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Markets, Institutions and Policies

Vulnerability to Climate Change:
Adaptation Strategies and Layers of Resilience

Quantifying Vulnerability to Climate Change in Thailand

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Abstract

The main objective of vulnerability analysis is to understand the extent to which the system is susceptible to the sustaining damage from climate change. The analysis was carried out based on the different sets of socio-economic variables using the standard IPCC methodology. The northeastern region of Thailand is highly vulnerable compared to the other regions. Further, the provincial vulnerability mapping for the northeastern region was also undertaken. This study was done as a precursor to the micro/household analysis on exposure, sensitivity and adaptive capacity.

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Quantifying Vulnerability to Climate Change in Thailand

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Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience

Quantifying Vulnerability to Climate Change in Thailand

1 Introduction

Vulnerability is an emerging concept for climate science and policy. It is the degree to which a system is susceptible or unable to cope with adverse effects of climate variability and extremes. The extent to which systems are vulnerable to climate change depends on environmental, physical conditions and socioeconomics of the area. Understanding the pattern, extent and driving factors of vulnerability is desirable for climate adaptation efforts.

The purpose of the analysis of vulnerability to climate change in Thailand is to identify, classify and map the vulnerability in regions/provinces based on a set of multivariate data. This vulnerability assessment is helpful for developing and prioritizing strategies to reduce vulnerability, and for determining the effectiveness of those strategies.

2 Literature review

A vulnerability assessment is the process of identifying, quantifying and prioritizing (or ranking) the vulnerabilities in a system. It has many things in common with risk assessment except that vulnerability assessment focuses on consequences of the object or threat. Risk analysis principally focuses on causes and consequences of the studied object/subject.

2.1 Vulnerability to climate change

Based on the IPCC Third Assessment Report in 2001, 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. Thus, vulnerability comprises three major components:

2.1.1 Exposure

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

2.1.2 Sensitivity

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

2.1.3 Adaptive capacity

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

2.1.4 Vulnerability to climate change in Thailand

Throughout the world, each country is facing new climatic challenges. Climate changes include higher global temperature, flood, drought, storm and sea level rise. The review on climate impacts, vulnerability and adaptation capacity in Southeast Asia, including Thailand is summarized in Table 1.

Table 1. Climate impacts and vulnerability to climate change in Southeast Asia.

Climate impacts	Vulnerability
1. Temperature - Warming temperature is similar to the global mean temperature	**1. Agriculture and Food Security** - Decrease in the crop yield - Reduced soil moisture may increase the land degradation and desertification.
2. Precipitation - Increase in precipitation in most of the areas causes landslides and severe floods	**2. Water** - Increased water stress due to decreased fresh water availability
3. Extreme events - Increase in extreme rainfall and winds associated with tropical cyclones - Heat waves, hot spells in summer for longer duration, more intense and more frequent	**3. Terrestrial Ecosystems** - Increased risk of extinction of many species due to climate changes - Increase in the frequency and extent of forest fires
	4. Coastal Zones - Millions of people living along the coastal area -- affected by sea level rise and increase in the intensity of tropical cyclones - Wetland, mangrove and reef are under a threat
	5. Health - Heat stress and changing patterns lead to diseases and affect health - Increases in endemic morbidity and mortality due to diarrhea

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

Climate changes can have a wide ranging effect on environments and several sectors including agriculture. Agriculture in Thailand employs 49% of the population and contributes to 10% of GDP. Agriculture plays an important environmental role as both victim and contributor to climate change. The climate change impact studies conducted in the recent years have considered crop loss and technological options for adapting to climate change. The severe yield loss of rice exposed to double carbon dioxide concentration was up to 22% (Reilly 1996). There is a pressure to adapt to the challenge involving weather, soil conditions and water availability. Among those that offer promise are seasonal and sowing date changes, different crop varieties or species, water supply and irrigation, other inputs and management adjustment and also short-term climate prediction.

