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Research article

Spatial Modelling Analysis for Potential Expansion of Cipanas City Candidate Area as Autonomous City

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Abstract

The establishment of the new autonomous city is considered a significant decision, and the proposal has been under review in Cipanas for several years. Therefore, this research aimed to address the proposal by conducting spatial modelling analysis for potential expansion of Cipanas as autonomous city, using Geographic Information System (GIS) method. The physical and social factors were analysed, using spatial overlay analysis to determine potential development area. SWOT analysis was also performed for qualitative insights into strengths, weaknesses, opportunities, and threats of the prospective Cipanas area. The results showed that Cipanas had significant potential to become autonomous city, with a particular focus on agriculture and tourism due to the varied topography and predominant natural land use. Overlay analysis identified areas in Pacet, Cipanas, and a small part of Cugenang Sub-districts as potential development zones for the capital city. In general, Cipanas area was found suitable for the development of a major city with an agropolitan concept. Certain areas were considered more appropriate with urban characteristics compared to other areas based on specific criteria. Based on the results, recommendations include infrastructure improvements, economic sector diversification, tourism promotion, and disaster risk reduction activities. GIS spatial analysis facilitated the accurate identification of potential areas, aiding in mapping and pinpointing optimal areas for the establishment of a new autonomous city.

Keywords: spatial modelling; Geographic Information System; Cipanas City; autonomous city.

1. Introduction

Administrative area development is the process of increasing the jurisdiction of a government or institution unit. This can be achieved through annexation, land acquisition, or adjustment of administrative divisions. In this context, regional expansion refers to forming areas into new autonomous cities according to Law Number 23 of 2014 concerning Regional Government. The implementation is based on Government Regulation Number 78 of 2007 concerning Procedures for the Formation, Abolition, and Merger of Areas (Rasyidin *et al.*, 2022). Urban expansion is an example of spatially and temporally complex behaviour influenced by numerous aspects including social economics, as well as geography and policy (R. Feng & Wang, 2021). The process imparts changes in urban form and the dynamics of spatial patterns of land use. Furthermore, urban form has been investigated in several areas across Indonesia, including Cianjur, Jakarta, and Cirebon (Jatayu *et al.*, 2020; Jatayu *et al.*, 2023). To achieve optimal outcomes, regional expansion should be supported by adequate development for even growth in the area.

Cianjur Regency has area of 3,614.35 km or about 10.85% of the total area in West Java Province, Indonesia. Administratively, this regency is bordered by several areas including Bogor, Purwakarta, Bandung, 34 Garut, and adjacent to the capital city of Jakarta, suggesting potential as a satellite city. The economic centre is located in Cipanas and the surroundings are widely developed as agribusiness and tourism areas, contributing approximately 60% of Original Regional Revenue (PAD) for Cianjur Regency (Suwaryo *et al.*, 2008).

Despite the significant economic role of Cipanas and surroundings to the regency, community welfare remains below expectations. This condition has led to the discourse on the expansion with the formation of Cipanas City, consisting of five sub-districts: Cipanas, Pacet, Cugenang, Sukaresmi, and Cikalongkulon. Regional expansion is considered an important instrument for empowering areas, improving service quality, increasing democracy, enhancing regional economy, managing potential, ensuring security, fostering harmonious relations between central and regional authorities, and spurring national integration (Rasyidin *et al.*, 2022). The adaptation strategy adopted independently must be in accordance with local environmental conditions. In the context of forming a new autonomous city, it is important to understand the environmental impacts of implemented adaptation policies and actions (Ricci, 2016; Zhu *et al.*, 2023).

The total area of the prospective Cipanas City is about 421.26 square kilometres with a total of 59 villages or kelurahan, and the population density reached approximately 7,718.63 people/km^2 in 2021 (BPS in figures, 2022). The city has experienced significant population growth and urbanisation in recent years, resulting in increased demand for housing and land for non agricultural

purposes that may lead to potential expansion. This expansion requires careful consideration of various factors, including the influence of urban heat islands on the environment, the introduction of environmental indices based on remote sensing data, and spatial patterns (Shi *et al.*, 2011; Fan *et al.*, 2022). In addition, it is crucial to consider accessibility factors, such as distance to major roads and city centres (Cheng *et al.*, 2022).

In response to several demands, the city is considering an expansion project to accommodate the increasing population as well as provide adequate infrastructure and facilities. The project also aims to address the socioeconomic factors driving urbanisation and ensure longterm sustainability (Tanjung *et al.*, 2021; Jatayu *et al.*, 2022). Cipanas City will become an attractive entity when all stages of expansion are executed according to plan. Examples of successful autonomous cities and selfgovernment in various countries include Hong Kong, Vatican City, Gibraltar, Macau, Singapore, and Puducherry, India (Borovik, 2023). Rasyidin *et al.* (2022) also defined regional expansion as the separation of area from the parent by obtaining a higher position, thereby increasing community welfare and development.

Cipanas City candidate area and the surroundings have high potential for expansion considering the strategic positioning for food trade to support the capital city of Jakarta. Geographical area at an altitude of 700 - 1,200 m above mean sea level causes the area to be very fertile and used as agricultural land. In addition, Cipanas has a tourist destination located in Cimacan Village, namely Gunug Gede Pangrango National Park (TNGGP). This area contributes significantly to regional income and increases Gross Regional Domestic Product (GRDP) of 55 Cianjur Regency (Sinurat & Fitrianti, 2016).

Padjajaran University Research Institute in 2008 assessed Indicators for Cipanas City Candidate areas, focusing on the evaluation of population, economic, regional potential, and financial capability factors. However, it is necessary to assess other factors to produce a comprehensive and accurate policy. In this context, the Geographic Information System (GIS) can be used as an analytical tool to evaluate policy. GIS is suitable for spatial analysis and modelling to evaluate the suitability of new autonomous city for urban development. This method has proven effective for assessing factors such as land use suitability, transportation networks, and environmental conditions (Luan *et al.*, 2021).

In determining the boundaries for the formation of new area, geospatial aspect is important and strategic. However, related problems such as regional boundary maps, area size, and others need to be considered (Rassarandi *et al.*, 2019). Spatial modelling analysis is a crucial tool in understanding and predicting urban expansion, as well as in informing decision-making processes for planning and development (J. Zhang *et al.*, 2013; Z. Zhang *et al.*, 2016; Butsch *et al.*, 2017; Zhao *et al.*, 2022). Several methods can be utilized to achieve this goal, such as predicting urban growth and using GIS analysis tools. These methods help in uncovering hierarchical patterns in cities and facilitate better decision-making (Al Jarah *et al.*, 2019; Li *et al.*, 2020). In addition, analysing the movement patterns of people and social groups is also important in geography and urban planning (Ahas *et al.*, 2016).

GIS provides visual elements that facilitate the analysis of area-related data. This method can create thematic maps by combining data information with area to identify specific relationships and trends. This visualisation process helps planners and stakeholders understand the possible impacts of development in the new autonomous city (Azzam & Robinson, 2012). Therefore, this research was conducted to spatially analyse important physical and social population factors related to the expansion of Cipanas City candidate. Recommendations were also provided for determining the new capital area through GIS spatial analysis. This was achieved by analysing several important factors that could be used as a reference for stakeholders in making informed decisions to ensure sustainable and effective development of new autonomous city.

This research is highly relevant to administrative regional development, specifically in the context of expanding Cipanas City in Cianjur Regency. The expansion of administrative area is an important policy that influences various aspects of lives, including economic, social and environmental (Temenggung *et al.*, 2020; Setiawan *et al.*, 2023; Wisesa *et al.*, 2023). Therefore, this indepth research attempts to provide policymakers, planners, and stakeholders with a comprehensive view regarding the impacts and implications of expansion.

