CAPTURING THE IMPACT OF URBANIZATION ON CARBON DIOXIDE EMISSIONS BY DMSP/OLS NIGHTTIME LIGHT DATA: A CASE STUDY IN YANGTZE RIVER DELTA

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ABSTRACT: The rapid urbanization in developing countries, a contribution to increasing greenhouse gas (GHG) emissions, plays an important role in the climate change issue. China is the largest energy related carbon dioxide (CO_2) emitter in 2008, contributing 23% of global emissions, while urban areas emit about 84% of it. This study estimate CO_2 emissions from cities located in Yangtze River Delta, China, jointly using remote sensing data and statistical data due to lack of energy statistical information. The results show that the CO_2 emissions in YRD cities increase rapidly in the past fifteen years, from 106 million tons C in 1995 to 296 million tons C in 2010. Shanghai, Suzhou, Hangzhou and Nibo are the top four emitters in the past fifteen years. The YRD cities are more crucial than those other less developed cities, which home to 7.8% of national population, and contribute 17.3% of total GDP, producing 12.8% of total emissions. Increasing urbanization is a national policy in China. It is foreseeable that energy use is continuous to increase due to rising incomes and the continuous concentration of energy consuming sectors within cities.

INTRODUCTION

In 2010, nearly 50% of Chinese population lives in urban, representing 670 million urban dwellers, and it is predicted that this proportion will increase to 60%, or 880 million urban dwellers, in 2030 (UN 2007) . One report by Mckinsey Global Institute (MGI) also showed that by 2025, the GDP generated by cities will increase from the current 75% to 95% (MGI 2009). Alone with rapid urbanization, built-up areas in China has expanded 3.6 times currently, compared to the area in 1985 .

Urban area itself does not emit or store much carbon, compared to forestland or cropland, globally. However, as central of economic and human activities, much as of energy is consummated in urban area. The International Energy Agency (IEA) estimates that urban areas currently account for over 67% percent of energy related global carbon emissions, which is expected to rise to 74% by 2030. It is estimated that 89% of the increase in CO_2 from energy use will be from developing countries, which keep a rapid urbanization process in this century (IEA 2008). In China, urban is more crucial than that in developed country, which contains 45% of the population, contributes 75% of the national economy, but, make up 84% of China's commercial energy related carbon emissions (Dhakal 2009). Increasing urbanization is a national policy in China, demanding greater energy use due to rising incomes and the continuous concentration of energy consuming sectors into urban areas. There is no doubt that urban areas will play a greater role than at present to shape China's energy demand and CO_2 emissions.

A growing number of studies have been carried out to investigate energy consumption and CO_2 emissions, from national or provincial perspective (Yu et al. 2012). Several of these studies focused on emission from a sectoral perspective, such as transport emissions (Cai et al. 2012), industrial and building emissions (Ke et al. 2012; You et al. 2011). Few studies have investigated urban's contribution to CO_2 emissions in China. Yu et al. (2012) only investigated CO_2 emissions from four highly urbanized cities in China. Dhakal (2009) generates a general view of urban energy consumption and CO_2 emissions in 35 key Chinese cities. However, very few studies provide a

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comparable estimated results in CO_2 emissions from urban, as Kennedy et al. (2011) does for global cities. The lack of comparative emissions investigations in cities blurs the emission situations in China and obstructs the development of appropriate policies to fit the disparities among different regions in China (Yu et al. 2012).

The objectives of this study is to estimate CO_2 emissions from 16 cities in Yangtze River Delta (YRD), one of the rapidest urbanization regions in China, and analyze the impact of urbanization on CO_2 emissions in the past fifteen years. The reminders of this paper are organized as follows. Section 2 will introduce the data issue in YRD, and the methods used to estimate CO_2 emissions at a city scale. The results will be given at section 3, the discussions and conclusions comes in the final section.

