# Design and Development of a Geographic Information System for Mapping the Distribution of Non-Communicable Diseases Using the Agile Method

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## ABSTRACT
The prevalence of non-communicable diseases (NCDs) continues to increase and poses a significant public health challenge. The impacts include premature mortality and long-term disability. Effective monitoring and spatial analysis are needed to support timely and accurate interventions in managing NCD cases. This study aimed to design and develop a Geographic Information System (GIS) for mapping the distribution of non-communicable diseases using the Agile development method. This study employed the Agile method, which consists of six phases: requirements, design, development, testing, deployment, and review. The research utilized a mixed-method approach, combining quantitative and qualitative data, with secondary data used as the primary data source. The findings indicated a consistent spatial pattern in which heart disease, stroke, and hypertension cases tended to cluster in subdistrict centers or densely populated villages. In contrast, diabetes mellitus cases were more widely distributed across the region, including both central and peripheral rural areas. Hypertension cases were frequently located near heart disease and stroke cases. Most clusters of non-communicable diseases were found around main roads and public service centers, suggesting that residential density and accessibility are associated with the distribution of cases. However, the spread of diabetes into rural areas indicates that non-communicable diseases are not only an urban issue but are increasingly expanding into rural communities. In conclusion, the developed GIS successfully identified spatial patterns of non-communicable disease distribution and can serve as a useful tool to support rapid and accurate public health interventions.
**Keywords:** Agile method; geographic information system; mapping; non-communicable diseases; system design

## INTRODUCTION

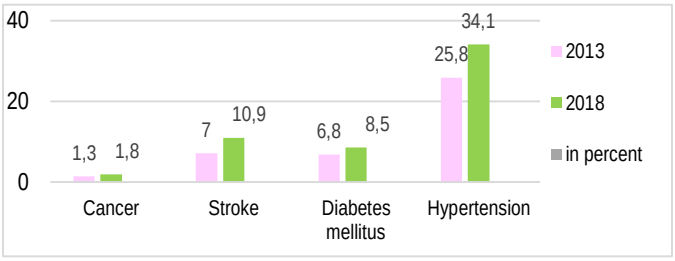


Figure 1. Percentage of NCDs in Indonesia in 2013 and 2018

Global health has experienced a shift in disease burden from communicable diseases to non-communicable diseases (NCDs) [1]. NCDs, also known as chronic diseases, constitute the largest proportion of the global disease burden [2]. These diseases account for approximately 65.5% of deaths and 54% of morbidity worldwide. According to Sustainable Development Goals (SDGs) Indicator 3.4.1, major NCDs include cardiovascular diseases, cancer, chronic respiratory diseases, and diabetes mellitus (DM) [3]. Data on the percentage of non-communicable diseases in Indonesia in 2013 and 2018 are presented in Figure 1.

The prevalence of cancer increased from 1.3% to 1.8%. Stroke prevalence rose from 7% to 10.9%, while DM increased from 25.8% to 34.1% [3]. One of the major impacts of NCDs is the loss of Disability-Adjusted Life Years (DALYs), which measures the overall burden of disease by reflecting years of healthy life lost due to premature death or living with illness or disability. Globally, in 2021, deaths attributable to NCDs reached 1.7 billion DALYs lost, with ischemic heart disease contributing 188.3 million, stroke 160.4 million, and DM 14.0 million [4]. In Indonesia, approximately 69% of DALYs lost are attributed to NCDs, including stroke (10.9%), ischemic heart disease (8.6%), and other related conditions [5]. If NCDs continue to increase, they will affect social burdens and economic sectors. Moreover, the burden of NCDs can negatively impact economic growth and national income [6,7].

Priority disease control initiatives are required to enable rapid responses in understanding the prevalence of NCDs across regions and different geographic levels, in line with *Asta Cita* priority 8, which focuses on strengthening human resource development, science, technology, education, health, achievements, gender equality, and the empowerment of women, youth, and persons with disabilities [8]. Understanding the characteristics of where people live at different geographic levels can provide deeper insights into variations in risk factors and the prevalence of NCDs. Therefore, the application of Geographic Information Systems (GIS) is essential to help reduce the impact of NCDs [9]. GIS are powerful analytical tools due to their ability to integrate multiple datasets for spatial analysis [10]. The development of GIS has also been integrated with emerging [11]. However, the utilization of GIS in the health sector, particularly for mapping various diseases, remains limited [12].

