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Carbon footprint of urban areas: An analysis based on emission sources account model

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ABSTRACT

The concept of carbon footprint (CF), as a fundamental quantization parameter of carbon emissions measurement, captures the interest of policy makers, businesses and consumers' attention. However, the lack of CF assessment model of urban areas makes it difficult to confirm or refute best practices and policies. This article presents an emission sources account (ESA) model, to analyze the CF of urban areas, which can help provide benchmarks and expand our understanding of carbon emissions. Based on the conception of carbon footprint and the precondition of human activity, this study analyzes the emission source of four accounts: energy consumption account, soil and crop account, livestock account and solid waste account. Four accounts are summed together for the total carbon footprints of urban area by following the standard IPCC emission inventory methods. Per capita CF and the CF of ten thousand Yuan GDP are also calculated to highlight the link between human activities and environmental consequences. Using the ESA model offers a clear mechanism to estimate the carbon footprint of urban areas, and it provides a different perspective of the drivers for carbon emissions at the city level. To contribute to the model verification, this article investigates the carbon footprint of Dongguan city from 1990 to 2010 through ESA model, which opens the way for a new set of comparisons among different cities, helping promote regional emission reduction policies.

1. Introduction

The catastrophic and conceivable warning of climate change has been increasing in the recent years. To contribute to the survival and development, we urgently need to control the emission of carbon dioxide (CO_2) and to mitigate climate change. The concept of carbon footprint, as a fundamental quantization parameter of carbon emissions measurement (Wiedmann and Minx, 2007), captures the interest of policy makers, businesses and consumers' attention.

Approximately half of the global population lives in urban areas, which are responsible for roughly 67% of the world's

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energy demand (IEA, 2008). Urban areas tend to offer easier access to more energy-intensive fuels, as well was electricity, and also have higher concentrating emissions sources. Roughly three-quarters of all carbon emissions from fossil fuel combustion, cement manufacture and wood use come from urban areas (Mitra et al., 2003). And cities are responsible for emitting 80% of the world's total greenhouse gases (Eilperin, 2007). Clearly, the record on the carbon footprint of urban areas is both a key contributor to climate change and a key factor in mitigating it.

As a newly-emerging word, the qualitative and quantitative research is still under discussion so there is no unified and acknowledged method to calculate the carbon footprint. At present, the current methods include, input–output (IO) analysis (Druckman and Jackson, 2009; Munksgaard et al., 2005; Jackson et al., 2006), life cycle assessment (LCA) approach (Schmidt, 2009; Lenzen, 2008) and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories calculating method (IPCC method) (IPCC, 2006). Almost all elements and segments of CO_2 emission would be involved in those methods (Barthelmie et al., 2008; Strutt et al., 2008).

The previous studies were mostly focused on the carbon footprint of the products or certain industrial level based on LCA (Bakhshi and Demonsabert, 2012; Pattara et al., 2012; Teodoru et al., 2012). On national level, such as Intergovernmental Panel on Climate Change (IPCC), World Resources Institute, and World Bank, estimate and track emissions profiles for different countries (Hertwich and Peters, 2009; Sinden, 2009; World Wildlife Fund, 2008) and for individuals (per capita emissions) (Lenzen et al., 2007).

On city or regional level, the previous researches were mostly focused on carbon emission estimation of each sector and the corresponding measures. For examples, based on LCA, carbon sequestration by growing trees of urban green space project in Leipzig, Germany were simulated (Strohbach et al., 2012). The direct and indirect greenhouse gas emission footprint of economic system in Singapore was studied (Schulz, 2010).

However, as a complicated large scale system, the boundary of urban areas would be hard to confirm because of feedback effects. And the drivers and the emission sources of CO_2 in city eco-system are so complex that double accounting is easily generated. Furthermore, unlike a single product or natural ecosystem, the carbon footprint of urban areas is particularly hard to assess because of the ecosystem complexity (Matthews et al., 2008). The lack of CF assessment model of urban areas makes it difficult to confirm or refute best practices and policies. To help provide benchmarks and expand our understanding of carbon emissions, this article presents an emission sources account (ESA) model, to analyze the CF of urban areas.

As the largest developing country and the second largest energy producer and consumer in the world, China's carbon dioxide emission problem has become the focus of academia and governments all over the world. China is experiencing a rapid development of urbanization, which is of high energy consumption and climate change implications because the per capita energy use of urban areas there is about 80% higher than in the country as a whole (Mitra et al., 2003). Therefore, the study of China's carbon dioxide emissions has great and positive influence on the scientific development, the realization of sustainable development and the moderation of global climate change.

2. Methods and data

Firstly, we started with defining a "carbon footprint". As a newly-developing word, carbon footprint is actually referred to large number of different conceptions (Edwards et al., 2009; Larsen and Hertwich, 2009). In our research, the carbon footprint is defined as the carbon dioxide emissions in the direct and indirect human activity (Chambers et al., 2007; Kenny and Gray, 2009), which is measured in ton as a unit.

Calculations of the account framework method in this paper are based on the following assumptions:

(i) The CO_2 emission of energy resources and animals could be estimated.
(ii) Urban area is a closed system, which means that the quantity of CO_2 does not exchange with the outside world.
(iii) The default parameter in calculation can represent general norm values.

Based on the conception of carbon footprint and the precondition of human activity, our study only takes the estimation of carbon dioxide emission produced by human activities into consideration, including the energy consumption in the industrial process, land use changes and crop growth in agricultural production, and livestock raising and solid waste in cities. The carbon footprint calculated in this study is just involved the carbon dioxide emission under the influence of human activities. The carbon sink existed in the natural ecosystems is not calculated in this paper through the negative value.

We analyze the emission source of four accounts: energy consumption account, soil and crop account, livestock account and solid waste account. In this calculation of each account, we follow the standard IPCC emission inventory methods (IPCC, 2006), which is always the basic of international climate agreements. And we weight the different accounts together for the total carbon footprints of urban area.

The carbon footprints of urban areas can be calculated by

$$CF = CF_E + CF_S + CF_L + CF_W \quad (1)$$

where CF is the carbon footprints of urban areas, CF_E, CF_S, CF_L, and CF_W are the carbon footprints of energy consumption account, soil and crop account, livestock account and solid waste account respectively.

2.1. Energy consumption account

According to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, energy account includes coal, crude oil, liquefied gas, etc. In the burning process of fossil energy, most carbon would be rapidly released in the form of CO_2 while the rest part is released in the form of methane (CH_4), nitrous oxide (N_2O), and Non Methane Volatile Organic Compounds (NMVOC). The proportion of CH_4 and N_2O is so tiny that only CO_2 emission is being calculated in this paper.