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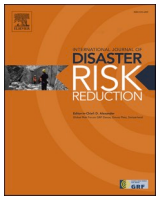

Livelihood vulnerability and adaptability of coastal communities to extreme drought and salinity intrusion in the Vietnamese Mekong Delta

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ABSTRACT

Many deltas worldwide have increasingly faced extreme drought and salinity intrusion, which have adversely affected millions of coastal inhabitants in terms of lives and property. The Vietnamese Mekong Delta (VMD) is considered one of the world's most vulnerable regions to drought and saline water intrusion, especially in the context of climate change. This study aims to assess livelihood vulnerability and adaptation of the coastal people of the VMD under the impacts of drought and saltwater intrusion. A multi-disciplinary approach was applied, including desktop literature reviews, field surveys, interviews, and focus group discussions with 120 farmers and 30 local officials in two representative hamlets of Soc Trang, a coastal province of the VMD. A vulnerability assessment tool in combination with a sustainable livelihood framework was used to evaluate livelihood vulnerability using the five capital resources to indicate the largest effects of drought and salinity intrusion on the migration of local young people to large cities for adaptation. Livelihood Vulnerability Indexes revealed higher vulnerability in terms of the five capitals of coastal communities living in Nam Chanh hamlet compared to Soc Leo. Results of interviews with officials indicated an optimized mechanism between social organizations and local communities before, at the time, and after being impacted by the drought and salinity intrusion. Our findings contribute evidence-based knowledge to decision-makers to enable coastal communities in the VMD and other deltas worldwide to effectively adapt to the impacts of drought and salinity intrusion.

1. Introduction

Climate change has posed direct impacts on the settlement and livelihoods of coastal populations worldwide [1–3]. Damages from climate change impacts have occurred in many places in coastal areas such as dryland losses, environmental degradation, food insecurity, water-borne diseases, and lack of energy use and available water resources [4]. Additionally, the changes in precipitation patterns and extended droughts have exacerbated disasters with adverse impacts on humans, the natural ecosystems, and the quality of human life. These impacts have placed significant pressure on humankind for effectively using surface-water and ground-water resources for agricultural production [4], because the lack of fresh surface-water in many saline-affected areas requires farmers increasingly exploiting fresh/-brackish groundwater for crop production. Due to climate change and sea level rise, saltwater intrusion and droughts have strongly affected coastal settlements in terms of social disruption and reductions in local economies. Hence, the livelihoods of coastal communities are unsustainable due to their vulnerable exposures to increasing salinity intrusion and droughts [5]. In this context, adaptive options that could help farmers minimize their vulnerability and maximize their livelihoods' sustainability need further exploration [6,7].

Many studies have considered adaptations as solutions to reduce vulnerability due to climate change driven sea-level rise effects [8–10]. Of those studies, Wijayanti and Pratomo [9] analysed the adaptation to the vulnerability of socio-economic activities for coastal communities of

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Semarang, Indonesia. The adaptation was found in social and economic livelihoods based on natural resources (i.e., pond fish cultivation) and other factors (i.e., change to industrial jobs, taxi driver, trader, and so on). Fatorić and Chelleri [11] indicated that the five options for climate change adaptation to decrease vulnerability are building artificial barriers, protecting deltas from saltwater intrusion with underwater obstructions, raising the ground level, making dunes and natural beach barriers, and human migration. According to Somboonsuke et al. [10], adaptation strategies to respond to the impacts of climate variability include enhancement of capacity in impact assessments, prevention and avoidance and mitigation of negative effects, reduction of loss from negative influences, and rehabilitation of devastated areas from the losses. Salik et al. [12] recommended adaptation options for coastal communities to climate change effects, including the provision of safe drinking water facilities, ensuring environmental river flows as the minimum flow necessary to sustain freshwater ecosystems, safeguard from climatic disasters and settlements in high-risk areas, improving education access, and capacity development for climate change preparedness and innovations.

The abovementioned studies have assessed the vulnerability of livelihoods under natural disasters impacts without investigating communities' perspectives. Livelihood Vulnerability Index (LVI) is an effective tool commonly applied in many fields to identify the variability in vulnerability of affected households due to the effects of natural disasters [13–17]. The LVI includes various different components depending on the scope of study. Hahn et al. [17] applied the LVI based on seven major components, i.e. socio-demographic profile, livelihood strategies, social networks, health, food, water, and natural disasters and climate variability to estimate climate change vulnerability in the Mabote and Moma districts of Mozambique. Another study of Madhuri [13] used the LVI tool to assess the vulnerability of the seven blocks of the Bhagalpur district in the state of Bihar, India under the impacts of floods. In order to measure vulnerability of subsistence communities in Pakistan, Qaisrani et al. [15] used the LVI approach of the Intergovernmental Panel on Climate Change (IPCC) to analyse the determinants of household livelihood vulnerability defining vulnerability in terms of exposure as effects from climate change risks, sensitivity as the degree to which the system is affected by the exposure to risks, and adaptive capacity as ability of an individual or households to cope with the risks. In Vietnam, this tool was also used to evaluate the vulnerability to climate variability and change for three agricultural and natural resources dependent communes in northwest Vietnam [16] and the livelihood vulnerability of five communities of farmers exposed to droughts in one of the more vulnerable regions of Vietnam—Dak Nong Province [14].

In coastal areas of the Vietnamese Mekong Delta (VMD), salinity intrusion and drought increased by climate change have adversely affected the livelihoods of people, especially among socially vulnerable and disadvantaged groups [18]. In 2016, saltwater intruded further inland up to more than 90 km from the coast, an extreme record for saltwater intrusion [19]. This event affected 11 out of 13 provinces of the VMD, causing severe damage to agricultural production and water scarcity. Also, a total agricultural area of 210,000 ha was damaged, and 250,000 households (equivalent to 1.3 million people), schools, clinics, hotels, and production facilities were strongly affected due to freshwater shortages [20]. However, there has been limited exploration to assess the principal factors perceived by farmers and local officials i.e., health, food security, migration, gender role, and social institutions, and how the disasters affect the sustainability of the livelihoods of these coastal households. In addition, it is unknown to what extent these crucial factors influence the livelihoods in terms of vulnerability and adaptation assessment.

This study aims to assess the livelihood vulnerability and adaptation of two coastal communities to extreme saltwater intrusion and droughts in Soc Trang Province of the VMD. Soc Trang is one of the most vulnerable coastal provinces in the VMD due to saltwater intrusion and droughts. We assess the impacts of saltwater intrusion and droughts on rural livelihoods in terms of health, food security, migration, gender role, and social institutions. We also seek to better understand the vulnerability of rural communities due to the impacts of saline intrusion on local people's livelihoods. Besides, we identify alternative livelihood adaptation strategies of local communities to saltwater intrusion and droughts.

