



Analysis of Spatial Distribution Patterns of Non-Communicable Diseases (NCDs) and Risk Factors with GIS in Central Regions of Thailand

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Abstract

Non-communicable diseases (NCDs) are leading causes of mortality in Thailand, representing 74% of all deaths. Behavioral, social and environmental issues are the primary drivers contributing to the increasing incidence of NCDs across Thailand. This study aimed to examine the spatial distribution trends of hypertension, diabetes, and coronary heart diseases in Thailand using Geographic Information System (GIS) techniques, including Inverse Distance Weighting (IDW), clustered analysis with local Moran's I and bivariate correlation analysis, to identify associations with urbanization, demographic aging, and environmental exposure. The consolidation of national health statistics, demographic and environmental datasets, applied spatial interpolation (IDW) and correlation analysis examined the relationship between the prevalence of NCDs and risk factors. As a result, the highest concentration of NCDs was observed in Bangkok Metropolitan Regions (BMR) and industrial corridors, while coastal areas showed decelerated rates of increase based on the result of spatial distribution pattern and clustered analysis. And the most severe air pollution occurred in winter season therefore the government should focus on the tackle of air pollution affected on the community in this season, especially in the Mueang Samut Songkhram, Mueang Ratchaburi, Mueang Phetchaburi, Mueang Supanburi, Mueang Samut Sakhon Districts and Saraburi Province. From correlation results, hypertension and diabetes prevalence showed a strong positive correlation with urbanization and aging population density, while no significant correlation was found with PM_{2.5} exposure and income. Therefore, this study can support the recommendations of prioritization provinces and districts in the cases of NCDs control and prevention. By combining GIS and spatial statistical analysis on health data, it would be helpful to expose the relationship of NCDs risk factors and beneficial to policy makers in decision making of prevention and surveillance NCDs.

Keywords : NCDs; risk factors; spatial statistical analysis; Local Moran's I; GIS

Introduction

Non-communicable diseases (NCDs) are a kind of chronic disease that derives from genetic, physiological, environmental and behavioral factors. According to the statistical data of WHO, 41 million people died every year due to NCDs [1]. NCDs such as cardiovascular diseases, chronic obstructive pulmonary diseases, diabetes, and cancers are leading causes of mortality in Thailand, which is 400,000 deaths each year, referring 74% of all deaths nationally. The risk factors – tobacco use, harmful alcohol consumption, unhealthy diets, physical inactivity and environmental pollution are the primary drivers contributing to the increasing incidence of non-communicable diseases (NCDs) across Thailand [2]. The Thai Health Report 2023 indicated that Samut Sakhon, located in the Central Region of Thailand, is among the provinces with the lowest percentage of adequate physical activity, with only 25.4%. Air pollution is the most significant factor, causing 6.7 million deaths worldwide, with around 5.7 million of these due to NCDs [3]. Besides air pollution, solid and hazardous industrial wastes continue to be a challenge across Thailand. The highest levels of hazardous industrial waste were found in provinces with significant industrial activity, such as Rayong, Chonburi, and Samut Prakan [3]. Addressing NCDs issues as urgency, 2030 Agenda for Sustainable Development identified NCDs as a significant obstacle to sustainable development. By 2030, one third of premature mortality from non-communicable diseases will be reduced through prevention and treatment and promote mental health and well-being [4]. As a literature review, Nawamawat et al. (2020) examined the prevalence and behavioral risk factors of NCDs in a semi-urban Thai community, identifying significant associations with demographic and lifestyle variables. However, the limited geographical scope and small sample size underscored the need for broader spatial analyses to inform targeted public health strategies [5]. Laohasiriwong et al. (2018) utilized Night-Time Light (NTL) data and spatial association techniques to understand hypertension hotspots across Thailand's 76 provinces, revealing strong spatial clustering in urban areas such as Bangkok. But the study did not explore underlying environmental determinants and integration with

other diseases, indicating a gap for more comprehensive spatial analyses, especially air pollution [6]. Based on the existing gaps in the literature, Regional Health Zones 4, 5, and 6 among 13 Regional Health Zones divided by the Ministry of Public Health were selected for this study based on their geographical positions, socio-environmental characteristics, and the availability of health, social, and environmental datasets across all provinces. Each zone contains 8 provinces, therefore sufficient data in 24 provinces including 201 districts for 3 zones were captured to explore spatial patterns in NCD prevalence. This study aimed to analyze spatial distribution patterns of NCDs including coronary heart diseases, hypertension and diabetes across 24 provinces (201 districts). And risk factors such as air quality, landuse and demographics associated with prevalence of NCDs at district level were assessed and correlation and clustered analysis between NCDs and related factors were applied to detect and explore the relationships of diseases and factors. Surveillance, in the healthcare industry, of the diseases and conditions that are significant public health threats is necessary for the development of healthy communities. GIS can track patient demographics and where the source of diseases began and spread. It can also help state and local governments understand the condition of a public health emergency, predict its movement to inform resource deployment and monitor processes and outcomes [7]. GIS can provide a conceptual framework for understanding the geographic variability of diseases and health. To effectively control NCDs transmission, it's crucial to prioritize regions with the high incidence of NCDs by applying GIS tools. Based on this analysis, policymakers and health authorities could strategically execute the control plan of NCDs and devote resources to strengthen NCDs prevention and control activities from the perspective of environmental and health science.

