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Social, Economic, Environmental, and Physical Vulnerability Assessment: An Index-Based Gender Analysis of Flood Prone Areas of Koshi River Basin in Nepal

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Abstract: Gender analysis in vulnerability assessments is needed in disaster risk reduction (DRR). This study examined headship-based household vulnerabilities in the Koshi River Basin of Nepal. This comparative study between male-headed households (MHHs) and female-headed households (FHHs) analyzed the social, infrastructural, economic, and environmental components of vulnerability assessments. A mixed method was used to collect data, including a survey of 216 households, 15 key informant interviews, 40 in-depth interviews, and 8 focus group discussions. The results from the weightage average index (WAI) revealed that the FHHs are more vulnerable in all components. Social and physical components show greater vulnerability for FHHs compared to economic and environmental components. The *t*-test showed that the difference in multidimensional vulnerability is highly significant ($F = 3.423$, p -value = 0.000). The WAI calculation showed 42%, 51%, and 7% FHHs and 6%, 35%, 49%, and 10% of MHHs are in very high, high, moderate, and low levels of vulnerability, respectively. Sociocultural norms were the main factors driving the gap which affected households' ability to respond to and recover from flood disasters and impacted the DRR process. The study suggests that more attention is given to FHHs through increased access to services, capacity building, awareness training, livelihood initiatives, participation in preparedness activities, and inclusion in the DRR process to minimize the impact of floods in the future, particularly for FHHs.

Keywords: vulnerability; assessment; flood; gender; Koshi River Basin; Nepal



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1. Introduction

The increasing trend in the frequency and intensity of disasters [1,2] has had significant impacts on human lives, assets, social systems, and values exposed to hazards [3]; and their consequences are severe for households [4]. The paradigm shift in disaster management to disaster risk reduction is the main thrust of the Sendai Framework for Disaster Risk Reduction's (DRR) emerging concept of resilience in policies and practices [5]. To reduce disaster risk, mitigation measures need to be identified [6] by assessing the risk to communities. Risk is considered to be a combination of hazard and vulnerability [7,8], thus, it is important to understand the degree of vulnerability at the household level to reduce risk and potential harm [9,10].

Hazards turn into disasters when they strike vulnerable people. Vulnerability is the human dimension of disasters, and poverty, inequality and discrimination can make people vulnerable. For instance: informal workers often lack insurance, people with disabilities are not always able to evacuate, and minorities may be refused access to shelters. Wisner [8], p.11, defined vulnerability as "the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard." Disasters impact different segments of the population unequally based on different levels of vulnerability linked to social, physical, and environmental resources people have access to or control over. The state of vulnerability results in differentiated

physical, social, psychosocial, socioeconomic, sociodemographic, and political impacts on society [11]. The level of vulnerability of the people can affect every stage of disasters from coping, preparing, and also in terms of recovering from the impact of the disaster. The identification of vulnerable populations and the factors that contribute to their vulnerability is a crucial process for effective disaster risk reduction [12]. Population growth, distribution, social diversity, social and economic characteristics, culture, and languages determine vulnerability to disasters.

The impact of natural hazards on people is not equal [13], and gender is an important factor determining how societies shape their responses to disasters [14]. Gender norms influence women's and men's disaster vulnerability differently [15,16], and gender inequalities affect women's vulnerability more during and after natural hazards [17,18]. Over the last few decades, many studies have been conducted on gender-differentiated disaster impacts and many researchers argued that the subordinated and dependent status of women has made them more vulnerable to disasters due to existing gender roles. This vulnerability is particularly acute in resource-poor developing countries [14]. These barriers have resulted in greater economic insecurity, inaccessibility to resources, and less community participation, which contribute further, in a vicious cycle, to women's vulnerability in times of disaster [19]. In a study, Bradshaw and Fordham [20] found that the root causes of disaster vulnerability are limited access to income, health and social services, educational attainment, and social network. All these factors tend to have large gender gaps and/or more limited access for women.

In the disaster literature, most of the gender-based vulnerability studies have focused on intrahousehold assessment. Some other studies are from a thematic perspective, that is food and nutrition [21,22], public health [23], livelihood diversification [24–26], and agriculture production [27,28]. Though there is an increasing trend in empirical studies on disaster vulnerability [29], household headship-based studies have been largely missing in the literature [24]. On the other hand, studies show that the number of female-headed households (FHHs) has been continuously growing globally [30,31]. In Nepal, the number of FHHs has rapidly increased over the years, from 12% of all households in 2001, 19% in 2006, 24% in 2011, and 31% in 2016 [32]. Due to unequal social norms, FHHs have limited access to services and resources in the community and have fewer opportunities to participate in community work [33–35]. FHHs have less access to land, labor, credit, and insurance [36]. They are socially discriminated against, resulting in a high work burden, less control over resources, more mobility constraints, and less social support from social networks [37].

Studies show that gender roles influence the ability of MHHs and FHHs to face the impacts of disaster differently in terms of access to resources and opportunities. Moreover, gender norms restrict women's mobility, choice, and ability to make decisions [38]. This affects FHHs' preparedness and coping strategies to be resilient to flood disasters. MHHs have more access to participate in community activities in many countries. Moreover, many empirical social studies have shown that vulnerability to disasters is often determined based on different social characteristics like class, religion, and gender [39].

Gender-specific social norms shape the power structures of the head of households [25] and influence their capacity to make decisions to be resilient to disaster impacts [40]. In Nepal, gender roles influence the headship's ability to access economic opportunities such as income, savings, and consumption to sustain the households. FHHs have less access to these opportunities, which contributes to their vulnerability [41].

Moreover, some previous studies show that the HH work burden limits women's access to participate in community activities and is contributing to their greater vulnerability to disasters in Nepal [42,43]. Women are primarily responsible for care work, preparing food, and fuel collection [44] and their responsibilities to care for the children, family, livestock, and household belongings [44] increase during disasters.

MHHs and FHHs may experience vulnerabilities differently during flood disasters, and they may have different needs to address [33,45]. Using headship-based empirical

research in disaster vulnerability is essential to assess the level of household vulnerability and generate needed policies and interventions to reduce flood risk and build a resilient community [33]. In this context, it is imperative to assess MHH- and FHH-based multidimensional vulnerability in order to help reduce flood risk. As such, this research proposes a multidimensional methodology for assessing gender-based vulnerability and its application using the four components (social, physical, economic, and environmental) suggested by UNISDR [46]. So, the main objective of the paper is to assess the male- and female-headed households' vulnerability in a flood-prone area in Nepal in order to recommend policies and interventions to reduce flood risk and build a resilient community. Vulnerability has diverse components and is multifaceted, thus, it requires an integrated methodology to assess all its components together [47]. This study will attempt to quantify a series of indicators to measure gender-based social, infrastructural, economic, and environmental dimensions of vulnerability assessments.

Nepal stands in the top 20 multi-hazard-prone countries and its vulnerability has been ranked 4th in climate change, 11th for earthquake, and 30th in flood [48]. A global report shows that Nepal ranks 23rd globally in the death toll from natural hazards for the period from 1971 to 2015; 7th in ranking in terms of deaths by floods, landslides and avalanches combined; and 8th for flood-related deaths alone [49]. As 23.74% of the population is under an annual threat to flood, Nepal ranks 11th in terms of disaster vulnerability in the world [50]. Steep and rugged topography, fragile geology, and very high intensity rainfall patterns during monsoon are the causes of floods, especially in the southern part (Terai plain) of Nepal. Each year, thousands of people are affected by floods, which result in massive death and loss of property, land, assets, and livestock. In the context of increasing numbers of FHHs [32] in rural communities in Nepal, we hope the study will be useful to improve policies and interventions for disaster risk reduction, preparedness, and mitigation.

2. Gender and Disaster Vulnerability

In the literature conceptualizing disaster risk, vulnerability is considered an important and defining part of DRR [8]. Various fields of science have used this multifaceted term according to their applicability. In disaster risk science, biophysical, social, economic, and environmental factors determine the level of vulnerability to disasters [21,32]. So, vulnerability is in part a socially constructed phenomenon that ultimately manifests in stratification and unequal impacts among different groups of people in society. Consequently, any risk reduction process needs to take into account a vulnerability assessment of the community. The assessment produces the knowledge and analysis of social, economic, physical, and environmental associated factors and their root causes [21,36,51].