METHODOLGY
Research area and data
The Yangtze River Delta (YRD) lies in the east of China, which includes Shanghai and Parts of Jiangsu and Zhejiang Province. There are 16 cities in YRD currently (Figure 1), covering only 1.9% of the Chinese territory but homing to over 7.8% of national population, generating 12.8% of total emissions in 2010. Shanghai is one of four central administrative cities, known as the financial central of China. Nanjing and Hangzhou are the capitals of Jiangsu and Zhejiang province, respectively, while the less of 13 cities are important cities in eaten China, with large population and high economic output (Table 1).

Figure 1 the research cities

Table 1 per capita GDP of 16 cities 1995-2010

city	1995	2000	2005	2010
SHANGHAI	17779	30047	51474	76074
NANJING	11242	18872	40887	64037
SUZHOU	15784	26692	54164	93043
WUXI	17565	27633	62331	92166
CHANGZHOU	11171	17635	31997	67327
ZHENJIANG	10719	16967	29534	63280
NANTONG	5912	9378	19979	47419
YANGZHOU	6749	10515	20389	49786
TAIZHOU	5303	8082	17474	44118
HANGZHOU	12797	22342	44853	69828

NINGBO	12024	21208	44156	69368
JIAXING	9564	15845	34706	52143
HUZHOU	8569	12733	25030	45323
ZHAOXING	9561	16586	33283	63770
ZHOUSHAN	7579	12353	28936	66581
TAIZHOU	5176	11257	22438	41172

The China Statistics Bureau publishes national and provincial energy balance sheets annually. The city energy data are difficult to access, often incomplete and inconsistent. Due to lack of energy data at a city scale, we propose to estimate city CO_2 emissions, jointly using nighttime light data and statistical data. Other socioeconomic data, such as population size, GDP and urbanization index, are collected from China City Statistics Yearbook (1996-2011).

Nightime light data

DMSP/OLS instrument, which was launched at 1972, was initially designed to observe clouds illuminated by moonlights globally twice per day (Elvidge et al. 1997). Due to its low light imaging capability, this instrument can also detect light on Earth's surface as such as those generated by human settlements, gas flares, fires and night fishing. NOAA's National Geophysical Data Center (2010) processed and published Versions 4 of the DMSP/OLS night time image on its website. The products are a set of annual composites for each satellite (i.e. F10, F12, F14, F15, F16, and F18), with 30 arc second grids, spanning -180 to 180 degrees longitude and -65 to 75 degree latitude. Stable lights imagery, one kind of the Version 4 produces, contains the lights from cities, towns, and other sites with persistent lighting. Sunlit, moonlit, and ephemeral events such as wildfires have been discarded. The digital number (DN) of each grid range from 1 to 63, indicating the brightness intensity of stable light.

