GIS Mapping of CO₂ Emission from Population of Metropolis: Case Study of Ho Chi Minh City in Vietnam

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Abstract. The issue of CO₂ emissions, the major cause leads to climate change has always been of particular interest in the context of the industrialization process and urbanization taking place more and more complex. Ho Chi Minh City is a large city of Vietnam with a high rate of urbanization and thus the CO₂ emissions management process needs to be studied. In this work, we have developed the Geographic Information System (GIS) to build the mapping of CO₂ emission from population of Metropolis, case study of Ho Chi Minh City in Vietnam for the first time. The mapping CO₂ emissions for Ho Chi Minh city from the population have been calculated from human respiration and combustion gas in daily activities. We found that the highest level of CO₂ emissions is located the western suburbs of the city including Binh Tan district, Tan Phu district, Tan Binh district, Go Vap district, District 12, Binh Chanh and Hoc Mon district. In seven districts with emission levels high, Binh Tan has the highest CO₂ emissions and opposite Can Gio district has the lowest CO₂ emission due to Can Gio district is a district adjacent to the sea and mainly mangroves forests, traffic condition is not conducive to the process of industrial development, therefore no attract workers from the others district, the province as Binh Tan district and local people trend to industrial zones making the district’s population the lowest. The results of this work can make reasonable policy in the management and reduction of CO₂ emissions for future cities with low carbon city.

1. Introduction
Nowadays, climate change taking place definitely complex and its tremendous on the living environment of humans and other organisms on the world. The cause of climate change is the number of greenhouse gasses (CH₄, N₂O, NO₂, CO₂) in the atmosphere has increased rapidly, in which CO₂ has the most significant impact on emissions in both scale and level of impact. CO₂ emissions are mainly due to human activities such as burning fossil fuels, industrial production, agriculture, transport…. Vietnam is likely to be one of the several countries is bearing adverse effect on climate change. According to Institute of Strategy and Policy on Natural Resources and Environment [1], the annual average temperature of Vietnam has increased approximately 0.5 °C - 0.7 °C and the sea level has also risen about 20 cm. Furthermore, Vietnam has also seriously influenced due to the El-Nino and La-Nina...
phenomena, during the last 50 years. In addition, the severe and/or frequent occurrences of natural
disasters, especially cyclonic storms, floods, and droughts, which a result of climate change is also
intimidating to the living environment of citizens in Vietnam.

According to Asian Development Bank, Ho Chi Minh City (HCMC) is one the among ten cities has
to bear an adverse effect on climate change, which is the significant vulnerability to Vietnam's
development due to the HCMC accounts for 23 % of the national gross domestic product (GDP) and
20% of the foreign direct investment [2]. The negative impact of climate change such as sea level 40 %-
45 % of land cover in HCMC is 0-1 m in elevation, 15 %-20 % is 1-2 m. Chi Minh City is the large city
of Vietnam with the population resident number more than 6.3 million and it attracts a lot of labor of
others place. At present, the storms, storm surges, and tidal flooding appear with intensity, resulting in
directing of climate change [2]. Ho Chi Minh City places the junction between the Southeastern and
South West, includes 19 urban districts and 5 suburban districts, which is illustrated in Figure 1. The
size of the area is 2095.06 km². According to the General Statistics Office in 2017, the population is
about 7,162,861 residents that mean the average density is 3419 people/km². The population growth in
Ho Chi Minh City is 3 times higher than the nation’s average population growth. It created abundant
labor resources, labor quality rose promote economic development but also creates a number of
challenges such as rapid urbanization rate, impact on the environment and affect the health of people.

(Source: Van Buuren and Potting, 2011)

**Figure 1.** Map of Ho Chi Minh City in Vietnam

In Vietnam, there have been many reports for CO₂ emissions of the Ho Chi Minh City but mainly
studies on traffic and industrial activities and only stop at the statistical calculations of CO₂ emission
sources, not many studies have calculated emission from the population and use of such data to build
CO₂ emissions map of the city. With the pressure of urbanization, industrialization, HCMC becomes a
city has highest CO₂ emissions in the country. Therefore, calculating and evaluating CO₂ emissions of
Ho Chi Minh City is considered to be one of the most necessary, urgent and practical research. A
geographic information system (GIS) is a conceptualized framework that provides the ability to capture
and analyze spatial and geographic data. GIS applications are computer-based tools that allow the user
to create interactive queries (user-created searches), store and edit spatial and non-spatial data, analyze
spatial information output, and visually share the results of these operations by presenting them as maps.

