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ESTIMATING PUBLIC HEALTH VULNERABILITY IN FLOOD PRONE AREAS OF PUNJAB, PAKISTAN AN APPLICATION OF ANALYTICAL HIERARCHY PROCESS (AHP)

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Abstract
In global perspective, climate change severely influenced developed and developing economies owing to higher occurrence of natural disasters such as floods, drought, earthquakes, heat waves and landslides and tropical cyclones. Pakistan ranked world fifth most higher climate change affected country of the world having higher frequently of floods disasters. Increasing erratic rains and glacier melting owing to higher temperature consider responsible for increasing frequency of riverine and flash flooding. Increasing flooding causing rising livelihood issues more particularly the health vulnerability specifically the communities residing in neighboring of river areas. The objective of this research work is estimating the public health vulnerability in flood prone areas of Punjab, Pakistan. This study used the multistage random sampling approach for collection the data of 240 household from flood prone district Vehari. In data collection procedure, a well-developed pretested questioner with all relevant information of respondents and study was applied. Analytical Hierarchy Process (AHP) was applied for assigning significance of different indicators regarding household characteristics and STATA software was applied to estimate vulnerability status of study area with various indicators. Household indicators include such as water, sanitation, hygiene (WASH) and hospital facilities, access to relief, disaster state and adaptation strategies. Estimates of the study indicated as these six indicators of the study significantly contribute to public health vulnerability. Flooding conditions in the study area consider most influencing factors followed by wash facilities, hospital facilities, access to relief and adoption strategies availability. In research area, among six selected union councils, two union councils Sahuka as most vulnerable while 291EB union councils consider moderate health vulnerable. Sahuka as most vulnerable owing to confronting regular floods, inaccessibility of relief and low socioeconomic status while 291EB union councils is moderately health vulnerability because of substantial measures of disaster risk reduction and frequent occurrence of flood disasters. Disaster management need to focus on reactive and proactive approaches which can immensely influence community health. Findings of this research can facilitate to detect gap in current public health system in vulnerable area and can undertake influential disaster risk reduction measures according to build resilient and health community.

Keyword: Analytical Hierarchy Process, Public Health, Vulnerability, Punjab, Pakistan

1. Introduction

In recent decades, climate change has severely influenced social lives and environment because of increased severity and frequency of natural calamities (Rana et al., 2020; Ahmad and Afzal, 2022). In global perspective, environment change dynamics have increased occurrence of natural calamities such as floods, drought, volcanic activity and storms (Ahmad et al., 2023). In Asian region, climate inconsistency leads to major livelihood issues especially in the agrarian sector where most Asian countries susceptible due to natural hazards are Pakistan, India, Thailand, Philippines and China (Padhan and Madheswaran, 2022). In developing economies, natural events consecutively occurred which affected majority of population that is 20 times higher than in developed countries (Ahmad et al., 2022). Over the past 20 years, flooding has been the most frequent type of natural disaster, making up 47% of all recorded events and impacting 2.3 billion people globally (Muhammed, 2023). In worldwide perspective, Pakistan considered 5th major environment change affected country which continuously confronted climatic event (Ahmad and Afzal, 2022). Flood risk is not only a threat to rural but also to urban areas where health issues are most severe challenges in increasing stress factors (Ahmad and Afzal, 2024). In Pakistan's 76-year history, the country has experienced severe minor and major floods from 1950 to 2023 (UNDP, 2023). Flood of 2010 considered most severe event, affected 45 out of 135 districts caused major economic losses, affected 160,000 km^2 agricultural and residential areas, destruction of 436 medical basic health units with demonstrating 1.1 million homes while more than 20 million people affected due to flood (UNDP, 2023). In 2022, flash floods, riverine floods, and urban flooding caused severe losses of 1700 lives, affected 33 million populations, displaced 8 million population, damaged partially infrastructure of 1.2 million houses where 0.8 million houses were completely destroyed (UNDP, 2023). In 2022, flood caused severe impact on public health, worsening inhabited population livelihood and rising new challenges of mental health issues among affected population due to displacement and migration (Ahmad et al., 2023). Increased frequency and intensity of floods had severe impact on health by directly such as injury while indirectly such as mental health issues like anxiety, depression, and disruption of health care services. Water borne diseases like cholera, hepatitis A, and leptospirosis considered some common diseases of flood affected areas. In flooding year of 2022, 6.4 million people need humanitarian aid, 1460 health facilities were damaged in which 432 fully destroyed and102 are partially damaged (Ahmad and Afzal, 2021). In various affected districts 142249 patients take session for psychological support and mental health protection, health and hygiene life skill to reduce trauma and anxiety (Ahmad and Afzal, 2024).