Adaptation to climate change has become an important policy in recent years. The relation between the level of development and climate risk was conducted through the comparative study between Thailand and Laos PDR. Several indicators were employed for the classification of climate risk. Both countries were exposed to similar climate change; however, Laos was categorized as low risk while Thailand was categorized as moderate or high risk to climate change (Chinvanno et al. 2008). It appeared from this study that limited coping capacity was the most important factor contributing to the risk as found in Thailand. In addition, the majority of farm households have little diversification in farm production and income sources, which create a high level of exposure and sensitivity to climate impacts.

3 Methodology

3.1 Data source

Reliable and systematic climatic data integrated with socioeconomic conditions help in determining vulnerability. This analysis is based on the secondary data obtained from the various sources as presented in Table 2. Some available data in Thailand are already in digital form, which is distributed to the public.

Table 2. Secondary data collected and their sources.

Data	Sources	Type of data
Administrative boundary	- Land Development Department	- Regional and provincial boundary
Climate	- Meteorological Department	- Rainfall quantity
		- Maximum and minimum temperature
Forest	- Royal Forest Department	- Forest area
Agriculture	- Office of Agricultural Economics	- Provincial crop planting area and production yield
Irrigation	- Royal Irrigation Department	- Area of large, medium and small irrigation projects
	- Department of Ground Water Resource	- Area of electrical water pump
		- Area of underground water use
Demography	- Internal Affairs ministry	- Population number
	- National Statistic Office	- Proportion of people below the poverty line
		- Literacy rate
Economy	- Office of Agricultural Economics	- Farm size
	- Office of the National Economic and Social Development Board	- Fertilizer utilization
		- Gross Provincial Product (GPP)

3.2 Description of Variables

Vulnerability indices were computed using regional and provincial level data. Indicators were selected based on the availability of data, previous research and their underlying reasons of vulnerability. Data in 2006 was used as the baseline data to construct the vulnerability index. Changes in climatic variables in 2006 were compared to the average of 30 years. The totals of 15 variables were included in the vulnerability index analysis (Table 3).

3.3 Vulnerability analysis

There were several steps in the construction of vulnerability index as shown in Figure 1. A set of indicators was 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

Table 3. Indicators used in the computation of vulnerability indices and their functional relationship to vulnerability.

Determinants of vulnerability	Component indicators	Description of the indicator	Functional Relationship
Exposure	Change in climate variables	Change in rainfall (%)	+
		Change in the maximum temperature (degree)	+
		Change in the minimum temperature (degree)	+
Sensitivity	Irrigated land	Percentage of irrigated land to agricultural area (%)	-
	Population density	Total population per unit area (pop/km^2)	+
	Forest area	Percentage of forest area to land area (%)	-
	Percentage of land managed	Percentage of paddy land to agricultural land (%)	-
	Fertilizer use	Consumption of fertilizers for rice per unit area (kg/ha)	-
Adaptation capacity	Literacy rate	Proportion of persons who are able to read and write	-
	Farm holding size	Average farm size (ha)	-
	Poverty incidence	Percentage of people below poverty line (%)	+
	Gross Provincial Product (GPP)	Amount of income generated in a particular province per capita (Baht)	-
	Food crop production	Amount of rice produced per hectare (kg/ha)	-
	Non-food crop production	Amount of cassava produced per hectare (kg/ha)	-
	Cropping intensity	Gross area by net area under cultivation (%)	-

(+) positive relationship to vulnerability, (-) negative relationship to vulnerability

using the method of unequal weights following Iyengar and Sudarshan's method (Ranganathan et al. 2009).

The first two components together represent the potential impact, and adaptive capacity is the extent to which these impacts can be averted. Thus, vulnerability is potential impact (I) minus adaptive capacity (AC). This leads to the following mathematical equation for vulnerability:

$$V = I - AC$$

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, higher the vulnerability), the standardization is achieved by employing the formula.

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

When the values are negatively related to the vulnerability, higher the productivity of a crop in a region, the lower will be the vulnerability.

