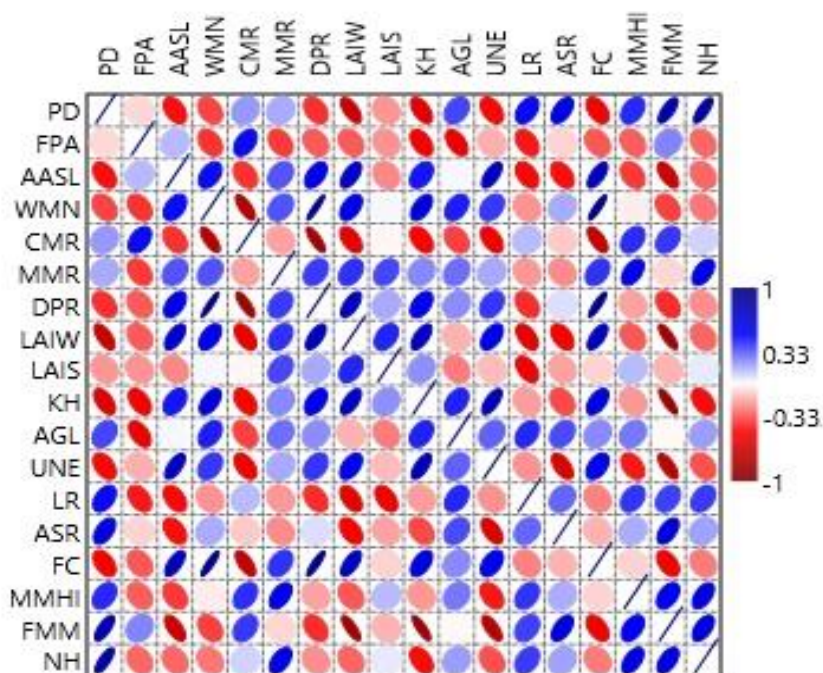


Figure 19: Correlation Matrix among Indicators for District Level Flood Vulnerability Assessment

Table 5: Descriptive Statistics for District Level Flood Vulnerability Assessment

Indicators	N	Mean	SD	Minimum	Maximum
PD	9.00	913.00	1048.00	30.10	3396.00
FPA	9.00	39.20	21.50	17.90	69.20
DPR	9.00	104.00	10.10	90.80	121.00
MMR	9.00	190.00	171.00	30.00	557.00
LAIS	9.00	22.50	14.90	2.25	50.90
KH	9.00	71.30	14.50	51.60	91.60
AGL	9.00	66.60	19.90	42.40	92.20
LR	9.00	44.40	8.79	30.00	56.00
ASR	9.00	0.26	0.12	0.10	0.47
FC	9.00	25.20	25.10	0.00	64.30
MMIH	9.00	1.39	0.28	1.00	1.75
FMM	9.00	3.78	2.68	0.00	8.00

N- Number of districts, SD- Standard deviation

6.1.1 Flood Vulnerability Index

The flood vulnerability index values as a comparative measure of flood vulnerability across the selected districts of Khyber Pakhtunkhwa are shown in Figure 20. It can be seen that the district of Shangla is ranked first, followed by Charsadda, Dir Upper, Swat, D. I. Khan, Peshawar, Chitral, Nowshera and Dir Lower.

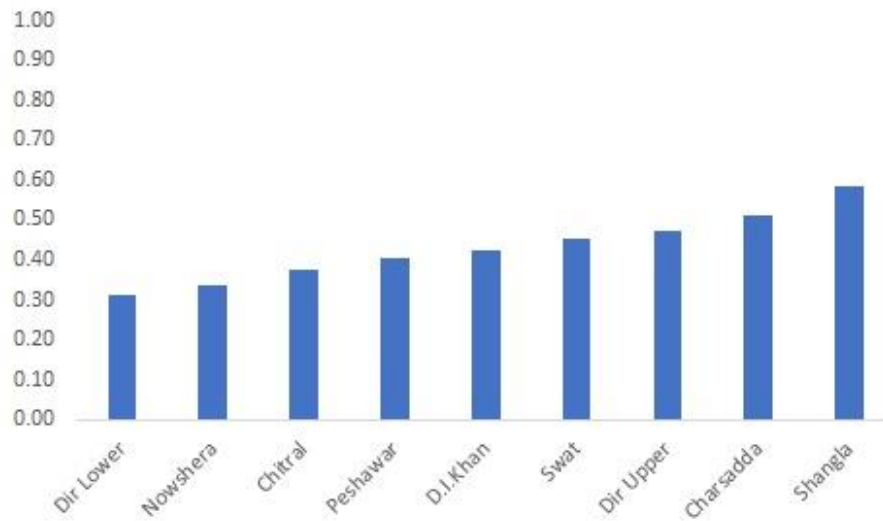


Figure 20: Flood Vulnerability Index for the Selected Districts of Khyber Pakhtunkhwa

The flood vulnerability index is the aggregate of its three sub-indices as shown in Figure 21. It is shown that Dir Upper, D.I. Khan, Chitral and Dir Lower seemed to have comparatively small flood exposures relative to Shangla, Charsadda, Swat, Peshawar and Nowshera. Whereas, the sub-index susceptibility has showed a relatively high contribution in districts Dir Upper, Chitral, Dir Lower and Charsadda. While the Shangla, D. I. Khan, Charsadda, Chitral and Swat districts showed a relatively high lack of flood resilience.

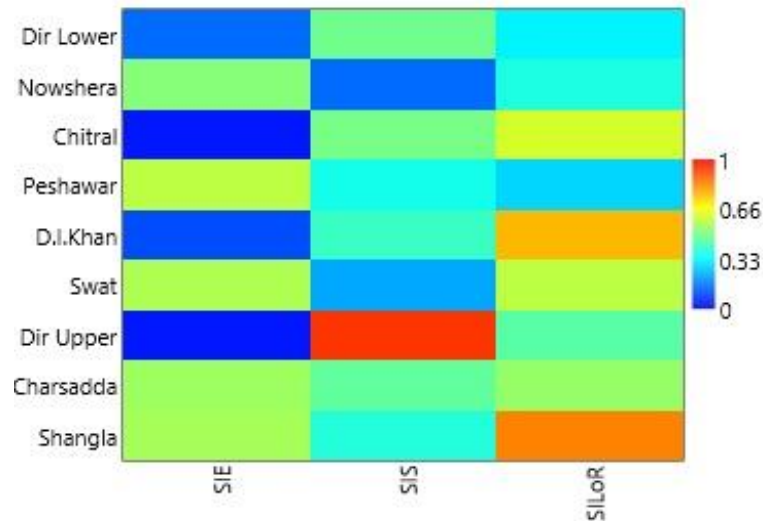


Figure 21: Contribution of Sub-indices in Flood Vulnerability Index for District Level Flood Vulnerability Assessment

6.1.2 Sub-index Exposure

Figure 22 illustrates the comparative measure of flood exposure through the values of the sub-index exposure across the selected districts. It can be seen that five out of nine districts showed exceptionally higher flood exposure. District Peshawar stood on ranked first followed by Swat, Shangla, Charsadda, Nowshera, Dir Lower, D. I. Khan, Dir Upper and Chitral.

Sub-index exposure has two main contributors, PD and PFA, as shown in Figure 23. It can be seen that the Peshawar district has a relatively low FPA but an infinitely higher PD. Swat and Shangla, on the other hand, have a comparatively low PD but a significantly higher FPA. Comparably, FPA had a high contribution in the district of Nowshera, while Charsadda demonstrated a relatively uniform contribution of both indicators to its exposure to floods. The contribution of both indicators in Dir Lower, D. I. Khan, Dir Upper and Chitral was found to be relatively low.

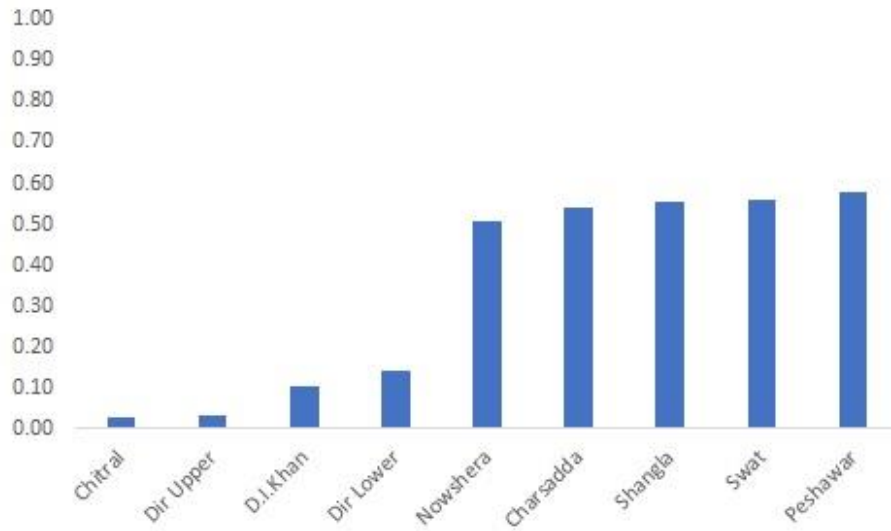


Figure 22: Sub-index Exposure for the Selected Districts of Khyber Pakhtunkhwa

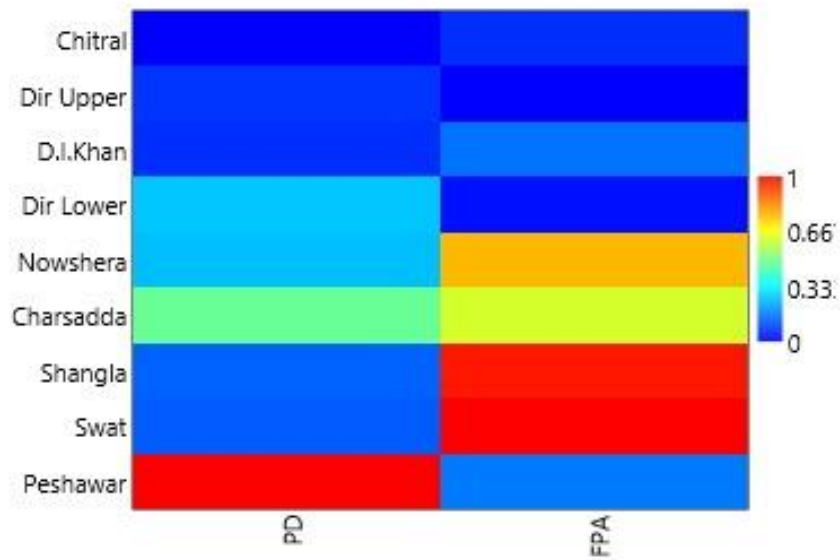


Figure 23: Contribution of Indicators in the Sub-index Exposure for District Level Flood Vulnerability Assessment

6.1.3 Sub-index Susceptibility

Sub-index susceptibility values as a relative measure of flood susceptibility across selected districts of Khyber Pakhtunkhwa is shown in Figure 24. Dir Upper showed exceptionally high levels of susceptibility to flooding compared to the other selected districts. Sub-index susceptibility values showed a very nominal differentiation for the districts of Chitral, Dir Lower and Charsadda. Nowshera was realized to be low in its flood susceptibility factor.

Sub-index susceptibility has five key indicators namely DPR, MMR, LAIS, KH and AGL, as shown in Figure 25. Almost all indicators make a significant contribution in the case of Dir Upper. While in Chitral, KH and AGL have shown a high contribution in its susceptibility to flood as compared to the rest of the indicators. In the case of Dir Lower, DPR, KH and AGL are contributing more to its susceptibility to flooding. In the case of the Charsadda district, AGL and KH were identified as the major contributors to the flood susceptibility. LAIS has been identified as the major contributor to D. I. Khan's susceptibility to flooding, followed by KH. While, DPR and KH in district Shangla, MMR and AGL in district Peshawar and DPR in Swat are found the fairly high contributors relative to other indicators in these districts. In the case of Nowshera, LAIS was found to be slightly higher compared to other indicators.

