

Visualising CO₂ Emissions in an Urban Area: A Preliminary Research

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A spatial analysis of urban CO₂ emissions has been made using the case study of Beppu city, Japan. Three sectors namely business, manufacturing and residential sectors were considered. The results show that the spatial pattern of total CO₂ emissions from the three sectors shows the highest emissions in the central business district, with a decreasing trend moving to the outskirts of the city. These findings concur with literature that suggests that the urban structure has a strong influence on the spatial distribution of CO₂ emissions. These maps visualize urban CO₂ emissions in a way that the public and policy-makers can understand, and this may promote deeper discussions about how to address the problem of global warming and energy use in an urban planning context.

Key Words : CO₂ emissions, visualization, urban area

1. INTRODUCTION

While there remains considerable debate about the projections of global warming, a growing scientific consensus exists with regards to the negative consequences of greenhouse gas emissions (Glaeser and Kahn, 2009; Zhou, 2010). The carbon dioxide released to the atmosphere remains there for 100 to 200 years contributing to global warming. Hence there is a pressing need from the global to the local level to create policies for reducing the amounts of CO₂ emissions (Stern, 2008). The city level is particularly important because the majority of global CO₂ emissions are in fact from urban sources which include industrial, household and mobile sources (Denman et al., 2007). Given that CO₂ emissions are not a spatially random process, understanding the spatial pattern of these emissions is essential in order to better inform greenhouse gas regulation and mitigation decisions and to improve urban ecosystems (Zmyslony and Gagnon, 1998; Gurney, 2011). Unfortunately often times policy makers have to rely on blunt figures for the entire country or city. The major problem is how to visualize the spatial distribution of CO₂ emissions?

This study assesses the possibility of visualizing the distribution of urban CO₂ emissions in space and

time. We use the case study of a small city, Beppu city in Japan, because for a preliminary study it presents a relatively less complex pattern of business, industrial and residential areas thereby placing us in a better position to map the emissions from different sectors. To address this challenge we rely on the city's CO₂ emission estimates and the spatial densities of businesses, industries and households. This assessment is preliminary in other ways for example we discuss in the final section of this paper.

2. METHODOLOGY

(1) Data source –CO₂ emissions

Accounting CO₂ emissions at a local level has been a big research and policy issue. Fortunately, Japanese government has published CO₂ emissions for its autonomies (see the website of the Ministry of Environment of Japan). The CO₂ emissions from Beppu estimated by the national government is shown in Table 1. In this preliminary study, we focus on three large emitters: manufacturing, household and business, and take year 1990 for example.

Table 1 CO₂ emissions of Beppu 1990 (t-CO₂)

		1990
	Manufacturing	170,689
Industry	Construction	15,124
	Agriculture	21,009
Household		138,496
Business		171,392
	Automobile	164,534
Transport	Railway	7,653
	Ship	48,014
Waste		7,904
Total		744,815

Source: MOE website

(2) Data source – spatial distribution of household and activities

For analyzing the distribution of residential emissions, the household number of the Population Census is used. And for manufacturing and business sectors, the employee numbers for each sector in the Economic Census for Business Activity are used. These databases with ArcGIS shp files facilitate the analysis of spatial patterns of the activities in these sectors.

(3) Data processing

The major steps towards the spatial distribution of CO₂ emissions are, taking household emissions for example:

i) Calculate the density of households in the shp file in each census district (polygon) and then convert the shp file to a raster dataset so that each cell has a density value.

ii) Sum up the density value of all cells and get the weight for each cell by using the formula below:

$$\text{Cell value} / \text{the sum}$$

iii) Assign the CO₂ emissions (in this case, 138,496 t-CO₂) to the weights to get the result (t-CO₂ per cell). The area is divided in 44,279 cells and each cell represents an area of 2,808 m² (53m×53m).

In data processing and visualization, Excel, ArcGIS and IDRISI are used.

3. RESULTS AND DISCUSSION

Figures 1-3 show the CO₂ emissions from business, manufacturing and residential sectors respectively over Beppu city Japan. In Fig. 1 we observe that the highest levels of CO₂ emissions are distributed in the main central business district (CBD) and they decrease outwards towards the residential areas. The concentration of business emissions towards the CBD is expected because Beppu's urban structure generally follows the concentric zone model.