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

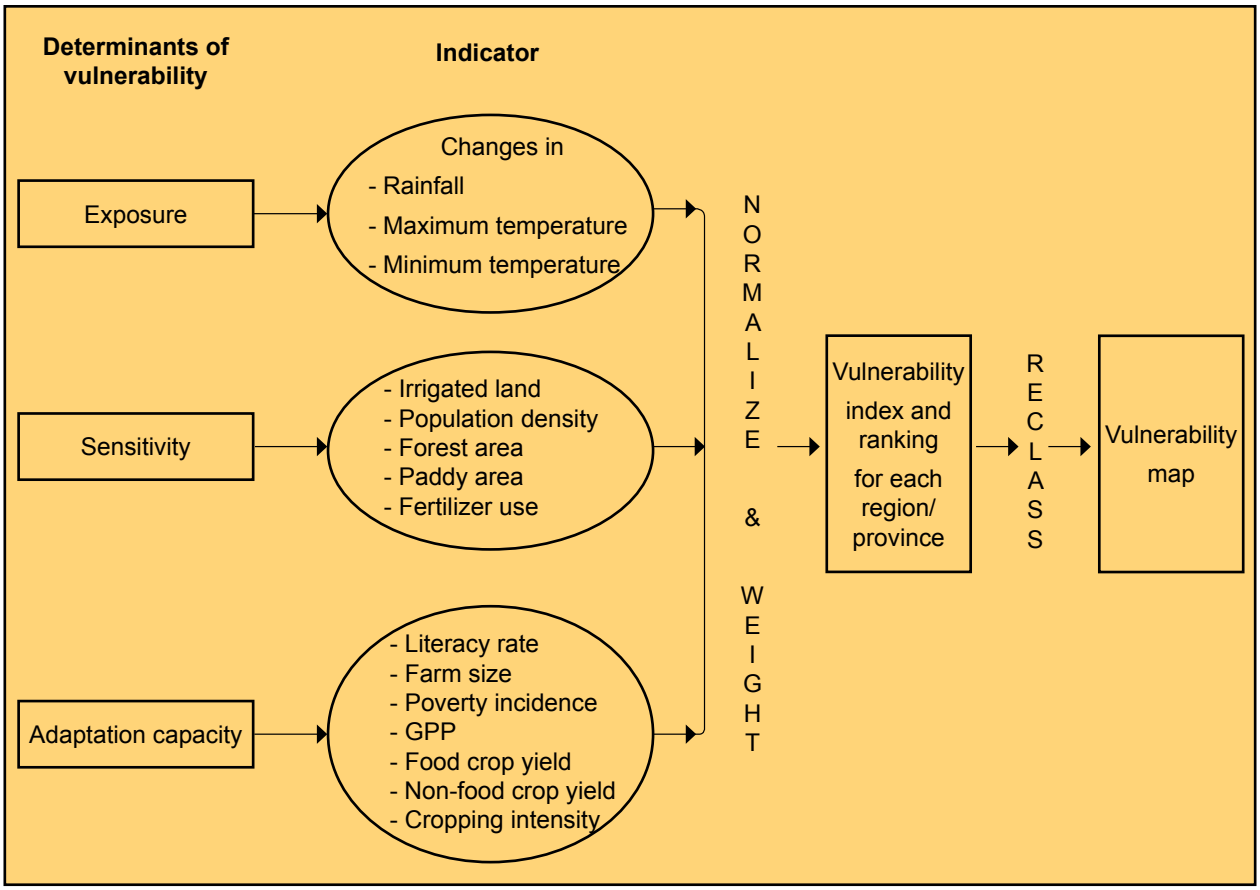

Figure 1. Methodology for vulnerability index analysis.

4 Findings and Discussion

4.1 Regional Vulnerability

Vulnerability mapping in this study was in the context of the present situation and the assessment conducted in the course of climatic variability and development activities. Analysis of the aggregated data at the regional scale showed that the northeast is the most vulnerable to climate change. It is characterized as a very highly vulnerable region (Figure 2). Other regions such as the North, East and South were less vulnerable regions while the central region is the least vulnerable. This analysis is consistent with climate analysis in report No. 1 that the northeastern region was exposed to high climate variability during the past 40 years.

