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Assessment of the Household's Flood Social Vulnerability in Vietnam's Mekong River Delta

ABSTRACT

Flooding is a natural phenomenon that occurs annually from September to October in Vietnam's Mekong River Delta (MRD). However, its trend is becoming more destructive and unpredictable in recent years, which tends to threaten people's livelihood, properties, and health. This study attempted to examine the flood vulnerability among households in 14 districts of the delta. The analysis helped identify communities that were subjected to floods and needed more attention in disaster management. People in the MRD had remarkably low exposure, which was the result of investment in water structures. About 59.2 % of the surveyed households were moderately vulnerable to flooding. Families in O Mon, Thanh Binh, Cai Be, and Cho Lach district had the highest vulnerability indices. The most significant indicators to explain the flood-prone state were rice-related indicators, elderly dependency ratios, and social capital. The study suggested that plans to reduce flood vulnerability should focus on the family's adaptability because it had the largest impacts.

Key words: *flood, vulnerability, principal component analysis, Vietnam Mekong River Delta*

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INTRODUCTION

The Mekong River originates from Tibet and consists of an Upper Mekong Basin (UMB) and a Lower Mekong Basin (LMB). The LMB encompasses territories of Lao PDR, Thailand, Cambodia, and Viet Nam, supporting millions of people living along the river banks (*MRC 2011*).

Vietnam Mekong River Delta (MRD) is in the downstream of the Cambodian floodplain and also the lowermost portion of the LMB. Approximately 63% of the delta is used for agricultural production (*ICEM 2010*). This region contributes more than 50% of Vietnam's total agricultural output. Every year, farmers in the MRD have to face seasonal floods. The annual flood season lasts from July to October or November, affecting rice production and livelihoods. The number of people living in flooded areas is up to 8.5 million people (*Ninh 2007*).

Cambodia and Vietnam are most vulnerable to flood hazard among LMB countries. In 2000, the most severe flood within 70 years occurred. After the disaster, among four LMB countries, Vietnam ranked second only to Cambodia in terms of impacts; there were 319 fatalities, and the economic damage was US$ 125 M (*MRC 2015*). The vulnerability was once again highlighted through the flood of 2011. In the entire LMB, there were 396 fatalities recorded, 26% was in Vietnam (104 deaths). Economic damage amounted to US$260 Min Vietnam, US$100-160 M in Cambodia, and US$22.6 M in Laos (*MRC 2015*).

The exposure to floods focuses more on rural areas. While major towns and cities are usually protected by engineering works and constructions, the countryside is not. This leads to a more susceptible condition for farmers and their livelihoods, properties, and health. The production in the MRD is under direct impacts from floods because it mainly consists of activities that depend on natural resources (rice farming, aquaculture, and fishing) (*Nguyen et al. 2015*).

In areas that are sensitive to natural hazards, the vulnerability can be studied to understand a natural event and its impacts on a system. Regarding flood risks, many studies attempted to examine the vulnerability to flooding from regional levels to household levels. (*Antwi et al. 2015; Karagiorgos et al. 2016; E. Murphy and Scott 2014; Mwale et al. 2015*). *Antwi et al.* (*2015*) calculated the community vulnerability to flood-prone in Ghana by using four components based on ecological, socioeconomic, engineering, and political aspects. Based on the score of each category, it was found that there was no component played the dominant role in the vulnerability index but depended on the situation and context of each community. *Mwale et al.* (*2015*) also conducted a quantitative assessment of community vulnerability with a different approach. Indicators were selected based on exposure, susceptibility, and capacity. The study of *Mwale et al.* (*2015*) indicated that social indicators contribute significantly to susceptibility. *Ha Anh et al.* (*2018*) applied partial least squares structural equation modeling to discover the interrelationship of household flood vulnerability determinants in Cambodia's floodplain and Vietnam's Mekong River Delta. The study of *Ha Anh et al.* (*2018*) showed that demographics and social capital have direct influences on flood exposure. Also, socioeconomic status can reduce flood effect levels through the mediation of coping capacity.

In the context of the MRD, rural households are the basic unit of production and consumption. However, these households are exposed to environmental changes since their daily livelihood depends on natural resources. Thus, estimations at the household level will help identify the threats and provide detailed information for adaptation strategies (*Fang et al. 2016*). The urgent need to assess the flood prone-state of rural areas was raised in various studies (*Arias et al. 2012; MRC 2010; Nguyen et al. 2015; Okazumi et al. 2014; Pearse-Smith 2012*). Therefore, this study attempted to construct and quantify the household social vulnerability to flooding in the MRD. The assessment will reveal the most vulnerable areas to flooding and drivers that can mitigate or exacerbate the susceptible state. These results will serve as useful information to determine which factor should be prioritized in flood management. They also contribute to the understanding of the physical and socio-economic facets of flooding in Vietnam.

MATERIALS AND METHODS

The construction and calculation of flood vulnerability

Vulnerability is the susceptibility of a given population, system or place being exposed to hazards (*Cutter et al. 2003*); it is the degree to which a system is susceptible to, or unable to cope with, adverse effects (*Adger 2006; IPCC 2001*). In this study, vulnerability is a function of exposure, sensitivity, and adaptive capacity. It applied the approaches of *Hahn et al.* (*2009*) and *Piya et al.* (*2012*) to construct the flood vulnerability index. The indicators were chosen after reviewing previous studies and their compatibility with the study areas.

Exposure is the degree of disturbance or stress upon a particular unit of analysis (*Hung et al. 2016; IPCC 2001*). Its indicators describe the flood characteristics and the system's affected elements (*Balica et al. 2009; Messner and Meyer 2006*). Flood duration and maximum flood level were selected to represent the former part. The latter part included distances from houses or fields to the river, and variables representing flood impacts on production.

Fekete and Brach (*2010*) viewed sensitivity as the characteristic that makes a system weak against stresses. There were eight indicators selected for sensitivity based on the demographics and economics of the family. The variables related to dependent groups (children and elders) were especially examined. Children are victims of many natural hazards such as earthquakes, tsunamis, and floods because they need parents' support and protection (*Działek et al. 2016*). Senior citizens, similarly, are also one of the most vulnerable groups to hazards because of their limited mobility and physical difficulties during evacuation. Besides, senior citizens are unwilling to leave home and take longer to recover (*Rygel et al. 2006*). Children and elderly dependency ratios were categorized by gender to examine possible gender differences. Economic variables included the poverty status, unemployment rate, and the engagement in natural-based occupations.