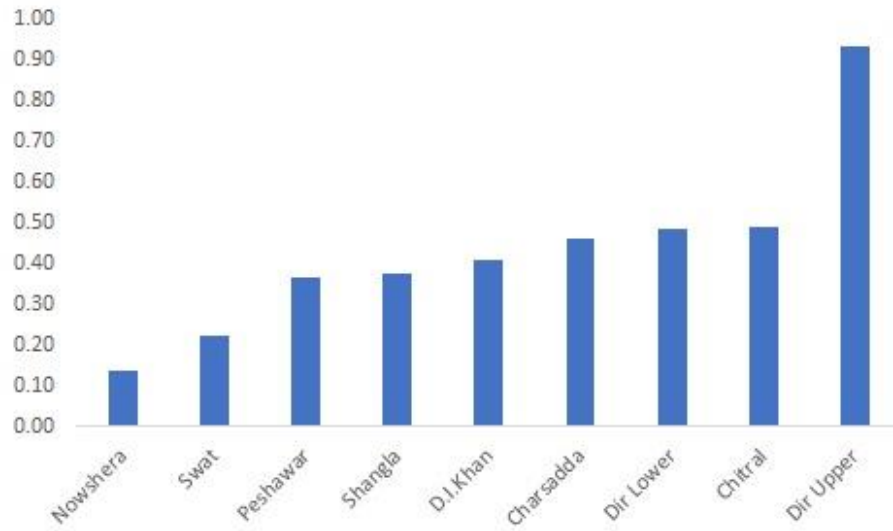


Figure 24: Sub-index Susceptibility for the Selected Districts of Khyber Pakhtunkhwa

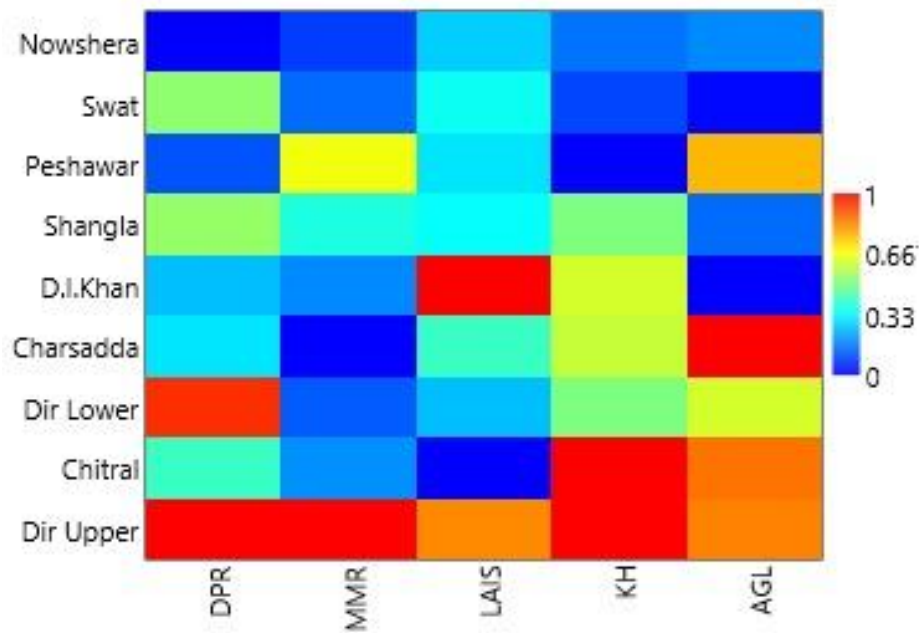


Figure 25: Contribution of Indicators in the Sub-index Susceptibility for District Level Flood Vulnerability Assessment

6.1.4 Sub-index Lack of Resilience

Figure 26 shows the sub-index lack of resilience as a comparative measure of the lack of resilience to floods across selected districts. District of Shangla showed a high lack of resilience to the floods, followed by D.I. Khan, Chitral, Swat, Charsadda, Dir Upper, Nowshera, Dir Lower and Peshawar.

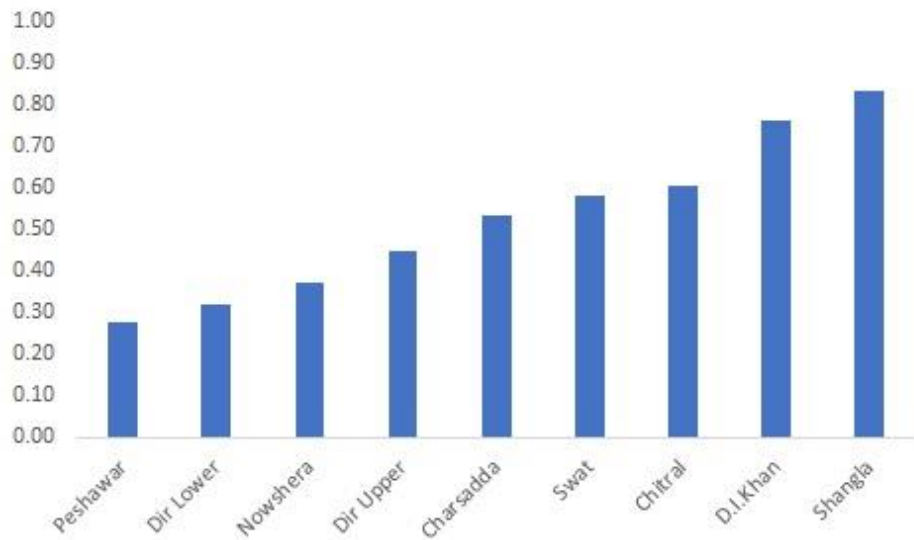


Figure 26: Sub-index Lack of Resilience for the Selected Districts of Khyber Pakhtunkhwa

The key contributors to the sub-index lack of resilience in the selected districts can be seen in Figure 27. Almost all indicators have been observed to make a significant contribution to the high lack of resilience in district Shangla. More or less identical conditions have been observed in the case of D. I. Khan. In the case of Chitral, only LR has been observed fairly small. Likewise, Swat also shows a relatively high contribution of all indicators. FC was recognized as the major contributor to the province's central and southern districts. These results suggest that the provincial situation is even worse in terms of lack of resilience, with the exception of some districts.

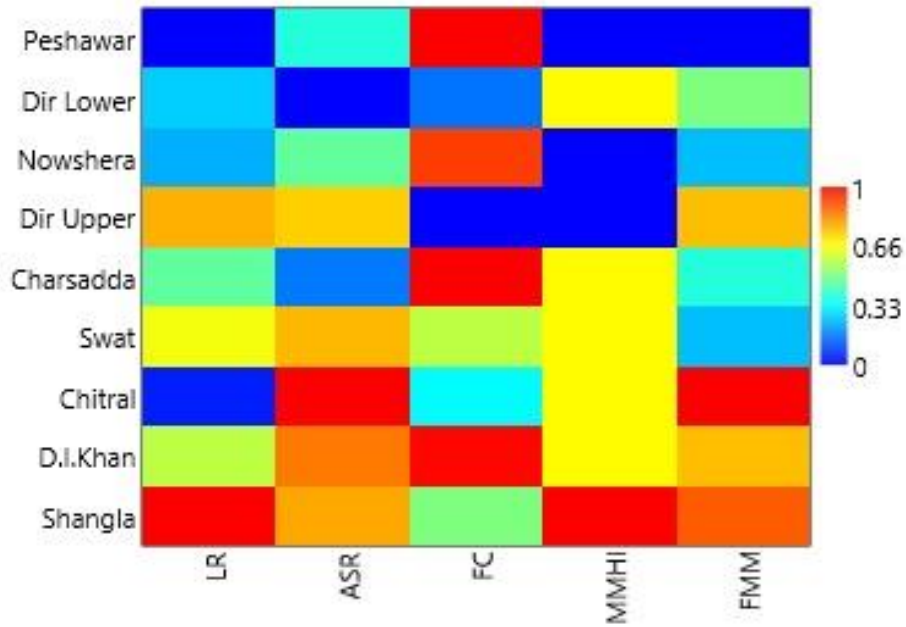


Figure 27: Contribution of Indicators in the Sub-index Lack of Resilience for District Level Flood Vulnerability Assessment

6.1.5 Robustness Check

The robustness tests were done by comparing the ranks that are derived through different methods with median ranks using average shift in rank (\bar{R}_s) approach (Table 6). No change in ranking is observed with respect to data rescaling. With respect to aggregation, very nominal shift in rank (0.22) is observed. Interestingly, empirical weights that are derived through PCA as well as IS methods showed similar values of \bar{R}_s (1.56).

Table 6: Shift in Ranks

MMEA	MMISA	MMPCA	ZSEA	MMEG
0.00	1.56	1.56	0.00	0.22

The weights for each empirical method can be seen in appendix A2 and A3, respectively. These findings are also demonstrated through the correlation coefficients that ranged from 0.80 to 1.00 between median ranking and the other methodological approaches (Table 7).

Table 7: Spearman Correlation between Median Ranking and other Methods

	MMNA	MMISA	MMPCA	ZSNA	MMNG	MR
MMNA	—					
MMISA	0.80	—				
MMPCA	0.80	1.00 ***	—			
ZSNA	1.00 ***	0.00	0.80	—		
MMNG	0.98 ***	0.71	0.71	0.98 ***	—	
MR	1.00 ***	0.80	0.80	1.00 ***	0.98 ***	—

Note. *** $p < .001$

However, a slightly higher \bar{R}_s and lower Spearman of weighted approaches means that the flood vulnerability indices derived through these methods might differ than base model. To know this, all the derived ranking through different approaches (representing by line) were plotted against median ranking (representing by triangle mark) in ascending order (Figure 28). The results indicate that a maximum of two degrees shift in ranking can be seen in Charsadda, Dir Upper, Swat, Chitral and D.I. Khan due to differential weights. While not using these weighted methods, only two districts (Dir Upper and Swat) can shift their ranks up to one degree due to geometric aggregation as shown in Figure 29. These results imply that the weights have substantially influence on the overall flood vulnerability indices in the context of current study as compared to data rescaling and aggregation through multiplicative method. The perfect matching of MMNA with ZSNA ($\bar{R}_s = 0.00$, Spearman rho = 1.00) and MMNG ($\bar{R}_s = 0.22$, Spearman rho = 0.98) indicates that the flood vulnerability indices derived

through these approaches will not largely affect the overall ranking of the selected districts.