Flooding has been shown to cause significant and wide-ranging effects on affected populations, including physical, psychological, social, and behavioral impacts. Various studies have identified the physical consequences of flooding, such as injuries, infectious disease outbreaks, malnutrition, decreased birth rates, and the onset or worsening of chronic illnesses (Batzakis et al., 2024). The psychological impacts of flooding have also been widely documented and include post-traumatic stress disorder, anxiety, depression, emotional distress, insomnia, nightmares, and suicidal thoughts. Moreover, the long-term effects of floods on physical health to contrast from the instant and short-term outcomes likes as drowning, distress, poisoning and infection diseases outbreaks (Ahmad and Afzal, 2019). Overtime, health deterioration can occur due to prolonged flood exposure, injuries, contaminated drinking water, food shortages and disruptions to medical care and health services. While effective post flooding management can improve long term health outcomes. As a result, the health effects of flooding shift from acute outcomes caused by initial flood exposure to chronic outcomes influenced by the living conditions of the affected population.

In literature viewpoint, climate change feature sustained in the discussion where some studies focused on climate induced hazards and losses assessment (Amsalu and Adem,2009; Yu et al., 2010; Gall, 2015; Campbell et al., 2016; Chen et al., 2017;Komolafe et al., 2018; Shrestha, 2019; Mbow et al., 2020; Bhowmik et al., 2021; Ahmad and Afzal, 2021; Ahmad and Afzal, 2022; Farooq et al., 2022; Batzakis et al., 2024; Toromade et al., 2024),climate based flood disasters and food security (Gregory et al., 2005; Hallegatte et al., 2010; Baldos and Hertel, 2015; Gallina et al., 2016; Gitz et al., 2016; Giardino et al., 2018; Formetta and Feyen, 2019; Atanga and Tankpa, 2021; Sahana et al., 2021; Sirba and Chimdessa, 2021; Bahinipati and Gupta, 2022; Mirzabaev et al., 2023; Ahmad and Afzal., 2024), climate

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change adaptation and mitigation strategies (Kane and Shogren, 2000; Laukkonen et al., 2009; Sumi et al., 2010; Pinto,2014; Buhaug et al., 2015; Chaubey et al., 2016; Rojas-Downing et al., 2017; Jayamaha et al., 2018; Landauer et al., 2019; Mack et al., 2021; Sweijs et al., 2022; Ahmad et al., 2023; Kim and Garcia, 2023)climatic dynamics and violent conflicts (Halsnæs and Verhagen, 2007; Theisen, 2012; Vijaya et al., 2012; Ide and Scheffran, 2014; Scheffran et al., 2017; Chen et al., 2017; Van and Mobjörk, 2018; Scheffran, 2020; Thalheimer and Webersik, 2020; Buhaug and Von 2021; Ahmad and Afzal, 2022; Ide, 2023; Wang et al., 2023; Ahmad and Afzal, 2024). However, in above mentioned literature various aspects of flood disasters highlighted while in the current scenario the aspect of flood hazards influence on public health vulnerability not addressed in perspective of Pakistan and more particularly in flood prone region of Punjab Pakistan. In this research work to addressing this research gap this study focused to estimate the public health vulnerability in flood prone areas of Punjab, Pakistan. It also attempted to investigate public health vulnerabilities faced by flood affected communities during flood disaster events. The objective of this research work is to estimate public health vulnerability not addressed in perspective of Pakistan and more particularly in flood prone region of Punjab Pakistan. This study is characterized into four segments as first segment indicated introduction material and method explained in second segment. Results and discussion of the research is elaborated in the third segment while conclusion and suggestions are highlighted in the last segment of the study.