Despite the array of available evidence, this research aims to make a novel and different contribution by detailing spatial analysis using GIS. There is currently no research specifically focused on the expansion of Cipanas City candidate area using this method. Meanwhile, the urban data ecosystem is continuously developing with digital mapping, smart asset management, and mobility (Norman, 2018). A very progressive development from geospatial aspect is contained in Law

No. 20 of 2012 concerning the formation of North Kalimantan Province using geospatial data (Rassarandi *et al.*, 2019). By combining the latest data and spatial digital mapping (GIS), this research is expected to provide deeper and more accurate insights.

This research is different from previous investigations in terms of analytical method. Padan *et al.* (2019) explained the role of natural capital in forming a new autonomous city in Krayan Regency, North Kalimantan, Indonesia, stating that natural resources could be designated as a sign of great potential to support the formation of a new area. Furthermore, Rasyidin *et al.* (2022) reported that the expansion of Panton Labu City, North Aceh Regency, was influenced by political orientation. Ambya *et al.* (2019) analysed the convergence of absolute sigma and beta while also measuring the speed of economic growth in new autonomous city on Sumatra Island. The majority of previous research focused more on certain aspects such as natural resource potential, regional politics, economics, or regional potential. Therefore, this research combines factors for the formation of new autonomous city comprising physical, social, population, and economic in spatial analysis using GIS, to provide a more holistic and integrated picture. The results are expected to offer further guidance in the decision-making process regarding the expansion of administrative area.

2. Research Methods

This research spatially examined several supporting specimens related to the expansion of Cipanas City into autonomous area, reaching approximately 41,673.1 hectares. Candidate area consists of five administrative subdistricts, namely Cipanas, Pacet, Cugenang, Sukaresmi, and Cikalongkulon, with a total of 59 villages. Administrative map of Cipanas City candidate area is shown in Figure 1.

The method used was GIS, which allowed users to analyse data in certain areas comprehensively and specifically (Mohammed *et al.*, 2016; Habibi *et al.*, 2021; Guzzini *et al.*, 2023). This research spatially examined the condition of Cipanas City candidate area being proposed to become new autonomous city. Several factors such as physical and social were assessed to evaluate the prospects of the area. Spatial analysis was conducted through GIS supported by other geographic scientific analysis methods. Visualised maps were generated through mapping and spatial analysis software tools, namely ArcGIS version 10.8.

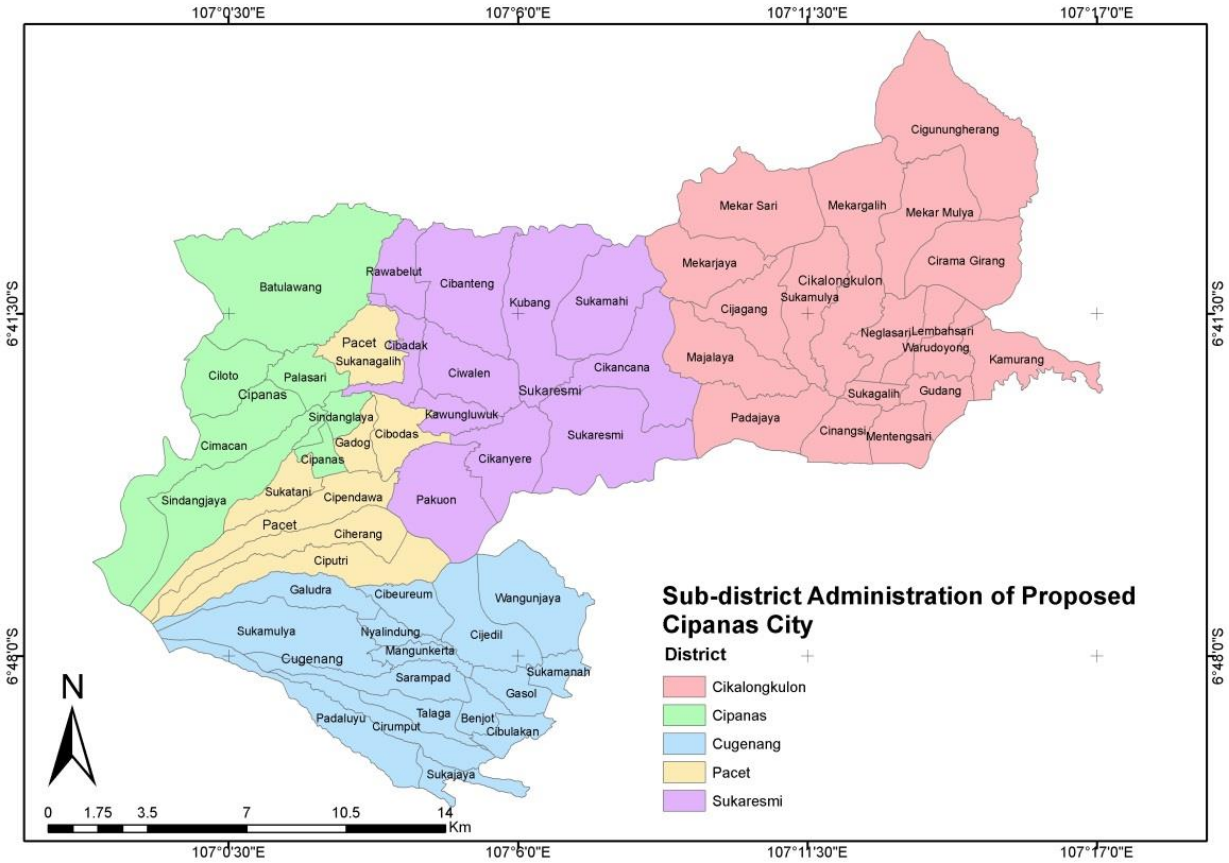

Figure 1. Administrative map of Cipanas City.

2.1. Data

The data used consisted of various forms and were obtained from different sources. Knowledge related to the social conditions of the research area was acquired through a literature review of news, journal articles, and reports, while remote sensing was used to extract information related to the physical conditions. Spatial data used in shapefile (.shp) format was obtained from various sources, such as administrative boundary data through Geospatial Information Agency (BIG). Moreover, ArcGIS 10.8 software was used to create a geospatial database and perform the analysis. The details of the data used in this research are presented in Table 1.

Table 1. Details of Data Used.

Data	Source	Details
Spatial Data		
Administrative Boundaries	Geospatial Information Agency (BIG)	Official administrative data including subdistrict boundary and village boundary data from the research areas.
Land Use	Geospatial Information Agency (BIG)	Land use data that provides information on the variation of land use in the research areas.
Road Network	OpenStreetMap (OSM)	Road network data obtained for free through the internet
Disaster Data	InaRISK BNPB	Disaster data includes disaster risk data that is used as an analysis parameter for determining the centre of government in the prospective city of Cipanas.
Remote Sensing Data		
SRTM Imagery	USGS Erth Explorer	Remote sensing satellite observation data that has information related to altitude and topography for analysing the physical condition of the research area
Tabular Data		
Resident Population	Cianjur Regency Central Bureau of Statistics (BPS)	Population data per subdistrict used in analysing population density conditions in the research area

2.2. Scoring and Overlay

The suitability analysis used in this research entailed scoring and overlay methods. This analysis aims to determine the most suitable areas for developing the capital city of Cipanas. At the scoring stage, the areas to be evaluated were assessed based on various criteria relevant to the development objectives as shown in Figure 2. Each criterion was assigned a relative value based on the importance to the development objectives, while the area was scored according to the extent to which the criteria were met.

