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Vulnerability to Climate Change:
Adaptation Strategies and Layers of Resilience

Quantifying Vulnerability to Climate Change in Vietnam

Pham Quang Ha, Mai Van Trinh, Tran Van The, Dang Thu Hien, Nguyen Thi Hue, Naveen P Singh and Cynthia Bantilan

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Abstract

This paper characterizes eight agro ecological regions of Vietnam based on the vulnerability to climate change. Cross-section data set belonging to a set of variables representing 3 components of vulnerability, ie, exposure, sensitivity and adaptive capacity were selected for this analysis. The vulnerability was computed based on the standard methodology and regions were mapped based on the extent of vulnerability to climate change. This analysis delineated agro-ecological regions based on the degree of vulnerability, ie, Red River Delta (RRD), North West mountainous (NWM), South east region (SER), Central Highland (CHR), Mekong river delta (MRD) as being vulnerable – very highly vulnerable to climate change.

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I. Introduction

The socio-economic activities of humans with high level of fossil energy consumption are the cause for increased greenhouse gas (GHG) emission into the atmosphere. This has induced climate change. Mainly manifested through global warming and rising sea levels, the most important impact of climate change consists of four phenomena: rise in the global temperature, rise in the sea level, frequent occurrence of natural disasters that are more intense, and some form of loss or unwelcome change in natural resources and biodiversity.

Global warming and climate system change (CC) go together. According to the Stern report, climate change is a global and long term problem with many unstable uncertainties; climate change is likely to affect on a very large scale and is almost irreversible. These changes will create more unpredictable impacts in the future. The impacts of climate change have been visible quite clearly in recent times.

The unusual heat waves and drought in Europe and Africa; floods in Asia and in America are becoming increasingly unpredictable and causing a lot of destruction. Recent floods in Pakistan, France and China destroyed millions of houses and killed thousands of people, while heat waves in Moscow had temperatures going up to 40 degrees Celsius (8/2010). Forest fires destroyed thousands of hectares of forest, houses and villages, which have forced the Russian President to declare a state of emergency across the six provinces. Such a phenomena showed evidence of instabilities and uncertainties. The biggest threat is long-term climate change, which leads to unusual climate and severe weather and has direct impact on agricultural production and people's lives, especially on poor people. Droughts, floods, water logging and salinization will occur more often. Severity levels are also reflected in the ability to adapt to cold conditions.

In the context of climate change there are many definitions of vulnerability. It varies according to the purpose and context of each study. Chamber (1983) indicated that vulnerability has two sides. One is the external side of risk, shocks to which an individual or household is subject to due to climate change and the other, the internal side, which is defenseless, meaning a lack of means to cope with the damaging loss.

For the purpose of this study, according to the IPCC Third Assessment Report of 2001, vulnerability is defined as "the degree to which a system is susceptible to or unable to cope with, adverse effect of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity". Vulnerability comprises three components: exposure; sensibility and adaptive capacity. These three components are described as follows:

Exposure

Exposure can be interpreted as the nature and extent of changes to a regions' climate variables. A rise in extreme events such as high temperature, low precipitation will have effects on health and lives as well as associated environmental and economic impacts.

Sensitivity

Sensitivity describes the human-environmental conditions that can worsen the hazard, ameliorate or trigger an impact of climate change.

Adaptive capacity

Adaptation is a process through which societies are taking measures to reduce negative effects of climate change. There are many opportunities to adapt such as better water management in times of drought, early warning systems for extreme events, improve risk management and various insurance measures.

This report formulates the study to quantify vulnerability to climate change in Vietnam according to agro-ecological zone (AEZ) bases. It may help to understand quantitatively how climate change may affect Vietnam's Agriculture according to the different agro-ecological zones (Chinvanno et al. 2008).

Table 1. Climate change and exposure list adapted to Vietnamese cases.

Climate Change	Vulnerability
1. Temperature - Temperature increased - Unpredicted variation (extremely hot, cold)	1. Agriculture and Food Security - Yield production decreases due to low efficiency of fecundation or flowering - Crop, animal diseases due to irregular cold or high temperatures
2. Precipitation - Irregular precipitation	2. Water Stress - Increasing water stress due to dry and wet scenarios; water shortage or flooding
3. Extreme events - Increase in extreme rainfall and wind associated with tropical cyclones - Heat waves, hot spells in summer for a longer duration, more intense and more frequent	3. Land loss - Land in Mekong & Red river delta indicated as two (Rice bowl of Vietnam) will be heavily submerged
	4. Coastal Zones/ Habitation - Millions of people along the coastal area are affected by sea level rise and increase in the intensity of tropical cyclones - Land, Wetland, mangrove and reef are under threat.
	5. Terrestrial Ecosystems and Biodiversity - Increased risk of extinction of many species due to climate changes - Increase in the frequency and the extent of forest fires

Source: Modified from Christensen et al. 2007, Cruz et al. 2007.

Today, Vietnam accounts for more than 86 million people. Vietnam's inland surface is 33,115,000 ha. Most of the Vietnamese lands are covered by forests (44.7%), only 28.4% are used for agriculture with the total surface of 9,420,300 ha (Table 2). The agriculture sector, including crops, livestock, fisheries and aquaculture accounts for more than 20% of national GDP, 65% of employment and 30% of exports. Its performance has considerable influence on the economic growth and the status of poverty and malnutrition in the country. With high population pressure, food security has become an overriding factor along with political and economic goals in the recent twenty years with the challenges of climatic changes.