Data obtained from the One Data Ponorogo platform indicate that the prevalence of diabetes mellitus reached 15,774 cases and hypertension reached 291,057 cases in 2022, and these numbers are expected to continue increasing due to unhealthy lifestyle factors. Surveys conducted in Ponorogo Regency regarding NCDs have not yet provided detailed data on specific populations with different backgrounds or geographic locations. In addition, information regarding the spatial distribution and risk factors across geographic regions is still limited. Therefore, this study aims to develop a Geographic Information System for mapping the distribution of non-communicable diseases using the Agile method. This approach supports software development by actively improving user satisfaction, reviewing existing software systems, and reducing risks related to both technical and non-technical losses [13].

This research proposal supports the National Research Priority (PRN) in the theme of engineering technology, focusing on mapping the distribution of non-communicable diseases using a Geographic Information System. The Agile method is considered an effective methodology in software development. One of the main advantages of the Agile model is its ability to enhance user satisfaction, continuously review existing systems, and minimize risks related to technical and non-technical losses [14,15]. In principle, Agile is a software development methodology based on short development cycles and emphasizes adaptability to changes throughout the development process [16,17].

This study aimed to design and develop a Geographic Information System (GIS) capable of mapping the distribution of non-communicable diseases and identifying spatial patterns of NCD cases within the service areas of community health centers in Ponorogo Regency.

## METHODS

The study was conducted in Ponorogo Regency, Indonesia, using data obtained from community health centers (*Puskesmas*) across the region. The research utilized spatial data of Ponorogo Regency and secondary data on the distribution of non-communicable diseases collected from the

health service system. This study employed design and development research aimed at designing and developing a GIS to map the distribution of NCDs. A quantitative approach was used to evaluate the feasibility and usability of the developed system through a questionnaire-based instrument.

The object of the research was the GIS developed for mapping the distribution of non-communicable diseases. The data sources included secondary data on NCD cases obtained from community health centers in Ponorogo Regency as well as spatial data of the administrative areas. The main variables included system feasibility and system usability. These variables were measured using a questionnaire distributed to system users to assess the performance, usefulness, and functionality of the developed GIS.

The system development process applied the Agile method consisting of six stages: requirements, design, development, testing, deployment, and review. The first stage involved problem identification, which revealed the absence of a GIS capable of visualizing and monitoring the distribution of NCDs in a real-time and interactive manner. The second stage involved data collection, including data on the distribution of non-communicable diseases from all community health centers in Ponorogo Regency and spatial data of the region. The third stage involved identifying functional requirements related to system users, including administrators (data input and map editing), health workers at community health centers (data reporting on NCD distribution), and the public (map visualization). The system was developed using ArcGIS software and produced static map visualizations of disease distribution. Data analysis was conducted descriptively to evaluate the feasibility and usability of the developed system based on questionnaire responses.

## RESULTS

The first stage involved problem identification, which indicated the absence of a GIS capable of visualizing and monitoring the distribution of NCDs in a real-time and interactive manner. The second stage was data collection. At this stage, the researchers obtained data from the Ponorogo District Health Office regarding the number of NCDs cases within the service areas of *Puskesmas* in Ponorogo Regency. Additional data on the distribution of non-communicable diseases were collected from several health centers, including *Puskesmas* Balong, *Puskesmas* Sukorejo, *Puskesmas* Jambon, and *Puskesmas* Sawoo. The third stage involved identifying functional requirements related to system users, including administrators (data input and map editing), community health center health workers (data reporting on the distribution of non-communicable diseases), and the public (map visualization). At this stage, the GIS was designed using a use case diagram to define system interactions and functionalities. The fourth stage was system design, in which the GIS was developed using ArcGIS software to generate static maps illustrating the spatial distribution of non-communicable diseases.