Methodology

The yearly incident data of NCDs - Coronary Heart Diseases, Hypertension and Diabetes which occurred in the Regional Health Zone 4, 5 and 6 as shown in Figure 1 were collected from the Ministry of Public Health for 5 years spanning 2019 to 2023 [8]. These data were compiled and verified national

health data reports, ensuring the reliability and representativeness of the health outcomes used in this study. The social data including total population, age group and number of hospitals were also downloaded from the Ministry of Public Health for the year 2023. And income data was collected from the Community Development Department (CDD). For environmental factors, the updated landuse data for each district between 2019, 2021 and 2023 was downloaded from Land Development Department (LDD), which updated its datasets based on survey of the provinces [9]. As the changes of landuse occur slowly, the updated frequency was deemed appropriate for the scope of this analysis. As well as the daily $PM_{2.5}$ data in 2023 from fixed ground-based monitoring stations were collected from the Pollution Control Department (PCD). As initial state, the social data – total population, age, number of hospitals and income were manipulated to be useful and applicable in ArcGIS by data cleaning, sorting, filtering and joining. For $PM_{2.5}$ analysis, the locations of $PM_{2.5}$ monitoring stations and the daily $PM_{2.5}$ value across stations were obtained from Air4Thai for year of 2023 [10]. There are 34 monitoring stations in Regional Health Zone 4,5 and 6. Data for each station was gathered on a daily basis, although there were gaps in some data points. The $PM_{2.5}$ concentrations for 31 days in January were added up and the result was divided by 31 to determine monthly average $PM_{2.5}$ for January. And similar method was used to convert into monthly data in the following months. Of the two monthly data stations, 21T station in Samut Prakan Province has no January data while 84T station in Supanburi Province was also missing data for February. For that, the IDW calculation method was applied to more accurately calculate missing value. The 2023 annual data was calculated by totaling the 12-month data from each monitoring station and dividing that total by 12 after obtaining monthly data for all stations. Once the process of data preparation was completed, the monthly and annual point value of $PM_{2.5}$ were converted into polygon value with IDW interpolation and zonal statistics in ArcGIS, enabling an estimated pollution value for each district. The reason for choosing IDW interpolation method was due to

its computational simplicity, suitability for datasets, evenly distributed monitoring points and calculation of concentrations at unsampled locations based on the weighted average of nearby monitoring points. Unlike Kring and Spline methods, IDW focuses on the influence of closer observations which allow for continuous surface that reflects localized variations in air pollution levels. Furthermore, the landuse was classified into 5 classes – Agriculture, Forest, Urban, Water and Miscellaneous to identify the influenced land area in the study area. After getting all data at the district level, the spatial distribution pattern of diseases and related factors was evaluated in order to understand the distribution pattern across districts. And then, the correlation analysis was conducted to find the relationship between them by using SPSS. If the data were statistically correlated with each other, the clustered analysis with Local Moran's I was carried out to investigate the specific districts of high and low prevalence rate of diseases and other factors.

Results and Discussion

The rates of non-communicable diseases (NCDs) between 2019 and 2023, as shown in Figure 2, have shown a simultaneous increase in the cases of diabetes and hypertension and minimal gradual increase in coronary heart disease. Cases of hypertension increased from 13,000 in 100,000 population in 2019 to 15,000 in 2023. Likewise, diabetes was set to increase from around 6000 to 7500 per 100,000 population. While 3 diseases revealed a steady upward growth in the prevalence of NCDs for 5 years, the most widespread disease was in hypertension cases and coronary heart diseases remained the lowest occurrence. These trends could potentially be caused by several factors such as more sedentary lifestyles, diet, lack of physical exercise associated with urbanization, and an aging population. Understanding these drivers helps the public health system to take relevant action. The data for all factors in this study was done through 2023 due to lack of multi-year environmental and social information. Trend analysis was only used for prevalence of NCDs from 2019 to 2023. As the temporal changes on environmental and social risk determinants could not be fully captured, this

limitation may impact on the findings. Certain urban districts - particularly Mueang Samut Prakan, Mueang Nonthaburi and Mueang Nakhon Pathom – should be focused on further study as these districts contributed to the rise of hypertension and diabetes cases throughout five-year period. These regions both included high baseline prevalence and showed a steady yearly rise, suggesting a growing burden of NCDs.