Table 2. Land use in Vietnam.

Areas as classified by land used (2008)	Area (ha)	%
Agriculture land	9,420,300	28.4
Forestry land	14,816,600	44.7
Non-agricultural land	3,385,800	10.2
Aquaculture land	728,600	2.2
Other lands	3,666,300	11.1
Water surface	1,097,400	3.3
Total land area of Vietnam	33,115,000	100

GSO (2008, 2009).

Rice, maize, cassava, peanut, soybean, sweet potato are the main food crops. Rice remains the dominant crop in area and production in Vietnam with the total annual planted area of more than 8.3 million ha and a production of 35.9 million tons (data 2008, Table 3). It is noted that only less than 4,000,000 ha of land is allocated for rice planting, but farmers have two or even three rice seasons annually.

Table 3. Production of main crops in Vietnam.

		1000 ha	1000 tons	
No.	Crops	Planted area	Production	Crop classification
1	Rice	8,304,700	35,942,700	Food
2	Maize	1,096,100	4,303,200	Food
3	Cassava	495,500	9,395,800	Food & cash
4	Peanut	254,500	510,000	Food & cash
5	Soybean	187,400	275,200	Food & cash
6	Sweet potato	175,500	1,437,600	Cash
1	Rubber	556,300	605,800	Industrial
2	Coffee	509,300	915,800	Industrial
3	Cashewnut	439,900	312,400	Industrial
4	Sugarcane	293,400	17,396,700	Industrial
5	Coconut	135,300	1,034,900	Industrial
6	Tea	126,200	705,900	Industrial
7	Pepper	48,400	89,300	Industrial

A recent overview of rice production in Vietnam (Tuat NV and Ha PQ 2010) reported that over the last 50 years (1960-2010), rice production in Vietnam has increased in yield (2.51 times) and area (1.53 times) and therefore rice production had increased by 3.84 times. Vietnam produced 35,942.7 million tons of rice in 2007 and 38,725.1 million tons in 2008. This provided enough food for more than 85.6 million Vietnamese and has contributed to world food security. Vietnam stands second in the world in rice export with a total of about 4-5 million tons of rice annually.

Rubber, coffee, cashewnut as well as tea and pepper are also promising cash crops for Vietnam. The areas planted for rubber and coffee were 536,300 ha and 509,300 ha, respectively, in 2007.

As rice production areas in Vietnam are located mainly in Mekong River (51%) and Red River delta (15%), these zones are considered to be the most affected by climate change where high sea level rise is expected in different scenarios. With the worst cases, by 2100, more than 1.1 million ha of rice land in Mekong delta will be deeply submerged and some thousands of hectares of rice land in Red River delta will be salted. Due to other factors like irregular storm and rainfall distribution, drought and plant diseases, it will be a big challenge for Vietnam to keep rice production stable by the end of this century. Different measures and actions were considered and taken by the Vietnamese government and the Ministry of Agriculture and Rural Development. Both adaptation and mitigation options were mentioned. It is hoped that Vietnam can take up the new challenges in the coming decades to reach successfully the target of 3.8 million ha of soils for rice with an annual production of 43 million tons of rice as formulated by the year 2020.

II. Vietnam Agro-ecological zones

Three-fourths of Vietnam's territory is covered by mountains and hills. The plains are concentrated in the downstreams of two big rivers, the Red River and the Mekong River. Vietnam has more than 3,200 km of coastline. Vietnam stretches from 80° 30'N to 230° 30'N latitude, and can be divided into eight agro-ecological zones from north to south based on topography, climate, soil, geology and agronomy, as indicated in the table below.

Table 4. Eight agro-ecological zones of Vietnam.

No.	Description	Abbreviation
1	North East Mountainous Area	NEM
2	North West Mountainous Area	NWM
3	Red River Delta	RRD
4	North Central Coast	NCC
5	South Central Coast	SCC
6	Central Highland	CHR
7	South East Region	SER
8	Mekong River Delta	MRD

1. North East Mountainous Area (NEM)

Located in the northeast of Vietnam, this Region includes 11 provinces: Hagiang, Caobang, Baccan, Tuyenquang, Lao Cai, Yen Bai, Thainguyen, LangSon, QuangNinh, Bacgiang, PhuTho. The main feature of this region is, it is mountainous with a lot of bare hills and a small parcel of land with low agricultural productivity.

