PRECIPITATION SCENARIOS IN HO CHI MINH CITY IN THE CONTEXT OF CLIMATE CHANGE

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ABSTRACT

This work aimed at developing precipitation scenarios in Ho Chi Minh City (HCMC) corresponding to scenarios of RCP2.6, RCP4.5, RCP6.0, and RCP8.5. By means of data collecting and processing and SimCLIM software, results showed the average annual precipitation in HCMC would increase over the years and RCP scenarios: from 13.4 % to 24 % in 2100 compared to that in the period of 1986-2005. The dry seasonal precipitation would tend to decrease while the rainy seasonal one would increase. By space, average annual and seasonal precipitations in HCMC decrease from the northwest to the southeast: the highest one are in the north (Cu Chi, Hoc Mon) and the city center while the lowest are in the coastal area (Can Gio). These results are an important basis for assessing impacts and vulnerability due to precipitation variations in particular and climate change in general in HCMC.

Keywords: climate change, climate change scenario, rainfall, precipitation.

1. INTRODUCTION

Many studies on climate change (CC) have been conducted from local to national and global scales due to its impacts on the socio-economic and environment [1]. There are 3 main groups of CC studies where CC scenario generation is the important task [2]. CC scenarios contain various driving forces of CC, including population growth and socio-economic development, and then emissions of greenhouse gases (GHG) and sea level rise (SLR) [1]. According to the Intergovernmental Panel on Climate Change (IPCC), the basic changes of the last Assessmet Report (IPCC-AR5, 2013) are related to GHG emission scenarios where RCPs (Representative Concentration Pathways) has been used: RCP2.6, RCP4.5, RCP6.0, and RCP8.5 corresponding to CO2 concentrations to be 490 ppm, 650 ppm, 850 ppm, and 1370 ppm [1].
There are two main methods to generate CC scenarios: (i) Statistical and (ii) motivation simulation method. The first one has been developed in season forecast [3, 4]. So far, the experimental models for season forecast with different methods have been studied and developed [5-9]. Statistical method is a popular tool, divided into 3 main groups [10]: traditional statistical method; Statistical Downscaling (SD); Model Output Statistics (MOS). Global Climate Model (GCM), developed since 1980s, are mathematical formulations of the processes that comprise the climate system [11-13]. Climate models can be used to make projections about future climate based on GHG emission scenarios—a basis to generate CC scenarios [14] and the knowledge gained can contribute to policy decisions regarding CC.

Ho Chi Minh City (HCMC) is one of the most developed cities in Vietnam as well as sensitive with CC. There were CC scenarios for this city [15] generated based on CC and SLR scenarios for Vietnam in 2009 [16] with the reference period of 1980-1999 and hydrometeorological data till 2009. These results have supported CC response plan for HCMC, however, the hydrometeorological database and simulating techniques need updating, and subsequently to propose suitable response measures. The SD method by SimCLIM software (Waikato University – Newzealand) integrating 40 and 24 GCMs of hydrometeorological fators and SLR simulation, respectively thus was used to generate precipitation scenarios in HCMC (according to RCPs) to 2100 with the reference period of 1986 – 2005 and the hydrometeorological data till 2015.

2. METHODS

2.1. Data collection and analysis

Hydrometeorological data in the period of 1978 – 2015 was collected at 13 rainfall and 6 meteorological monitoring stations in HCMC and nearby areas including: Cat Lai, An Phu, Pham Van Coi, Cu Chi, Hoc Mon, Le Minh Xuan, Mac Dinh Chi, Ha Tien cement, Long Son, Binh Chanh, Nha Be, Tam Thon Hiep, Can Gio, Tan Son Hoa, Tay Ninh, So Sao, My Tho, Vung Tau, Bien Hoa.

2.2. Climate change scenario generation

Diagram of generating CC scenarios was presented in Figure 1.
As mentioned, from the results of GCMs, SimCLIM was used to downscale to the research area. To choose a suitable model to simulate CC scenarios in HCMC, some of 40 GCMs integrated in SimCLIM (compatible with Vietnam) were selected to calculate for the period of 1995-2014, including: CSIRO, Hadcm3, NOR-M, MRI-MR, CNRM, BBC, CCSM, HadGEM, INMCM4, MIRCM3, and EC (data was not shown). Simulating results were compared to monitoring data at Tan Son Hoa monitoring station. The errors between them were then calculated. Subsequently, the model CSIRO-KM3-6-0 (with the smallest error of 2.0) was chosen to generate precipitation scenarios in HCMC in the future.

3. RESULTS AND DISCUSSIONS

3.1. Scenarios of average annual precipitation

**RCP2.6 scenario**

At the beginning of the 21st century, rainfall in the north of the city (Cu Chi district), the central districts, and Can Gio district would be about 2200 mm, 1990 mm, and 1500 mm, respectively. By the end of the century, rainfall would increase all over the city – ranging from 600 to 2400 mm. Compared to that in 2025, rainfall in these corresponding areas would increase by 400 mm, 150 mm, and 100 mm, respectively. It could be realized that rainfall would tend to increase in high rainfall areas (Figure 2).