4.2 Vulnerability in the Northeastern Region

Regional vulnerability assessment showed that the northeastern region was the most vulnerable area in Thailand but provincial breakdown revealed that there were different degrees of vulnerability. The vulnerability indices were ranging from 0.34 to 0.65 and the greatest was found in the eastern part of the region, ie, Sakon Nakhon and Nakhon Phanom provinces (Table 3). Other provinces were less vulnerable to climate change with the shift from the eastern to the western part of the region.

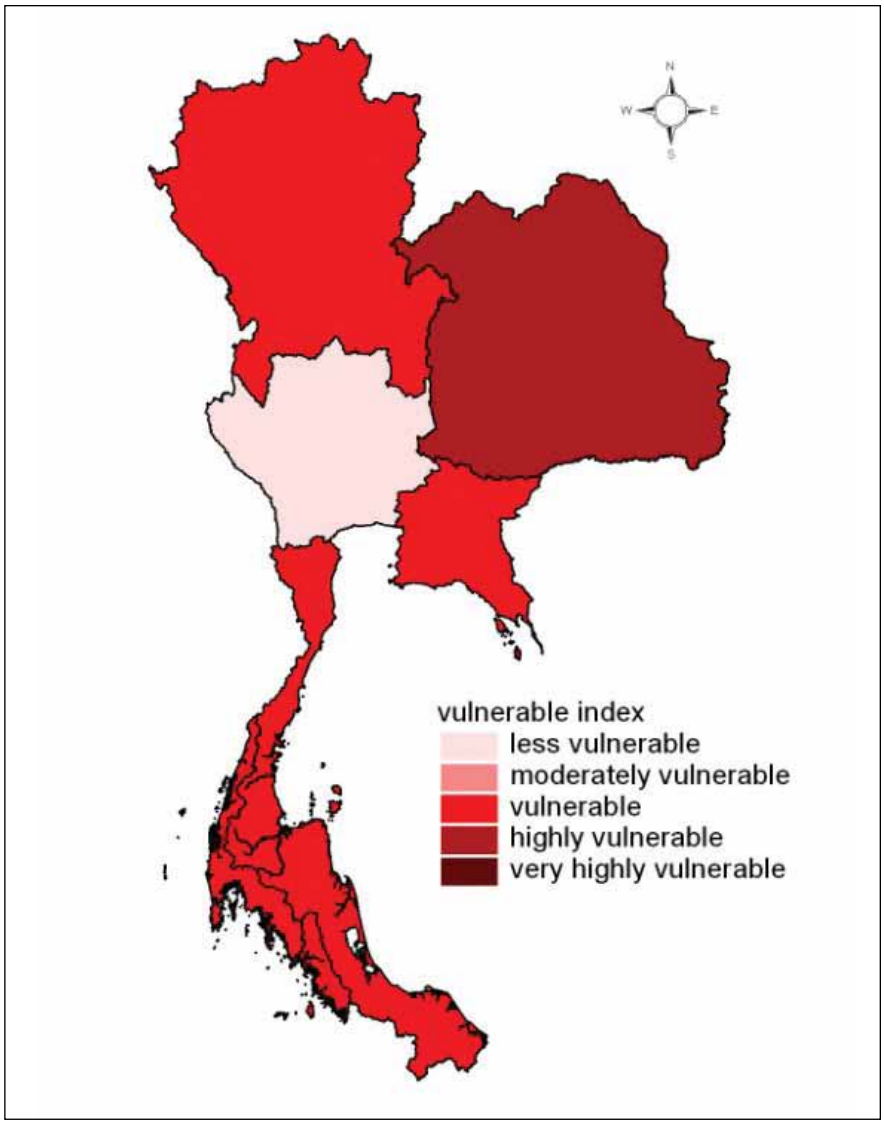

Figure 2. Regional vulnerability to climate change in Thailand, 2006.