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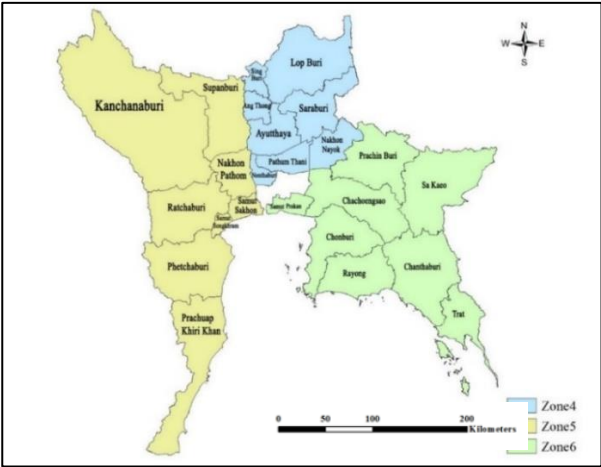


Figure 1 Locations of Regional Health Zone 4, 5 and 6

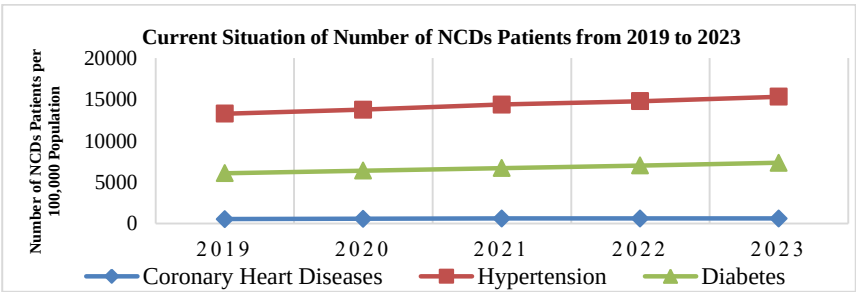


Figure 2 Current Situation of NCDs Prevalence from 2019 to 2023

Spatial Distribution Analysis

The spatial distribution patterns revealed that the lighter to darker color of the regions can be defined as the pattern of lowest to highest value of maps, except map (f) and (g) in Figure 3. The map (f) was illustrated as the graduated symbol of the pattern, showing the biggest circle of a huge number of hospitals and smallest circle directing the minimum number of hospitals. And the map (g) was described the classification of landuse; agriculture with yellow color, forest showing green color, miscellaneous referring brown color, urban highlighting with red color and water body with blue color. As result of the analysis, the distribution pattern of coronary heart diseases, hypertension and diabetes showed that a significant number of patients were highlighted with the darkest color, suggesting regions with greater prevalence of NCDs. The highest severe affected NCDs have been widespread in Mueang Nonthaburi District with 4,015 coronary heart diseases patients and Mueang Samut Prakan District with 42,690 patients and 23,049 patients who suffered hypertension and diabetes respectively. Among 3 diseases, the high prevalence rate of hypertension and diabetes were nearly identical in shown in map (b) and (c), especially in these provinces: Nonthaburi Province in Zone 4, Ratchaburi, Samut Sakhon and Nakhon Pathom Provinces in Zone 5 and Chonburi, Samut Prakan and Rayong Provinces in Zone 6. Combined with landuse applications, the red color of urban areas mostly occurred in these provinces. It proved that the provinces in Thai Health 2023 report [3] as having the highest levels of hazardous industrial waste were definitely same with the provinces of highest prevalence NCDs rate in Zone 6. When the lowest prevalence rate of NCDs across the provinces and districts were analyzed, Ko Kut District in Trat Province is the lowest patients for all 3 diseases, showing the coastal regions suffering low incidence case of NCDs. And the findings from the urban density and total population maps were that the dark red regions of urban density absolutely aligned with the some of the dark green regions of total population, showing that areas with high total population occupied high urban-density area. The significant volume of total population was found in Mueang Nonthaburi District with 371,899 people having

the highest urban area density. Land use patterns play a significant role in shaping the spatial distribution of non-communicable diseases. Urbanization often leads to reduced physical activity, increased air pollution, and limited access to green spaces, all of which are linked to higher risks of hypertension and diabetes. Similarly, lack of forest areas around BMR may limit opportunities for recreation areas and stress reduction, contributing to adverse health outcomes. For hospital mapping, larger circles represented the districts with more hospitals including rural and sub-district areas. The highest number of hospitals with 37 hospitals in total can be found in Mueang Nakhon Pathom District, indicating most hospitals were found in places where NCDs were most prevalent. For the social factors, the highest income level was in Khao Khitchakut District, Chanthaburi Province with 501,573 baht annually, showing a low prevalence rate of NCDs in high-income region. From the environmental point of view, another indicator of 2023 $PM_{2.5}$ pattern highlighted regions with high $PM_{2.5}$ concentrations, particularly in Phraphutthabat District, Saraburi Province with the highest level of $30.686 \mu\text{g}/\text{m}^3$, where transportation and agricultural burning can be contributed to poor air quality. The lowest $PM_{2.5}$ levels with $16.325 \mu\text{g}/\text{m}^3$ was observed in Mueang Trat District which is near coastal areas, resulting in fewer pollution sources. Finally, the spatial distribution patterns of NCDs and risk factors can be pointed out that the most widespread distribution pattern mostly happened in Mueang (City) of the districts and Nonthaburi, Ratchaburi, Samut Sakhon, Nakhon Pathom, Chonburi, Samut Prakan, Rayong and Saraburi provinces should be focused on handling of NCDs controlling process based on the results of spatial distribution pattern.