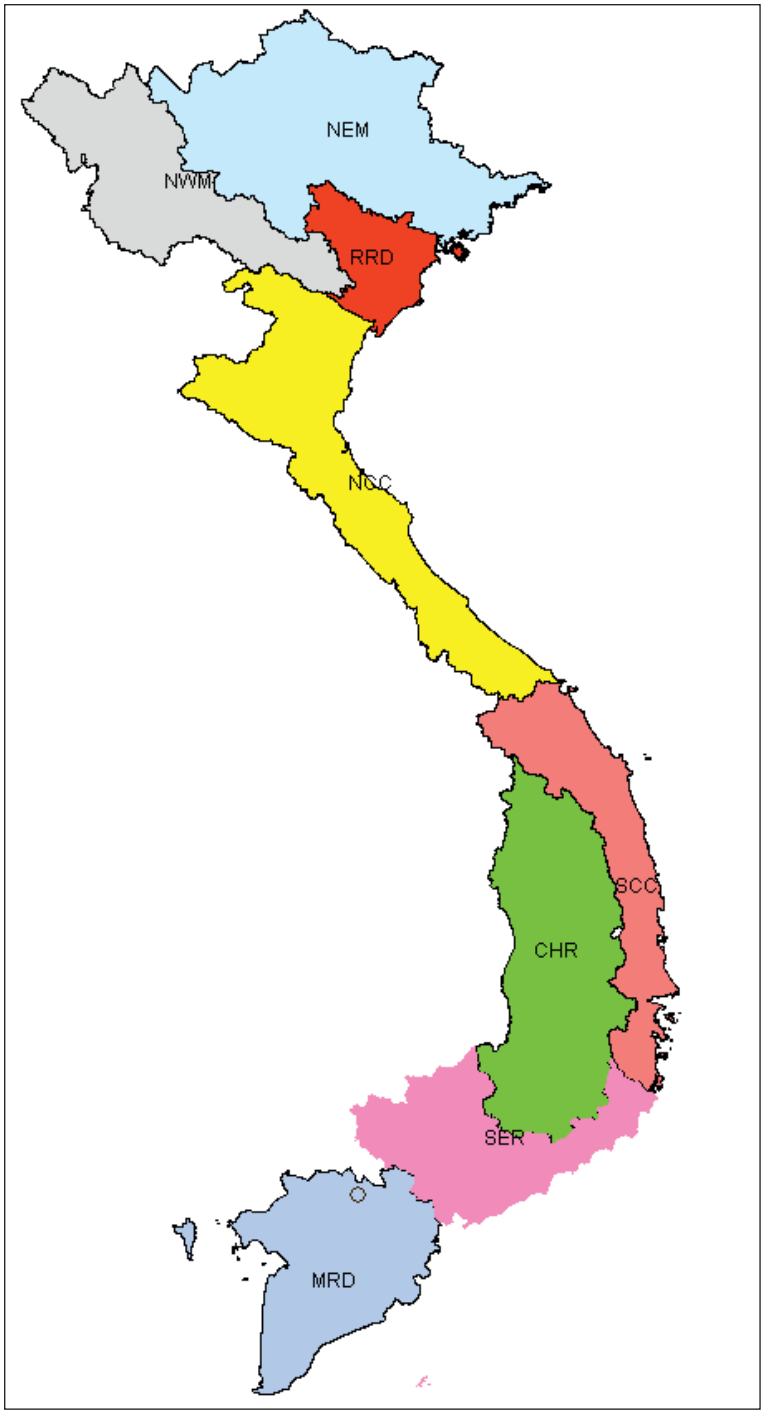


Figure 1. Eight agro-ecological zones of Vietnam.

2. North West Mountainous Area (NWM)

Located in the northwest of Vietnam, this region includes 4 provinces: DienBien, Lai Chau, Son La and Hoa Binh. The main feature of this region is high mountains and the lack of a coastline with several mountains at heights of 800-1000 m. The mountains and highland river valley zones are separated by springs, which move from Northwest to Southeast. This region is considered as mountainous with little market opportunities and lower standard of living.

3. Red River Delta (RRD)

This region includes 9 provinces, HaNoi (HaNoi and HaTay), HaiPhong, HaiDuong, HungYen, HaNam, NamDinh, ThaiBinh and NinhBinh, and has a terrain that is relatively flat. Together with the Mekong River Delta, this region is known as one of Vietnam's rice bowls, with the soil formed from Red River alluvial, which has very high agricultural productivity.

4. North Central Coast (NCC)

This region includes 6 provinces: ThanhHoa, NgheAn, HaTinh, QuangBinh, QuangTri and ThuaThienHue. The main feature of this region is narrow land, coastal sandy soil with low agricultural productivity. This region is heavily affected by typhoons and storms and often considered a food deficit area.

5. South Central Coast (SCC)

This coastal area is located in south-central Vietnam, and includes 8 provinces: DaNang, QuangNam, QuangNgai, BinhDinh, PhuYen, KhanhHoa, NinhThuan and BinhThuan. This region is characterized by a prolonged dry season. In this area, ruminant production is quite dominant.

6. Central Highland (CHR)

This highland region has no coastline. It includes 4 provinces: GiaLai, KonTum, DakLak, DacNong, LamDong. The topography is quite specific, which is clearly evident with its natural forests and the high terrain is the Eastern and the low terrain is the Western regions. The average height is 500-800 m; some areas have mountains that are above 2000 m high. The main feature of this region is a large plateau of basaltic soil with very high productivity. The red soil on the basalt is good for growing of industrial plants such as pepper, rubber, coffee. Water is the most limiting factor for crop production. This area is very windy with a prolonged dry season.

7. The South East Region (SER)

This region includes 6 provinces: BinhPhuoc, Tay Ninh, BinhDuong, Dong Nai, HCM city, Ba Ria-Vung Tau. The main feature of this region is grey degraded soils with low agricultural productivity. However, this region showed very high dynamism for industrial development, including livestock industry. Pig, chicken and duck rearing, and dairy production are very well developed.

8. Mekong River Delta (MRD)

This region includes 13 provinces: LongAn, TienGiang, BenTre, TraVinh, VinhLong, DongThap, AnGiang, KienGiang, CanTho, HauGiang, SocTrang, BacLieu and CaMau. This region is known as the "Rice basket" of Vietnam. Mekong River Fluvisol is the main soil of this area and is found in more than 2,000,000 ha. It is very good for agriculture. Along with the development of food crop production, animal husbandry is also developed (pig, poultry, cow, buffalo, fish and shrimp). This region is considered to be the most affected area with regard to a rise in the sea level.

