Urban Flooding in the Context of Climate Change in Ho Chi Minh City: A Case Study of Nha Be District

Le-Minh Ngo, Dao Chi Vo, Le Thi Kieu, Pham Thi Ngoc Diep, and Hai-Yen Hoang

Abstract Located by Nha Be River and within 30 km of the South China Sea, the Nha Be District is one of the outer districts of Ho Chi Minh City that has suffered severe urban flooding. For a comprehensive understanding of urban flooding in this district within the larger context of global climate change, this quantitative study aims to describe the frequency, intensity, and impacts of floods on the locals as well as summarize multi-scale responses. In surveying 210 households in the Nha Be District, and by conducting 14 in-depth interviews with community representatives and land management officers, the study found that rapid urbanization and climate variability in the last ten years have contributed to the complexity of flooding in this area, which is characterized by low-lying terrain and an interlocking waterway system. Among the surveyed households, half of them have frequently faced flooding throughout the year, and 39.4% of them have been impacted at one time. Flood intensity is variable, with the average depth at approximately 20 cm. Since flooding has negatively influenced living quality, commuting, and housing quality, several solutions have been implemented by homeowners, the community, and the local government to cope with the growing impacts of flooding. Despite certain approaches taken by different stakeholders, it is critical to propose further approaches for dealing with urban flooding in Nha Be District. These approaches might take into account the solutions relating to flood-proof housing and urban areas in response to urban flooding in the context of climate change.

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1 Introduction

Located by Nha Be River and within 30 km from the South China Sea, Nha Be District is one of the outer districts of Ho Chi Minh City (HCMC) that has undergone severe urban flooding caused by multiple factors such as its topography (Asian Development Bank 2010; Tran TN 2011), a large and growing impervious area due to urban expansion (Vietnam Climate Adaptation Partnership 2013), and so on. In the context of climate change, Nha Be is highly vulnerable to sea-level rise, tides from rivers, and ground subsidence (Nguyen 2016). It is necessary to understand the frequency, intensity, and impacts of the floods on living quality, commuting, and housing quality for residents, as well as the solutions implemented by homeowners, the community, and the local government. On that basis, the following research proposes solutions for how best to adapt to climate change and flooding.

This paper summarizes certain findings from a quantitative study on the frequency, intensity, and impacts of floods on the locals and local housing, as well as the multi-scale responses from various stakeholders. Among the methods, a survey was used to collect data from one town and six communes (wards) of Nha Be District with the participation of 30 households in each ward. The research objectives are to understand urban flooding in Nha Be District in the context of climate change and support further suggestions and recommendations for this urban area. Also, this research aims to help communities and local authorities take initiative and adapt to climate change and urban flooding.

2 Study Area

Located in the southeast of HCMC, Nha Be District spreads out over an area of 100 km^2 and includes one town (Nha Be) and six wards (Hiep Phuoc, Long Thoi, Nhon Duc, Phu Xuan, Phuoc Kien, and Phuoc Loc). Among them, Nha Be Town is the administration and business center that is the most urbanized. Situated near several industrial zones, export processing zones, and on the main gate to the city, Nha Be, Hiep Phuoc, Phuoc Kien, and Phu Xuan are the most populated areas in the district.

Due to its topography, this district consists of low-lying terrain that partly helps drain water out of the city center (Tran TN 2014). However, the recent rapid urbanization has transformed this outer district significantly, reducing its capacity for water storage and drainage. Since its infrastructure has not been well developed, the development of Nha Be has resulted in several issues for the district, including flood inundation. This entire district is estimated to be at risk of flooding due to the backfill projects along Sai Gon, Dong Nai, and Soai Rap River (Bui and Nguyen

2015). Additionally, due to the various impacts of climate change, housing in Nha Be District has suffered, seriously threatening people's safety and quality of life. Within the district, the most intense flooding has been recorded in the neighborhoods located along Le Van Luong, Huynh Tan Phat, and Nguyen Binh Street (Ngo et al. 2019; Vietnam Climate Adaptation Partnerships 2013).

Due to these impacts, several projects have been implemented involving flood reduction and mitigation efforts at multiple scales. Besides the efforts from the government, people living in Nha Be District have used various approaches to respond to floods. However, due to the mentioned topographic characteristics, the complexity of climate change, flooding, and other factors, still threatens harmful damage to the area.