This study addresses the following objectives:

- To *explore* the vulnerability of coastal rural communities to the impacts of saltwater intrusion and drought;
- To *assess* the impacts of saltwater intrusion and droughts on farmers' livelihoods in terms of health, food security, migration, gender role, and social institutions; and
- To *identify* alternative livelihood adaptation strategies to the impacts of saltwater intrusion and droughts.

2. Case study

Soc Trang is one of the provinces in the VMD that is annually vulnerable to drought and salinity intrusion [21]. In this province, a recent extreme salinity and drought event occurred during the dry season from December to May in 2015–2016. As a result, a large area of rice (9531 ha) was severely affected by salinity intrusion [22].

Salinity intrusion is an annual natural phenomenon occurring in the VMD [23]. The magnitude of salinity depends mainly on the four following factors: i) low discharges from the upstream river, ii) water storage capacity during the ending time of the flood season or the early period of the dry season, iii) coastal water level conditions, and iv) water use situation. In 2015, the peak flood discharge upstream and the total water volume measured at Tan Chau station of the VMD were the lowest for the 90-year record from 1926 [23]. Therefore, the flow into the delta during the 2015–2016 dry season was too low to flush away saline water intrusion to the sea.

This study investigated two communities of Nam Chanh and Soc Leo hamlets of Lich Hoi Thuong commune, Tran De district, Soc Trang province to assess the vulnerability and adaptability of coastal people. These hamlets are located nearby coastal areas (see Figs. 1 and 2) see Table 1; therefore, they have been recently affected by salinity intrusion and droughts at different concentration levels. In 2015–2016, salinity intrusion caused the most severe damage to both agricultural production in Lich Hoi Thuong commune (816.4 ha out of 1.170 ha of rice production area was damaged) and livelihoods of local people. The assessed area damaged by salinity intrusion for 2016 was less than 30% for Soc Leo and greater than 70% for Nam Chanh. Moreover, drinking water shortage was an issue and many farmers migrated to big cities for seeking jobs during the 2015–2016 drought [22].

According to the Lich Hoi Thuong People's Committee, many local farmers have migrated recently to other cities and provinces such as Ho Chi Minh City and Binh Duong. These farmers moved to look for temporary jobs because the majority of their land was negatively affected by salinity intrusion. Job and freshwater shortages were not only problems for Lich Hoi Thuong commune, but also for many other coastal communities of the VMD. These people are confronted with a wide range of issues related to saltwater intrusion and droughts. Livelihood vulnerability and adaptation should be assessed to identify alternative livelihood adaptation strategies for coastal communities to cope with the increasing impacts of salinity intrusion and droughts.

3. Methodology

The methods for data collection include interviews with farmers and in-depth interviews with local officials and focus group discussions.

3.1. Data collection

Interviews with stakeholders: A questionnaire was formulated with

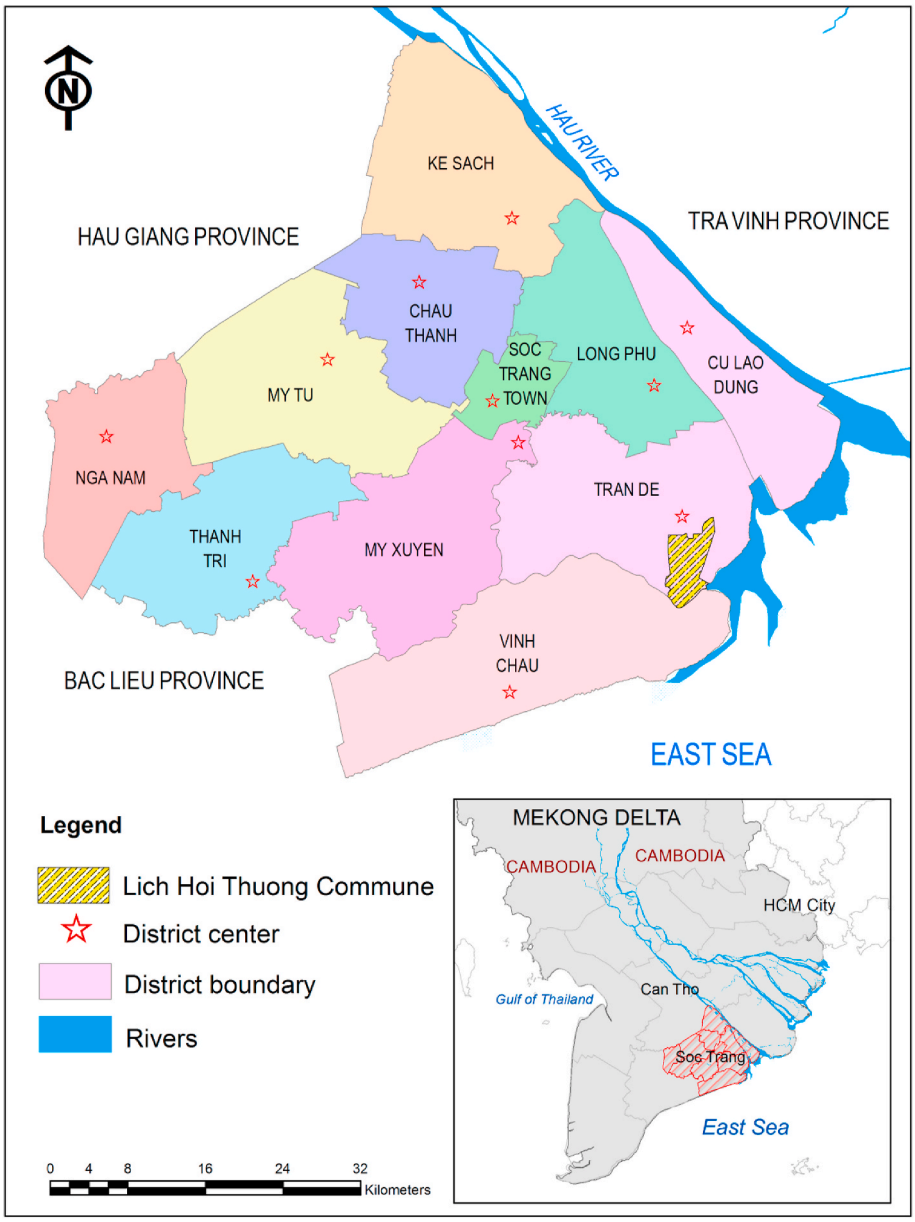

Fig. 1. Case study area in the Vietnamese Mekong Delta.

