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Effect of Urbanization in Nantong on Climate Change

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Abstract

According to the meteorological observation data in Nantong, 1951-2010 and the economic and social statistics, this paper studies the correlation between climate change and urbanization, discusses the impact mechanisms of different indicators of urbanization on different climatic factors, puts forward the responsiveness and adaption countermeasures to the climate change that will provide decision-making basis for the realization of the sustainable urban development in the context of climate change in Nantong and draws up the urban planning to respond and adapt to the global climate change for the government and provides a reference for the development strategies on the basis of the analysis of the climate change and urbanization development of the city's nearly 60 years.

Key words: *urbanization, climate change, Nantong*

Urbanization is an important process of human society, an objective trend of the economic and social development, a significant symbol of the national industrialization and modernization and the most obvious progress of altering the surface. It will bring about great changes of the local nature of the underlying surface and the surface coverage pattern.

Urbanization has both positive and negative effects: on the one hand, urbanization can promote economic prosperity and social progress; the other hand, urbanization will also produce a series of negative effects that cannot be ignored. The rapid urbanization not only has profound significance for regional economic and social development, but also produces certain influences on the microclimate of cities. For example, the differences of temperature between rural and urban areas resulted from the changes of the nature of the underlying surface and the exchanging processes of the original ground-air matter and energy and the emission of anthropogenic heat will necessarily lead to the adjustment of the local flow field, and then contribute to the redistribution of the local climatic factors such as temperature, precipitation, wind and so on. With the development of the construction of urban environment and climate change, the relationship between urbanization and climate has become the subjects concerned and reached by the domestic and foreign scholars.

1. Study Area

Nantong is a city in the north subtropical humid environment, located in the alluvial plain of the downstream of the Yangtze River with about an average altitude of four meters, situated in the region with latitudes raging from 31°41′N to 32°43′N and longitudes 120°12′E to 121°55′E. Nantong is one of the first 14 opening coastal cities, having jurisdiction over 3 Districts and 2 Counties with two economic and technological development zones and a

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function area. Nantong also is one of birthplaces of China's modern industry with the economy mainly in textile, petrochemical, ports, machinery, electronics, chemicals, construction, *et al.*, Currently, with the rapid development of emerging industry, the six emerging industries such as marine engineering equipment, new energy, new materials, biotechnology and new medicine and smart equipment and energy saving and environmental protection are growing fast. Regional economic society is situated in the stage of rapid development and the urbanization faces enormous challenges.

2 Data and Methods

2.1. Data

The data about urbanization mainly come from China City Statistical Yearbook (1985-2011), Nantong Statistical Yearbook (1999-2011) and Jiangsu Statistical Yearbook (1991-2011), a total of 27 years of data. The major urbanization indicators considered are: non-agricultural population, the density of city population, employment in secondary and tertiary industries, GDP per capita, average wage, the output value of secondary or tertiary industry to GDP, the proportion of built-up area, green coverage ratio in built-up area, green coverage area, road area per capita, residential area per capita, the annual electricity consumption, urban water penetration ratio, urban gasification ratio, the number of buses per ten thousand people and the number of college students. The meteorological data during 1961-2010 is mainly used from the weather stations in Nantong in Jiangsu province. This paper analyzed the weather variables such as average maximum temperature, average minimum temperature, extreme minimum temperature, extreme maximum temperature and precipitation. In this paper, the missing data are filled by using the linear trend interpolation method. The criteria of the classification of seasons are: spring, from March to May; summer, from June to August; autumn, from September to November; winter, January, February and December. The inter-annual division standards are: 1961-1970 considered as the 1960s, 1971-1980 as the 1980s, and so on.

2.2. Methods

For analyzing the level of urbanization, the trend of climate change and the relationship between urbanization and climate change, analytic hierarchy process (AHP), moving average and estimation of linear tendency are used in this paper.

