VNU Journal of Science, Earth Sciences 28 (2012) 115-124

Dimension index method for climate change vulnerability assessment

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Received 10 April 2012; received in revised form 24 April 2012

Abstract. Vulnerability assessment plays a key role on mitigation and adaptation to climate change. It can be a tool for managers and policy makers to define the area or sector which is the most sensitive to climate change in order to make appropriate policy and management decisions. Vulnerability is defined as a function of 3 components: exposure, sensitivity and adaptive capacity. As such, a method which can synchronizethe dimension of these 3 components is required to formulate the vulnerability level. This article describes a dimension index method for climate change vulnerability assessment and the result of pilot application in agriculture sector in Ca Mau province, Vietnam.

Keywords: Climate Change, DimensionIndex, Vulnerability, Assessment, CaMau.

1. Overview of climate change vulnerability

Vulnerability is a central concept in Climate Change research as well as in a number of other research contexts. However, there are many different ways of conceptualizing vulnerability terminology by the various scientific communities. According to the International Federation of Red Cross and Red Crescent Societies [1], vulnerability is defined as "the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural or man-made hazard". In the reports of Inter governmental Panel on Climate Change (IPCC), the concept of vulnerability was used differently, and IPCC had launched distinct vulnerability definitions throughout the years. In 1992, vulnerability was defined as "the degree of incapability to cope with the consequences of climate change and accelerated sea level rise". In the Second Assessment Report of IPCC [2], vulnerability was defined as "the extent to which climate change may damage or harm a system; It is a function of both sensitivity to climate and the ability to adapt to new conditions". This definition combined exposure and sensitivity and included adaptive capacity to cope with climate change. In the Third Assessment Report of IPCC [3], vulnerability was defined as "the extent to which a natural or social system issusceptible to sustaining damage from climate change. Under this definition, vulnerability is a function of the sensitivity of a system to changes in climate

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(the degree to which a system will respond to a given change in climate, including beneficial and harmful effects), adaptive capacity (the degree to which adjustments in practices, processes, or structures can moderate or offset the potential for damage or take advantage of opportunities created by a given change in climate), and the degree of exposure of the system to climatic hazards". In 2007, the Forth Assessment Report of IPCC [4], vulnerability was defined as "the degree, to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. 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". As stated by this latest definition, the vulnerability will be reduced if the adaptive capacity is strengthened.

2. Approach and methodology of climate change vulnerability assessment

The approach is a combination of the IPCC approach to vulnerability assessment for natural systems and a risk-based approach focusing on the impacts of natural hazards on human systems. Figure 1 shows the methodological framework for vulnerability assessment.

