EVALUATION OF CLIMATE CHANGE-RELATED VULNERABILITY FOR NATURAL RESOURCES AND ENVIRONMENT IN THAI NGUYEN PROVINCE

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ABSTRACT

In 2021, the upgraded scenarios of climate change using Coupled Model Intercomparison Project 6 global climate models are released by Intergovernmental Panel on Climate Change. This information is a very important data source for scientists to continuously upgrade their studies in the behaviors of a natural system as extreme climate events are frequently observed. In the context of fast urban expansion, tourism development with a huge reservoir of NuiCoc, construction of industrial parks in Thainguyen, a province in northeast Vietnam could lead to unexpected vulnerability in natural resources and environment. Therefore, the study is to evaluate the climate change-related vulnerability for natural resources and environment of Thainguyen province at the scale of districts and cities. The equal weight method of Intergovernmental Panel on Climate Change in 2007 is used to evaluate the vulnerability level based on a set of hydrometeorological and socio-economic sources for Thainguyen. The results indicate that thirty percent of districts out of nine districts and cities have high vulnerability with the low resilience of system on climate variations and extreme climate events in near future.

ĐÁNH GIÁ MỨC ĐỘ TỔN THƯƠNG CỦA BIẾN ĐỔI KHÍ HẬU TỚI TÀI NGUYÊN THIÊN NHIÊN VÀ MÔI TRƯỜNG TỈNH THÁI NGUYÊN

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TỪ KHÓA

Thái Nguyên
Tài nguyên thiên nhiên
Biến đổi khí hậu
Tổn thương
Môi trường

TÓM TẮT

Vào năm 2021, Ủy ban liên chính phủ về Biến đổi khí hậu đã công bố các dữ liệu kịch bản biến đổi khí hậu mới nhất sử dụng mô hình biến đổi khí hậu toàn cầu trong dự án đối chứng các mô hình khí hậu lần thứ 6. Đây là một nguồn thông tin dữ liệu rất quan trọng cho các nhà khoa học để tiếp tục cập nhật những nghiên cứu của mình về phản ứng của tự nhiên và môi trường khi các hiện tượng khí hậu cực đoan xuất hiện với tần suất thường xuyên hơn. Trong bối cảnh của sự mở rộng nhanh chóng các khu vực đô thị, sự phát triển du lịch với hồ chứa Núi Cốc lớn và xây dựng các khu công nghiệp ở Thái Nguyên, một tỉnh ở phía đông bắc của Việt Nam có thể dẫn tới những tổn thương không mong muốn tới tài nguyên thiên nhiên và môi trường. Do vậy, nghiên cứu này hướng tới việc đánh giá mức độ tổn thương của biến đổi khí hậu tới tài nguyên thiên nhiên và môi trường tỉnh Thái Nguyên ở cấp huyện và thành phố. Phương pháp bình quân được đưa ra bởi Ủy ban liên chính phủ về Biến đổi khí hậu năm 2007 được sử dụng cho nguồn dữ liệu khí tượng thủy văn và kinh tế xã hội của Thái Nguyên. Kết quả đã cho thấy rằng 30% số huyện trong tổng số 9 huyện và thành phố có sự tổn thương cao với khả năng chống chịu thấp của hệ thống trước những biến đổi khí hậu và hiện tượng khí hậu cực đoan trong tương lai gần.