According to *Smit and Wandel* (2006), adaptive capacity is the potential or the capability of a system to adjust to stresses. In this study, its indicators represent the efforts to cope with flooding and focus on pre-disaster preparedness. These efforts can come from an individual, the entire family, or even from social networks (*Rufat et al. 2015*). This study categorized these into human capital, social capital and financial capital. Human capital consisted of education (*Działek et al. 2016*) and experience. Indicators of social capital described the household's participation in social associations (farmer associations, women associations, extension clubs, or cooperative groups), duration of residence, chances of obtaining support from external sources, and the reliability of flood warnings in the local. Finally, the income share from water-related occupations (agriculture, aquaculture, and fishing), and livelihood diversification index (LDI) were indicators of financial capital. LDI was calculated to measure the diversification of the household's economy. The larger index indicates that the household's income is stable and less affected by risks. LDI is calculated by the formula: $LDI_k = 1 - \sum_{i=1}^{N}(S_{i,k})^2$ (*Kimenju and Tschirley 2009*), where LDI_k is the diversification index, i is the specific livelihood activity, N is the total number of livelihoods, k is the particular household, and $Si_{,k}$ is the share of activity ith to the total income of household k^{th}.

Table 1. Indicators of Vulnerability.

No.	Vulnerability component	Indicator group	Indicator	Explanation	References
1		Flood characteristics	Flood duration	The average flood duration	*Kissi et al. (2015); Balica et al. (2009)*
2			Max flood level	Highest water level during floods	
3			River to house	The distance from the river to the house	
4			River to farm	The distance from the river to the farm	
5			Flooded rice area	Rice area that was flooded	
6			Lost rice production	Rice yields that were lost due to flooding	
7	Exposure	Exposed elements	Rice lost value	Monetary value of rice production losses	*Balica et al. (2009); Borden et al. (2007)*
8			Flooded aquaculture area	Aquaculture area that was flooded	
9			Lost aqua. production	Aquaculture yield that was lost due to flooding	
10			Aqua. lost value	Monetary value of aquaculture losses	
11			Other losses to floods	Monetary value of other losses	*Karagiorgos et al. (2016); Lokonon (2016)*
12			Male children dependency ratio	Ratio of male children under 15 years old	*Kissi et al. (2015); Hung et al. (2016); Karagiorgos et al. (2016); Lokonon (2016); Hahn et al. (2009); Shah et al. (2013); Cutter et al. (2003)*
13			Female children dependency ratio	Ratio of female children under 15 years old	
14		Demographics	Male elders dependency ratio	Ratio of male senior citizens above 60 years old	
15			Female elders dependency ratio	Ratio of female senior citizens above 60 years old	
16	Sensitivity		Household head's age	Age of the household head	*Fekete and Brach (2010); Lokonon (2016)*
17			Poverty	The household is under poverty standard (1=yes, 0=no)	*Karagiorgos et al. (2016); Mwale et al. (2015); Rufat et al. (2015)*
18		Economics	Unemployment	Share of unemployed people over total family members	*Fernandez et al. (2016); Karagiorgos et al. (2016); Rufat et al. (2015); Murphy and Scott (2014); Fekete and Brach (2010); Borden et al. (2007)*
19			Total farmers	Number of farmers engaged in agriculture, aquaculture and fishing	*Hahn et al. (2009), Shah et al. (2013)*
20			Highest Education	The highest education level in the family	*Działek et al. (2016); Cutter et al. (2003); Fekete and Brach (2010); Piya et al. (2012); Balica et al. (2009)*
21			Training Courses	The household head has attended any training course (1=yes, 0=no)	
22		Human capital	Changed Agriculture	Agriculture was adjusted to cope with flooding	
23			Changed Fishing	Fishing was adjusted to cope with flooding	
24	Adaptive Capacity		Changed Aquaculture	Aquaculture was adjusted to cope with flooding	
25			Work experience	Number of years that the household has been working in its most important livelihood	*Linnekamp et al. (2011); Rufat et al. (2015)*
26			Social Associations	Number of social associations wherein the household is a member	*Działek et al. (2016); Karagiorgos et al. (2016)*
27		Social capital	Duration of residence	Number of years that the family has been living in the region	*Działek et al. (2016); ; Lokonon (2016); Rufat et al. (2015)*
28			Receiving support	The household received support from relatives, the government, or NGOs (1 = Yes, 0 = No)	*Parker et al. (2009)*
29			Local Information	The reliability of local disaster information channels	*Działek et al. (2016); Sadia et al. (2016); Hahn et al. (2009); Shah et al. (2013); Piya et al. (2012)*
30		Financial capital	Share of income from Agriculture, Fishing and Aquaculture	Income share from Agriculture, Fishing and Aquaculture in the total income	*Piya et al. (2012)*
31			Livelihood Diversification Index (LDI)	Higher LDI indicates that the household have more alternative livelihoods	

After the indicators had been selected, the corresponding weights were identified. Because of the complexity of the nature of the data, this study applied Principal Components Analysis (PCA) to construct the weights. PCA is widely applied in the vulnerability assessment of various fields (*Abson et al. 2012; Hoque et al. 2012; Hughes et al. 2012; Johnson et al. 2012; Li et al. 2006; Sietz et al. 2011*). This method is very useful when analyzing high dimensional data since it can compress the data by reducing the number of dimensions without major loss of information.

This study used a correlation matrix when conducting PCA. Previous studies widely use PCA with correlation matrix when the scales or units of variables are different because it standardizes the data and avoids bias results (*Boik 2013; Borgognone et al. 2001; Helena et al. 2000; Korhonen 1984; Kotz et al. 1984; Velicer 1976; Visconti et al. 2009*). The selected variables are suitable for PCA if the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy is larger than 0.5 and the p-value from Bartlett's Test of Sphericity is less than 0.05 (*Abson et al. 2012; H. F. Kaiser 1974*). When applying the Kaiser criterion, only factors whose eigenvalues greater than one are retained (*H. G. Kaiser 1960*). For interpretation, Varimax rotation with Kaiser Normalization was used to rotate the component matrix. The first principal component is the scoring factor or the weights of the indicators and was used to calculate the vulnerability index (*Deon Filmer & Pritchett 2001; Gbetibouo & Ringler 2009*).