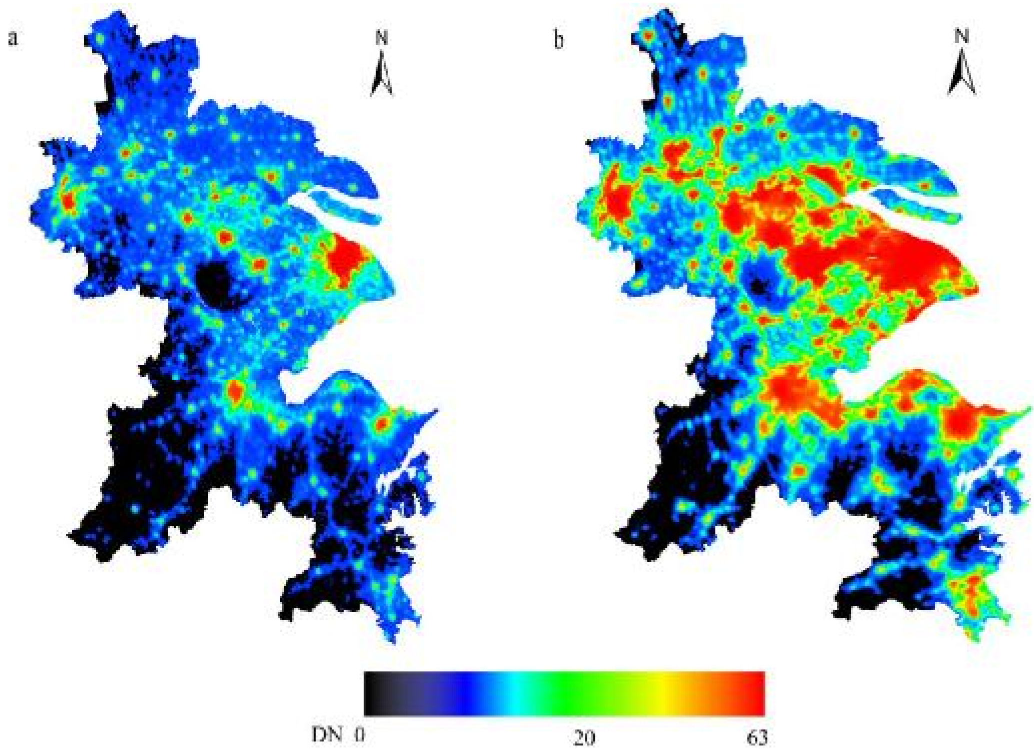

Figure 2 the night time light imageries in YRD, a) 1995; b) 2010.

Due to the difference in satellite orbits and empirical intercalibration procedures, a time series of night time imageries could fluctuate (DN value goes up and down) significantly (Figure 3 a) , even when no changes are occurring on the ground (Elvidge et al. 2009; Zhang and Seto 2011), which would produce errors in our estimates. Thus, we use a new, reprocessed and intercalibrated version of night time imagery by the method proposed by (Elvidge et al. 2009), and Japan is selected as the referenced samples due to the sufficient stable lights over time and across satellite sensors in Japan (Figure 3 a). Figure 3 shows the raw versus intercalibrated sum DN values in China.

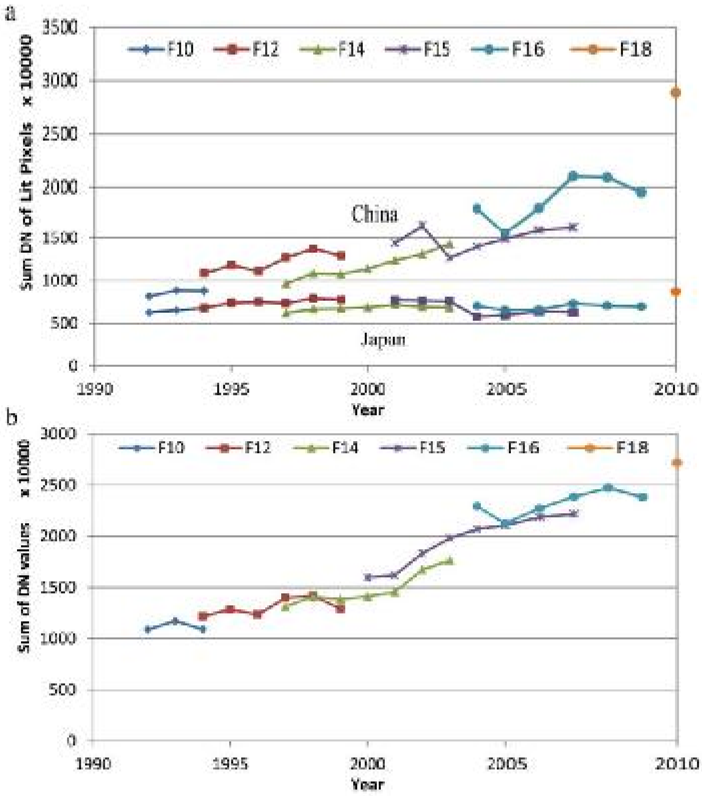

Figure 3 the sum of DN values in China with and without intercalibration, a) without intercalibration; b) with intercalibration.