12 sections (Table A1 in the Appendix). The principal objective of the questionnaire was to understand farmers' perspectives and to explore the impacts of salinity intrusion and droughts in the study area during 2016. A total of 120 interviews were carried out to question local households in Nam Chanh and Soc Leo hamlets in 2017. In each hamlet, 60 interviews were conducted by randomly selecting farmers who owned lands used for rice or vegetable production or aquaculture.

In-depth interviews: This method proceeded as a confidential and secure conversation through two-way communications between an interviewer and a respondent. By means of a thoroughly composed interview guide, which was approved by the interviewee, the interviewer ensured that the conversation encompassed the topics that were crucial to ask for the purpose and the issue of the survey. In this study, semi-structured interviews were carried out with 30 governmental officials or heads of governmental units at commune, district, and province levels of the Soc Trang Province, i.e., People's Committee of Lich Hoi Thuong commune and Departments of Agriculture and Rural Development. The main aim of the interviews was to request officials to improve the existing roles and the coordination between governmental agencies and social organizations that are directly and indirectly responsible for supporting communities during salinity intrusion and drought events. Data were recorded in audio tape and notes taken.

Focus Group Discussions (FGDs): Four sessions of FGD were carried out in the two hamlets in May 2017 using the method of Participatory Rural Appraisal (PRA). This method has been in use in many developing countries since the 1980s [24]. In this study, the FGDs with PRA aimed to investigate and assess perspectives of various stakeholders including farmers, agricultural workers and migrants on their common understanding of relevant livelihood matters via interactive discussions. Different groups had knowledge about saltwater intrusion and drought problems from various geographical contexts. Participants invited included cultivated rice and vegetable farmers, aquaculture farmers, landless or poor farmers and hired agricultural labour.

3.2. Data analysis

3.2.1. Livelihood vulnerability index (LVI) analysis

The LVI analysis, which was developed by Hahn et al. [17], has been

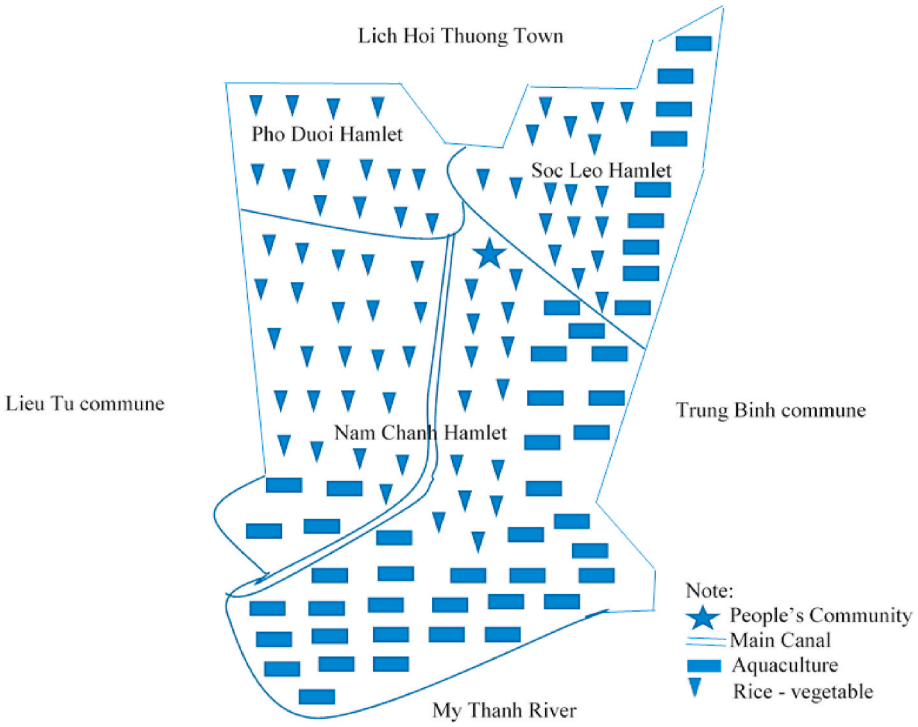

Fig. 2. Soc Leo and Nam Chanh hamlets in Lich Hoi Thuong commune.

Table 1
General characteristics of households in Nam Chanh and Soc Leo hamlets.

No	Hamlet	Total number of households	Total number of poor households[a]	Aquaculture (ha)	Rice (ha)	Vegetable (ha)
1	Nam Chanh	1190	126	795 (52%)	662 (44%)	62 (4%)
2	Soc Leo	490	32	203 (37%)	330 (59%)	21 (4%)

[a] The poor household is identified by commune authorities based on a number of standards regulated by the nation for rural areas (low income, landless and so on).

applied in several studies to assess livelihood vulnerability [13,16,25]. To compute the LVI or LVI-IPCC, we need a composition of seven key components that include socio-demographic profile, livelihoods, health, social networks, food, water, and natural disasters and climate variability.

In this study, LVI analysis was applied to identify the levels of livelihood vulnerability of coastal communities under the impacts of salinity intrusion and droughts. Therefore, key components are classified into indicators or sub-components of community vulnerability to impacts of saltwater intrusion and droughts. Different with Hahn et al. [17], we classified the components under five different livelihood capitals in the sustainable livelihood framework established by the Department for International Development (DFID) in the UK [26], including Human, Physical, Social, Natural, and Financial capitals (see Table 2 in Result section for the details). Human and Physical capitals consist of health, knowledge and skills, livelihood strategy, and land and equipment of housing vehicles and production means. Social and Natural capitals include social networks covering social institutions and migration, socio-demography, media means, and natural disasters and climate variability. Financial capital, in principle, is finance and income. The selection of sub-components or indicators was based on literature review, our knowledge of the study area and discussion with experts. In total, we have 26 sub-components or indicators classified into seven main components.