The PCA was conducted in SPSS. After the weights had been determined, the normalized variables were multiplied with them to calculate the indices of exposure, sensitivity, and adaptive capacity by applying the formula:

$$Index_j = \sum_{i=1}^{k} b_i \left[\frac{a_{ji} - x_i}{s_i}\right] \quad \text{(Piya et al. 2012)}$$

where I is the respective index value, b is the weight of the indicator, a is the indicator's value, x is the mean indicator value, and s is the standard deviation.

The calculated indices were normalized again to provide values ranged from 0 to 1 for comparison. Finally, the flood vulnerability index (FVI) was determined as:

Vulnerability= Exposure+Sensitivity-Adaptive Capacity

Data collection

The primary data are from the survey conducted by the Vietnam Ministry of Natural Resources and Environment (MoNRE) in September and October 2014.

The questionnaire includes many questions divided into two sectors, livelihood and economic. The livelihood sector consists of various categories such as household demographics, livelihood options, fishing activities, navigation, flood impacts, warnings and preparations, and adapting strategies. The economic sector includes detailed information about household economic activities: agriculture; rice, fishing, and aquaculture; financial information; other crop production; and household expenses.

Besides quantitative data, Participatory Rural Appraisal (PRA) was also organized in several study sites to collect additional information for analyses. A total of 1260 households were surveyed in 14 districts of 12 provinces in Vietnam MRD (**Table 2**).

Table 2. Selected survey areas.

Zone	Geographic properties	Province	District
1	High flood zone in the upper part of the MRD	An Giang An Giang Vinh Long	An Phu Chau Phu Tam Binh
2	Freshwater zone in the north-east middle of the MRD	Can Tho Dong Thap Tien Giang Ben Tre	O Mon Thanh Binh Cai Be Cho Lach
3	Freshwater zone with low pH and high acidity in the south-west of the MRD	Hau Giang Kien Giang	Chau Thanh A Tan Hiep
4	Saline zone in the west of the MRD	Soc Trang Tra Vinh Ben Tre Ben Tre Tien Gian	Tran De Tra Cu Ba Tri Thanh Phu Go Cong Dong

RESULTS AND DISCUSSION

Exposure

For exposure indicators, the KMO was 0.605 and the p-value of Bartlett's test was smaller than 0.05, suggesting that the selected variables were fit for PCA analysis. There were four extracted components, explaining 62 % of the total variation. The first factor (EC1) explained 19 %, the second factor (EC2) 16 %, the third factor (EC3) 14 %, and the fourth factor (EC4) 11 % (**Table 3**). EC1 was named as Exposed.

EC1 contained indicators related to rice cultivation, all of which had positive loadings. The flooded rice area had the highest loading, followed by the lost value and

Table 3. Loadings of exposure indicators on four significant components.

Indicators	Components of Exposure			
	1	2	3	4
Flooded rice area	0.900	-0.006	0.006	-0.006
Rice lost value	0.849	-0.004	0.029	-0.020
Lost rice production	0.798	-0.002	-0.021	0.031
Aquaculture lost value	-0.005	0.852	-0.004	-0.022
Lost aquaculture production	-0.004	0.833	0.027	-0.025
Flooded aquaculture area	-0.002	0.590	-0.004	0.032
Max flood level	0.011	-0.009	0.883	0.012
Flood duration	0.002	0.021	0.873	-0.006
River to farm	-0.034	-0.027	-0.191	0.775
River to house	0.048	0.009	-0.013	0.764
Other losses by flooding	-0.008	0.009	0.157	0.303
Eigenvalue	2.173	1.782	1.623	1.247
Variance Explained (%)	19.734	16.086	14.588	11.637
Cumulative Explained (%)	19.734	35.820	50.408	62.045

lost production. Since rice farming is the dominant livelihood in the MRD, it is reasonable that flood exposure was highly loaded on its variables. Rice fields are most likely the first affected element when the floodwater rises. This impact leads to other costs such as lost yield or land. Inundated farmland was also the main element of the most exposed villages in the Mono River Basin, Africa (*Kissi et al. 2015*). In the region, rice planting schedules are different among areas and depend on the hydrological regime and available irrigation systems. If there are closed dikes, farmers can grow three rice seasons per year even in flood-prone or coastal areas. The advantages of flood control structures on paddy farming have been reported by *Ninh* (*2007*).

EC2 was strongly correlated with aquaculture exposure indicators. Aquaculture lost value had the highest loading. A flood might not cause inundation on aquaculture, but it still creates negative impacts such as damaged fish cages or disturbed water, leading to leakages or deaths of fishes. Production losses were also one of the main contributors to the hazards vulnerability index in the US (*Borden et al. 2007*).

EC3 loaded on two indicators that represented the flood characteristics. These indicated the severity of the hazard through water level and flood duration. The scores were high and almost identical, meaning that both have an equal role in explaining floods. Households that experienced floods with longer duration and deeper inundation would have higher physical exposure.