3 Methodology

Data was collected by questionnaire and in-depth interviews conducted in one town and six communes (wards) of Nha Be District. The questionnaire was structured with four main parts (See Appendix). Part 1 aimed to collect the background information of respondents who imply their knowledge of the studied area, their houses, the flood situation, and their desires. Part 2 asks for their housing details relating to physical attributes such as, construction, renovation, and their evaluation of the house condition as it relates to their accommodation demands. Part 3 consists of questions regarding flood situations with information about frequency, intensity, sea-level rise, causes, and effects. Part 4 includes concerns about the previous solutions suggested by multi-stakeholders at housing and neighborhood scales. This study focuses on analyzing the results of Part 3 and 4 and uses the information attained from Part 1 and 2 for reference if necessary. The in-depth interviews mainly discussed the actions taken by the local governments, through the perspectives of community representatives and land management officers, to deal with floods over time. There were 210 survey respondents from households and 14 in-depth interviews from community representatives and land management officers at the mentioned administration units. Regarding the sampling size, Nha Be District's population is about 76,985 people (According to the data of the 2019 Census). The sampling size is calculated with a confidence level of 93%, and the tolerance is within 7%. The number of questionnaires is calculated by the formula for calculating sample size as follows:

$$n = \frac{N}{1 + N * e^2}$$

Note:

n: the number of units of the sample population.

N: the number of general units ($N = 76{,}985$).

e: the tolerance.

The tolerance (e) was chosen is 7%, the result for $n = 203.5$ samples. Rounded out 210 samples for one town and six communes (wards) of Nha Be District.

Besides a questionnaire, a guided observation was also used to record the related information in the survey by taking photos.

Data evaluation and analysis were implemented by descriptive statistical methods with support from IBM SPSS software (Ngo 2020). Multiple percentage calculation was mainly used to process data from the questionnaire that included a percentage of identical answers among the sample size and accumulative percentage.

4 Results

4.1 Frequency and Intensity

The findings in Fig. 4 show that flooding is a phenomenon that has been occurring in all wards of Nha Be District for more than ten years. In general, approximately 50% of the surveyed population reported that floods frequently take place in Nha Be District, while nearly half of the respondents just experienced floods at a specific time of the year, mainly during the rainy season. In addition, the study found that there are differences in flood frequency in different wards. Figure 4 provides the whole picture of floods taking place in Nha Be District; in which Nha Be town, which has the highest rate of urbanization, has the most frequent flooding (86.2%), followed by Nhon Duc, Phuoc Kien, and Phuoc Loc (57.2%, 55.6%, and 52%, respectively). Flooding happens more frequently in the rainy season, especially in Hiep Phuoc and Long Thoi, where flooding was found in approximately 80% of the surveyed households. Although flooding was reported by only 14.3% and 8% of respondents in Nhon Duc and Phu Xuan as an abnormal event, it still raises a concern about the capacity of drainage in such areas in case heavier rain comes in the years to come.

With regards to flood status, generally, there is a variation of flood depth among the surveyed households; the average depth is recorded at 23.72 cm. Some households are experiencing serious 70 cm-deep floods. Specifically, flooding severely occurs in the wards with a high urbanization rate, namely, Nha Be and Phuoc Kien with 29.7 cm and 26 cm in depth, respectively, followed by Nhon Duc (20.8 cm), Phu Xuan (17.6 cm), and Long Thoi (17.1 cm). The smallest flood depth was found in Hiep Phuoc and Phuoc Loc with roughly 15 cm (Fig. 5).