At the overlay stage, the assessment results of the various criteria were used to create thematic maps or information layers. Each criterion might have a separate thematic layer with colour gradations or symbols reflecting the level of suitability. These layers were then combined (overlaid) to create an overall suitability map, which provided a comprehensive picture of the most suitable areas for development as the capital city of Cipanas. The classification of suitability scores resulting from each parameter is shown in Table 2.

Table 2. Classification of Suitability for Development of the Capital Area of Cipanas City Candidate.

No	Suitability Level	Suitability Score	Description
1	I	1 – 4	Not Suitable
2	II	5 – 9	Less Suitable
3	III	10 - 13	Moderate Suitable
4	IV	14 - 18	Highest Suitable

A total of six parameters were considered to determine the suitable area to be used as the capital centre. These include land use, population density, volcano eruption hazard index, landslide hazard index, as well as proximity to road network and commercial centre (Figure 2). Some of the parameters analysed were tabulated to group the data according to the respective values. The value acquired was used in the overlay process to determine the suitability level of the area for the development of Cipanas capital city. Table 3 shows the class and score for each criterion used.

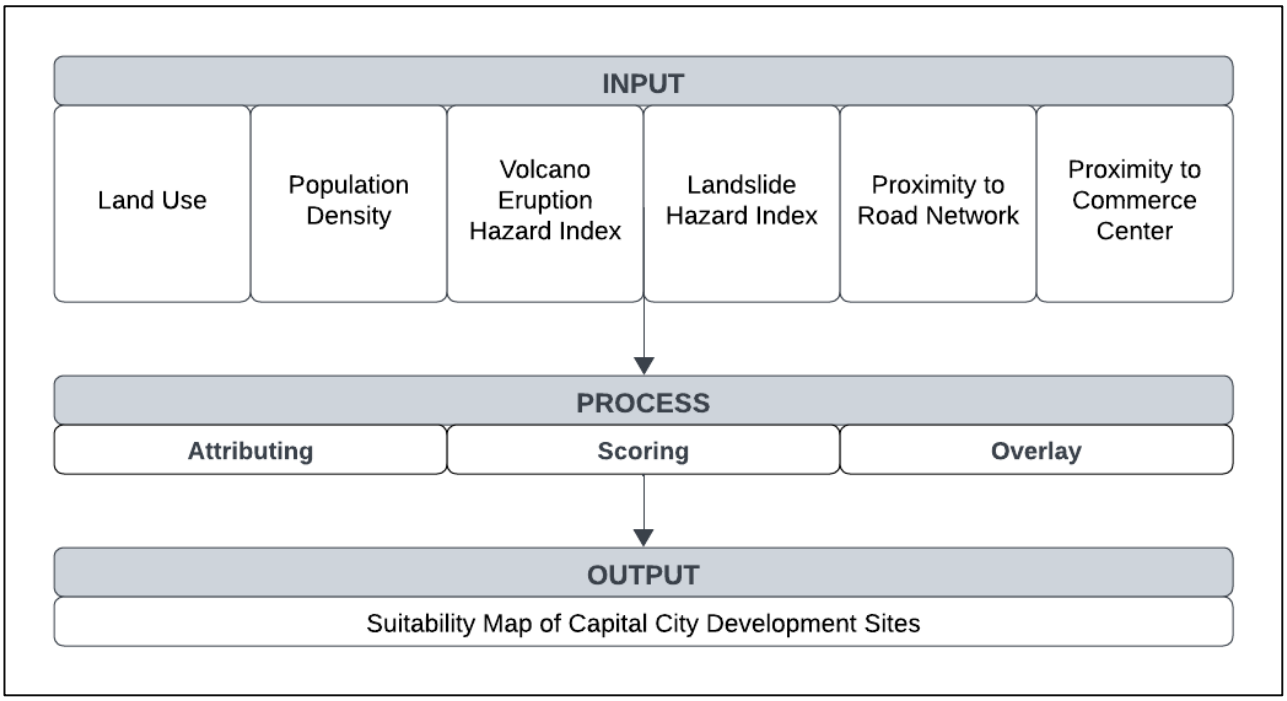

Figure 2. Analysis chart for determining potential capital city area.

Table 3. Parameters for determining the suitability of developing the area of Cipanas capital city

No	Parameters	Class	Score
1	Land Use	Built up Area	3
		Empty/bare land	2
		Moor/Field	1
		Others Natural Area	0
2	Population Density	High	3
		Medium	2
		Low	1
3	Volcano Eruption Hazard Index	High (0,6 - 1)	1
		Medium (0,3 - 0,6)	2
		Low (0 - 0,3)	3
4	Landslide Hazard Index	High (0,6 - 1)	1
		Medium (0,3 - 0,6)	2
		Low (0 - 0,3)	3
5	Proximity To Road Network	100 m	3
		300 m	2
		500 m	1
6	Proximity To Commerce Center	1 km	3
		3 km	2
		6 km	1

3. Results and Discussion

3.1. Physical Condition of Cipanas City Candidate Area

Cipanas City candidate area was found to be directly adjacent to several areas including the north border by Bogor and Purwakarta Regency and the west border by Sukabumi Regency. The altitude ranges from 137 to 3016 meters above sea level, strongly supporting business development in the area, specifically in the agribusiness sector (Suwaryo *et al.*, 2008). Due to the favourable land and climatic conditions, Cipanas City candidate area is capable of meeting the rice needs (rice self sufficiency) of the inhabitants and has great potential for the cultivation of ornamental plants.

Some of the problems faced, such as the limited capacity of the roads have recurrently caused congestion, disrupting the mobility of residents. To meet community needs, it is necessary to improve facilities and areas for trading and optimise the use of tourism resources. This will open up opportunities to develop more convenient trading facilities for Cipanas City Candidate area residents.

