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研究課題名（和文） Development and Pilot Testing of a Standardized Method to Map Urban CO2 Emissions

研究課題名（英文） Development and Pilot Testing of a Standardized Method to Map Urban CO2 Emissions

研究代表者

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研究成果の概要（和文）：さまざまな都市形態と炭素排出量との関連を調べました。 Local Climate Zone（LCZ）フレームワークを使用して、都市の形態とCO2排出パターンの関係を調査しました。 2015年に、ボルチモア、インディアナポリス、ロサンゼルスの3つの選択された都市のLCZマップを作成しました。次に、Hestiaプロジェクトの年間炭素排出量データを使用して、各LCZの1人当たりの消費量と年間CO2排出量を測定しました。クラス。プロジェクトの結果は、全体として、植生が少ないかまったくない高密度地域の炭素強度が高いことを示しました。

研究成果の学術的意義や社会的意義
The results of thus study are important as they provide insights on the emission implications of different urban forms and can guide planners and policy makers towards creating more sustainable and resilient cities. The results offer more supports to compact city policies.

研究成果の概要（英文）：In this project I examined the association between different urban forms and carbon emissions. I used the Local Climate Zone (LCZ) framework to investigate the relationship between urban form and CO2 emission patterns. This framework divides urban areas into 17 classes according to their urban form characteristics. I developed the LCZ map of the three selected cities of Baltimore, Indianapolis, and Los Angeles for 2015. Next, I used the annual carbon emission data of the Hestia project to measure the per capita consumption and the amount of annual CO2 emissions in each LCZ class. Results of the project showed that, overall, carbon intensity of high-density areas with low or no vegetation is high. It was also found that per capita emissions increase with urban sprawl. But in the case of Los Angeles in particular, urban sprawl was not necessarily associated with the amount of per capita CO2 emission.

研究分野： City planning

キーワード： LCZ　Urban mitigation　Urban adaptation　Climate change　CO2 emissions

１．研究開始当初の背景

The amount of CO_2 in the atmosphere has already surpassed 400 parts per million and is expected to double the pre-industrial levels in the coming years. This will significantly reduce the chances of limiting global warming to well below 2 °C above the pre-industrial levels (IPCC, 2013). As this trend continues, the proportion of world population living in cities is also rapidly increasing. It is widely recognized that urbanization trends have major implications for efforts aimed at mitigating climate change through reducing CO_2 emissions. Currently, about 75% of energy-related CO_2 emissions are associated with urban activities and this proportion will further increase in the future (IPCC, 2013).

Recognizing this, many cities around the world are increasingly taking efforts to mitigate their CO_2 emissions. However, there is still no sufficient information on their impacts and very limited efforts have been made to manage and evaluate the performance of mitigation actions and policies. This is partly due to the resource- and data-intensity of CO_2 emissions accounting at the local scale where human activity occurs (i.e., buildings, streets, factories, etc.) (Gurney et al., 2015). Furthermore, there is a lack of standardized, consistent, and scalable methods for mapping emissions at the sub-city levels (i.e. neighborhoods, blocks, etc.). Such methods are needed to deal with data availability issues and to understand the magnitude and driving forces of emissions at the local scale in order to design effective and efficient interventions and mitigation pathways.

