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Evaluation system and case study for carbon emission of villages in Yangtze River Delta region of China

Jian Ge [a], Xiaoyu Luo [a, *], Jiang Lu [b]

[a] Department of Architecture, Zhejiang University, China
[b] Department of Civil Engineering, Zhejiang University of Science and Technology, China

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ABSTRACT

Using data on carbon emissions and carbon sinks in the villages of the Yangtze River Delta region of China, this research utilised the management function of grassroots government and selected four factors of these villages' carbon emissions: natural ecology, economic industry, residential development and infrastructure. Then, a carbon-emissions inventory of these villages was conducted, collecting data on the emissions-activity levels and emissions factors. Finally, a method of evaluating the villages' carbon emissions was developed. Meanwhile, four types of landforms (mountains, hills, plains and islands) and eight villages with different industry types in the Yangtze River Delta region were selected for the case study and evaluation of carbon emissions. These villages' carbon emissions had a range of 1.302–3.296 t per capita, except for Xinligang, which had the highest emissions, at 36.206 t per capita. The mountain villages had the highest carbon sinks (0.7–1.89 t per capita), while the sinks of villages in other landforms were much lower (0–0.43 t per capita). Based on the evaluation results, the villages' carbon emissions were divided into four types. The villages' characteristics were analysed according to the different types of carbon emissions, and then optimisation suggestions to reduce emissions and increase sinks were proposed. The study results can support low-carbon planning and development for villages in the Yangtze River Delta region.

1. Introduction

China is currently facing an unprecedented level of pressure to reduce its carbon dioxide (CO_2) emissions. The data from the Carbon Dioxide Information Analysis Center (CDIAC) showed that China has become the world's largest emitter of CO_2. In 2013, China's carbon emissions accounted for 29% of global carbon emissions, and its per capita carbon emissions were more than those of the European Union, reaching 7.2 t per capita (CDIAC, 2006a,b). The urbanization rate of China increased from 17.9% in 1978 to 56.1% in 2015 (Ouyang and Lin, 2017). There are 691,510 administrative villages in China, and about 0.674 billion people (or 50% of China's overall population) live in the countryside, which is different from most western countries (NBSPRC, 2012). With the rapid growth of urbanization, the traditional urban planning and design developed without regard to "high carbon emissions." The originally simple ecological environment and traditional construction models were destroyed, and carbon emissions consequently increased (Li et al., 2015). Additionally, the constant expansion of towns and associated construction made the abundant natural ecological environment gradually shrink; the ecological system structure and function were destroyed to different degrees, and the "carbon sinks" function of villages was gradually weakened as energy consumption increased. As a result, carbon emissions showed rapid growth, increasing to 2.874 billion tons (2007) from 0.889 billion tons (1979) in rural areas in China (Liu et al., 2013a,b). Hence, it is necessary to scientifically evaluate the carbon emissions of villages and create sustainable village development plans that reduce carbon emissions and increase carbon sinks.

Many carbon emissions studies have been conducted with a large-scale scope, covering countries and large cities. The Intergovernmental Panel on Climate Change (IPCC) established a greenhouse gas (GHG) inventory system that provides a basic methodology system for each country. Five categories of emissions sources were defined in this system, including energy; industry process and product; agriculture, forestry and land use; waste; and

* Corresponding author.
E-mail address: 120819598@qq.com (X. Luo).

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others (IPCC, 2006). Based on the IPCC inventory system, the Energy Research Institute of National Development and Reform Commission issued The People's Republic of China National Greenhouse Gas Inventory in 2007 and estimated carbon emissions in China over several years. In 1999, the GHG emissions of Barcelona, Spain were first calculated as a city scale case (Baldasano et al., 1999). Subsequently, many other cities developed inventory models for carbon emissions which were calculated, for example, four large cities in China (Dhakal, 2009) and the City of New York (Dickinson et al., 2012). A purely geographic production-based carbon accounting method was chosen in most of the studies mentioned above. However, human activity in cities stimulates in-boundary GHG emissions within the geopolitical boundary of the community as well as trans-boundary emissions (Ramaswami, A., 2011). A method that uses "geographic-plus infrastructure supply chain GHG footprints" was developed to calculate carbon emissions, for example, for eight U.S. cities (Hillman and Ramaswami, 2010) and Shanghai in China (SLDRSTWWFN, 2011). There are two types of study objects in the existing large-scale carbon emissions research. One is focused on carbon emissions from energy uses only (Hillman and Ramaswami, 2010; Lin and Ahmad, 2017), and the other is focused on carbon emissions from all factors referred to in the IPCC (Dickinson et al., 2012; SLDRSTWWFN, 2011).