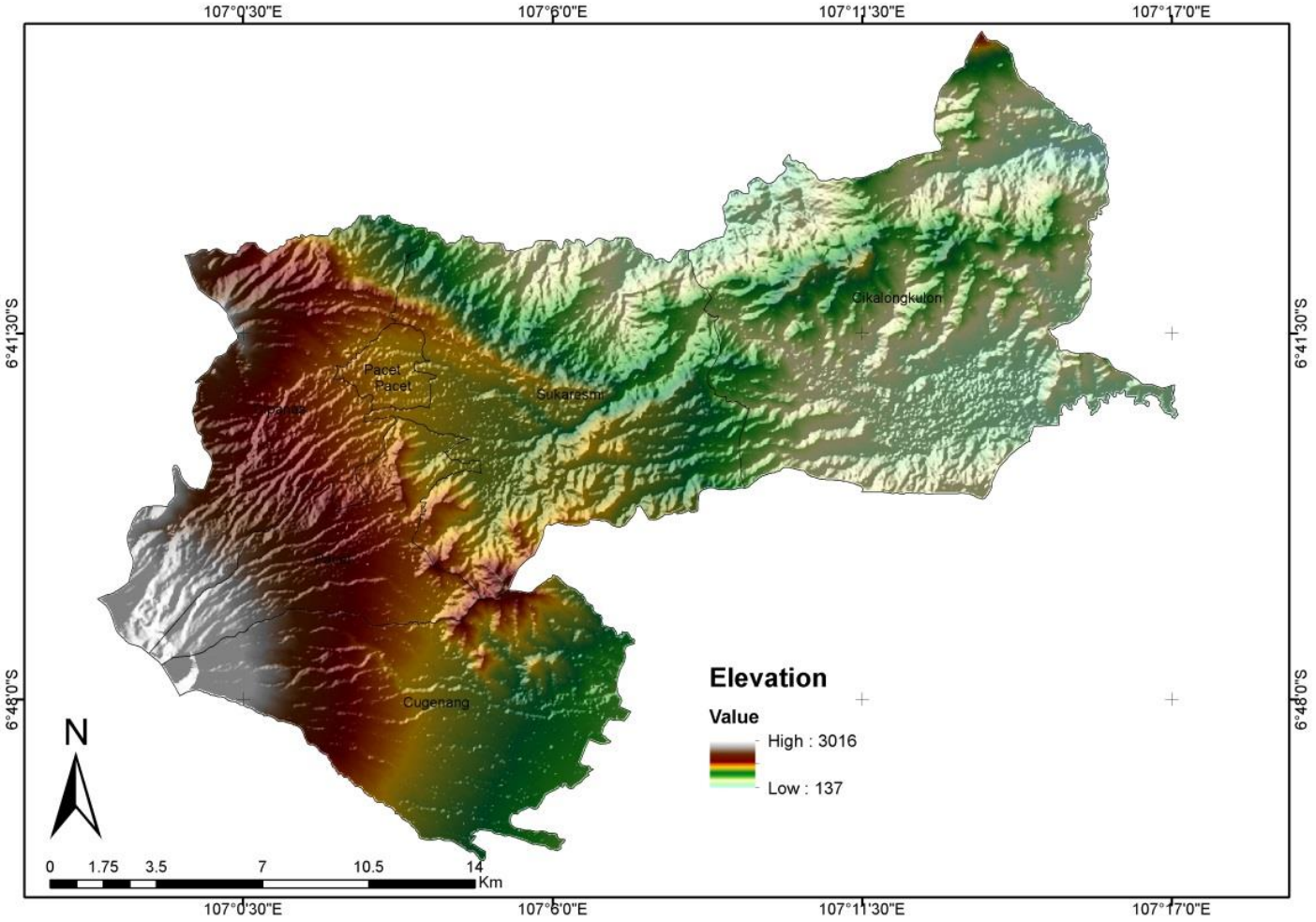

Figure 3. Map of Topographic Conditions of Cipanas City Candidate area

Figure 3 shows the topographic conditions of Cipanas City candidate area visualised using Shuttle Radar Topography Mission (SRTM) remote sensing satellite data. SRTM has a resolution of about 30 M and presents the form of elevation or height as depicted on the map in meters above sea level units. Based on the map, the lowest elevation found in the area was 137 meters above sea level, while the steepest was 3016 meters above sea level. This condition was attributed to the mountainous nature of the area, particularly the presence of Gunung Gede Pangrango.

Elevation information is an important factor in determining the distribution and characteristics of forests in the area, for example, forests tend to be distributed at certain heights and slopes. This factor is an important consideration in autonomous city management and sustainable development (Cui *et al.*, 2021). Forests are one of the main factors to be considered in establishing new autonomous city due to the ability to greatly influence the existence in the future (Padan *et al.*, 2019). According to Padan *et al.* (2019), the availability of sufficient natural capital such as forests influences the feasibility of autonomous city. For example, areas with abundant natural resources, such as oil, minerals, or fertile land for agriculture, may attract individuals or groups who desire greater control and autonomy over those resources (Nikiforova, 2019).

Cipanas City candidate area had varied topographic conditions from flat to very steep, affecting the condition of the slope. According to Luan *et al.*, (2021), slope is one of the factors considered in land use analysis and identifying areas suitable for various urban functions. Santosh *et al.* (2018) also considered the slope factor in analysing the suitability of areas for urban development

in Chikodi Taluk, Belagavi District, Karnataka, India. In addition, Kumar & Biswas (2013) applied the slope aspect in identifying potential areas for urban development in Shimla City Area, Shimla District, Himachal Pradesh, India.

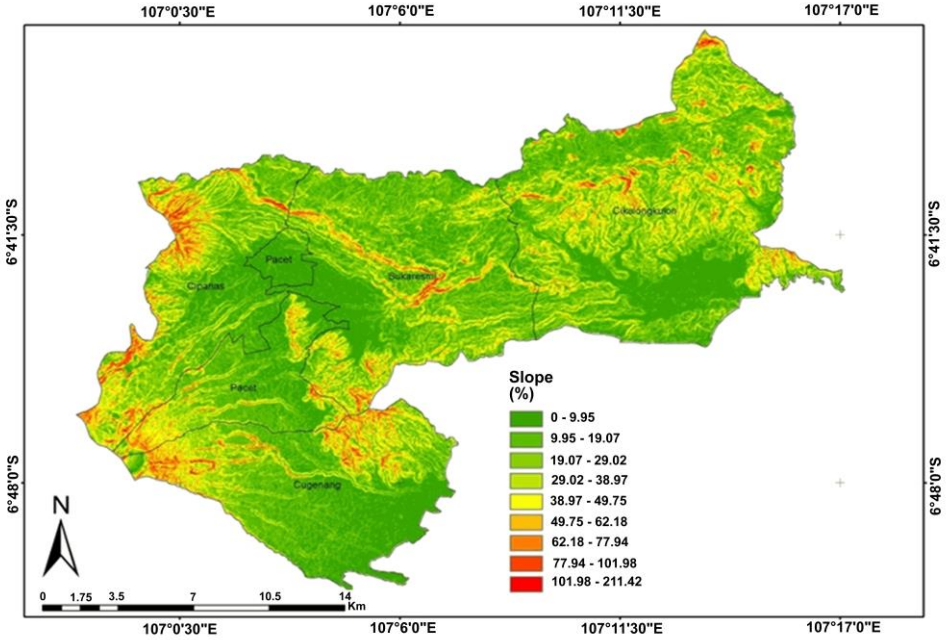

Figure 4. Map of Slope Condition of Cipanas City Candidate Area

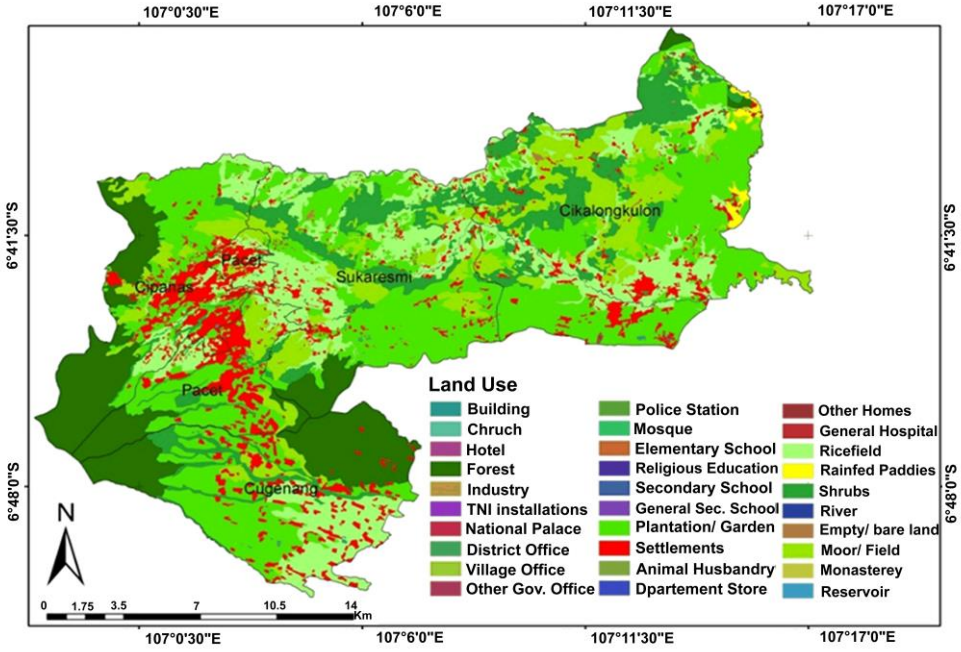

Figure 5. Map of Land Use Condition of Cipanas City Candidate Area

Based on the extracted information from remote sensing data, the Cipanas City candidate area slope ranged from 0 to 211%, as depicted in Figure 4. These varied slopes have various consequences in planning and developing the area, specifically in the context of infrastructure development, disaster mitigation, and land use. Slope and changes in land use are known to influence soil quality. Furthermore, soil quality assessment is important in determining sustainable land use and management practices for development (Nabiollahi *et al.*, 2018). Special attention is needed in managing and planning land use in areas with diverse topographic conditions to ensure environmental sustainability and safety.