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1. Introduction

Vietnam is one of the countries strongly impacted by climate change causing substantial economic and human losses [1]. Followed the report of World Bank [2], it is observed that over East Asia and Pacific regions, more 70% population is exposed to single or multiple types of natural hazards (e.g., flooding ans storm surge). Furthermore, the issues of socioeconomic-related development (e.g., population rate, industrial sectors) make further stresses on the natural resources and environmental system. It is found that there are specific vulnerability to climate change in several regions of Vietnam (e.g., Mekong delta) [3]. It is observed that upgraded climate change scenarios with the Shared Socio-Economic Pathway (SSP) in Coupled Model Intercomparison Project 6 (CMIP6) models in 2021 are different from the previous versions with the Representative Concentration Pathway in CMIP5 in 2014 or Special Report on Emissions Scenarios in CMIP3 in 2001. It is illustrated that there is a significant change in temperature and precipitation in comparison with the previous climate change scenarios [4]. Until now, academic writings and researches mostly used the climate change scenarios of RCPs released by Ministry of Natural Resources and Environment of Vietnam in 2015. This could lead to uncertain under the current climate conditions. Therefore, it is a necessary to investigate the impacts of climate change with upgraded scenarios in CMIP6.

Thainguyen is considered as the center of cultural, economic and political of Viet Bac region of Vietnam. In recent years, however, urbanization rate, tourism development, construction of industrial parks or population rate could lead to changes in natural resources and environment. According to the ADB report [5], it is showed that there is a deficient water supply for Thainguyen City by the mentioned factors. Dealing with the vulnerability, the likelihood vulnerability index (LVI) is used to assess the vulnerability of household livelihoods to climate change impacts for DinhHoa district of Thainguyen [6]. The results show a relative high level of exposure and sensitivity to climate change impacts [6]. For other regions, lots of studies in vulnerability are implemented with a different subjects (e.g., mangroves in Nga Son and Hau Loc districts, Thanh Hoa province [7]; agriculture in coastal communes of Quang Tri Province [8]; Coastal plain in Mekong Delta [9]). Generally, the studies apply a various number of approaches with indicators to define the vulnerability with the specific region without upgraded climate change scenarios and only focus on LVI. Therefore, the key objective of this study attempts to evaluate the vulnerability level due to climate change based on the upgraded scenarios of SSP3-7.0 for natural resources and environment in Thainguyen province in near future.

2. Materials and Methods

Thainguyen is one of the provinces in the northern midland and mountainous region of Vietnam. It has a natural land area of 3,526.64 square kilometres and a population of 1,286,751 as of 2019 [10] and covered the provinces of Bac Kan in the north, Tuyen Quang and Vinh Phuc in the west, Hanoi in the south and Bac Giang and Lang Son in the east (Figure 1). Mountainous and hilly areas account for 48.3% and 31.3%, respectively [11].

Completely located in tropical monsoon climate region, Thainguyen climate has four seasons in a year, spring (February, March, and April), summer (May, June, and July), autumn (August, September, and October) and winter (November, December and January). In the period of 30 years (1990-2019) at Thainguyen meteorological station, the annual average temperature is about 23.8 °C while the yearly average precipitation is 1833.9 mm. Importantly, it is noticed that the temperature is getting the highest in summer (July) and reducing gradually to the lowest points in winter (January) at 29 ^{o}C and 16.4 ^{o}C, respectively. In general, summer is the rainy season which is strongly dominated by the summer monsoon. The maximum amount of rainfall over 400 mm is normally recorded in July combined with strong winds (Figure 2). Two distinctive seasons, rainy season normally from May to Octobor and dry season from November to April in which rainfall

in the rainy season could contribute to nearly 80% of the total annual precipitation. The annual relative humidity is recorded with 80%; maximum and minimum temperature are 27.7 ^{o}C and 21.2 ^{o}C, respectively. The rainfall and sunshine data are collected from over 300 in the whole country to calculate the natural resources dealing with rainfall and solar resources.