Each of the sub-components is measured at different scales. Therefore, these sub-components need to be standardized to become an index, according to the equation referenced from Hahn et al. [16] as follows:

$$Index_{S_d} = \frac{S_d - S_{min}}{S_{max} - S_{min}} \quad (1)$$

where: $\mathbf{S_d}$ is one of the sub-components of the area d, either Nam Chanh and Soc Leo hamlets, and $\boldsymbol{S_{max}}$ and $\boldsymbol{S_{min}}$ are the maximum and minimum values, respectively. For example, the "fraction of households regularly visiting clinic" is from the percentage of interviewed households 's responses (63.9% in Soc Leo and 86.4% in Nam Chanh) over the min value of 0% and max value of 100%. Another example is the "average number of members per household" in Nam Chanh with 4.38 members on average and min and max values of 2 and 7. After the sub-components are standardized, they are averaged to calculate the value of each main component using the following equation:

$$M_d = \frac{\sum_{i=1}^{n} Index_{S_{d_i}}}{n} \quad (2)$$

$\boldsymbol{M_d}$ is one of the seven main components in the area d (Nam Chanh and Soc Leo hamlets), or one of the indexes for dimension of vulnerability. $\boldsymbol{IndexS_{di}}$ represents the sub-components of the area d indexed by *i*, and *n* is the number of sub-components in each main component. When the value of the key components is determined, livelihood vulnerability index is calculated as follows:

$$\mathrm{LVI}_d = \frac{\sum_{i=1}^{7} w_{M_i} M_{d_i}}{\sum_{i=1}^{7} w_{M_i}} \quad (3)$$

$\boldsymbol{LVI_d}$ is the livelihood vulnerability index for the susceptibility in the area *d* (Nam Chanh and Soc Leo hamlets), corresponding to the weighted average of all seven main components. The weight of each main

Table 2
Detailed LVI results for the Soc Leo (SL) and Nam Chanh (NC).

Sub-components/ Indicator	Sub-component index		Component index		
	SL	NC	Components	SL	NC
Fraction of households regularly visiting clinic	0.639	0.864	Human	0.503	0.615
Fraction of households visiting clinic in the dry season	0.313	0.459			
Fraction of non-literate household heads	0.096	0.189			
Fraction of household heads who did not have access to disaster preparedness trainings	0.964	0.946			
Fraction of households having agricultural land irrigated by natural resources (i.e. rainfall and river water resources)	0.879	0.864	Natural	0.720	0.716
Fraction of households did production during the time of saline intrusion	1.000	1.000			
Fraction of households exploiting natural resources (i.e. rainfall and river water resources)	1.000	1.000			
Fraction of households with dependent labour	0.964	0.892	Social	0.510	0.501
Fraction of household heads with female members	0.060	0.135			
Average number of members per household	0.506	0.476			
Fraction of households not having help when facing difficulties	0.518	0.405			
Fraction of households did not join social organizations	0.831	0.811			
Fraction of households having temporary houses	0.072	0.081	Physical	0.175	0.203
Fraction of households not enough to meet basic needs.	0.277	0.324			
Rate of household borrowing	0.699	0.676	Financial	0.350	0.365
Fraction of households without income source during the dry season	0.000	0.054			
Agricultural average subsistence livelihoods (1/households with agricultural activities +1)	1.875	4.563	Livelihood strategy	0.253	0.350
Fraction of households having main income from agriculture	0.711	0.676			
Fraction of households engaged in non-agricultural activities	0.289	0.324			
Fraction of households migrating due to salinity intrusion	0.301	0.459			
Fraction of households not working in drought	0.000	0.054			
Average years of large salinity intrusion in the past 10 years	0.010	0.010	Natural disasters and climate change	0.371	0.389
Fraction of households affected by saline intrusion in 2016	0.518	0.601			
Fraction of households who did not receive warning about salinity intrusion affected	0.603	0.595			
Average standard deviation of annual rainfall in Lich Hoi Thuong commune	0.352	0.352			
LVI_{SL} (overall)					**0.446**
LVI_{NC} (overall)					**0.484**

component, w_{M_i} is determined by the number of sub-components contributing to the main components. LVI values ranged from 0 as the lowest vulnerability to 1 as the most vulnerable level.

3.2.2. LVI – IPCC index (exposure, sensitivity, and adaptive capacity)

LVI-IPCC index is an alternative method used to calculate LVI according to the IPCC definition of vulnerability under climate change and natural disasters [27]. The contribution of IPCC factors to the seven main vulnerability components follows the three pillars of adaptive capacity, sensitivity, and exposure. Of those, exposure is the magnitude and duration of the climate-related phenomenon such as drought or change in precipitation, sensitivity is the level at which the system is affected by the exposure, and adaptive capacity is the system's ability to cope or recover from the exposure [17]. Based on the methodology of Hahn et al. [17] used for LVI-IPCC calculations, adaptive capacity in this study includes social-demographics, livelihood strategies, social networks; sensitivity consists of health, knowledge, skills, land, natural resources, finance; and exposure comprises of Natural disasters and Climate variability. The main components are combined using the following equation:

$$\mathrm{CF}_d = \frac{\sum_{i=1}^{n} w_{M_i} M_{d_i}}{\sum_{i=1}^{n} w_{M_i}} \quad (4)$$

$\boldsymbol{CF_d}$ are the contributing factors according to the IPCC; $\boldsymbol{M_{di}}$ is a key factor for area d (Nam Chanh and Soc Leo hamlets) – indexed by i; w_{M_i} is the weight of each main component and $\boldsymbol{n}$ is the number of the main components of each contributing factor. Once exposure, sensitivity, and adaptive capacity are computed for each area d, the combination of these three contributing factors is calculated using the following equation:

$$\mathrm{LVI-IPCC}_d = (\mathrm{Exposure}_d - \mathrm{Adaptive\ \ Capacity}_d) \times \mathrm{Sensitivity}_d \quad (5)$$

Where $\mathrm{Exposure_d}$, $\mathrm{Adaptive\ Capacity}_d$, and $\mathrm{Sensitivity}_d$ are the calculated exposure, adaptive capacity, and sensitivity scores for households in area d including Nam Chanh and Soc Leo. LVI – IPCC values are scaled from −1 as the least vulnerable to 1 as the most vulnerable.

Descriptive Statistics: Descriptive statistics are used to describe quantitatively the current situation based on interview data. In addition, we analyse the data of livelihoods, health, migration, property losses, and other relevant factors such as the impacts of saltwater intrusion and droughts.

Stakeholder Analysis with Spider Diagram (SASD): A spider diagram is a useful tool that has been applied in many studies for assessing the livelihood vulnerability [13,16,25]. Spider diagram based stakeholder analysis thus has been used as a tool to analyse measures or to solve a specific problem [28]. In this study, SASD is conducted to weight the LVI and the impacts of social institutions in supporting communities to

overcome or adapt to salinity intrusion and droughts.

4. Results

4.1. Livelihood vulnerability index (LVI) and LVI-IPCC

Fig. 3 presents the diagram for the seven major components of LVI for Soc Leo and Nam Chanh, and Table 2 presents the LVI results in more detail. Overall, Nam Chanh shows greater vulnerability to salinity intrusion and droughts than Soc Leo ($LVI_{NC} = 0.484$; $LVI_{SL} = 0.446$).