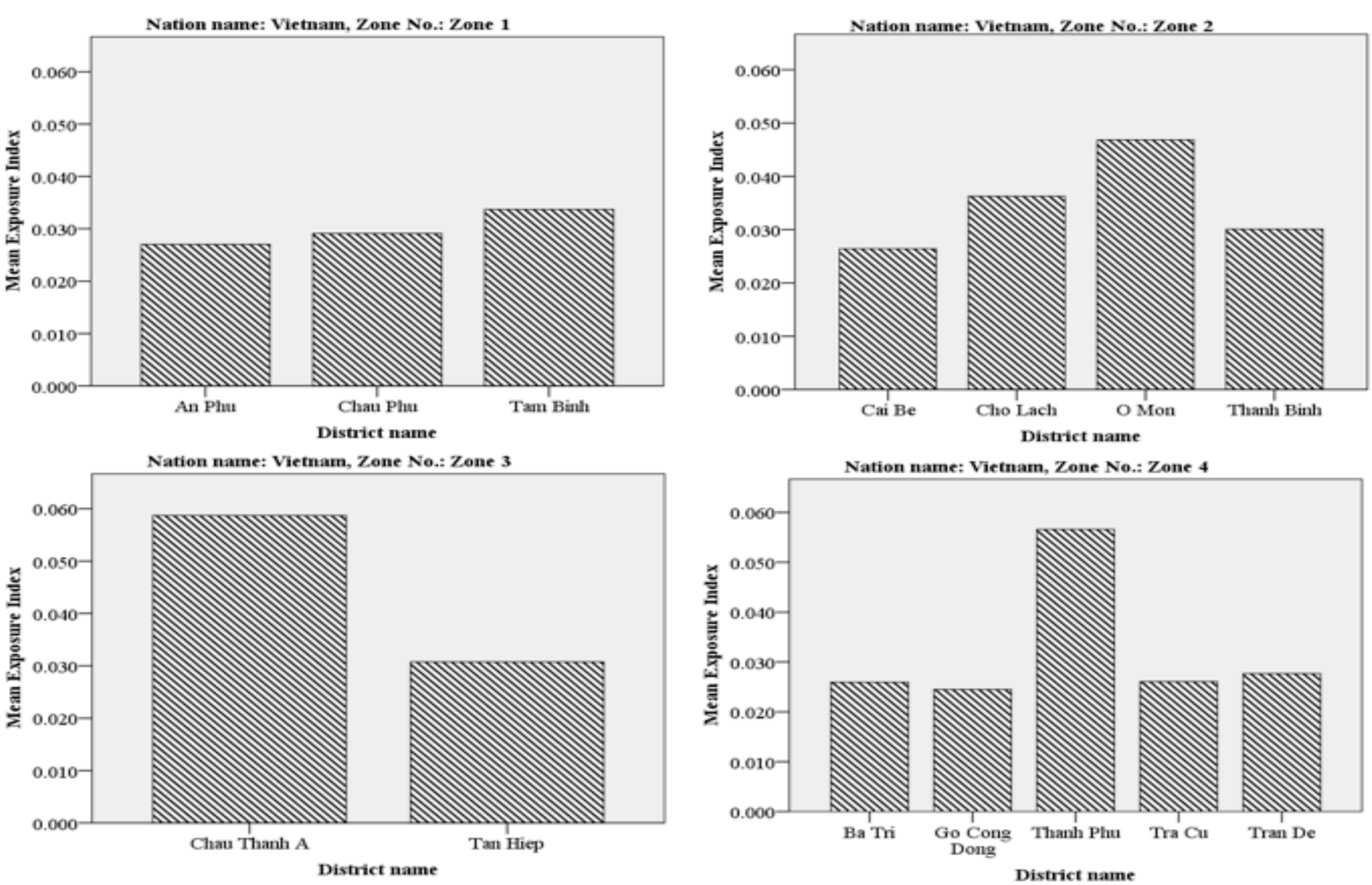

Figure 1. Calculated exposure indices.

EC4 was associated with two distance variables and other losses. The loading values of the two distance indicators were strongly positive, which was unexpected. This means that the household's exposure may not decrease when the house or the farm is situated further from the river. A similar result was found in the Mono River Basin, Togo, when villages that experienced more severe floods were the ones furthest away from the water (*Kissi et al. 2015*). Another indicator in EC4 was other losses due to flooding. These costs included damages from other sectors such as fishing, livestock, working days, properties, or health. The loading was positive but relatively low, indicating that this indicator had a minor role.

The loadings in EC1 were selected to assign weights for indicators (*Deon Filmer & Pritchett 2001; Gbetibouo & Ringler 2009*). The calculation showed remarkably low exposure. There were 1236 surveyed families whose exposure indices ranged from 0.000 to 0.100, 16 ranged from 0.101 to 0.500, and 8 had indices above 0.500. The average value was just 0.034.

In the MRD, the floods are highest and strongest from September to October. After the extreme flood in 2000, there have been investments in stronger flood control structures, thus minimizing flood impacts. The high dikes protected people living inside and alleviated any adverse impacts. The investment in flood control structures indicated a high awareness of flood management. Even in sites with uncompleted dikes, the number of affected households and costs were remarkably small, resulting in the very low indices.

Zone 1, including An Phu, Chau Phu, and Tam Binh district, had the lowest exposure to flooding. An Phu and Chau Phu had closed dikes built since 2002 to protect the civilians and production. These constructions were very efficient since they prevented the districts from river overflows and allowed intensive rice farming despite this area being in the high flood zone of the Delta. Infrastructure changes such as dredging the canals, raising the embankments, and raising roads can slow down flood propagation and decrease the inundation as much as 0.1-0.4 m in An Giang province (*Le et al. 2008*). There was an extreme flood in 2011, but only five of 180 questioned families in the two districts encountered costs due to lost working days.

The second-lowest index was found in coastal districts of Zone 4. These areas were affected by salinity intrusion more than flooding (*Kotera et al. 2008; Tuong et al. 2003*). Thanh Phu district had a higher exposure because a flood in 2012 fractured the riverbanks and flooded the fields for one week.

Sensitivity

For the sensitivity indicators, the KMO was 0.618, and the p-value of Bartlett's test was 0.000, showing that the chosen variables were suitable for PCA. There were four retained components, explaining nearly 66 % of the variance. The first component (SC1) explained 25 %, the second (SC2) 14 %, the third (SC3) 14 %, and the fourth (SC4) 13 % (**Table 4**). The rotated component loadings suggested the component names as Elders (SC1), Farmers and Poverty (SC2), Children (SC3), and Unemployment (SC4).

SC1 encompassed the male elders ratio (r = 0.770), female elder ratio (r = 0.755) and household head's age (r = 0.808). All of the loadings indicated strong correlations with sensitivity. According to the weights, the elders significantly increase the household's susceptibility to flooding. Senior citizens are most at-risk to natural disasters because they need special treatment (*Ngo 2001; Wang & Yarnal 2012*). The loading values of male and female elders were almost similar, so there was no noticeable gender difference. It was unexpected that SC1 positively correlated with household head's age because household heads were anticipated to reduce the sensitivity through their experience. According to the weight, the family in MRD would be more sensitive to flood when its household head is older.

SC2 was correlated with total farmers and poverty status. The loading was negative on total farmers (r= -0.741) but positive on poverty (r= 0.593). The sensitivity

Table 4. Loadings of sensitivity indicators on four significant components.