Land use refers to the human use of land for economic and cultural activities such as agriculture, housing, industry, mining and recreation. The map shown in Figure 5 was sourced from BIG.

Land use data plays several roles in the quest to expand the administrative area of Cipanas City, including planning zones (residential, commercial, and industrial) and determining the area of infrastructure, namely roads and necessary public facilities. It also helps safeguard the environment by identifying sensitive areas as well as economic potential including agriculture or natural resources (Wang *et al.*, 2021).

As shown in Figure 5, land use in Cipanas City candidate area based on data obtained from BIG was still dominated by green areas such as rice fields, forests and shrubs. Built-up land showed a small percentage, but some of the areas demonstrated urban characteristics such as several villages in Cipanas and Pacet. These sub districts have several built-up land such as settlements, industries, and various other community activities. Table 4 shows the area of each land use type, divided into built up and natural.

Table 4. Extent of Land Use Types in Cipanas City Candidate Area

Land Use	Area (Hectare)	Land Type
Building	76.98	Built-up Area
Church	0.15	Built-up Area
Hotel/Motel/Hostel/Inn	0.52	Built-up Area
Forest	5785.48	Natural Area
Pharmaceutical Industry	0.16	Built-up Area
TNI installations (AD/AL/AU)	0.12	Built-up Area
National Palace	0.55	Built-up Area
District Office	0.16	Built-up Area
Village Head's Office	1.71	Built-up Area
Other Government Offices	0.31	Built-up Area
Police Station	0.03	Built-up Area
Mosque	0.57	Built-up Area
Elementary School	1.75	Built-up Area
Religious Education	0.23	Built-up Area
Secondary School	1.06	Built-up Area
General Secondary School	0.49	Built-up Area
Plantation/Garden	13599.51	Natural Area
Settlements and Places of Activity	3845.99	Built-up Area
Animal Husbandry	0.12	Built-up Area
Mall/Department Store	0.43	Built-up Area
Other Homes	0.002	Built-up Area
General Hospital	0.19	Built-up Area
Ricefield	7351.08	Natural Area
Rain-Fed Rice Fields	194.23	Natural Area
Shrubs	5114.4	Natural Area
River	59.19	Natural Area
Empty/bare land	48.69	Natural Area
Moor/Field	5197.59	Natural Area
Monastery	0.09	Built-up Area
Reservoir	0.06	Natural Area

Based on land use data, Cipanas City candidate area was dominated by natural land including gardens, forests, moor or fields, shrubs, and rice fields. Built-up land consists of several public, education, and worship buildings. The settlements and associated activities occupy a large portion of the area due to the increasing need for shelter every year. In the context of forming new autonomous city, information regarding land use is very important to reduce negative impacts that may occur due to development, such as forest conversion capable of triggering agrarian conflicts.

The formation of a new autonomous city facilitates the conversion of forest and agricultural land into residential, industrial, and infrastructure areas, resulting in environmental damage and loss of natural habitat (Lestari, 2011; Wicaksono, 2023). Uncontrolled land-use changes could cause social, economic, and environmental problems (Wardana et al., 2016 in Sadewo & Buchori,

2018). For example, the relationship between land use and grassland fire occurrence in the northeastern Inner Mongolia Autonomous Area underscores the importance of understanding how certain practices influence environmental factors such as fire incidents (Li *et al.*, 2017).

3.2. Social Condition of Cipanas City Candidate Area

Population growth has both positive and negative effects on administrative expansion, but responsible government policies can help reduce the negative effects and facilitate sustainable growth. The population in Cipanas City candidate area in 2021 based on the results of the population census by Central Bureau of Statistics (BPS) was estimated at 547,143 thousand people. This number has increased from the previous year which amounted to 540,917 thousand people. Figure 6 shows a dot density map illustrating the number of people in Cipanas City candidate area, with one dot representing 3,000 people.

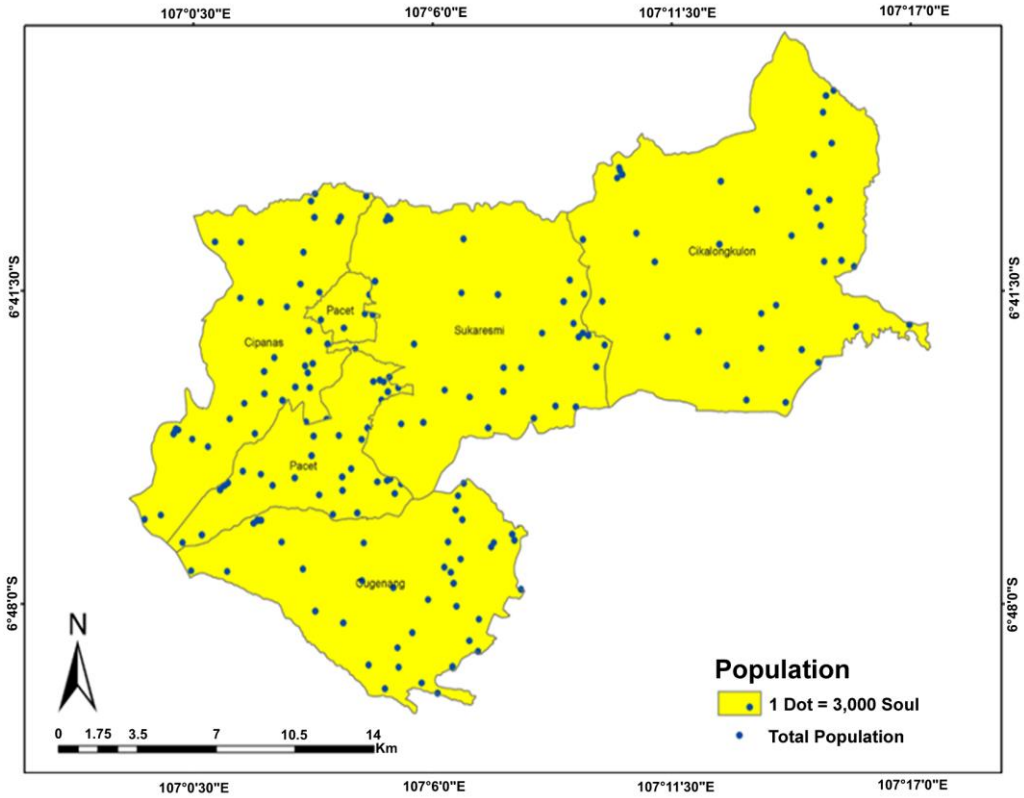

Figure 6. Map of Population in Cipanas City Candidate Area

Some areas, such as Cipanas and Pacet, have dots indicating high density, while others have a sparse distribution with a lower population, including Cikalongkulon and Sukaresmi. The data used in formulating the map was acquired from BPS of Cianjur Regency in 2021, integrated with administrative spatial data from BIG.