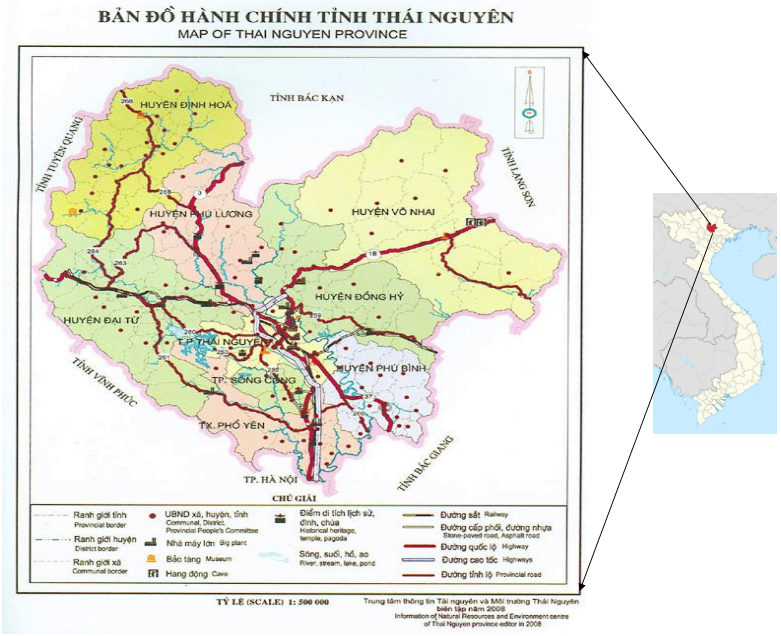

Figure 1. *Map of Thainguyen province*

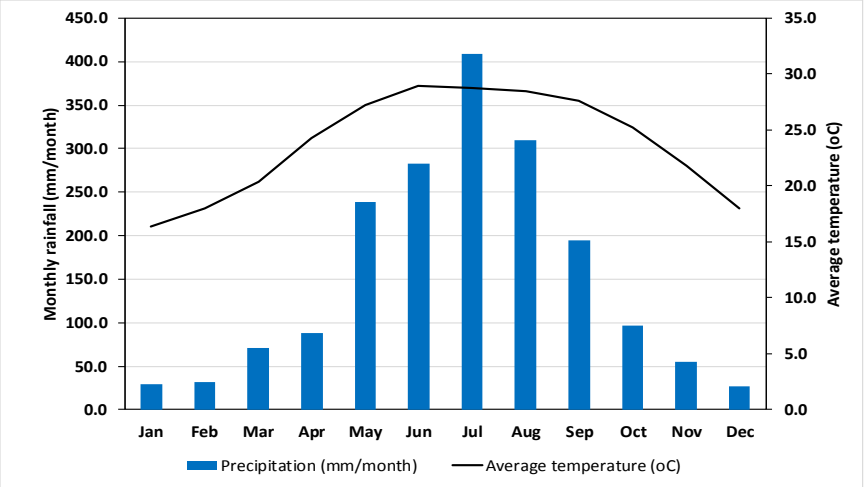

Figure 2. *Climate conditions in Thainguyen province*

More importantly, climate change is affecting multiple aspects of natural and socio-economic conditions. Additonally, the development of modern technologies (e.g., high computing performance) improves the quality of global climate models in space grids and the accuracy. With the state-of-the-art global climate models, a set of eight new scenarios based on the Shared Socioeconomic Pathways (SSPs) in the sixth phase of the Coupled Model Intercomparison Project (CMIP6) data is defined with the name of SSP1-1.9, SSP1-2.6, SSP4-3.4, SSP5-3.4 OS (overshoot scenario), SSP2-4.5, SSP4-6.0, SSP3-7.0 and SSP5-8.5. This assignment refers the most recent versions of the global climate models that cover the spectrum of future SSPs in comparison with the previous data (e.g., CMIP5). In this study, the global climate model of CNRM-ESM2-1 [11] of CMIP6 is used. A method of bias correction [12] is implemented for the

study with the scenarios of SSP3-7.0 climate change for the period of 2021-2040. The data of social-economic and natural conditions (e.g., population density) are collected from statistical yearbook of Vietnam in 2019 [10] and Thainguyen statistical yearbooks in 2019.