Indicators	Components of Exposure			
	1	2	3	4
Household head's age	0.808	-0.200	-0.200	0.146
Male Elders Ratio	0.770	0.028	0.028	-0.036
Female Elders Ratio	0.755	0.237	0.237	-0.103
Total farmers	0.063	-0.741	-0.741	-0.003
Poverty	0.118	0.593	0.593	0.107
Female Children Ratio	-0.269	0.241	0.241	-0.235
Male Children Ratio	-0.290	0.285	0.285	-0.249
Unemployment rate	-0.042	0.126	0.126	0.937
Eigenvalue	2.020	1.145	1.145	1.019
Variance Explained (%)	24.917	14.405	14.405	12.997
Cumulative Explained (%)	24.917	39.322	39.322	65.902

increases if the family is under the poverty line and decreases when there are more members participating in traditional livelihoods. Poor farmers do not have extra income for disaster preventative measures, they often settle in risk areas, and the properties are in a poor state, which is easily damaged (*Brouwer et al. 2007; Działek et al. 2016; Fekete 2012*)

SC3 encompassed the two children dependent ratios. The loading values were equal, but the signs were opposite. The sensitivity is lower when there are more girls in the family, while it increases together with boys. Although a susceptible group (*Walker et al. 2012*), children in some cases can facilitate disaster resilience through education or assisting their families (*Kuhlicke et al. 2011*). The loadings in SC3 indicated that there was a difference in the children's gender. Previous studies found that the children and elders variables adversely affected the susceptibility, but the gender differences were not discussed (*Cutter et al. 2003; Hung et al. 2016; Lokonon 2016*).

SC4 only loaded on the unemployment rate. Its loading value was strong and positive, meaning that households with more unemployed members would be more susceptible to the disaster.

The sensitivity scores were higher compared to exposure. The mean index (0.32) revealed that the MRD had a moderate susceptibility to floods. In terms of spatial distribution, the indices spread equally in most districts and zones (**Figure 2**). Zone 1 once again obtained the smallest sensitivity (0.31), although it was just slightly lower than the remaining zones.

The smallest sensitivity (0.286) located in Tam Binh district which had the lowest ratios of elderly and zero unemployment rate. O Mon's sensitivity ranked first (0.348); it also had the highest elderly ratios and household head's age. In the study areas, the average household head's age was 50 years old. The elderly ratios were around 4 % for males and 5.5 % for females. These low ratios showed that the senior citizens only accounted for a small proportion of the population. Hence the impacts on sensitivity would be lessened. The children ratios were higher than that of the elders; about 9.4 % of the population were female children, and 8.8 % were male children.

On average, every family had two people engaging in traditional livelihoods. This rate was higher in Zone 2 and Zone 3, with three farmers per household. However, the distribution among traditional jobs was not balanced;

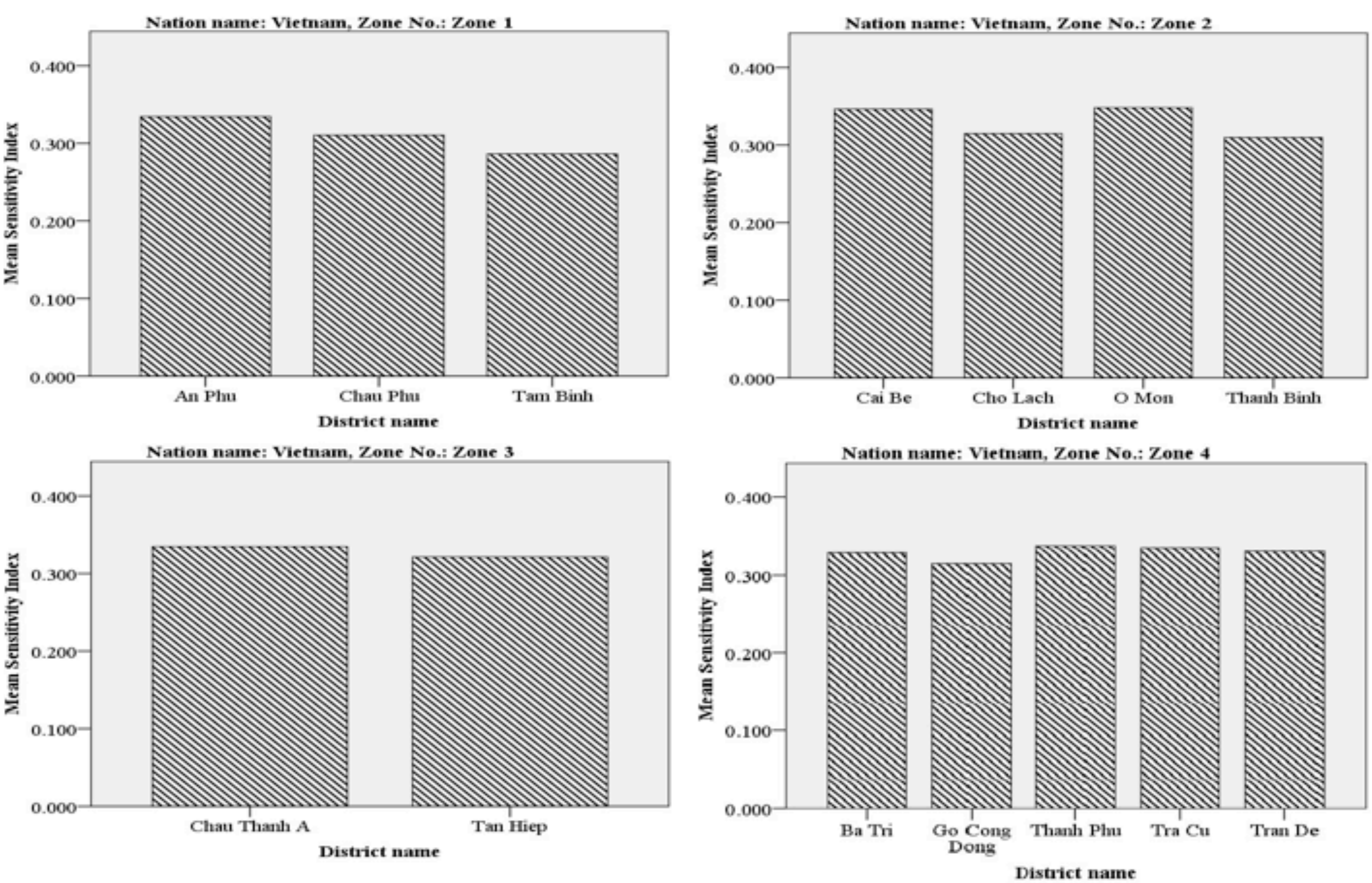

Figure 2. Calculated sensitivity indices.

about 65 % of the farmers worked mainly in agriculture, 24 % in aquacultural, and 11 % in fishing. The unemployment rate in the region was trivial; the highest rate was only 0.015 in Go Cong Dong. The poverty problem was also limited; the highest rate was in Chau Thanh A district (13 %), and the lowest was in Cho Lach district (1 %).