2.2.1. Analytic Hierarchy Process

AHP is proposed by Sarti, a professor of American strategist Pittsburgh University in the early 1970 of the 20th century. Its methods of qualitative and quantitative analysis were on the basis of the element of decision-making cut into goals, standards, programs and other levels, it can better remove the adverse effects caused by subjective judgment. The most important role of AHP is filtering the indicators which can best reflect the level of urbanization. AHP main has five basic steps: establish a hierarchical model; constructing judgment matrix; Single sort; Consistency checking; Total sort levels. Since this method is relatively subjective, so must do the consistency test:

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad CR = \frac{CI}{RI}$$

Where CI is the consistency of the judgment matrix index; λ_{max} is the maximum eigenvalue; CR is the satisfactory consistency index; RI is the average consistency index.

2.2.2. Sliding Average

Sliding average is the most basic method about trend fitting which is equivalent to a low-pass filter, displaying the trends by using the mean values of the determined time series. If the sample size for sequence X is n, the moving average sequence is represented as:

$$x_j = \frac{1}{k}\sum_{i=1}^{k} x_{i+j-1} \quad (j = 1,2,\cdots,n-k+1)$$

where k is the sliding length. As a rule, k had better take an odd number, so that the average values can be added to the time coordinate of the middle of the time series. When k is an even number, the mean values of each two new sequences through the moving average can be computed in order to align the sliding average values in the middle. It can be proved that through the sliding average, the sequences shorter than the sliding length are cycle cut to highlight the change trends.

2.2.3. Estimation of Linear Tendency

Set x_i to explain a variable of climate which contains the sample size is n. Set t_i to denote the time series which mapping the x_i. According to the relationship between x_i and t_i, the linear least squares regression equation is given as:

$$x_i = a + bt_i \quad (i = 1,2,\cdots,n)$$

where a and b are regression constant and regression coefficient, respectively. The coefficients a and b can be estimated by least squares. It means that the relationship between x and t can be expressed by a reasonably straight line.

3. Effect of Urbanization on Climate Change

Considering the average level of Beijing and Shanghai as the optimal level of urbanization through analytic hierarchy process, the level of urbanization in Nantong is analyzed. The results show that: now the ratio of urbanization in Nantong is 80%, where the levels of urbanization of economy and social life are higher, and also close to the standard level. The levels of urbanization of population and geographical landscape are about two-thirds of the standard level. Among each single indicator, the levels of development of the output value of secondary industry to GDP, road area per capita, residential area per capita, water penetration ratio and urban gasification ratio are higher, which are above or close to the optimal level. However, compared with the optimal level, the levels of green coverage area, annual electricity consumption, the number of buses per ten thousand people and the number of college students are low. According to the meteorological observational data for the period from 1951 to 2010 in Nantong, the changes of climate variables on the time series for nearly 60 years are analyzed through estimation of linear tendency and sliding average. It is found that: in the past 60 years, the average temperature is rising at the rate of 0.297℃/decade, where the warming trend in spring is the most significant, and that in summer is the least. The trends of the min-mean and max-mean temperature are on the rise. The rapidly increasing changes of the extreme minimum and maximum temperature are observed. Over the past 60 years, the tendency of precipitation is generally on the rise with the small rate. The increasing trend of precipitation in summer is the most pronounced, followed by winter. Precipitation in spring and autumn is slightly decreasing. The contribution of the increase in precipitation mainly derives from the addition in summer and winter. On the basis of the analysis of the

development of urbanization and the trend of climate change, the influences of urbanization on temperature and precipitation are analyzed by using estimation of linear tendency.

3.1. Effect of Urbanization on Temperature in Nantong

In Figure 1, Figure 2 and Table 1, it can be found that: the correlation between the change of temperature and population is large, but the correlation between temperature and built-up area is small. At the seasonal scale, the correlation between the tendency of temperature in spring and population is the largest, the second is autumn, and the correlation in winter is the smallest. Among the correlations between built-up area and the trend of temperature, summer and autumn are the largest, and winter is the least. In other respects, the correlation between population and max-mean temperature is the most significant, but the correlation between population and extreme minimum temperature is the least. The correlation between built-up area and extreme maximum temperature is the largest, and that between built-up area and min-mean temperature is the smallest. It can be observed that the relations between the increase of population, the expansion of built-up area and the trend of temperature are noticeable, where the effect of population on temperature is larger compared with the expansion of built-up area, which is the major reason for the increase of temperature in Nantong.