For the Human component, Nam Chanh is generally more vulnerable than Soc Leo ($LVI_{NC} = 0.615$ compared to $LVI_{SL} = 0.503$). The proportion of interviewed households regularly visiting doctors is 0.864 in Nam Chanh, higher than 0.639 found in Soc Leo. However, the fraction of households not accessing disaster preparedness training is 0.946 in Nam Chanh but is still lower than Soc Leo with 0.964. The natural component indicates that the value is the same (0.716 versus 0.720) for both hamlets with high vulnerability. For the social component, households in Soc Leo are more vulnerable to disasters than those in Nam Chanh ($LVI_{SL} = 0.510$ compared to $LVI_{NC} = 0.501$). Notably, a higher proportion of households not receiving help when facing difficulties in Soc Leo (0.518) than Nam Chanh (0.405) means the former may receive more timely help with food or freshwater from local authorities during the difficult time. Additionally, the labour dependency ratio index in Soc Leo hamlet is 0.964, which is higher than the ratio of 0.892 found in Nam Chanh. In terms of the physical component, households in Nam Chanh are likely to be more vulnerable (0.203) than those in Soc Leo (0.175). For the finance component, households in Nam Chanh are more vulnerable than those in Soc Leo ($LVI_{NC} = 0.365$ compared to $LVI_{SL} = 0.350$). For the livelihood strategy component, households in Nam Chanh (0.350) are more vulnerable than those in Soc Leo (0.253). Finally, results for the Natural disasters and Climate change component reveal a relatively similar vulnerability for households in Nam Chanh (0.389) than those in Soc Leo (0.371).

Fig. 4 and Table 3 show the LVI-IPCC analysis results by presenting the contributing factor scores for adaptability, sensitivity, and exposure. Overall, Nam Chanh (− 0.037) households are relatively less vulnerable to disasters than those in Soc Leo (− 0.027). Fig. 4 shows the highest sensitivity values for households in both hamlets compared to those under adaptive capacity and exposure. The triangle illustrates that Nam Chanh may be more exposed (0.389) to the impacts of salinity intrusion and droughts than Soc Leo (0.371). Similarly, according to the health status, knowledge and skills, land, natural and financial resources, Nam Chanh may be more sensitive to the impacts than those in Soc Leo (0.521 compared with 0.541). Finally, based on the socio-economic conditions, livelihood strategies and social networks, Nam Chanh shows a higher adaptive capacity than Soc Leo (0.461 versus 0.420).

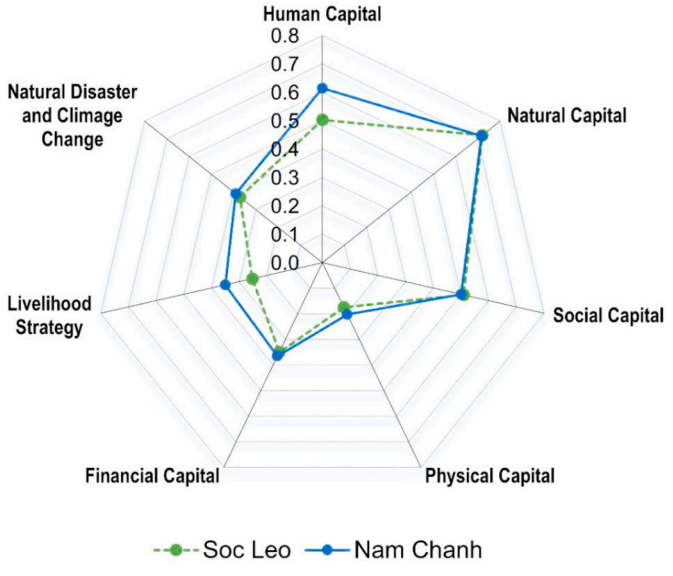

Fig. 3. Vulnerability spider diagram of the LVI major components for Soc Leo and Nam Chanh.

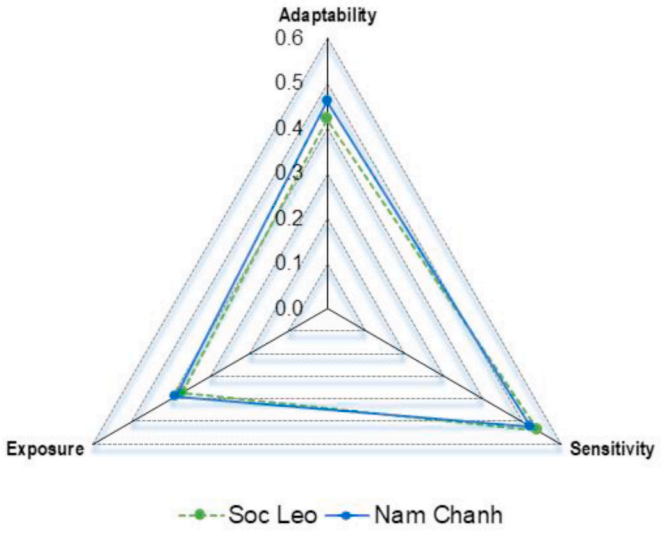

Fig. 4. Vulnerability triangle diagram of the contributing factors of the LVI-IPCC major components for Soc Leo and Nam Chanh.

Table 3
The contributing factors to vulnerability of the LVI-IPCC major components for Soc Leo and Nam Chanh.

Factors affecting IPCC to vulnerability	Soc Leo	Nam Chanh
Adaptability	0.420	0.461
Sensitivity	0.541	0.521
Exposure	0.371	0.389
LVI-IPCC	**−0.027**[a]	**−0.037**[a]

[a] Negative numbers of LVI-IPCC means the higher exposure than adaptive capacity are found in both hamlets.

4.2. Livelihoods sustainability assessment in terms of health, food security, migration, and gender role

4.2.1. Health risk of farmers under the impacts of salinity intrusion and drought

The impact of droughts was measured by increasing air temperature and lack of water for irrigation as indicators for farmers' health risks. Based on these indicators, our interviews show that 50.6% of farmers used to visit doctors in the dry season to consult for their sicknesses such as headache and fatigue, compared to 14.6% in the rainy season. On the other hand, 84% of farmers understood that salinity intrusion affected soil and water, and the death of crops required them to spend more time mitigating the negative influences on their lands. Due to the impacts of salinity intrusion and drought in 2016, most surveyed farmers (71%) reported that they regularly visited health facilities.