Some scholars argue that vulnerability is determined by social inequalities rooted in gender, class, culture, race, age, power structures, health condition, education status, household size, and resources available to cope with crises [52,53]. Studies found that women tend to be at higher risk from disasters because of pre-existing disadvantages in social, economic, political, legal, and cultural status and opportunities [54,55]. This situation is particularly evident in developing countries where a higher proportion of women and girls lack access to resources and decision-making in information, finance, personal health, education, training, and rights [56]. Due to the lack of training and education, women are forced to work in low-wage informal sectors and earn lower incomes, which may limit their ability to diversify their livelihood capabilities or increase their resilience against floods [57]. For instance, nearly 90% of women in agriculture and more than 70% of women in street vending, garments, and construction are working as informal workers in India [58]. Similarly, more than 70% of the workforce in the low-wage agriculture sector is composed of women in rural Africa [59]. Low-waged employment tends to increase women's vulnerability to disasters [60].

Some other studies show that poverty, social marginalization, and lack of life-saving skills have increased women's vulnerability to disasters [61]. Scholars argue that socially

constructed unequal sources of vulnerability should be addressed to build a gender-sensitive resilient community [56]. Enarson [62] argued that, apart from poverty, women's susceptibility to disaster is also influenced by their gendered roles as mothers and caregivers, and that their ability to seek safety during disaster emergencies is often restricted by their responsibilities to the very young and the very old, both of whom require help and supervision [59], and such gendered responsibilities are historically rooted in cultural practices and power structures in societies [56]. Similarly, in the case of household headship, FHHs are dependent on agriculture and land as their most productive asset but statutory or customary laws often restrict women's land and property rights [36]. Such laws hinder de facto FHHs from using their lands as collateral to enable economic recovery in post-disaster situations.

A study in South Africa found that FHHs have lower earnings, fewer assets, and less access to productive resources such as land, financial capital, and technology than MHHs. Moreover, FHHs are more likely to have a higher work burden, and consequently, FHHs have mobility constraints and have to work fewer hours or choose lower-paying jobs [25]. Furthermore, FHHs face various barriers to accessing financial support or services, including lack of financial literacy, lack of financial confidence, limited use of networks, as well as cultural prejudices and negative stereotyping towards women as entrepreneurs [63]; and their access to and control over resources contributes to their socioeconomic disadvantages and makes them more vulnerable to disasters [25]. While the exposure to disaster may be the same for men and women in any given location, researchers argue that there are varied gender-based differences in vulnerability [7].

In the disaster literature, some researchers have assessed vulnerability in different aspects separately. The most common aspects are social [8,52,64], physical [65,66], economic [67], institutional [68], and livelihood-based [69]. Some researchers [69–73] have used IPPCC models (exposure, sensitivity, and capacity) to assess disaster vulnerability. Some other researchers have suggested using a trend analysis approach to the economic damage of past occurrences [74]. Though there are all these vulnerability assessment models, it has been argued that what is missing is a single assessment framework that integrates different components within different disciplines [9,51,75]. So, this study will propose a gender-based framework to assess multidimensional vulnerability using the four components (social, physical, economic, and environmental) suggested by UNISDR [46].

3. Methodology

3.1. Research Design and Methods

The study used a mix-method research design to collect and analyze the data. The mix-method approach aims to complement, triangulate, and validate the data and findings; and it also provides a better interpretation of a greater depth for a comprehensive answer to the research problem [76,77]. This study applied mixed sampling techniques such as simple random sampling for household selection and nonprobability sampling for cluster selection based on the elements (MHHs and FHHs in the flood-prone community) and the objectives of this research.

Four communities (Barahakshetra, Mahedranagar, Shripur, and Haripur) in the Sunsari district of Nepal (Figure 1), which are highly prone to annual flooding and occasional bank erosion of the Koshi River, were purposively selected for this study. The Koshi, a unique river in the world that has horizontally changed its course more than 120 km in the last 250 years [78], is the largest river in Nepal flowing from the hillside to the plain area of those four communities of the Sunsari district; and making the communities highly vulnerable to flood hazards compared to other districts. Moreover, the study area is located in the lower part of the Koshi river basin in the southeastern part of Nepal, where the altitude is in the range of 65 m above sea level in the Terai to over 8000 m in the high Himalayas. The river originates from the Tibetan Plateau of China, flows to the Sunsari district of Nepal, and ends at the Ganga in Bihar (a northern state of India).

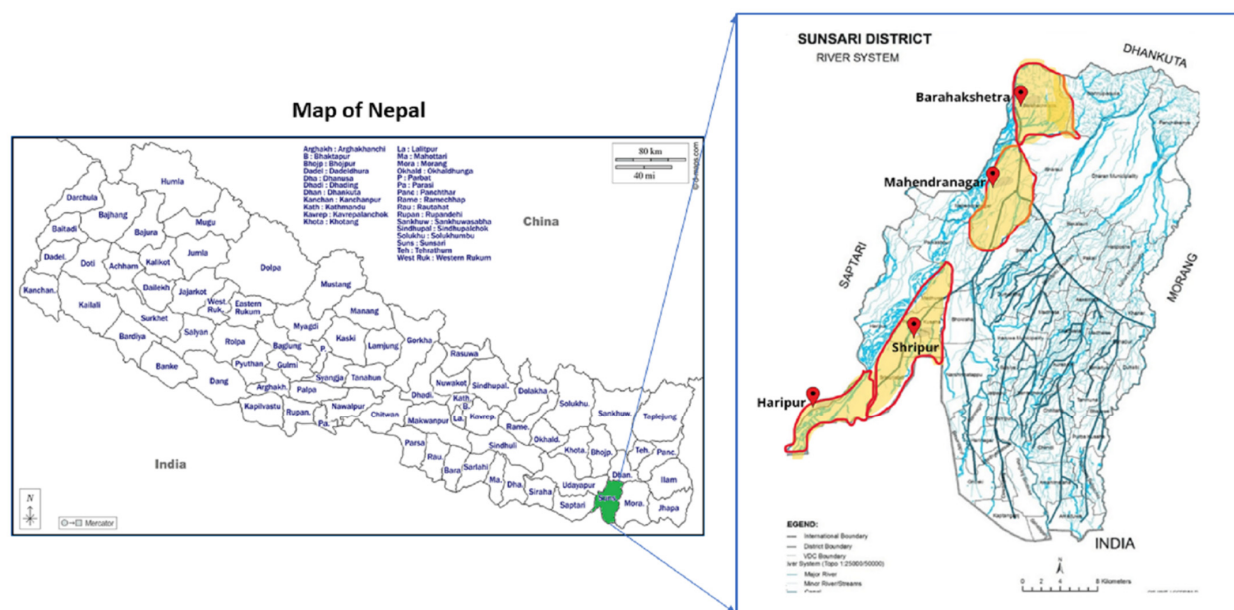


Figure 1. The study area: the flood-prone areas of Koshi Basin in Nepal.

The government of Nepal has ranked Sunsari District under the category of high vulnerability to flood disaster considering several indicators (i.e., population density, ecology/protected area and forest coverage area, occurrence, death, injured population, property loss, rainfall exposure, socio-economic-human development index, human poverty index, gender development index, human empowerment index, infrastructures-road length, area, landline phone and population technology-irrigation coverage area [79]). Based on the historical events during the period of 1971–2009, deaths, injuries, affected population, and properties damaged, the Sunsari District is ranked 7th in different classes of flood risk among all districts of the country [80].

A structured questionnaire for the household surveys and semi-structured checklists for key informant interviews (KII), focus group discussions (FGD), and in-depth interviews (IDI) were developed to gather the gender-based information of male- and female-headed households on the social, physical, economic, and environmental dimensions of flood vulnerability. Pretesting was done in the field in May 2018 to streamline the questionnaire. After finalizing the questionnaire, KIIs of 15 persons, IDIs of 40 HHs, 8 FGDs, and 216 HHs surveys were done.

Using the Yamane [81] formula [$n = N / 1 + N(e)^2$], out of a total of 14,020 HHs [82], 216 HHs were sampled for the quantitative data collection of the household survey (Haripur: M-21, F-21; Shripur: M-26, F-26; Mahendranagar: M-39, F-39; and Barahakshetra: M-22, F-22). Out of the total sample size, a proportionate number of households were chosen from each community and equal numbers of MHHs and FHHs were determined from the respective communities for the household survey. There may be chances of maximizing the statistical strength analysis in equal-sized groups of the sample [83]. Moreover, the primary purpose is to ensure a comparison of the data between MHHs and FHHs. The formula was used with a confidence level of 95% and a precision of 7% to determine the sample size. Since the socio-economic background of all villages was comparable and they shared similar cultural backgrounds, and considering the specific population, 7% precision was applied as suggested by Lwanga and S. Lemeshow [84]. An equal number of MHHs (108) and FHHs (108) were interviewed. As respondents were household heads from each respective household, this non-proportional sample was decided in light of the focus of the study on FHHs (and MHHs as a comparative group).

