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Climate change vulnerability assessment for Can Tho city by a set of indicators

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Abstract

Purpose – The city of Can Tho, located on Vietnam's Mekong Delta, has been identified as one of the nation's most vulnerable sites for adverse climate change-induced impacts. Can Tho's policymakers are faced with tackling these challenges but lack the necessary tools and funds to properly address the situation. The study aims to develop a set of indicators to assess the degree of climate change vulnerability so that policymakers can determine which of Can Tho's districts are most in need of attention, and then propose the best options for climate change adaptation activities.

Design/methodology/approach – The indicators, including quantifications of exposure, sensitivity and adaptive capacity, were categorized in three tiers, from 1 to 3, to reflect their importance with regard to the situation. The higher tier indicators comprised a number of lower tier indicators, which were developed based on real-life, practical situations at the local level.

Findings – The results showed that the Thoi Lai District, with a vulnerability indicator estimated at 0.59, is more vulnerable to the impacts of climate change than other districts because of its lower adaptive capacity and higher sensitivity. In contrast, Ninh Kieu District's climate change indicator of 0.24 demonstrates it has higher resilience to climate change impacts.

Originality/value – This study showed that the set of indicators developed provides a promising approach for supporting local policymakers in Can Tho to actively respond to climate change-related challenges, and that this approach has the potential to be upscaled for other cities in Vietnam.

Keywords Climate change, Vulnerability indicators, Mekong Delta

Paper type Case study

1. Introduction

Located in the Mekong Delta region, Can Tho is Vietnam's fourth largest city, with a population estimated at 1.4 mn. The rapidly growing urban metropolis is divided into nine

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districts: Ninh Kieu, O Mon, Binh Thuy, Cai Rang, Thot Not, Vinh Thanh, Co Do, Phong Dien and Thoi Lai (Figure 1). As the city has developed, the climate change-induced effects have threatened its sustainability. According to the Can Tho Climate Change Coordination Office, natural disasters such as tropical storms, drought, salt intrusion, climate extremes, among others, have occurred with increasing frequency and unpredictability over the past two decades. Salt intrusion was never previously observed in Can Tho, whereas the salinity in the city's central Hau River was measured at 2000 mg/L in 2016 (Vietnam Ministry of Science and Technology, 2016). According to the updated climate change scenarios released by the Vietnam Ministry of Natural Resources and Environment, if the sea level rises by 1meter, 20 per cent of the city's area will be under water [Vietnam Ministry of Natural Resources and Environment (MONRE), 2016]. Women and children, ethnic minorities and the elderly are most vulnerable to these effects.

The local government, well aware of the situation, has sought to develop proper measures with which to respond, but a lack of tools to identify what level of vulnerability the different areas of the city are facing has prevented policymakers from acting effectively. The development of such tools, therefore, is crucial to providing the local government with support in this matter.

According to the Intergovernmental Panel on Climate Change (IPCC, 2007), vulnerability to climate change is defined as the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change. This vulnerability is a function of the nature, intensity and extent (range) of climate change and is affected by the sensitivity and adaptability of a system to fluctuations in the environment.

Studies on vulnerability assessment are generally divided into first- and second-generation approaches (UNFCCC, 2007; Hahn *et al.*, 2009). The first-generation approach, also known as the "climate change" or "top-down" approach, is designed to understand the long-term impacts of climate change. In contrast, the "second generation" approach, also known as the "climate change adaptation" or "bottom-up" approach, focuses on adaptation and community involvement (UNFCCC, 2007) (Figure 2).

The top-down approach focuses on assessing long-term climate risks over several decades, often extending to the year 2100, and frequently based on climate change scenarios. The top-down approach can provide important information for decision-making and focuses more on the impacts of climate change on the environment. However, this approach does not clearly demonstrate local interaction and adaptability (UNFCCC, 2007).

The bottom-up approach, which is based on local coping strategies, indigenous knowledge and technology, local capacity and the ability of communities and governments to cope with current climate fluctuations, has also been launched in recent years. For this approach, many researchers have used the definition of climate change, sensitivity and adaptability to quantify vulnerability (Sullivan, 2002; O'Brien *et al.*, 2004; Vincent, 2004; Ebi *et al.*, 2006; Thornton *et al.*, 2006; Polsky *et al.*, 2007). This approach is useful in developing specific strategies and policy implementation but does have some limitations. First, these studies, based on secondary data, may change the structure of research, according to data availability (Sullivan and Meigh, 2005). Second, errors or omissions in a secondary information data set can cause difficulties in sensitivity analysis (Hahn *et al.*, 2009). Third, future climate change issues are not well-integrated in this approach (UNFCCC, 2007).

