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Impacts of Land Use Changes on Urban Heat Islands in Hanoi, Vietnam: Scenario Analysis

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Abstract

This study aims to investigate the impacts of land use changes brought by the Hanoi Master Plan 2030 (HMP) to the urban heat island (UHI), using the Weather Research and Forecasting (WRF). A scenario analysis was carried out to assess the effectiveness of urban greening for mitigating UHI. The urban climate under the influence of global warming was also investigated by downscaling the results of global climate simulation (MIROC5 RCP4.5) in the scenario analysis for 2030s. The results show that the land use change does not significantly increase the peak average air temperature (T_{avg}) in urban areas: the peak T_{avg} remains at almost in the same level of 37°C. Instead, it increases the number of hotspots and raises the nocturnal T_{avg} particularly in new urban areas by up to 1°C. Further, if the green coverage ratio in new urban areas is increased to 30% and the mixed forest is adopted as vegetation type in the green spaces, T_{avg} is lower by up to 0.5°C and the hotspots are reduced by up to 28%. Meanwhile, it was found that the urban air temperature is predicted to increase by up to 1.8°C due to the global warming in 2030s. This increment has surpassed the cooling effect of UHI mitigation through urban greening.

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Keywords: WRF; green coverage ratio; master plan; global warming; direct dynamical downscaling.

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1. Introduction

In Hanoi, Vietnam, the city government started to implement a long-term urban development plan, known as the Hanoi Master Plan 2030 (HMP) in 2011. According to the master plan, about 28% of natural land will be converted to built-up land to accommodate a total of 9.2 million people by 2030 [1]. Meanwhile, the weather records at the Hanoi weather stations show that the urban-rural annual air temperature difference gradually increased from approximately 0 to 0.3°C in 1980 to 0.6 to 0.8°C in 2010. This shows that Hanoi has been experiencing urban heat islands (UHIs) as a result of the rapid urbanisation. Moreover, the massive land use change brought by HMP is predicted to affect the intensity and formation of urban heat islands (UHIs) in the future.

In order to maintain the natural environment, the master plan proposed a series of green network in the city, consisting of the green belts and the green buffers. Both green spaces would form a large and centralized green spaces (see Fig.1). Nevertheless, the previous study showed that the proposed green network was seen to be effective to cool the areas adjacent to the green areas and not enough to cool the entire urban areas [2]. Instead of designing a large and centralized green spaces, Trihamdani et al. suggested to implement smaller and equally distributed green spaces to the city [2].

In fact, allocating new green spaces would make a significant modification to HMP. Instead, we proposed to improve the urban greening without allocating any new lands. The additional urban greening is simulated by increasing the green coverage ratio (GCR) in each lot of built-up lands determined by the HMP. This results in more distributed green space in the city (see Fig.1f).

Meanwhile, the global warming caused by the increase of greenhouse gases is expected to further enhance the increasing temperature in urban areas [3]. The further increase of greenhouse gas emission are expected to be derived from the growing cities in the emerging economies in Asia in the future [4]. Moreover, the degree of temperature increase varies according to geographic location [5]. Hence, it is important to consider the influence of global warming while projecting the future urban climate condition in the growing cities in Southeast Asia.

The objective of this study is to examine the impacts of land use changes on UHIs through a scenario analysis, using a regional climate model, namely Weather Research and Forecasting (WRF). The scenario analysis includes the proposal for UHI mitigation which focuses on the urban greening through the increment of GCR; as well as the predictions of UHIs in Hanoi under the influence of global warming in 2030s.

2. Data and method

2.1. WRF

Meteorological modelling was performed to obtain basic weather elements such as air temperature, humidity, and surface wind. This present study used WRF version 3.6, known as the Advanced Research WRF (ARW), which was developed by National Center for Atmospheric Research (NCAR) [6].

The WRF simulations in this study applied three domains configuration that have horizontal resolution of 4.5, 1.5, and 0.5 km for domains 1, 2, and 3, respectively (Fig.1). Domain 3 covers the whole administrative boundary of Hanoi. The urban canopy model (UCM) was employed to simulate the effect of urban geometries [7]. Physics schemes configuration are listed in Table 1.

The WRF simulations employed two initial boundary conditions for current and future climate conditions, respectively. For the current condition, the NCEP FNL (Final) Operational Global Analysis data with 1°x1° resolution were used. While the future climate conditions utilized the data predicted by the Global Climate Models (GCMs).

2.2. Dynamical downscaling method of GCM

As previously discussed, the future climate conditions are predicted by GCM. GCM is a comprehensive model that couples the atmosphere and ocean together with land and sea ice circulation model. The future climatic conditions projected by GCMs are based on the assumption that the concentrations of greenhouse gases, such as CO_2 will change in the future. It is referred by the Intergovernmental Panel on Climate Change (IPCC) as