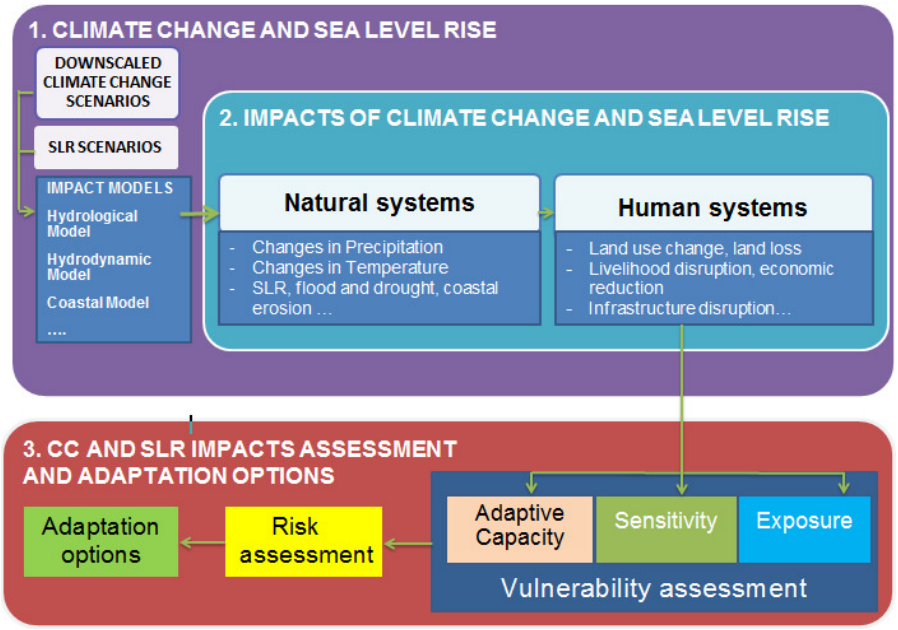

Figure 1. Methodological Framework for Vulnerability assessment (adapted from [5]).

2.1. Climate change vulnerability assessment

According to the latest definition of IPCC [3], Vulnerability (V) is expressed mathematically as a function of three components: Exposure (E), Sensitivity (S) and Adaptive Capacity (AC) as follows:

$$V = f(E, S, AC) \quad (1)$$

Of which:

- Exposure is the nature and degree to which a system is exposed to significant climatic variations [3]. Exposure is defined by maps, GIS models in terms of the degree of projected climatic hazards.

- Sensitivity is one referring to the degree to which a system is affected, either adversely or beneficially, by climate related variables including means, extremes and variability [4]. The sensitivity assessment is based on several indices such as number of affected people, the area of affected natural resources.

- The capacity of an organization or system is to moderate the risks of climate change or to realize benefits, through changes in its characteristics or behavior [4].

Based on the Equation (1), if adaptation measures that result in high adaptive capacityare implemented, the vulnerability can be reduced accordingly. Adaptation measures need to be implemented in order to protect the system from the exposures and to reduce its sensitivity to adverse impacts of climate change. For example, the climate scenarios indicate that there is a shift of precipitation pattern, as a result some areas will become drier whereas other parts will become wetter, an option of adaptation measures that could be taken into considerations is to move the agricultural production activities from the less arable land to the more climate susceptible land. On the other hand, finding alternative livelihood sources for farmers or improving their economic resilience is also one way to reduce their sensitivity to climate change impacts.

2.2. Dimension index method in climate change vulnerability assessment

The characteristics of vulnerability are expressed by indicators (exposure, sensitivity and adaptive capacity), and specific sectorial baseline characteristics for population, poverty, agriculture and livelihoods to create vulnerability profiles. Vulnerabilityand its componentsare relative measures, and do not exist as something we can observe and measure directly, so we need to use proxy indicators of Exposure, Sensitivity and Adaptive Capacity. Such indicators can only be selected based on available collected data, and these indicators have their own dimensions representing the vulnerability components in the study area. Therefore, it is necessary to develop the method which can synchronize the dimensions of these indicators in order to produce a quantitative measure of the climate change vulnerability. This study uses the dimension index method which was developed by UNDP, 2006 [6]:

$$Dimension\ \ Index = \frac{Actual\ Value - Minimum\ Value}{Maximum\ Value - Minimum\ Value} \times 100 \qquad (2)$$

The role of each component indicator is different from vulnerability assessment. Therefore each indicator will be weighted individually based on the available collected data in the study area and the evaluations of climate change assessment experts. By applying standardization with different measurement indicators, vulnerabilities at a district level could be assessed. In order to do this, it is necessary to rank the proportional climate change vulnerability of each district in relation to their “comparative exposure”, and then rating

their respective sensitivity (low to high) to current and future hazard projections generated from hydrological and coastal models. The vulnerability level is then combined using weighting factor for each indicator.