Fifteen KIIs with the heads of the communities, local DRR Committee, and local NGO were conducted, followed by the HH survey using structured questionnaires that contained multiple choice and Likert scale questions exploring their experiences of disasters.

The HH survey was followed by IDIs of 20 MHHs and 20 FHHs (5 MHHs and 5 FHHs for each of the 4 villages) exploring in-depth the ‘how’ and ‘why’ of what was found in the survey and their stories as narratives. The IDI respondents were a subset of the survey since the information collected from both methods was different. The quantitative data were collected with the help of eight research assistants, followed by in-depth interviews and then 8 FGDs (2 in each community). Local village representatives and women’s groups supported the selection of the participants of FGDs. Using the checklist, the first author of this paper facilitated all of the FGDs with the support of research assistants by taking prior consent of discussants.

Quantitative data were analyzed using descriptive and inferential statistics, while the thematic analysis method was used for qualitative analysis as suggested by Braun and Clarke [85]. Both primary data sources were used to complement the results to elaborate on the findings.

3.2. Indicator Selection, Weights, and Composite Index

This study has applied the composite index (CI) method to assess the gender perspective of household-based flood vulnerability to flood disasters. The composite index is considered a powerful tool for vulnerability analysis, for summarizing the diverse data in a simpler way for easy comprehension [86], and different domains can be measured through a combination of various indicators. After proper allocation of weights to classes of each indicator, the index for each factor was calculated, as the original datasets were transformed to respective weights for computation of the composite index, following the method some researchers performed in their studies [47,87,88]. According to the vulnerability model of UNISDR [46], disaster risk is primarily rooted in the situation of four inherent factors of social, physical, economic, and environmental vulnerabilities that need to be assessed and managed to reduce disaster risk. The index-based approach of this study was developed to assess those four factors to analyze the household-based gender perspective of flood vulnerability.

For smooth and clear interpretation of the Social Vulnerability Index (SVI), Physical Vulnerability Index (PVI), Economic Vulnerability Index (EVI), and Environmental Vulnerability Index (EnVI), the quartile method was used to group the households into four classes of vulnerabilities (such as low, moderate, high, and very high) to understand the degree of MHH- and FHH-based vulnerability to flood disaster. A *t*-test was used to judge the difference between MHHs and FHHs in each component. Indices were developed to analyze the gender-based vulnerability between MHHs and FHHs considering all the indicators mentioned in Appendix A. The method was a reference to a similar type of empirical study by different researchers [23,47,87,89], where similar indices of vulnerability were created to assess the vulnerability status in their respective studies. The originality of this research is to construct and use the indices to test the male- and female-headed household-based vulnerability in the context of flood disasters.

The primary dataset was used towards the subjectively weighting technique to assign values to respective classes of phenomena of each indicator, and further formulated indices based on Equation (1). Indicators were chosen through an extensive literature review for each dimension of vulnerability. The interpretation of researchers and relevance is mentioned in Appendix A, the subjective assessment method for giving weights to different indicators was based on the number of studies of disaster vulnerability and household headship-based gender analysis, from which these indicators have been selected. These indicators were chosen from empirical studies in the disaster risk science and climate change fields. Indicators were scrutinized with a view to the local conditions and were adjusted accordingly. Ten indicators were used for the social component and six indicators were used for physical, economic, and environmental components. Each component

has been given equal importance, as all communities experience flood hazards primarily because of the Koshi River. Therefore, an average has been calculated for all factors to analyze the MHH- and FHH-based multidimensional vulnerability index.

For the computation of the headship-based vulnerability composite index, this study used the reference of the data calculation technique applied by other empirical studies on flood vulnerability assessments [47,65,87,88]. This study used the original equation as the standard.

$$CI = (W_1 + W_2 + \dots + W_n) / n = \sum_{i=1}^n \frac{W_i}{n}. \quad (1)$$

The CI stands for the composite index, W_1 to W_n are the weightage of individually transformed values of indicators, and n is the number of indicators used in particular components for computing the composite index. Following this general principle, this study calculated the SVI, PVI, EVI, and EnVI of every sampled household. Similarly, the Multidimensional Vulnerability Index (MVI) for both MHHs and FHHs was calculated using Equation (2).

$$\begin{aligned} \text{Social Vulnerability Index (SVI)} &= \sum_{i=1}^{10} SW_i / n; (n = 10) \\ \text{Physical Vulnerability Index (PVI)} &= \sum_{i=1}^6 PW_i / n; (n = 6) \\ \text{Economic Vulnerability Index (EVI)} &= \sum_{i=1}^6 EW_i / n; (n = 6) \\ \text{Environmental Vulnerability Index (EnVI)} &= \sum_{i=1}^6 EnW_i / n; (n = 6) \end{aligned}$$

$$\text{The Multidimensional Vulnerability Index (MVI)} = \frac{SVI + PVI + EVI + EnVI}{4} \quad (2)$$

As the general principle of WAI methodology, the original values of the indicators have been transformed to 0 and 1, based on the vulnerability level, in order to compute the indices. The values closer to 0 signify low vulnerability, whereas values closer to 1 denote high vulnerability. Each variable was further divided into classes depending on its characteristics. For example, the nature of the response was divided into two (yes or no response), three, four, five, and six classes as required. With extensive support from the literature, classes were framed to demonstrate the degree of variation as much as possible. In dual classes, the values were 0 and 1. The indicators with three classes were assigned the values 0.33, 0.66, and 1; for four classes, the values were 0.25, 0.50, 0.75, and 1; for five classes, the values were 0.2, 0.4, 0.6, 0.8, and 1; and for six classes, the values were 0, 0.83, 0.67, 0.5, 0.33, and 1. Thus, the composite index for each component fell between 0 and 1. Appendix A shows the list of the indicators used for the different dimensions, the classes and values, and the empirical studies that have used these indicators.

4. Results

The headship-based gender-disaggregated indices for each component were calculated using the methodology described in the previous section along with the demographic profile of respondents. Statistical tests were performed to understand the level of difference between MHHs and FHHs in each dimension. Each of the dimensions of the vulnerability of MHHs and FHHs have been described separately, followed by an explanation of the headship-based perspective of multidimensional vulnerability.

4.1. Demographic Profile of Respondents

Table 1 shows the headship-based summary of the demographic characteristics of the sampled respondents. The majority of respondents were between the ages of 40 and 60 from MHHs, and 30 to 50 years old from FHHs. The data suggest that 47% of total HH respondents and 47% of MHHs have a family size of six to nine members, whereas the family size of 49% of FHHs is limited to less than five members. Agriculture is the main occupation of 71% of MHHs and 79% of FHHs are engaged in agriculture along with household work. The monthly income of 74% of MHHs and 59% of FHHs is less than NPR 25,000, and 18% of MHHs and 59% FHHs have a monthly income ranging from NPR 25,000 to NPR 50,000. The results suggest that FHHs have comparatively higher monthly incomes

than MHHs. This is due to the fact that 51% of MHHs rely only on agriculture as the source of income, whereas 48% of FHHs rely on their income from agriculture as well as from remittances. Spouses of 90% of FHHs are away from home for economic employment in a foreign country (29%) or the same country (61%). The data on education suggest that 30% of FHHs and 26% of MHHs are illiterate, 33% of FHHs and 21% of MMHs are capable of simple reading and writing. Around 53% of MHHs and 63% of FHHs do not have any formal education.

4.2. Social Vulnerability

The social vulnerability index of households varied from 0.20 to 0.96, with a mean value of 0.57 in the study area. The vulnerability of the FHHs is significantly higher than MHHs ($F=1.106$, p value = 0.000) as shown in Table 2. The results showed that 6% of MHHs and 53% of FHHs are in the category of high vulnerability, whereas 8% of FHHs were in the very high category. Moderate levels of the category were observed in 37% of MHHs and 34% of FHHs. About 57% of MHHs and only 4% of FHHs were in a low category of vulnerability.

The WAI results in Figure 2 also indicate that FHHs are more vulnerable than MHHs. Swimming skills (MHHs—0.9 and FHHs—0.81), participation in awareness activities (MHHs—0.9 and FHHs—0.63), and trust in religious organizations (MHHs—0.49 and FHHs—0.71) have contributed to more FHHs' vulnerability than MHHs. There is a significant difference in swimming skills ($\chi^2 = 113.64$, p value = 0.000) between MHHs' and FHHs' members. About 91% of MHHs and only 18% of FHHs have a family member who has swimming skills. A family that has a member with swimming skills can better save a life during a flood.

