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Urbanization impact on carbon emissions in the Pearl River Delta region: Kuznets curve relationships

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ABSTRACT

Research on the impact of urbanization on carbon emissions has great significance to the development of low-carbon cities. Although various studies have found a causal relationship between urbanization and carbon emissions, the mechanisms by which land urbanization (especially the spatial agglomeration changes of construction land), population urbanization, and economic urbanization affect carbon emissions are still unclear. This paper presents a comprehensive analysis of the impact of urbanization on carbon emissions in the Pearl River Delta region from 1990 to 2014. The data were analyzed on the basis of a spatial agglomeration function, grey correlation model, Kuznets curve model, etc., according to three aspects of urbanization, namely, land urbanization, population urbanization, and economic urbanization. The associated Kuznets curve relationships between these three aspects of urbanization and carbon emissions were assessed to explore the mechanisms of influence. The main results were as follows. (1) From 1990 to 2014, carbon emissions increased significantly in the Pearl River Delta region from 18.6×10^6 t to 151.31×10^6 t, of which carbon emissions increased much faster from 2000 to 2013. Guangzhou and Shenzhen were the cities with the largest carbon emissions in the Pearl River Delta region. (2) The influence of urbanization on carbon emissions in the Pearl River Delta region showed that economic urbanization had the most obvious impact on carbon emissions followed by land urbanization. Population urbanization had a minimal impact on carbon emissions. The land urbanization and economic urbanization displayed a Kuznets curve relationship with carbon emissions, and the respective models were as follows: $y = 145.78x - 839.87x^2 - 2.84$, $y = 0.51x - 0.005x^2 + 1.56$. (3) The composition structure of carbon emissions showed that priority should be given to emissions from energy consumption and industrial production. Frequent changes of land use were also an important reason for the increase in carbon emissions. The Pearl River Delta region should aim for the construction of low-carbon cities as a goal and attach importance to the harmonious development of the economy and environment in its policies.

1. Introduction

Global climate change caused by carbon emissions is a major focus area in academic circles (Saidi and Mbarek, 2016; Abdallh and Abugamos, 2017; Bekhet and Othman, 2017). Human economic activities and energy consumption are concentrated in cities, and more than half of the world's population lives in cities; these cities, which make up approximately 2% of the global area, produce 75% of the world's CO_2 (Muneer et al., 2011). Because most carbon emissions are from urban areas, cities have been called “keys” that can lead to effective solutions for climate warming by the Worldwatch Institute (2009). On the basis of three aspects of urbanization, namely, land urbanization, population urbanization, and economic urbanization, comprehensive analyses of the effects of urbanization on carbon emissions and the associated Kuznets curve relationships are important, as such efforts can yield valuable information

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for the protection of urban ecological environments, coordinated development of the social economy and resource environment, and construction of low-carbon cities in the future (Aslanidis and Iranzo, 2009; Zhang et al., 2012).

The impact of urbanization on carbon emissions was first studied in the 1990s, and such studies found that there were discrepancies in the carbon emissions from urban and rural areas (e.g., Heil and Wodon, 1997). Since 2005, the impacts of urbanization on carbon emissions have been widely researched (e.g., Galeotti et al., 2006; Fong et al., 2009; Glaeser and Kahn, 2010). According to the relationships between urbanization and carbon emissions, scholars have documented the following four tendencies: (1) there are positive influences between urbanization and carbon emissions, including one-way positive influences (Parikh and Shukla, 1995) and two-way positive influences (Gam and Ben, 2012; Al-Mulalia et al., 2013); (2) the effects of urbanization on carbon emissions are negative (Zhao and Chen, 2013); (3) urbanization has no significant impact on carbon emissions (Ji et al., 2013); (4) the effects of urbanization on carbon emissions take the form of an inverse U-shaped curve (Dong and Yuan, 2011). In regard to the complete process of urbanization, from the early stage of urbanization to the post-urbanization stage (reverse urbanization), different urbanization stages can have different influences on carbon emissions, which may be promotional or inhibitory (Li et al., 2013; Shafiei and Salim, 2014).

From a functional mechanistic perspective of the urbanization effects on carbon emissions, the urbanization process results in changes to economic production, life styles, and land use types, which affect the carbon emissions. Urbanization involves a process whereby large numbers of people flock to the cities from the countryside and agricultural activities shift to non-agricultural activities (Lebel et al., 2007; York, 2007a; Lin and Ouyang, 2014). Because human consumption levels rise continuously and industrialization is associated with increasing energy consumption during urbanization, this leads to more carbon emissions (Wang et al., 2017a, 2017b), which can contribute to climate change (Wang and Wang, 2017). However, at the same time, the effects of concentration can increase the per capita energy efficiency (York, 2007b; Chikaraishi et al., 2014). In the later stages of industrialization, as industrial structures improve, technological progress and energy efficiency can help to curb carbon emissions (Stern, 2008; Zha et al., 2010; Aunan and Wang, 2014).