To evaluate the climate change-related vulnerability, the vulnerability index (V) are used based on the method given by IPCC (2007) [13]. This index is a function of parameters like exposure, sensitivity and adaptative capacity. It is defined arithmetic average of sensitivity (S) and adaptive capacity (AC) by the equation (1). Indicators for these parameters are defined in Table 1.

$$V = \frac{1}{3}\left[E + S + (1 - AC)\right] \quad (1)$$

Obviously, the parameters have different units and scales and therefore, it is a need to normalize using the method introduced in UNDP's Human Development Index (HDI) (UNDP, 2006). It is noticed that before doing this, the functional relationship between the indicators and vulnerability is defined. Let xij represents the jth value of nomarlized ith indicator. Xij represents the jth value of non-nomarlized ith indicator. Max(Xij) is maximum value of indicator. Min(Xij) is minimum value of indicator. If i indicator is directly proportional to the vulnerablity, the equation (2) is used and vice verse the equation (3) is used. It is clear that all these scores will lie between 0 and 1. Importantly, an assumption of equal weights for all indicators is made since there is not enough knowledge of the degree of importance of each hazard in assessing the vulnerability.

$$x_{i,j} = \frac{X_{i,j} - \mathrm{Min}(X_{i,j})}{\mathrm{Max}(X_{i,j}) - \mathrm{Min}(X_{i,j})} \quad (2)$$

$$x_{i,j} = \frac{\mathrm{Max}(X_{i,j}) - X_{i,j}}{\mathrm{Max}(X_{i,j}) - \mathrm{Min}(X_{i,j})} \quad (3)$$

3. Results and Discussion

First and foremost, it is very important to select indicators used for calculating the vulnerability index. Based on the documents of statistical yearbook of Thainguyen province and general statistics office of Vietnam, the study selected several indicators described in Table 1.

Exposure indicators: Using the meteorological data downscaled and bias-corrected the global climate model of CNRM-ESM2-1 is implemented with the scenarios of SSP3-7.0. As a result, the change in rainfall and temperature are projected and interpolated for each district of Thainguyen province.

Sensitivity indicators: There are eight indicators as shown in Table 1. Their component includes several resources (e.g., rainwater resources labeled with S7, renewable resources lableled with S5 and S6 or land resources labeled from S1 to S4). It is noteworthy that S6 and S7 indicators are estimated from the data of over 100 meteorological and 300 rainfall stations over the country. For each of these indicators represent aspects of natural resources that is quantitatively analysed. To estimate for each districts of Thainguyen province, the initerpolation of IDW is used. The S5 indicator is adopted from the global wind atlas (https://globalwindatlas.info/).

Table 1. *List of indicators selected for analysis of climate change-related vulnerability*

Group	Indicators	Code	Unit
Exposure (E)	Change in annual temperature	E1	^oC
	Change in autumn temperature	E2	^oC
	Chang in spring temperature	E3	^oC
	Change in summer temperature	E4	^oC
	Change in winter temperature	E5	^oC
	Change in annual precipitation	E6	%
	Change in autumn precipitation	E7	%
	Change in summer precipitation	E8	%
	Change in winter precipitation	E9	%
	Change in spring precipitation	E10	%
Sensitivity (S)	Agricultural production land	S1	ha
	Forestry land	S2	ha
	Specially used land	S3	ha
	Homestead land	S4	ha
	Power density	S5	W/m^2
	Sunshine duration	S6	hours
	Total precipitation	S7	mm
	Households that do not have a sewage system	S8	%
Adaptive Capacity (AC)	Net turnover from business of enterprises	AC1	Bill.VNĐ
	Employees in agricultural, forestry and fishery with intermediate or higher degrees	AC2	%
	Communes with centralized domestic water supply works	AC3	%
	Communes with gathering the domestic waste	AC4	%
	Housholds using directly clean water in the house for daily living	AC5	%
	Population density	AC6	$Person/km^2$

Adaptive capacity indicators: The socio-economic conditions having a bearing on the adaptive capacity component include economic capacity with the indicator of AC1, human capacity with the indicator of AC2, environmental capacity and physical connectivity with the indicators of AC3 to AC6.