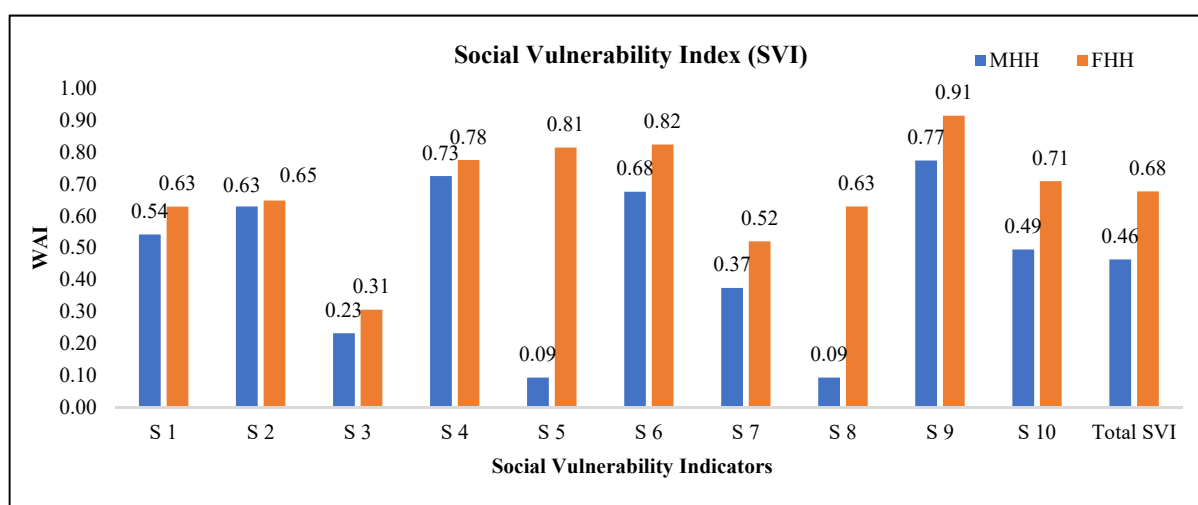


Figure 2. Social Vulnerability Index (SVI) of MHHs and FHHs. S1 to S10 are mentioned in the Appendix A.

Table 1. Demographic profile of respondents (percentage).

Profile	Description	MHH (<i>n</i> = 108)	FHH (<i>n</i> = 108)	Total (<i>n</i> = 216)	Profile	Description	MHH (<i>n</i> = 108)	FHH (<i>n</i> = 108)	Total (<i>n</i> = 216)
Age	21–30	4	16	10	Occupation	Agriculture	71	8	40
	31–40	19	34	27		HH work	1	6	4
	41–50	30	28	29		HH work and agriculture	0	79	39
	51–60	30	15	22		Services	5	1	3
	61–70	15	6	11		Wage Labor	16	1	8
	>71	2	1	1		Business	7	5	6
Household Size	<5	45	49	47	Religion	Hindu	67	75	71
	6–9	47	47	47		Buddhist	4	4	4
	>10	8	4	6		Muslim	29	21	25
Monthly HH Income	<25,000 NPR	74	59	67	Main Source of Income	Agriculture	51	31	41
	25,000–50,000	17	32	25		Daily wages	14	10	12
	50,000–75,000	3	4	3		Business	6	4	5
	75,000–100,000	5	3	4		Remittances	22	48	35
	>100,000	1	2	1		Employment Salary	7	7	7
Education	Illiterate	26	30	28	Spouse Togetherness	Domestic Migration	0	61	31
	Literate	21	33	27		Foreign Migration	1	29	15
	Primary (1–7)	22	16	19		Widow	0	10	5
	Secondary (8–10)	23	18	20		Widower	3	0	1
	High School (11–12)	8	3	5		Staying Together	96	0	48
	Graduate and above	0	1	0					

Table 2. Household-level Social Vulnerability (MHH; $n = 108$ and FHH; $n = 108$).

Gender	Classes	Low	Moderate	High	Very High	Descriptive Statistics	T-Test
	Range	0.20–0.39	0.39–0.58	0.58–0.77	0.77–0.96		
is	No.	62	40	6	0	Min = 0.20	F = 1.106 df = 214 p value = 0.000
	%	57.4	37	5.6	0	Max = 0.96	
FHHs	No.	5	37	57	9	Mean = 0.5706	
	%	4.6	34.3	52.8	8.3	SD = 0.16381	
						Range = 0.76	
Total HHs	No.	67	77	63	9		
	%	31.02	35.65	29.17	4.17		

During an in-depth interview, a 35-year-old from a FHH stated that the selection agency selects only males for swimming training. The same respondent commented that the decision-maker in the agencies who selects those for swimming training is usually a man and prefers a male member for the training. The men are more trusted, according to her, because of their greater physical strength than females. Moreover, women, due to their heavy household work and the usual rush to leave the swimming training place, are not preferred participants. Therefore, the work burden of women as heads of households is the main factor that limits their full participation in skill development training, making them more vulnerable during exposure to disaster. Another 44-year-old from a FHH mentioned that only educated men had a chance to participate in community-level awareness training (IDI-2018). The result shows that 91% of MHHs and 37% of FHHs had participated in flood awareness-related training and programs. The FHHs have reported that the factors that prevent them from attending awareness activities are household work (42%), less priority (24%), feeling old (18%), having less confidence (11%), and religious restrictions (5%) (HHS, 2018). A female FGD discussant noted that “In some cases, a woman was asked to be in the group only to show a number but is rarely consulted during the project and budget work, while the socially active men get every chance to participate in every community activity” (FGD, 2018). Regarding the religious organizations’ activities for disaster, a 48-year-old MHH respondent said that “religious organizations do not have any budget to use in a disaster” (IDI-2018) except for some small portion of the levy of membership. About 47% of women poorly and very poorly trust religious groups, whereas only around 2% of MHHs trust poorly. This study showed that the FHHs’ trust in organizations was low because there was no disaster plan, a lack of any effort to explore resources from other support organizations, and no female participation in religious organizations. Female participation in meetings, planning, and resource generation would raise the trust of FHHs in religious organizations.

Regarding the other social indicators, the result shows that 47% of MHHs have six to nine members, followed by 45% with less than five family members, whereas 49% of FHHs have less than five family members, followed by 47% with six to nine members. The survey showed that about 65% of FHHs and 63% of MHHs had dependent family members. Similarly, about 31% of FHHs and 23% of MHHs had family members with a chronic illness, pregnancy, or disability and need extensive care inside the households. The study showed that there were no significant differences ($\chi^2 = 8.417$, p value = 0.135) between MHHs and FHHs in educational attainment, whereas 30% of FHHs and 26% of MHHs were illiterate and 33% (FHHs) and 21% (MHHs) had just simple literate skills and could only read. The result also showed that 63% of FHHs and 53% of MHHs never received a formal education, whether primary or secondary. About 32% of MHHs and 18% of FHHs have family members who have knowledge of first aid. First aid knowledge can reduce vulnerability. The data showed that there is a significant difference ($\chi^2 = 41.609$, p value = 0.000) between MHHs and FHHs in their perception of the strengths of community cooperation during the disaster. Based on the experience, the MHHs have a comparatively higher level of trust toward the community’s cooperation in disaster situations. The

survey result showed that only 17% of MHHs and 8% of FHHs trusted government programs for DRR.

A key informant, the village head, acknowledged the low female participation in development activities, particularly in DRR activities. The men participate in leadership roles in community work. They are involved in all processes of activities. Male participants are more aware of the limitations and opportunities regarding the available resources. So, their trust in government activities is higher than women, since women have fewer opportunities to get involved in all processes of activities.

4.3. Physical Vulnerability

Having the range of 0.30–0.97, the physical vulnerability index shows that the FHHs (0.74) scored higher than MHHs (0.58) according to Figure 3. The study revealed that about 27% of FHHs and 3% of MHHs are in very high, and 48% of FHHs and 34% of MHHs are in a high level of the physically vulnerable situation; and this component has a statistically highly significant ($F = 4.533$, p value = 0.000) difference between MHHs and FHHs (Table 3).

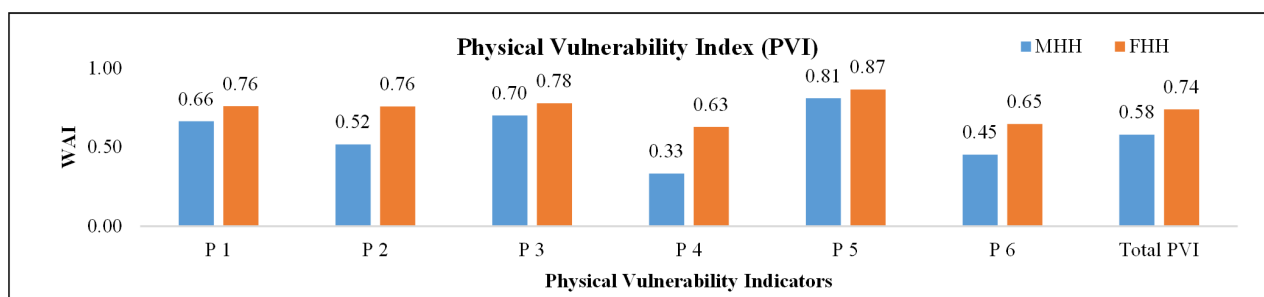


Figure 3. Physical Vulnerability Index (PVI) of MHHs and FHHs. P1 to P6 are mentioned in Appendix A.