III. Climate change with relation to a change in Vietnam's climate

In over 20 years of economy innovation reform, the Vietnam agricultural sector has achieved great results, particularly in food production. Climate change is very complex, including the greenhouse gas emissions, rise in the air temperature, acidic rains, storms and natural disasters. The relationship between climatic changes and agriculture is particularly important, as world food production is under pressure from a growing population.

According to the fourth assessment report of IPCC in 2007, the average global temperature has risen by about 0.74 °C during the period 1906 to 2005 and the rate of temperature nearly doubled that of 50 years earlier. The temperature in the continent increases at a faster rate than in the ocean. In the last 100 years, rainfall tended to increase in high latitude regions. The intensity of rainfall has increased in many regions of the world. Global sea-level increased by 1.8 mm/year during the period 1963-2003, and during the period 1993-2003 was 3.7 mm/year (IPCC 2007). Vietnam is among the few countries that will be the worst affected by the impacts of climate change (Nguyen 2009). In fact, the country has already witnessed several manifestations of climate change in the past decades, including temperature increase, rise in the sea level, and more damages from hydro-climatic disasters such as cyclones and flash floods. Cruz et al. (2007) reported that increased occurrence of extreme rains caused flash floods in Vietnam. They also concluded that the frequency and intensity of tropical cyclones originating in the Pacific have increased over the last few decades while cyclones originating from the Bay of Bengal and Arabian Sea have been noted to decrease since 1970 but the intensity has increased. In both the cases, the damage caused by intense cyclones has risen significantly in the affected countries, including Vietnam (Cruz et al. 2007). These are primarily attributed to the tropical location, long coastal line, mega river deltas, and the economy's heavy reliance on water and agriculture (WB 2010).

Increase in the temperature scenario and rise in the sea level in Vietnam

The scenario for temperature increase and rise in the sea level in Vietnam in 21 centuries has been developed and released in June 2009 (MONRE 2009) based on high emissions scenario (A2), medium (B2) and low (B1). Results showed that by 2100, annual average temperature in different agro-ecological zones of Vietnam can increase from an average of 1.1 to 1.9 °C for the B1 scenario; from 1.6 to 2.8 °C for the B2 scenario and from 2.1 to 3.6 °C for the A2 scenario.

Table 5. Scenarios of temperature increase in Vietnam (°C) during the period 1980-1999.

Emissions scenarios	The increase in temperature	2020	2050	2100
B1	High increase °C	0.5	1.4	1.9
B1	Low increase °C	0.3	0.8	1.1
B2	High increase °C	0.5	1.5	2.8
B2	Low increase °C	0.3	0.8	1.6
A2	High increase °C	0.5	1.5	3.6
A2	Low increase °C	0.3	0.8	2.1

According to the World Bank (WB 2010), world efforts and commitments urge to reduce GHG emissions so that by the end of this century, global temperature will show an increase below 2°C. This is corresponding to the low-emissions scenario (B1). In such a case, average temperature in Vietnam will be increased only from 1.1 to 1.9 °C.

Table 6. Scenarios of Vietnam's sea level rise (cm) when compared with the period 1980-1999.

Emissions scenarios	Emissions	2020	2050	2100
B1	Low	11	28	65
B2	Medium	12	30	75
A2	High	12	33	100

IPCC (2007) estimated a sea level rise of about 26-59 cm by 2100. Some scientists believe that the calculation of the IPCC on sea levels is slightly lower because it does not fully take into account the level of ice melts.

Sea level rise scenarios for Vietnam in low, medium and high emission hypotheses are computed in Table 6. Results showed that in 2050 the sea level will be higher than the level today, from 28 to 33 cm and in 2100, it would increase from 65 to 100 cm.

Vietnam possesses a tropical climate with intense heat and humidity but due to the lengthy territory stretching to many latitudes and diversified topography, the differentiation of climate among the regions is very clear. Annual mean temperature in different regions ranges from 18 to 29^{o}C. Monthly temperature of the coldest month is about 13 to 20^{o}C in the north mountainous part and from 20 to 28^{o}C in the southern parts. Temperature in the summer varies from 25 to 30^{o}C. Vietnam is located in the area affected by typhoon and tropical cyclones in the northwest Pacific Ocean. On an average, annually, there are 4-5 typhoons/tropical cyclones affecting Vietnam. Annual rainfalls are very different in different regions, ranging from 600 mm to 5,000 mm. About 80-90% of the rainfall occurs in the rainy season and the number of rainy days in the year is also very different between the regions and ranges from 60 to 200. In several regions, floods and inundation occur during the rainy season but in the dry season, drought is often recorded as the rainfall distribution is not even during the year.

Loss of rice land, a real potential damage to rice production

By 2100, at 1 meter sea level rise scenarios, most of the provinces in Cuu Long River Delta Region (MRD) will be submerged or serious saline water intrusion will occur (Figure 2, MONRE 2009).

The predicted loss of rice land based on scenarios of climate change for Vietnam is very serious. Most of the potential flooded area (Red River Delta and Mekong River Delta) is the rice bowl of Vietnam. Computed figures showed the loss of rice production in 10 provinces in Mekong Delta and Ho Chi Minh (TP. HCM) to be hypothesized in the most affected areas, where 38.29% of land will be submerged in sea water. Of this, 31.16% is agricultural land and it is mainly allocated for rice production. Results showed that these areas will lose 7.6 million tons of rice per year, equivalent to 40.52% total rice output of the Mekong River Delta today.