3. Application of dimension index method for climate change vulnerability assessment of agriculture sector in Ca Mau province

3.1. Background of study area

As a southern province of the Mekong River Delta (Figure 2), Ca Mau has an extensive canal system throughout the province which plays animportant role in water drainage and storage as well as water transportation.With a population of more than 1,2 million, Ca Mau can be classified as a rural province with a 79% of the population living in rural areas and 21% living in urban areas. Ca Mau's economy grew robustly in the period 2001-2010 with an annual GDP growth rate of 12%. In 2009, total provincial GDP reached US$ 1.107 million and GDP per capita reached US$ 923. The greatest contribution to household income is from agriculture and fisheries, followed by industry, construction and services. Agricultural production remains stable generally producing two crops per year, mostly rice.

The area of Ca Mau is 533.318 ha, of which 300.00 ha is used for aquaculture. Rice is still the major crop which is mostly double cropped in salt free zones. Total land area used for rice is 130.000 ha, of which 70.000 ha is double cropped and 60.000 ha is used for single crop only.

Figure 2. Ca Mau administration map (Source: Wikimap, 2011).

3.2. Development of a climate change vulnerability index for the agriculture sector in Ca Mau province

Based on the vulnerability assessment approach and dimension index method, we conduct the climate change vulnerability assessment for agriculture sector in Ca Mau province. In Vietnam, agriculture includes some sub sectors: crop, livestock, forestry and aquaculture. All of them are very sensitive to the climate change effects. Interactions between agricultural sectors depend significantly on climate, climate change and natural resource availability, and is assessed quite complex and interdependent for the livelihoods of rural communities in Ca Mau. The purpose of this study is a pilot assessment of climate change vulnerability for the agriculture sector. It describes the degree of vulnerability of agricultural activities, infrastructure and livelihood in Ca Mau to climate change impacts. The vulnerability of agriculture sector is identified based on the three components: Exposure, Sensitivity and Adaptive Capacity (Equation 1). The proxy indicators used for each component are described below.

In this study, Exposure is assessed by 3 proxy indicators for 3 main hazards: inundation/flooding, salinity intrusion and storm surge (Figure 3).

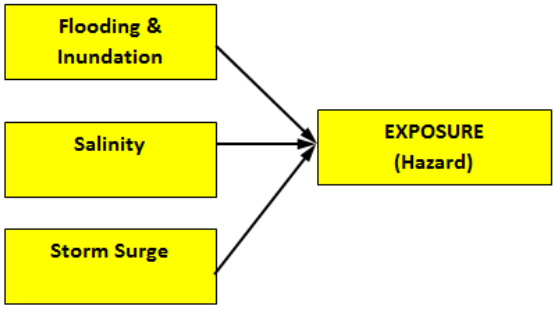

Figure 3. Main hazards in exposure assessment (adapted from [7]).

The proxy indicators contribute to exposure assessment of 3 main hazards are collected and assessed from field survey, local consultation as well as modeling results carried out by IMHEN.

Sensitivityis defined based on the degree to which human systems and natural resources are affected by their exposure to the main hazards (Figure 4).

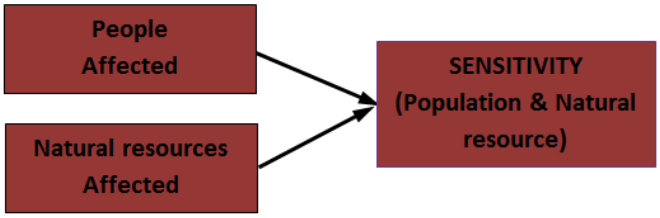

Figure 4. Sensitivity Index (adapted from [7]).

The available proxy indicators of this component are the percentage of population living in rural areas, the number of available livelihood streams, the average annual GDP per capita, and the availability of agricultural land per capita. The data of the indicators was collected from the survey and public consultant.

Adaptive Capacityis assessed based on socio-economic indicators, infrastructure condition indicators and institution indicators as shown in Figure 5.