There is no doubt that there is a strong association between the rising sea levels and flooding. In this chapter, exploring the perception of households regarding sea level was included to examine not only the view of the locals to the climate variation, but also their knowledge about sea-level rise in relation to flooding issues in such areas. Generally, 57.15% of the surveyed households have perceived water variation as abnormal, while 30% and 11.9% of them see a slight increase and significant rise, respectively, in flooding over the last 10 years (2009–2019). There is a variation of

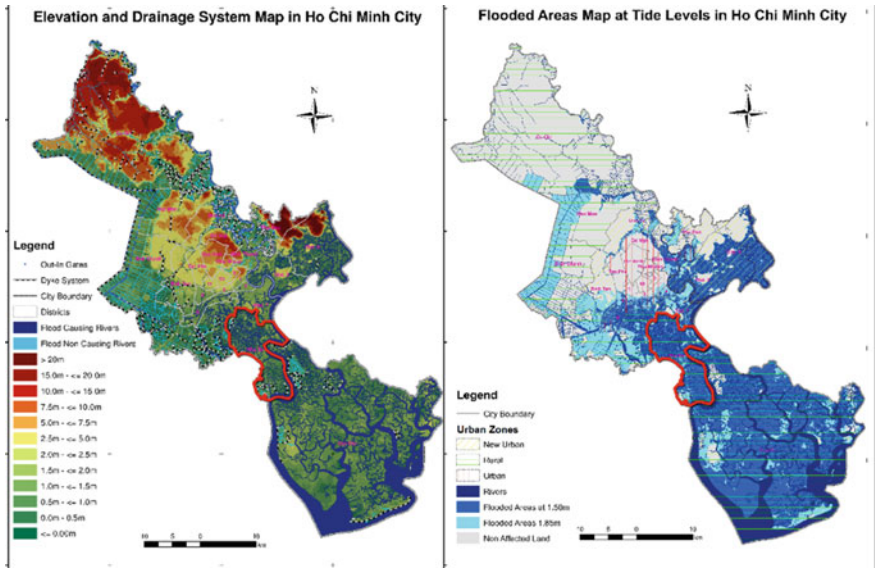

Fig. 1 Studied area (the red marked zone) in the maps of elevation and the drainage system (left) and flooded areas at tide levels (right) in Ho Chi Minh City (Tran TN 2014)

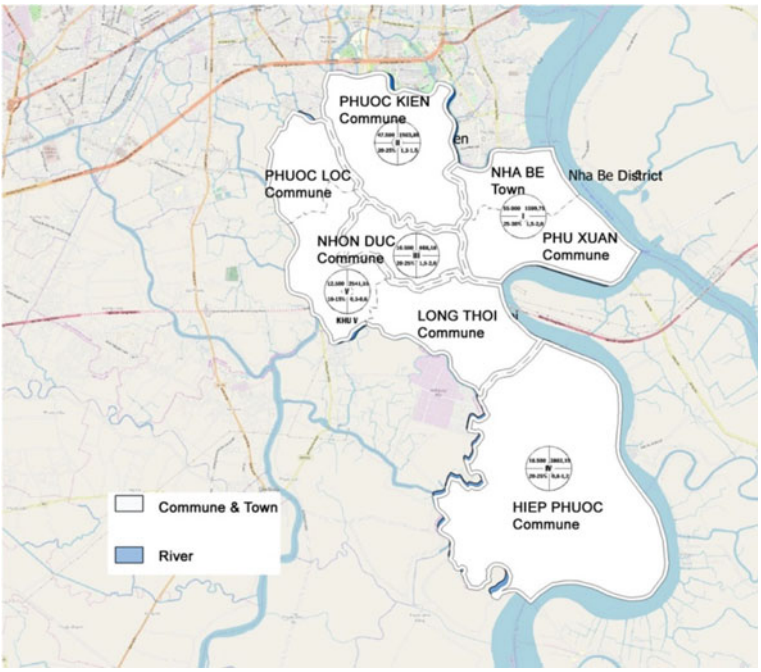

Fig. 2 Nha Be District map which shows a town and six communes (wards) (*Source* This figure is created by the first author, 2019)

Fig. 3 Housing was eroded in Nhon Duc Ward, Nha Be District (Authors, 2019)