The influence of population on the formation of a new autonomous city can be observed in various contexts. In Indonesia, this concept is based on the Special Autonomy Law which aims to strengthen relations between regional governments and local communities in the context of growing democracy (Wisesa *et al.*, 2023). Population growth and the desire for greater autonomy may lead to the formation of a new autonomous city. For example, the Basque Country is autonomous city of Spain, formed due to the population's desire for greater autonomy and self-government. This area has strong cultural identities and distinct languages, contributing to demands for autonomy (Gross, 2003). Furthermore, Åland Islands is autonomous city in Finland, formed due to the desire of the population for greater autonomy and self-government (National Research Council, 2000). In general, population size influences the formation of a new autonomous city by influencing the political, economic, and social dynamics and demands for greater autonomy and self-government. Population density is a social metric enabling an understanding of concentrated population areas. The most prevalent method to define this metric is by assessing the population to area ratio, referring to the count of individuals per specific area (Somantri *et al.*, 2023). Economists have long considered population density to be a central factor in economic growth, population size, and agglomeration effects. It also affects the degree of social cohesion associated with

a given population. Areas with high population density may experience elevated social tension due to the presence of more people nearby (Lu *et al.*, 2023).

According to BPS, Cipanas City candidate area has a small population compared to other cities such as Cimahi, and Bandung. This is attributed to the prevalence of natural land use, while other cities are mostly dominated by built-up and only limited natural land. Various types of natural land developed in Cipanas City candidate area include agriculture, plantations, forests, and others.

Figure 7 showed that the population density in Cipanas candidate city area ranged from 757 to 2698 people/km^2. The area with the highest population density was Pacet, while the lowest was found in Cikalongkulon. Based on the condition of land use, Pacet was dominated by built-up lands, such as settlements and various public facilities, resulting in a high population density. This is also in line with the principle of regional expansion proposed by Harmantyo (2011) and Sutojo (2015), stating that the development of area is demonstrated in the increasingly dense road network, the expanding area of offices and trade, the growing spread of residential areas with high population density, and the significant realisation of employment opportunities for community.

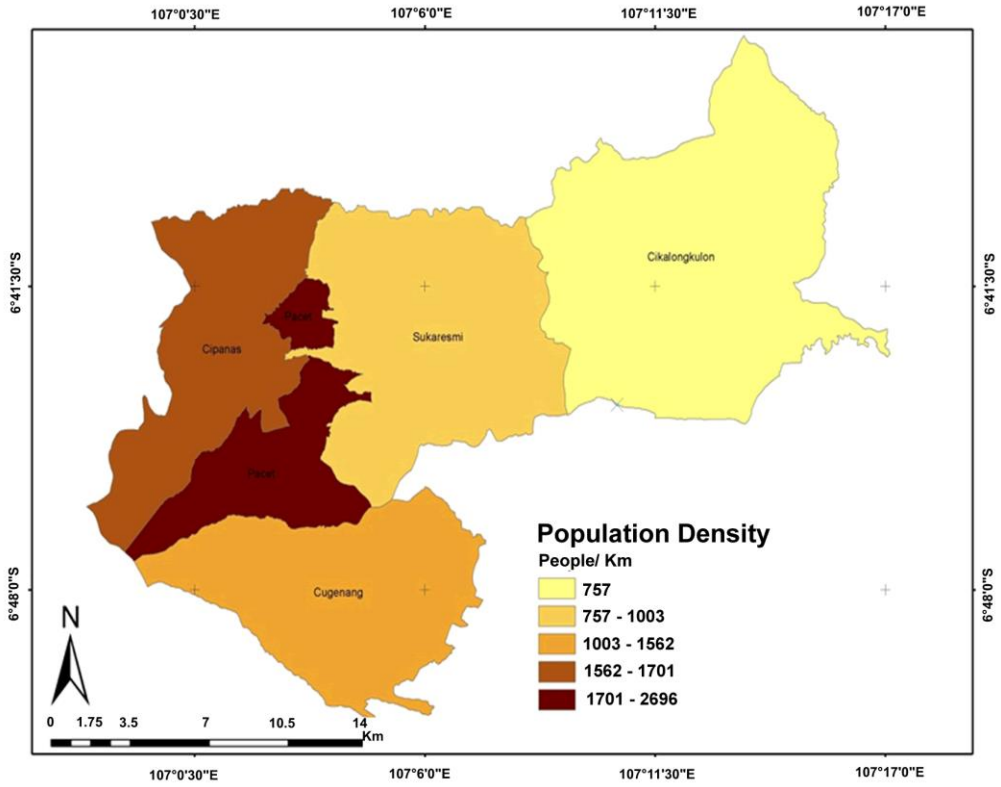

Figure 7. Map of Population Density in Cipanas City Candidate Area

3.3. Identification of Regional Potential Capital City Development in Cipanas City Candidate Area

The development of the capital city area is indispensable in regional administration due to the crucial role in the operational function of the central and major government institutions. This includes the parliament, government offices, and various other important institutions. Based on the previous reports, Cipanas City candidate area has potential to be developed as autonomous area when viewed from several physical and social aspects. However, it is important to consider the social and environmental impacts. This entails good planning, consideration of environmental sustainability, and attention to the social changes that could result from the development. Land use decisions for sustainable urban development require consideration of various physical, environmental, demographic, natural, economic, planning, social, and managerial factors (Karim *et al.*, 2020).

As a new decision-making tool, GIS can be used to solve complex spatial problems with sophisticated analysis functions (Withanage, 2021). This method plays an important role in urban planning by comprehensively analysing spatial data, identifying potential development areas, and proposing optimal land use strategies (Zakarya *et al.*, 2021). Land suitability evaluation includes assessing suitable areas for development by determining the suitability index of a particular area

(Karim *et al.*, 2020). It is considered the best and most effective method for finding areas that suit different parameters or criteria influencing the decision to settle in a place (Saha & Roy, 2021).

Land suitability analysis aims not only to isolate the best alternative but to map a suitability index for the entire area under investigation (Kumar & Biswas, 2013). For suitability analysis, GIS is widely applied in the preparation of various data sets, including slope, drainage density, elevation, as well as to calculate proximity distances, overlay data sets, and analyse the results (Habibi *et al.*, 2021). This research assessed the suitability of regional development for areas suitable as capital in Cipanas City. A total of six parameters were considered as shown in Figure 8, then overlay and scoring analysis was carried out to classify suitable areas.