Additionally, $PM_{2.5}$ is one of the critical environmental factors influencing the patterns of NCDs. According to the air pollution concentration equivalent to Air Quality Index (AQI) defined by PCD, the range of $PM_{2.5}$ (0 to $15 \mu\text{g}/\text{m}^3$) defined with blue color code which is showing excellent level of very good air quality, followed by 15.1 to $25 \mu\text{g}/\text{m}^3$ with green color of defining satisfactory for good air quality, 25.1 to $37.5 \mu\text{g}/\text{m}^3$ with yellow color with moderate level of air quality, 37.6 to 75

$\mu\text{g}/\text{m}^3$ with orange color of indicating unhealthy air quality and above $75.1 \mu\text{g}/\text{m}^3$ with red color which is mentioned to avoid outdoor activities and wear masks due to very unhealthy air conditions [10]. The monthly distribution pattern of $\text{PM}_{2.5}$ value in 2023 showed the same defined value of AQI value in Figure 4. It revealed that the $\text{PM}_{2.5}$ value captured during January, February, March,

April and December in 2023 exceeded the standard value of $37.5 \mu\text{g}/\text{m}^3$, covering the orange color in most districts in the maps. In the remaining months, monthly $\text{PM}_{2.5}$ value captured the low value which was below the standard number of $37.5 \mu\text{g}/\text{m}^3$. Therefore, further analysis was carried out in 5 months which were over the standard limit of AQI.