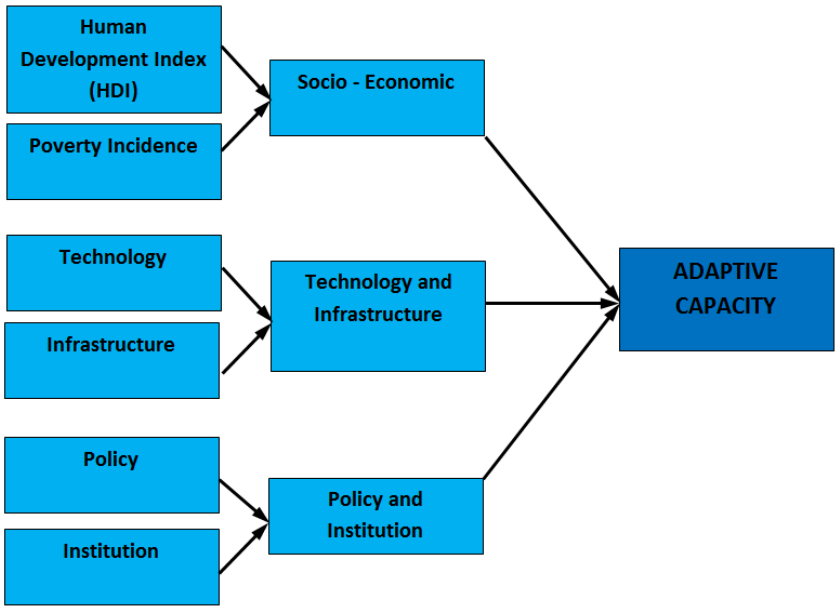

Figure 5. Adaptive Capacity Index (adapted from [7]).

3.3. Results and discussions

Data of affected area was determined based on the outputs of dynamic models such as ISIS, MIKE 11 and data collected from the field trip in March 2011, as shown in Table 1.

Table 1. Areas affected by salinity intrusion, inundation and flooding, storm surge in Ca Mau province (Source: [5]).

District	Area (km^2)	Affected area (%)		
		Inundation and flooding	Salinity intrusion	Storm surge
Ca Mau	250	8	12	0
Cai Nuoc	640	25	14	0
Dam Doi	775	5	3	0
Nam Can	716	14	4	1
Ngoc Hien	417	5	4	96
Phu Tan	464	16	7	1
Thoi Binh	826	3	2	0
Tran Van Thoi	509	22	50	1
U Minh	733	3	4	1

The figures in the Table 1 show that Tran Van Thoi district was highly affected by salinity intrusion and flooding, Ngoc Hien district was the most affected by storm surge therefore the vulnerability of these 2 districts to climate change was subjected to high potential.

Table 2 below shows the values for the major indices which support the quantitative assessment of climate change sensitivity.

Table 2. Major agriculture indices in Ca Mau province (Source: [5])

District	% rural population	Number of livelihood streams	Average annual income per household (VND)	Rice crop land per capita (ha)	Aquaculture land per capita (ha)
Ca Mau	33	5	12.208.744	0.05	0.06
Cai Nuoc	74	4	3.624.178	0.06	0.24
Dam Doi	95	6	3.955.556	0.09	0.33
Nam Can	72	5	5.664.000	0.10	0.34
Ngoc Hien	94	7	3.308.824	0.04	0.37
Phu Tan	86	6	3.527.855	0.05	0.33
Thoi Binh	92	7	2.285.923	0.07	0.39
Tran Van Thoi	77	7	3.095.238	0.26	0.28
U Minh	98	8	2.329.898	0.34	0.35

Table 2 shows the major population of most districts in Ca Mau, except Ca Mau city, depends on agricultural activities, therefore their vulnerability to climate change was considered to be potentially high. The data of arable land area, livelihood streams and household income are the major indices for climate change sensitivity.

Each proxy index was synchronized using Equation 2 and the indices for each component were combined to produce a single value for each component and for the vulnerability evaluation. Table 3, 4, 5 show the results of Dimension Index of Expose, Sensitivity and Adaptive Capacity:

Table 3. Dimension Index of Expose

District	Flooding & Inundation	Salinity Instruction	Storm Surge	Dimension Index of Expose
Ca Mau	0.08	0.12	0.00	0.18
Cai Nuoc	0.25	0.14	0.00	0.24
Dam Doi	0.05	0.03	0.00	0.02
Nam Can	0.14	0.04	0.01	0.06
Ngoc Hien	0.05	0.04	0.96	1.00
Phu Tan	0.16	0.07	0.01	0.11
Thoi Binh	0.03	0.02	0.00	0.00
Tran Van Thoi	0.22	0.50	0.01	0.92
U Minh	0.03	0.04	0.01	0.04

Table 4. Dimension Index of Sensitivity

District	Affected people	Affected area	Dimension Index of Sensitivity
Ca Mau	87.51	0.00	0.85
Cai Nuoc	33.06	0.00	0.09
Dam Doi	21.86	0.05	0.14
Nam Can	13.05	0.20	0.58
Ngoc Hien	10.67	0.32	1.00
Phu Tan	22.29	0.08	0.26
Thoi Binh	21.92	0.02	0.00
Tran Van Thoi	26.38	0.06	0.24
U Minh	13.20	0.26	0.83

Table 5. Dimension Index of Adaptive Capacity

District	Social Economy	Technology & infrastructure	Policy and Institution	Dimension Index of Adaptive Capacity
Ca Mau	0.60	0.72	0.52	0.24
Cai Nuoc	0.34	0.45	0.32	0.05
Dam Doi	0.31	0.54	0.52	0.12
Nam Can	0.40	0.62	0.52	0.17
Ngoc Hien	0.25	0.46	0.38	0.05
Phu Tan	0.37	0.38	0.52	0.10
Thoi Binh	0.32	0.38	0.52	0.09
Tran Van Thoi	0.32	0.45	0.38	0.07
U Minh	0.20	0.51	0.58	0.10

The result of the pilot climate change vulnerability assessment for the agriculture sector is presented in Figure 6 below:

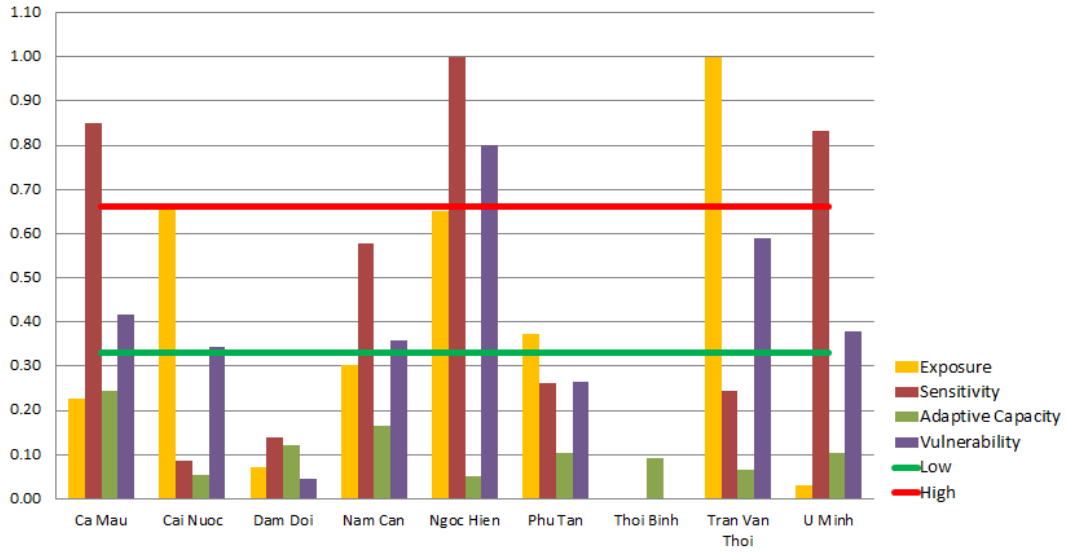

Figure 6. Climate change vulnerability index of agriculture sector in Ca Mau province (Source:[8]).

According to Figure 6, Ngoc Hien and TranVan Thoi districts are most vulnerable to climate change in agricultural sector because these two districts were completely exposed to the risk of flooding, salinity intrusion and storm surge. In particular, Ngoc Hien district has very high sensitivity. Moreover, the adaptive capacity of these two districts is limited that makes their vulnerability high. Strategies aimed at enhancement and improvement of adaptive capacity and reducing their sensitivity to the climate change impacts are urgent requirements for both the short and long termin these two districts. Despite Dam Doi district also being exposed to the risk of flooding, salinity intrusion and storm surge, its vulnerability is at the lowest level because there are not many arable land areas. Moreover this district has a good climate change adaptive capacity and resilience, well managed aquaculture activities and good income sources for local people. This is a helpful example for other districts in Ca Mau in terms of adaptive capacity and resilience to the climate change impacts.

Since the scope of this study focused on the exposure to the 3 main hazards of inundation and flooding, salinity intrusion and storm surge, Thoi Binh district has low exposure and sensitivity to these 3 hazards. However, when assessing the integrated impacts of other climate hazards, the low adaptive capacity means that the district may be highly vulnerable.

Vulnerability can be displayed on GIS maps as in Figure 7 in order toassist policy makers in identifying and comparing the degree of vulnerability of the districts, from which they can make concentrated and effective adaptation and response planning to climate change impacts.

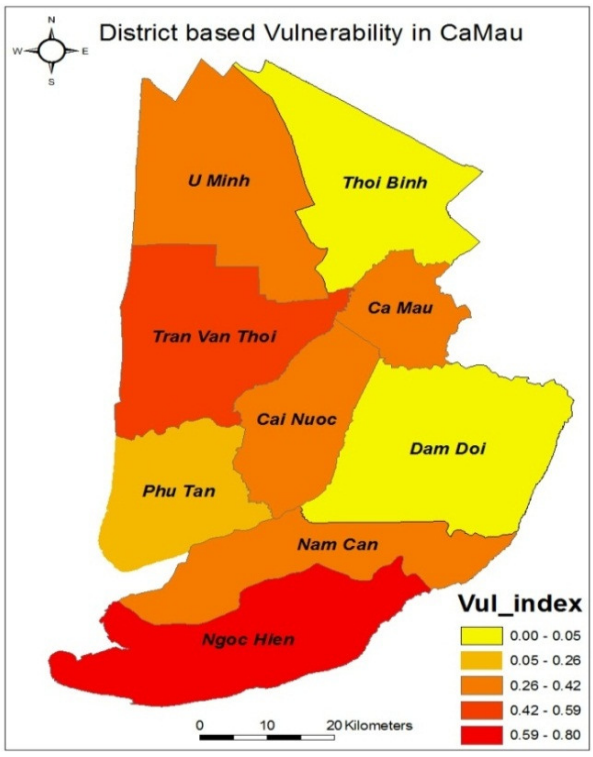

Figure 7. Spatial distribution of Agriculture Vulnerability in Ca Mau (Source: [8]).

4. Conclusions

The vulnerability to climate change impacts are urgent emerging issues, especially for developing countries. Vulnerability is closely linked to poverty because climate change adaptive capacity and resilience of the poor is very low. Dimension index method in assessing climate change vulnerability is a viable and applicable method for developing countries when the input data is still limited. Pilot calculation result for the agriculture sector in Ca Mau province is a good initial result which will support local managers and policy makers in climate change adaptation. Vulnerability research and assessment will help managers and policy makers to determine where and what areas are the most vulnerable to climate change, from which they can make effective decisions on planning, strategy development, and adaptation planning to climate change.

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