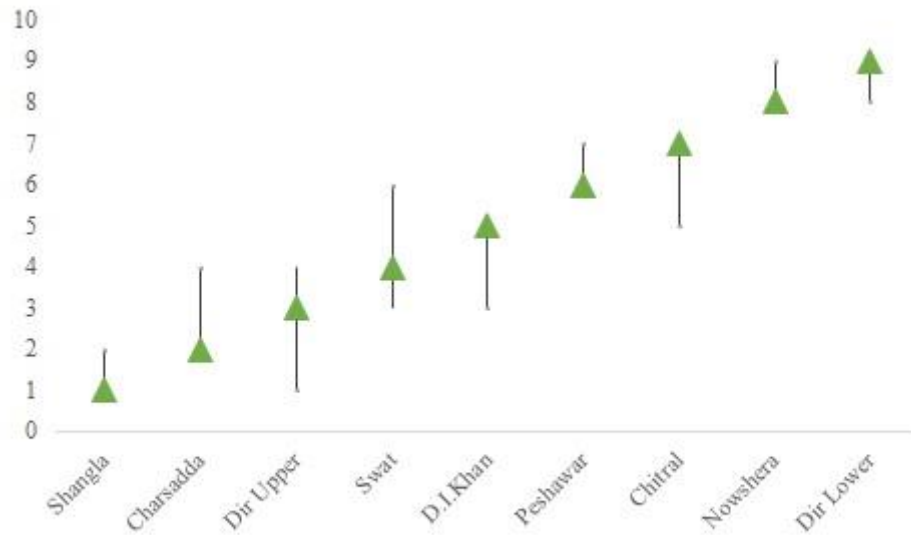


Figure 28: Range and Median Rankings included MMISA and MMPCA

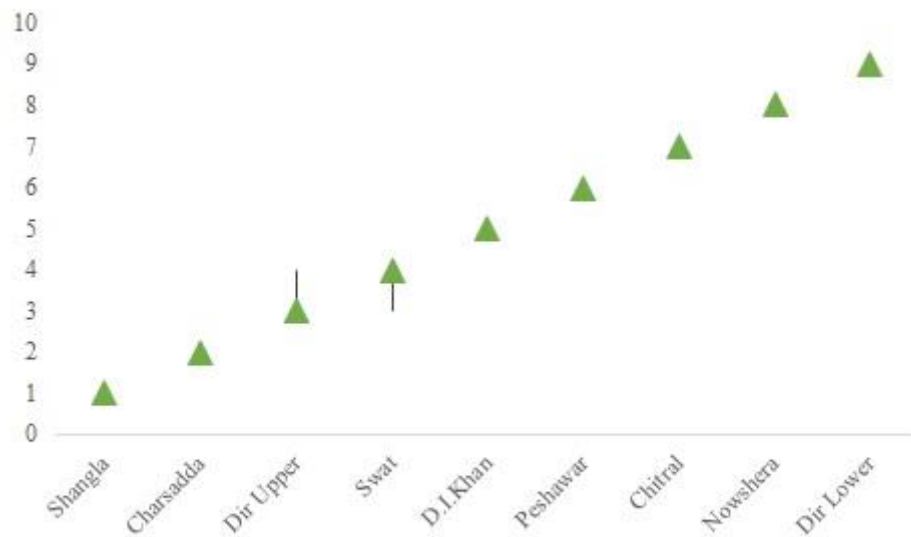


Figure 29: Range and Median Rankings excluded MMISA and MMPCA

6.2 LOCAL LEVEL FLOOD VULNERABILITY

The data was analyzed using the Pearson correlation matrix to understand highly correlated indicators, their linear relationship and direction (Figure 30). HNESL was found to be highly correlated with LASR, which has a clear logic as both of these indicators belong to the built environment. Houses that are not situated on a paved route / street usually have difficulty with a reference in defining a foundation. In this case, only LASR is retained while the HNESL is discarded. HHS has been found to be highly correlated with OWD, which makes sense that the higher the number of household members in an area, the higher the production and practice of open waste disposal. So, only HHS is retained. KH, SOI, MMHI, WCS, LEH, and LPFT were found to be highly correlated; suggesting predominantly socio-economically disadvantaged circumstances and therefore only LEH is retained. As the lack of household' head education may be a reason to influence all of these related features. Although LAMF was found to be highly correlated with KH and SOI but there was no strong correlation between MMHI, LEH and VO and most of them are already discarded from the final list of indicators, in order to avoid the loss of this important information, LAMF is included in the final list of indicators. Finally, eight indicators are retained for the development of the flood vulnerability index (Table 8). It can be seen that the data are fairly normal compared to the district level flood vulnerability assessment.

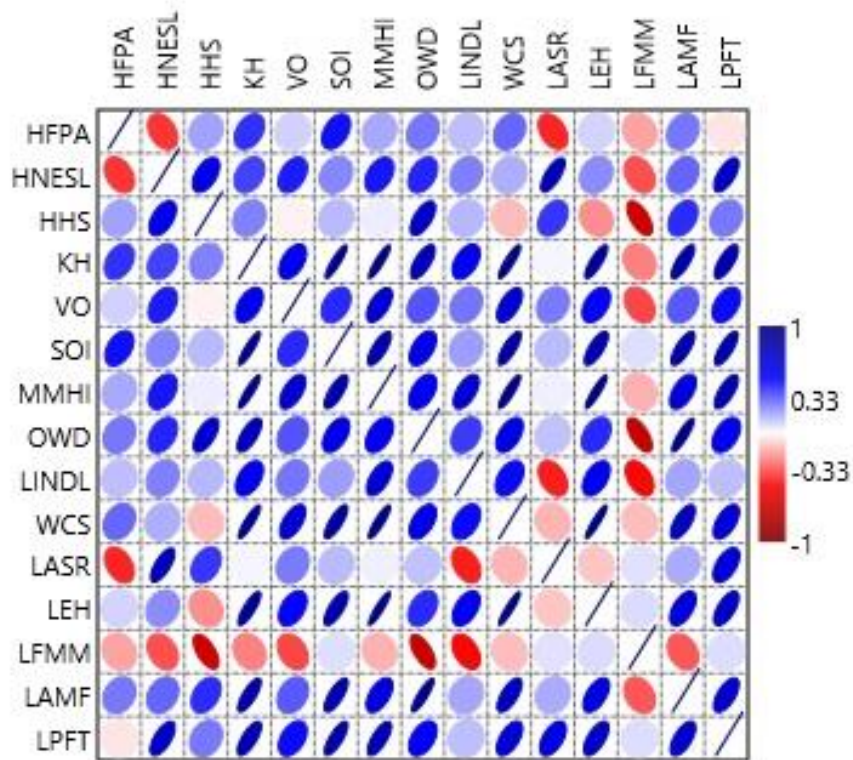


Figure 30: Correlation Matrix among Indicators for Local Level Flood Vulnerability Assessment

Table 8: Descriptive Statistics for Local Level Flood Vulnerability Assessment

	N	Mean	SD	Minimum	Maximum
HFPA	7.00	80.60	16.90	54.40	100.00
HHS	7.00	67.40	10.50	55.40	84.30
VO	7.00	68.00	14.80	50.00	89.30
LINDL	7.00	73.20	11.30	59.00	87.50
LASR	7.00	22.60	15.40	3.60	39.90
LEH	7.00	61.20	12.10	45.10	76.80
LFMM	7.00	27.70	18.20	5.90	53.60
LAMF	7.00	32.20	15.20	11.50	50.70

6.2.1 Flood Vulnerability index

The values of the flood vulnerability index as a relative measure of flood vulnerability of the selected villages are shown in Figure 31. It can be seen that AGR is the highly vulnerable village to floods followed by DZD, BSI, SKR, HZI, MB and PGI. These results imply that communities' households situated in district Charsadda have comparatively higher flood vulnerability except BSI of district Nowshera.

The flood vulnerability index is the aggregate of three sub-indices, including exposure, susceptibility and lack of resilience factors, as shown in Figure 32. It is shown that PGI and HZI seemed to have comparatively small flood exposure compared to other selected communities. AGR and DZD showed comparatively high flood susceptibility. A relatively high lack of resilience was observed for SKR, HZI and DZD.

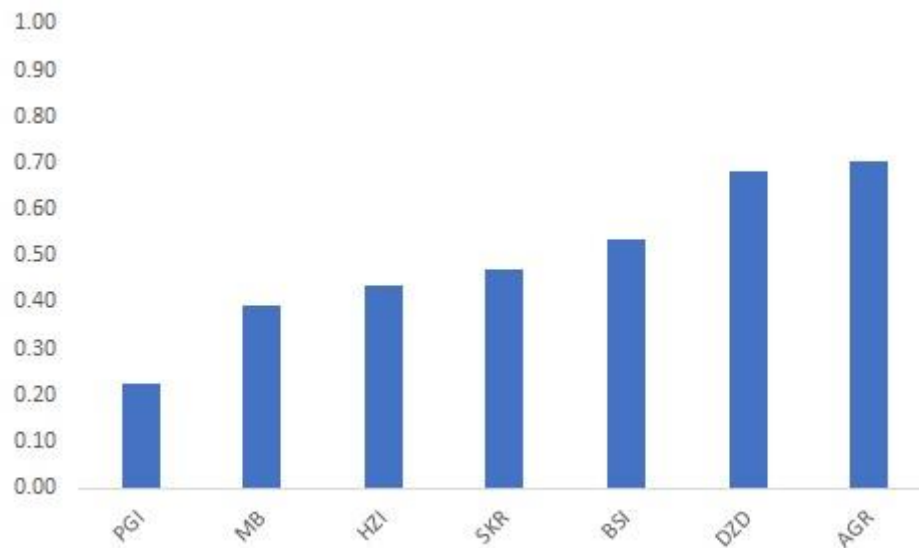


Figure 31: Flood Vulnerability Index for the Selected Villages of Peshawar Vale

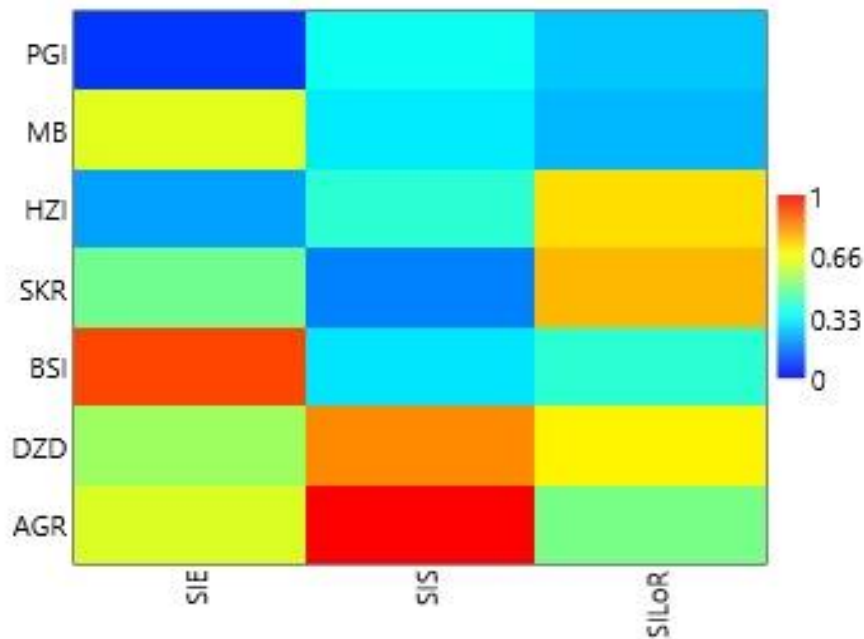


Figure 32: Contribution of Sub-indices in the Flood Vulnerability Index for Local Level Flood Vulnerability Assessment

6.2.2 Sub-index Exposure

Figure 33 illustrates the comparative measure of flood exposure through the sub-index exposure values for the selected villages in Peshawar vale. It can be seen that BSI has comparatively high flood exposure followed by MB, AGR, DZD, SKR, HZI and PGI. These results imply that flood exposure is quite higher at the outlet of River Swat in River Kabul where the three communities of BSI, MB and AGR are located. Whereas, the communities located in upstream and downstream in the current study showed comparatively less flood exposure.

Sub-index exposure has two main contributors, HFPA and HHS, as shown in Figure 34. It can be seen that PGI has a relatively low HFPA and HHS. On the other hand, BSI has a comparatively high HHS and HFPA. It was also observed HFPA has a high contribution in MB, AGR and SKR. Whereas, HHS ' contribution to flood exposure for the DZD has been found to be relatively high.

