Chapter 53
Climate Change Vulnerability of Urban Development in Phanrang-Thapcham (Ninh Thuan, Vietnam)

Tuy Bao Van, Tho Tran Quang, and Kien Nguyen The

Abstract The impacts of climate changes and extreme weather events in recent years have had destructive impacts on urban development. Climate change increases the frequency and severity of floods, and as we are well aware, the impacts of flooding include loss of human life, damage to property, destruction of roads, schools, hospitals, markets, irrigation channels, dams, crops, loss of livestock, and deterioration of health conditions owing to waterborne diseases. This chapter recognizes key aspects of urban development that could be adversely affected by climate change, and develops measures and standards for assessing the urban vulnerability, develops an urban database of the sensitive variables consistent with vulnerability assessment measures, and applies the criteria in a study of vulnerability of urban Phanrang-Thapcham. Key findings highlight that approximately 50% of the area has a medium level of vulnerability and 10% of the area is highly vulnerable. Areas along the Dinh river and the central urban area have low vulnerability.

Keywords Climate change · Vulnerability assessment · Impacts · Urban · Phanrang-Thapcham · Vietnam

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1 Introduction

All human activities such as land use change and fossil fuel burning increase the release of greenhouse gases into the atmosphere, which results in climate change. The main characteristics of climate change are changes in precipitation, increases in average temperature on a global scale (global warming); melting of ice and glaciers inducing rises in the sea level (UNFCCC, 2007). According to The Fourth Assessment Report of the IPCC, over the last century, the average global temperature rose by 0.74 °C and is predicted by 2100 to range from 1.8 °C to as much as 4 °C. During the twentieth century, sea levels rose by 0.17 m and by 2100, they are projected to rise between 0.18 and 0.59 m (IPCC, 2007). There are many negative impacts of climate change, such as water resources for human use will be exhausted because of the ice and glaciers melting in places such as Greenland in recent years (UNEP, 2007). Moreover, the type, frequency, and intensity of extreme events, such as hurricanes, typhoons, heavy precipitation events, floods, and droughts are also expected to rise (Greenough et al., 2001). If the average global temperature were to rise around 2 °C, approximately 59% of population in the world would be exposed to water shortage (Rockstrom et al., 2009).

Vietnam is one of the countries predicted to be most severely affected by climate change owing to its long coastlines, the high concentration of population, and economic activity in coastal areas, as well as a heavy reliance on agriculture, natural resources, and forestry (Adger, 1999). The impacts of climate change such as typhoons, floods, prolonged droughts, and sea level rises would increase risks to properties, livelihoods, and urban infrastructure assets (MONRE, 2012).

Phanrang-Thapcham is the urban coast of the Ninhthuan province, which is often affected by natural disasters and is predicted to be severely affected by climate change in the coming decades. Recently, droughts and depletion of water resources have frequently occurred, which have severely affected agriculture, aquaculture, urban water supply, and the environment. Moreover, the frequent heavy rains and floods have greatly damaged the urban area and its surroundings. Salinity intrusion, bank erosion, and coastal erosion are also severe impacts in these areas. All consequences have a negative effect on urban development (NinhThuan Provincial People Committee [NinhThuan PPC], 2012).

Vulnerability is a concept to describe a weakness in a system; its susceptibility to physical harm or damage. This concept is used across multiple disciplines, which are often place- or sector-specific. Many literature reviews on climate change have assessed these definitions of vulnerability (Ribot, 1995). The most common use is that the exposure and sensitivity to a hazard and the capacity to adjust to the hazard impacts are essential parts of the vulnerability (Brooks, Adger, & Kelly, 2005). From a social perspective, vulnerability can be considered as the exposure of people to livelihood stress caused by impacts of climate extremes or environmental change (Kelly & Adger, 2004). As such, the vulnerability can be a combination of social factors and environmental risk (Adger, 2006). The vulnerability of climate change is known as a function of biophysical and socio-economic factors (O'Brien, Eriksen, Nygaard, & Schjolden, 2007). Vulnerability is also an equation of the character, magnitude, rate of climate variation to which a system is exposed, sensitivity, and capacity to adjust to the impacts of climate change (McCarthy, Canziani, Leary, Dokken, & White, 2001). Vulnerability to climate change is also defined as the degree to which a system is susceptible to and unable to cope with the negative impacts of climate change, including climate variability and extremes (Adger et al., 2007). The definition of the IPCC is criticized for being too vague and the resulting difficulty in making it operational (Hinkel, 2011). But the definition could be considered as an integrative concept that can link the social and biophysical dimensions of environmental change (Turner et al., 2003).