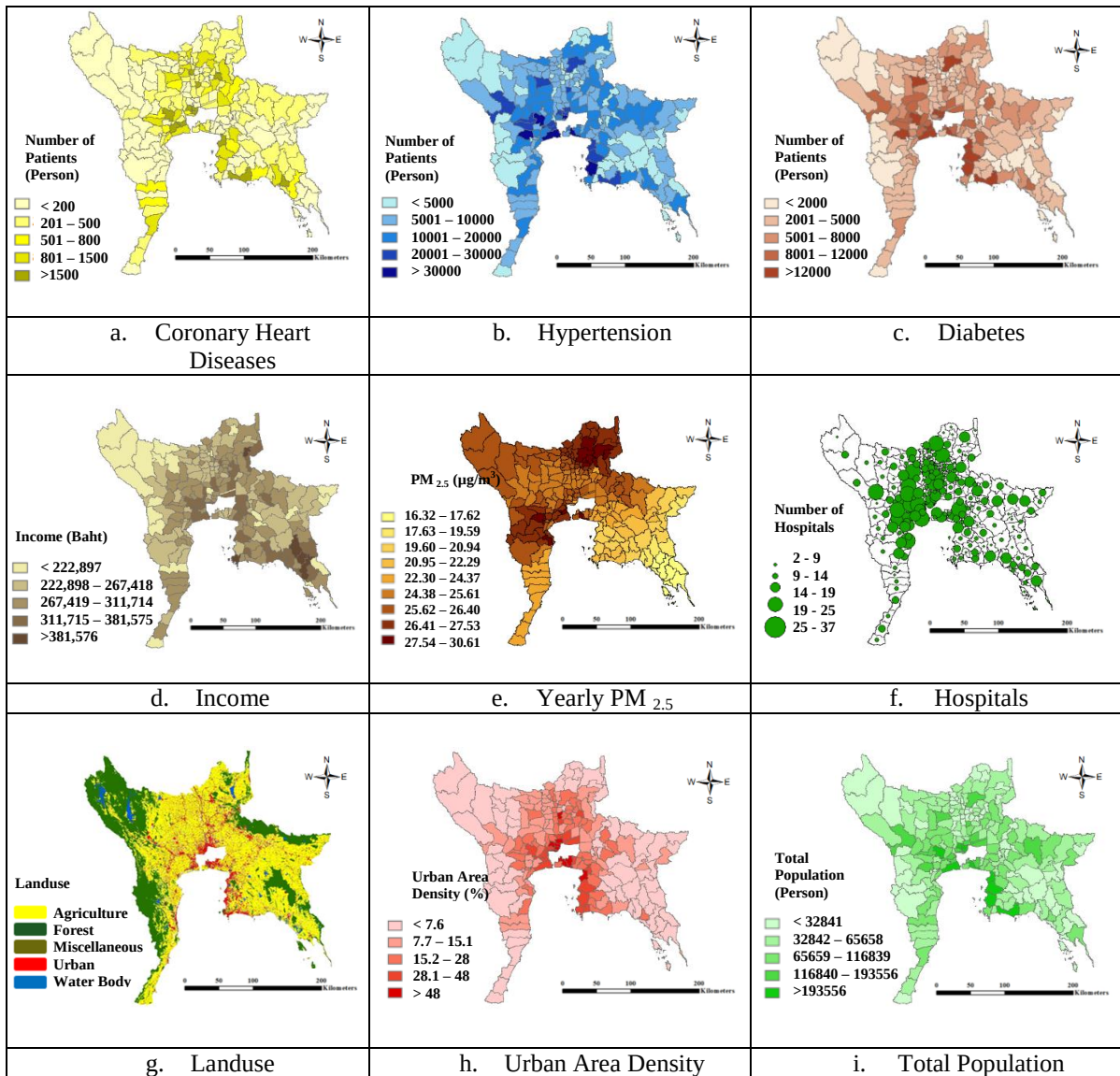


Figure 3 Maps of Spatial Distribution Patterns of NCDs and related Factors in 2023

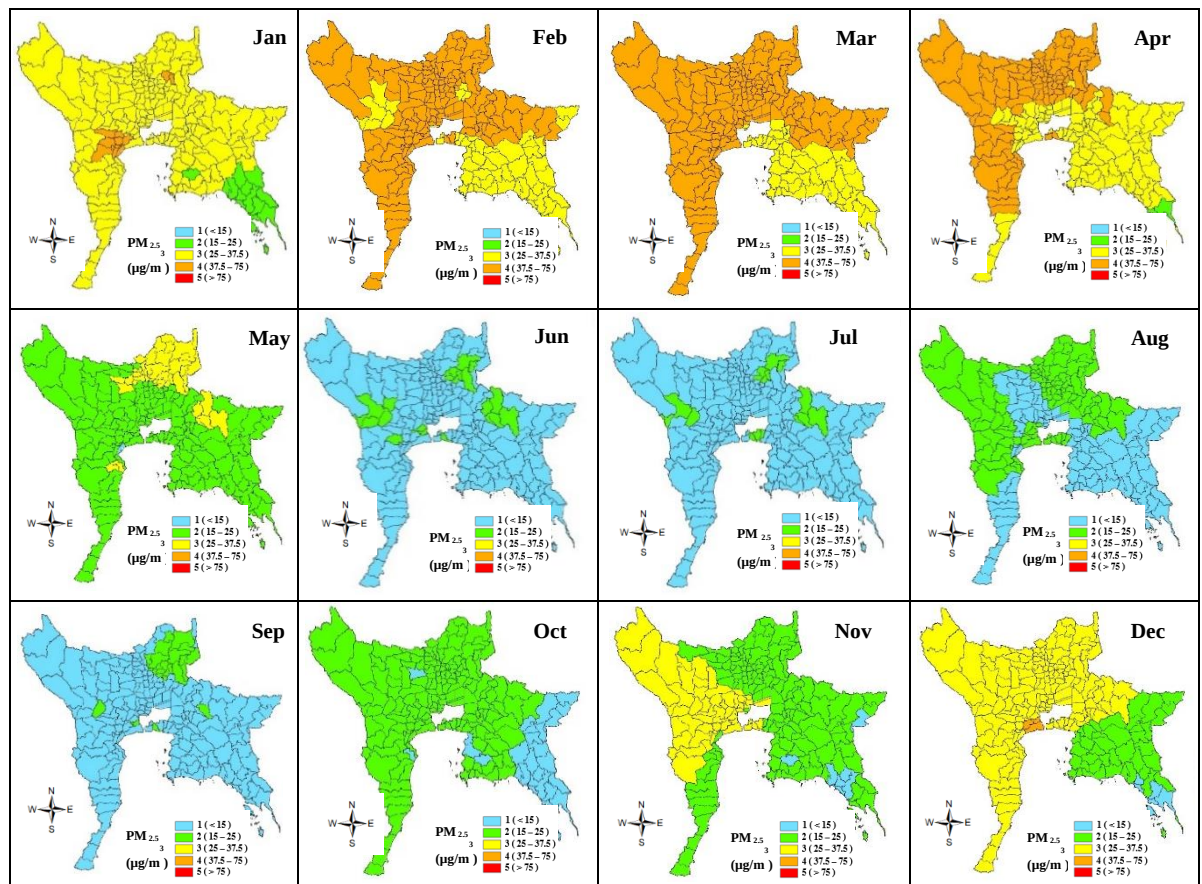


Figure 4 Maps of Spatial Distribution Patterns of Monthly $PM_{2.5}$ Value in 2023 according to AQI of PCD