Estimate method

We introduce an IPCC-based method by ICLEI (2010) to estimate city CO_2 emissions that has been widely used in global cities. Different from other studies, we acquire city energy data by a top-down and aggregation model, due to lack of city energy data, assuming that total final energy consumption is positively correlated with human activities. And, what is more, nighttime light intensity is an ideal spatial index for human activities (Ghosh et al. 2010):

$$E_i = E_p \times \left(\frac{DN_i}{\sum_p DN_i} \right) \tag{1}$$

Where Ei is the amount of total final energy consumption in pixel (location) i, Ep is the provincial total final energy consumption, DN is pixel value. Thereafter, total final energy consumption from each city is aggregated from pixels within city's boundaries. Once the energy data is acquired, we estimate the CO_2 emissions by the following model:

$$CE_c = E_{cf} \times EF_f \tag{2}$$

Where CEc is the carbon emissions from cities, Ecf is the amount of fuel f consumption within cities, while EFf is the emissions factor of fuel f, which are acquired from IPCC (2006). The emissions from electricity and district heating are account into the city in which they are consumed, not the city in which they are generated. The emissions factors for electricity and district heating are calculated from the energy balance sheets.

RESULTS

Carbon emissions in YRD cities

Carbon emissions in YRD cities increase rapidly in the past fifteen years, from 106 million tons C in 1995 to 296 million tons C in 2010. The CO_2 emissions of Shanghai increase from 45 million tons to 93 million tons, corresponding to 25% of the total increasing in YRD cities. Shanghai, Suzhou, Hangzhou and Nibo are the top four emitters in the past fifteen years (Figure 4), which are also the core cites in YRD. Spatially, the cities closer to Shanghai emit more carbon, and the cities in the southern YRD contains higher carbon emissions than in the northern YRD.

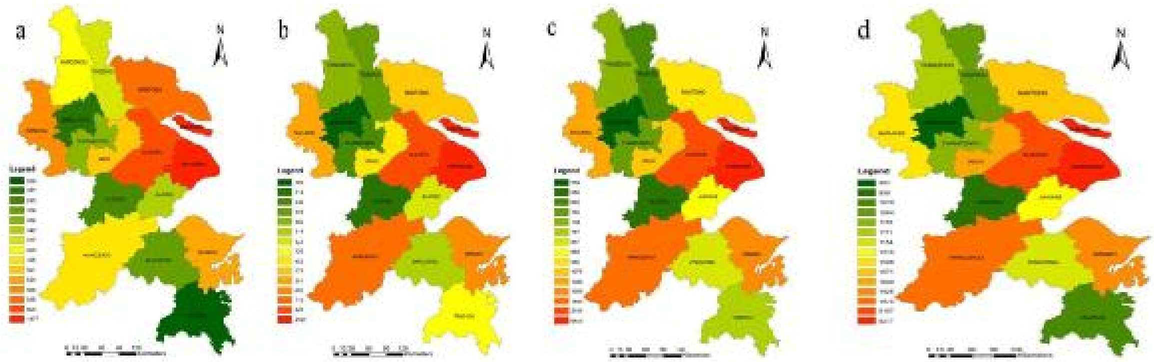

Figure 4 carbon emissions in YRD city, a) 1995; b) 2000; c) 2005; d) 2010.

Figure 5 shows the trends of per capita emissions in YRD cities from 1995 to 2010. Visually, Shanghai has a much higher value of per capita carbon emissions than other cities. Per capita carbon emissions in YRD cities rarely changes from 1995 to 2000, and then increase rapidly since 2000, being 3 times higher than 1995's, by the end of 2010.