The general objective of this research study is to calculate the vulnerability index of urban development to climate change, to discover which urban assets are vulnerable, and to classify the major risks concerning resource stress, growth pressure, and management ability. The results of the vulnerability index computed from these basic components should provide the administrators with an estimation of the prevailing situation, modify current policies, and implement mitigation and adaptation measures for sustainable management of water resources in the study region (Figs. 53.1 and 53.2).

Fig. 53.1 Map of Phan Rang-Thap Cham city and surroundings

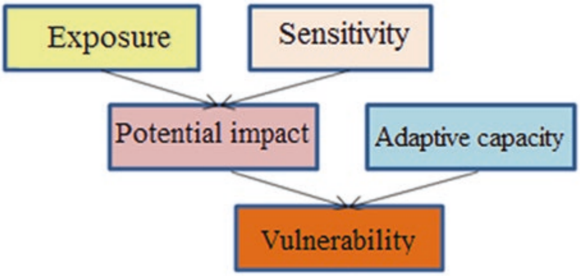

Fig. 53.2 Framework for vulnerability assessment (IPCC, 2007)

2 Methodology

Vulnerability is the degree to which a system is susceptible to the adverse effects of climate change, including climate variability and extreme events. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

$$V = f\left(E, S, AC\right)$$

Of which:

- Exposure (E): the extent to which a system is exposed to the climate change. E depends on the threats (threat intensity, frequency, duration) and location of the system with respect to the threat (how far between the system and the threat).
- Sensitivity (S): the degree to which exposure to a threat arising from climate change will negatively affect the operation of the system. S may be influenced by the integrity of assets under threats and related factors.
- Adaptive capacity (AC): a measure of the potential, ability, or opportunities available to decrease exposure or sensitivity of a system to a climate-induced stress.

2.1 Set up Indicator Set

According to IPCC, vulnerability index is a function of E, S, and AC (IPCC, 2007). To calculate these primary indicators, a set of secondary indicators should be constructed. In this study, the set of secondary indicators are made based on the characteristics of natural resources—environmental, socio-economic, data availability of the study area, as well as the expert consultation results. The set of indicators E, S, and AC are described in detail in Table 53.1.

Table 53.1 The indicator set of exposure (E), sensitivity (S), and adaptive capacity (AC)

Indicator	No.	Sub-indicator	Explanation
Expose	1	Flood depth	Flood depth is measured in meters. It is classified into five categories from very low to very high
	2	Frequency	Frequency reflects the number of flood events in a year
	3	Percentage of affected areas	Percentage of affected areas in a commune/ward. It is classified into five categories: Very high (>30%), high (10–30%), medium (5–10%), low (2–5%), and very low (<2%).
Sensitive	1	Population density	Population density is measured in people/km^2)
	1	Percentage of resident area	Percentage of area per capita, allowed to build houses (%)
	3	Percentage of park/ tree areas	Percentage of park/planting tree areas per capita (%)
	4	Percentage of surface water areas	Percentage of surface water areas per capita (%).
	5	Percentage of ethnic minority groups	Percentage of ethnic minority groups among the groups (%)
	6	Percentage of permanent house	Percentage of households having semi-permanent and permanent houses (%)
	7	Percentage of houses before 2000	Percentage of houses built before 2000 (%)
	8	Percentage of threatened areas	Percentage of households in natural disaster-prone areas (%)
Adaptive capacity	1	Life expectancy	High life expectancy is high AC to extreme climate events
	2	Percentage of females	Percentage of the population that are female (%)
	3	Percentage of working population	Percentage of the population of working age (%).
	4	Percentage who are poor	Percentage of the total population that are poor (%)
	5	Percentage with health insurance	Percentage of people who have health insurance in the total population (%)
	6	Percentage of medical staff	Number of medical staff percentage per 10,000 inhabitants
	7	Percentage of literate people	Percentage of literate people over 15 years old (%)
	8	Percentage with the internet	Percentage of households that have the internet (%)
	9	Percentage with a TV	Percentage of households that have TV (%)
	10	Percentage with radio broadcasting	Percentage of wards/commune that have a radio broadcasting system (%)
	11	Income	Income per capital (mil VND/person/year)
	12	Percentage of trained employees	Percentage of trained employees in the total population (%)
	13	Financial support	Percentage of the household supported by a credit loan (%)