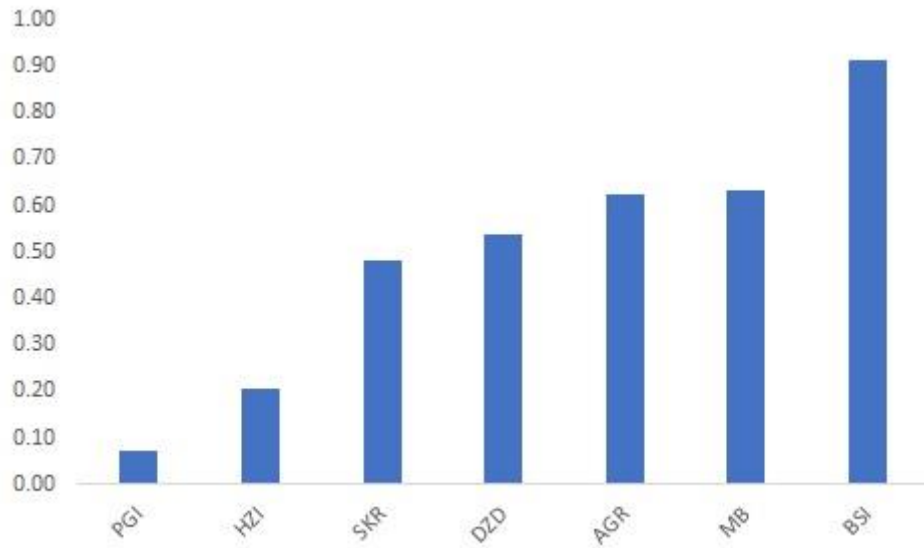


Figure 33: Sub-index Exposure for the Selected Villages of Peshawar Vale

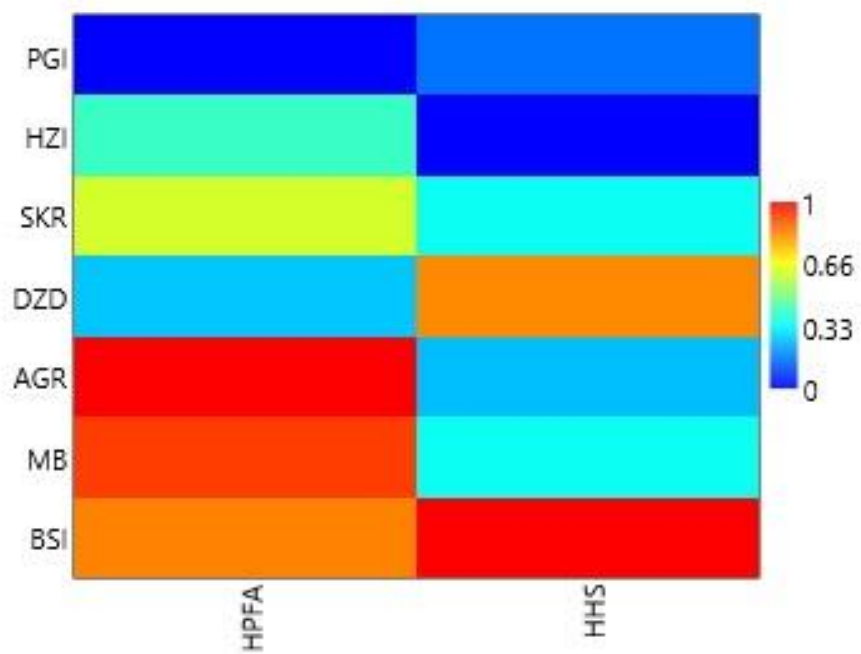


Figure 34: Contribution of Indicators in the Sub-index Exposure for Local Level Flood Vulnerability Assessment

6.2.3 Sub-index Susceptibility

The values of sub-index susceptibility as a relative measure of flood susceptibility across the selected villages of Peshawar vale is shown in Figure 35. The results indicate that AGR is the highly susceptible village to flood followed by DZD, HZI, PGI, MB, BSI and SKR.

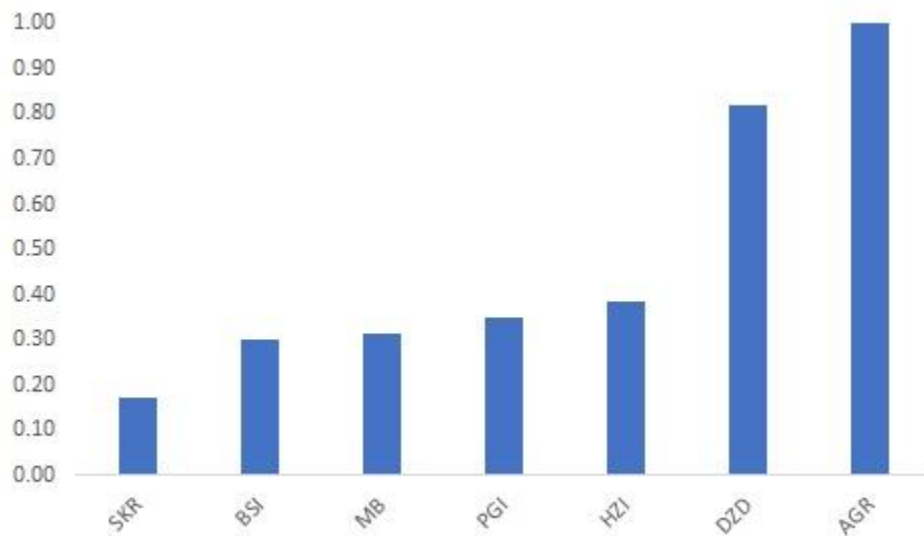


Figure 35: Sub-index Susceptibility for the Selected Villages of Peshawar Vale

Sub-index susceptibility has two main indicators, VO and LINDL, as shown in Figure 36. Both indicators make a significant highly contribution in the case of AGR and DZD. While in HZI, VO has shown a high contribution compared to the very low contribution made by LINDL. In the case of BSI, VO is contributing more for its susceptibility to flooding. LINDL was found a high contributor also in the case of MB.

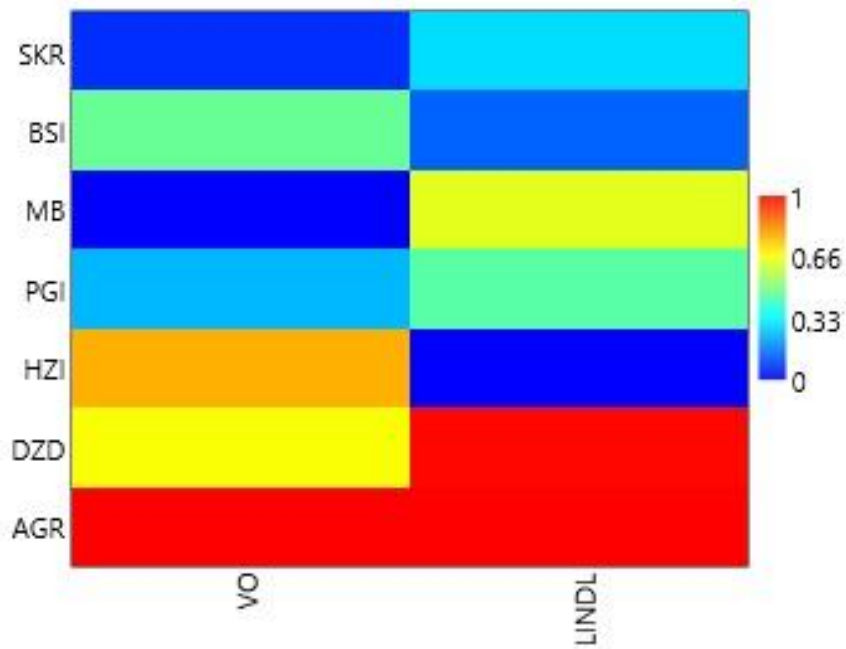


Figure 36: Contribution of Indicators in the Sub-index Susceptibility for Local Level Flood Vulnerability Assessment

6.2.4 Sub-index Lack of Resilience

The values of sub-index lack of resilience as a relative measure of lack of resilience factor to flood across the selected villages of the Peshawar vale is shown in Figure 37. It can be seen that SKR was ranked first, followed by HZI, DZD, AGR, BSI, PGI and MB. These results suggest that the lack of resilience to floods is fairly lower in the households of the communities of Nowshera than in the Charsadda district.

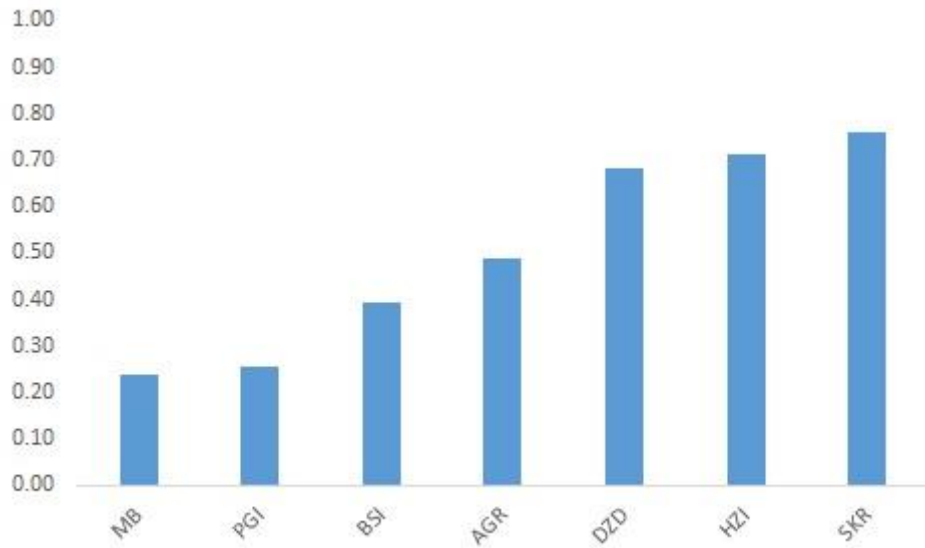


Figure 37: Sub-index Lack of Resilience for the Selected Villages of Peshawar Vale

The key contributors to the sub-index lack of resilience in the selected villages are shown in Figure 38. Almost all indicators have been found to make a significant contribution to the high lack of resilience in SKR. Nearly similar conditions have been observed in the case of HZI and DZD. In the case of AGR, LEH and LAMF have been observed comparatively higher contributors. LASR and LAMF were found comparatively high contributors in BSI. One can see that flood management measures in terms of infrastructures are quite satisfactory that indicates that authorities are primarily focusing on infrastructural measures.

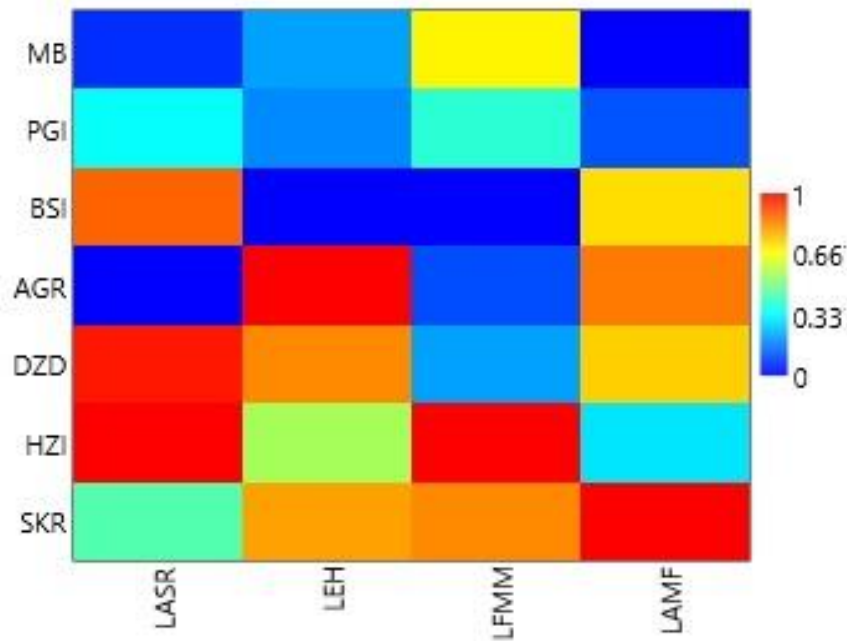


Figure 38: Contribution of Indicators in the Sub-index Lack of Resilience for Local Level Flood Vulnerability Assessment

6.2.5 Robustness Check

The robustness tests were carried out by comparing the ranks derived by different methods with the median ranks using the average shift in the ranking approach (Table 9). The weights derived from the PCA and IS methods can be seen in Appendices B2 and B3, respectively. A very nominal shift in rank values was observed for all methods with respect to median ranking (0.29) except for geometric aggregation (0.00). These findings are also demonstrated through the correlation coefficients (Table 10).

