The Effect of Urbanization on Temperature Trend in Some Regions across Vietnam during the Past Decade

Ha Thi Thu Pham and Toan Kim Tran

Abstract—Throughout time and history, urbanization has proven itself to be a significant impact on climate in urban areas. In this study, we investigate urbanization effect on temperature trends in several regions across Vietnam based on statistical relationship between these trends and local population growth as well as the change in the annual mean temperature in the past decade by applying statistical analysis to the results. Population data from 2008-2018 and the temperature data from 1988-2018 were obtained from the Annual Abstracts of Statistics and the Institute of Hydrology and Meteorology Science and Climate Change, respectively. Although most of our findings indicate a very small correlation between temperature rise and local population growth, there were exceptions with reasonable values. The results suggest that urbanization contributes to the change in temperature trend of different regions. The type of region (based on its population) also determines if the change in temperature is positively or negatively correlated with the population growth. Furthermore, by using ArcMap, we also constructed several surface temperature maps in the past few decades in order to gain further insights into how temperature changed with time.

Index Terms—Climate, mean temperature trend, population growth, urbanization.

I. INTRODUCTION

The importance of urbanization to the continuous development of a country had long been acknowledged [1], [2]. However, urbanization is a long process which, if handled wrongly, could result in negative changes that greatly affect the life of people and the environment. This is especially true for developing countries that had gone through urbanization in recent times, as they are now facing an increasing amount of extreme weather events or altered climate pattern [3], [4].

It is generally accepted that urbanization tends to correlate with an increase in temperature. This is mostly observed by people and scientists in developing countries [3], [4]. However, there are instances where researches and reports indicate signs of inconsistency or even contradiction [5]. For example, in the same country, the effect of urbanization on the air temperature could be positive in a city but negative in another. There are many reasons to these contradictions, such as the urbanization effect in a country having a lesser impact on an area than the others, outside factors, or even because some data were incompletely written. Nevertheless, it is mostly agreed upon that the process of urbanization can greatly affect the environment and thus, the temperature [1].

Ever since the renovation process after the war, Viet Nam had been undergoing urbanization with the goal of fostering economic development. In 2000, it was decided that efforts would be made in order to transform agricultural lands into urban lands. The purpose of this process was to improve the economy, industry and build better living areas for the citizens [6]. However, there were trade-offs in the form of urban poverty, pollution and public unrest, especially in smaller urban areas less equipped to address these problems [7]. Thus, it is crucial to learn more about how urbanization could directly and indirectly affect various aspects of life in Vietnam, which led to the creation of many researches about Vietnam’s urbanization process and how it affects the country’s economy, people or its infrastructures [8], [9]. However, there is a lack of studies regarding the relationship between Vietnam’s urbanization process and its environment, or more specifically, the changing temperature due to the rapid urbanization. The few studies that address the correlation, on the other hand, only limit their findings on one or a few specific regions and not cover a wide range of areas across the country [10]. Thus, these findings might not apply to the entirety of Vietnam itself. And so, it is necessary that there are more researches about how urbanization can affect the temperature trend of the majority of Vietnam, especially when similar researches around the world have proven to an extent that there is a link between the area undergoing urbanization and the temperature surrounding it [11].

In this study, we will examine the urbanization effect on recent changes in temperature over many regions across Vietnam by assuming that urbanization is proportional to population growth. The paper is structured as follows: Data utilized are described in Section II. The effect of urbanization on temperature trend is examined in Section III. Section IV provides a brief summary and discussion.