Table 53.2 Determine indicators of (E), (S), and (AC)

Indicator	Equation	Explanation
Exposure (E)	$E = \frac{\sum_{i=1}^{n} E_i}{n}$	E_i is the standardized value of the exposure of i
		n is the number of (E) sub-indicators
Sensitivity (S)	$S = \frac{\sum_{i=1}^{n} S_i}{n}$	S_i is the standardized value of the sensitivity of i
		n is the number of (S) sub-indicators
Adaptive capacity (AC)	$AC = \frac{\sum_{i=1}^{n} AC_i}{n}$	AC_i is the standardized value of the adaptive capacity of i
		n is the number of (AC) sub-indicators

2.2 Determine Vulnerability Index

2.2.1 Determine Indicators (E), (S), and (AC)

Indicators (E), (S), and (AC) were three main elements to determine vulnerability index. These indicators were calculated in both RCP 4.5 and RCP 8.5 in 2030 and estimated according to the methodology and equations in Table 53.2.

The value of indicators is classified into five categories as below:

Value	0.0–0.2	0.2–0.4	0.4–0.6	0.6–0.8	0.8–1.0
Categories	Very low	Low	Average	High	Very high

2.2.2 Determine Vulnerability Indices

As shown in Fig. 53.1, the potential impact is calculated from (E) and (S), based on the assessment matrices in Tables 53.3 and 53.4. As Fig. 53.2, after (E) and (S) are calculated from Tables 53.1 and 53.2, the potential impact is combined between (E) and (S), based on the follow assessment matrix.

Vulnerability (V) is calculated based on the Potential Impact (I) and Adaptive Capacity (AC) ($V = I \times AC$).

2.3 Climate Change Scenarios

Vulnerable indices are an important element to develop the adaptive plan to climate change. Therefore, the vulnerable indices calculated should cover both average and severe climate change impacts in the short future. It is the reason the RCP 4.5 and RCP 8.5 scenarios in 2030 are chosen.

Table 53.3 The assessment matrix of (I)

	Exposure (S)					
Sensitivity (S)		Very low	Low	Average	High	Very high
	Very high	Average	Average	High	Very high	Very high
	High	Low	Average	Average	High	Very high
	Average	Low	Average	Average	High	Very high
	Low	Low	Low	Average	Average	High
	Very low	Very low	Low	Low	Average	High

Table 53.4 The assessment matrix of (AC)

	Impact (I)					
Adaptive capacity (AC)		Very low	Low	Average	High	Very high
	Very low	Average	Average	High	Very high	Very high
	Low	Low	Average	Average	High	Very high
	Average	Low	Average	Average	High	Very high
	High	Low	Low	Average	Average	High
	Very high	Very low	Low	Low	Average	High

3 Results

3.1 Vulnerability Indices under the Baseline Scenario

The results of the vulnerability assessment points out that the vulnerability of several communes is average (15/32 ward/commune). Only three communes, including Phuoc Dan, An Hai, and Phuoc Hai, have high vulnerability because these communes have high exposure and low adaptation. Low vulnerability is identified in communes along the Dinh River owing to low exposure and high adaptation. These communes are located in the urban center (Table 53.5 and Fig. 53.3).