Both top-down and bottom-up approaches have advantages and disadvantages. In some cases, if researchers are more concerned about the long-term impacts of climate change, the top-down approach would be more appropriate. In other cases, the bottom-up approach would be more useful, for example, if researchers were interested in short-term climate

Figure 1. Geographical location of Can Tho

change. It is now clear, however, that this traditional division into two approaches, top-down and bottom-up, is no longer valid. The integration of climate projections and adaptation decisions into vulnerability assessments is necessary to meet the priority of needs, both in the context of community-based action as well as disaster-risk reduction (UNFCCC, 2007).

Recently, a number of researchers have performed indicator-based vulnerability assessments, namely, De Brito *et al.* (2017), El-zein and Tonmoy (2017), Fatemi *et al.* (2017), Hazbavi *et al.* (2018), Kumar *et al.* (2016), Senapati and Gupta (2017) and Tapia *et al.* (2017). The set of indicators used were based on a combination of the two approaches mentioned

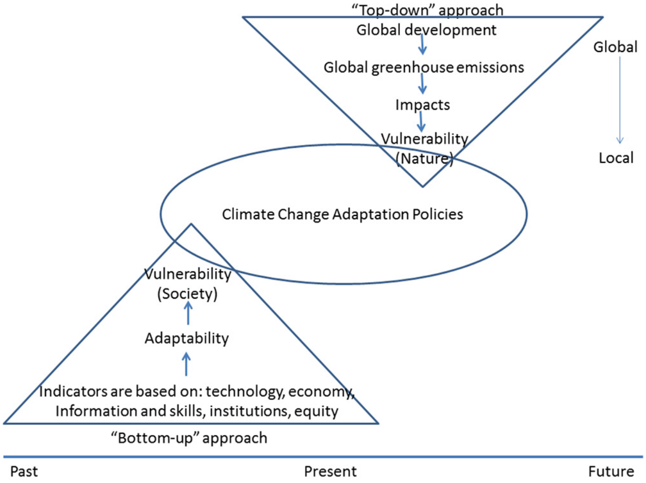

Figure 2.
A top-down and bottom-up approach for assessing vulnerability

Source: Dessai and Hulme (2004)

above. Most of those studies were implemented for countries or cities located in Europe, Australia, South America or the Middle-East region. Few studies of indicator-based vulnerability assessment were performed for Asia and no case studies were conducted for Vietnam, even though this region and country, respectively, are likely to be most affected by climate change and sea-level rises. Therefore, the objective of the current research was to develop a scientifically based set of vulnerability indicators, and apply this set of indicators for a city in Vietnam.

2. Methodology

According to the intergovernmental panel on climate change (IPCC) definition, vulnerability can be expressed as a function of exposure, sensitivity and adaptation capacity:

$$V = f(E, S, AC) = f\,(\boldsymbol{exposure\ level}, \boldsymbol{sensitivity}, \boldsymbol{adaptive\ capacity})$$

Where *exposure* is defined as the nature and extent to which a system is affected by particular weather conditions; *sensitivity* is the level of an affected (directly or indirectly) system of interest or disadvantage caused by climate-related stimuli; and *adaptive capacity* measures adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, to moderate harm or exploit beneficial opportunities.

2.1 Approach

This research applied the IPCC definition of vulnerability and was simultaneously based on Hahn *et al.* (2009), Yusuf and Francisco (2009) and the method of Iyengar and Sudarshan (1982) to develop a set of vulnerability indicators for Can Tho City in Vietnam. In addition, the indicators were developed based on SMART criteria and data available for Can Tho City; the five SMART criteria include: specific (S), measurable (M), achievable (A), relevant (R) and time-phased (T).

In total, a set of 33 vulnerability indicators were developed and tailored to the situation in Can Tho; they included six exposure indicators, 19 sensitivity indicators and eight indicators for adaptive capacity. These indicators were developed in consultation with national experts from the Ministry of Agriculture and Rural Development, MONRE and local policymakers. The indicators represent a mixture of top-down and bottom-up approaches. The "exposure indicators" are linked more closely to the top-down approach, whereas the "sensitivity" and "adaptive capacity" indicators are more aligned with the bottom-up approach. The complete list of indicators is shown in Table I.