![Figure 2. Distribution of average annual precipitation of RCP2.6 scenario: (a) 2025; (b) 2100.](image)

**RCP4.5 scenario**

According to RCP4.5 scenario, the average rainfall in HCMC at the beginning, in the middle, and the end of this century would range from 1550 mm – 2250 mm, 1600 – 2350 mm, and 1700 – 2450 mm, respectively. The rainfall would decrease from north-western to south-eastern: rainfall would be the highest in northern and central areas, then decrease in the coastal area (Can Gio district) due to the influence of land-sea wind circulation. This can also be recorded in the coastal area from Vung Tau to Bac Lieu with lower rainfall as compared to nearby areas.
**RCP6.0 scenario**

For space distribution, it is relatively similar to that of RCP4.5, but for value, it is higher. In the middle of the century, rainfall would range from 1600 to 2300 mm. By the end of the 21\textsuperscript{st} century, rainfall would be about 1700 to 2500 mm where 1700 - 2000 mm in Can Gio district, 2200-2300 mm in the central and 2300 - 2500 mm in Hoc Mon and Cu Chi districts.

**RCP8.5 scenario**

In the middle of the 21\textsuperscript{st} century, rainfall in (i) Cu Chi and Hoc Mon district, (ii) the central districts (District 1 to 8, Binh Thanh, Phu Nhuan, and Tan Binh districts), (iii) the south-eastern (Can Gio district) would range from 2000 - 2300 mm, about 2100 mm, and 1630 - 1850 mm, respectively. The rainfall would continuously increase till the end of the 21\textsuperscript{st} century, the corresponding data would be 2400 - 2500 mm, 2500 - 2750 mm và 1850 - 2200 mm (Figure 3).

![Figure 3. Distribution of average annual precipitation (mm) of RCP8.5 scenario: (a) 2025; (b) 2100.](image)

**To sum up**, the calculated results by SimCLIM showed the average annual rainfall would increase by the time and RCP scenarios (till the end of the 21\textsuperscript{st} century) (Table 1). The rainfall would tend to increase in north-western and decrease in south-eastern of the city. Rainfall would be concentrated in Cu Chi area, but very few in Can Gio district.

**Table 1.** The average annual precipitation (mm) in HCMC.

<table>
<thead>
<tr>
<th>Year\Scenario</th>
<th>RCP 2.6</th>
<th>RCP 4.5</th>
<th>RCP 6.0</th>
<th>RCP 8.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986 – 2005</td>
<td></td>
<td></td>
<td>1812</td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td>1929</td>
<td>1931</td>
<td>1945</td>
<td>1957</td>
</tr>
<tr>
<td>2030</td>
<td>1942</td>
<td>1956</td>
<td>1959</td>
<td>1969</td>
</tr>
<tr>
<td>2050</td>
<td>1984</td>
<td>1999</td>
<td>2020</td>
<td>2046</td>
</tr>
<tr>
<td>2100</td>
<td>2018</td>
<td>2050</td>
<td>2209</td>
<td>2291</td>
</tr>
</tbody>
</table>
For the variation levels of rainfall as compared to that of the reference period, at the beginning of the 21st century (2025, 2030), the increase levels would not much different among scenarios (ranging from 7.6 to 10.4 %). In the middle and the end of the century, differences among scenarios would have been recorded, especially between RCP8.5 and RCP2.6, corresponding to 5.4 % and 10.6 %.

3.2. Scenarios of average seasonal precipitation

Figure 4 showed seasonal rainfall distribution in HCMC. The rainfall distribution in rainy season was quite similar to the annual one (because the rainfall in rainy season often accounts for over 80 % of annual rainfall). In the middle of century, rainfall would range from 1450 to 2000 mm and from 1500 to 2050 mm corresponding to RCP4.5 and RCP8.5 scenarios. In the end of the century, the rainy season rainfall would significantly increase. According to RCP4.5 scenario, rainfall would range from 1500 to 2100 mm, where the coastal area (Can Gio district) would have the lowest rainfall (about 1500 mm), followed by the central districts (about 1900 - 1930 mm), the highest one would be in Cu Chi and Hoc Mon districts (above 1950 mm). According to RCP8.5, the highest rainfall would be in the northern and central areas (2200 - 2400 mm), the lowest one would be in the coastal area (about 1600 - 1700 mm). Rainfall in the dry season would tend to decrease from the northwest to southeast and gradually decrease till the end of the 21st century. According to RCP4.5, rainfall would range from 156 to 300 mm (usually around 200mm in central areas). For RCP8.5, rainfall would range from 110 to 270 mm (around 150 mm in central areas).

In general, the uncertainty of CC scenarios is affected by uncertainty of GHG scenarios in the future, the complex climate system, as well as the simulating errors of GCMs. According to the Paris Agreement, all countries do the efforts to control the increase in global temperature in the end of this century below 2°C as compared to that in pre-industrial period; thereby, the RCP4.5 scenario would be more likely to occur than others.
4. CONCLUSIONS

Based on the CSIRO-MK-3-6-0 model, by SimCLIM software, this research established precipitation scenarios in HCMC to 2100. By over the time and under the RCPs (RCP2.6 - RCP8.5), the average annual precipitation in HCMC would increase: 13.4 - 24 % by 2100 as compared to that in the period of 1986-2005 (1812 mm). The rainy season precipitation tends to decrease while the dry season one increases: as compared to the period of 1986-2005, the increase levels of scenarios of RCP4.5 and RCP8.5 by 2100 would be 15.2 % and 23.9 %, respectively. By space, the precipitation (annual and seasonal) in HCMC gradually decreases from the northwest to the southeast: Cu Chi, Hoc Mon districts and the city center to the coastal area (Can Gio district). The research results are an important basis for impact and vulnerability assessment due to precipitation variations and CC in general in the local.

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