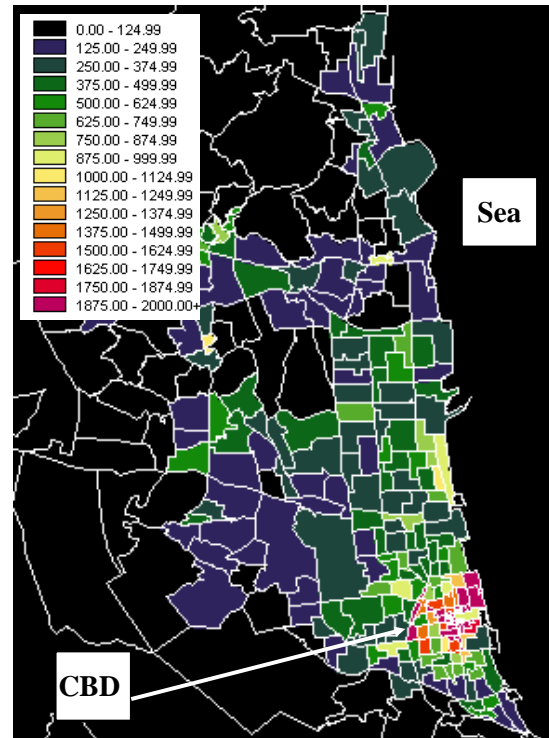


Fig.1 CO₂ emissions from business sector (t-CO₂/cell)

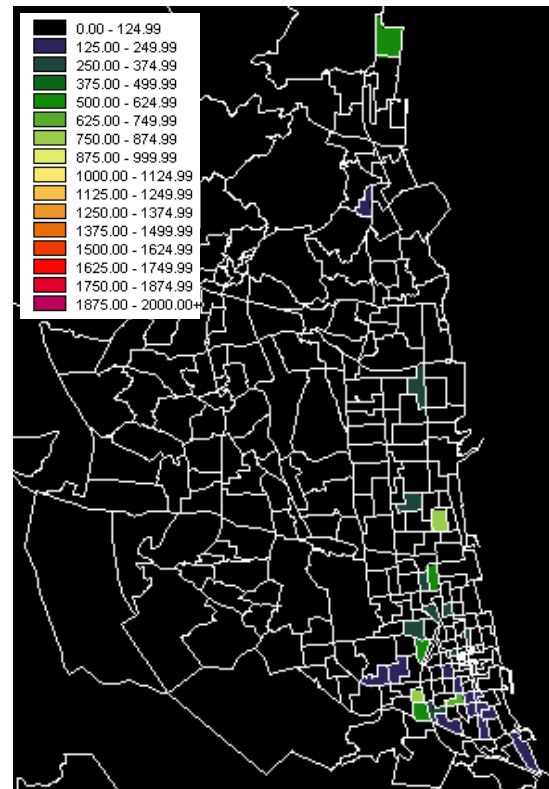


Fig.2 CO₂ emissions from manufacturing sector (t-CO₂/cell)