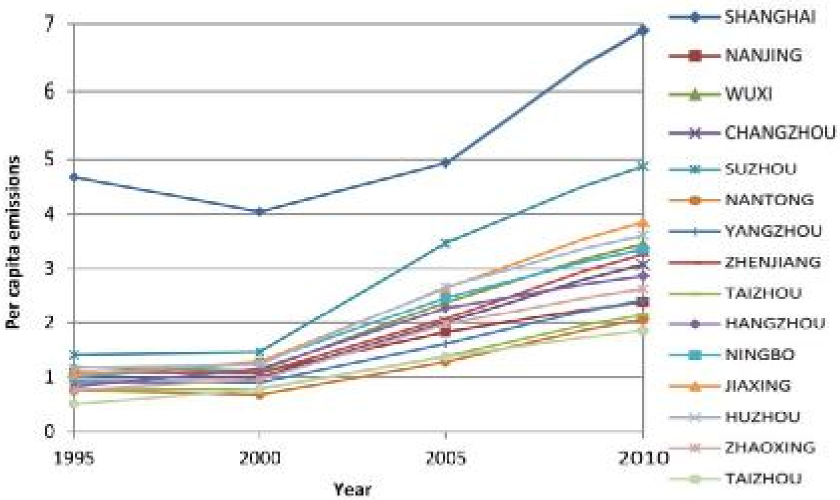

Figure 5 per capita emissions in YRD cities, 1995-2010.

The impact of urbanization to carbon emissions at a city scale

Figure 6 describes the impacts of economic growth to CO_2 emissions, clearly illustrating that per capita emissions increase as the economy grows. There is no doubt that the income level, life style and traffic situations can influence per capita emissions. Industry, however, contributes the majority of economic production in all Chinese cities, especially those in highly urbanized cities, so does the carbon emission. Actually, city itself does not emit or store much carbon, compared to forestland or cropland, globally. However, as central of economic and human activities, much as of energy is consummated in cities. The International Energy Agency (IEA) estimates that 89% of the increase in CO_2 from energy use will be from developing countries, which keep a rapid urbanization process in this century(IEA 2008). In China, YRD cities are more crucial than those other less developed cities, which home to 6.2% of national population, and contribute 17.3% of total GDP, producing 10% of total emissions. Increasing urbanization is a national policy in China; it is foreseeable that energy use is continuous to increase due to rising incomes and the continuous concentration of energy consuming sectors within cities.

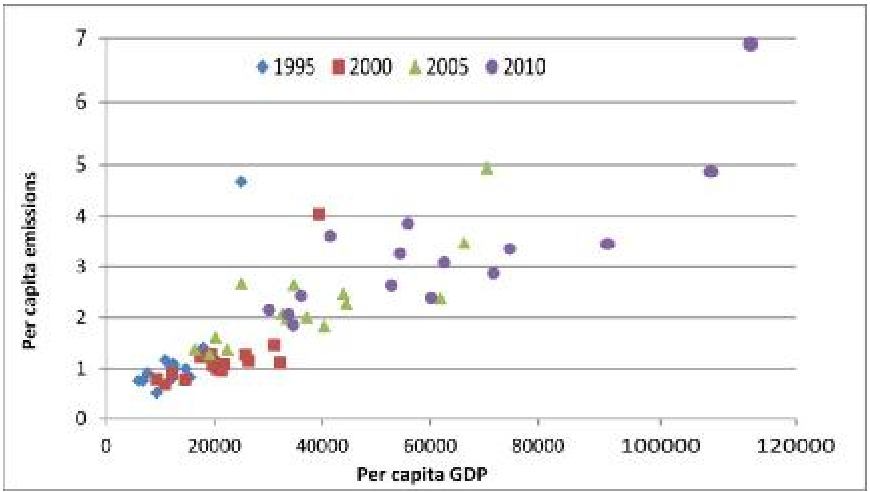

Figure 6 the scatter of per capita emissions against per capita GDP

Discussion and conclusions

This study estimates CO_2 emissions from Chinese YRD cities based on the ICLEI (2010), jointly using remote sensing data and statistical data due to lack of energy data. The results show that the CO_2 emissions in YRD cities increase rapidly in the past fifteen years. Per capita emissions have increased quickly since 2000, due to explosively economic growth and urbanization. Increasing urbanization is a national policy in China; it is foreseeable that energy use is continuous to increase due to rising incomes and the continuous concentration of energy consuming sectors within cities.

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