In the Red River Delta, although less land will be inundated than in MRD, most of the lands there will be affected by the intrusion of saline water from the rise in the sea level. The Vietnam Institute of Water Resources Planning reported recently that water with 4% salinity level will occur 40 km inland, which will affect at least 300 thousand ha of rice fields, currently producing the highest yield.

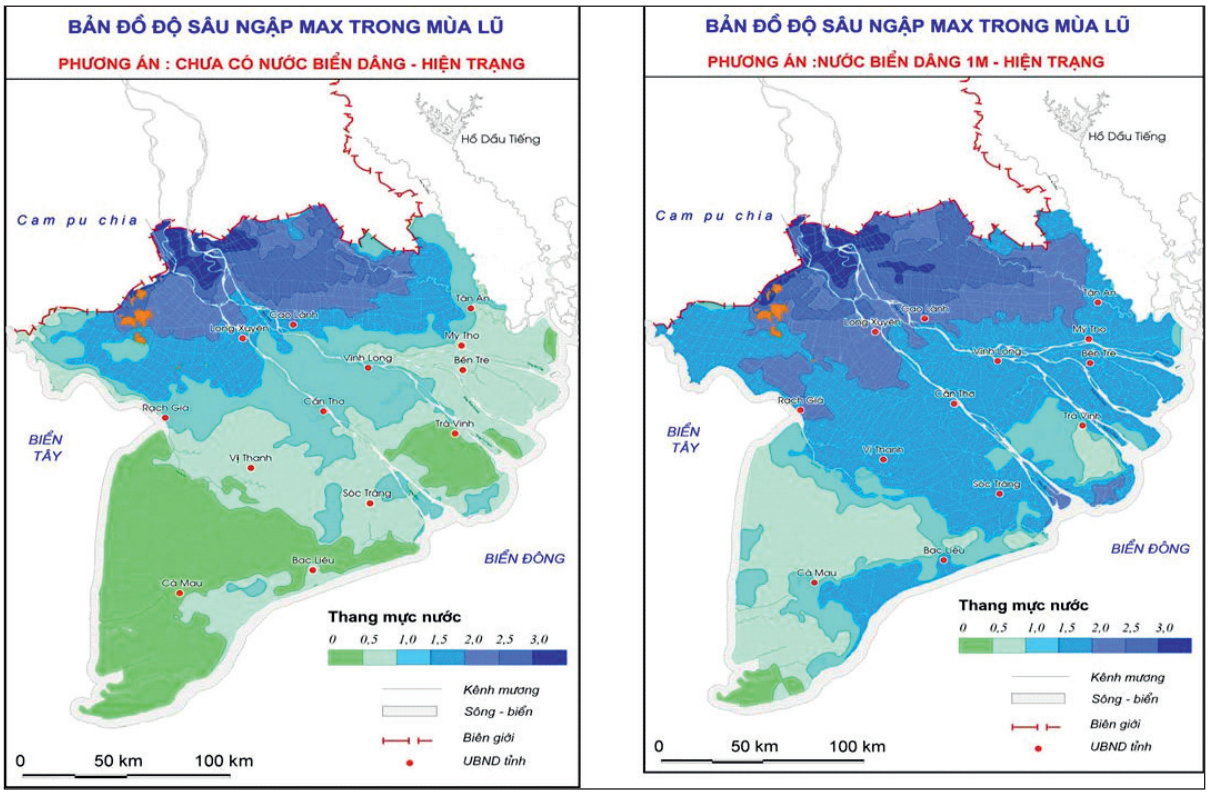


Figure 2. Current flood maps (left) and at 1 meter sea level rise scenario (right) in the MRD Region during the flood season (MONRE 2009).

The research conducted by the authors at Hanoi Agricultural University and Thai Nguyen Agricultural University have shown that the scenarios for rising sea level due to the impact of climate change are as follows: 0.17 m sea level rise by the year 2030, the area of paddy rice would decrease from 51,000 ha to 85,000 ha, rice land would be also reduced from 469,000 ha to 439,000 ha. There is a heavy pressure on the region regarding food security in the future. The strategy set for RRD in the coming years is to stabilize the rice area, reduce the population growth rate and apply scientific and technical measures to improve rice yield and productivity.

Table 7. Distribution of soil in Vietnam and dominant crops.

No.	Main soil types	Main distribution areas	Dominant crops types	Annual harvesting seasons
1	Sandy soil	Coast central	Rice, peanut & cash crops	> 2
2	Saline soil	Coastal north and south	Rice, cassava & cash crops	1-2
3	Acid sulphate soil	Red & Mekong Rivers Deltas	Rice, cassava & cash crops	1-2
4	Alluvial soil	Mekong (MKRF) and Red Rivers (RRF) and others (ORF)	Rice, maize & cash crops	>2
5	Red Soil	Central high plateau; North hills & mountains	Maize, coffee, rubber & other industrial crops	1-2
6	Grey degraded soil	Midlands of north & southeast	Rice, maize, & cash crops	>2
7	Ferralitic soils	Hills & mountainous areas	Forestry & cash crops	1-2

IV. Construction of Vulnerability Index for Vietnam's Food Production

IV.1 Selecting variable

In our study, the construction of vulnerability index consists of the selection of study areas with 8 agro-ecological zone (AEZ) bases and the list of indicators. In each AEZ, a potential list of indicators is selected for each of the three components of vulnerability. The indicators are selected based on the availability of data concerning the agricultural activity and food security as well as farmers' incomes.