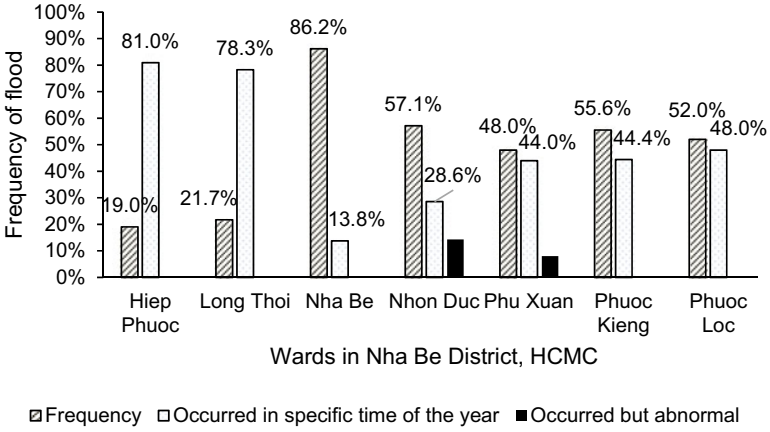

Fig. 4 Frequency of flood occurring in Nha Be District (Authors, 2019)

perceptions of residents' viewpoint among the wards of Nha Be District (Fig. 6). Inhabitants living in Nha Be Town, Nhon Duc, Phu Xuan, Phuoc Kieng, and Phuoc Loc are aware of the water variation from sea-level rise over time, which is reflected by the results in more than 50% of the surveys.

Characterized by a complex waterway system, Nha Be District respondents stated that flooding was mostly due to tides and heavy rains, as their frequencies are 43.5 and 31.9% among all causes, while the operation of water drainage system accounts for only 15.4%. Sea-level rise and landslides, along with dams, are the other rare causes, with roughly 3% of frequency (Table 1).

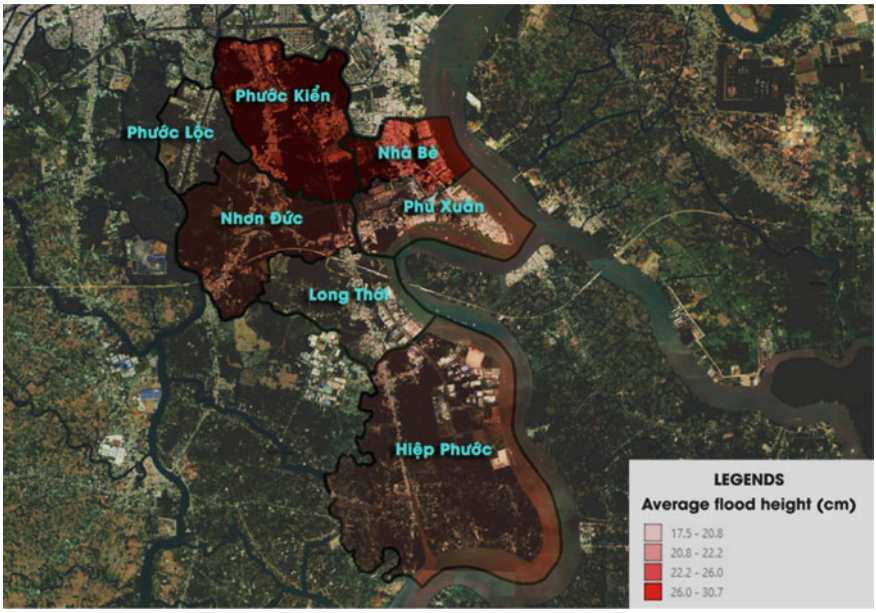

Fig. 5 Intensity of flooding reflected by the flood depth (Authors, 2019)

Intensity	N.	%
Slight increase	63	30
Slight decrease	2	0,95
Significant increase	25	11,9
Abnormal (sea level	120	57,15
Total	**210**	**100**

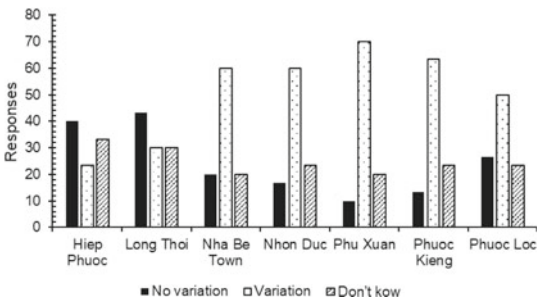

Fig. 6 Fluctuation of sea-level rise by year, taken from residents' viewpoints between 2009 and 2019 (Authors, 2019)