2. Materials and methods

2.1 selection of study area

Punjab the most populated province of Pakistan sharing 52.59% population and 53% agricultural GDP of the country. In the last two decades, Punjab consider most vulnerable province of Pakistan where fourteen districts out of thirty-six consider higher flood risk districts (PBS, 2024). Vehari district is one of the flood risk districts of Punjab in neighboring of Sutlej River (PBS, 2024). Vehari district is located in the Punjab situated in the southern Punjab and is known for its agricultural significance. Vehari is part of the Multan Division and is bordered by the districts of Multan, Khanewal, Lodhran, Bahawalpur, and Pakpattan. In 2017, Vehari district having total population of 2.90million with urban inhabitant 506129 and rural 2395952 respectively. Administratively district Vehari having three tehsils Mailsi, Burewala and Vehari with 105 union councils. Vehari one of fertile land of the region with cultivation of various crops wheat, cotton, sugarcane, and vegetables. Multistage random sampling approach was applied for selection of study area regarding various perspectives such as firstly, Punjab among four provinces was selected for the study due to higher susceptibility to climatic events mostly the flood disasters. Secondly, district Vehari due to flood risk and flood disasters losses of 2022 was chosen and thirdly two most severely flood affected tehsils Mailsi and Burewala were selected for the study. Fourthly, two union councils from each tehsil regarding flood affected severity and flood losses were selected and lastly, two villages from each union were selected and twenty flood affected households from each village were selected. In overall study 240 flood affected households' data was collected through well developed and pre-tested questionnaire. In selection of sample size from the study Yamne (1967) formula was used which is given below equation 1 where n indicated sample size, N elaborated population size while e highlights error margin.

$$n = \frac{N}{N + N(e)2} \qquad (1)$$

2.2 Model Specification

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Analytic Hierarchy Process (AHP) is used in this study which was introduced by Thomas L Saaty (1980) as this method is the most significant and widely used weighting method which helps in decision making process. AHP method indicated pairwise comparison between categories to measure relatively which assigned the value with in Saaty scale in the analysis. Afterward comparison, consistency ratio is checked and after that the calculated value are normalized where the consistency ratio is defined as

$$CR = \frac{CI}{RI} \qquad (2)$$

In the above-mentioned equation 2, CR as consistency ratio which is determined by consistency index and random index. RI shows the random index while CI is the consistency index, the consistency index (CI) is used to measure the degree of consistency in the pairwise comparisons estimated during the decision-making process where consistency index is calculated as

$$CI = \frac{\lambda - n}{n - 1} \qquad (3)$$

In above equation, CI as the consistency index where λ indicated average value of consistency ratio and n as the number of criteria. Formerly calculating vulnerability all indicator data of household are normalized where to normalize the value it is used the max-min dimensional method for cost and benefit criteria which is mentioned in equation 4 and 5.

$$\text{Benefit criteria} = nij = \frac{r_{ij} - r_j^{min}}{r_j^{max} - r_j^{min}} \qquad (4)$$

$$\text{Cost criteria} = nij = \frac{r_j^{max} - r_{ij}}{r_j^{max} - r_j^{\min}} \qquad (5)$$

Here r_j^{min} indicate minimum value of indicator and r_j^{max} indicate maximum value of indicator where on the basis of characteristics factors divided into two criteria such as benefit criteria and cost criteria in equation 4 and 5. Factors positively impact by vulnerability is called benefit criteria and factors which are inversely relate to vulnerability is known as cost criteria.

2.3 Estimation of public health vulnerability

Public health vulnerability estimated through multiplying the weighted average with the normalize value of each indicator. Average vulnerability was calculated the all values of the categories sum up and divided by total number of the categories. Vulnerability measured through following equation 6.

$$V_s = \sum_{i=1}^{n} \frac{(S_{1wn} + S_{2wn} +, \ldots\ldots\ldots + S_{kwn}) * S_{nv}}{k} \qquad (6)$$

$$V_T = V_S + V_T \ldots \ldots . . + V_Z$$

In the above-mentioned equation as S, T….Z considered different categories, $S_{1,2,3,\ldots\ldots n}$ as indicator under S category, S_w as weighted average of each indicator, S_{nv} as normalizes value of S category, k as total number of households and V_t as total vulnerability.