The maps of spatial distribution patterns of $PM_{2.5}$ across (January, February, March, April and December) in 2023 by using IDW method were illustrated in map (a). High concentrations of $PM_{2.5}$ were shown in red while low concentrations were displayed in blue color. From IDW mapping, the worse air quality with red color occurred in some specific regions. The highest concentrations of $PM_{2.5}$ were observed in Ratchaburi, Phetchaburi, and Saraburi provinces during January to March, as indicated by red and orange pollution levels. In April, pollution levels shifted toward Suphanburi, Phetchaburi, and Kanchanaburi provinces, while in December, $PM_{2.5}$ concentrations were predominantly concentrated in Samut Sakhon, Kanchanaburi, and Ratchaburi provinces. When the months which received severe air contamination were identified, the air pollution levels which are above the standard limit of $37.5 \mu\text{g}/\text{m}^3$ mostly happened in the months of February, March and April. In addition, the $PM_{2.5}$ values were classified into 9 classes (from 19 to $55 \mu\text{g}/\text{m}^3$) to

highlight the specific regions where suffered the worst air pollution across the months as shown in image (b). When the spatial distribution patterns of $PM_{2.5}$ in January were analyzed, it was observed that the hazardous air pollution level over $37.5 \mu\text{g}/\text{m}^3$ was recorded in Mueang Samut Songkhram District at $45.27 \mu\text{g}/\text{m}^3$. In February, Mueang Ratchaburi District obtained the highest polluted level of $49.55 \mu\text{g}/\text{m}^3$. Notably, Mueang Phetchaburi District recorded the highest values in March with $58.13 \mu\text{g}/\text{m}^3$ and in April, the highest air quality of $51.51 \mu\text{g}/\text{m}^3$ was reached in Mueang Supanburi District. In December, Mueang Samut Sakhon District experienced the region which affected the most air pollution with $41.29 \mu\text{g}/\text{m}^3$. Therefore, the peak air pollution which causes unhealthy conditions for the community mostly occurred in winter season and Mueang Districts of Samut Songkhram, Ratchaburi, Phetchaburi, Supanburi and Samut Sakhon in Zone 5 were significantly polluted the worse air concentrations among districts as illustrated in Figure 5.

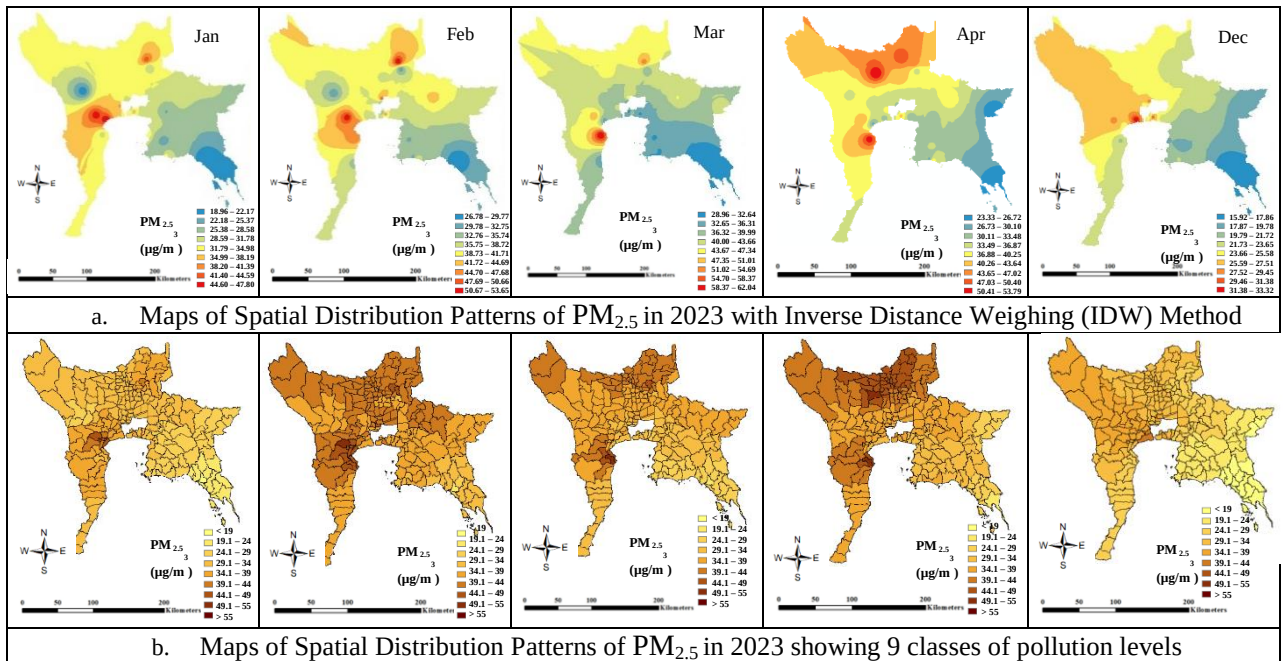


Figure 5 Maps of Spatial Distribution Patterns of PM_{2.5} in 2023 showing the months which are over standard value ($37.5 \mu\text{g}/\text{m}^3$)