4.2.2. Food security and migration

Crops are negatively affected by the salinity intrusion and drought, i.e., decrease in yields or failure of crops. The People's Committee of Lich Hoi Thuong informed us that food security is not an issue during a disaster event. Most farmers had enough food and money saved from previous years as well as receiving support from their relatives or local authorities. However, food security, in terms of its indirect impacts on migration, should be taken into account.

In Fig. 5a, our data analysis reveals that 42 of the 120 surveyed households (35%) migrated from Lich Hoi Thuong to large cities for new livelihoods. Households that had one-member migration accounted for 54.8% (23 households), two-member migration accounted for 33.3% (14 households), and three-member migration accounted for 4.8% (2 households). With 7.1% households that had over 4 members migrating, 1 household (2.3%) had four members migrating, and 2 households (4.8%) had five migrating members. Of the total of 42 households having migration, the proportion of male members accounts for 70%.

Fig. 5b shows the percentage of household member migration in the two hamlets. For Soc Leo, there were 17 households with migration (40% of total households having members migrating). For these migrations, 7 households had 1 migrant, and 9 households had 2 migrants, equivalent to 41.2% and 52.9% respectively. Only one household had 4 migrants, which accounted for 6%. For Nam Chanh, there were 25 households having migration of family members (60% of total households having members migrating), with 16 households with 1 migrant (64%), 5 households with 2 migrants (20%), 2 households with 3 migrants (8%) and 2 households with 2 members migrating (8%).

4.2.3. Gender inclusiveness in agricultural activities against the impacts

Male heads of household accounted for 91.7% of the total surveyed households, while female heads accounted for only 8.3%. The cause for the discrepancy is due to the Vietnamese tradition that men usually make important decisions in a family. In addition, the gender difference also reflects the unspoken situation that rural-agricultural societies require muscular strength, so most household heads are male. Also, men play more important roles in seeking adaptation options for mitigating the impacts of salinity intrusion and droughts.

4.3. Adaptive capacity of farmers during and after the impacts

Our data analysis found that 13 out of the total 120 interviewed households (10.8%) changed to salt tolerance seeds during the salinity intrusion and drought of 2016. In addition, four households (3.3%) rescheduled their seasonal planting calendar, and one household said that the installation of irrigation-drainage would reduce salinity intrusion. Many households have had strategies to cope with salinization and were willing to improve their livelihoods yet the number of households (18 households) doing so was still small and unpopular. Most households still did not have any strategy to cope with salinity intrusion with long-term effectiveness.

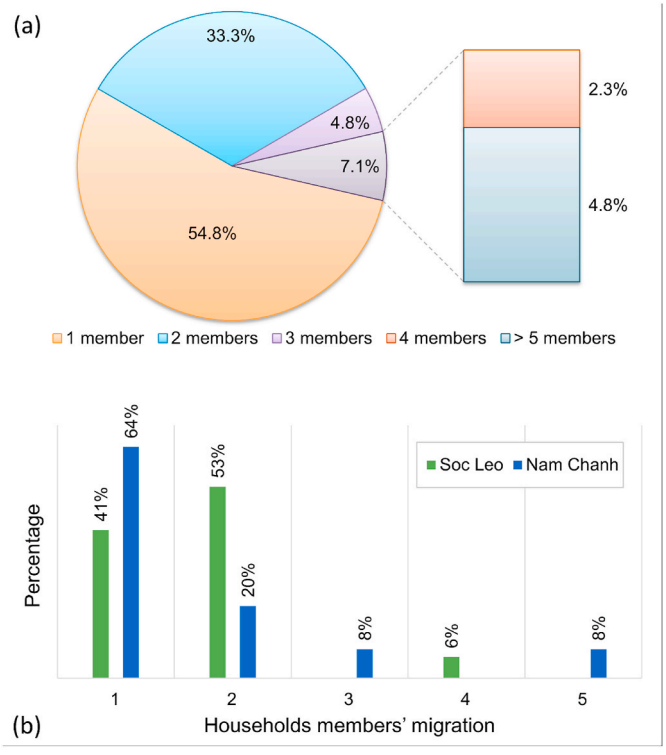

Fig. 5. The percentage of household's members' migration (n = 42) in Lich Hoi Thuong commune (a) and the two hamlets of Soc Leo and Nam Chanh (b) due to the saltwater intrusion and drought in 2016.

Lands used for agricultural production varied considerably after the impacts of drought and salinity intrusion. Of the 120 surveyed households, 105 (87.5%) had agricultural land, and 22 out of 105 households changed arable area. Notably, 5 out of those 22 households expanded their land area by buying or renting because they had good economic conditions. The remaining 17 out of 22 households had decreased their land size to be re-rented or sold to other households due to significant losses from the salinity and drought impacts. Also, 53 households now have water pumps (44% increase compared to 38% before the salinity), whereas 67 households own chemical sprayers (56% increase compared to 49% before the salinity).

The means for living and entertainment also increased because the salinity intrusion led to residents receiving more attention from local authorities and social organizations. For instance, 96.7% (116 out of 120) households had owned televisions after the salinity disaster compared to 85.8% (103 out of 120) before the salinity intrusion, and 112 out of 120 households had gas stoves, equivalent to 93.3% increase compared to 90.8% before the salinity intrusion.

After the salinity intrusion and drought, the interaction between residents and social organizations was more significant; however, the participation of residents in these social organizations remains unchanged. The number of households participating in social organizations is less than 10% (10 households), 7.5% (8 households) joining the farmer associations, and only 4.2% (5 households) joining the women's union.

4.4. Roles of government and social institutions and coordination in response to extreme salinity intrusion and droughts

A coordination needs to be active and coherent between governmental agencies and social institutions when the salinity intrusion and drought occurs (Fig. 6). The Commune People's Committee (CPC) reports damage, receives information and reports to the District and Provincial People's Committee (DPPC). The CPC and DPPC then provide information on the situation to the media (newspapers, television, radio, etc.) to report the situation to local people, private enterprise, and charity organizations/groups or local sectoral agencies. The PPC then reports to the On-duty Office of Steering Committee for Natural Disaster Prevention and Rescue Search (SCNDPRS). Afterwards, the head of the SCNDPRS directs a delegation, including leaders from provincial, district and commune levels in the affected regions, to set up a task force to assess the damage before declaring appropriate supportive measures. This delegation is established as soon as possible at the occurrence of salinity intrusion and droughts. After the task of assessing the damage and with the unified direction of the head of the SCNDPRS, local agencies or organizations assist affected people overcome the damage and restore their livelihoods from the impact.