Table 3. Household-level Physical Vulnerability (MHH; $n = 108$ and FHH; $n = 108$).

Gender	Classes	Low	Moderate	High	Very High	Descriptive Statistics	T-Test
	Range	0.3–0.47	0.47–0.64	0.64–0.80	0.80–0.97		
MHHs	No.	25	43	37	3	Min = 0.30	F = 4.533 df = 214 p value = 0.000
	%	23.1	39.8	34.3	2.8	Max = 0.97	
FHHs	No.	1	26	52	29	Mean = 0.6602	
	%	0.9	24.1	48.1	26.9	SD = 0.16228	
Total HHs	No.	26	69	89	32	Range = 0.67	
	%	12.04	31.94	41.20	14.81		

Based on the WAI value, the FHHs have scored higher than MHHs in all of the indicators of physical vulnerability. About 63% of FHHs did not have any means of transportation, 76% of FHHs did not give priority to raising the plinth level of the house, and 65% of FHHs did not have an alternative source of drinking water. These were the major reasons for FHHs being more physically vulnerable than the MHHs.

A 44-year-old female respondent shared: “If I were able to buy a bicycle, I would learn to ride and would not depend on others for local transportation” (IDI, 2018). A 58-year-old Muslim male respondent shared: “Most of the women do not cycle because it’s our cultural practices not to encourage women to use bicycles” (IDI, 2018).

The survey showed that only about 2% of HHs have cemented houses. Among them, less than 1% of FHHs and around 3% of MHHs have constructed a fully cemented house; and around 76% FHHs and 52% of MHHs have not done anything to increase the plinth level of the house to survive the floods. “My husband is out of the country, and it is difficult for me to do any kind of maintenance and construction of the house. So, the repair of the

plinth level was not a priority when a male spouse is not at home”, a 55-year-old female respondent shared (IDI, 2018). In FGD, participants said that repairing houses is a matter of money and human resource, which affects income and saving for the family (FGD, 2018).

In Nepal, early warning messages are sent mostly through radio and TV, but the HH survey showed that around 92% of FHHs and 79% of MHHs do have not any reliable means of communication to receive an early warning message. Even when they do, as one FGD participant noted, “We know that we have to keep a radio or any means of communication inside the home, but we give less priority to news type of message” (from women FGD, 2018). Most importantly, around 65% of FHHs and 45% of MHHs could not manage to have an alternative source of drinking water during a disaster. Some of them had managed either a tube well, hand pump, or any small well nearby their kitchen garden. Around 74% of FHHs and 40% of MHHs had poor access to any kind of irrigation for agriculture purposes. There was no irrigation project in the study area, but some of the households that could afford it would try to manage it on their own. While applying a chi-square test, almost all the physical vulnerability indicators were statistically highly significant (p value = 0.000) in MHHs than FHHs, except in communication for an early warning message (p value = 0.028) and alternative source of drinking water during a disaster (p value = 0.004).

The study reveals that remittance as income is higher in FHHs than MHHs, but their priority for expenses is given to paying loans, daily consumption of food, children’s education, health care, etc. Even if FHHs have some savings, they have to wait for their husbands to decide regarding expenses for the physical construction of a house and transportation such as buying a bicycle. The decision-making role is with the husbands, who are not at home. So, on one hand, they do not have enough money to afford it, and if they do, they are not the decision-maker. For transportation, there is a barrier in terms of affordability, but also a cultural barrier that exists for a woman who considers using transportation, which is usually associated with men. In contrast, since men are always the decision-maker in MHHs, they would most likely give priority to physical construction and maintenance.

The study found that the expenses pattern of FHHs does not prioritize the physical infrastructure for drinking water, irrigation, etc., but rather supports immediate daily activities around food, clothes, education, and health, and it suggests that FHHs face a higher level of vulnerability than MHHs.

4.4. Economic Vulnerability

Income and savings are crucial components of economic vulnerability. The result of the study revealed that the MHHs have higher vulnerability than the FHHs with regards to income (monthly income, source of income, and multiple sources), whereas FHHs are more vulnerable than MHHs with regards to saving (monthly saving, insurance, the value of resources).

The WAI of the economic vulnerability of MHHs and FHHs has shown that FHHs (0.79) are economically more vulnerable than MHHs (0.72) (see Figure 4). The economic vulnerability results in Table 4 show that 24% and 35% of MHHs and FHHs, respectively, are in a very high category, while 44% of MHHs and 52% of FHHs are in the high category for economic vulnerability. The t -test shows a highly significant difference ($F = 5.597$, p value = 0.000) in economical vulnerability between MHHs and FHHs.

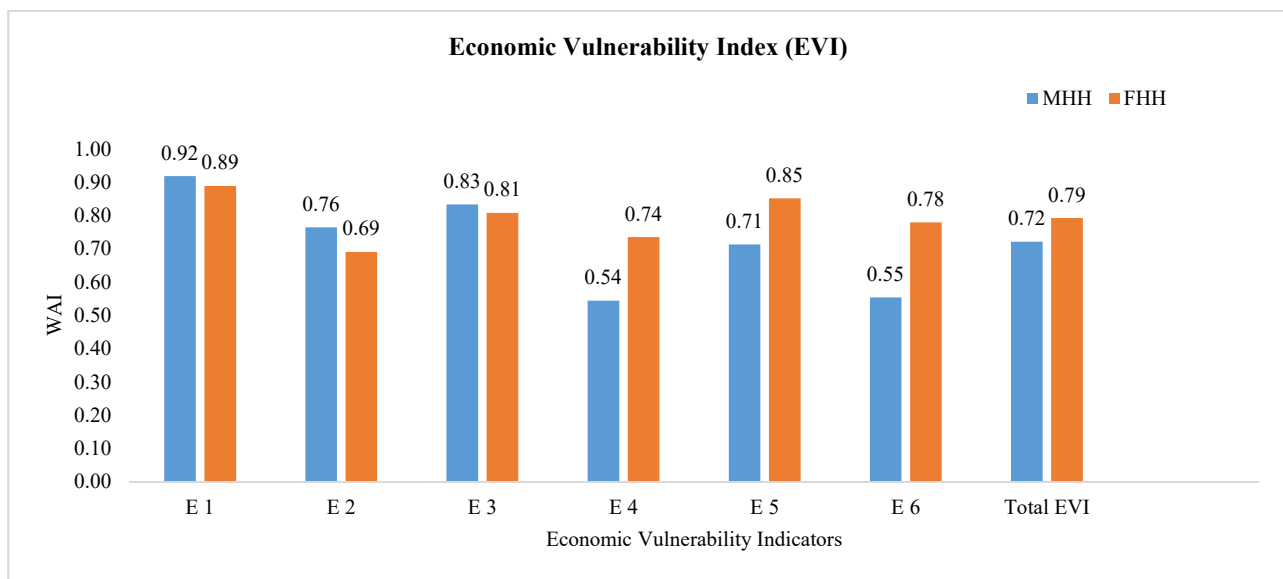


Figure 4. Economic Vulnerability Index (EVI) of MHHs and FHHs. E1 to E6 are mentioned in Appendix A.

Table 4. Household-level Economic Vulnerability (MHH; $n = 108$ and FHH; $n = 108$).

Gender	Classes	Low	Moderate	High	Very High	Descriptive statistics	T-Test
	Range	0.19–0.39	0.39–0.58	0.58–0.78	0.78–0.97		
MHHs	No.	8	27	47	26	Min = 0.19	F = 5.597 df = 214 p value = 0.000
	%	7.4	25	43.5	24.1	Max = 0.97	
FHHs	No.	0	14	56	38	Mean = 0.7567	
	%	0	13	51.9	35.2	SD = 0.14178	
Total HHs	No.	8	41	103	64	Range = 0.78	
	%	3.70	18.98	47.69	29.63		

It has been observed that there is no significant difference ($\chi^2 = 7.495$, p value = 0.112) in average monthly income between MHHs and FHHs. Around 71% of MHHs and 67% of FHHs have a monthly income of less than NPR 25,000, whereas 18% of MHHs and 33% of FHHs have between NPR 25,000–50,000. The main sources of income for the MHHs are agriculture (51%), remittances (23%), daily wage (13%), small business (8%), and salary (5%). Similarly, the incomes of FHHs are from agriculture (45%), remittances (47%), daily wage (8%), and small business (3%). The results revealed that agriculture is the main source of income for 51% of MHHs (and remittances for 47% of FHHs). Salaried employment is considered the most reliable income, which none of the FHHs have, whereas around 5% of MHHs have it. About 55% of MHHs and 45% of FHHs do not have multiple sources of income. Regarding saving practices, a significant variation ($\chi^2 = 76.300$, p value = 0.000) has been observed between MHHs and FHHs. MHHs have more monthly savings than FHHs. Similarly, 71% of MHHs and 85% of FHHs do not have any kind of insurance. Regarding the HH-based property, MHHs have more valuable resources inside the HH than the FHHs.