II. MATERIALS AND METHODOLOGY

In order to determine the degree of urbanization, we used population data as its growth could make a good indicator. Population data from 2008-2018 were obtained from the Statistical Yearbook of Vietnam in the 2018 of General Statics office [12]. On the other hand, climatic data from 1988-2018 were provided by the Institute of Hydrology and Meteorology Science and Climate Change, these include daily mean temperature, maximum temperature and minimum temperature [13]. They were then analyzed alongside the linear trend for the 10-year period (2008-2018) to determine the changes in weather patterns.
There are many indicators that can be used to determine urbanization growth, such as fertility rate, economic growth, traffic density, etc... In this study, population growth was selected as an assessment indicator of urbanization. We chose 20 regions across Vietnam (Thai Nguyen; Dong Da; Ha Dong; Viet Tri; Tam Ky; Da Lat; Bao Loc; Son Tay; Ba Vi; Hoai Duc; Duc Trong; Dong Xoai; Bac Me; Hoang Su Phi; Dinh Hoa; Phu Tho; Tam Dao; Bac Ha; Ba To; Phuoc Long). Data from these regions were chosen based on availability of the population and the corresponding station data. However, about half of the corresponding stations fall under rural category, so a simple averaging over the 20 stations might not reflect closely the urbanization effect. Therefore, we divided the 20 stations into four groups to better determine the effect of urbanization on temperature. This grouping is similar to the one used in the study by Kug and Ahn [11]. The definition of the groups and stations are listed in Table 1.

Statistical analysis was used in this research in order to describe the nature of the analyzed data, explore the relation of the temperature data to the underlying population as well as creating models to summarize the relationship between the temperature data and the underlying population. Meanwhile, ArcMap helped us view, edit, create and analyze geospatial data. The surface temperature maps drawn with ArcMap show the changes in the annual mean temperature over space and help describe the large-scale weather patterns across a region during different periods in time, thus providing us with insights on how to further analyze our findings.

### TABLE 1: DEFINITION OF GROUPING AND STATIONS

<table>
<thead>
<tr>
<th>Group</th>
<th>Definition</th>
<th>Regions</th>
<th>Corresponding stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metropolitan city</td>
<td>Metropolitan cities</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Medium city</td>
<td>greater than 300,000 people in 2018</td>
<td>Thai Nguyen; Dong Da; Ha Dong</td>
<td>Thai Nguyen; Lang; Ha Dong</td>
</tr>
<tr>
<td>Small city</td>
<td>greater than 100,000 people in 2018</td>
<td>Viet Tri; Tam Ky; Da Lat; Bao Loc; Son Tay; Ba Vi; Hoai Duc; Duc Trong</td>
<td>Viet Tri; Tam Ky; Da Lat; Bao Loc; Son Tay; Ba Vi; Hoai Duc; Lien Khuong</td>
</tr>
<tr>
<td>Countryside</td>
<td>less than 100,000 people in 2018</td>
<td>Dong Xoai; Bac Me; Hoang Su Phi; Dinh Hoa; Phu Tho; Tam Dao; Bac Ha; Ba To; Phuoc Long</td>
<td>Dong Xoai; Bac Me; Hoang Su Phi; Dinh Hoa; Phu Tho; Tam Dao; Bac Ha; Ba To; Phuoc Long</td>
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III. RESULTS

A. Population Change due to Urbanization

Fig. 1 depicts the correlation between the number of population in 2018 and population growth of 2008-2018. At a glance, the population in all regions is shown to increase with time. However, areas with a higher population size tend to have a larger growth. Thus, we can safely assume that the growth of a region’s population is closely linked to its own population size. The correlation is around 0.85, which is very significant. All in all, the results indicate that we could safely consider population growth to be an estimation of the urbanization effect.

B. Temperature Change due to Urbanization

We drew graphs which only denoted the 20 stations and one region type (medium, small or countryside) in order to determine the effect of urbanization on said group personally while excluding the effects of the other two. Fig. 2 and 3 show the relation between population growth and annual mean temperature trend as well as the mean temperature trend of different seasons in the recent 10 years. The annual correlation coefficient for all 20 stations is 0.53 while the annual slope statistically indicates that adding every thousand people in a limited region could lead to a temperature increase of 0.005°C during the 10 years. Despite the correlation coefficient only being average, it could nevertheless offer valuable input to the relation between the two variations. It is suggested that more urbanization usually leads to a rise in temperature.

![Graph](image)

**Fig. 2. Relation between the population growth and annual mean temperature trend.** Blue and red lines denote linear regressions for the 20 regions (blue dots) and the 8 regions (red dots) categorized as “small city”, respectively.