The provinces selected for this study, Nakhon Ratchasima and Chaiyaphum, were categorized as moderately vulnerable and less vulnerable areas. The conflicting outputs from vulnerability analysis to the climate analysis were due to different variables being included. The study sites were first selected based on biophysical data and the single socioeconomic variable as poverty incidence was incorporated. These two provinces were the most drought prone areas of the region and revealed a great development of cropping patterns (Report No. 1). However, 12 socioeconomic variables reflecting sensitivity and adaptation capacity were included in this vulnerability analysis. Several development variables would probably be the factors that lower the degree of vulnerability in the selected provinces.

To identify the major components influencing vulnerability, the indices for each component were analyzed. Table 4 shows indices and ranks of vulnerability in 19 provinces in the Northeast. The indices range from 0.026-0.043 for exposure, and 0.145-0.158 for sensitivity. Adaptation capacity contributed the greatest vulnerability index ranging from 0.345 to 0.373. This finding was consistent with the study of vulnerability in Ubon Ratchathanee province that coping capacity was the most important factor contributing to the climate risk (Chinvanno et al. 2008).

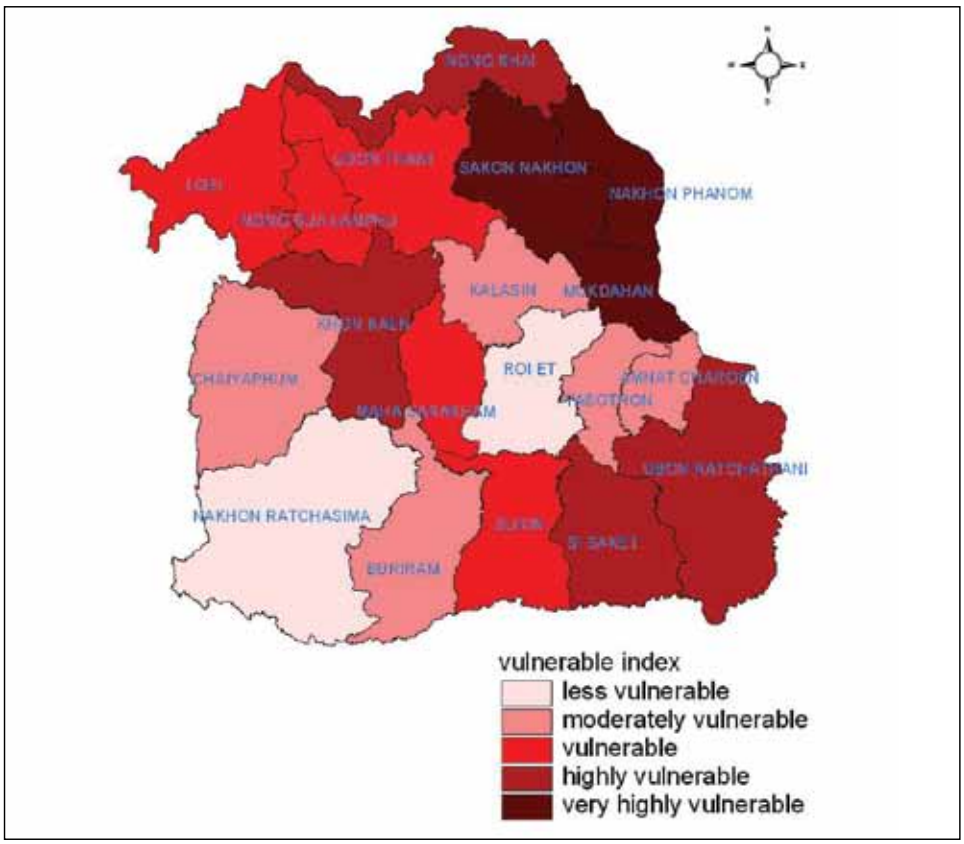

Figure 3. Vulnerability to climate change in the Northeast, Thailand, 2006.

Table 4. Vulnerability index and ranks for different provinces in the Northeast.