A composite vulnerability indicator (CVI), therefore, consists of three main indicators (Tier I indicators): exposure level (E), sensitivity (S) and adaptive capacity (AC). Each Tier I indicator includes a number of Tier II indicators, and each Tier II indicator is made up of a number of Tier III indicators. The identification of indicators at Tiers II and III was based on a combination of information from the literature and actual experience.

In the present study, the authors used data from 2013 and compared them with the annual average data for the period 1980-1999 to calculate the vulnerability indicators, thus obtaining the exposure index (E) for the current conditions.

2.2 Calculation methods

As each Tier II indicator is calculated in different units, it is necessary to calibrate each of these indicators to the same standard system.

If an increase in the value of a Tier III indicator results in an increase in vulnerability, then the normalization value is calculated according to equation (1):

$$\boldsymbol{s} = \frac{s - s_{min}}{s_{max} - s_{min}} \tag{1}$$

Where s = a Tier III indicator; s_{min} = the minimum value of a Tier III indicator; and s_{max} = the maximum value of a Tier III indicator.

In contrast, if an increase in the value of a Tier III indicator results in a decrease in vulnerability, the functional relationship is decreased, and the normalized value is calculated using equation (2):

$$\boldsymbol{s} = \frac{s_{max} - s}{s_{max} - s_{min}} \tag{2}$$

Where s = a Tier III indicator; s_{min} = the minimum value of a Tier III indicator; and s_{max} = the maximum value of a Tier III indicator.

The value of Tier III indicators is used to calculate the value of each Tier II indicator, using equation (3):

$$\boldsymbol{M} = \frac{\sum_{i=1}^{n} S_i}{n} \tag{3}$$

where M = the value of a Tier II indicator; s_i = as defined in equation (1) or (2); and n = the number of Tier III indicators that comprise a Tier II indicator.

Based on the value of the Tier II indicators, the value of a Tier I's contributing factor (CF) can be calculated according to equation (4):

$$\boldsymbol{CF} = \frac{\sum_{i=1}^{n} M_i}{n} \tag{4}$$

Where CF = Tier I indicators as defined (exposure, sensitivity and adaptive capacity); M_I = Tier II indicators that constitute CF; and n = number of Tier II indicators that comprise a Tier I indicator.

Table I.
A set of indicators for vulnerability assessment

No.	Tier I indicators	Tier II indicators	Tier III indicators	Unit	Data source
1	Exposure (E)	Extreme events (E1)	Average number of storms and tropical depressions (E1-1)	–	Statistical yearbooks for nine districts in Can Tho City during 2013
2			Average number of floods (E1-2)	–	
3			Heavy rain (E1-3)	mm	
4		Climate variation (E2)	Increase in annual average temperature (E2-1)	°C	
5			The change in annual rainfall (E2-2)	%	
6		Sea-level rise (E3)	Sea-level rise (E3-1)	cm	Vietnam's climate change and sea level of MONRE (2016)
7	Sensitivity (S)	Water resources (S1)	Change in potential evaporation compared with a baseline period (S1-1)	%	Results from the CROPWAT model
8			Change in flow compared with a baseline period (S1-2)	%	Results from the MIKE NAM model
9		Society (S2)	Population density (S2-1)	Person/km^2	Statistical yearbooks of nine districts in Can Tho City during 2013
10			Water use per capita (S2-2)	l/person.day	
11			Female rate (S2-3)	%	
12			Poverty rate (S2-4)	%	
13			Unemployment rate (S2-5)	%	
14		Agriculture (S3)	Area of agricultural land (planted area of paddy, planted area of annual industrial crops and planted area of perennial industrial crops) (S3-1)	Thous. ha	
15			Yield of crops (yield of paddy, annual industrial crops and perennial industrial crops) (S3-2)	quintal/ha	
16			Output value of agricultural production (S3-3)	dong (billions)	
17			Livestock population (S3-4)	Head	
18			Rural population (S3-5)	Person	
19		Forestry (S4)	Area of forest (S4-1)	ha	

(*continued*)

No.	Tier I indicators	Tier II indicators	Tier III indicators	Unit	Data source
20			Output value of forestry (S4-2)	dong (billions)	
21		Aquaculture (S5)	Area of water surface used for aquaculture (S5-1)	ha	
22			Number of vessels for offshore fishing (S5-2)	Piece	
23			Output value of fishing (S5-3)	dong (billions)	
24		Industry (S6)	The number of different industrial activities (S6-1)	activities	
25			Industrial output value (mining and quarrying, manufacturing, electricity, gas and water supply) (S6-2)	dong (billions)	
26	Adaptive Capacity (AC)	Communication (AC1)	Number of telephone subscribers/100 persons (AC1-1)	%	
27			Number of Internet subscribers/100 persons (AC1-2)	%	
28		Social-infrastructure (AC2)	Number of health establishments (AC2-1)	–	
29			Number of doctors (AC2-2)	Person	
30			Number of schools (AC2-3)	School	
31			Working-age population (AC2-4)	Person	
32			Upgraded rural roads (AC2-5)	km	
33			Irrigation constructions (AC2-6)	Construction	

Table I.