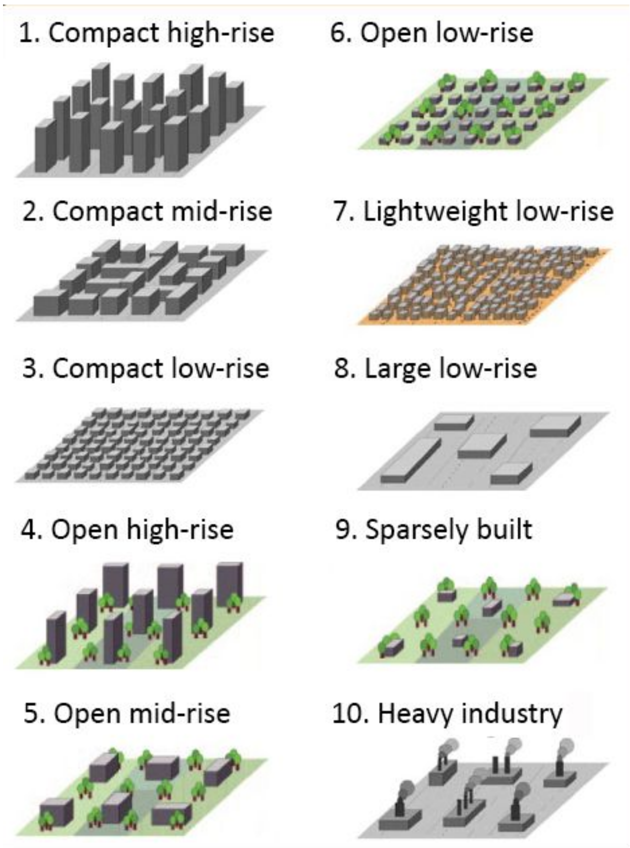

Figure 1. Local Climate Zone (Stewart and Oke 2012)

In collaboration with organizations such as the Global Carbon Project, I have done some preliminary efforts to examine the possibility of developing a standardized method for urban carbon mapping at the sub-city level (Sharifi et al., 2018). I have worked on the idea of using the Local Climate Zones (LCZs) classification system as a consistent platform for urban carbon mapping. The LCZ framework provides a consistent methodology for classifying urban areas around the world into 10 urban classes (see Figure 1). Each class (cluster/zone) exhibits the physical properties of a typical area in the city (http://www.wudapt.org). Using this approach, some preliminary results have also been prepared. The project proposed here will build on those efforts by focusing on the following key questions:

- To what degree is the LCZ classification system suitable for standardizing CO_2 emissions mapping/accounting at the urban scale?
- Can typologies associated with CO_2 emissions be identified and are typologies identified for one city extensible to other cities?

２．研究の目的

Against the above-mentioned background, the main objectives of this research are as follows:

- To use the LCZ classification system as a basis to develop a standardized method for accounting and mapping CO_2 emissions at sub-city levels (e.g., neighborhood, district, block)
- To pilot-test the method in several cities to find out if the method is applicable to different contexts
- To find out if there are universal urban typologies associated with urban CO_2 emissions and
- To examine the differences across the selected cities regarding drivers of CO_2 emissions

３．研究の方法

To address the four objectives mentioned in the previous section, the following steps will be undertaken:

1.3.A) Create LCZ maps for the selected cities (Baltimore, Indianapolis, and Los Angeles). These cities are selected because data for them is available. Also, they feature different urban typologies, making comparison possible.
1.3.B) Estimate CO_2 emissions for each LCZ in the selected cities
1.3.C) Conduct statistical analyses to understand patterns and behaviors of CO_2 emissions

1.3.A) To create LCZ classification, I follow the instructions outlined by the WUDAPT group (www.wudapt.org). A brief explanation of the steps is as follows:

1. Create LCZ training areas. A Training area is a polygon that represents an LCZ of a specific type. I digitize the training areas using Google Earth, based on the 10 LCZ types presented in *Figure 1*. The procedure is as follows: first, I download the Landsat image of the selected city; second, I define the Regions on Interest (ROIs) for each image and prepare the Landsat data using a Geographic Information System (GIS) software (SAGA GIS software); third, I open the files in Google Earth and digitize the training areas.

2. First, I open the files created in the previous stage using the GIS software and run the “Local Climate Zone Classification” geoprocessing tool. After setting the required parameters, the geoprocessing tool generates the LCZ classification for the city. Next, I open the generated file in Google Earth to validate the accuracy of the classification. If not satisfactory, I add more training areas and repeat the process until the result is satisfactory. Once completed, the LCZ classification map of the selected city will be ready for use.