Variable	Exposure	Sensitivity	Adaptation	Index	Rank
Kalasin	0.043	0.149	0.345	0.537	17
Khon Kaen	0.036	0.157	0.346	0.539	15
Chaiyaphum*	0.030	0.149	0.361	0.540	14
Nakhon Phanom	0.028	0.152	0.373	0.553	1
Nakhon Ratchasima*	0.032	0.145	0.349	0.526	19
Buriram	0.031	0.149	0.360	0.540	12
Maha Sarakham	0.036	0.155	0.353	0.544	9
Mukdahan	0.037	0.145	0.370	0.553	2
Yasothon	0.031	0.154	0.353	0.538	16
Roi Et	0.026	0.150	0.353	0.529	18
Loei	0.034	0.149	0.357	0.540	13
Si Saket	0.031	0.156	0.362	0.548	6
Sakon Nakhon	0.038	0.148	0.368	0.553	3
Surin	0.036	0.152	0.358	0.546	7
Nong Khai	0.029	0.156	0.366	0.551	4
Nong Bua Lamphu	0.030	0.157	0.361	0.549	5
Amnat Charoen	0.032	0.149	0.360	0.541	11
Udon Thani	0.030	0.158	0.354	0.543	10
Ubon Ratchathani	0.038	0.149	0.358	0.545	8
Standard Deviation	0.004	0.004	0.008	0.007	

*Selected study provinces

4.3 Determinants of Vulnerability

Understanding the driving factors of vulnerability is important for future policy formulation. A matrix of exposure to climate risks and development helps to focus on the most substantial factors that can be managed. The Bartlett test of sphericity, a statistical test for the presence of correlations among variables, is such a measure. It provides the statistical probability that the correlation matrix has significant correlations among at least some variables (Hair et al. 1992).

A total of 15 climatic and socioeconomic variables were included in the analysis. The correlation matrix showed the significant relationship between 13 variables and vulnerability index (Table 5). Out of the 13, only three variables were statistically positive correlation to vulnerability. Changes in the minimum temperature, forest area and poverty incidence were among the variables that boosted vulnerability. In contrast, ten climatic and development variables that reduce vulnerability were found in both the sensitivity and adaptation capacity components. Variables that showed the greatest relationship with vulnerability index were fertilizer use (X8) and food crop production per area (X13), which had the correlation coefficients of -0.790 and -0.761, respectively. The other variables that contain correlations greater than 0.50 were irrigated land (X4) and cropping intensity (X15) while population density (X5) was found to have the lowest significant correlation with vulnerability.

A high correlation to vulnerability indicates the strong relationship with vulnerability to climate change. It also implies the policy intervention that would lower the climate impacts. In order to reduce the vulnerability to climate change, the policy on increasing crop production through intensive cropping system, and the use of fertilizer and irrigation water should be considered. These resources are fundamental elements for farm production.

The analysis identifies an urgent need to reduce vulnerability and increase the capacity to adapt by undertaking proactive measures. It is an urgent measure to reduce vulnerability and increase the capacity to adapt. The analysis of determinant variables of vulnerability pointed out the existing coping strategies from the studied rural households. However, this analysis is based on secondary data, which can provide limited description of coping strategies. A qualitative assessment, through interviews or focus groups will provide a rich context for considering the relative risks of climate variations and potential response strategies.

5 Conclusion and the Way Forward

Vulnerability or the extent to which a system is susceptible to sustaining damage from climate change is assessed through the index from underlying variables. Fifteen climatic and socioeconomic variables were analyzed following ICRISAT/ADB guidelines. In Thailand, the Northeast, which is the poorest region, was the most vulnerable area to climate change. Provincial breakdown showed that the most vulnerable area was in the eastern part of the region while the selected study sites were categorized as less and moderately vulnerable provinces. Based on earlier climatic analysis, the two selected provinces were among the most drought prone areas of the region. Lower vulnerability to climate change in these provinces implied the effective adaptation of the area. Lessons learnt from these areas would be useful for future policy formulation in the other areas. Further correlation analysis revealed that the variables were highly correlated with the vulnerability index. Determinants such as fertilizer use, crop yield, irrigated area and cropping intensity had high negative correlations to vulnerability.