Table 9: Shifts in Ranking

MMEA	MMIA	MMPCA	ZSEA	MMEG
0.29	0.29	0.29	0.29	0.00

Table 10: Spearman Correlation between Median Ranking and other Approaches

	MMNA	MMISA	MMPCA	ZSNA	MMNG	MR
MMNA	—					
MMISA	0.93	—				
MMPCA	0.93	1.00 ***	—			
ZSNA	1.00 ***	0.93	0.93	—		
MMNG	0.96	0.96	0.96	0.96	—	
MR	0.96	0.96	0.96	0.96	1.00 ***	—

Note. *** $p < .001$

To know the variation in shift in ranking, all the derived rankings through different approaches (representing by line) were plotted against median ranking (representing by triangle mark) in ascending order Figure 39. The results indicate that a maximum of one-degree shift in ranking can be seen in first four villages. These results imply that these four villages can exchange their overall ranking with respect to different methods. These results are not unexpected as the data at local scale are quite uniform where these approaches are highly influenced by the data structure and linear strength. Though the base model did not show a higher value of average shift in ranking with respect to other methods but multiplicative aggregation showed a smaller average shift in ranks. However, not showing more average shift in ranking with respect to other methods implies that the results of base model are not biased.

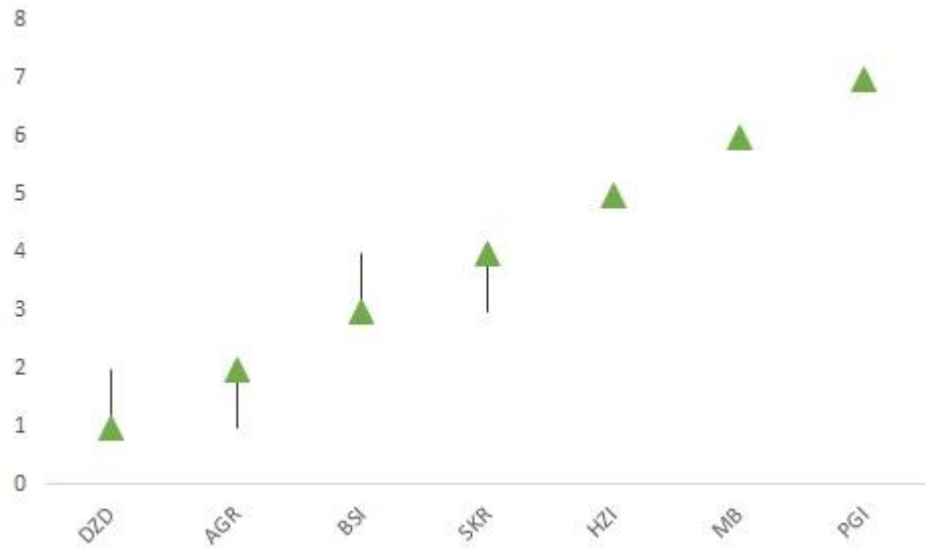


Figure 39: Range and Median Rankings

6.2.6 Up-scaling the Local Flood Vulnerability Assessment

The results of sub-index exposure, sub-index susceptibility and sub-index lack of resilience and their aggregate as a flood vulnerability index by additive aggregation and multiplicative aggregation are shown in Figures 40 and 41, respectively. It can be seen that in both cases there is no differentiation which means the outcomes are not biased. Indeed, District Nowshera has higher flood exposure than District Charsadda but less overall flood vulnerability, susceptibility, and lack of resilience.



Figure 40: Flood Vulnerability Indices using Linear Aggregation



Figure 41: Flood Vulnerability indices using Multiplicative Aggregation

7 DISCUSSION

7.1 DISTRICT LEVEL FLOOD VULNERABILITY ASSESSMENT

A thorough knowledge of the most vulnerable regions, populations and key drivers that actually create such vulnerability is an effective tool for reducing disaster risks, rebuilding strategies and policy making (Birkmann 2007). Vulnerability assessment research in general and flood vulnerability assessment research in particular are very raw within this part of the world. Despite having a much higher vulnerable profile, much less research has been done. Only a few studies exist where significant parts are restricted to the central districts of Charsadda, Nowshera and Peshawar. At the broad (district) level vulnerability assessment is hardly found in Rafiq & Blaschke (2012) and Khan & Ali (2012) research studies that were conducted at national level. However, the earlier reported that there was a great deal of simplification due to lack of sufficient data and the later took into account climate change and resource-based vulnerability, which focused primarily on agriculture and economic assets. Whereas there is no a comprehensive study in the author's knowledge that assessed the flood vulnerability of Khyber Pakhtunkhwa at district level. In order to fill this gap, the objective of this study is to assess the relative level of flood vulnerability of the selected districts in Khyber Pakhtunkhwa.

The study facilitates a “flood vulnerability snapshot” that indicates that districts that may have similar geographical or climatic conditions might have different levels of flood vulnerability. Through the findings of this study the policy makers can get a vivid picture of the overall flood vulnerability of the selected districts that will help them to get valuable information for robust decisions making to reduce flood risk reduction. The results were presented not only to give a broad picture through the indices, but also to provide the contribution behind that value that can provide a quick idea for further actions. Variability of flood vulnerability across districts is influenced by a number of issues. Limited to the conceptual framework, mainly the system’s dimensions (i.e. -

socio-economic and biophysical) and the degrees of the vulnerability factors (i.e. exposure, susceptibility and lack of resilience) can describe this variation. From the findings, it can be seen that districts in nearly identical geographical conditions showed different levels of vulnerability to floods and vice versa. Based on these results, it has been assessed that geographical location, physical features and climatic conditions are only one-half of the vulnerability, while socio-economic conditions account for the second half of the vulnerability (Cutter et al, 2003; Fekete 2010, p. 17) of the system. Similarly, in such assessments, not only the dimensions but also the combined effects of their vulnerability factors are of paramount importance. As the vulnerability assessment is the combined effect of exposure, susceptibility and lack of resilience. It does not necessarily mean that if the area has a high level of exposure, low susceptibility or lack of resilience will always be highly vulnerable (Chakraborty & Joshi 2014).

The results of the study can be interpreted as the “extent of harm that can be expected under certain conditions” (Balica et al. 2009) of the system in flood disaster. The results are for large scale that are not able to discriminate heterogeneity within the districts therefore the results are generalized form of flood vulnerability that can be viewed as average (Fekete 2010, p. 120) and homogeneous flood vulnerability (Kienberger, et al. 2014). That means to identify homogenous regions in terms of their degree of vulnerability as well as their inherent characteristic (ibid). Such an assessment always focuses on "highly" vulnerable areas and not necessarily on "most" vulnerable areas (INRM Consultants and Colleagues, 2016) which can be used as an evidence to highlight vulnerable areas for further investigation (Vincent, 2004, Sec.5). One of the important results can be seen from sub-index exposure and overall flood vulnerability indices. It was observed that the central districts (Charsadda, Nowshera and Peshawar) along the northern Swat district showed higher exposure to flooding. Though the overall flood vulnerability index results, it can be seen that, in addition to Charsadda district, the remaining districts showed relatively low flood vulnerability. These results are in line with the socio-economic conditions of the area. As it is reported that the central part of

the province comprised 10% of geographic area and 36% of overall province's population where district Swat alone has 7% of overall province's population, but the socio-economic conditions of these districts are also considered fairly good as most economic activities are concentrated in these districts of Khyber Pakhtunkhwa (see IGC, 2015). The finding is in agreement with the general concept of the flood vulnerability that wealthy region or households may suffered more (in monetary terms) than poor or weak regions or households during flood (due to high exposure) but they have the capacity (or resilience) to recover as soon as possible (Flanagan et al. 2011). The results are also in line with Fekate (2010, p. 83) who reported that certain areas or regions are sometime more susceptible in socio-economic conditions than other by giving an example of Eastern Germany. However, it was noted that mainly the developmental activities have strong correlation with population density that indicates that the developmental activities (e.g. healthcare, flood infrastructure etc.) in the selected districts are mainly based on population magnitude rather than necessities. This issue needs to be further investigated.

7.2 COMMUNITY LEVEL FLOOD VULNERABILITY ASSESSMENT

This section of the dissertation was aimed at assessing community-level flood vulnerability in Pakistan's Khyber Pakhtunkhwa province through a methodologically robust and easy-to-understand approach. Much study has been performed in this part of the province, taking into consideration flood risk modeling, water-affected by flooding, agricultural damages, gender role in flood disaster etc. (Bibi, et al. 2018; Farish, et al. 2017; Khan & Ali 2012; Khan & Mohmand 2011; Nasir & Tabassum 2014; Qasim, et al. 2015; Qasim, et al. 2016; Qasim, et al. 2017; Shah et al. 2013; Shah, et al. 2018; Saleem 2013). However, the flood vulnerability based on indicators is very nominal. Note that some studies have been conducted in the last two years, with the current study begun in 2016. However, for latest results they were incorporated in this study. It was discovered that some methodological and practical implications are missing in indicators-based flood vulnerability studies in the area such as to build the flood

vulnerability composite indicators with different methodological approaches and its applicability on community level rather than to generalized the results for district level.

Often flood vulnerability studies in the context of the study area are methodologically very restricted using a readily available methodology to put some indicators in a readily available model to draw results without focusing on the complication that will arise with such an approach, e.g. the subjectivity issue. Qasim et al. (2015) and Qasim et al. (2017) provide a very good background for the assessment of flood vulnerability in the study area. The most recent study of Shah et al. (2018) is another good improvement in the assessment of flood vulnerability. However, besides up-scaling the flood vulnerability assessment results at district level and following a ready-made approach, these studies exclusively ignore the relationship exists between indicators. Birkmann (2007) points out that, at community or local level (flood) vulnerability assessment, some indicators are certain redundant and need to be clearly scrutinized. While, Baptista (2014, p.14) found that the literature suggested that the deductive synthesis used a relatively small set of indicators. For instance, the earlier studies used all such logically related indicators like house structure and household income or employment etc., which were not examined for linear strength even though they used subjective weights. If a household has multiple sources of income, it will certainly have a better type of house as well.

It has been found that the results of the current study are somehow compatible with earlier studies such as the high vulnerability of Agra. Although there is no study that suggests that the village is highly vulnerable to others. There are, however, plenty of studies on the Agra Union Council. For instance, Bibi et al. (2018), Akhter et al. (2017), Malik (2012), Khan & Ali (2012), grey literature by the Provincial Disaster Management Authority and various development organizations have indicated that the Agra Union Council is at high risk of flooding due to its geographical location. However there are some differences in findings with respect to earlier studies. For instance, Shah et al. (2018) reported that households in District Nowshera communities are more

vulnerable to flooding than the Charsadda district. This finding is not coherent with the findings of the current study as well as with Qasim et al. (2017), where the value of the composite indicators for Nowshera was less than that of the Charsadda district. One possible reason for such variability in results is the use of different dataset, as the vulnerability indices values are largely influenced by the indicators numbers and their values. However, Charsadda has been reported to be economically resilient due to female labor force than Nowshera. This is not the case in this study as well as in the Qasim et al. (2015) study, which showed that women are not even allowed to participate in surveys due to cultural and religious limitations, replicated by several authors, including Shah et al. (2018). Perhaps they questioned the participants about their female workforce, or maybe they meant working inside their home for economic activities. The vulnerable occupation, however, including farmers and labor in Charsadda, was found to be much higher than Nowshera in the current study. The findings of Nowshera's higher exposure than Charsadda are consistent with Shah et al. (2018). The other issue that needs much concentration is the framing of indicators. For instance, Shah et al. (2018) reported that majority of the houses are constructed far away from flood protection infrastructures in both districts developed by government and NGOs that make the houses less resilient. Similarly, they add an indicator “houses within one kilometer of flood sources” is highly vulnerable. It makes a little confusion that if houses are “far away” from water source, then how they are less resilient to flood? Nelitz et al. (2013, p.66) posits in this regard that the usefulness of composite indices depending on appropriate and applicable indicators.