4.2 Impacts

Flooding has negative impacts on several aspects of the studied area. 30.5% of respondents found the effects of floods on traffic, namely making it inconvenient in commuting. A similar number of people (approximately 25%) saw damage to housing and a reduction in their quality of life caused by the seasonal floods. Noticeably, despite a small percentage of the flooding impacts, negative impacts on local

Table 1 Causes of flood in Nha Be District (Authors, 2019)

Items	N	Percentage over the sample (%)
Heavy rainfall	110	31.9
Tide	150	43.5
Sea-level rise	12	3.5
Low efficiency in water drainage system	53	15.4
Landslides	11	3.2
No dam	7	2.0
Others	2	0.6
Total	345	100.0

Table 2 Impact of floods on residents in Nha Be District (Authors, 2019)

Items	N	Percentage over options (%)	Percentage over sample (%)
No impact	29	8.3	16.2
Land loss (household along the waterway)	13	3.7	7.3
Housing damage	88	25.1	49.2
Negative impacts on business (house along the main road)	28	8.0	15.5
Traffic difficulties (traffic jam, vehicle damage, etc.)	107	30.5	59.8
Quality of life (activities, environment, health, etc.)	85	24.2	47.5
Others	1	0.3	0.6
Total	351	100.0	196.1

Note The result was calculated from a multiple-choice question

business and land loss should be taken into account in flood response and adaptation, especially for the houses located by the main roads and along the river. Figure 7 shows that the houses situated in Le Van Luong Street are considerably vulnerable to be re-flooded because most of them are small retailers and are just slightly higher than the main road elevation.

4.3 Solutions

To cope with flooding, there are many possible solutions (Table 3). Raising the ground level of the houses is the most referenced household-based solution among inhabitants, accounting for 53.7% of responses. However, nearly 37% of households

Fig. 7 House with business activity located on the main road in Nha Be District (*Source* This photo was taken by the first author, 2019)

suggested no solution in Nha Be District. A reason for this may be the dominance of low-income households that have limited to no financial capacity to apply renovation techniques. Only 0.5% of the respondents have applied concrete-based reinforcement. Some households have still coped with flooding with temporary measures such as leveling up furniture and investing in individual pumps for their self-drainage.

Local governments have taken certain measures to counteract the negative impacts of flooding as well. Based on in-depth interviews with community leaders, because of severe floods taking place on Huynh Tan Phat Street (from the joint with Tran Xuan Soan Street to Phu Xuan Bridge), the local government, with contributions from the residents, has upgraded alleys, namely 1716, 1806, and 1897. This project

Table 3 Selective solutions to cope with floods in Nha Be District (Authors, 2019)

Items	N	Percentage over sample (%)
Do nothing	69	36.8
Level up the ground floor	101	53.7
Built with concrete base	1	0.5
Floating house	0	0
Resettle to high-level floor	0	0
Other	17	9.0
Total	188	100

Note The result was calculated from a multiple-choice question

has partly reduced the flooding issue in the area. Plus, the local government has adopted soft measures such as cleaning sluice and sewage frequently, contributing to the increased efficiency of waterway function, especially when tides and rain take place. This includes dredging the Ba Lao Canal to foster drainage of water during high tide. However, with limited financial resources, the local government has been challenged by the efficiency of the drainage system, which is still poorly aligned between the main roads and narrow alleys. Thus, the participation and engagement of the community are important mechanisms for coping with climate change in Nha Be District. In this way, the effort to raise awareness via communication, propaganda of environmental protection, and trainings has been carried out.

5 Discussion and Conclusion

The study found, conclusively, that flooding has impacted multiple aspects of Nha Be District. Without early protection, it harms the existence of the community in the future. The findings reflect the frequency, intensity, and causes of flooding from the perspectives of the residents, which may contribute to further assessment and analysis of the flood risk in the area. However, to propose appropriate approaches for combating floods, more analysis and mitigation strategies are suggested, i.e., mapping, modeling, and simulation as well as further questionnaires for the area. All of these strategies, as well as those used in this study, can help residents deal with the complexity of climate change.