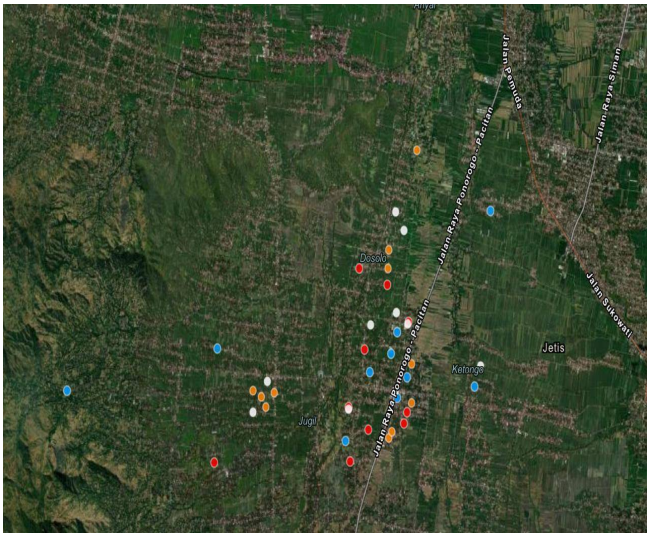


Figure 2. Map of the distribution of NCDs in the *Puskesmas* Jambon

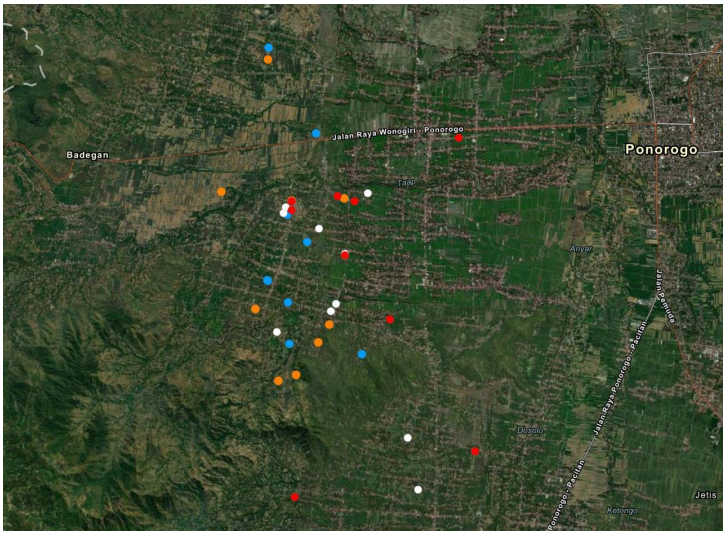


Figure 3. Map of the distribution of NCDs in the *Puskesmas* Sukorejo

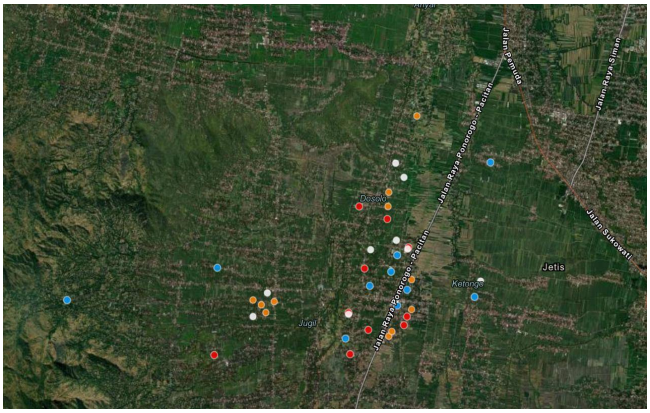


Figure 4. Map of the distribution of NCDs in the *Puskesmas* Balong

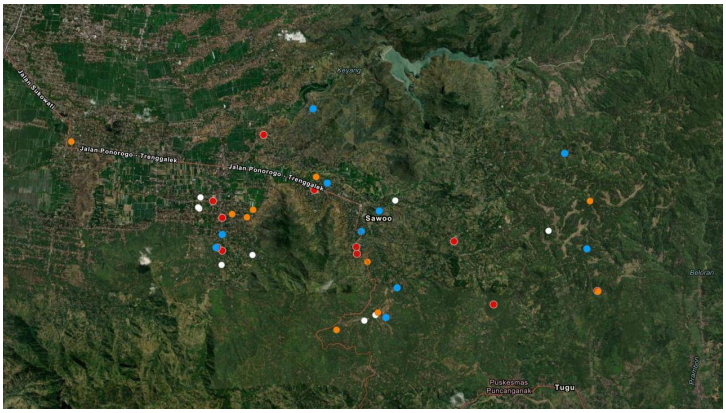


Figure 5. Map of the distribution of NCDs in the *Puskesmas* Sawoo

Figure 2 represents the output of the GIS showing the spatial distribution of NCDs within the service area of *Puskesmas* Jambon. Each colored point represents a different disease category, allowing spatial patterns of distribution to be analyzed. Red points represent heart disease cases. The distribution appears dominant in the eastern area, particularly along the main transportation route connecting Wonogiri–Ponorogo Road and extending toward Ponorogo–Pacitan Road. Several points also appear in the southern area, indicating that heart disease cases are distributed across both densely populated and rural areas. Blue points indicate cases of DM. The distribution is prominent in the central area of the map and tends to form clusters in residential areas. This clustering pattern may indicate a concentration of DM cases within specific communities. White points represent stroke cases. The distribution appears relatively scattered across several locations within the *Puskesmas* Jambon area, including both central and southern regions. No clear clustering pattern is observed, suggesting that stroke cases occur sporadically. Orange points represent hypertension cases. Hypertension distribution is

prominent in the western to southern parts of the region, particularly near Badegan District and the surrounding hilly areas. This pattern suggests that hypertension cases are common in rural areas, potentially influenced by environmental and lifestyle risk factors.