Charity associations are largely responsible for providing support to people in short term, such as distributing rice and clean drinking water. This short-term support from charities is very important to help people overcome the difficulties before receiving support from the local agencies. On the other hand, official social civic organizations at the provincial, district and commune levels, such as the Youth Union, Military, Extension Organization, and Women's Union are responsible for immediately supporting and making action plans to help the communities in the long-term. For instance, the Military Region No. 9 coordinated with Soc Trang military to mobilize soldiers to transport more than one hundred cubic meters of clean water free of charge to affected

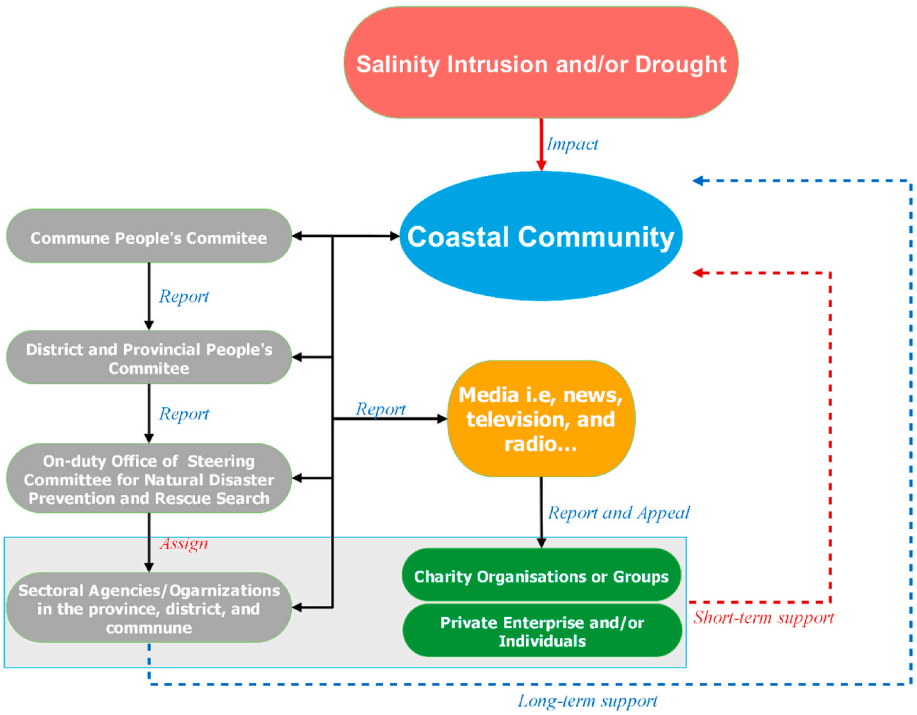

Fig. 6. Coordinated actions between governmental agencies and social organizations during the occurrence of the salinity intrusion and drought.

people during the disaster event in 2016. Besides, private enterprises/companies and individuals are also involved in supporting people, although they are mainly engaged in agriculture.

5. Discussion

5.1. Livelihood vulnerability and adaptability in wider context

Our research findings present that farmers' livelihoods in two coastal hamlets of the Vietnamese Mekong Delta (VMD) were vulnerable to the impacts of salinity intrusion and droughts in 2015–2016. LVI indexes indicate that Nam Chanh hamlet (LVI = 0.484, LVI-IPCC = −0.027) has a higher vulnerability than Soc Leo (LVI = 0.446, LVI-IPCC = −0.037). Still LVI-IPCC indexes show Nam Chanh is relatively less vulnerable than Soc Leo due to the higher adaptive capacity found in the former. These findings are relevant to Somboonsuke et al. [10] and Wijayanti & Pratomo [9], which found that the closer to the coastal area, the more vulnerable livelihoods of inhabitants are due to the salinity intrusion. However, this study is one of the first ones that use a vulnerability assessment framework to evaluate the livelihood vulnerability of coastal households in the VMD in the context of the impacts of salinity intrusion and droughts in 2015–2016.

Our results revealed that more attention should be paid to Human, Natural, and Financial resources in improving the capacity of people to cope with climate change and adaptation to saline intrusion and droughts. For the Human capital, the high fraction of households that regularly visits clinics and has low preparedness in training to cope with the salinity intrusion and droughts increased the vulnerability. For the Natural capital, the high proportion of households has used rainwater and river water resources for their agricultural production that put more attention to local authorities for protection. For the Financial resources, the high rate of households that borrowed money for their production presents a venerable status in both hamlets. However, both hamlets have relatively good livelihood strategies that play important roles to help communities to mitigate vulnerability [14]. We also found that adaptation options are highly appreciated by farmers in both Nam Chanh and Soc Leo; however, the support from various organizations should be implemented urgently and effectively for more vulnerable areas [17].

Analysis of results of five capital resources based on the DFID framework indicated various impacted levels of salinity intrusion and droughts on the perspectives of vulnerability and adaptation. Specifically, analysis of the Human component indicated that the extreme drought year of 2016 affected agricultural labour and their health in the coastal communities. For the Natural component, land-use conditions with agricultural production have varied considerably under the combined impacts of salinity intrusion and drought. Through assessment of the Physical component, most farmers showed their perspectives in improving agricultural activities to reduce threats by purchasing necessary production means. Regarding the Financial component, farmers had to borrow more money to recover their lives and agricultural lands after drought and salinity intrusion. Also, the high proportion of dependent labour in households and their limited participation in social organizations indicated high vulnerability to the salinity intrusion and drought events under the Social component assessment.

Migration should be taken into account since 35% of interviewed households informed that their family members had to move to big cities during and after the salinity intrusion and drought. We also found a close relationship between saltwater intrusion and droughts and migration in terms of food security, health risk, and gender. For instance, most male household members migrated to earn money in other large cities to send back their family members to buy food, recover health and reclaim saline lands due to the impacts of the salinity intrusion and drought. Our findings are similar to those from Meehl [29] who conducted a study on islands of the Tropical Pacific region and demonstrated that El Niño events during the 1980s – early 1990s and severe droughts resulted in freshwater scarcity and had pushed local people to leave their homes for urban areas. Furthermore, the decrease in the cultivated area, food and labour shortage, mechanised agriculture under saltwater intrusion and drought will lead to increased migration in the VMD in the next few decades. In addition, the salinity intrusion and drought events have increased long-term unemployment, declined quality of life, and polluted urban environments and water sources [30]. Additionally, extreme weather patterns likely threaten the livelihood and food security [31].