It is noteworthy that Thai Nguyen – the region determined as a “medium city” with the second largest population growth in 10 years, is located below the slope (blue line). Meanwhile, Ha Dong – the medium city with the largest growth, is located above the line. Based on our understanding, this might stem from its expansion during the urbanization process during the period of 2008-2018. For example, the area of Thai Nguyen in 2016 was 170 km², which then shot up to over 222 km² the following year due to the merging of surrounding lands. This also brought about a huge increase in the population size. Thus, this might make the calculation for the urbanization effect not completely correct due to data of different variations not being updated correctly, especially in regions where the urbanization process is progressing rapidly. Of course, there could also be other factors, such as regional...
topography and climate or the effectiveness of urbanization being lowered when the size of the population exceeds a certain threshold.

Fig. 2 shows that the small cities’ annual mean temperature trend increased by 0.0258°C/10 years with every population growth of one thousand people during the period of 2008-2018. This is larger than the trends for all 20 stations, medium cities and countryside regions. Its R-squared value is also considerably large, at 62%. Thus, the differences between the observed data and the fitted values could be neglectable, which helps to confirm the relation between the temperature trend and population growth. The R-squared value for small cities in different seasons from Fig. 3 is also quite high, except in autumn and winter. In general, temperature trends have a positive relation with population growth and the highest value is in spring. Although all four seasons show a rise in mean temperature trend, this value differs. This could indicate that the urbanization effect varies with seasons.

![Graph](image)

**Fig. 3. Relation between the population growth and mean temperature trend in (a) spring, (b) summer, (c) autumn and (d) winter. Blue and red lines denote linear regressions for the 20 regions (blue dots) and the 8 regions (red dots) categorized as “small city”, respectively.**

<table>
<thead>
<tr>
<th>TABLE II: CORRELATION AND LINEAR REGRESSION COEFFICIENT BETWEEN TEMPERATURE TREND AND POPULATION GROWTH FOR THE RECENT 10 YEARS (2008-2018) IN 20 REGIONS OF VIETNAM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Correlation</strong></td>
</tr>
<tr>
<td>All 20 regions</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Annual</td>
</tr>
<tr>
<td>Spring</td>
</tr>
<tr>
<td>Summer</td>
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<tr>
<td>Autumn</td>
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<td>Winter</td>
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It can be observed that the slope of each group show different changes depending on the season. Medium cities’ annual temperature rises slightly; small cities have their mean temperature increased throughout the year and in different seasons; countryside regions have their mean temperature decreased throughout the year and in different seasons, except in winter. Furthermore, the mean temperature trend of small cities displays a clear, positive relation with population growth. This value is strongest in spring and summer then quickly drops in autumn and spring. The same pattern could also be applied for the correlation and slope of 20 regions. The correlation of medium cities and countryside regions are
smaller than the correlation of 20 regions, except in autumn. Thus, the relation between mean temperature trend and population growth for the two groups can only be approved in autumn.

Aside from mean temperature trend, we also compare the differences between annual mean temperature, maximum temperature as well as minimum temperature in 1988, 1998, 2008 and 2018 in order to gain a better understanding of their changes (Fig. 5). In general, the graphs for annual mean temperature, maximum temperature and minimum temperature show similar patterns. There is a disparity between the average temperature of 1988-1998 as well as 2008-2018. The majority of the regions that have a large population size also have a bigger margin compared to those with fewer people. For example, station 1, 2 and 3 belong to “medium city” group and their corresponding regions have the largest population size and the widest margin. However, the size of a population alone does not determine how high or low the average temperature of a region is. There are many factors involved, which is why in addition to the population, we also compare the region type (based on population), region area, population growth (2008-2018) and population density in 2018. From the results, it can be said that a combination of several factors above, when reaching a high value, would simultaneously signify a high temperature. Of course, there are also exceptions since urbanization is not only affected by population.

In order to determine the temperature pattern during the past few decades, we built temperature maps of 1988, 1998, 2008 and 2018 using the annual mean temperature data of the 20 stations mentioned above plus 8 other local stations (Fig. 6 to 9). The maps cover 11 provinces across Vietnam with each belongs to either Northern, Central or Southern Vietnam. In Northern Vietnam, there are 18 stations in Ha Giang, Lao Cai, Thai Nguyen, Phu Tho, Vinh Phuc and Hanoi provinces. In Central Vietnam, there are 8 stations in Quang Nam, Quang Ngai, Dak Nong and Lam Dong provinces. In Southern Vietnam, there are 2 stations in Binh Phuoc province.