2.4 Statistical analysis

In this study statistical analysis such as correlation, regression and frequency analysis were estimated where frequency analysis is used to analyze the flood situation according to household type. Regression analysis was performed in two types, firstly between the individual union vulnerability value with their category value and another indicted between the public health vulnerability value and the categories.

$$y = \beta_{\circ} + \beta_1 X + \epsilon \qquad (7)$$

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In equation 7, liner regression as analyzed here, y as dependent variable, X as independent variable, $\beta_\circ, \beta_1$ considered parameters of the study and ϵ as error component.

3. Results and discussion

In this study, major components and sub-components indicated there such as demographic, disease out-break, WASH, hospital facilities, household characteristics, adaptation strategies, during disaster state and access to relief. Demographic information as major components indicating four subcomponents as gender, age, education and marital status. Diarrhea, fever, malaria, typhoid and skin diseases five sub-components of disease outbreak second major component. Third major component of the study as WASH facilities with six sub-components water accessibility, water safety, water availability, sanitation type, sanitation cleaning facilities and sanitation sewerage system. Hospital facilities consider fourth major component of the study with three sub-components as preferred hospital type, distance from household (KM), and treatment cost (PKRs). Household head's (HH) highest education level, primary occupation, secondary occupation, monthly income (PKRs), monthly expenditure (PKRs), monthly expenditure (PKRs) on food, monthly expenditure (PKRs) on health, and household type consider different indicators of fifth component of household characteristics. Adaptation strategies as sixth major components of the study which consists on seven sub-components as shelter during last flood, type of temporary place, distance to shelter (KM), preferred to evacuate to shelters (embankment/ pucca house/ school/ hospital/ shelters), keep dry foods for flood time, keep ready moving cooking materials and having any indigenous knowledge or not. During Disaster state as seventh major component of the study with five various sub-component as flood affected (in last flood) or not, flood frequency in last few years, flood height in house (feet), number of days of flood, and sanitation option during floods. Last major component of the study is access to relief with sub-components as access dry foods or not from Govt./ NGO/ CBO, access medicine or not from Govt./ NGO/ CBO and access water purification tablet or not from Govt./ NGO/ CBO.

Description of the study variables where majority of household heads (94.58%) were male while (5.42%) were female. Highest numbers of respondents 37.08% were in age of 20-35 while 0.416% as lowest numbers of respondents age were above than 70 years. Majority respondents 93.33% were married and 6.66% were of unmarried. Mostly household head as 48.75% were illiterate, 27.91% can sign, read and write only while only 2.91% of household completed their graduation. In occupational status 36.7% of the household head as day laborer and mostly 61.25% of household head as farmer. Description of six categories discussed correlated with public health vulnerability such as wash facilities, hospital facilities, household characteristics, adaptation strategies, during disaster situation and access to relief. These six categories are further divided into total 32 indicators. Distribution of disease according to disease indicated in table 1. These includes as water born disease in this fever considered most common disease for all group of peoples. All group of population mostly affect with fever then typhoid, malaria is a least effective disease among people. Mostly males are affected with these diseases mostly 20-35 and 26-45 age group peoples are more affected.

Table 1: Diseases in various age groups and gender based in percentage

Age	Diarrhea	Malaria	Fever	Typhoid	Skin disease
Below 20	0	0	4	2	1
20-35	8	3	28	7	3
26-45	10	3	41	9	12
46-60	5	1	30	15	3
61-75	2	1	20	18	3

Gender					
Male (227)	53		117	48	20
Female (13)	2	0	6	3	2

Public health vulnerability categories with six union council indicated in table 5. In Burana, Allampur and Karampur union councils' vulnerability status of various categories as WASH facility 12.81, 12.76 and 12.97 indicated most vulnerable status while access to relief 1.78, 1.81and 1.79 less vulnerable status in other categories. In union council Sahuka, Jamlera and 291EB vulnerability status of various categories as WASH facilities considered most vulnerable status as 13.97,13.23 and 13.44 whereas lowest vulnerability was indicated in access to relief as 1.82, 1.84 and 1.80. In overall estimates of vulnerabilities higher vulnerability was estimated in wash facilities while lowest vulnerability in access to relief in all union councils of the study area. Hospital facilities, household characteristics, adaptation strategies and during disaster state having the moderate status of vulnerability among all unio councils as indicated table 2.