When Tier I indicators of exposure, sensitivity and adaptability are calculated, the composite vulnerability indicator can be determined based on the value of the three CFs according to equation (5):

$$\boldsymbol{CVI} = \frac{E + S + (1 - AC)}{3} \tag{5}$$

where CVI = a composite vulnerability indicator that uses the IPCC definition of vulnerability; E = the exposure value; S = the sensitivity value; and AC = the adaptive capacity value.

2.3 Data and assumptions

The data used in this study were primarily provided by the Can Tho Statistics Office. Climate data were provided by the Vietnam Institute of Meteorology Hydrology and Climate Change. Water resources data were derived from results based on a hydrological model (MIKE NAM).

In this study, equal weights were applied to all indicators that together comprised the composite vulnerability indicator.

3. Results and discussion

This study has shown that each of Can Tho's districts is experiencing very similar levels of vulnerability to climate change. Only Ninh Kieu, a large residential district with a variety of important socio-economic, educational, medical and security facilities, scored low on the vulnerability indicator. All other districts are facing moderate levels of vulnerability. Thoi Lai and O Mon Districts show high levels of exposure to climate change, so the proportion of affected people represented by these two areas is quite large. At the same time, these two areas with high vulnerability reflect other indicators, such as high poverty rates, a high proportion of ethnic minorities, low literacy rates, poor health and low awareness of the issues around climate change compared with other local authorities. Therefore, Thoi Lai and O Mon districts have been ranked as the two most vulnerable districts (Table II, Figure 3).

It can be seen that Co Do, Thot Not and Vinh Thanh districts have the highest levels of sensitivity because these districts have the largest areas of agricultural and aquacultural production. In addition, all three of these districts are located in low-lying areas that are frequently affected by flooding.

Table II. Values for exposure, sensitivity, adaptive capacity and composite vulnerability indicators for districts in Can Tho city

		Vulnerability indicator			
No	District	E	S	AC	CVI
1	Ninh Kieu	0.30	0.30	0.88	0.24
2	O Mon	0.56	0.35	0.29	0.54
3	Binh Thuy	0.40	0.28	0.18	0.50
4	Cai Rang	0.35	0.14	0.21	0.43
5	Thot Not	0.33	0.42	0.34	0.47
6	Vinh Thanh	0.09	0.41	0.37	0.38
7	Co Do	0.24	0.49	0.19	0.51
8	Phong Dien	0.44	0.31	0.23	0.51
9	Thoi Lai	0.67	0.37	0.28	0.59

The industrial and service sectors are considered to be two areas that are not as sensitive to the impacts of climate change as the agriculture and fisheries sectors. Of the nine districts analyzed, climate change has imposed the most significant impact on industrial areas in Binh Thuy. In Co Do district, although there is not a lot of industrial land, the rate at which industrial land is being affected by climate change is high. The greater the contribution of a district to the gross domestic product from these two sectors, the less likely they are to be sensitive to climate change. The industry and services of Binh Thuy district are relatively developed, which is a factor that lowers the degree of sensitivity in that district. In contrast, the industry and services of Co Do district are underdeveloped; hence, the sensitivity in this district is high.

To provide policymakers with an efficient means to view which areas of the city are most vulnerable, it is necessary to present the data graphically, as in other studies that included indicator-based vulnerability assessments. For example, Tapia *et al.* (2017) calculated the vulnerability index for 571 European cities; they did not, however, include exposure factors. The vulnerability map in that study was also presented based on the value of degrees of vulnerability, ranging from high level (> 0.75), medium to high level (median to 0.75), medium to low level (0.25 to median) and low level (< 0.25).

Following consultation with national and local experts, the values of composite vulnerability indicators in this study were divided into two levels (Figure 4):

1. Low (CVI < 0.35), represented by pink.
2. Medium ($0.35 \leq$ CVI < 0.75), represented by red.

Figure 4 shows that only Ninh Kieu district was identified as an area with low vulnerability to climate change. All other districts in Can Tho show a similar CVI, at the medium level. Thai Lai is recognized to be the district that is most vulnerable to climate change in Can Tho. Decision makers and planners in Can Tho will need to pay more attention and develop suitable measures to enhance the resilience of Thai Lai district to the impacts of climate change.