3.2 Vulnerability Indices under the RCP 4.5 Scenario in 2030

In 2030, the vulnerable index of most communes shows an upward trend. There are five communes and one town with a high vulnerability index, Nhon Son, Phuoc Thuan, Phuoc Huu, Phuoc Hai, Phuoc Dan, and An Hai communes, whereas most in the urban areas suffer only a low to average index. This can be explained by the fact that the urban area has the lowest to average impact level and the highest adaptation compared with other areas (Table 53.6 and Fig. 53.4).

Table 53.5 The vulnerable index of each ward/commune under the baseline scenario

Ward/commune	Vulnerability	Ward/commune	Vulnerability
Do Vinh Ward	Medium	My son commune	Medium
Phuoc my Ward	Low	Nhon son commune	Medium
Bao an Ward	Medium	Khanh Hai town	Medium
Phu ha Ward	Low	Xuan Hai commune	Medium
Thanh son Ward	Low	Ho Hai commune	Medium
My Huong Ward	Low	Phuoc dan town	High
Tan tai Ward	Low	Phuoc son commune	Medium
Kinh Dinh Ward	Low	Phuoc Thai commune	Medium
Dao long Ward	Medium	Phuoc Hau commune	Medium
Dai son Ward	Low	Phuoc Thuan commune	Medium
Dong Hai Ward	Medium	An Hai commune	High
My dong Ward	Medium	Phuoc Huu commune	Medium
Thanh Hai commune	Medium	Phuoc Hai commune	High
Van Hai Ward	Medium	Phuoc Vinh commune	Medium
My Binh Ward	Medium	Phuoc Nam commune	Medium
My Hai Ward	Low	Phuoc Ninh commune	Medium

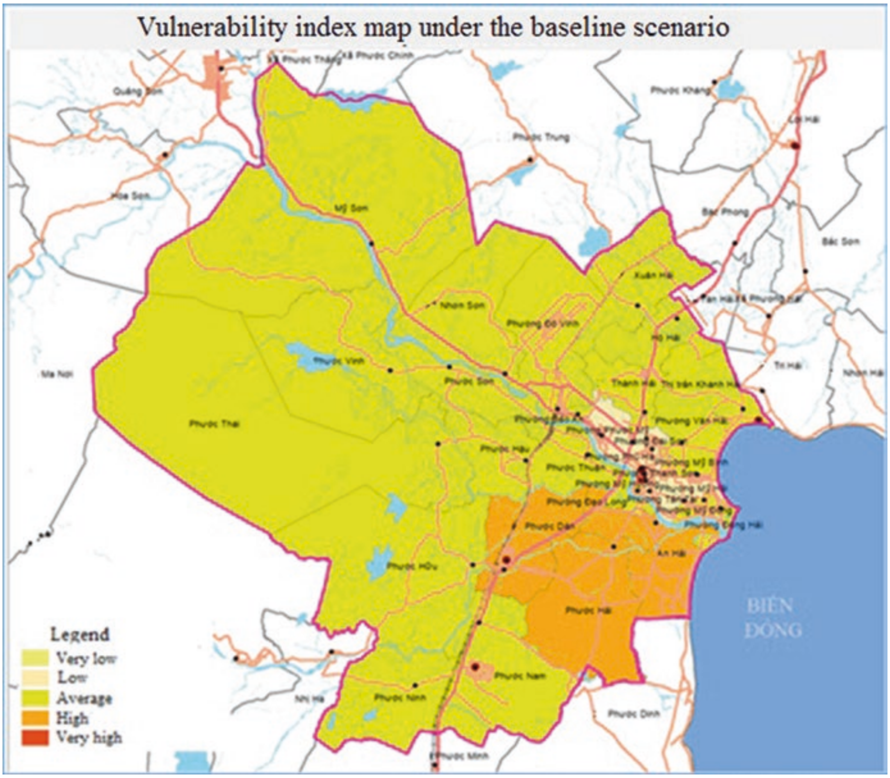

Fig. 53.3 The vulnerability index map under the baseline

Table 53.6 The vulnerability index of each ward/commune under the RCP 4.5 scenario