Differences and similarities in results in all of these studies may not be unusual due to different datasets. One thing that distinguishes this study from previous studies, however, is its logical and methodological soundness. Nearly all stakeholders recognize that the economic situation, lack of resources, health facilities, education, etc. are the key aspects of high flood vulnerability not only in the area of study, but generally throughout the (developing) world. Giving a general discourse on increasing education,

providing health care facilities, reducing unemployment, and so on will add nothing unique. And to be practical, what is the aim of the assessment of vulnerability? If it ignores the vulnerability's purpose (to identify the exact hotspots and key drivers) and characteristics (that vulnerability differs across different locations / communities). The novel idea is not only to define accurate hotspots and key drivers for further analysis or intervention, but also to ensure that a methodologically unbiased approach is put into practice. The majority of the flood vulnerability assessment studies are silent on robustness tests as reported by Nasiri et al. (2016), that uncertainty analysis is one of the main weaknesses in the assessment of flood vulnerability. As stated earlier, assessing uncertainty and sensitivity is not optional, but crucial to ensuring transparency of vulnerability assessment indices (Baptista 2014, p.20).

Villordon (2014, p.106) has integrated very sound and robust indicators to assess flood vulnerability, such as living in or near degraded land, open waste disposal, etc. The majority of participants respond that they reside either in saline or water-logged areas, which is consistent with the statement of Amir (2013) that seeping from rivers in the low-lying Peshawar Vale is going to worry the residents of the area. Integrating these elements in the flood vulnerability assessment can expand the scope of the research and will draw the attention of the competent authority to also concentrate on these elements in rural areas of the province. Some random snapshots of the aspects mentioned are provided in Appendix C.

8 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Vulnerability is different to different peoples and with the passage of time it is getting more interdisciplinary. Similarly, flood vulnerability is the combined effort of different stakeholders and policy makers. Fekete (2010, p.107), however, quoted in such perspective that interdisciplinary flood vulnerability assessment is “a field that is full from landmines”. Finding a prevalent language among natural science, social science, and engineering is hard. Meeting scientists who simply gave up speaking to the "other side" is not unusual. He also posits that apart from having a lot of definitions and approaches to frame vulnerability still “researchers have agreed not to agree” (Fekete 2010, p.106).

Now the question is arising that “to think outside the box”, i.e. Is it possible to frame such a flood vulnerability assessment that can be acceptable to wide range of stakeholders? Related to this question, there are a series of questions that how is it possible to develop such an approach that can be applied at large scale (district level) as well as at local (community) level? How the approach should be fairly simple not only in construction but also in comprehensibility to non-technical users? And how much the adopted approach is transparent with fairly stable results with respect to other methodological assumptions?

8.1 FRAMING FLOOD VULNERABILITY

The study is based on the concept of UNESCO-IHE flood vulnerability assessment and MOVE vulnerability assessment frameworks. However the methodological approach adopted in the study is distinct. These frameworks considered flood vulnerability as a product of exposure, susceptibility and (lack of) resilience factors. In simple words, its means that certain conditions of a system or society (district and community in current study) can manifest the extent of harm that can be expected under flood disasters. Some of these conditions may serve as exposure due to the presence of a

location where the flood is expected to occur, a susceptibility which suggests the probability for being adversely affected and (lack of) resilience that can help to cope with and recover from flood disasters. The frameworks are based on a general vulnerability assessment concept that covers not only the multidimensional aspects (social, economic, physical, environmental, etc.) but also the degree of vulnerability factors (exposure, susceptibility and lack of resilience) that can create a simple image of the complex human-environmental system for flood risk reduction.

8.2 METHODOLOGICAL ASPECTS

The interdisciplinary nature of flood vulnerability has been kept in mind in the current study. Developing a composite indicator for flood vulnerability has several challenges. The MOVE vulnerability has no indication for assessment method, while the UNESCO-IHE methodology employs a fixed model of analytical procedure for the quantification of indices. Such an approach is good in the sense that it keeps track of the readily available structure for the development of composites. Nevertheless, its non-flexible nature hardly makes it easier to test such an approach for other implications, because such an approach is often inconsistent with the different types of data rescaling, weighting and aggregation. These might be the reasons that the authors of the UNESCO-IHE flood vulnerability approach quoted several limitations of their approaches such as that uncertainty cannot be removed, the flood vulnerability index is not “one size fits all scenario”, the results can be distorted in uneven number of indicators etc. (see Balica et al. 2012). Taking these aspects into account, the OECD (2008) approach to composite development is the only ground that can to some extent overcome these challenges. The first merit of the OECD approach is that it can help to develop a composite indicator through a step-wise and detailed approach in contrast to develop composite indicator in scattered form where the readers (especially non-technical or new comers) are unable to understand the methodological procedure. This is also considered against the transparency and reliability of composite indicators where subjectivity and technical artifacts are not open to common readers. Second, it provides information that how to

interpret the results in an easy to use approach. And finally, it facilitates a fairly simple non-sophisticated approach to test the methodological bias in terms of average shift in rank from reference ranking with respect to different data rescaling, weighting and aggregation schemes. As the median ranking are not highly influenced by outliers, that can help to assess the robustness of the selected approach. If the simple approach shows great variations in results through average shift in rank or Spearman correlation, the modeler may think for alternative approaches that have less influence on the overall results.

8.3 FLOOD VULNERABILITY INDEX

The data was selected through official portals for the selected districts in case of district level flood vulnerability assessment and through survey for local level flood vulnerability assessment. In first case the data was mainly available in raw form and in different units that need commensurability to further process it for the development of flood vulnerability composite indicators. The data was also processed for linear relationship using Pearson correlation matrix in order to remove the certain collinear indicators that have a clear logic in its relationship. Note that collinearity means weakening the linear relationship in the sense of highly correlated indicators and not completely overcame the correlation issues. Only those indicators have been retained for the final list that follow the above criteria, i.e. they do not have a strong correlation and that fits best in the context of the study. The indicators have been rescaled through a "Min-Max" approach that brings the indicators within the range of zero and one where zero mean minimum and one means maximum for the respective indicators across the comparative units (districts / communities). In the first case, no weights were allocated to indicators to overcome the subjectivity issue. The indicators were aggregated through a hierarchical approach by aggregating the indicators of exposure factor as sub-index exposure, aggregating the indicators of susceptibility factor as sub-index susceptibility and aggregating the indicators of lack of resilience as sub-index lack of resilience using additive function. These three sub-indices were ultimately aggregated into the overall

flood vulnerability composite indicators for selected districts as a relative measure of flood vulnerability. This was the base model (i.e. MMEA) in the current study. The reason behind this approach is that it is often used in the scientific community. It is fairly simple to construct, while a variety of end users can understand it. The results were presented through column graphs in fairly simple way by ascending order from low (left) to high (right). In the current study, the graphs of the contributors (indicators) are shown at the same time as the index graphs, that readers can get a clear and quick comprehension of the index values and the main contributors behind those values. In order to know the methodological robustness of the base model, these steps are repeated to construct the flood vulnerability index using different data rescaling, weighting and aggregation schemes. All of these approaches have different ideas that are different from each other. The “average shift in rank” approach of the OECD is applied for robustness, as it is quite straightforward and demonstrates all the variance in a single value.

In the second case, i.e. a community level flood vulnerability assessment, almost the same approach is applied. However, data is collected through questionnaires that have been processed utilizing statistical software. Response frequencies were recorded as in percentage for each specific indicator (question) in each selected village. And these frequencies are normalized by the "Min-Max" approach where no weights were allocated to indicators and aggregated by the additive function. A hierarchical approach is adopted, as demonstrated in the assessment of flood vulnerability at district level. That was the base model in local scale flood vulnerability assessment. The remaining procedure was the same as in the case of district level flood vulnerability assessment.

8.4 LIMITATIONS

Methodologically, most of the requirements described in the previous literature are met for reliable results. There are, however, certain limitations. These limitations can be broadly divided into two classes: (1) with respect to the assessment of flood vulnerability in the scientific community, and (2) with respect to the current study.

In the first case, it was observed that analytic versus pragmatic issues are the top most issue of controversy between aggregators (who favor composite indicators) and non-aggregators (who oppose composite indicators) reported by Saisana & Saltelli (2011). Nelitz et al. (2013, p.66) reported that techniques for developing aggregate or composite vulnerability indices are not technically complicated, though they can be highly contentious due to a number of subjective and intrinsic assumptions that need to be made. Similarly, Greco et al. (2018) reported that each step of the composite indicator is “between the devil and deep blue sea” that can compel the developer to make compromises in each step, keeping in mind the drawbacks. While the OECD (2008, p.137) stated that even well-known indices are not exempted from analytical problems.

With respect to this study, there are several limitations. Institutional and administrative data are missed to widen the scope of study to other areas. The current study describes methodological bias in a simple and comprehensive manner. Whereas it is difficult to overcome complete subjectivity, particularly in the selection of indicators, as there is no single definitive set of indicators (OECD 2008, p.23). Moreover, such studies are primarily based on assumptions that can best fit the phenomena to be assessed. For instance, the indicator “flood management measures” in the district level flood vulnerability assessment only indicates the number of floods management projects while lack specification (type, length, width, height, materials used etc.). Balica et al., (2013) reported that flood vulnerability indices can give only a presumed snapshot and not the exact extent. So, these kinds of studies are the simplification of a complex real system (Merz et al. 2011; Damm, 2010, p.6) and its results can hardly be validated (Vincent, 2004, sec.5.3.3; Damm 2010, p.180; Merz et al. 2013). Simpson (2006, p.5) considered vulnerability indices are “reified snapshot”. Though, (flood) vulnerability is a dynamic process which is less likely to remain constant (Downing et al. 2006, p.9; Simpson 2006, p.7), still the indices can serve as a proxy for identifying ways to increase resilience (Vincent, 2004, sec.5.4.3). Fekete (2010, p.120) rightly said that that these snapshots of (flood) vulnerability indices are the “starting point” and not the “end”

for flood risk reduction and monitoring. It is also noted that the frequent use of multi-faceted flood vulnerability tools such as flood vulnerability indices will definitely help to track flood risk management measures in a cost-effective manner (Sebald, 2010, p. 66). Vink (2014, p. 103) suggests that interventions that can minimize losses from one hazard are often not distinct from other hazards (although some do not agree with a completely different type of hazard). Thus, the results of the current study can be used as a benchmark for subsequent studies. In addition the difference in data time span is another limitation in the district-wise flood vulnerability assessment. Nevertheless, almost all (flood) vulnerability assessment studies, which are based on indicators, are making compromises on this issue. Time and resources may also be an obstacle to local vulnerability assessment. A huge amount of sample will be required to cover all area (Kablan et al. 2017). There is also a limitation in the community-based vulnerability assessment when it comes to vulnerability features (i.e. vulnerability is differential). That means the proposed sample size may not provide the “full snapshot” of the vulnerability. Nevertheless, due to time and money, it is not feasible to achieve more "realistic results" by surveying all households in a community. However, the study provides a tool that can be extended by the authorities concerned to all of the households in a community. Note that composite indicators must be seen as a way to start a debate (OECD 2008, p.13) or a dialog of public interest. The findings of the current study may therefore be used for such purposes, and not for practical application solely on the basis of these analyzes. It should be noted that all these communities or districts are at high risk of flooding. Here, only their relative levels of vulnerability are assessed. This means that a village or district with a higher flood vulnerability index does not necessarily mean that it is a highly vulnerable village or district to flooding in general, but slightly more than the other selected villages or districts in this study, as suggested by Vincent (2004) in the case of social vulnerability.