In this study, we have studied and constructed map model which contains information about the CO₂
emission associated with different ward spatial units from the population in 2017 by on GIS modeling
for 24 districts in HCMC, Vietnam. The results of this work can make reasonable policy in the
management and reduction of CO2 emissions for future cities with low carbon city.
2. Data and methods

2.1. Data
The datasets used in this study comprise of map network of wards, towns and communes have been digitized. The map network data was obtained from the Data Warehouse, which is national socio-economic information system maintained by General Statistics Office. Besides the population figures, the database is represented in spatial form for different wards in the network. As for the study area, there are adequate of the population in 2017 of every wards, towns, and commune in Ho Chi Minh City.

2.2. Methods
Collecting the baseline data for calculation. Collected data include population numbers by district and ward /commune/town of HCMC. Based on the collected data, CO₂ emissions from breathing activities and fuel use per capita are calculated. The method of calculating CO₂ is based on the formula according to the greenhouse gas calculation manual of IPCC, 2006 for flue gas. The formula for calculating emissions from electricity from UNEP 2017. Create assessment map of CO₂ emissions by administrative unit of ward/commune/town.

In which, the study used spatial and non-spatial data for the process of mapping CO₂ assessment and used coefficients CO₂ calculation method for the calculation process CO₂ emissions are calculated based on the data from human respiration (exhaling) and gas consumption per capita. Formula as follows IPCC [3].

\[ A_i = \sum P_i \times E \]

Where \( A_i \) is the CO₂ emissions for each ward in 2017, \( P_i \) is the population of each ward in 2017 (data from the General Statistics Office), and \( E \) is the coefficient of CO₂ emission based on the respiration process (exhaling) and household gas consumption. [3-5]. Methods of calculating GHG emissions based on GHG emission factors of IPCC 2007 and collecting and data mining, analyze data population 2017 from the General Statistics Office, Vietnam. Next, GIS software was applied to build up the CO₂ mapping for CO₂ Emission from Population of Metropolis. Finally, map editor of CO₂ emissions the wards, districts in Ho Chi Minh City from total CO₂ emissions. [6-10].

3. Results and discussion
The amount of CO₂ emissions by each ward for 24 districts in Ho Chi Minh City is from the population data collected in 2017 from the statistics and ignores the number of immigrants. The calculation of the emission factor is calculated from breathing activities and using gas per capita. CO₂ emissions are calculated in units of kg/day for all 322 communes and wards of HCMC. Districts with a large number of the population will produce more CO₂ emissions.

Figure 2 shows that the lowest total CO₂ emissions are in Can Gio District with about 7,500 gCO₂/day and the highest is in Binh Tan District with more than 700,000 gCO₂/day. More important, 24 districts in HCM can be divided according to 3 CO₂ emission levels. The lowest CO₂ emission level from about 7,500 gCO₂/day-300,000 gCO₂/day for Can Gio District, District 2, District 4, Nha Be District, District 5, District 3, District 1, District 10, District 6, District 9, District 7. The average level of CO₂ emission is about 300,000 gCO₂/day-520,000 gCO₂/day including districts such as Cu Chi District, District 8, Hoc Mon District, Tan Binh District, Binh Tan District, Tan Phu District, Thu Duc District, District 12. The highest CO₂ emission level has quite high emissions from about 520,000 gCO₂/day-700,000 gCO₂/day for Go Vap District, Binh Chanh District and Binh Tan District. The lowest CO₂ emission level and medium emissions level are concentrated in suburban districts. Binh Tan District and Binh Chanh District have a high total emission, which can be explained because these district are a longstanding district in Ho Chi Minh City, so the number of people is quite large. Interestingly, Can Gio
district is a district adjacent to the sea and mainly mangroves forests, traffic condition is not conducive to the process of industrial development, therefore no attract workers from the others district, the province as Binh Tan district and local people trend to industrial zones making the district’s population the lowest.