Ward/commune	Vulnerability	Ward/commune	Vulnerability
Do Vinh Ward	Medium	My son commune	Medium
Phuoc my Ward	Low	Nhon son commune	High
Bao an Ward	Medium	Khanh Hai town	Medium
Phu ha Ward	Low	Xuan Hai commune	Medium
Thanh son Ward	Low	Ho Hai commune	Medium
My Huong Ward	Low	Phuoc dan town	Medium
Tan tai Ward	Low	Phuoc son commune	Medium
Kinh Dinh Ward	Low	Phuoc Thai commune	Medium
Dao long Ward	Medium	Phuoc Hau commune	Medium
Dai son Ward	Low	Phuoc Thuan commune	High
Dong Hai Ward	Medium	An Hai commune	High
My dong Ward	Medium	Phuoc Huu commune	High
Thanh Hai commune	Medium	Phuoc Hai commune	High
Van Hai Ward	Medium	Phuoc Vinh commune	Medium
My Binh Ward	Medium	Phuoc Nam commune	Medium
My Hai Ward	Low	Phuoc Ninh commune	Medium

3.3 Vulnerability Indices under the RCP 8.5 Scenario in 2030

Vulnerability in the RCP 8.5 scenario tends to be higher than in the RCP 4.5. Two communes (Phuoc Dan and An Hai) have a very high level of vulnerability and five communes reached high vulnerability (Nhon Son, Phuoc Thuan, Phuoc Huu, Phuoc Hai, and Phuoc Nam). The vulnerability of the urban wards is ranges from a low to an average level. Unlike the RCP 4.5 scenario, the vulnerability in some areas is higher than the level in the RCP 8.5 scenario. In detail, the vulnerability index of Phuoc Dan town and An Hai communes rise from a high to a very high level and Phuoc Nam commune will go from a medium to a high level (Table 53.7 and Fig. 53.5).

4 Discussion and Conclusions

4.1 Discussion

Owing to the steep topography upstream, flooding downstream happens quickly (about 4–5 h). The flood risk map (Fig. 53.6) shows that the flooding occurs almost in the urban area, mainly along the banks of the Dinh river. The districts of Ninh Hai, Ninh Son, Thuan Nam, and PR-TC (Phan Rang-Thap Cham), especially Ninh Phuoc district, are the areas that are often severely flooded (accounting for nearly 50% of the district area). The areas with a high flooding risk are mainly located in Nhon Son (Ninh Son District); Phuoc Vinh; the neighboring areas of Phuoc Hau,