Table 8. Computing total vulnerability to climate change.

Indicator group	Relationship to vulnerability	Description of the indicator (variable)	Formulation	Name
Exposure	Positive	Change in rainfall (%)	V_1	X_1
		Change in maximum temperature (degree)	V_1	X_2
		Change in minimum temperature (degree)	V_1	X_3
		Change in average temperature (degree)	V_1	X_4
Sensitivity	Positive	Population density (pop/km^2)	V_1	X_5
		Overall poverty (% population)	V_1	X_6
		Food poverty (% population)	V_1	X_7
		Km coastal lines/AEZ	V_1	X_8
Adaptation capacity	Negative	Rice Yield (ton/ha)	V_2	X_9
		Food production (million ton/EAZ)	V_2	X_{10}
		Animal farm (N. Farm/AEZ)	V_2	X_{11}
		% Forest cover/AEZ area	V_2	X_{12}
		Number of enterprises	V_2	X_{13}
Index	Average score	(Sum of V_i)	$\Sigma(V_i)/n$	AI

Functional relationship to vulnerability is important for normalization of indicators. When the observed values are related positively to the vulnerability (for example, higher the variation in rainfall, the higher will be the vulnerability), the standardization is achieved by employing the formula:

$$V_1 = (X_{id} - Min\ X_{id}) / (Max\ X_{id} - Min\ X_{id})$$

When the values are negatively related to the vulnerability (for example, higher the productivity of a crop in a region, lower the vulnerability)

$$V_2 = (Max\ X_{id} - X_{id}) / (Max\ X_{id} - Min\ X_{id})$$

Since vulnerability is dynamic over time, in this study, the computation will be based on the available data of the year 2008.

Table 9. Population and land in AEZ zones.

	Population (1000 people)	%	Area (km2)	%	Density (per/km2)
NEM	9,458.50	11.24	64,025.20	19.33	148
NWM	2,606.90	3.10	37,533.80	11.33	69
RRD	18,207.90	21.64	14,862.50	4.49	1,225
NCC	10,668.30	12.68	51,552.00	15.56	207
SCR	7,131.40	8.47	33,166.10	10.01	215
CHR	4,868.90	5.79	54,659.60	16.50	89
SER	13,798.40	16.40	34,807.70	10.51	396
MRD	17,415.50	20.69	40,604.70	12.26	429
Whole country	84,155.80	100.00	331,211.60	100.00	254

Sources: GSO 2008.

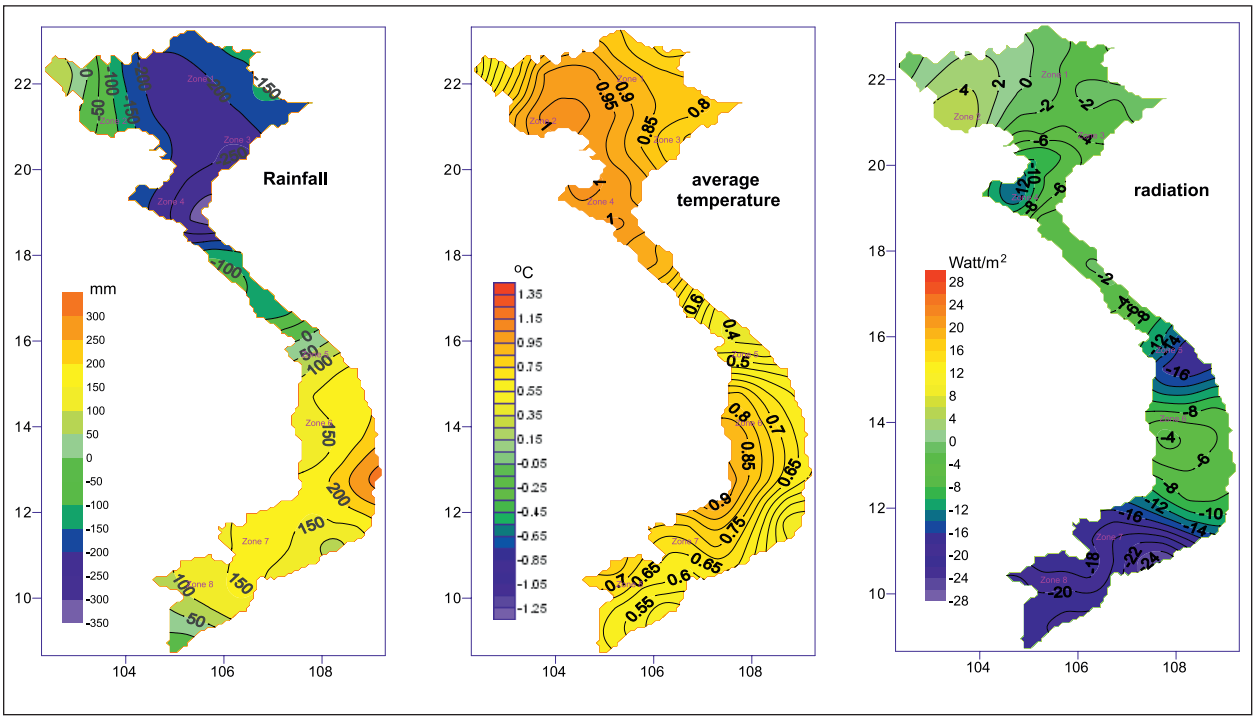
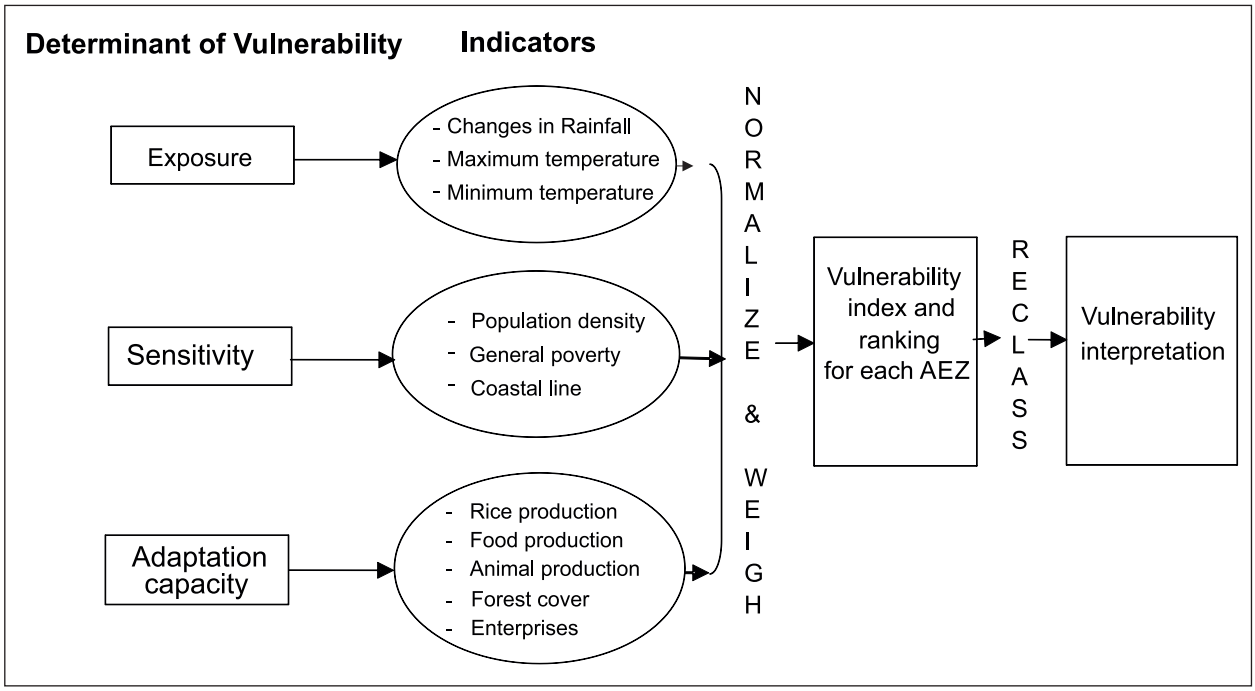