1.3.B) Estimate CO_2 emissions for each LCZ in the selected cities

In this stage I estimate CO_2 emissions for each LCZ. Direct emissions generated from transportation and building heating sources, as well as indirect emissions that occur due to the use of grid-supplied electricity, heating, steam, or cooling will be considered. The following steps will be taken for predicting emissions:

1*. For building-related emissions**: I **first** establish an Energy Use Intensity (EUI) database for different building uses (e.g. residential, commercial, etc.) and types (e.g. detached, apartment, high-rise, etc.). EUI is an indicator of the amount of energy consumed per square meter per unit of time. **Next**, I use emission factors (corresponding to each specific energy type) to predict building level emissions. In other words, per unit of time emissions of a given building can be calculated as: ***EUI × Emission Factor × Floor Area. EUI and emission factor values can be obtained from local and national sources and documents published by the Intergovernmental Panel on Climate Change (IPCC). **In case such data are not available**, I will predict the building CO_2 emissions using building energy modelling software sets (e.g. EnergyPlus). **Finally**, I will calculate emissions associated with each LCZ by aggregating emissions estimated for each building in that particular LCZ.

2. **For transport-related emissions**: I will follow the procedure outlined by Gurney et al. (2012). **First**, I acquire GIS road data for the selected cities that will identify "primary roads" "secondary roads", and "local neighborhood roads". **Next**, I will estimate hourly traffic density for individual road links of these three road types using traffic data (public and private) provided by planning organizations. **Following this**, the emission factors for different vehicle types/transportation modes will be applied to estimate emissions associated with each road link. **Finally**, the emissions data for all road links in each LCZ will be summed to obtain transport-related CO_2 emissions. This method assumes that traffic flow density is equal throughout a road link. This might add some uncertainty to the calculation, but the method provides reasonably accurate emission estimation.

1.3.C) Conduct statistical analyses to understand patterns and behaviors of CO_2 emissions. In this final stage I will conduct different analyses as follows:

1. I conduct spatially-explicit statistical analyses to find out if there is any association between LCZ type and CO_2 emissions. These analyses will elucidate the time-based emission behavior of LCZs and demonstrate whether other factors such as the location of a LCZ in the city affect its emission behavior. For instance, it will be possible to understand whether per capita emissions for a particular LCZ are comparable within and between the selected cities. The cross-city comparisons will also make it possible to examine whether universal urban typologies associated with CO_2 emissions exist.

2. Based on the results of within and cross-city comparisons, I will examine the suitability of the LCZ framework for standardizing emission accounting at the sub-city. The method is suitable if extensible results can be achieved. If found not suitable, I will explore possible adjustments that need to be made.

3. To better understand the emission drivers, I conduct statistical analyses to find out how different physical/non-physical components (e.g., density, socio-economic factors, etc.) related to the LCZs are associated with CO_2 emissions in each city. Also, I will conduct cross-city comparisons to understand similarities and differences.

４．研究成果

The results showed that high-density urban areas had higher total CO2 emissions than those of lower density and more vegetation (Fig.2). In fact, overall, the second three classes of LCZ (LCZ 4, 5, and 6) emitted less CO2 than the first three classes of LCZ (1,2, and 3), because of more vegetation. This can indicate the importance of green space in absorbing CO2 emissions in urban areas. But, LCZ 4 class in Baltimore represented a significant impact of density on CO2 emission even with vegetation. However, a definite statement in this regard requires further study and also the study of the impact of urban form on CO2 emission related to transportation, residential, commercial, industrial buildings, etc. separately in each urban area.

Fig.2 shows that areas with low and semi-high industrial structures mostly without trees or with a few trees, with paved areas, and with metal, steel, and concrete as the main building materials emit high amounts of CO2. Besides, LCZ8 and LCZ E classes revealed that urban areas with low or no buildings and asphalt cover had significant amounts of emissions. In particular, the significant emission in class LCZ E, which in a way shows the urban transport infrastructure, highlights the importance and necessity of reviewing emissions related to the transportation sector more than before.

