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A Path-analysis using Structural Equation Model on the Impacts of Urbanization on Precipitation in urban areas of Beijing-Tianjin-Hebei Region

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Urbanization has important impacts on the variation of urban precipitation. Understanding of those impacts is a critical issue for the regulation of human activities and urban planning in cities. According to previous studies, urbanization affects precipitation in urban areas mainly through three aspects, namely, urban heat island effect (UHI), aerosol and underlying surface changes. Many researchers have worked on the pairwise relationship between one of these aspects with precipitation. However, the interactions between different aspects may have complicated influences on the total effects of urbanization on precipitation. The effect of one aspect may strengthen or counteract the effect of another. Until now, there is no quantitative analysis on the path and magnitude of those interactions.

The objective of this study is to carry out a quantitative path-analysis on the impacts of urbanization on precipitation in urban areas of Beijing-Tianjin-Hebei Region of China, with the hope to reveal the mechanism how the different effects of urbanization interactively influence on the precipitation in urban areas. The 151 towns and cities in the Beijing-Tianjin-Hebei region were selected as study areas. The data we used mainly included the night light remote-sensing data, aerosol concentration, Urban Land Surface Temperature (LST) data, NDVI, forest cover and precipitation in 2000, 2005, 2010 and 2015. First, we calculated five indicators for each urban area and for each month, namely, the urbanization intensity, aerosol concentration, UHI intensity, vegetation index and precipitation. Then, we analyzed the total effect of urbanization intensity and the individual effect of aerosol concentration, UHI intensity, and vegetation to precipitation using a fixed effect model. Based upon that, we built a structural equation model to analyze the proportion that urbanization impacts on precipitation through aerosol concentration, UHI intensity, and vegetation, and the magnitude of the interactions. The results show that urbanization intensity and urban vegetation are positively correlated with precipitation with a ratio of 0.39 and 0.28, respectively, while UHI is negative correlated with precipitation with a ratio of -0.30 in urban areas in Beijing-Tianjin-Hebei Region throughout the year. The relationship between aerosol concentration and precipitation is not stable. Urbanization intensity impact negatively vegetation with a ratio of -0.15. The total effects of urbanization intensity, vegetation and UHI on precipitation were -0.177, -0.088 and -0.104, respectively, while the indirect effect of urbanization through vegetation and UHI was -0.028. This indicates that urban precipitation is greatly affected by vegetation, and the increase of vegetation has a great role in promoting the increase of urban precipitation. In the process of urbanization, attention should be paid to the protection of vegetation and afforestation.

The results help to comprehensively understand the mechanism of urbanization on precipitation and the environmental effects of urbanization, and provide suggestions for the rational planning of the underlying surface in the urbanization process of the Beijing-Tianjin-Hebei region.