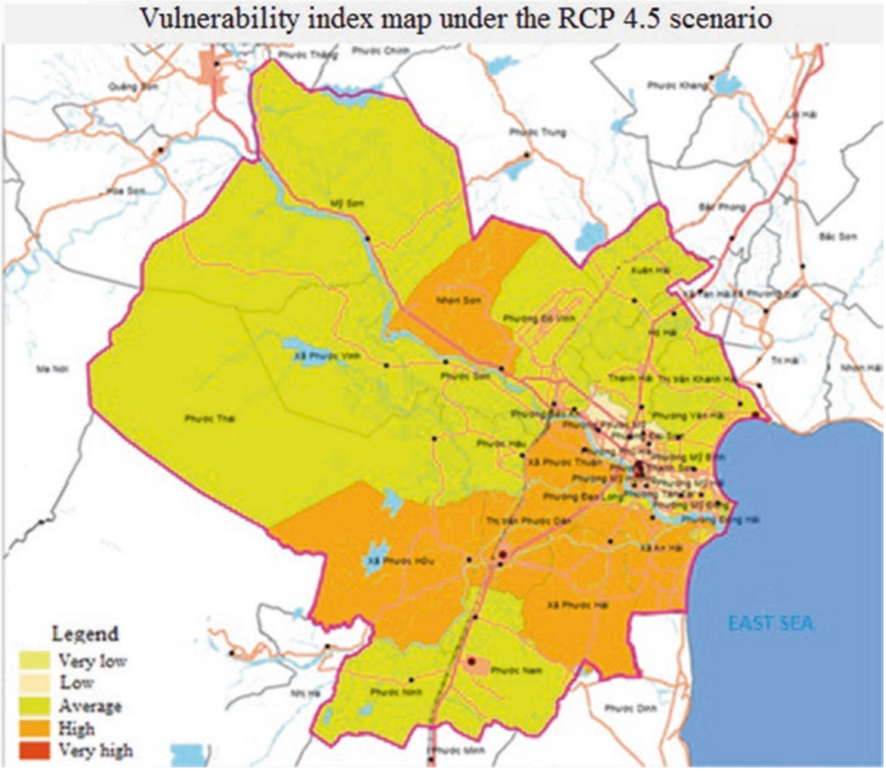

Fig. 53.4 The vulnerability index map under the RCP 4.5

Table 53.7 The vulnerability index of each ward/commune under the RCP 8.5 scenario

Ward/commune	Vulnerability	Ward/commune	Vulnerability
Do Vinh Ward	Medium	My son commune	Medium
Phuoc my Ward	Low	Nhon son commune	High
Bao an Ward	Medium	Khanh Hai town	Medium
Phu ha Ward	Low	Xuan Hai commune	Medium
Thanh son Ward	Low	Ho Hai commune	Medium
My Huong Ward	Low	Phuoc dan town	Very high
Tan tai Ward	Low	Phuoc son commune	Medium
Kinh Dinh Ward	Low	Phuoc Thai commune	Medium
Dao long Ward	Medium	Phuoc Hau commune	Medium
Dai son Ward	Low	Phuoc Thuan commune	High
Dong Hai Ward	Medium	An Hai commune	Very high
My dong Ward	Medium	Phuoc Huu commune	High
Thanh Hai commune	Medium	Phuoc Hai commune	High
Van Hai Ward	Medium	Phuoc Vinh commune	Medium
My Binh Ward	Medium	Phuoc Nam commune	High
My Hai Ward	Low	Phuoc Ninh commune	Medium