Economic vulnerability is high for both MHHs and FHHs, but the difference can be seen as slightly lower compared to other vulnerabilities as FHHs (48%) rely on remittances since 90% of female respondents' spouses leave home (29% to foreign countries and 61% for domestic destinations) for economic employment. The reason behind the FHHs having a better income is that remittances are sent by their spouse and/or another family member (son), but the MHHs' spouses who are at home with a non-migrating male household head are not getting any remittance. Among the MHHs, the source of income for 51% of those

who are living at home is agriculture. So, they have to manage by selling other resources, fixed assets, farm animals, etc., while FHHs incur more expenses for daily consumption. A 54-year-old female IDI respondent said, “I have to spend the money that my husband sends for daily expenses and pay back the loan that we have taken to send him for foreign employment; and in terms of the amount of savings, FHHs have a lower amount than MHHs.” It has been found after the FGD discussion that the husband still decides (from a distance) on how much money to save and all the daily expenses. So, the lack of earning and decision-making roles has made FHHs more vulnerable than MHHs.

4.5. Environmental Vulnerability

As shown in Figure 5, the index value of WAI has shown that FHHs (0.76) have a higher vulnerability status than MHHs (0.70). The household-level environmental vulnerability shows that 20% and 31% of MHHs and FHHs, respectively, are in the very high category, and 32% (MHHs) and 36% (FHHs) are in the high category (see Table 5). The *t*-test shows a highly significant difference ($F = 24.45$, p value = 0.000) between MHHs and FHHs in environmental vulnerability.

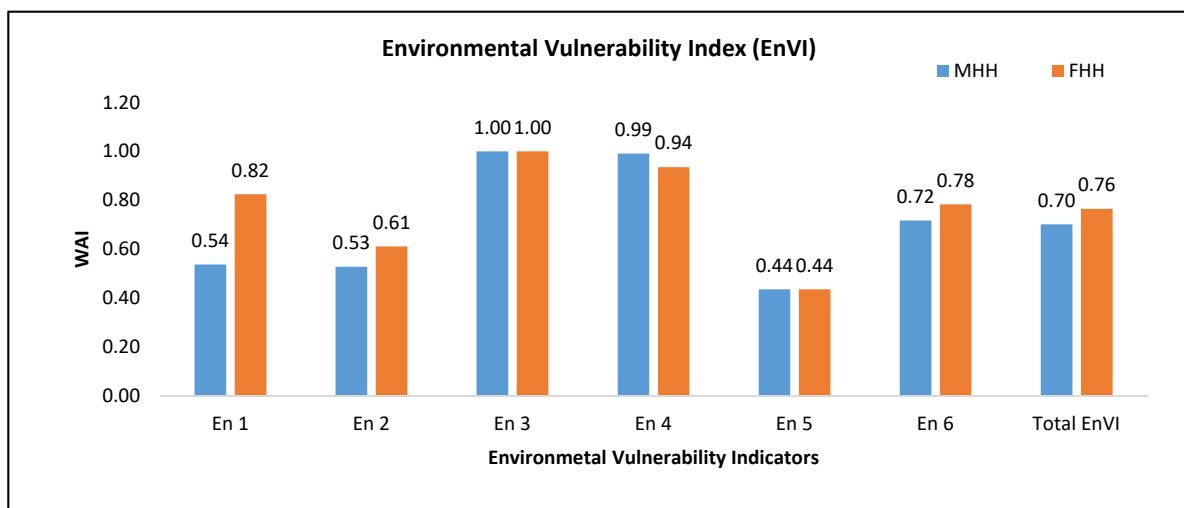


Figure 5. Environmental Vulnerability Index (EnVI) of MHHs and FHHs. En1 to En6 are mentioned in Appendix A.

Table 5. Household-level Environmental Vulnerability (MHH; $n = 108$ and FHH; $n = 108$).

Gender	Classes	Low	Moderate	High	Very High	Descriptive Statistics	T-Test
	Range	0.30–0.48	0.48–0.65	0.65–0.83	0.83–1.00		
MHHs	No.	21	31	34	22	Min = 0.30	F = 2.475 df = 214 p value = 0.000
	%	19.4	28.7	31.5	20.4	Max = 1.00	
FHHs	No.	11	25	39	33	Mean = 0.7333	
	%	10.2	23.1	36.1	30.6	SD = 0.18230	
Total HHs	No.	32	56	73	55	Range = 0.70	
	%	14.81	25.93	33.80	25.46		

This study has six selected indicators for the assessment of the environmental vulnerability of MHHs and FHHs. Around 54% of MHHs and 82% of FHHs do not have pipe-supplied drinking water, while 53% of MHHs and 61% FHHs are using an open toilet. It should be noted that all of the respondents do not have a sewage disposal system and 99% of MHHs and 94% of FHHs openly dispose of their animal wastes.

Due to the yearly flooding, the devastation caused by the Koshi flood of 2008 covered the farmland of 44% of respondents with sand. To increase crop productivity, 81% of

FFHs and 57% of MHHs used a high amount of chemical fertilizer and pesticides. While discussing its effect on health, a 43-year-old female respondent said, “I quickly get chemical fertilizer and pesticides from the market to increase the production to control crop diseases. I do not know its health effect.”

A 48-year-old female IDI respondent said: “I have a tube well for drinking water. There are official formalities to apply for water supply from the local government. My husband is not at home and this land and house are in his name. Once he comes home next year, we will apply to the municipality.”

4.6. The Multidimensional Vulnerabilities

Based on the model for assessment of flood vulnerability developed by UNISDR, the previous sections highlighted the results of four components of flood vulnerability and the weightage of factors that contributed to these components. The results of the composite index have shown that the FHHs are more vulnerable than the MHHs in all components (social, physical, economic and environmental). However, Figure 6 reveals interesting insights into the vulnerability of MHHs and FHHs in each component that most of the indicators (representing the factors that contributed to vulnerability) of the social and physical components have a larger gap between MHHs and FHHs than indicators of economic and environmental components.

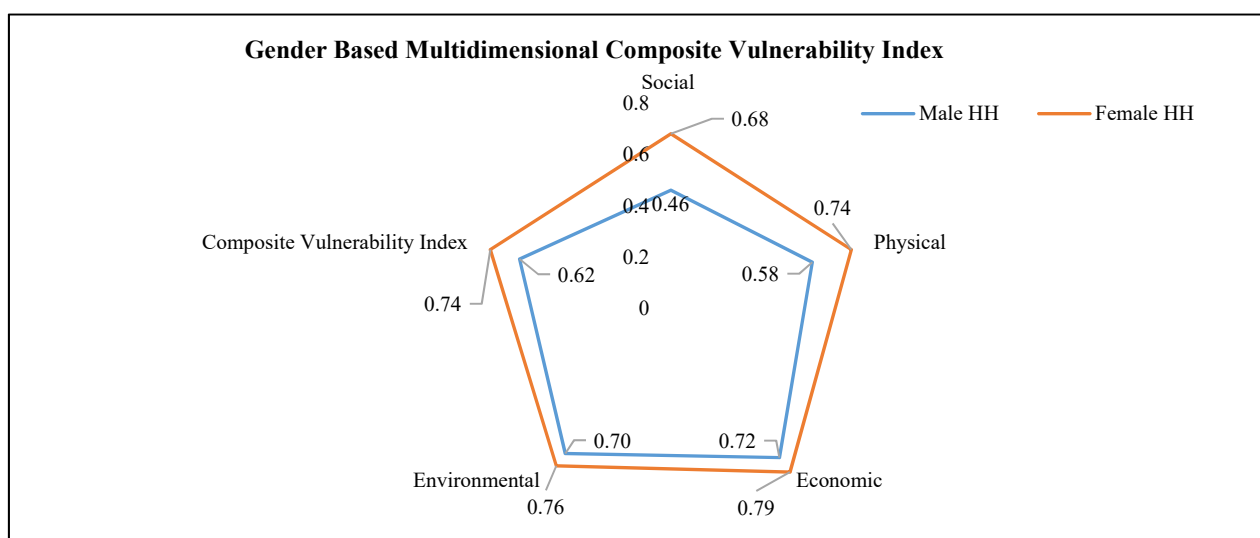


Figure 6. The Gender-Based Multidimensional Composite Vulnerability Index of MHHs and FHHs.