In the words of Merz et al. (2013) that such studies have a number of limitations that leave room for further research. Since each model is a simplification of the complex

real system and only those factors can be operationalized as the (official) data is allowed. However, due to its open structure, further indicators can be adjusted or the composite indicators can be updated. The approach employed in this study is relatively easy from an interdisciplinary point of view where flexibility is made to construct flood vulnerability indices without involving highly sophisticated empirical approaches.

8.5 TOWARDS SUSTAINABLE FLOOD RISK MANAGEMENT

Birkmann (2006, pp.10-11) opined that the global community doesn't really concoct guidelines for the development of indicators or indicator systems for vulnerability assessment, though the Hyogo Framework for Action highlights the need for such indicators to examine the impact of disasters on (1) social, (2) economic and (3) environmental conditions. The Hyogo Framework for Action strategy can be viewed as a link between vulnerability assessment and sustainable development. In addition, the declaration highlights the need to create methods and indicators that can be used in policy and decision-making processes based on those guidelines. He further added that integrating vulnerability with sustainability means that the social and economic aspects are closely linked with environment (for detail see Birkmann 2006). Sendai framework (2015-2030) is the successor of the Hyogo framework that also emphasizing on the resilience of the nations and communities to disasters for sustainable development (UNISDR, 2015). Cannon (2006 in Fekete 2010, p. 106) argues that "vulnerability" bears a certain resemblance to the word "sustainability" not only for identical purposes, but also for bewilderment as to what it actually means. Some authors have already lamented that the word might become meaningless if it is not best defined.

Sustainable flood risk management is being described from a variety of perspectives in the scientific community. It may seem that it was officially introduced by the Scottish Government for flood risk management. As it is reported, that the "term implies different things to different people. Four years after the National Technical Advisory Group on flooding suggested a definition Sustainable flood (risk) management, we really do not have a public agreement on the connotation of the term,

nor do we comprehend what it clearly means in reality” (Scottish Environment LINK, 2007). Green (2010) referred it to the Integrated Water Resources System while Kang et al. (2013) and Ko et al. (2013) defined it as protecting individuals and assets from floods, using resources economically and equitably, while taking into account the future and the environment. However, the explanation of Plate (2002 in Mustafaa et al. 2015) is more comprehensive that correctly linked sustainability with flood risk management. It says that sustainable principle encourages us to understand that future generations might have other requirements or expertise while building a flood protection measure to meet their requirements. While, Nur & Shrestha (2017) reported that that despite the effectiveness of reducing flood severity and magnitude, flood protection structures do not realize the vulnerability. As the leftover risk of flooding continues and is spread unequally among people or system.

Putting this scenario in the context of the study area, it has been reported that structural flood protection measures can only work if they are properly designed. However, the flood management strategy currently in use does not provide for floods that exceed design limits. Changes in river morphology, accumulation of sediment and leakage from these structures may also degrade their capacity. Its importance cannot, however, be underestimated (ADB 2013, pp. 24-25). During the 2010 flood, the peaks at Munda Headworks on the Swat River (Figure 42) and Nowshera on the Kabul River were much higher than the historic peaks, with a 100-year return period. While the flood that exceeds the limitations (designed capacity) of such structures will cause damage (ibid). That was observed in last super flood when the flood water submerged the residential areas (Figure 43). This issue needs to watch beyond than structural measures alone. Climate change can also be added here as the snow melt at high altitude may pose severe threat in the coming future. So, recognizing the spectrum of vulnerability, flood risk management programs can be intended inclusively in conjunction with other development programs such as poverty reduction, improvement in community health and social welfare etc. (Nur & Shrestha 2017).



Figure 42:Washed-out Munda Headwork due to Flood Water (source: NDMA 2016)



Figure 43: Flood Water in District Nowshera (source: NDMA 2016)

Sutton (2004, p.6) posits that sustainability has different connotations and with respect to its aim, sustainability includes protecting the environment and people, peace,

ending poverty, meeting human requirements, enhancing human well-being, promoting happiness, etc. This debate implies harmonizing flood risk management with other development programs in a sustainable manner to guarantee human and environmental protection while at the same time reducing the risk and vulnerability of the system. As human and environmental relationships are intricate, this can best be demonstrated by a robust vulnerability assessment. Green (2010) argues that the "starting point" to move towards sustainable flood risk management is to identify the nature of the system's interactions.

Balica et al. (2009) point out that risk evaluation can also allow decision-makers to prioritize flood-related investment. It is therefore not a sustainable solution to focus entirely on structural measures while ignoring other development sectors. Lumbroso et al. (2008) further added that in large and sparsely populated areas (giving the example of Mozambique), the structural approach to flood risk management cannot be justified on the basis of economic and environmental concerns. As a consequence, the flood risk approach should be on nonstructural solutions such as vulnerability assessment. This can be applicable to the case of Khyber Pakhtunkhwa where almost eighty-two percent populations are rural i.e. sparsely located. As there is no a universal implication of sustainable flood risk management. As a consequence, the current study suggests that flood risk management can be considered sustainable if the vulnerability of the system is reduced by improving its resilience while not focusing exclusively on structural measures. Nevertheless, it stressed that non-structural interventions can also be given equal priority in order to improve system's resilience.

Fekete (2010, pp. 120-21) argued that vulnerability, resilience, sustainability and climate change are at the top of the policy and research agenda. He also said that these are sectors where development in knowledge and understanding is needed to build future strategies in the light of population growth and environmental pressure. Knowledge of intricate interactions translated into measurable indices will be a key field for identifying and valuing future action priorities. As reducing vulnerability leads to raise

sustainability, the flood vulnerability assessment using composite indicators can be a valuable tool to move towards sustainable flood risk management.

8.6 CONCLUSIONS

Mainstreaming flood risk conceptualization, coupling flood vulnerability with a general vulnerability framework, offering an easy-to-use approach to composite indicator development and robustness testing and providing decision-makers with a meaningful tool for defining, quantifying and prioritizing certain vulnerable areas and actions to reduce the existing flood vulnerabilities in the province at two different scales are the main contribution of the current study. Some conclusions that can be drawn from the current study are;

- **District Level Flood Vulnerability:** Based on the results of the flood vulnerability assessment in the present study, it can be concluded that the Shangla has a relatively high vulnerability to flooding across the selected flood-prone districts of Khyber Pakhtunkhwa, followed by Charsadda, Dir Upper, Swat, D. I. Khan, Peshawar, Chitral, Nowshera and Dir Lower.
- **Local Level Flood Vulnerability:** The village of Agra is comparatively high vulnerable to flooding followed by Dheri Zardad, Banda Shaikh Ismail, Sukkar, Haji Zai, Mohib Banda and Pashtun Garhi. It has been discovered, however, that the Dheri Zardad can take over ranked first under various methodological assumptions, which need further investigation.
- **Up-scaling Flood Vulnerability:** Up-scaling results at the district level indicated that households in the communities residing in the Charsadda district were found to be relatively high vulnerable to flooding compared to the Nowshera district using current dataset.
- **Methodological Soundness:** The study ensured the transparent construction of flood vulnerability assessment through a detail step-wise procedure that could be applied to various scales. There is no sophisticated approach (with

the exception of differential weightings) that could hinder the understanding of the study. The results are presented in such a way that even lay people can understand the entire content.

- **Policy Intervention:** The study attempts to reduce the gap between policy and science by keeping the interdisciplinary nature of flood vulnerability in such a way that it can encourage its readers, policy makers, researchers, students and even common mass to modify, update, criticize and improve the approach for future studies.
- **A Single Approach:** A comprehensive single approach for the building of flood vulnerability indices at two different scales is a valuable initiative to provide a common ground to various stakeholders by reducing their time and resources.
- **Strength or Limitation:** The adaptation of a flexible methodology that can leave room for further experimentation should be seen as strength rather than a limitation, as experimentation leads to more creative techniques.
- **Encouraging New Comers:** The study emphasizes to encourage the new-comers from human-geography or related fields to build composite indicators for floods, droughts or related hazards in a fairly simple and methodologically defensible way, that is demonstrated in the current study in a great detail..
- **Local Scale or Large Scale:** The adopted methodology can be tailored for any scale. A compromise can be made between “homogenous” vulnerability and “decision making scale” in the case of district level flood vulnerability, if data is exists only for large scale. Similarly, a great amount of time and resources are needed for community level flood vulnerability assessment to get the “full snapshot”.

8.7 RECOMMENDATIONS

The current study found several issues that need further investigations such as;

- The definition of a clear and concise flood vulnerability assessment notion and underlying definitions is highly recommended as vulnerability has infinite implications.
- The addition of institutional and governance indicators will add depth to the overall vulnerability of floods, if there is any.
- Updating flood vulnerability indices at a certain time interval (5 years or 10 years) may help to give a clearer picture of flood risk reduction measures across comparative units and will provide a reference for validation of results.
- The combination of individual indicators to the overall flood vulnerability index by functional relationship will not only reduce the number of indices and the issue of equal weights, but will also make it easier to assess the sensitivity of each indicator to the overall flood vulnerability index.
- There will be some interesting results from the inclusion of other approaches in the robustness check.
- Expanding flood vulnerability assessments for all districts can provide a good background for creating flood vulnerability spatial maps.
- Developing flood vulnerability indices without a fixed structure through inductive reasoning can help to improve empirical adequacy.
- The study strongly suggests an inductive reasoning for the local flood vulnerability assessment using composite indicators, despite the use of a completely associated array of indicators that do not add anything significant.
- Selecting indicators “outside of the box” will help to address those issues rather than to replicate the socio-economic indicators.

- This study describes sustainable flood risk management in the context of the "vulnerability-sustainability" relationship. However, when implementing this type of strategy, care should be taken to frame the notion of flood risk.