Figure 3 illustrates the results of the GIS that maps the spatial distribution of NCDs within the service area of *Puskesmas* Sukorejo. Each colored point represents a specific type of NCD case, reflecting spatial variation at the regional level. Red points represent heart disease cases. The distribution is relatively dominant in the northeastern area of the map, particularly around the main Wonogiri–Ponorogo Road corridor. The concentration of red points along this transportation route indicates that heart disease cases tend to occur more frequently in densely populated areas with high transportation accessibility. Blue points represent DM cases. These cases are widely distributed across the central and southern areas and tend to form clusters. This clustering pattern may indicate localized pockets of DM cases potentially influenced by community lifestyle factors. White points represent stroke cases. Their distribution appears more evenly spread across the Sukorejo region, from central areas to southern parts of the district. This pattern suggests that stroke cases can occur across different environments rather than being concentrated in a single area. Orange points represent hypertension cases. These points are relatively prominent in the western and southern parts of the region, particularly near the border of Badegan District. This pattern may indicate that hypertension is more common among populations living in hilly or rural environments with specific lifestyle or environmental characteristics.

Figure 4 illustrates the spatial distribution of NCDs within the service area of *Puskesmas* Balong. The color-coded symbols represent different types of diseases experienced by the community. Heart disease cases (red points) appear relatively dominant around Ngraket Village and along the Ponorogo–Pacitan main road. This pattern indicates a concentration of heart disease cases in densely populated residential areas. DM cases (blue points) show a wider distribution, with points spread across the western region toward the hilly areas and the eastern region around Jetis and Balong villages. Stroke cases (white points) appear to be concentrated around Ngraket Village, forming a visible cluster pattern. Hypertension cases (orange points) appear frequently and form clusters around the Balong District area. The distribution of hypertension cases is also closely located near stroke and heart disease.

Figure 5 illustrates the spatial distribution of NCDs within the service area of *Puskesmas* Sawoo. Each point on the map indicates the location of patients with specific disease categories. Heart disease (red points) are distributed across several locations, with the highest concentration near the center of Sawoo District and several rural areas toward Tugu. Some points also appear along the Ponorogo–Trenggalek road corridor, indicating a relationship with densely populated residential areas. DM (blue points) are widely distributed from the northern region near Keyang to the eastern border areas. Many cases are concentrated around densely populated settlements in central Sawoo. This pattern indicates that diabetes mellitus is not only an urban disease but also affects rural populations. Stroke (white points) appear to form clusters around the central area of Sawoo and along the main route toward Trenggalek. Some cases are also scattered in the eastern region, although in smaller numbers compared with the district center. Hypertension (orange points) are frequently found around the main Ponorogo–Trenggalek road and in densely populated residential areas of Sawoo. Orange points are also visible in several eastern villages, indicating that hypertension cases are more evenly distributed compared with stroke cases.

## DISCUSSION

The spatial analysis results indicate several important patterns in the distribution of NCDs, particularly cardiovascular diseases and metabolic disorders, across the observed regions. One prominent finding is the clustering of cardiovascular diseases. The clusters of cardiovascular conditions show a consistent pattern in which heart disease, stroke, and hypertension tend to concentrate in subdistrict centers or densely populated villages. These areas are typically characterized by higher population density, more intensive economic activities, and greater mobility of residents. Such environments often expose communities to a variety of cardiovascular risk factors. This pattern aligns with theoretical and epidemiological perspectives suggesting that cardiovascular risk factors are more prevalent in populations experiencing higher levels of urbanization, sedentary lifestyles, dietary changes, and increased psychological stress. Urban or semi-urban communities often have greater exposure to processed foods, reduced physical activity due to occupational patterns, and environmental stressors that collectively increase the likelihood of cardiovascular disease occurrence. Consequently, the spatial clustering of heart disease, stroke, and hypertension in these central areas reflects the interaction between demographic density, lifestyle patterns, and environmental influences that contribute to cardiovascular risk [18].