The reason behind the FHHs having a better income is found in the remittance sent by their spouses and/or another family member (son), whereas MHHs are at home with their spouses and not receiving remittance. Due to the income aspect of the economic component, FHHs are better off than MHHs, but in terms of savings, they are worse off than MHHs as their expenses are higher. So, FHHs are still more economically vulnerable compared to MHHs. In some of the factors in the income part of the economic (monthly household income, source of income, and having multiple sources of income) and environmental (managing animal waste) components, MHHs are seen as more vulnerable than FHHs.

Two indicators (sewage disposal system and farmland covered by sand and debris) have equal weightage in the environmental component. The result revealed that the degree of multidimensional vulnerability has been observed as significantly different ($F = 3.423$, p value = 0.000) and varied between MHH (0.37–0.80) and FHH (0.57–0.89).

Based on the WAI, the result according to Figure 7 shows that 42%, 51%, and 7% of FHHs are in a very high, high, and moderate level of vulnerability, respectively. Similarly, 6%, 35%, 49%, and 10% of MHHs are in very high, high, moderate, and low levels of vulnerability, respectively. The result revealed that the FHHs have a higher percentage

than MHHs in the high and very high categories, and a lower percentage in the low and moderate categories.

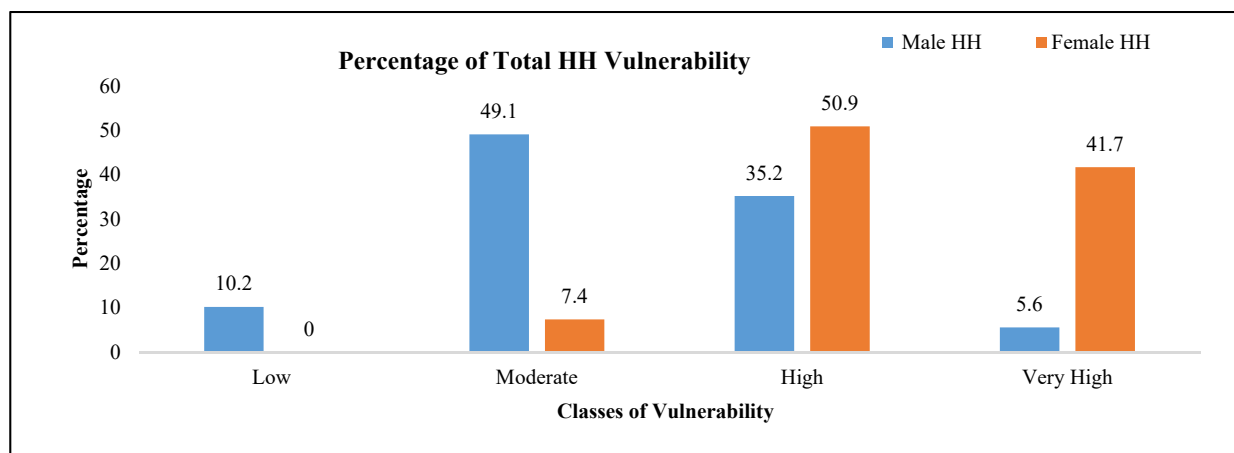


Figure 7. Total Vulnerability Index of MHHs and FHHs.

Based on the WAI calculation, an interesting insight into the result of CVI is that, though the range of difference in vulnerability between MHHs and FHHs is more pronounced in social and physical components than in economic and environmental components, the level of vulnerability is higher in the economic and environmental than in the social and physical components. In the component-wise ranking, the economic component has the highest ranking for both MHHs and FHHs at a WAI of 0.72 and 0.79, respectively. Furthermore, the environmental component is second in ranking for MHHs and FHHs at a WAI of 0.70 and 0.76; the third is physical at a WAI of 0.58 and 0.74 and the last ranking components are social at a WAI of 0.46 and 0.68 for MHHs and FHHs, respectively. Overall, the gender-based multidimensional vulnerability shows that the FHHs need to be given more attention in terms of capacity building, awareness training, livelihood initiatives, participation in community preparedness activities, and the inclusion planning process, etc.

5. Discussion and Conclusions

The burden of work inside the household limits women's participation in preparedness activities, which may cause differential vulnerability. There are partially unobserved factors such as gendered inequalities in bargaining power in the community, and social and legal institutions [90]. However, this study shows that the vulnerability is likely not only caused by flood hazards but also by participation in community activities, deciding roles on income, and dependency on other family members, which are contributing factors to female-headed households being more vulnerable. Beyond men generally controlling income and other resources, they tend to control decisions even when they are absent from the household. This draws the attention of this study to the possible presence of sources of differential vulnerability, as well as characteristics particular to FHHs. For instance, it is likely that the social networks and access to social institutions for female heads are limited. This is attributed to their lack of ties with other community members and relatives [91].

Intra-household decision-making is important and female heads are more restrained than male heads from seeking help from others since they are not able to meet reciprocal demands for assistance in return [92]. Unequal access to the use of social opportunities for female-headed households possibly explains the remaining inequality in vulnerability. So, the findings of the study suggest that FHHs' vulnerability to disaster is higher socially, physically, economically, and environmentally than MHHs.

The studied communities have been facing multidimensional vulnerability to floods for a long time. Government and other support agencies are working on disaster preparedness and relief activities each year. The proper outcome of these activities has not

been achieved because the proper methods of vulnerability assessment are not applied. Moreover, planners and practitioners need to consider household characteristics in terms of headship. One influencing attribute in the headship-based study of vulnerability is needed to address the disaster problem of the community. While the study indicated that FHHs have higher flood vulnerability than MHHs in every component of multidimensional vulnerability (social, physical, economic, and environmental), interesting insights into the results also revealed that the gap between MHHs and FHHs is larger in the social and physical components, while it is smaller in the economic and environmental components.

Participation opportunity is a key social variable for men and women in relation to vulnerability [8]. The confidence of households in the working procedure of governmental and social organizations to support disaster activities also plays a key role in feeling vulnerable. Besides these, educated households get the confidence through proper planning and decide to execute their plan [10]. The results of this study are similar to other studies, suggesting that higher educated respondents seemed better at reducing vulnerability in terms of using information [69] such as early warnings. Those studies revealed that education can help individuals fulfil their role as household heads and build up their confidence to get support from development agencies. Therefore, in this case, educated household heads have an increased analytical capability and can manage the household more efficiently. The key informants of this study also confirmed that female participation in different community activities was very low, which needs rethinking with regard to the selection process in order to achieve meaningful and balanced participation.

Economic activities play a vital role, directly or indirectly, in disaster vulnerability. To maintain the economic status inside the households, income and expenditure patterns are to be studied. Remittance has the highest contribution to the national GDP of Nepal. Around 90% of male spouses of FHHs leave their homes for economic migration (61% international and 29% domestic destinations). Most of them go for informal work with a low wage. However, this income is not enough to provide for every need and their priorities are the physical maintenance of the house, irrigation, and source of drinking water. Moreover, the study found that, comparatively, FHHs have more income because of the remittance they receive, but their priorities are to pay loans and expenses of daily consumption. They also do not have decision-making roles with regard to income and they do not prioritize physical activities for disaster preparedness. In the income aspect of the economic component, FHHs are better than MHHs, but in terms of savings, they are lower than MHHs, as their expenses are higher. So, FHHs are still more economically vulnerable than MHHs.

Based on the qualitative and quantitative results, this study shows that MHHs and FHHs experience flood vulnerability differently. This research suggests that multidimensional factors (social, physical, economic, and environmental) be considered when using gender-based models for the assessment of disaster vulnerability. In the context of measuring headship-based gender dimensions of flood vulnerability, the study has provided a contextual and useful methodology that more broadly measured the factor-based dimensional composite degree of MHHs' and FHHs' vulnerability. The advantage of using this model of study for assessing the degree of vulnerability of MHHs and FHHs in the rural areas of Nepal is that it facilitates the identification of different categories (very high, high, moderate, and low) of vulnerable populations and the causes and factors that make these populations vulnerable. Having the value for each indicator and dimension and using the index ranking, the methodology of this study can help planners and policymakers identify gaps between MHHs and FHHs and address the underlying factors that are responsible for increased vulnerability. Furthermore, in contrast to a blanket approach to vulnerability assessments, the approach taken in this study can reveal unequal flood vulnerability between MHHs and FHHs, so that planners can apply appropriate and gender-responsive methods of action for a DRR program.