The classification of exposure, sensitivity, adaptive capacity and vulnerability levels are devided into five groups (i.e., very high for $1 \geq V > 0.8$, high for $0.8 > V \geq 0.6$, Moderate for $0.6 > V \geq 0.4$, low for $0.4 > V \geq 0.2$ and very low for $0.2 > V \geq 0$). Based on this, a set of the map is built as shown in Figure 3.

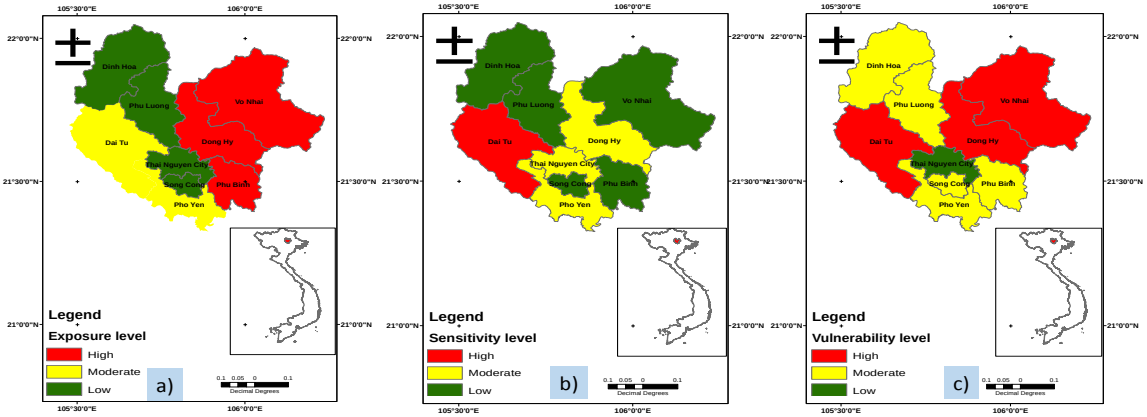

Figure 3. *Climate conditions in Thainguyen province*

Figure 3a-c shows the exposure, sensitivity and vulnerability levels for districts in Thainguyen province, respectively. As shown in Figure 3a, districts of VoNhai, DongHy and PhuBinh get a high level of exposure, while PhoYen and DaiTu districts get a moderate level of exposure. The low level of exposure is seen for the remaining districts. It is noticed that there is only DaiTu district getting a high level of sensitivity (Figure 3b). This refers that natural resources and environmental conditions in DaiTu that can be adversely affected at the highest level by climate change-related stimuli compared with other districts of Thainguyen province. Importantly, Figure 3 shows vulnerability levels for districts of Thainguyen province. It shows that there is only Thainguyen City that has a low level of vulnerability. There are three districts including DaiTu, DongHy and VoNhai belonged to a high level of vulnerability. This indicates the vulnerability level of natural resources and environmental facing the adverse impacts of climate change, including climate variations and extreme climates. In other words, their resilience in DaiTu, DongHy and VoNhai is the lowest comparing with other system in the remaining districts.

4. Conclusion

The study presents an evaluation of climate change-related vulnerability for natural resources and environment based the downscaled climate data from global climate model. The scenarios of climate change of SSP3.7-0 are used for near-future of 2021-2040. The twenty four indicators of exposure, sensitivity and adaptive capacity are selected based the available database sources. Then, vulnerability index is defined and estimated based equal weight method for all indicators. The results show that Thainguyen City has low vulnerability, meanwhile DaiTu, DongHy and VoNhai have high vulnerability to climate change. This information will be a valuable reference source for policy-makers to give the proposals to adapt the climate change variations and extreme climate in near future for Thainguyen province.

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