4. Conclusion

Climate change has emerged as a major threat to both natural systems and socio-economic activities in Can Tho, particularly in the agriculture, water resources and

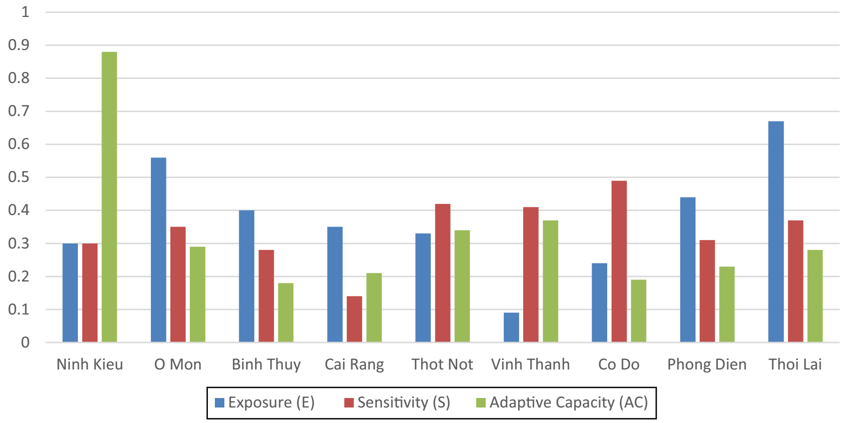

Figure 3. Comparison of E, S and AC values among Can Tho city's districts

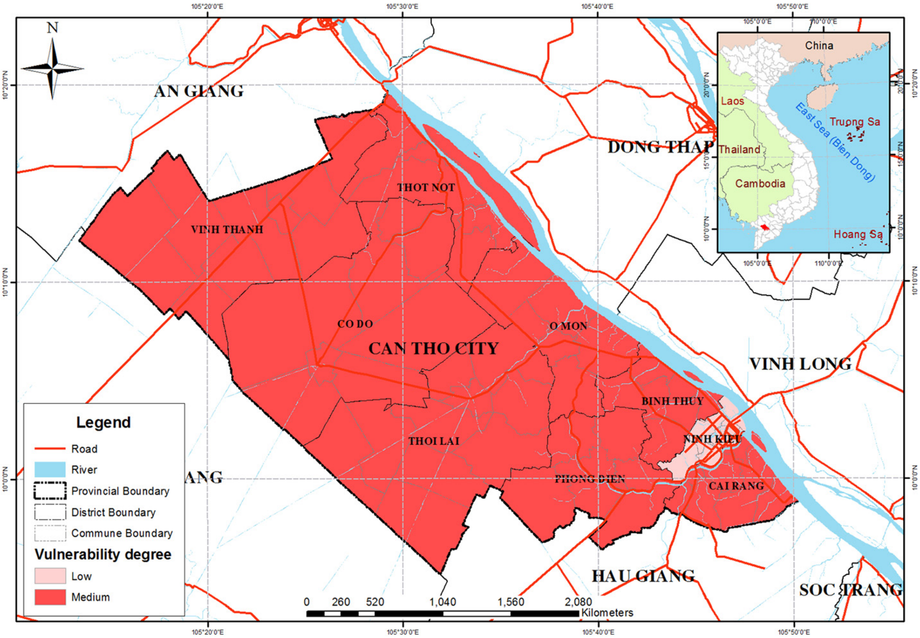

Figure 4.
Vulnerability assessment for districts of Can Tho city

energy sectors. Women and children, ethnic minorities and the elderly are the most vulnerable to these effects. O Mon, Co Do, Phong Dien and Thoi Lai districts are predicted to have the highest vulnerability to climate change impacts among the nine districts and should therefore be prioritized for adaptive investments, such as increasing the area of green spaces, building water-storage areas, combining floodplains and wetland parks, preserving biodiversity and planning for biodiversity conservation to improve environmental resilience. In summary, the pilot calculations described here show that the indicator set used provides an intuitive view, facilitating managers to easily delineate those areas with the highest vulnerability and in greatest need of investment. The set of indicators used is also highly applicable because most of the input data are taken from the local statistical yearbook, which is published annually. Therefore, this set of indicators could be scaled-up for other cities and/or provinces in Vietnam and undergo continuous improvement.

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