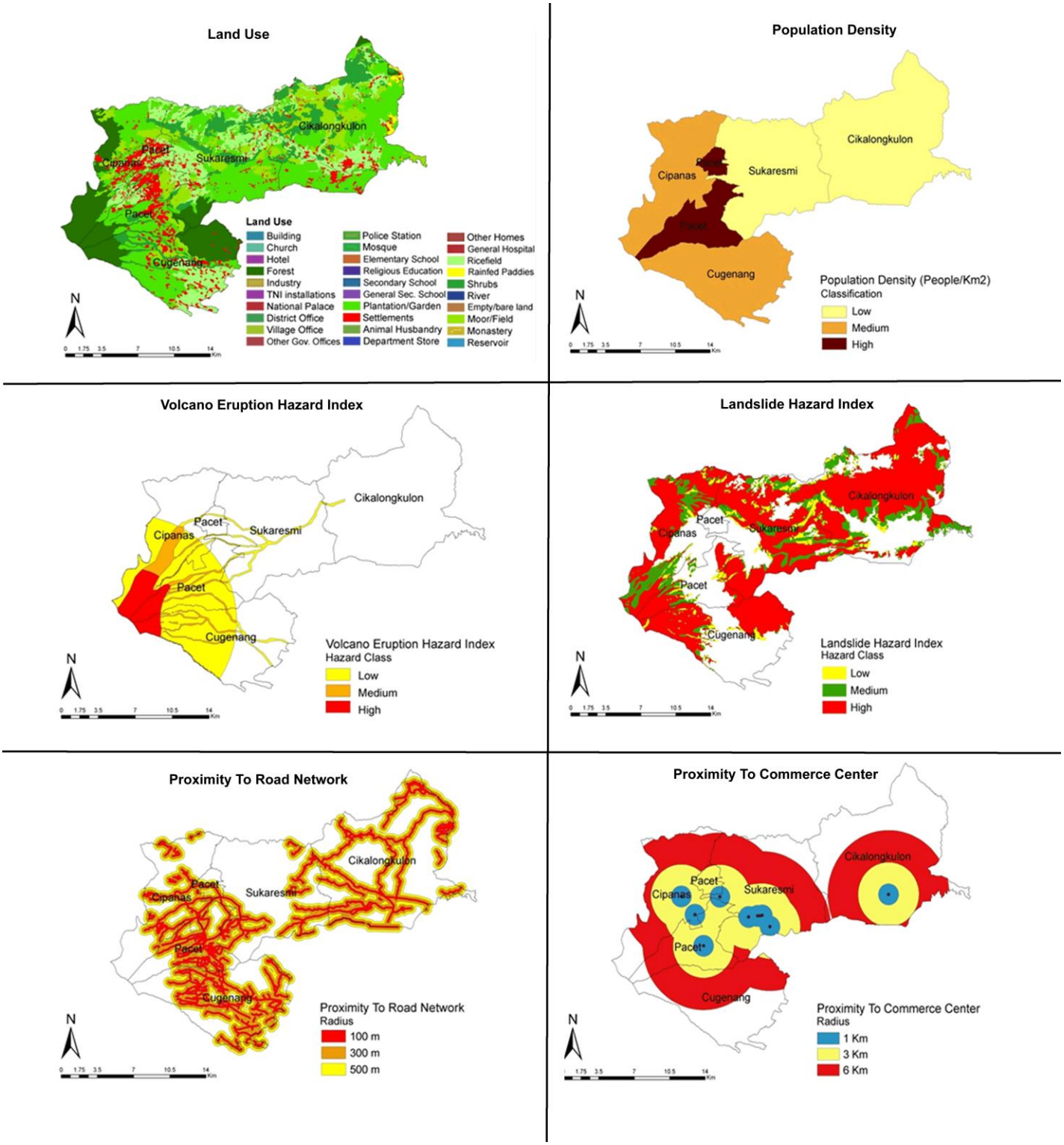

Figure 8. Criteria used in determining suitability map.

Based on the overlay and scoring analysis results, several classes were produced, namely unsuitable, as well as low, medium, and high suitability for the development of the capital city area in Cipanas. The final suitability map represents areas with or without potential, indicated by a score ranging from 1 to 18.

The suitability map shown in Figure 9 provides a clear overview of potential capital city development. Based on the analysis, areas located around hills with low elevations and gentle slopes, accompanied by the presence of many community activity centres, were identified as top choices. Community activities, including the presence of schools, hospitals, and other public facilities are indicators of potential urban development, often attracting people and businesses (UNDRR, 2013). The community centres could be for trade, education, or other public facilities that support the social and economic life of the area.

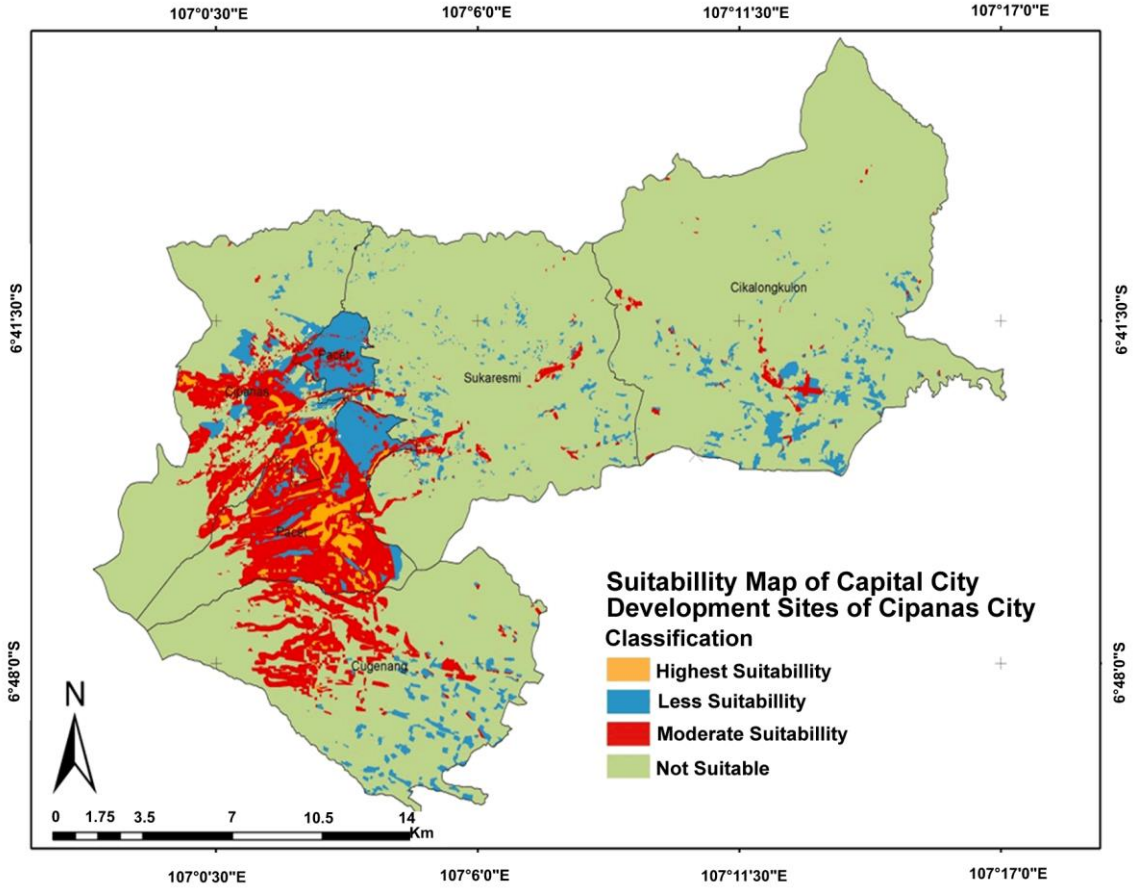

Figure 9. Final suitability map of Capital City development sites.

This comprehensive analysis provides a deeper understanding of the suitability criteria for developing the area as an efficient capital city. Factors such as low elevation and gentle slope, together with diverse community activities, are crucial indicators in determining potential of area for urban development. Low elevation and gentle slope indicate a higher risk of flooding, which can be a deterrent to urban development. However, when the area is located near a major transportation route or has a high concentration of population, it may still be considered despite the flood risk (Feng *et al.*, 2021; Son *et al.*, 2023). Based on the results, Pacet, Cipanas, and a small part of Cugenang Sub-districts are potential spots that should be considered as promising capital city areas in the development plan.

Areas with flat elevations such as Sukaresmi are unsuitable for developing the capital city due to the potential challenge of maintaining agricultural land. Meanwhile, the sector contributes most significantly to the economy and is an asset in developing Cipanas City area with the concept of Agropolitan City. The planning for capital city development must ensure that negative impacts on rural communities and agricultural land are minimised. This method will balance the needs of urban and rural areas, protect agricultural land and preserve the environment, while also promoting economic growth and development (Mattos, 2015; Sallet, 2022). Furthermore, areas with moderate to high suitability categories have many developed centres of community activities including commercial, industrial, and residential, resulting in low sensitivity.