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APPENDICES

A1: Indicators Calculation and Commensurability:

- Population Density:

$$PD = \frac{\text{Number of people}}{\text{Land area}} = \frac{\text{persons}}{\text{Km}^2}$$

- Flood Prone Area:

$$FPA = \frac{\text{Affected union councils}}{\text{Total union councils}} \times 100$$

- Altitude above Sea Level: Readily available
- Women Gender:

$$WMN = \frac{\text{Number of women}}{\text{Total population}} \times 100$$

- Maternal Mortality Rate: Readily available
- Child Mortality Rate: Readily available
- Dependency Ratio: Readily available
- Lack of access to Improved Drinking Water: Readily available
- Lack of access to Improved Sanitation: Readily available

- Unemployment:

$$UNE = \frac{\textit{Number of unemployed}}{\textit{Total population}} \times 100$$

- Kacha House: Readily available
- Agricultural Land: Readily available
- Literacy Rate: Readily available
- Number of Hospitals: Readily available
- Length of paved/asphalt Roads: Readily available
- Forest Cover:

$$FC = \frac{\textit{Forest area (ha)}}{\textit{Total reported area (ha)}} \times 100$$

- Mean Monthly Household Income: Readily available
- Flood Management Measures: Readily available

A2: Indicators Weights for District Level Flood Vulnerability using PCA Approach

	Factor Loadings				Factor Weights			
	1	2	3	4	1	2	3	4
PD	-0.79	-0.33	-0.31	0.11	0.21	0.04	0.04	0.01
FPA	-0.18	-0.19	0.80	-0.31	0.01	0.01	0.25	0.05
DPR	0.12	0.97	-0.03	0.13	0.01	0.36	0.00	0.01
MMR	-0.02	0.32	-0.23	0.83	0.00	0.04	0.02	0.36
LAIS	0.23	0.02	0.29	0.75	0.02	0.00	0.03	0.29
KH	0.74	0.45	-0.39	0.08	0.18	0.08	0.06	0.00
AGL	-0.16	0.28	-0.83	-0.02	0.01	0.03	0.27	0.00
LR	0.27	0.43	0.76	0.28	0.02	0.07	0.23	0.04
ASR	0.80	-0.20	0.19	0.24	0.21	0.02	0.01	0.03
FC	-0.28	-0.87	0.17	-0.05	0.03	0.29	0.01	0.00
MMIH	0.40	0.22	0.41	-0.63	0.05	0.02	0.07	0.21
FMM	0.90	0.35	-0.04	-0.07	0.27	0.05	0.00	0.00
Method: PCA								
Rotation: Varimax with Kaiser Normalization								
Expl. Var.	3.04	2.61	2.52	1.90				
Expl. Tot.	0.30	0.26	0.25	0.19				

A3: Indicators Weights for District Level Flood Vulnerability using IS Approach

PD	FPA	DPR	MMR	LAIS	KH	AGL	LR	ASR	FC	MMIH	FMM
0.09	0.07	0.09	0.09	0.10	0.08	0.07	0.09	0.09	0.07	0.08	0.09

B1. Questionnaire used as Pre-test (Source: Villordon 2014)

SOCIO-ECONOMIC

1. Occupational background of the respondent or anyone working in the family. Please put a check mark on the choices below. <input type="checkbox"/> Fisherman <input type="checkbox"/> Skilled worker <input type="checkbox"/> Laborer/Helper <input type="checkbox"/> Saleslady/Salesman <input type="checkbox"/> Public Employee <input type="checkbox"/> Private Employee <input type="checkbox"/> Pedicab/Easyride Driver <input type="checkbox"/> Private Driver <input type="checkbox"/> Laundry <input type="checkbox"/> Others, pls. specify _____
2. Estimated Monthly Income from all sources of livelihood. Please put a check mark on the choices below. <input type="checkbox"/> Below 3000 <input type="checkbox"/> 3001-10,000 <input type="checkbox"/> 10,001 above <input type="checkbox"/> Others, pls. specify _____
3. Do you own your residential place, both the house and lot? <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Just the House <input type="checkbox"/> Just the Lot
4. Is your housing property insured? <input type="checkbox"/> Yes <input type="checkbox"/> No
5. What construction material is your house mostly made of? Please put a check mark on the choices below. <input type="checkbox"/> Concrete <input type="checkbox"/> Wood <input type="checkbox"/> Cartoon <input type="checkbox"/> Steel <input type="checkbox"/> Galvanized Iron <input type="checkbox"/> Coconut leaves <input type="checkbox"/> Nipa material <input type="checkbox"/> Plastic <input type="checkbox"/> Bricks <input type="checkbox"/> Tiles <input type="checkbox"/> Salvage materials <input type="checkbox"/> Others, pls. specify _____

PHYSICAL ENVIRONMENT

1. How often is your place flooded from heavy rains? <input type="checkbox"/> Every month <input type="checkbox"/> Every 4 months <input type="checkbox"/> Every year <input type="checkbox"/> Every 6 months <input type="checkbox"/> Every Year <input type="checkbox"/> Sometimes <input type="checkbox"/> Rarely <input type="checkbox"/> Never
2. Did it reach inside your home? <input type="checkbox"/> Yes <input type="checkbox"/> No
3. How high was the flood waters in your immediate surrounding have reached? <input type="checkbox"/> Ankle high <input type="checkbox"/> Knee high <input type="checkbox"/> Waist high <input type="checkbox"/> Shoulder high <input type="checkbox"/> Above the head <input type="checkbox"/> Roof high <input type="checkbox"/> Beyond the roof Others, pl. specify _____
4. Is the immediate surroundings of your home clean? <input type="checkbox"/> Yes <input type="checkbox"/> No
5. Are there water logged areas in your surroundings? <input type="checkbox"/> Yes <input type="checkbox"/> No
6. Are there open sewage or canals in your surroundings? <input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is your house situated near a river, creek/pond or coastal? Write down your answer _____
8. Is your house located in an elevated area? <input type="checkbox"/> Yes <input type="checkbox"/> No
9. Location where adult/child member of the household usually go to defecate: <input type="checkbox"/> In your own latrine <input type="checkbox"/> In a neighbors latrine <input type="checkbox"/> Public latrine <input type="checkbox"/> On the ground <input type="checkbox"/> In a water body <input type="checkbox"/> Anywhere Others, pls. specify _____
10. What type of latrine do you have at home? <input type="checkbox"/> Water-sealed <input type="checkbox"/> Antipolo type <input type="checkbox"/> Pour flush <input type="checkbox"/> We don't have a latrine <input type="checkbox"/> Others, pls. specify _____
11. Where do you dispose your household water waste? <input type="checkbox"/> Into the septic tank <input type="checkbox"/> Brgy. drainage <input type="checkbox"/> Into the pit <input type="checkbox"/> Anywhere <input type="checkbox"/> Others, pls. specify _____
12. Where do you dispose your household solid waste? <input type="checkbox"/> Garbage collected by LGU <input type="checkbox"/> Composting <input type="checkbox"/> Burying in the ground <input type="checkbox"/> Burning <input type="checkbox"/> Throwing into the river <input type="checkbox"/> Others, pls. specify _____
13. Do you practice segregation? <input type="checkbox"/> Yes <input type="checkbox"/> No
14. Major source of drinking water at home during ordinary days: <input type="checkbox"/> Communal faucet <input type="checkbox"/> House to house connection <input type="checkbox"/> Spring <input type="checkbox"/> Well <input type="checkbox"/> River <input type="checkbox"/> Water pump <input type="checkbox"/> Commercial water seller dispensers <input type="checkbox"/> Bottled water from industries <input type="checkbox"/> Others pls. specify _____
15. Major source of drinking water at home during heavy rains or flooding: <input type="checkbox"/> Communal faucet <input type="checkbox"/> House to house connection <input type="checkbox"/> Spring <input type="checkbox"/> Donations <input type="checkbox"/> Well <input type="checkbox"/> River <input type="checkbox"/> Water pump <input type="checkbox"/> Commercial water seller dispensers <input type="checkbox"/> Bottled water from industries <input type="checkbox"/> Others pls. specify _____
16. Do you think your source of drinking water is clean? <input type="checkbox"/> Yes <input type="checkbox"/> No

17. How is your drinking water treated or sterilize? ___ Boiling in less than 10 minutes ___ Boiling in 10 minutes ___ Chlorination ___ Settling ___ Filter ___ Nothing ___ Others, pls. specify _____
18. Check the following domesticated animals that you owned: ___ Pig ___ Cow ___ Chicken ___ Goats ___ Birds ___ Doves ___ Cats ___ Dogs ___ Horse ___ Others, pls. specify _____
19. Where do you dispose the fecal materials from your domesticated animals? ___ In your own latrine ___ In a neighbors latrine ___ Public latrine ___ On the ground ___ In a water body (river) ___ Into the pit ___ Anywhere ___ Others, pls. specify _____
20. What are the domesticated animals you have observed from your neighbor's vicinity? ___ Pig ___ Cow ___ Chicken ___ Goats ___ Birds ___ Doves ___ Cats ___ Dogs ___ Horse ___ Others, pls. specify _____
21. Is it permitted to raise domesticated animals in your vicinity? ___ Yes ___ No
22. Have you seen rats roaming around your vicinity? ___ Yes ___ No
23. Have you seen rats roaming around your neighbor's vicinity? ___ Yes ___ No
24. Have you seen domesticated animals without an owner roaming outside your vicinity? ___ Yes ___ No
25. What sanitation and hygiene programs you have heard before? ___ About water safety ___ Environmental sanitation ___ Garbage Segregation ___ Disease outbreaks during typhoon and flooding ___ The right way of washing of hands with soap and water ___ Owning a latrine
26. From whom you have heard about the sanitation and hygiene program? ___ Own family ___ From neighbors ___ NGO worker ___ LGU's ___ Health Center ___ Brgy. Officials ___ Brgy. Health ___ Workers ___ School/Teachers ___ Religious Groups ___ TV ___ Radio ___ Newspaper/Magazines ___ Billboard ___ Others, pls. specify _____

SOCIAL ENVIRONMENT

1. Are you friends with your neighbors? ___ Yes ___ No
2. Are you willing to help your neighbor if in need of your help during or after heavy rains or flooding? ___ Yes ___ No
3. Were there any health related meetings held in your place every now and then? ___ Yes ___ No Did you participate on this? ___ Yes ___ No
4. Have you observed your neighbors helping each other in whatever way they can during typhoon and flooding events? ___ Yes ___ No
5. If your house is very near from the river (about 5-10 meters) do you know that you can be at risk of flooding? ___ Yes ___ No
If the government would advice that your area is no longer safe, are you willing to vacate your place? ___ Yes ___ No If your answer is YES, then why? Give your reasons _____ If your answer is NO, then why? Give your reasons _____

B2: Indicators Weights for Local Level Flood Vulnerability using PCA Approach

	Factor Loadings				Factor Weights			
	1	2	3	4	1	2	3	4
HPFA	0.03	0.12	-0.18	0.89	0.00	0.01	0.02	0.63
HHS	-0.03	0.92	0.24	0.16	0.00	0.42	0.04	0.02
VO	0.76	0.18	-0.05	-0.19	0.27	0.02	0.00	0.03
LINDL	0.40	0.30	-0.80	-0.04	0.08	0.04	0.40	0.00
LASR	0.20	0.25	0.81	-0.43	0.02	0.03	0.41	0.15
LEH	0.91	-0.24	-0.22	0.12	0.39	0.03	0.03	0.01
LFMM	-0.14	-0.89	0.32	-0.01	0.01	0.40	0.06	0.00
LAMF	0.71	0.31	0.25	0.44	0.24	0.05	0.04	0.15
Method: PCA Rotation: Varimax with Kaiser Normalization								
Expl. Var.	2.12	1.99	1.61	1.26				
Expl. Tot.	0.30	0.29	0.23	0.18				

B3: Indicators Weights for Local Level Flood Vulnerability using IS Approach

HPFA	HHS	VO	LINDL	LASR	LEH	LFMM	LAMF
0.13	0.13	0.13	0.12	0.11	0.13	0.13	0.12

C1: One of the Selected Community



C2: Open Waste Disposal



C3: Degraded Land



C4: Kacha Houses at Street Level



C5: Flood Management Measures



Eidesstattliche Erklärung

Hiermit erkläre ich, Muhammad Nazeer, an Eides statt, dass ich die von mir vorgelegte Arbeit „Towards Sustainable Flood Risk Management in the North-West Khyber Pakhtunkhwa, Pakistan: A Flood Vulnerability Assessment Approach” – abgesehen von der Beratung durch meinen Betreuer – nach Inhalt und Form nur mit den angegebenen Hilfsmitteln verfasst habe. Ich erkläre weiter, dass die vorliegende Arbeit weder ganz noch zum Teil im Rahmen eines Prüfungsverfahrens an anderer Stelle vorgelegt oder veröffentlicht wurde. Die Richtlinien guter wissenschaftlicher Praxis der Deutschen Forschungsgemeinschaft habe ich bei der Erstellung dieser Arbeit berücksichtigt und eingehalten. Mir wurde kein akademischer Grad entzogen.

Signature:

Date and Place:
