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Assessing the Water Resources Vulnerability in Camau Peninsula, Vietnam

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Abstract*: To assess the vulnerability of water resources in the Ca mau Peninsula in Vietnam, this paper adopts an indicator-based approach wherein vulnerability is expressed as a function of water stress and adaptive capacity. Water stress encompasses indicators of water resources variation, scarcity, exploitation, and water pollution, whereas adaptive capacity covers indicators of natural, physical, human resource, and economic capacities. Based on the evaluation of four indicators, with nine vulnerability parameters in terms of resources stress, development pressures, ecological insecurity, and management challenges in the Ca mau Peninsula that leads to suggest differential policy options to reach sustainable development. The vulnerability indices obtained show that the studied region isgenerally in a prospective condition to realise sustainable water resources management due to richness of water availability, natures and human sources. However, it still face to such matters like safe drinking water accessibility, sanitation improvement, water pollution, ecosystem deterioration and conflict management capacity.Hence,strong policy interventions should be designed to overcome key constraints, and great efforts should be made to provide technical support related to water exploitation, land uses, and management capacity to cope with the main challenges.*

Keywords: *Ca mau Peninsula, water stress, vulnerability index, policy, management capacity*

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I. Introduction

Water is likely "blood" of the natural ecosystems, has an indispensable role for most functions of an ecosystem, and also is one of the most critical resources needed to support the socioeconomic development, and ithas been one of the scarcest resources,thus, sustainable water resource management has been one of top priorities of many national agendas.

Understanding of the vulnerability of water resources (here referred to as freshwater resources) being a key element for formulation of an integrated water resource management policy. Vulnerability is usually a term used to describe weakness existing in a system, the susceptibility of a system to a specific threat or the challenges coping with the threat agents. Additionally, vulnerability of freshwater resources will be explored by isolating strategically- important issues related to different uses of freshwater systems, and represents a considerable departure from preconceived notion of a water crisis, and logical conceptual foundation being of paramount importance, comprising stress, adaptation and cooperation. Onperspective term of water resource management, vulnerability was defined details as in (*UNDP 2009*).

Vulnerability of a natural and socio-economic system can be determined by the character, magnitude, and rate of the hazard on the one side and the system's sensitivity and its adaptive capacity (*IPCC 2001*). Vulnerability of water resources systems is multifaceted and is related to change and variability in flow, pollution, population growth, competition over water, data availability and quality, and knowledge gaps (*Brooks et al. 2005*).

Thus, vulnerability assessmentis an examination and investigative process to evaluate a system's sensitivity to potential threats, and to identify key challenges to the system in mitigating the risks relatedto the negative consequences. Such an assessment for a water system takes into account the balance of the water supply and demands, the tenure system and policy to support water resources management and conservation as well as the hydrological variations.

Water resources vulnerability assessment provides a framework for developing risk reduction options, for each identified issue, a water resource vulnerability assessment process needs to determine driving forces; estimate the pressures; understand the current state and trends; analyze the impacts; and formulate responses to cope with vulnerability of the water system.An effective vulnerability assessment serves as a guide to water utilities by providing a prioritized plan for security upgrades, policy changes to mitigate the risks.

Several studies on vulnerability assessment, vulnerability indicators development, and on mitigation and action assessment, those can be directly accessed in (i.e. *IPCC 2001; Adger et al. 2003; Brooks et al. 2005*).

Those provide an overview of the vulnerabilities and adaptation possibilities by major region of the world (Africa, Asia , Europe, North America etc..), and explore the implications for sustainable development and equity concerns, and form the standard scientific reference for all those concerned with the environmental and social consequences of climate change, including natural resource management, and natural hazards.

This paper aims to demonstrate and assess the fresh water resources vulnerability over Ca mau Peninsular-Vietnam due to social-economic development, and based on guidelines in such references mentioned.

II. Methodology

Following the analytical framework (*UNDP 2009*), known as the Drivers, Pressures, State, Impacts and Responses, the threats can be assessed from 3 different components of water resource and use (i.e.,resource stresses; development and use conflicts; ecological security), while challenges in coping capacity can be measured within the context of the region's water resource management capacity. Thus, the vulnerability of water resources can be expressed as:

VI = f (RS, DP, EH, MC) (1)

Where:

VI = Vulnerability index; RS = Resource Stress; DP = Development Pressures; EH = Ecological Insecurity; and MC = Management Challenges.

High vulnerability is apparently linked with higher resource stresses, development pressures and ecological insecurity, as well as severe management challenges. In order to quantify the vulnerability index, the indicators for each variable should be determined and quantified. The principles for this selection and quantification is presented in (*UNDP 2009*), here follow: (a) Four indicators, with nine parameters are applied, and theselected ones are representative; (b)The selected parameters are measurable, and easilyexpressed in formulations with available data support; (c)The math expressions are determined, allthe parameters are valued in the range of 0 to 1; (d) The contribution of each parameter to thevulnerability index is weighted according to its importance, in this paper equal weights are assigned among the parameters in the same category, and also among different categories due to the difficulties of assessment what extend they are contributed to the vulnerability; and (e) The value of vulnerability index ranges from 0to 1, in which 1 being the most vulnerable, and 0 being non-vulnerable.

(1) Resource Stress (RS): The general influence of water resources to vulnerability will be the quantity and quality of water resources, with the pressures from them being expressed as the stress and variation of water resources

$RS = 0{,}5RSs + 0{,}5RSv$ (2)

Where,

(i) Water Stress Parameter (RSs): The richness of water resources will decide to what extent it can meet the water demands of the population. Therefore, the water resources stresses can be expressed as the per capital water resources of a region, compared to the generally-agreed minimum level of per capital water resources (1700 m^3.person-1), as follows:

$$RSs = \frac{1700 - R}{1700}, \qquad if\ R \leq 1700$$

And

$$RSs = 0, \qquad if\ R > 1700$$

RS = water stress parameter; and R = per capital water resources (m^3.person-1).

(ii) Water Variation Parameter (RSv):Thevariation of the water resources can be expressed by the coefficient of variation (CV) of precipitation

$$RSv = \frac{Cv}{0{,}3}, \qquad if\ Cv < 0{,}3$$

And

$$RSs = 1, \qquad if\ Cv \geq 0{,}3$$

(2) Water Development Pressures (DP) can be defined as follow:

$DP = 0{,}5DPs + 0{,}5DPp$ (3)

Where,

DP = Water resources exploitation parameter

(*i) **Water Exploitation Parameter** ***(DPs): Freshwater resources are recharged through a natural hydrological process. Over-exploitation of water resources will disrupt the normal hydrologic process, ultimately causing difficulties for the recharge of the water resource base. Thus, the water resources development rate (i.e., per cent of water demand, compared to the total water resource availability), can be used to demonstrate the capacity of a river basin for water supply capacity, and as follow:

$$DPs = \frac{Wu}{W}$$

Where; Wu is referred to total water demand; and W is total water resource availability

***(*ii*)* Safe Drinking Water Inaccessibility Parameter (DPp):** In addition to the water stress parameter, which indicates the natural process of adaptation capacity, the safe drinking water accessibility parameter is designed to present the state of social adaptation of freshwater use This is an integrated parameter that reflects a comprehensive impact of the capacity of all stakeholders, from farmers to the government. Thus, the degree of stratification of water accessibility can be demonstrated by analysis of the proportion of the population without accessibility to improved water sources. Thus, the contribution of the safe drinking water accessibility parameter (DPp) can be calculated with the following equation:

$$DPp = \frac{Pp}{P}$$

Where: Pp = population without access to improved drinking water sources; and P = total population.

(3) Ecological Health (EH): The ecological health of a region can be measured with two parameters; namely, water pollution parameter and the ecosystem deterioration parameter.

$$EH = 0,5EHp + 0,5EHe \qquad (4)$$

Where,

(i) Water Pollution Parameter (EHp): In addition to their influence on the hydrologic process, water development and use activities will produce wastes, polluting the water resources base. Thus, another very important factor influencing the vulnerability of water resources is the total wastewater produced within the region. The contribution of water pollution to water resources vulnerability, therefore, can be represented by the ratio between the total untreated wastewater discharge and the total water resources of a river basin. Thus:

$$EHp = \frac{Ww}{W}$$

Where, Ww = total wastewater discharge (m^3); and W = total water resources (m^3).

(ii) Ecosystem Deterioration Parameter (EHe): As a result of the population expansion, the natural landscape was modified by the consequent urbanization and other socioeconomic development activities.Removing vegetation from landscapes changed the hydrological properties of the land surface, and can cause severe problems in supporting the functioning of ecosystems, in terms of water resources conservation, and contributed to the vulnerability of the region's water resources. Thus, the land ratio without vegetation coverage can be used to represent the contribution of ecosystem deterioration to the vulnerability of water resources, expressed as:

$$EHe = \frac{Aw}{A}$$

Where, Aw = land area without vegetation coverage (expressed in km^2); and A = total land area (km^2).

(4) Management Capacity (MC): This component will assess the vulnerability of freshwater by evaluation of the current management capacity to cope with 3 types of critical issues, including: (i) efficiency of water resources use; (ii) human health condition closely dependent on, and heavily influenced by, accessibility to freshwater resources; and (iii) overall capacity in dealing with trans- boundary conflicts. Hence, the management capacity will be measured with 3 parameters representing the above 3 key management issues; namely (i) water use efficiency parameter; (ii) improved sanitation accessibility parameter; and (iii) trans-boundary management capacity parameter, and can be expressed:

$$MC = 0,33MCe + 0,33MCs + 0,33MCc \quad (5)$$

Where,

(i) Water Use Efficiency Parameter(MCe): The integrated capacity of water use policy and technology innovation will impact general water use efficiency.Thus, the inefficiency of a water resources management system can be demonstrated by examining the gap between water use efficiency and the defined world average water use efficiency. This can be represented by the GDP value of 1 m3 of water, compared to the world average for selected countries.

$$MCe = \frac{WEwm - WE}{WEwm}\ ,\ if\ WE < WEwm$$

And

$$MCe = 0, \qquad if\ WE \geq WEwm$$

Where, WEwm is referred to GDP value produced from 1 m^3 of water; and WE is mean GDP value produced from 1 m^3 of water, compared to the world average.

(ii) Improved Sanitation Inaccessibility Parameter *(MCs):* Sanitation facility accessibility is highly dependent on the availability of freshwater resources. One of the crucial aims of wise freshwater management should be making water sources accessible by communities (rural and urban) to support their basic livelihoods. Thus, the management system should make efforts to achieve this goal, increasing the availability of water sources to communities to meet their basic livelihood needs. Accessibility to improved sanitation, therefore, is used as a typical parameter to measure the capacity of a management system to deal with livelihood improvement matters. Computation of the parameter will be the proportion of population without accessibility to improved sanitation facilities, as follows

$$MCs = \frac{Ps}{P}$$

Where, Ps is number of population without access to improved sanitation; and P = total population

(iii) Conflict Management Capacity Parameter *(MCc):* This is a parameter that demonstrates the capacity of the river base management system to deal with trans-boundary conflicts. A good management system can be assessed by its effectiveness in institutional arrangements, policy formulation, communication mechanisms, and implementation efficiency. Thus, the conflict management capacity can be assessed utilizing the matrix illustrated in *UNDP(2009*). The final score of the conflict management capacity parameter (MC) can be determined by an expert consultation based on the scoring criteria.

Based on the above-noted formula (1), and following the agreement mentioned previously for assigning weights to each parameter, the vulnerability index can be calculated as follows:

$VI = 0{,}25RS + 0{,}25DP + 0{,}25EH + 0{,}25MC$ (6)

III. Study area description

Ca Mau Peninsula (CMP) is located in the southwest of the Lower Mekong Delta, is embed by the Cai San canal in the north, Hau River in the northeast, and the west sea in the south and east in the East. Natural area is 16,780 km^2, andis taken into account for 43% of the Lower Mekong Delta,includesprovinces: Bac Lieu, Soc Trang, Ca Mau, Hau Giang, Can Tho and a part of Kien Giang.

The hydrological regime in CMP is influenced by the tide of the East Sea, the West Sea, the flow of Mekong River, the annual average rainfall in the region is about 2200mm, of which the rainfall in the rainy season accounts for about 95% of the total. Therefore, freshwater resources for CMP is combined the water source of the Hau River, and rainfall.

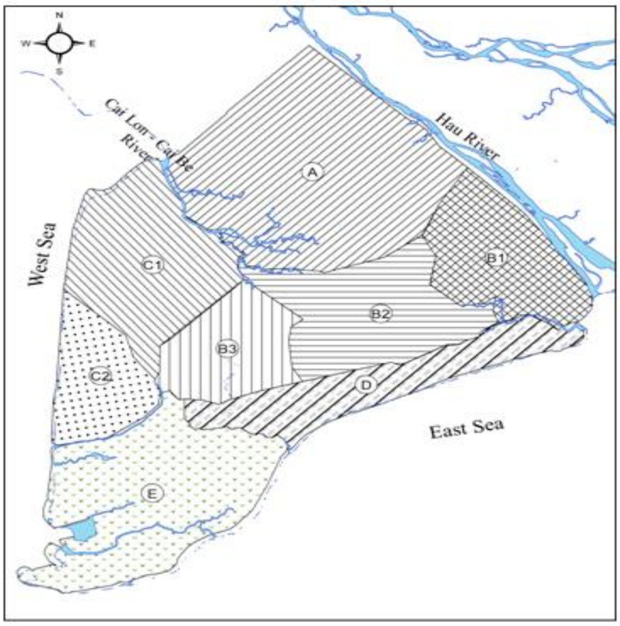

Fig.1 Map of Ca Mau Peninsula and its sub-regions (Source: SIWRP, 2007)

Based on water resources distribution, ecology systems and potential social development, CMP is divided into 8 sub-regions namely A,B1,B2,B3,C1,C2,D and E (see in Fig.1), for the details you are directed toSIWRP(2007).

IV. Data description

The rainfall records were collected at 8 metrological stations, available data span the period of 1990 to 2015 over the CMP, and the data wereobserved and treated previously by Ministry of Natural Resource & Environment.The temporal and spatial distribution of water resources are accessed in SIWRP (2011). Other data were collected from the province's specialized reports (waste sources, discharge point, water quality...), and from the provincial statistical yearbook. In this study, data from the questionnaires related to the use of water, soil and economic efficiency were also used. Moreover, relevant information isaccessed from the official website of the provinces

V. Resutls and discussion

Resource stress

Resource Stress is expressed by stress and variation of water resources related to per capital water resources and variation of precipitation of a region.The results of RS shown in table 1range from 0,217 to 0,325 imply the influence of water resources to vulnerability seem to be at reasonable level. The details can be seen in Table 1 below.

Table 1 Results of Resource Stress Indicator

Sub-regions	RSs	RSv	RS
A	0,000	0,533	0,267
B1	0,000	0,577	0,289
B2	0,000	0,650	0,325
B3	0,000	0,433	0,217
C1	0,000	0,620	0,310
C2	0,000	0,467	0,234
D	0,000	0,583	0,292
E	0,000	0,483	0,242

As shown in table 1,there can be no potential water stress in the studied sub-regions,shown zero values (RSs) in all sub-regions.This can be stated that total water availability is around 36 bil.m^3, while the water demand is only one-third compared to the total water available, and consequently higher value of water supply capacity per person of any sub-region, two to four times, compared to the world average (1700m^3 per person).

The water variation parameter (RSv) is exposed by the variation of the annual rainfall, the results obtained indicatesignificant variation of annual rainfall at each selected station, this can be understood the influence on water availability due to early/late rainy season start and late/early ending dry-season. Moreover, the annual average rainfall in the region varies from1800mm to 2600mm, high value gauged at stations located in coastal areas, and lower values measured in sub-regions nearby Hau River, this shows the plentiful water availability from precipitation generally, however 95% amount of annual rainfall obtained through rainy season must be taken into account.

Water Development Pressures

The water development pressures compose the rate of water demand compared to total water availability, and percentage of population without accessed to improved drinking water resources in any region. In general, high values of water development pressures parameter (DP) in almost studied sub-regions are estimated over 0,4 (high pressure), suggest that a real significant issue need to be solved at community to government level on water supply and sanitation.

Table 2 Results of Water Development Pressures Indicator

Sub-regions	DPs	DPp	DP
A	0,351	0,420	0,385
B1	0,328	0,450	0,389
B2	0,393	0,450	0,422
B3	0,525	0,530	0,528
C1	0,320	0,530	0,425
C2	0,308	0,550	0,429
D	0,490	0,600	0,545
E	0,263	0,700	0,481

As shown in table 2, the parameters of water supply (DPs) based on percentage of annual total water demand compared to annual total water availability, these fluctuate from 0,263 (referred to sub-region covered most by mangroves) to 0,525 (B3, sub-region embed complex tides), in the fact is that coastal sub-regions and central sub-regions are faced to scarcity of water resources in dry-season. The values (DPp) are achieved from legal, specialized reports and provincial statistical yearbook indicate 40% to 70% of population in sub-regions without accessed improved drinking water sources, henceforward should be put on top priority actions to make renewable and innovative techniques to reduce the influence of water development pressures to vulnerability.

VI. Ecological health

The Ecological Health Indicator includes water pollution and ecosystem deterioration parameter, the values shown in table 3 based on available data retrieved in our ongoing research (field-data surveyed on waste water sources, land-uses), these show the percentage of waste water compared to total water availability (referred to EHp),and EHe indicates the ratio between non-agricultural area and total natural area.

Table 3 Results of Ecological Health Indicator

Sub-regions	EHp	EHe	EH
A	0,106	0,232	0,169
B1	0,111	0,174	0,142
B2	0,112	0,139	0,125
B3	0,352	0,692	0,522
C1	0,073	0,270	0,171
C2	0,070	0,288	0,179
D	0,374	0,821	0,598
E	0,170	0,466	0,318

As the results in table 3 show that ecological health indicator seen to be acceptable due to richness of water resources availability in all sub-regions mentioned above, the high value of EH obtained for sub-regions namely D and B3 due to high value of EHe, this can be explained by less vegetation cover in mentioned sub-regions than other land uses(i.e.intensive shrimp). Additionally, other factors likewaste from intensive shrimp, pesticide, chemical fertilizers, and other pollution sources need to be gracefully taken into account to inspect accurate results in terms of ecological health indicator in future research.

Management Capacity

The management capacity indicator comprises three useful factors in terms of water use efficiency, improved sanitation inaccessibility and conflict management. The results gained in table 4 are estimated as details below.

Table 4 Results of Management Capacity Indicator

Sub-regions	MCe	MCs	MCc	MC
A	0,990	0,300	0,125	0,467
B1	0,984	0,500	0,125	0,531
B2	0,984	0,550	0,125	0,548
B3	0,932	0,600	0,125	0,547
C1	0,970	0,600	0,125	0,559
C2	0,979	0,600	0,125	0,562
D	0,920	0,600	0,125	0,543
E	0,909	0,700	0,125	0,572

The values of MCe are represented value of 1 m^3 of water that contributes to GDP of a province (converted to value of sub-region by average estimation), compared to the world average, referred to 8,6 USD. The value ranges from 0,909 to 0,99, is similar to the result obtained in*Mukand and Shahriar (2009*). The MCs values in table 4 show that over half of population in almost studied sub-regions cannot access to improved sanitation, this implies the management systems at community to government level should make strong actions to deal with livelihood improvement matters.

Regarding to the capacity of conflict management illustrated in (*UNDP 2009*) is applied, here based on data collected, questionnaire gained from experts, communality officers, stakeholders, and found in such institutions show that loose institutional arrangements are existing; agreement capacity indicates in general agreement only; communication mechanismsare only at policy or operational level; and implementation efficiency assigned to individual joint project or program but poor management. In consequence, MCc values are approved to 0,125 (average value applied between the worse and the best due to difficult estimation). The details are presented in table 4 for all parameters related to management capacity indicator.

In conclusion, high values of MC obtained in all sub-regions imply the management system need to be enhanced innovative techniques,to improve sanitation accessibility and trans-boundary management capacity.

Vulnerability of Water Resource

After obtaining the results from the calculation presented in tables 1,2,3 and 4 above, each parameter in any indicator is examined and estimated from reliable factors, and consequently the water resources vulnerability index of studied sub-regions is shown in Figure 2. It can be seen that the most values of overall water resources vulnerability in studied sub-regions present in period between 0,2 to 0,4 that expose to moderate vulnerability, and values obtained over 0,4 for sub-regions namely B3, D and E indicate these sub-regions are experiencing high stresses.

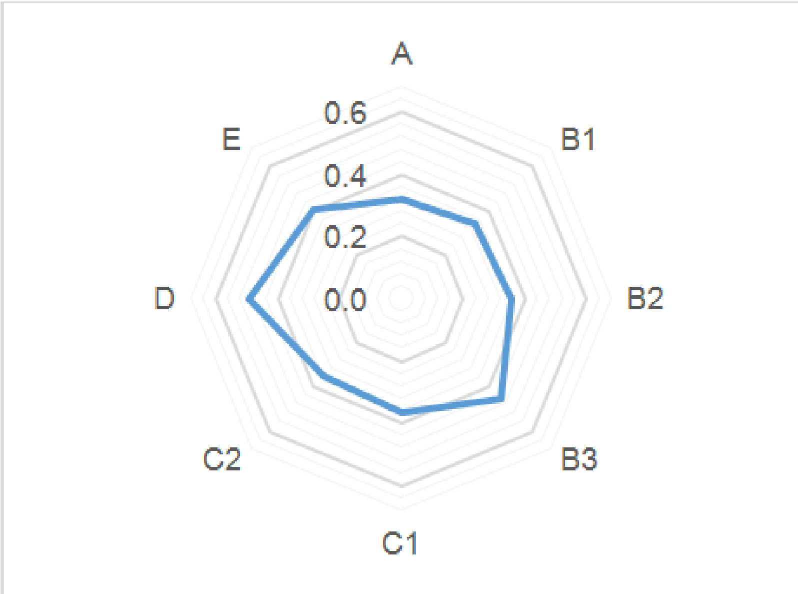

Fig. 2 Calculation of water resources vulnerability index for studiedsub-regions in Ca mau Peninsular, Viet Nam

According to references for interpretation in UNDP (*2009*), this indicates the studied region is generally in a good condition to realise sustainable water resources management due to richness of water availability, natures and human sources. However, in terms of technical support regards to water exploitation, land use and management capacity-buildingshould be taken into account. Thus, policy design should focus on the main challenges identified above, and strong policy interventions should be designed to overcome key constraints for the region.For sub-regions, of which high values of water resources vulnerability performed, moreover, great efforts should be made to provide technical support related to water exploitation, land uses, and a longer-term and appropriate strategic plan for management in terms of trans-boundary, sanitation improvement, and pollution control to deal with the main threatening mentioned above

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VII. Conclusion

The calculation of water resources vulnerability for Ca mau Peninsula in Vietnam, is based on the evaluation of four indicators, with nine vulnerability parameters in terms of resources stress, development pressures, ecological insecurity, and management challenges.

Each parameter exposes relevant factor that reflects the influence to vulnerability, the results obtained in this research show that although abundant water availability but the region still face to such matters like safe drinking water accessibility, sanitation improvement, water pollution, ecosystem deterioration and conflict management capacity, those are presented by high values shown in previous section.

In conclusion, the studied region isgenerally in a prospective condition to realise sustainable water resources management due to richness of water availability, natures and human sources but still face to unfit land uses, water scarcity, water inaccessibility, water quality, management capacity due to technical weakness, ineffective policy interventions. Hence,strong policy interventions should be designed to overcome key constraints, and great efforts should be made to provide technical support to cope with the main challengesmentioned.

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