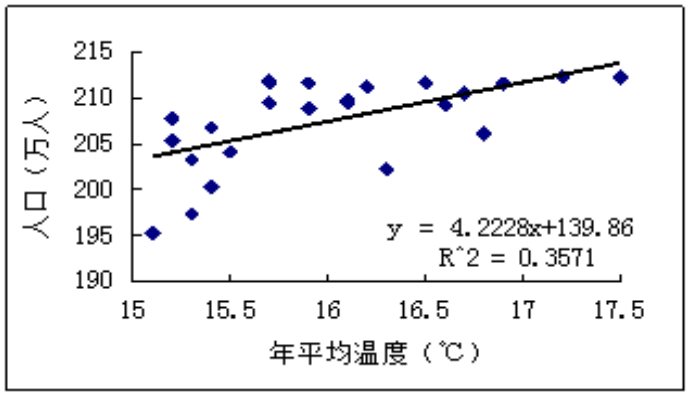

Figure 1. The Relationship between Mean Temperature and Population in Nantong

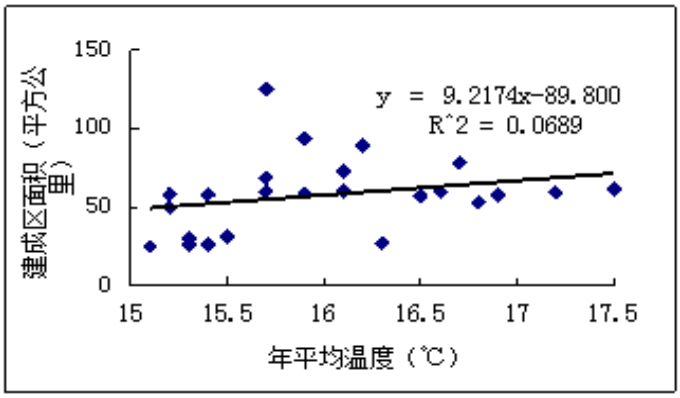

Figure 2. The Relationship between Mean Temperature and Built-up Area in Nantong

Table 1. The Correlation Coefficients between other Indexes of Temperature and Population and Built-up Area in Nantong

	Spring	Summer	Autumn	Winter	Min-mean temperature	Max-mean temperature	Extreme minimum temperature	Extreme maximum temperature
Population	0.406	0.2073	0.3194	0.0374	0.192	0.5141	0.0018	0.247
Built-up area	0.0492	0.0735	0.0656	0.0044	0.006	0.1931	0.0254	0.2001

Since the reform and opening up, especially in the middle and late 1980s, the rapid development in Nantong has been implemented. The urban population in Nantong has exceeded 2.1 million. At the same time, the built-up area is constantly expanding, from 25 square kilometers in 1987 to 125 square kilometers in 2010, an increase of four times. The continuous development of urbanization contributes to the extension of road area, the considerable increase in the number of various types of vehicles and the rapid development of different industries such as textile, petrochemical, chemical, construction and port, *et al.*, The rising tendency of urban temperature derives from the rapid development of city, the continuous increase of urban population, the expansion of urban area and the more and more emissions of anthropogenic heat. For example, when the properties of the underlying surface are changed, namely the original grass land or bare land is replaced by construction materials such as cement and asphalt that will be rapidly warming through absorbing the solar radiation, making the surrounding temperature rise quickly. In addition, due to close to Shanghai, Nantong will also be affected by a certain amount of radiation.