Adaptive Capacity

From the PCA, adaptive capacity had three eigenvectors retained, accounting for 46 % of the variance (**Table 5**). They can broadly be interpreted as social factors (AC1); economic factors (AC2); experience and education (AC3).

AC1 explained 20 % of the total variation. It loaded on the training courses attendance (r = 0.815), number of social associations (r = 0.790), and changes in aquaculture (r = 0.717). Following these three, the local information reliability was found to be negatively correlated with AC1 (r = -0.462). Strong social ties presented through the participation in the social network can facilitate the coping ability and make people more involved in planning processes (*Adger 2003; B. L. Murphy 2007; Nakagawa and Shaw 2004*). Changes made to protect aquacultural production also enhanced people's adaptability.

The second component (AC2) accounted for 13.6 % of the variance. It was correlated with the income share from agriculture, fishing, and aquaculture (r = -0.714), LDI (r = 0.658), changes in fishing (r = 0.583) and chances of receiving support (r = -0.414). The moderate loadings of LDI and changes in fishing indicated that people can cope with the risk better if they make adjustments to secure fishing activities and try to diversify their income. The strong and negative loading of the income share from traditional occupations expressed that families who heavily depend on traditional jobs are less likely to adapt to natural hazards. Similar findings were found in the cases of farmers in Ghana (*Armah et al. 2010) and fishermen in Sri Lanka (Birkmann & Fernando 2008*).

Table 5. Loadings of sensitivity indicators on three significant components.

	Components of Adaptive Capacity		
	1	2	3
Training Courses Attendance	0.815	-0.04	0.117
Number of Social Associations	0.790	0.019	0.156
Changes in Aquaculture	0.717	-0.229	-0.257
Local Information Reliability	-0.462	0.074	0.065
Share of income from Agriculture, Fishing, and Aquaculture	0.164	-0.714	-0.132
Livelihood Diversification Index	-0.045	0.658	0.262
Changes in Fishing	-0.214	0.583	-0.141
Receiving support	-0.104	-0.414	0.186
Duration of residence	-0.089	-0.02	0.736
Work experience	-0.411	0.13	0.617
Highest Education	0.21	-0.218	0.446
Changes in Agriculture	0.268	0.225	0.387
Eigenvalue	2.671	1.582	1.292
Variance Explained (%)	19.955	13.577	12.678
Cumulative Explained (%)	19.955	33.532	46.21

The third component (AC3) explained 12.6 % of the variance. It loaded on the duration of residence (r = 0.736), years of experience (r = 0.617), highest education (r = 0.446), and changes in agriculture (r = 0.387). Aside from formal education, the ability to understand the local nature and types of extreme events that it can produce serves as an advantage in adaptation (*McEwen et al. 2012*). This kind of information can be obtained from long-term settlement (*Willis et al. 2011*) or working experience.

The MRD's adaptability was not high, the average adaptive capacity index was 0.362. Zone 1 and zone 2 had almost similar scores (0.354 and 0.353); zone 4 was the second-highest (0.364), and zone 3 had the best adaptability (0.386). Among the districts, Chau Phu had the smallest index at 0.274; the first and second ranks were in O Mon (0.415) and Thanh Phu district (0.414).

In the MRD, people completed only secondary school, except for O Mon, Thanh Binh, Ba Tri, and Tan Hiep where people achieved high school on average. Farmers had an average of 18 years of work experience and 44 years of residency. There were only 10.8% of the surveyed families that adjusted their agriculture, 11.6% adjusted their fishing, and 24.2% adjusted their aquaculture, indicating low efforts to protect the productions. Together, agriculture, fishing, and aquaculture accounted for 80 % of the household's income; the minimum was 75 % in Tan Hiep district. This high income share and low LDI (0.252) described a heavy dependence on natural resources, which increased the exposure and lessened coping ability. Low participation in the social networks and training courses significantly decreased the adaptive capacity index. Sixty-seven percent of the sample did not participate in any social association and only 37 % experienced training, indicating communities lacked cohesion and advanced knowledge to manage floods.

Vulnerability

The flood vulnerability index was derived from the estimated exposure, sensitivity, and adaptive capacity. In