In conclusion, the study finds that floods occur all around Nha Be District, with the highest intensity and frequency recorded in Nha Be Town. Respectively, tide, precipitation, inadequate drainage systems, and sea-level rise are considered the primary causes of flooding. For people living in the district, floods have negatively impacted traffic and housing conditions as well as their quality of life. In response to the floods, the government has leveled up certain roads and improved the drainage system, while survey respondents prefer to elevate the floors in their homes. Since these measures are still limited, the findings of this chapter imply a need for further actions to deal with flooding in this area. These measures can be proposed and carried out from multiple stakeholders at various scales. Further strategies are recommended to integrate top-down with bottom-up and short-term with long-term solutions. Besides a discussion on flood impact measures, this chapter also contributes to the flood risk assessment, which may support the government in finding proper approaches for this area at the district level. The findings of the chapter can be used as a source of reference for other areas with a similar context in topographic and socio-economic features, such as the other coastal cities, in the developing countries in South and Southeast Asia.

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Appendix A—Questionnaire Form and Sample Survey Results

Sheet code:Kindly check and confirm the edit made in the tables, since empty cells are not allowed in tables. Amend if neccessary.Please delete these empty cells. Clearly they were used to record a reference number, but that becomes unclear when placed here - george

Questionnaire Form

For Residents in NHA Be and Can Gio District, Hochiminh City

Dear Mr/Ms,

I am a member of a research team from Ton Duc Thang University. We are collecting information to serve the research project assessment of the impact of flooding due to climate change on housing in Nha Be, Can Gio (HCMC), and propose planning and architectural solutions to respond. Please take a few minutes to read and answer this questionnaire by placing an X in ☐ of the answers you choose. The information you provide will be very important for the study of the topic and are committed to keeping it confidential, only for scientific research purposes. Thank you very much!

Investigator: ……

Respondent: ……

Respondent's phone number: ……

Address: ……..

Survey time: from ……., to ……., ……

A. RESPONDENT'S INFORMATION

A1: Gender: 1. ☐ Male 2. ☐Female

A2: Year of birth: ……

A3. You are:

1. ☐ Head of household
2. ☐ Parent of household head
3. ☐ Children of household head
4. ☐ Other (specify): ……

A4. Current accommodation:

A5. How many years have you lived and worked here?…….

A6. Reside planning in the future?

1. ☐ Continue to live and work here
2. ☐ Intend to move to another place to live and work
3. ☐ Other (specify): ……

A7. What is your FAMILY's level of participation in community activities (neighborhood, residential areas)? (may include other people in the household)

1. ☐ Regularly
2. ☐ Occasionally
3. ☐ Never
4. ☐ Other (specify): ……

B. CURRENT HOUSING INFORMATION:

B1. Features of the current location of the house:

1. ☐ Townhouse without yard, close to traffic road
2. ☐ Townhouse with yard, close to traffic road
3. ☐ House in a residential cluster with a shared yard
4. ☐ House located far away from the traffic road
5. ☐ Other: ……

B2. Please indicate and rate your current housing suitability according to the following criteria:

B3. What is the main material of the house's foundation: (Choose multiple answers if any, write % and take pictures)

1. ☐ Reinforced concrete
2. ☐ Brick/stone
3. ☐ Wood
4. ☐ Ground floor
5. ☐ Other: ……

B4. What is the main material of the wall covering the house: (Choose multiple answers if any, write % and take pictures)

1. ☐ Reinforced concrete
2. ☐ Brick/stone
3. ☐ Wood, metal
4. ☐ Fence, linoleum, plywood,…
5. ☐ Other:.……

B5. What is the main material of the roof of the house: (Choose multiple answers if any, write % and take pictures)

1. ☐ Reinforced concrete
2. ☐ Tile
3. ☐ Roofing sheets (cement, metal…)
4. ☐ Leaves, straw, oil paper
5. ☐ Other: ……

B6. Life expectancy of the current house

Built in: ……(year).

Number of renovations: ……..…

Renovated in *(most recent year first)*: (1): …….; (2): ……..; (3):

C. Land/Housing Condition With the Impact of Sea Level Rising

C1. Is there a flood situation where you are living, and how often does it happen?