In contrast to the cardiovascular disease pattern, the distribution of diabetes mellitus demonstrates a broader and more dispersed spatial pattern. Diabetes mellitus cases are not concentrated exclusively in densely populated areas but are instead spread across various geographic locations, including both subdistrict centers and peripheral rural villages. This difference in spatial pattern suggests that diabetes mellitus is influenced by a wider set of lifestyle and metabolic risk factors that are not limited to urban settings. Dietary habits, obesity, reduced physical activity, and long-term metabolic changes may occur in communities regardless of population density. The expansion of modern dietary patterns, increased consumption of high-calorie foods, and reduced physical activity are increasingly observed in rural communities as well, which contributes to the widespread distribution of diabetes mellitus cases. Therefore, unlike cardiovascular disease clusters that appear more concentrated, DM shows a more diffuse distribution across both urban and rural environments, reflecting the broader lifestyle transition experienced by communities in many regions [19].

Another significant observation from the spatial mapping is the close proximity between hypertension cases and other cardiovascular diseases, particularly heart disease and stroke. The mapping results reveal that many hypertension cases are located near clusters of heart disease and stroke cases. This spatial relationship strengthens existing epidemiological evidence indicating that hypertension is a major risk factor for both heart disease and stroke. Persistent high blood pressure can lead to structural and functional damage to blood vessels and organs, increasing the likelihood of cardiovascular complications. When hypertension occurs within communities, it often precedes the development of more severe cardiovascular conditions. Therefore, the proximity of hypertension clusters to heart disease and stroke clusters provides additional spatial confirmation of the well-established causal pathway between these conditions. Identifying such spatial relationships through geographic analysis can be particularly valuable for early intervention and risk reduction strategies in public health programs.

The spatial analysis also highlights the role of infrastructure and accessibility in shaping the distribution of non-communicable diseases. A substantial proportion of NCD clusters appear to be located near major roads, transportation corridors, and public service centers such as health facilities, markets, and administrative hubs. These areas typically represent zones of higher human activity and settlement density. The presence of disease clusters near these locations suggests that accessibility, population concentration, and mobility patterns may influence the observed distribution of cases. Areas with better infrastructure often attract more residents and economic activity, leading to higher population density and, consequently, a greater likelihood of disease detection and reporting. Additionally, proximity to health facilities may facilitate diagnosis and recording of cases, which can contribute to the observed clustering in mapped data. These findings suggest that residential density and accessibility are important contextual factors associated with the spatial distribution of NCD cases [20].

Despite the concentration of certain diseases in urbanized or densely populated areas, the spread of diabetes mellitus into rural regions indicates that NCDs are no longer limited to urban populations. The presence of DM cases in peripheral and rural villages reflects the ongoing epidemiological transition affecting both urban and rural communities. Rural populations are increasingly experiencing lifestyle changes associated with modernization, including shifts in dietary patterns, reduced physical activity, and increased exposure to processed foods. These changes

contribute to the gradual expansion of NCD risk factors beyond urban centers and into rural environments. As a result, NCD prevention and control strategies must address both urban and rural populations rather than focusing solely on cities.

The application of GIS in this study provides valuable spatial insights into the distribution of non-communicable diseases such as hypertension, diabetes mellitus, and heart disease based on data obtained from health service facilities. The GIS-based digital maps generated in this research are capable of displaying the geographic location of disease cases, the prevalence levels across different areas, and the spatial patterns of disease distribution within the service coverage of various community health centers. By visualizing disease patterns geographically, GIS allows researchers and policymakers to identify clusters, detect high-risk areas, and analyze the relationship between environmental, demographic, and health variables.

Furthermore, the spatial visualization provided by GIS offers practical benefits for public health planning and decision-making. The availability of digital disease maps enables health authorities to more effectively design targeted interventions, allocate resources strategically, and prioritize areas that require immediate public health attention. In addition, GIS-based mapping can support the development of preventive and promotive health programs by identifying communities that are particularly vulnerable to certain diseases. Such information can guide the implementation of health promotion campaigns, screening programs, and early detection initiatives tailored to specific geographic contexts. Therefore, the use of GIS in mapping NCDs not only enhances epidemiological understanding but also strengthens the capacity of health systems to respond more effectively to the growing burden of NCDs [21].

## CONCLUSION

The use of GIS in this study provides a spatial overview of the distribution of NCDs, such as hypertension, diabetes mellitus, and heart disease, based on data obtained from health service facilities. The digital maps generated through the system are able to display the geographic location of cases, prevalence levels, and patterns of disease distribution across different community health center service areas. This spatial information is highly valuable for supporting evidence-based decision-making in the planning and implementation of promotive and preventive health programs.

## Ethical consideration, competing interest and source of funding

-This study utilized secondary data and ensured that all data were used solely for research purposes while maintaining data confidentiality and integrity.
-There is no conflict of interest related to this research and publication
-Source of funding is authors.

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