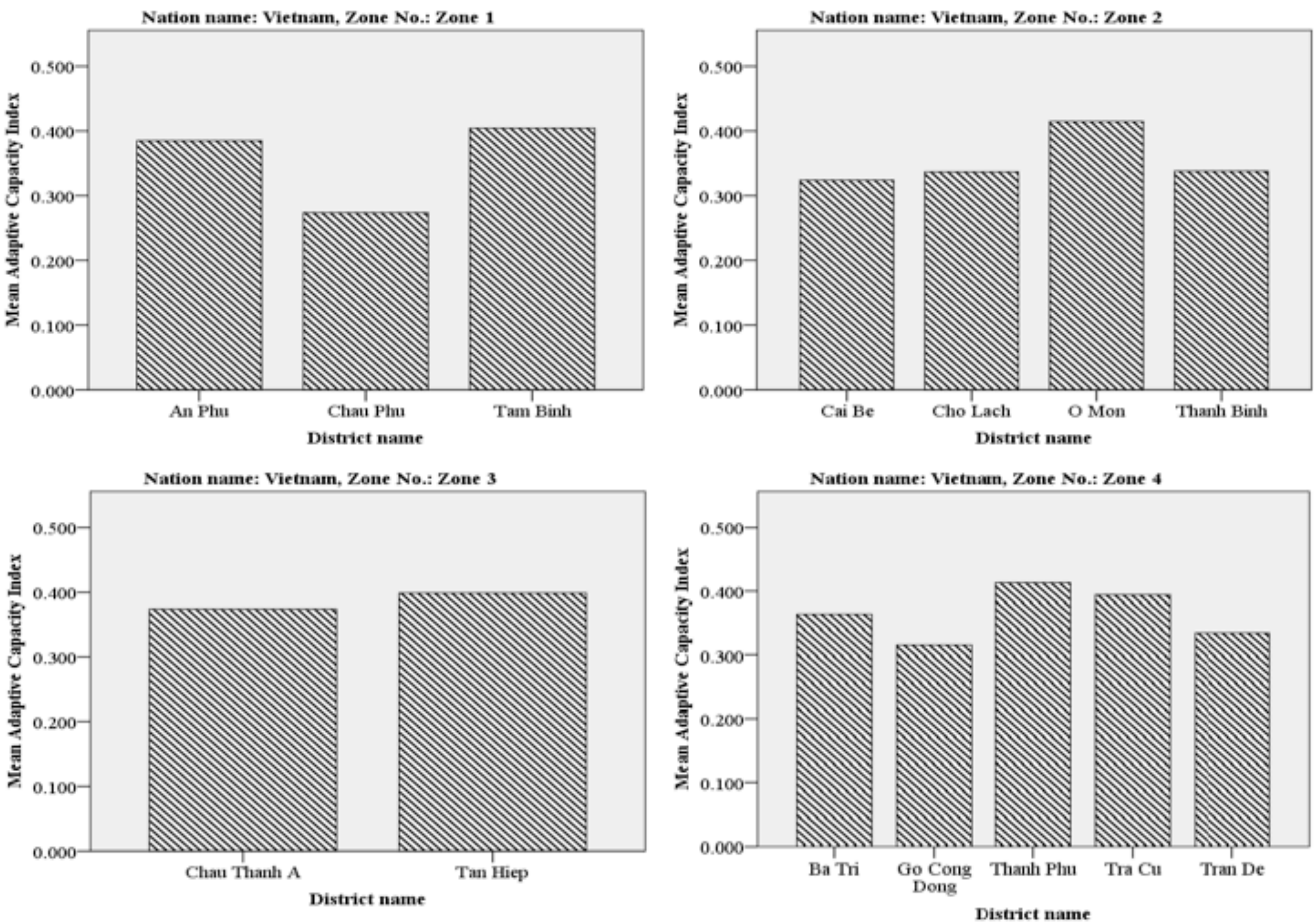

Figure 3. Calculated adaptive capacity indices.

the MRD, 59.2 % of the households had their vulnerability range 0.251-0.500, 23.3 % ranged 0.000-0.250, and 17.6 % above 0.501. On average, zone 1 and zone 3 had the equally lowest score (0.366), zone 4 ranked second (0.372), and zone 2 was the most vulnerable area (0.379) (**Figure 4**).

It was noticeable that zone 1 located in the high flood zone but turned out to be the least vulnerable; it also had the lowest exposure and sensitivity (**Figure 5**). Households here experienced minor impacts on rice and aquaculture farming due to the protection by flood control structures (*Käkönen 2008; Le et al. 2008*). Zone 3 had the same vulnerability as zone 1, but its attributes were different. The population in zone 3 suffered more losses due to inundation, especially in Chau Thanh A district. Farmers did not take action to protect their fishing. The social capital zone 3 was the highest in the MRD because people were more active in participating in the local networks and training courses. Moreover, houses here depended less on natural-based livelihoods and made efforts to diversify the family income.

Because the overall exposure of the Mekong Delta was remarkably low, sensitivity and adaptive capacity contributed more in the calculation of the vulnerability index. Their influences were proved by examining the standardized coefficients from the regression analysis. The estimation showed that the standardized coefficients of exposure, sensitivity, and adaptive capacity as dependent variables were 0.205, 0.403, and -0.895, respectively (**Table 6**). This means that adaptability had the largest impact on vulnerability.

The low exposure in the MRD that helped minimize flood damages was the result of appropriate flood management approach. After the extreme flood in 2000, the state adopted an approach for flood impact adaptation and mitigation, acknowledging that flooding in the MRD is unavoidable and has both positive and negative sides. Furthermore, the idea of "Living with Floods" is the implication of the practices that have been used by the locals in MRD (*Tinh and Hang 2003*). Communities in the region view flood as a natural event and have implemented various methods to cope with it. From the initial attempts to prevent floods, people realized that

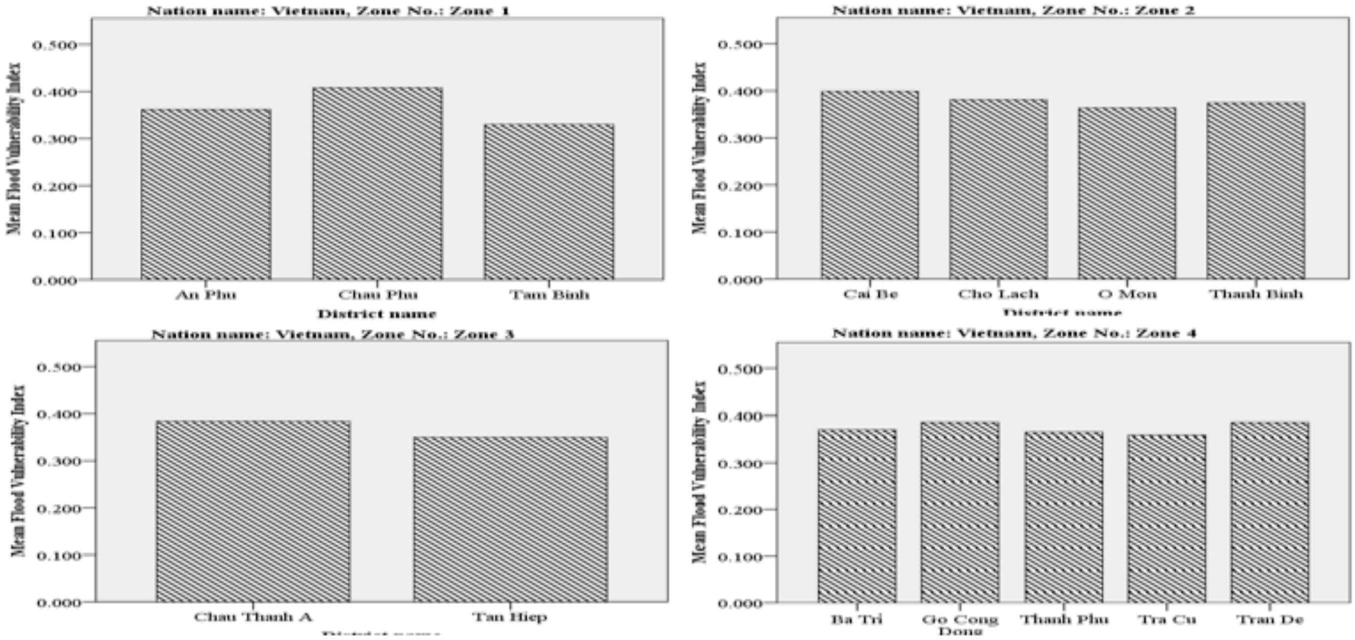

Figure 4. Calculated flood vulnerability indices.