1. ☐ Yes—happens often → go to C2
2. ☐ Yes—happens from time to time → go to C2
3. ☐ Yes—happens abnormally → go to C2
4. ☐ No → go to C7

C2. What is the average level of flooding (if any) in recent times? (cm) (recommended to record flood history in detail)

C2.1. Level of flooding in the most recent year: ……. cm (compared to the floor)

C3. How does sea-level rise change year by year?

1. ☐ No volatility → go to C4
2. ☐ With volatility → go to C3.b.
3. ☐ Unknown → go to C4

C3.b. Volatility of sea-level rise year by year:

1. ☐ Slightly increase
2. ☐ Slightly decrease
3. ☐ Strongly increase
4. ☐ Strongly decrease
5. ☐ Abnormal and can't be predicted

C4. According to you, what is the reason for the flooding? (Choose multiple answers)

1. ☐ Prolonged heavy rain
2. ☐ High tide
3. ☐ Sea-level rise
4. ☐ The drainage system does not work effectively
5. ☐ Ground subsidence
6. ☐ No dyke and sea barrier
7. ☐ Other: ……
   ……

C5. How does flooding and sea-level rise AFFECT your life? (Choose multiple answers)

1. ☐ No effect
2. ☐ Loss of residential land (For houses close to canals)
3. ☐ House damage
4. ☐ Jobs, shops (For houses close to the road/highway)
5. ☐ Traffic difficulties (traffic jams, cars stalled…)
6. ☐ Quality of life (Entertainment, sports, environment, diseases, bacteria, ...)

C6. What did you do to PREVENT flooding? (Choose multiple answers)

1. ☐ Nothing
2. ☐ Landfilling, raising the foundation of the house
3. ☐ Build house on piles
4. ☐ Build a floating house
5. ☐ Move to a higher place

C7. If sea-level rise (invasion, landslide) causes loss of living space and economic activities, what will you do?

1. ☐ Move to other places → go to C7.1.
2. ☐ Stay there and find a way to fix it → go to C7.2.
3. ☐ Unsure, seek for advice → go to C7.3.
4. ☐ Other……

C7.1. If moving, I will:

1. ☐ Temporarily rent elsewhere and will be back go to part D.
2. ☐ Stay somewhere else → go to part D.

C.7.2. I would fix it by:

1. ☐ Repairing the house → go to C.7.2.1.a and b
2. ☐ Build a new house → go to C7.2.2.
3. ☐ Other:……

C.7.2.1. a. How I will repair my house, including: (Choose multiple answers)

1. ☐ Raise the foundation
2. ☐ Build embankments, barriers
3. ☐ Other: ……

C7.2.1.b. Financial ability to repair house:

1. ☐ Below 50 million VND
2. ☐ From 50 to 100 million VND
3. ☐ From 100 to 200 million VND
4. ☐ More than 200 million VND

C7.2.2. Financial ability to build a new house:

1. ☐ Below 200 million VND
2. ☐ From 200 to 500 million VND
3. ☐ From 500 million to 1 billion VND

C7.3. The consultant is: (Choose multiple answers)

1. ☐ Family, relatives, friends
2. ☐ People with experience in renovating and building houses in flooded areas due to sea-level rise
3. ☐ Government

Knowledge/Personal Opinion on the Situation of Sea-Level Rise

D1. What information/instructions have you been given/instructed by local authorities on measures to prevent flooding for houses and residential land?

1. ☐ No instructions/notifications
2. ☐ Already informed/instructed
3. ☐ Unknown

D2. What support have you received from local authorities to prevent flooding for houses and residential land?

1. ☐ No support
2. ☐ Already supported *(financial, technical,…)*
3. ☐ Other: ……

D.3. Do you know/see any solutions for housing that are resistant to flooding caused by climate change?

1. ☐ Don't know
2. ☐ Know → go to D.3.1. and D.3.2.

D.3.1. Please list your solutions:

D.3.2. From where do you know the solutions?

1. ☐ Already have experience using these solutions
2. ☐ Have seen other people in the area use these solutions
3. ☐ On the media (TV, newspaper, radio,…)
4. ☐ Other: ……

D3. Do you have any suggestions to solve the current flood problem caused by climate change for housing?

……

THANK YOU!