3.2. Effect of Urbanization on Precipitation in Nantong

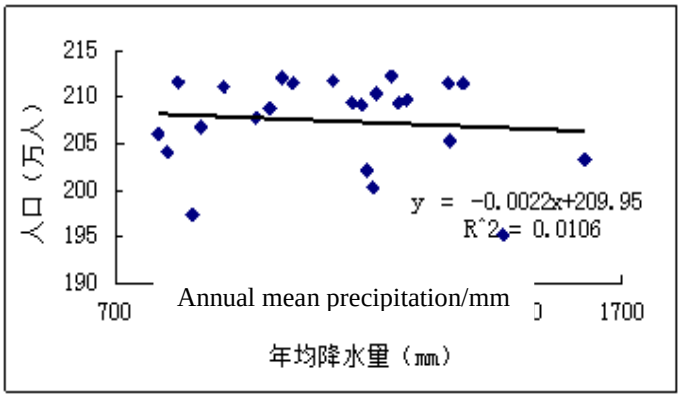

Figure 3. The Relationship between Average Precipitation and Population in Nantong

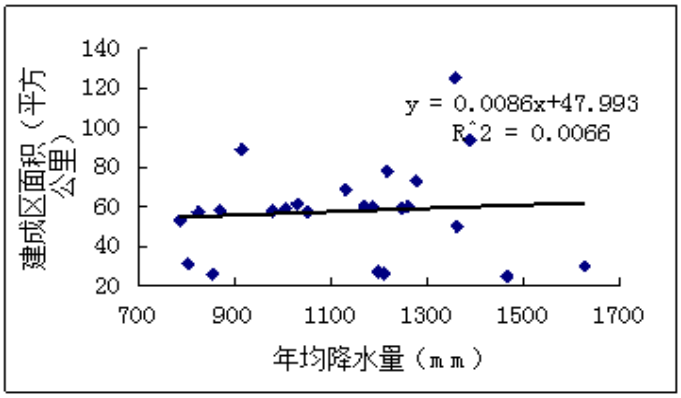

Figure 4. The Relationship between Average Precipitation and Built-up Area in Nantong

Table 2. The Correlation Coefficients between Precipitation at Seasonal Scale and Population and Built-up Area in Nantong

	Spring	Summer	Autumn	Winter
Population	0.0001	0.003	0.0048	0.0293
Built-up area	0.0006	0.0031	0.0054	0.0292

From Figure 3, Figure 4 and Table 2, it is observed that the correlation coefficients between the increase in urban population and the expansion of built-up area and precipitation are small without obviously direct linear correlation, so the impact of that on precipitation in Nantong is not very distinct. Therefore, factors that affect urban precipitation are complex, and population and built-up area are just a small part. The influence of urbanization in Nantong on precipitation mainly derives from the effect on temperature. Heat island effect resulted from the increase in temperature is conducive to the formation of thermal convection, thereby forming convective precipitation. The increase in types of high-rise buildings in city may cause the mechanical turbulence, thus slowing down the movement of the system of precipitation, resulting in the enhancement of intensity of precipitation and the extension of the time of rainfall. It is found that the direct effects of population and built-up area on climate change in Nantong are small and negligible whose correlation coefficients are 0.0022 and 0.0086, respectively, which is different from Nanjing and Ningbo. Meanwhile, this paper reveals that the impact of the development of city on precipitation is a multi-disciplinary result that is not merely determined by one aspect.

4 Conclusions

In the context of global warming and the rapid development of China's economic society, in order to take a full account of climatic factors in the process of urban planning, it is necessary to suit the right remedy, choosing the correct strategy of urbanization and detecting a green path of the development of urbanization. In order to better coordinate the relationship between urbanization and climate change, clear the effect of urbanization on climate change, slow down the adverse influence of human activities on climate change, enhance the regional capacity to respond and adapt to climate change, construct resource-saving and environment-friendly word-class city groups and achieve comprehensive, harmonious and sustainable development of economy, society and ecology. This paper studies the city with the rapid

development of economy, Nantong. Through the analysis for the period of nearly 30 years of the correlation between the process of urbanization and climate evolution in Nantong, the effect of the development of urbanization on climate change is further explored. Results show that there is a certain influence of urbanization on climate change in Nantong. During the twenties years of the rapid development of urbanization in Nantong, mean temperature, max-mean temperature, min-mean temperature and average precipitation suffered different degrees of rise, and the correlation between urbanization and climate change is larger. But the direct effect of urbanization on precipitation is not significant with a very small correlation.

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