Figure 2. The CO₂ emission in all Districts of Ho Chi Minh City, Vietnam

Binh Tan District has the highest density of the population compared to the others district in the city. According to Labor Unions Binh Tan District, the population increase rapidly in recent years, the population growth rate per year is 16.17% period 1999 – 2017 [6]. Figure 3 shows CO₂ emissions were calculated for every ward in the Binh Tan District. According to Binh Tan District with urbanization rate was quite fast, almost no longer the agricultural land of wards, resulting in the process of rapid urbanization in the district with the contribution of three large industrial zones of the city such as Tan Tao, Vinh Loc and Pouyen. These large industrial zones have been attracted a lot of workers from the others district, other province moved to Binh Tan District, making the district’s population grew the fastest. The highest CO₂ emissions (95,390.634 gCO₂/day) of Binh Hung Hoa Ward and the lowest CO₂ emissions (30,000gCO₂/day) for An Lac Ward of Binh Tan District (Figure 3).

Figure 3. The CO₂ emission in Binh Tan District, Vietnam

Figure 4 shows CO₂ emissions were calculated for every ward in the Can Gio District. The Can Gio district has the lowest emissions compared to the 23 remaining districts of the HCM city. Because of the low population, the district administrative unit has the highest emissions of less than 18,000
gCO₂/day (Binh Khanh commune) and the lowest is Thanh An commune with only more than 4,200 gCO₂/day.

![Figure 4. The CO₂ emission in Can Gio District, Vietnam](image)

![Figure 5. The GIS mapping of CO₂ Emission from Population in Ho Chi Minh City, Vietnam](image)

Figure 5 shows the GIS mapping of CO₂ Emission from Population in 24 districts of Ho Chi Minh City, Vietnam. According to the built-in emission map it can be seen that the highest CO₂ emissions are located in districts such as Binh Tan District, Tan Phu District, Tan Binh District, Go Vap District,
District 12, and gradually decrease to Binh Chanh District and Hoc Mon District. The lowest CO₂ emissions are in the two suburban districts of Cu Chi and Can Gio. Can Gio district has the lowest CO₂ emissions in the HCMC, which can be explained by the location of the district close to the sea area and mangroves, and the traffic and economic conditions are not conducive to industrial development. Therefore, it cannot attract resident from other districts as the center of city. In addition, local people also tend to migrate to large industrial zones, leading to the lowest population of Can Gio district compared to other districts in Ho Chi Minh City. In particular, Binh Tan district has the highest CO₂ emissions in the city, which can be explained by the highest population density because of long established district the compared to other districts of the city [6, 7].

4. Conclusions
This study developed into mapping CO₂ emissions for Ho Chi Minh City from the population (CO₂ emissions from human respiration and combustion gas in daily activities) using GIS model. We found that the lowest total CO₂ emissions are in Can Gio District with about 7,500 gCO₂/day and the highest is in Binh Tan District with more than 700,000 gCO₂/day. More important, 24 districts in HCM can be divided according to 3 CO₂ emission levels. The lowest CO₂ emission level from about 7,500 gCO₂/day-300,000 gCO₂/day, the average level of CO₂ emission is about 300,000 gCO₂/day-520,000 gCO₂/day and the highest CO₂ emission level has quite high emissions from about 520,000 gCO₂/day-700,000 gCO₂/day. The results of work can be contributed the data of CO₂ emission for government to have plan as well as policy in the management and reduction of CO₂ emissions for future cities via low carbon city. The government could have policies on planning, relocation of people, industrial zones, bringing the service to other districts or sparsely populated areas, resulting in the resource of human and land would be exploited in the location.

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References
[1]Strategy, I.o., P.o.N. Resources, and Environment 2017 Viet Nam Assessment Report on Climate Change (VARCC) Institute of Strategy and Policy on natural resources and environment, Viet Nam (ISPONRE)
[2] Hoa NT, Hasegawa T, Matsuoka Y 2014 Mitig Adapt Strateg Glob Chang 19 15–32
[3] Change, I.P.O.C. 2007 Agenda 6(07): p 333
[4] Nolt, J. 2011 Ethics, Policy and Environment 14(1): p. 3-10
[5] Hoa NT, Gomi K, Matsuoka Y 2014 Int Proc Chem, Biol Environ Eng 61 1–5
[6] Nguyen Thai Hoa & Yuzuru Matsuoka 2017Mitigation and Adaptation Strategies for Global Change 22 427–446
[7] Nguyen PT, Matsui Y 2009 Asian J Energ Environ 10 35–52