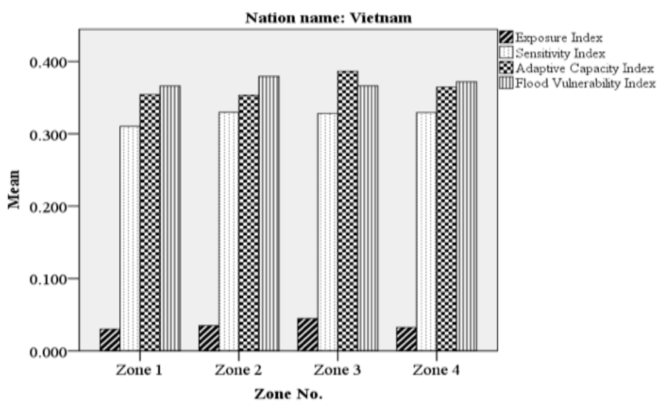

Figure 5. The comparison of indices among study zones.

"flood exploitation" is more appropriate than prevention because flooding has beneficial elements for local socio-economic growth (*Keskinen 2008*). Therefore, a combination of structural and non-structural measures has been conducted. From 2001 to 2005, safe residential areas in flooded provinces were built to secure that evacuation would be no longer needed even if devastating floods occur. Besides, there were more embankments constructed or upgraded at certain towns and villages. For example, there were 21 large canals invested in flooded areas of Kien Giang and An Giang provinces. In the MRD, the Summer-Autumn rice season used to experience heavy damage because it starts in July and finishes in November, which matches the annual flood season. Hence, the government promoted a shift in the cropping schedule; rice farmers were advised to begin the Summer-Autumn crop in April and harvest in August. This strategy, together with advantaged mechanization, has reduced the Summer-Autumn flooded rice field from

Table 6. Coefficients of regression between vulnerability and its sub-indices.

Model	Unstandardized Coefficients Standardized Coefficients			Sig.
	B	Std. Error	Beta	
(Constant)	0.373	0.000		0.000
Exposure	0.518	0.000	0.205	0.000
Sensitivity	0.518	0.000	0.403	0.000
Adaptive Capacity	-0.518	0.000	-0.895	0.000

551 million m^2 in 2000 to 45 million m^2 in 2001 and 1.06 million m^2 in 2002 (*Tinh and Hang 2003*). Besides, there were establishments of "flood kindergartens" and "health-care boats" to take care of children and victims during inundation (*Tinh 2003*).

CONCLUSIONS AND RECOMMENDATIONS

Understanding flooding and its impacts on society require the consideration of both physical and social contexts. While previous studies primarily used hydrodynamic models to analyze flooding's physical characteristics in the MRD, this paper attempted to fill the gap in social facets by examining rural households as the socioeconomic unit being affected by the hazard. The results showed that the majority of the delta is moderately vulnerable to floods. Zone 1 and zone 3 had the smallest vulnerability index; families in zone 2 were most vulnerable to flooding. Higher vulnerable households seemed to have low social capital and higher impacts on production, especially rice farming. Adaptive capacity was deemed to be more important than exposure and sensitivity in determining the flood vulnerability.

The examination of the household vulnerability and its components will provide policymakers with insights into flood management in the MRD. The indices helped identify the communities that were subjected to floods and needed more attention in the planning process. Also, this paper highlighted the drivers leading to the prone state, which were the exposed rice indicators, elderly ratios, and social bonds. By focusing on these factors, the flood vulnerability in the MRD can be reduced in the most efficient manner.

Up to 75 % of the family's income came from rice production. Rice-related variables explained most of the household's flood exposure. Damages were minimized by flood control structures at the locality. The benefits of infrastructure in the MRD were also acknowledged in the study of *Le et al.* (*2008*).

The elders played a major role in explaining the family's sensitivity. Regarding gender difference, the study found no difference in the effects between male and female senior citizens, but the PCA result showed that sensitivity was negatively correlated with female children while positively correlated with male children.

The social capital, attendance at training courses and adjustments made in aquaculture were the most significant indicators of adaptive capacity. Social capital is a special factor since it can interact with many other variables. For example, during the inundation, people with better social connections have better chances to receive assistance (*Chomsri and Sherer 2013*). *Thomas et al.* (*2005*) reported that community bonds and family cohesion are essential to lessen the natural risks-prone. Strong social ties can also facilitate other factors such as income or education (*Cutter et al. 2003; Elliott et al. 2010*).

The feasible solution to reduce flood vulnerability is to focus on the family's adaptability because it had the largest influence on vulnerability. Moreover, better-coping capability can indirectly reduce sensitivity or exposure. Promoting education and encouraging people to attend training courses will provide farmers with efficient methods to cope with floods, thus decreasing the potential adverse impacts.

Besides, strategies to help households diversify their livelihoods and create opportunities for non-farm income should also be prioritized. It will lessen the dependence on natural resources and solve the unemployment and poverty problems, thus mitigating the sensitivity towards natural hazards. Cow farming is a preferred option by many farmers and has the potential to develop since it is easy to feed and the beef price does not have many fluctuations. However, it requires high initial investments. In coastal areas, farmers can switch between rice and shrimp production, depending on the environment. In some regions where there are favorable conditions, people can plant vegetables or fruit trees for additional income.

Aside from factors related to the household level, this study also highlighted the efficiency of dike systems in reducing the exposure and protecting farmers from inundation. Therefore, infrastructure in the more vulnerable areas of the delta should be further invested. Basic construction projects such as riverbank fortification and irrigation facilities are necessary for people protection and agricultural intensification.

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