Table 2: Union council wise category-based vulnerability status

Union council	WASH facilities	Hospital facilities	Household characteristic	Adaptation strategies	During disaster state	Access to relief
Burana	12.81	7.04	4.36	2.71	3.36	1.78
Allampur	12.76	6.85	4.45	2.68	3.35	1.81
Karampur	12.97	6.41	4.16	2.73	3.43	1.79
Sahuka	13.97	6.24	4.06	2.50	3.38	1.82
Jamlera	13.23	6.46	4.11	2.55	3.40	1.84
291 EB	13.44	6.30	4.19	2.51	3.50	1.80

Vulnerability in selected union such as Burana, Allampur, Karampur, Sahuka, Jamlera and 291EB showed the high vulnerability of wash facilities in Sahuka union as compared to other union while low vulnerability of access to relief in Karampur as compared to other selected union council. Estimates in table 3 indicated the relationship in public health vulnerability and their six main categories. These estimates were investigated with linear regression in which model illustrated the 95.6% of (R^2). All these categories directly affect public health vulnerability with 98% level of significance. The link between WASH facilities and public health vulnerability is one unit deprivation of WASH facilities will increase 0.169 units of public health.

Table 3: Relationship between the various categories and public health vulnerability

Categories	Measurement (B)	Measurement statement	Significance
WASH facilities	0.169	One unit deprivation WASH facilities increase 0.169 unit of public health vulnerability	0.00
Hospital facilities	0.176	One unit deprivation hospital facilities increase 0.176 unit of public health vulnerability	0.00
Household characteristic	0.185	One unit decrease quality of HH characteristics increases 0.185-unit public health vulnerability	0.00
Adaptation strategies	0.183	One unit absence of adaptation strategies increases 0.183 unit of public	0.00

		health vulnerability	
During disaster state	0.191	One unit worsening disastrous (flood) condition increases 0.191-unit public health vulnerability	0.00
Access to relief	0.091	One unit deprivation of access to relief increase 0.091 unit of public health vulnerability	0.023

Estimates indicated the relationship between public health vulnerability and hospital facilities as one unit deprivation in hospital facilities increase 0.176 unit of public health vulnerability in the residents of study area. Public health vulnerability and household characteristics estimates highlighted as one unit decrease in quality of household characteristics increase 0.185 unit of public health vulnerability. Adaptation strategies and public health vulnerability estimates illustrated as one unit absence of adaptation strategies increase 0.183 unit of public health vulnerability. Relationship between during disaster state and public health vulnerability elaborated as one unit deprivation of access to relief increase 0.191 unit of public health vulnerability. Access to relief and public health vulnerability estimates indicated as one unit deprivation of access to relief increase 0.091 unit of public health vulnerability among the inhabitants of the study area.

4. Conclusion and suggestions

The research work focused on the estimation of public health vulnerability in flood prone areas of Punjab, Pakistan. Public health vulnerability estimated values indicated poor health status among rural flood prone inhabitants residing in neighboring of Sutlej River of district Vehari Punjab Pakistan. In this study particularly focused the association in various livelihood categories and public health vulnerability in flood prone areas. Estimates of the research illustrated as Vehari district flood prone communities deprived status regarding health perspectives and living standard. Higher deprived status of WASH facilities and hospital facilities indicated in overall study areas because of inadequate access of clean fresh water and inappropriate sanitation system. Outdated and poor sanitation sewerage system and lack of purified drinking water caused multiple household health issues. Deprivation in hospital facilities in these flood prone rural areas causes to rising severe health related issues. Increased floods frequency raised various agricultural crop losses which ultimately amplified food security issues to living communities of flood prone areas. Limited adaptation strategies and inadequate access to relief regarding flood disasters also consider reason of rising health vulnerability among research area. Deprived status of inhabited population regarding lower schooling, poor health and declined standard of living highlighted the higher public health vulnerability among flood prone communities. In this perspective some proper policy measures need to focus to protect flood prone inhabited communities from consecutive floods such as constructing new and upgrading existing water reserves to increasing water storage capacity.

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