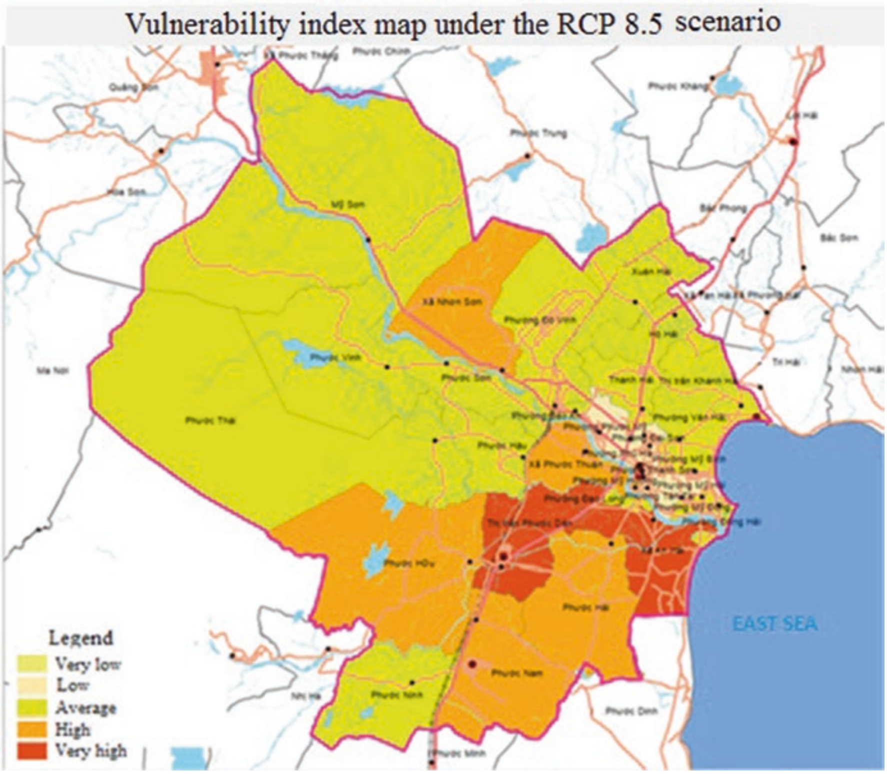

Fig. 53.5 The vulnerability index map under the RCP 8.5

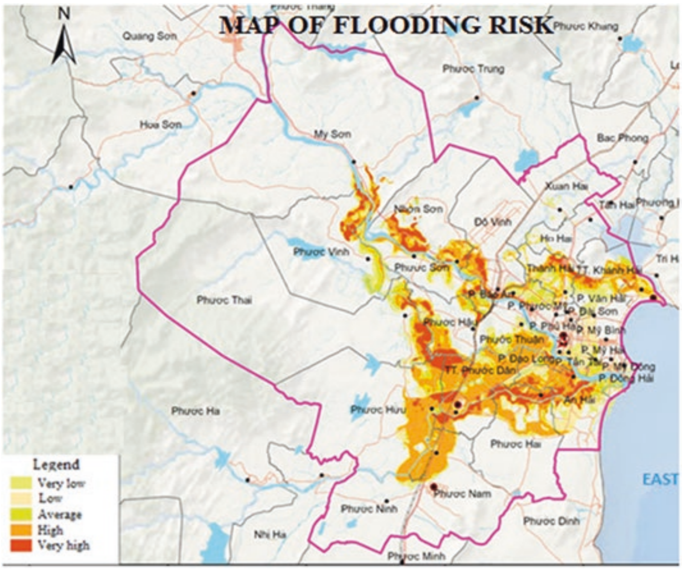

Fig. 53.6 The map of flooding risk

Phuoc Huu, and Phuoc Thai; and Phuoc Dan and An Hai of Ninh Phuoc district. The urban area is not severely affected because of the surrounding banks, but if extreme flooding occurs upstream, the urban area is affected more severely than other surrounding areas.

The exposure assessment shows that the high exposure occurs in Phuoc Dan, Phuoc Hai, and An Hai communes (Ninh Phuoc district), Bao An and Thanh Hai ward (the urban area). Other communes and wards of the urban area have different exposure levels, from very low to low.

The sensitivity assessment indicates that the sensitivity varies from low to high. In particular, My Son (Ninh Son) and Phuoc Ninh (Thuan Nam) are highly sensitive. The urban are has low sensitivity to the flood risk. The other communes in the flood-affected area have an average level.

In contrast to the sensitivity, the adaptive capacity of most wards of the urban area is high, except for Dong Hai, My Dong, and My Binh wards (average level), located near the coastal areas. The adaptive capacity is low in communes located in the surrounding areas.

Based on the indicators of exposure, sensitivity, and adaptation of ward/commune in the urban and surrounding areas, the vulnerability of several communes is average (15/32 ward/commune). Only three communes, namely, Phuoc Dan, An Hai, and Phuoc Hai, have a high vulnerability because these communes have high exposure and low adaptation. The low vulnerability is identified in communes along the Dinh River owing to their low exposure and high adaptation. These communes are located in the urban center.

Throughout the time to 2030, the climate change scenarios in Ninhthuan show that extreme weather events happen frequently and intensely. Therefore, the exposure and sensitivity indicators will be higher, leading to high vulnerability. The highly vulnerable areas are almost located in the surrounding areas, especially along the southern bank of the Dinh River, in the areas near the coast, etc., owing to high flooding and low adaptive capacity.

4.2 Conclusions

Recently, extreme weather events such as drought, water depletion, and floods have negatively impacted the Phan Rang-Thap Cham urban area. Therefore, the vulnerability of this area is very high. Throughout time, the vulnerability tends to be higher from the baseline to the RCP 8.5 scenarios. If in the baseline scenarios, there are only three communes with high vulnerability, then in the RCP 8.5, there are two communes with very high vulnerability and five communes with high vulnerability. Generally, approximately 10% of the area has very high vulnerability, 15% of the area has high vulnerability, mostly in the surrounding areas. Thirty percent have low vulnerability, and located mainly in the urban center. The remaining have average vulnerability, and are located near the urban area or are part of the urban area. One of the reasons why the urban area has low vulnerability is because it has high adaptive capacity, although the exposure is almost the same as that of other areas.

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