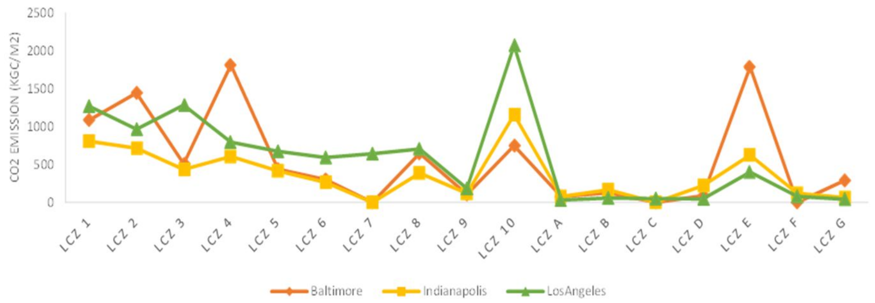

Fig.2. CO_2 emissions for each LCZ (Kg C).

Overall, Figure 3 shows the total CO2 emission in all three cities. The LCZ 10 class ranked first. Moreover, the LCZ 1 to LCZ 4 classes with high emission after industrial centers show that human activities are major contributing factors to emissions. On the other hand, the low emission of LCZ 5 and LCZ 6 classes due to higher vegetation density after the third and the eighth classes of LCZ show the significant role of green space in CO2 uptake. Furthermore, the high emission of LCZ 2 and LCZ 4 classes in Baltimore may be due to high population compared to other urban areas with similar or higher density.

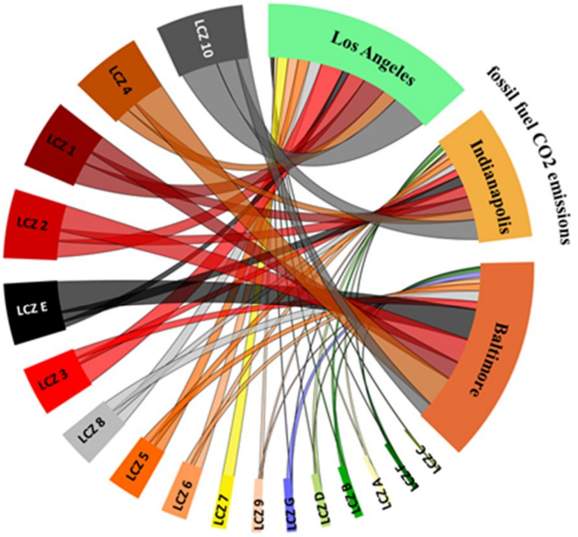

Fig. 3. The measure of carbon emissions in each LCZ for all three urban area

In general, in this study, no logical and clear trend was found for the per capita emission across different LCZs. However, specifically in Baltimore and, to a less likely, in Indianapolis, it was shown that high urban sprawl increases per capita emissions.

Although this project showed the utility of using the LCZ framework, further research is needed to gain a more comprehensive understanding. It is important to also apply this method in other contexts can compare the findings. For that, I have also prepared LCZ maps for some Chinese cities and will use them to do more related research on climate change adaptation and mitigation.

５．主な発表論文等

〔雑誌論文〕　計3件（うち査読付論文　3件／うち国際共著　3件／うちオープンアクセス　1件）

１．著者名 SHARIFI Ayyoob, JAVADPOOR Masoud	４．巻 9
２．論文標題 Spatial Analysis of Building-related Urban CO2 Emissions Based on the Local Climate Zones Classification System	５．発行年 2020年
３．雑誌名 Energy Proceedings	６．最初と最後の頁 1-5
掲載論文のDOI（デジタルオブジェクト識別子） なし	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

１．著者名 Long Yin, Sharifi Ayyoob, Huang Liqiao, Chen Jinyu	４．巻 44
２．論文標題 Urban carbon accounting: A bibliometric overview	５．発行年 2022年
３．雑誌名 Urban Climate	６．最初と最後の頁 -
掲載論文のDOI（デジタルオブジェクト識別子） 10.1016/j.uclim.2022.101195	査読の有無 有
オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 該当する

１．著者名 Yin Long, Yida Jiang, Peipei Chen, Yoshikuni Yoshida, Ayyoob Sharifi, Alexandros Gasparatos, Yi Wu, Keiichiro Kanemoto, Yosuke Shigetomi & Dabo Guan	４．巻 8
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2021年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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６．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

７．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

８．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関