As the Nepal government has reformed administrative units recently, and the local bodies are trying to develop the DRR framework depending on their local context, this

study can support these local institutions in the process of formulation of a DRR plan and develop strategies to address and consider the gender needs. Though this study is a vulnerability assessment of flood hazards, the applied methodology can be replicated in other natural hazards and social contexts in different spatial scales such as urban and rural setups, or upstream and downstream locations. The used indicators are based on previous empirical studies and more indicators can be included or sorted according to the local needs and availability of data. This multidimensional methodology may be used for vulnerability assessments in the DRR process. When it comes to policymaking and intervention, a gender-sensitive approach requires more than an analysis of disaggregated data. The strategy should be developed for the participation of FHHs in every DRR activity in the community. Their participation could encourage better preparedness to minimize disaster risks. This study may support developing and regulating a gender-responsive policy for institutional support to FHHs to increase women's access to government services including banking services, health services, etc. For example, access to banking loans, skill development training, minimum support in infrastructural maintenance, access to drinking water supply, and improved communications would minimize vulnerabilities. The government may make a plan for infrastructural development and maintenance, and de-sedimentation, to reduce the severity of flood hazards. Capacities can be further improved through subsidized education and health care schemes. The literacy rate needs to be raised in flood-prone communities so the community can build their capacities through preparedness plans. People living in flood-prone areas are aware that they are at risk, but empowerment is needed for self-preservation and preparedness, so that they may participate in government preparedness initiatives. Based on Sendai Framework for Disaster Risk Reduction (SFDRR) and the Hanoi recommendation to build a gender-friendly resilient community, the signatory countries like Nepal can apply such multidimensional methodologies at the national, provincial, and local levels.

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Appendix A

Table A1. List of selected indicators for household-level vulnerability assessment and their measurement methods, with weights and interpretation of respective empirical studies.

Social Vulnerabilities					
SN	Indicators	Data Class	Weights	Interpretation	Empirical Studies
S1	Household Size of Respondent	<5 6–9, >10	0.33 0.66 1	The higher the family size, the greater the vulnerability	[52,71,93]
S2	Households with Dependent family members	No Yes	0 1	Infant, children and elderly persons are more vulnerable than young and adult people because they are less mobile	[10,52,64,73]
S3	Households having family members with chronic illness/ pregnancy or disability	No Yes	0 1	Households with special needs will hinder mobility in case of emergency	[64,69,71,94,95]
S4	Level of educational attainment	Illiterate Literate Primary (1–7) Secondary (8–10) High School (11–12) Graduate	1 0.33 0.5 0.67 0.83 0	The lower the educational level, the higher the vulnerability	[10,69]
S5	Households having a family member who can swim	Yes No	0 1	Swimming skills will increase capacity as it will help save lives and household items	[96]
S6	Households having a family member who has First Aid Knowledge	Yes No	0 1	First aid knowledge will increase capacity by helping injured households and saving lives	[8]
S7	Strength of community cooperation in disaster response	Very Good Good Moderate Poor Very Poor	0.2 0.4 0.6 0.8 1	Cooperation strength represents the community's help and shared resources to cope with floods	[94,97]

Table A1. Cont.

Social Vulnerabilities					
SN	Indicators	Data Class	Weights	Interpretation	Empirical Studies
S8	Households’ participation in awareness training on flood preparedness	Yes	0	Awareness about flood preparedness and protocols will help prepare households for floods	[8]
		No	1		
S9	Household-level trust in Government’s DRR plan/program	Very High	0.2	Household not having trust in government plan and programs means they will not follow them and increase household vulnerability	[98]
		High	0.4		
		Moderate	0.6		
		Low	0.8		
		Very Low	1		
S10	Household-level trust in religious organizations to get effective support	Very High	0.2	Household not having trust means the community cooperation will not be stronger and increase household vulnerability	[99]
		High	0.4		
		Moderate	0.6		
		Low	0.8		
		Very Low	1		
Physical Vulnerabilities					
SN	Indicators	Data Class	Weights	Interpretation	Empirical Studies
P1	HH used the materials to construct the house	Full cemented	0.2	Houses made of bamboo and straw are more vulnerable	[65,88,93,100]
		Brick wall and Tin roof	0.4		
		Wood/Bamboo and Tin roof	0.6		
		Wood/mud and Tin roof	0.8		
		Bamboo/Straw	1		
P2	HH having raised the plinth level of the house to survive the flood	Yes	0	Households living in single-story residence or not having raised the plinth level for the single-story house will increase the vulnerability	[65,70]
		No	1		
P3	HH has enough access to irrigation	Very Good	0.2	Households having irrigation can support agriculture production for food security that reduces the vulnerability	[73,101]
		Good	0.4		
		Moderate	0.6		
		Poor	0.8		
		Very Poor	1		
P4	HH having any kind of vehicle for transportation	Yes	0	A household with no means of transportation will be hindered in evacuation	[64,101]
		No	1		

Table A1. Cont.

Social Vulnerabilities					
SN	Indicators	Data Class	Weights	Interpretation	Empirical Studies
P5	HH having reliable means of communication for early warning message	Very reliable	0.2	Households with no access to means of communication will be more vulnerable	[94,95,102,103]
		Reliable	0.4		
		Moderate	0.6		
		Less reliable	0.8		
		Worst reliable	1		
P6	Households having managed alternate water sources in disaster	Yes	0	Households are more vulnerable to not having alternative sources of drinking water	[69,72,73,101]
		No	1		
Economic Vulnerabilities					
SN	Indicators	Data Class	Weights	Interpretation	Empirical Studies
E1	Average Monthly Household’s Income (in NPR Amount)	75,000–100,000	0.25	Lower income results in higher vulnerability and more time to recover from flood	[52,70,73,102,104]
		50,000–75,000	0.75		
		25,000–50,000	0.5		
		<25,000 NPR	1		
E2	Main income source of household (Agriculture/Daily wages/business/Remittances/regular salary)	Employment (Salary)	0.2	Agriculture-dependent people are the most vulnerable and an unstable source of income from a particular occupation will increase the vulnerability	[64,93,101,104]
		Remittances	0.4		
		Business	0.6		
		Daily Wage	0.8		
		Agriculture	1		
E3	Households having multiple sources of income	5	0.2	Multiple sources of livelihood will increase capacity because even if one source is cut off, households can survive on another	[69,71,103,105]
		4	0.4		
		3	0.6		
		2	0.8		
		1	1		
E4	Average Monthly Households Savings (in NPR Amount)	>1001	0.2	Savings will increase the capacity to cope with floods and will help in recovery that makes households less vulnerable to flood	[8,52,106]
		501–1000	0.4		
		201–500	0.6		
		101–200	0.8		
		<100	1		
E5	Households having any kind of insurance (Life, Health)	Yes	0	Insurance will increase coping capacity and help households in recovery after floods	[71,105,106]
		No	1		

Table A1. Cont.

Social Vulnerabilities					
SN	Indicators	Data Class	Weights	Interpretation	Empirical Studies
E6	Average Value of having other resources of Household (bank balance, cash, gold/silver, farm animals, share, or any others) (in NPR Amount)	>20,0001	0.2	Households having other resources that can be sold during a crisis will decrease the vulnerability.	[8,52,106]
		150,001–200,000	0.4		
		100,001–150,000	0.6		
		50,001–100,000	0.8		
		<50,000	1		
Environmental Vulnerabilities					
SN	Indicators	Data Class	Weights	Interpretation	Empirical Studies
En1	Households having clean/safe piped drinking water	Yes	0	Households with no access to safe drinking water will be at more risk	[12,69,72,107]
		No	1		
En2	Household using an open place for defecating (Open toilet)	No	0	Open defecation can pollute the environment and cause health problems and lead to vulnerability	[108,109]
		Yes	1		
En3	Households having a sewage disposal system	Yes	0	Households not having sewage disposal systems are more vulnerable to the surrounding environment	[110]
		No	1		
En4	Households having open disposal of animal waste (ODAW)	No	0	Open disposal of animal waste provides breeding sites for insects, pests, snakes and vermin (rats) that increase the likelihood of disease transmission. It may also pollute water sources and the environment	[111]
		Yes	1		
En5	Households having farmland covered by sand/debris	No	0	Sediment and debris barriers to crop production and physical damage to the soil and plants that affect the environment	[112]
		Yes	1		
En6	Households using chemical fertilizer/pesticides to increase crops’ productivity	Very High	1	Chemical fertilizers cause land and water pollution and the chemical content of the crop leads to damage to the environment	[113]
		High	0.8		
		Moderate	0.6		
		Low	0.4		
		Very Low	0.2		

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