Figure 3. Changes in precipitation, temperature and solar radiation in Vietnam during 1971-2007.
Source: SiHymete (2010).

IV.2 Computing methodology

There were several steps in the construction of vulnerability index as shown in the figure below. A set of indicators were selected for each of the three components of vulnerability. The data was arranged in the form of a matrix and normalized using functional relationship. They were later subjected to computation using the method of equal weights followed by simple average of the score (AI) and vulnerability index (VI) is computed by the Patnaik and Narain method (Ranganathan et al. 2009)

$VI = n^{-1} [\Sigma(AI)^n]^{1/n}$



IV.3 Findings

Table 10. Climate variation computed as vulnerability index for Exposure (1971-2007).

No.	AEZ	Mean Annual Precipitation (mm)	Average T (°C)	Average T_{max} (°C)	Average T_{min} (°C)	AI_e
1	NEM	0.128	1.000	1.000	0.138	0.567
2	NWM	0.415	0.967	0.507	0.172	0.515
3	RRD	0.000	0.900	0.701	0.069	0.418
4	NCR	0.159	0.900	0.567	0.379	0.501
5	SCC	1.000	0.000	0.254	0.345	0.400
6	CHR	0.983	0.733	0.075	0.483	0.569
7	SER	0.926	0.300	0.239	1.000	0.616
8	MRD	0.806	0.167	0.000	0.000	0.243

For the average exposure vulnerability score (AI_e), results showed that the South East Region (SER), Central High Land (CHR) and North East Mountainous (NEM) region are the most vulnerable.

Table 11. Construction of vulnerability index for sensitivity (2008).

No.	AEZ	Population density	General poverty	Coastal line	AI_s
1	NEM	0.068	0.451	0.717	0.412
2	NWM	0.000	1.000	0.000	0.333
3	RRD	1.00	0.126	0.654	0.593
4	NCC	0.119	0.498	0.562	0.393
5	SCC	0.126	0.256	1.000	0.461
6	CHR	0.017	0.521	0.000	0.179
7	SER	0.283	0.000	0.412	0.232
8	MRD	0.311	0.265	0.834	0.470

The average sensitive vulnerability scores (AI_S) showed that RRD and MRD are the most vulnerable.

Table 12. Construction of vulnerability index for adaptive capacity (2008).

No.	AEZ	Rice yield	Food production	Animal production	Forest cover	Enterprise	AI_a
1	NEM	0.47	0.905	0.237	0.047	0.903	0.523
2	NWM	0.66	1.000	0.980	0.228	1.000	0.802
3	RRD	0.00	0.703	0.000	0.852	0.432	0.497
4	NCC	0.48	0.863	0.098	0.000	0.950	0.478
5	SCC	0.39	0.915	0.683	0.273	0.909	0.695
6	CHR	0.66	0.960	0.934	0.030	0.955	0.720
7	SER	1.00	0.979	0.822	0.789	0.000	0.648
8	MRD	0.84	0.00	1.000	0.789	0.819	0.652

The scores on average adaptive capacity vulnerability (AI_a), showed that the NWM and CHR are most vulnerable.