With the aim of promoting low-carbon technologies and sustainable cities, research into the effects of urbanization on carbon emissions is presently expanding, and notable projects have been conducted at diverse spatial scales including the intercontinental/country level (Inmaculada and Antonello, 2011; Martinez-Zarzoso and Maruotti, 2011; Al-Mulalia et al., 2015), region/province level (Wang et al., 2017c; Chuai et al., 2015), city level (Xu et al., 2016), community/park level (Poumanyvong and Kaneko, 2011), and family level (Liu and Wang, 2002). However, comprehensive studies on the effects of urban agglomeration are lacking (Peng et al., 2015).

Urbanization encompasses the comprehensive influence of land urbanization, population urbanization, and economic urbanization, and these different aspects of urbanization may have different impacts on the carbon dynamics of urban ecosystems (Peng et al., 2016, 2017). Although scholars have conducted a large number of studies on the influence of urbanization on carbon emissions, in which the proportion of the urban population is typically used to measure urbanization levels, more detailed studies that consider different aspects of urbanization, including land urbanization, population urbanization, and economic urbanization, and their influence on carbon emissions are needed; in particular, curve relationship analyses between carbon emissions and the different aspects of urbanization would be useful. Furthermore, during the process of rapid urbanization, the land use type, quantity, structure, and so on changes (Li et al., 2017), and these changes may have different influences on carbon emissions in urban systems; thus, the spatial characteristics of land use, e.g., land use structure, in relation to carbon emissions also needs to be evaluated.

Therefore, this article presents research on the effects of urbanization and urban agglomeration trends on carbon emissions in the Pearl River Delta region, which is an important urban agglomeration region with high levels of urbanization and economic development as well as dense populations. Land use data were derived from interpretations of Landsat Thematic Mapper (TM) imagery (from the years 1990, 2000, 2005, and 2014) and land use change data from 1996 to 2014 were compiled. We used the Intergovernmental Panel on Climate Change (IPCC) assessment method for carbon emissions along with a Grey correlation model, Kuznets curve model, etc., to analyze the carbon emission evolution characteristics during the period of rapid urbanization from 1990 to 2014 in the Pearl River Delta region in regard to three aspects, namely, land urbanization, population urbanization, and economic urbanization. Then, we explored the influencing factors and conducted a mechanistic analysis of the effects of urbanization on carbon emissions, which helped to reveal the evolution relationship between urbanization and carbon emissions.

2. Study area and methods

2.1. Study area and data sources

The Pearl River Delta region (21°17.6′N–23°55.9N′, 111°59.7′E–115°25.3′E) (Fig. 1) is formed of alluvial deposits. It falls within the southern subtropics, with subtropical evergreen broad-leaved forest vegetation. Average rainfall is about 1600 mm, and the rainfall is mainly concentrated in summer; conversely, winters are drier. The relief is flat, and the area is bounded to the west and north by the Luoping Mountains. There are 1900–2200 sunshine hours per year, while the annual average daytime temperature is greater than 20 °C. Land use is characterized by circle-type developments; the area of construction land has expanded rapidly from 2847.55 km^2 in 1990–7277.28 km^2 in 2014, while areas of cultivated and forest land have declined. The land use structure is thus changing from complex to simple forms. In terms of administrative areas, Guangzhou city lies at the center of the Pearl River Delta, and Shenzhen, Foshan, and Zhuhai represent important sub-

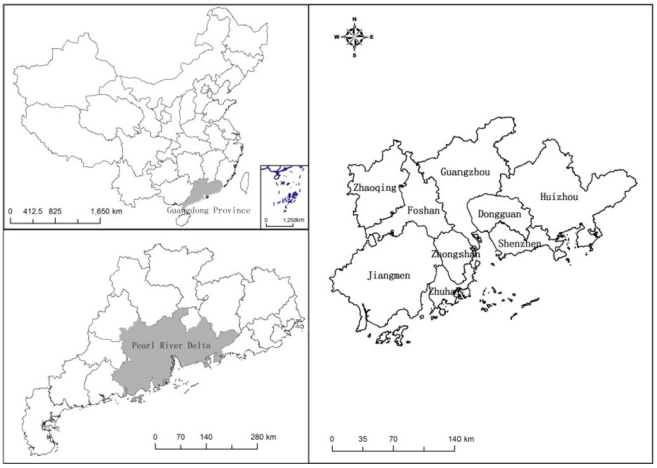

Fig. 1. Location of the study area.