The residential pattern, energy structure, and living behaviour in villages were significantly different from cities in developing countries including China (Liu et al., 2013a,b). It is found that although the urban population is much less than the rural population, the direct carbon emissions are markedly higher than those of the rural households because non-commercial energy consumption still plays a dominant role in Chinese rural households (Liu et al., 2011). There was similar household reliance on biomass and other traditional fuels in a study of nearly 3000 households across 10 different rural and agro-ecological locations in Sub-Saharan Africa (Adkins et al., 2012). Compared to cities, studies on village carbon emissions in villages are limited, and these have mostly focused on carbon emissions caused by residential households. As the smallest administrative unit, a village in China encompasses the residents' households, land use, agriculture, animal husbandry, and industrial activity. The GHG of residential households does not represent the GHG of the whole village.

In this study, we establish a new carbon emissions evaluation system focused on villages. Our system includes new inventory classifications, a "consumption-based" model, a "from bottom to top" data collection method, and a two dimensional grading system.

First, most of the existing carbon emissions evaluation systems utilize a 5-part inventory classification based on the IPCC inventory system. This kind of classification is suitable for carbon emissions management in a country or a large city, but it fails to classify carbon emissions by the specific terminal activities associated with government management departments at the village level in China. Because of this, some relevant data were very difficult to apply to specific planning and construction activities as well as to policy-making agencies. In our study, we classified carbon emissions in villages by specific terminal activities, and developed a new carbon emissions inventory that linked to village management departments directly. In our study, we classified carbon emissions in villages by specific terminal activities, and developed a new carbon emissions inventory that linked to village management departments directly.

Second, the approaches for "purely geographic production-based carbon accounting" and "geographic-plus infrastructure supply chain GHG footprints" belong to "production-based" calculation models that use "from top to bottom" data collection methods. These are very suitable for mesoscale and large-scale carbon emissions studies. However, most of the energy consumption of small-scale research areas, such as villages, originates from outside production. Therefore, it is very difficult to use a "production-based" model to estimate the emissions of greenhouse gases in villages. Moreover, village governments lack data that is not available "from top to bottom" data collection methods. In our study, we used a "consumption-based" model and a "from bottom to top" data collection method to make the carbon emissions evaluation system more accurate and operable.

Third, most of the existing studies of carbon emissions evaluation systems evaluated the results in one dimension: the amount of carbon emissions or the difference between carbon sinks and carbon emissions. In our research, we used an intuitive two-dimensional grading system that considers both carbon sinks and carbon emissions to determine a final calculated evaluation. Thus, two aspects of carbon fate can be carefully analysed and evaluated.

2. Methodology

2.1. Construction principles of our evaluation model

We built our carbon emissions evaluation model based on the following considerations:

1. Selection of carbon emission sources representing the characteristics of villages

National- and urban-level carbon emissions inventories cover a far larger scope and more types than rural-level inventories. Thus, in the selection of emission sources, this research first selects appropriate carbon sources and carbon sinks in accordance with the scope and types of rural carbon activities in Yangtze River Delta Region of China listed in the IPCC national carbon emissions inventory.

National-level carbon emissions inventories are comprehensive and cover a wide variety of emissions types; however, research on emissions types at the rural level is not very detailed. For some emissions activities closely related to villages, such as agricultural production, the national carbon-emissions inventory stays at the level of land type, so it is impossible to separately measure emissions behaviours, such as the utilization of agricultural materials and energy consumption by agricultural machinery during agricultural production. So, based on the relevant literature (Wang, C et al., 2011), this research refines the types of emissions activities.

Meanwhile, in the consideration and measurement of energy building, the national-level carbon-emissions inventory does not take into account the biomass energy often consumed in rural regions, such as the burning of wood and biogas. Accordingly, based on the relevant literature (Wang, 2002), this research details the emissions activities from this energy type.

2. Co-operation between the inventory framework and government management departments

The purpose of establishing the Greenhouse Emissions Inventory is to formulate specific targets for emissions reduction and to understand the different emissions sources and the means to eliminate them, transforming the targets into operational policy instruments. The framework of IPCC national greenhouse-gas inventory is established by calculating five factors: energy, industrial production processes, land use, waste disposal, and others. This classification of these five factors does not correspond to the division of government management departments, so the statistical results concerning carbon emissions sources and sinks cannot be easily applied to these departments (Fig. 1).