Table 13. Total vulnerability index and ranks for different AEZ of Vietnam (2008).

AEZ	Exposure	Sensitivity	Adaptation	Average score	VI	Rank
NEM	0.567	0.412	0.523	0.501	0.245	7
NWM	0.515	0.333	0.802	0.550	0.342	2
RRD	0.418	0.593	0.497	0.503	0.343	1
NCC	0.501	0.393	0.478	0.457	0.296	6
SCC	0.400	0.461	0.695	0.518	0.309	5
CHR	0.569	0.179	0.720	0.489	0.340	3
SER	0.616	0.232	0.648	0.498	0.342	2
MRD	0.243	0.470	0.652	0.455	0.323	4

The total vulnerability index (Table 12; Figure 4) in this study was in the context of present situation and the assessment conducted in the course of climatic variability and food production activities (without the sea level rise indicator). The analysis of aggregated data at regional scale showed that 5 regions (RRD, NWM, SER, CHR and MRD) are the most affected (very highly vulnerable). The regions NCC and SCC are highly vulnerable and NEM is relatively least vulnerable.

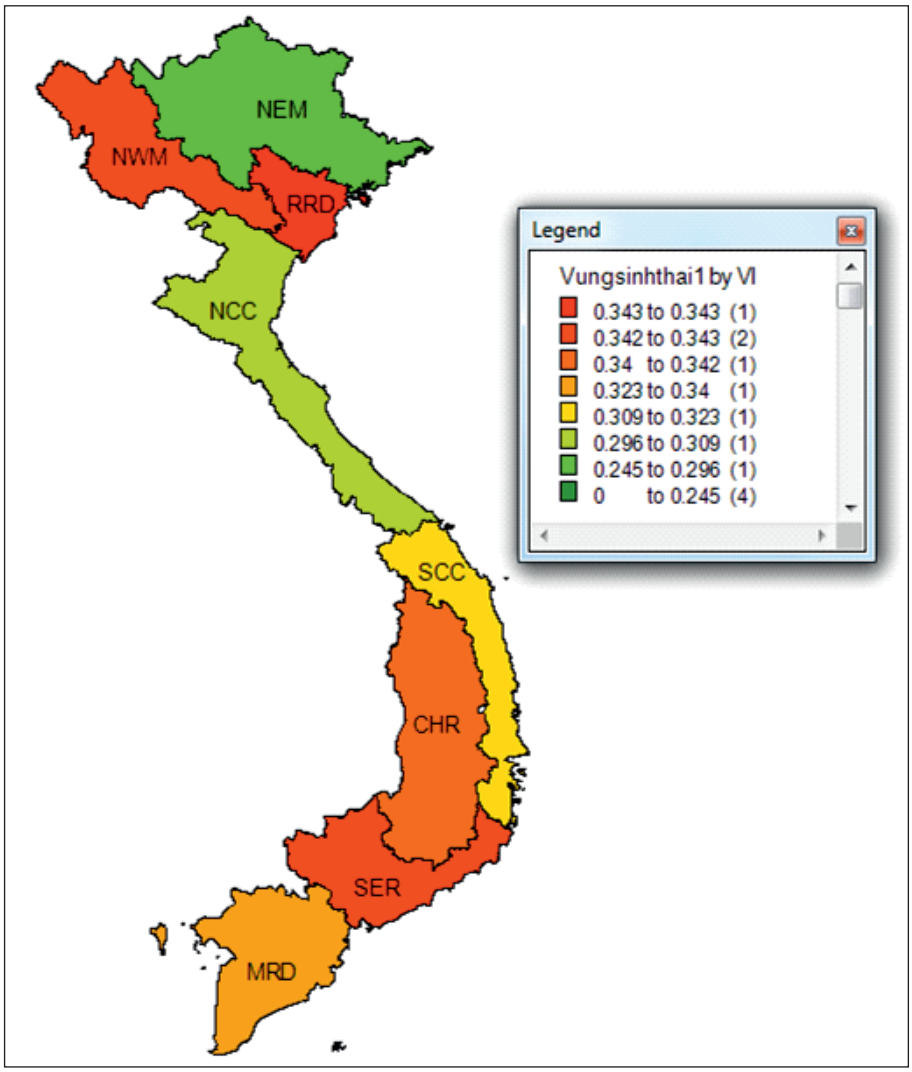


Figure 4. Vulnerability index (VI) as classified by AEZ of Vietnam.

V. Conclusion

Thirteen variables (indicators) represented in three groups (exposure; sensitivity and adaptive capacity) were computed for Vietnam's case of food production and poverty alleviation. Total vulnerability is a function of different indicators selected. Some indicators are very explicative regarding vulnerability in case of variation in temperature with regard to rainfall but not good in the case of sea level rise. The absolute value of vulnerability is highly dependent on the available set of input data and it may change over time for a definite AEZ.

The Agro-ecological regions, RRD, NWM, SER, CHR and MRD are the most vulnerable regions to climate change. The other regions are relatively less vulnerable. Further, a deeper study should be done to have a more accurate prediction on vulnerability index to explain better the real situation and therefore to formulate better the policy to adapt and mitigate the climate change in food production and poverty alleviation for Vietnam.

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