From the maps constructed, it is observed that areas from neighboring provinces which have a large population are more likely to have a higher annual mean temperature compared to those with a smaller population. This trend is most prevalent in stations from Northern and Central Vietnam compared to those from the south. The annual mean temperature from areas in Southern Vietnam (ranges from 25.6 to 27.3 °C) is markedly higher than that in Northern and Central Vietnam (ranges from 14.5 to 25.1 °C and 18.0 to 26.7 °C, respectively). While geography is one of the main reasons for said change in annual mean temperature, population density also plays a crucial role as the surroundings of areas with a high population density are much hotter than those scarcely populated and vice versa. This phenomenon appears in all of our temperature maps, which supports our previous results and conjectures.

The pattern of temperature change during the 1988-1998 period is similar to the 2008-2018 period with the annual mean temperature of 1998 being higher than that of 1988 and the annual mean temperature of 2018 being higher than that of 2008. This could suggest that there is a ten-year temperature cycle with the last few years in said cycle being hotter than the starting years. Furthermore, we also compared the global temperature maps in 2008 and 2018 from “NASA Global Climate Change: Vital Signs of the Planet” [14] to better observe the change in temperature trend in Vietnam.
All in all, Vietnam’s temperature has risen markedly over the decades.

Fig. 6. Annual mean temperature maps (°C) of research areas in 1988: (a) Northern Vietnam and (b) Central and Southern Vietnam.

Fig. 7. Annual mean temperature maps (°C) of research areas in 1998: (a) Northern Vietnam and (b) Central and Southern Vietnam.

Fig. 8. Annual mean temperature maps (°C) of research areas in 2008: (a) Northern Vietnam and (b) Central and Southern Vietnam.

Fig. 9. Annual mean temperature maps (°C) of research areas in 2018: (a) Northern Vietnam and (b) Central and Southern Vietnam.
IV. CONCLUSION

In this study, we examined the urbanization effect on recent changes in temperature over many regions in Vietnam by assuming that urbanization is proportional to the population growth. The results show that the mean temperature trend corresponds to an increase in population size, which is consistent with previous studies [10], [11]. This is most prominent with areas categorized as a “small city” where the population ranges from 100,000 to 300,000 people. Other data, such as annual mean temperature, maximum temperature and minimum temperature disparity were also analyzed alongside surface temperature maps. When we compared the average temperature disparity during the periods of 1988-1998 and 2008-2018, it was shown that highly populated regions tended to have a higher temperature difference compared to those with a small population. However, once the population size went down to a certain degree, other factors such as population growth or population density would influence the temperature disparity. Furthermore, the annual mean temperature of neighboring regions from Northern, Central or Southern Vietnam was observed to closely correlate with their population density. Our findings have achieved certain results, but in order to assess the effect of urbanization on temperature trend in Vietnam more completely, it is necessary to carry out further researches that take into account a wider variety of urbanization indicators.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

H.T.T.P—conceptualization and methodology; T.K.T and H.T.T.P—resources and investigation; H.T.T.P and T.K.T – formal analysis; T.K.T and H.T.T.P – writing (original draft preparation); H.T.T.P (review, editing); H.T.T.P and T.K.T (visualization); All authors had approved the final version.

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REFERENCES


Ha Thi Thu Pham was born in Hanoi, Vietnam. Her background is environmental science. She obtained her master’s degree in human ecology from the Free University of Brussels, Belgium in 2002 and successfully defended the doctoral dissertation in environment and sustainable development in 2014 at Vietnam National University, Hanoi. She has over 15 experience years in environmental researches. She is an experienced scientist in the fields of climate change, air and water environment, environmental modeling, urban environmental ecology. She has deep expertise in acid deposition, especially assessing its impacts on aquatic and terrestrial ecosystems as freshwater, agricultural ecosystems. She has published many articles in the prestigious international and domestic journal in the environmental fields.

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