Climatic conditions are likely to be changing at a greater speed; vulnerability of the system should be identified and monitored over time and space. A plan for the next step is to analyze vulnerability using the information collected from the villages. Such analysis would be useful for identifying the driving factors, to assess the effectiveness of past policies and plan for future policies.

Table 5. Correlation coefficients of vulnerability determination variables.

Variable	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	VI
X1	1	-0.082	0.035	-0.064	-0.037	0.174	0.202	-0.115	0.052	0.146	0.118	-0.015	-0.060	0.080	0.195	0.113
X2		1	0.096	0.158	0.175	-0.147	-0.137	0.063	0.042	-0.085	-0.170	0.317**	-0.044	0.075	-0.170	0.188
X3			1	-0.041	0.091	0.115	-0.278*	-0.132	0.014	0.027	0.040	0.151	-0.102	0.096	-0.192	0.323**
X4				1	0.842**	-0.303**	0.259*	0.613**	0.287*	-0.170	-0.339**	0.377**	0.699**	0.021	0.504**	-0.580**
X5					1	-0.338**	0.154	0.346**	0.322**	-0.158	-0.234*	0.285*	0.403**	0.200	0.321**	-0.231*
X6						1	-0.311**	-0.443**	-0.480**	-0.272*	0.292*	-0.251*	-0.100	-0.380**	-0.264*	0.338**
X7							1	0.207	0.121	-0.094	0.244*	-0.235*	0.192	-0.231	0.829**	-0.327**
X8								1	0.205	0.125	-0.475**	0.280*	0.738**	0.279	0.506**	-0.790**
X9									1	0.185	-0.356**	0.162	0.090	0.113	0.123	-0.307**
X10										1	-0.285*	0.211	-0.064	0.692**	0.038	-0.260*
X11											1	-0.400**	-0.338**	-0.263	0.048	0.521**
X12												1	0.248*	0.377*	-0.064	-0.332**
X13													1	0.036	0.578**	-0.761**
X14														1	0.062	-0.343*
X15															1	-0.614**
VI																1

* significant at the 0.05 level; ** significant at the 0.01 level

X1	Rainfall change	X9	Literacy rate
X2	Maximum temperature change	X10	Farm holding size
X3	Minimum temperature change	X11	Poverty incidence
X4	Irrigated land	X12	Gross Provincial Product (GPP)
X5	Population density	X13	Food crop production
X6	Forest area	X14	Non-food crop production
X7	Percentage of land managed	X15	Cropping intensity
X8	Fertilizer use		

It may be desirable to construct the model using data from both qualitative and quantitative assessment. Changes in the socioeconomic situation as well as climate risks can be tested against a range of scenarios of the future. However, developing techniques to deal with modeling and long time frames would be worth pursuing.

Synopsis

- The purpose of the analysis of vulnerability to climate change in Thailand is to identify, classify and map the vulnerability in regions/provinces based on a set of multivariate data.
- This vulnerability assessment is helpful for developing and prioritizing strategies to reduce vulnerability, and for determining the effectiveness of those strategies.
- Adaptation is a process through which societies are taking the measures to reduce the negative effects of climate change.
- Agriculture in Thailand employs 49% of the population and contributes to 10% of GDP.
- There is a pressure to adapt to the challenge involving weather, soil conditions and water availability.
- Among those that offer promise are seasonal and sowing date changes, different crop varieties or species, water supply and irrigation, other inputs and management adjustment and also short-term climate prediction.
- Analysis of the aggregated data at the regional scale showed that the Northeast is the most vulnerable to climate change.
- Changes in the minimum temperature, forest area and poverty incidence were among the variables that boosted vulnerability.
- 12 socioeconomic variables reflecting sensitivity and adaptation capacity were included in this vulnerability analysis.
- A high correlation to vulnerability indicates the strong relationship with vulnerability to climate change.
- An increase of crop production through intensive cropping system, the use of fertilizer and irrigation water should be considered.
- A qualitative assessment, through interviews or focus groups will provide a rich context for considering the relative risks of climate variations and potential response strategies.
- Determinants as fertilizer use, crop yield, irrigated area and cropping intensity had high negative correlations to vulnerability.

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