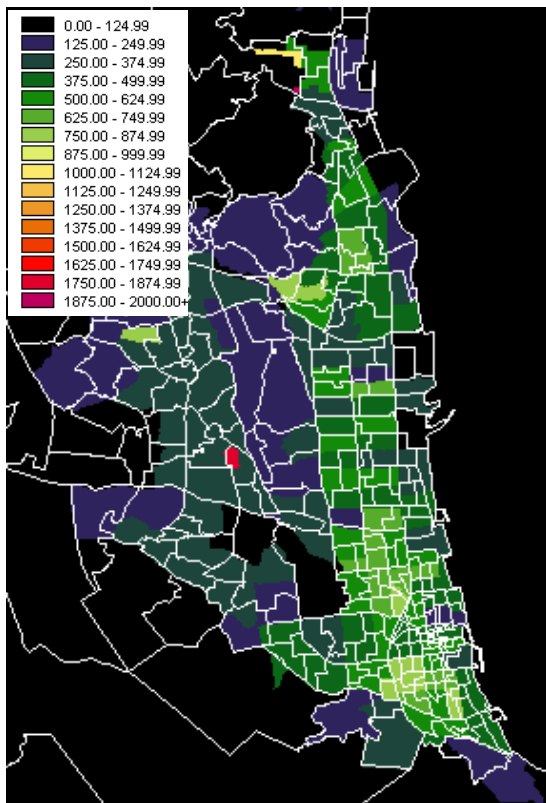


Fig.3 CO₂ emissions from residential sector (t-CO₂/cell)

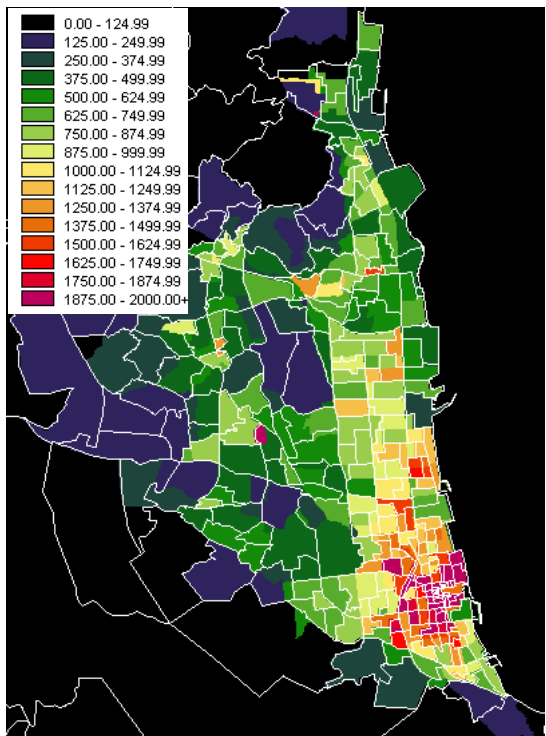


Fig.4 Total CO₂ emissions over Beppu City (t-CO₂/cell)

CO₂ emissions from the manufacturing sector are distributed outside of the CBD as shown in Fig. 2. Though the total CO₂ emissions in the manufacturing sector were almost equivalent to those of the business sector, the manufacturing sector emissions are distributed more evenly across the city than the

emissions from the business sector. Moreover Beppu city has a relatively small manufacturing sector.

The CO₂ emissions for the household sector (Fig. 3) are distributed widely across the city with slightly higher concentrations around the CBD and along the coast.

The total CO₂ emissions for the all three sectors of Beppu are shown in Fig 4. Each cell in this image represents the summation of CO₂ emissions from the manufacturing, business and household sectors. It can be seen that the highest CO₂ emissions are distributed in the CBD and they tend to decrease outwards in a pattern. Our results concur with literature which suggests that the urban structure significantly influences the distribution of CO₂ emissions in an urban area.

4. SUMMARAY

From this assessment we learn how the business, manufacturing and housing sectors contribute to the spatial distribution of CO₂ emissions in Beppu city. We discover that central business district, because of its high concentration of businesses exhibits the highest concentrations of emissions. We also note a pattern of high CO₂ concentrations following along the coastal lane. These results highlight that urban structure has a strong influence on the spatial distribution of CO₂ emissions. These maps of Beppu city provide a picture of emission sources in a way that the public and policy-makers can understand, which may be helpful in enhancing deeper discussions about how to address the problem of global warming problem and energy use in an urban planning context.

5. FUTURE WORKS

This work is at the early stages of development but is part of bigger project to visualize, with high resolution, CO₂ emissions from urban sources. Some key aspects that we hope to address in future works include incorporating emissions from mobile sources and to also include other sectors such as the agricultural and construction sectors. Furthermore we hope to investigate how the spatial patterns of CO₂ emissions have evolved over time. This therefore implies acquiring the more recent census and emissions data. Through these efforts we hope to contribute not only to carbon monitoring but also to support mitigation planning effort at the local level such as urban areas.

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(Received August 3, 2012)