Regarding gender inclusiveness under the disaster impacts, our findings revealed that poor households probably had less opportunity to change their livelihoods when their land and crops were damaged. This is relevant to the findings of [32]. Besides, poor and women suffer more impacts and have fewer job opportunities than men when moving away from their home as informed by Ref. [33]. Women suffered greater vulnerability to climatic hazards than men as they have limited skills and opportunities and are primarily responsible for taking care of family members during hazards response and rehabilitation periods [34]. These are some of the reasons why we need to pay attention directly to migration and food security, including gender roles for the study area. Assessing social vulnerability to climate change such as the salinity intrusion and drought will help to create regulation and awareness programs to minimize vulnerability [31].

5.2. Policy implications on the flexible and effective coordination mechanism

Our study elaborated on the existing roles and coordination between governmental agencies and social organizations that directly and indirectly support coastal communities before, at the time, and afterwards being impacted by salinity intrusion and droughts. The Steering Committee for Natural Disaster Prevention and Rescue Search (SCNDPRS) is the centre of the coordination mechanism. It is responsible for the appropriate and effective mobilizing of various related sectors and units from provincial, district to commune levels to participate in short and long term support for local people. However, the SCNDPRS requires recognition and inclusion of local informal civil society organizations to strengthen its effectiveness and to maximize its potential as well as providing timely and positive impacts for the affected people. It is necessary to apply a flexible, yet specific policy to integrate mitigation and response measures into local strategies and programs, with particular attention to the poor and landless farmers. In the long term, the government needs to set up a specialized management unit responsible for natural disasters in general and for saline intrusion, in particular, to ensure effective operations on natural disasters prevention and control.

During salinity intrusion and drought events, it is essential to establish a comprehensive mechanism for utilizing and integrating various social organizations into the SCNDPRS to provide timely support to local people in the affected areas. To also be effective, government agencies and related units must also implement support activities timely and effectively. Urgent support is needed to help provide employment for people who are required to move to new places. The following policies should therefore be carried out after the effects of drought and salinity intrusion. First, it is compulsory to strengthen innovation, investment in research, and technology transfer to cope with not only the impacts of increased climate change causing disasters such as the salinity intrusion and drought but also human impacts i.e. subsidence, coastal dam-break, and mangrove squeeze. Second, the focus should be more on applied research, plant seed production, and adaptive farming techniques engaged in building with nature i.e. extensively developing shrimp-fish models integrated with mangrove forest along the coast. Third, enhancing evidence-based studies is essential to prevent and adapt to drought and salinity intrusion for each affected area, as well as to set up operating procedures and implement agricultural activities prepared to respond to natural disasters specifically the drought and salinity intrusion. Finally, smart agricultural models need to be developed to help farmers to cope with and adapt to the drought and salinity intrusion.

5.3. Limitations and future outlook

This study has assessed the vulnerability of livelihoods of coastal farmers under the impacts of salinity intrusion and droughts, but some limitations exist. First, our findings would likely be strengthened if our study area extended to other coastal provinces in the VMD. Second, this study did not assess water scarcity as one of the main components to be assessed its LVI and LVI-IPCC due to drought [14]. Third, we interviewed governmental officials to explore a suitable coordination mechanism between social organizations to effectively respond the salinity intrusion and drought, but the method excluded a systematic evaluation with scale and rate based on officials' perspectives from weightings. These limitations should be taken into account by future studies.

6. Conclusion

This study has assessed the livelihood vulnerability and adaptability to drought and salinity intrusion of coastal communities in Soc Trang province of the Vietnamese Mekong Delta. Based on the research findings and discussion, we conclude:

- Coastal inhabitants, especially farmers in Soc Trang province, are strongly affected by the impacts of salinity intrusion and drought. Their agricultural livelihoods are vulnerable to shocks and stresses caused by the changes. However, farmers are willing to cope with and adapt to the changes, and likely require the support from the local government in the short term and long term.
- The coordination mechanism has been established and operated in the study area to help residents respond to the drought and salinity intrusion. However, this mechanism should be flexible and may be revised to suit the local living conditions and future changes if it is necessary. The roles of each organization in the coordination scheme have been declared, but the authorities need to put these into practice regularly to be well-prepared for any situation. An incentive policy has been announced but it should be strictly implemented to motivate stakeholders in the coordination mechanism.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Annex.

Table A1
The questionnaire content using in household surveys

No	Questionnaire sections	Content
1.	General information on the household	– Gender and ages of household's members – Marital status – Gender rate and illiteracy – Number of children under the age of 18 and members over 65 – Jobs of household's members – Average family income – Family income when salinity intrusion and droughts were occurring
2.	Human capital	– What are major characteristics of households regarding experiences and education of households in coastal areas? – What are the kinds of jobs, available labours of households, job security, and main career to meet or maintain their living?
3.	Physical capital	– What are major means or equipment for production that households can access? – What are pieces of electronic equipment, vehicles, type of house, safe place that households can access to? – What are the housing conditions and impacts of salinity intrusion or droughts in regard to housing and production damage?
4.	Natural capital	– What are agro-ecosystems profile, agricultural production (rice, vegetable, aquaculture, fisheries), and seasonality coastal areas? – What are the state of households with regard to land holder and land ownership in coastal areas?
5.	Social capital	– What are formal or non-formal social networks that households have been participating or evolving such as institutions, associations, organizations, and groups?
6.	Financial capital (livelihood and income diversification or strategies)	– What are major sources of income, activities and occupation of household members (before – in – after historical salinity intrusion and droughts)? – What is the contribution of each source to total household income, living condition of the households? – What are the financial sources of households when occurring saltwater intrusion and droughts or having needs? Borrowed or received financial supports in numbers? What are the reasons why households did not request assistance at the effecting time of the disaster, and what strategies?
7.	Migration	– Why did household members have to travel to other places? – After migration, what were the settlements, health and jobs? – What is the trend of the migration and what will it be? (secure or temporary) – How livelihood strategies are in the future?
8.	Social institutions	– What types of social institutions do coastal communities contribute to adapt to saltwater intrusion – droughts and its activities?
9.	Human health	– What are the health problems of members of household? – What are the health effects of saltwater intrusion and droughts? (both long-term and short-term) E.g. miss work or school. – How long do members of household spend in a health facility?
10.	Food security	– Do households have food shortages during salinity intrusion and droughts events? – What is average months needed to make an effort to find food? – What is the crop diversity of households? – Do households have seed or food storage?
11.	Agricultural production and drinking water management	– Do households have water scarcity during salinity intrusion and droughts events? (both production and domestic) – What time do households spend to take their main water sources? – What is the water supply status? – Do the average number of litters of water that households stored and used?
12	Natural disasters and climate vulnerability (salinity intrusion and droughts)	– Average number of salinity intrusion and droughts in the past. – Did households receive a warning about salinity intrusion and droughts? – What are the number of injuries or death of households, and damage crops?

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