Correlation Analysis

Once the spatial distribution pattern of NCDs and risk factors was accomplished, the specific provinces to be focused on controlling NCDs were pointed out. Continuously, the correlation analysis was conducted to analyze the range of influence and relationship between factors. Pearson's correlation coefficient was used to assess the strength and direction of linear relationships between prevalence of NCDs and variables such as urban, aging population, PM_{2.5} concentrations, income and number of hospitals. The result, with 99% confidence level with p-values less than 0.01 were considered statistically significant. The sign of correlation coefficient showed the direction of the relationship between variables and the magnitude of correlation indicated the strength of relationship. If the range is between 0.1 and 0.3, it means weak correlation. The value is from 0.3 to 0.5 which indicates moderate correlation and if it is greater than 0.5, it directs strong correlation [11]. Another study analyzed that NCDs were statistically correlated with unmodifiable risk factors which were affecting the prevalence of NCDs by surveying local population [5]. Due to this fact,

a correlation analysis was carried out to understand the influence of factors statistically. According to Table 1, the number of patients who suffered hypertension exhibited a strong and statistically significant correlation with all factors (All Age Group, Number of Hospitals and Urban Area), except 2023 PM_{2.5} pollution levels and income. Diabetes was high in correction with factors except PM_{2.5} and income also while coronary heart diseases were highly correlated with only the working age and elderly age group. According to the detailed analysis of pollution patterns, the relationship between PM_{2.5} and NCD prevalence was defined through visual spatial comparison rather than statistical analysis. Although PM_{2.5} did not show a statistically significant correlation with NCD rates in this analysis, it is recommended to consider other influenced factors such as transportation-related emissions, industries, crop burning and wind direction which may impact on the pattern of air pollution. Future research should analyze multi-year air quality data and urban traffic metrics to better capture NCDs exposure patterns and environmental health implications of NCD clustering. One of the social factors –

income was low correlated with diseases, showing that income is not a strong indicator for NCDs. The observed correlation between hypertension and diabetes with both urbanization and aging experienced the role of sedentary lifestyles, unhealthy diets, and lack of green space area which tends to increase physical vulnerability among older adults in urban areas. In contrast, the weak correlation between NCD prevalence, $PM_{2.5}$ concentrations and income levels may reflect limitations in data availability and temporal assessment. As a conclude, Hypertension and Diabetes have the highest correlations across multiple factors, indicating their strong association with both population growth and aging demographics, emphasizing the need for targeted healthcare policies in urban and aging populations.

Clustered Analysis

The clustered analysis described the spatial clustering pattern that indicated the relationship of NCDs and risk factors in the study area. The cluster mapping illustrated that High-High was specifically defined as the areas surrounded by other high value. Similarly, the areas with low values surrounded by low value were described as Low-Low. High-Low means the high areas surrounded by other low values and Low-High means the low areas surrounded by high values. In this study, High-High and Low-Low clusters were considered to define the groups of regions which were affected by NCDs and risk factors. As illustrated in Figure 6, the high-

high clusters of coronary heart diseases, hypertension and diabetes predominantly happened in the Bangkok Metropolitan Regions (BMR) - Nakhon Pathom, Samut Sakhon, Samut Prakan and Nonthaburi regions, demonstrating areas of a high prevalence of NCDs with similar spatial patterns while low-low cluster of diseases mostly occurred in And Thong, Ayutthaya, Chanthaburi, Chachoengsao and Kanchanaburi regions.

Compared to all diseases, the high-high clustered regions of hypertension and diabetes were more widespread than those of coronary heart diseases. Analyzing the factors, the clustered risk factors described that urban areas were predominantly concentrated in the BMR, Chonburi and Rayong, which corresponded to densely populated areas. Clustered populations who are less than 60 years were also similar pattern of urban density, but the High-High cluster pattern of elderly people was not found in Chonburi and Rayong. Therefore, the NCDs pattern was mostly influenced by the older people group. While certain red colors of $PM_{2.5}$ concentrations overlapped with urbanized and highly populated regions, one of the highly clustered groups of income – Chanthaburi province was found in the regions of low prevalence of NCDs, pollution and good air quality. When examining the link between diseases and risk factors, the high-high clustered pattern of NCDs (a, b and c) correlated with urban density (d) and aging communities (g, h and i) regions.