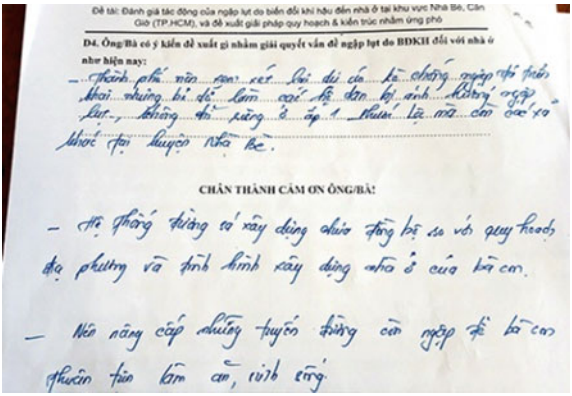
Appendix B

Figs. 8, 9, 10, 11, 12 and 13.

Fig. 8 In-depth interview conducted in a ward of Nha Be District (*Source* This photo was taken by the first author, 2019)

Fig. 9 Interview's group at Nhon Duc Ward People's Committee, Nha Be District, September 2019

Fig. 10 Examples of questionnaire surveys results displaying in depth detail, 2019



Đề tài: Đánh giá tác động của ngập lụt do biến đổi khí hậu đến nhà ở tại khu vực Nhà Bè, Cần Giờ (TP.HCM), và đề xuất giải pháp quy hoạch & kiến trúc nhằm ứng phó

D4. Ông/Bà có ý kiến đề xuất gì nhằm giải quyết vấn đề ngập lụt do BĐKH đối với nhà ở như hiện nay:

- Thành phố nên xem xét lại dự án kè chống ngập để triển khai nhưng bị dở làm cái hộ dân bị ảnh hưởng ngập lụt, không để riêng ở ấp 1 Nhơn Đức mà còn các xã khác tại huyện Nhà Bè.

CHÂN THÀNH CẢM ƠN ÔNG/BÀ!

- Hệ thống đường sá xây dựng chưa đồng bộ so với quy hoạch địa phương và tình hình xây dựng nhà ở của bà con.

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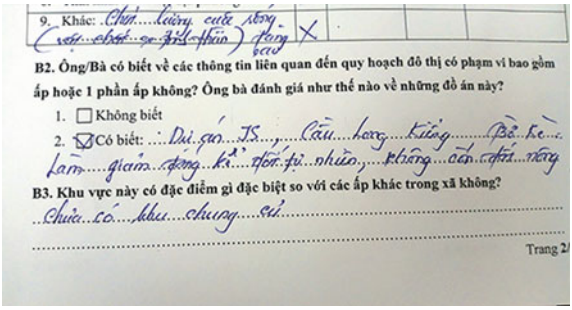

Fig. 11 Examples of questionnaire surveys results displaying further detail, 2019

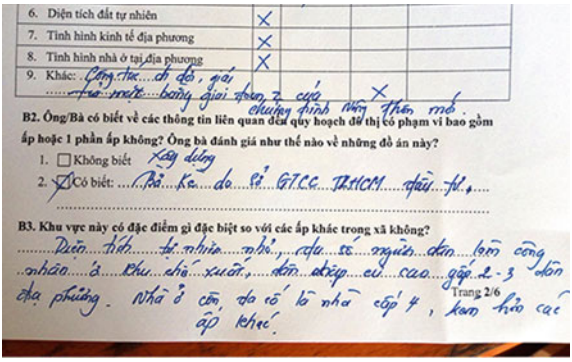

Fig. 12 Additional Examples of questionnaire surveys results, 2019

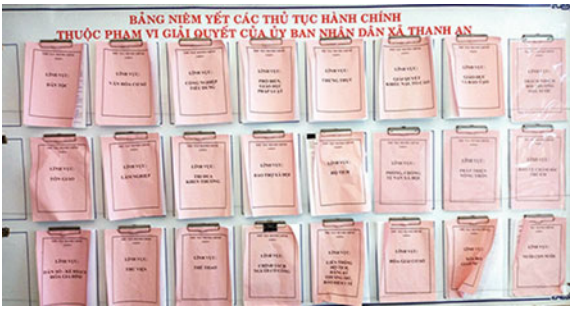

Fig. 13 Information board at Thanh An Commune People's Committee, 2019 (*Source* This photo was taken by the first author, 2019)

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