Table 1 Correlation of NCDs and Factors

Factors	Coronary Heart Diseases	Hypertension	Diabetes
Less than 16 years	0.495**	0.88**	0.89**
16 – 60 years	0.646**	0.929**	0.936**
Greater than 60 years	0.704**	0.951**	0.951**
No. of Hospitals	0.367**	0.708**	0.676**
Urban Areas	0.392**	0.742**	0.743**
2023 $PM_{2.5}$ Pollution Levels	-0.12	0.125	0.119
Income	0.223**	0.168*	0.174*

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

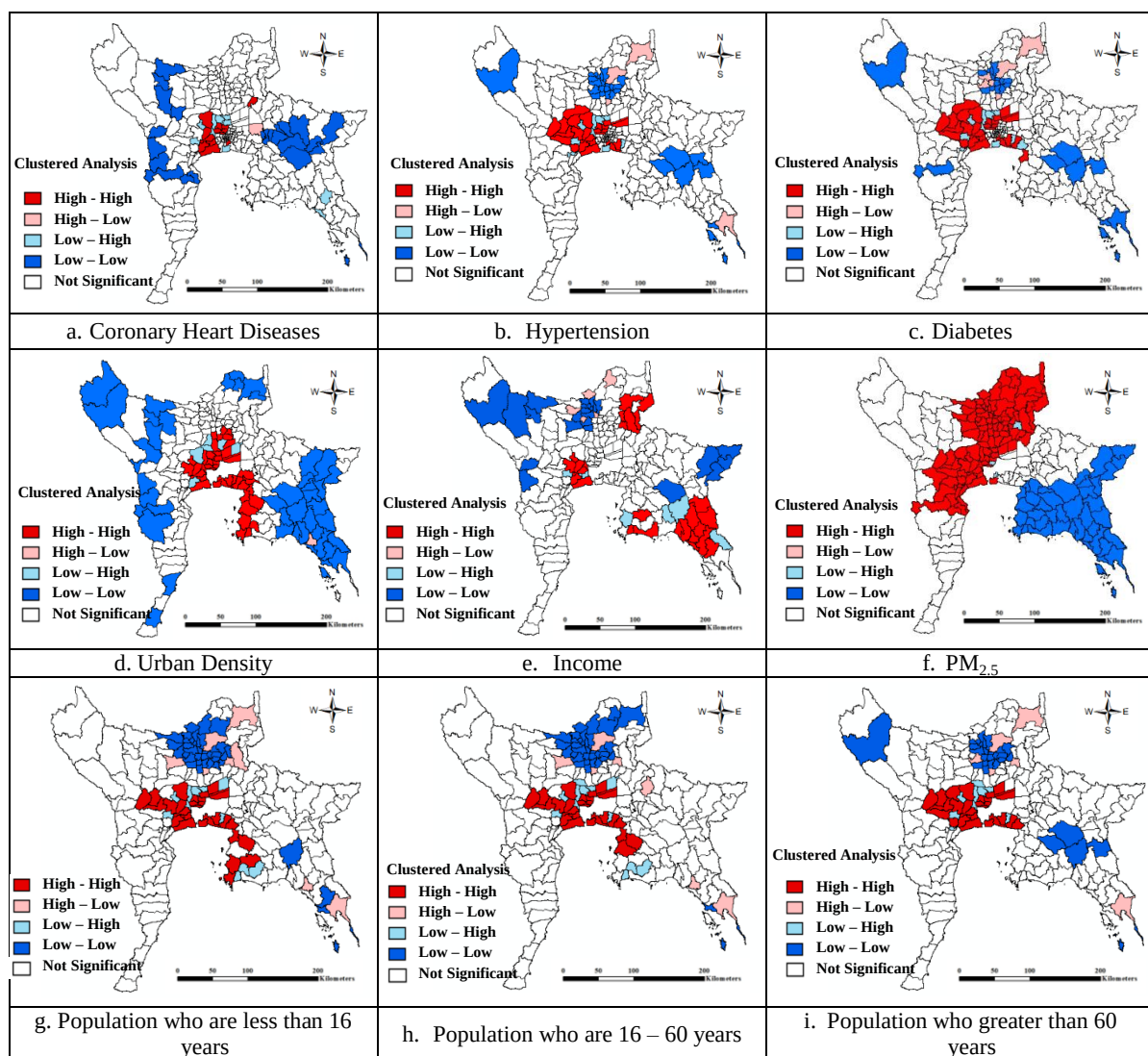


Figure 6 Maps of Cluster Analysis of NCDs and Risk Factors

Conclusions

The trend of prevalence rate of NCDs was gradually increasing so the prioritized provinces should be tackled and controlled to reduce the causes of NCDs. From this study, social factors and urban areas were mostly influenced by prevalence of NCDs and air pollution was hazardous in winter season of the year. From the findings from spatial and clustered analysis, urbanization around BMR tends to restrict green space area, leading to inadequate physical activity for aging populations which is associated with high incidence of hypertension and diabetes, therefore BMR and industrial zones should be

prioritized to support the effective action plan environmentally, socially and economically. Although the study faced limitation in temporal changes between environmental and social datasets, as well as in correlation analysis, the study highlighted the utility of GIS for identifying regions at high risk of NCDs prevalence due to intense urbanization and dense populations. By integrating spatial epidemiology with environmental and demographic data, this research provided decision-support analysis for more targeted public health strategies and reinforces the importance of spatial planning in addressing the growing burden of NCDs.

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