3.4. SWOT (strengths, weaknesses, opportunities, and threats) Analysis

SWOT analysis is a strategic planning tool used to assess an organisation, plan, project, or business activity, comprising two key internal and external dimensions. The internal dimension includes organisational aspects, specifically strengths and weaknesses, while the external dimension incorporates environmental factors, namely opportunities and threats (Gurel & Tat, 2017). The non spatial analysis regarding SWOT identification and strategies in the form of recommendations for the future development of Cipanas City is presented in Table 5.

Table 5. SWOT Analysis

	Identification	Strategy
Strengths	Cipanas City has abundant natural resources and is also known by the wider community for agricultural products and natural attractions. Therefore, economic growth will be faster if Cipanas is developed into autonomous city.	Infrastructure improvement, economic sector diversification, tourism promotion, farmer empowerment, private investment partnerships, quality public services, sustainable development, and sustainable natural resource management.
Opportunities	Cipanas City has a great opportunity because it is located on the main route between Jakarta, Bogor, Cipanas, Cianjur, and Bandung. The advantages of the area as an important crossing point in the transportation network can increase potential for trade, tourism, and economic growth.	The necessary development strategy for Cipanas is to take advantage of geographical area advantages with a focus on developing better transportation infrastructure, promoting tourism, and creating an attractive trade centre while paying attention to environmental preservation and sustainable development.
Weaknesses	Cipanas City faces constraints in developing the space due to mountainous topography, which makes it difficult to develop in an organised manner.	To overcome the constraints of the mountainous topography, Cipanas can adopt an efficient and integrated spatial layout with good transportation, while prioritising environmental preservation and sustainable tourism development.
Threats	The most prominent threat affecting the development of Cipanas City is related to the condition of the slope which is relatively steep, resulting in the area being very prone to landslides.	There is a need to increase understanding related to natural disasters and take various preventive actions related to disaster risk reduction (DRR) activities in Cipanas City candidate area.

By analysing SWOT, this research recommended a series of development strategies, including infrastructure improvements, diversification of economic sectors, tourism promotion, farmer empowerment, private investment partnerships, quality public services, sustainable development, and resource management sustainable nature. In addition, the strategy also underscored the development of better transport infrastructure, promotion of tourism, and the creation of attractive trade centres, with special attention to environmental conservation and sustainable development. Disaster risk reduction efforts were also identified as a crucial step in addressing the threat of landslides.

3.2. Discussion

Spatial modelling analysis is crucial to accurately predict and plan to expand the city candidate area as autonomous. This analysis entails the use of spatial planning as the primary strategy, supported by land use policies (Tiwari & Singh, 2023). Understanding spatial distribution of urban areas and spatiotemporal patterns is essential for sustainable growth (Benchelha *et al.*, 2020). The establishment of new autonomous area for Cipanas City certainly has challenges and must take into account various considerations. This research aimed to identify the new candidate area for

Cipanas City both physically and socially. The results obtained can be used as a reference to address some of the challenges often faced in determining the new administration area.

Physical aspects play crucial roles in creating autonomous city and determining suitable areas for infrastructure development. This aspect includes geographical conditions, soil structure, availability of relevant geospatial data, and accessibility to services, facilities, and amenities (Kranjčić *et al.*, 2019; Korneć, 2020). Cipanas City candidate area is physically dominated by green land for agriculture, plantations, and forests with topographic conditions and slopes from flat to steep. However, among the five subdistricts planned as candidate areas for the capital city, several areas already have strong urban characteristics, specifically Cipanas and Pacet. Based on spatial overlay analysis results, areas with great potential to be used as the capital city include Pacet, Cipanas, and a small part of Cugenang Subdistrict.

In terms of social population, Cipanas City has a low number and density compared to other autonomous cities such as Cimahi and Bandung. However, the influence of globalisation and civilisation has continued to affect the social conditions of community. Kurniati *et al.* (2020) stated that globalisation played a significant role in the development of Asian cities. Different backgrounds and patterns of life among urban communities affect the formation of autonomous cities (Wiryasa & Dwijendra, 2021). Globalisation potentially influences spatial and social patterns, leading to a crisis in urban space development. Some of the negative impacts include conflict and disintegration of urban space growth for commercial interests and land grabbing by capital owners (Alipbeki *et al.*, 2020; Wiryasa & Dwijendra, 2021).

In a broader perspective, future research could further deepen the use of Digital Twin (DT) for forecasting energy needs, specifically in the context of the built environment. Standard policies in resource management and increased energy efficiency are produced by improving the accuracy and precision of energy models. DT system was proposed based on the integration of software such as Building Information Modelling (BIM) and GIS (Agostinelli *et al.*, 2022; Piras & Muzi, 2024). The ability to accurately forecast energy needs facilitates efficient and sustainable infrastructure planning (Lamagna *et al.*, 2021). By utilising this technology, Cipanas City can more effectively optimise resources and plan environmentally friendly development.

DT system assists in updating and improving existing infrastructure, ensuring that changes made are based on accurate data and modelling (Banihashemi *et al.*, 2024). Pagani et al. (2019) and Lamagna *et al.* (2021) proposed a very detailed method to efficiently manage cities. The DT model was formulated for most cities and included all physical elements. It comprises modelling and sits for around 14,000 buildings, such as parking lots, transformers, and power lines of various voltages, alongside shops and homes. In addition, agent-based simulations were used to model the residents and migrants, enabling accurate evaluation of residents and mobility patterns. This method produced a holistic and detailed picture of the city, facilitating better management and smarter decision making for the future.

In general, the use of DT technology in modelling the built environment contributes majorly to urban planning and development, specifically in forecasting future energy needs. It enables more precise and dynamic modelling of energy use patterns, facilitating accurate decision-making for sustainable development (Lamagna *et al.*, 2021; Agostinelli *et al.*, 2022). By utilising DT technology, detailed modelling of the entire area can be carried out, including physical elements such as buildings, infrastructure, and activity centres.

Limitations of the scale and scope of this research restrict the generalisability of the results. The investigation focused majorly on Cipanas candidate area, hence, the results may not be directly applicable to other cities with different characteristics. Furthermore, the accuracy of spatial analysis and GIS methods was limited by several factors such as geographic complexity or dynamics of change. To increase generalisability, future research could utilise a larger scale and similar cities to understand the sustainability of the methods and results. Dynamic models that consider changes over time should be incorporated to provide a deeper understanding of factors influencing urban development.

4. Conclusion

In conclusion, spatial modelling analysis was identified as an essential tool for understanding the intricate spatial relationships and patterns influencing urban growth. Based on the results, Cipanas City candidate area had great potential to develop as autonomous. Factors such as physical conditions supporting agriculture, relatively low population density, and abundant natural resources were key in determining the most suitable area for development. Furthermore, SWOT analysis showed the challenges, such as the mountainous topography that could cause landslides.

Recommendations for infrastructure improvements, economic sector diversification, tourism promotion, and disaster risk reduction activities were important steps in overcoming the identified challenges. In addition, planning for sustainable urban growth was found as a key focus in urban development. This research provided a comprehensive view of potentials and challenges in the development of Cipanas City as autonomous area, offering a solid basis for decision making related to sustainable growth.

Integration of DT system could be a valuable asset to address the ever growing complexity of city development. This technology facilitated more accurate and dynamic modelling, enabling stakeholders to make more informed and sustainable decisions. By implementing DT, Cipanas can effectively plan infrastructure, manage disaster risks, and promote sustainable economic growth, supporting the vision of an innovative autonomous city.

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Conceptualisation: Somantri, L; **methodology**: Somantri, L; **investigation**: Somantri, L; **writing—original draft preparation**: Somantri, L;. **writing—review and editing**: Somantri, L; **visualisation**: Somantri, L.. The author have read and agreed to the published version of the manuscript.

Conflict of interest

All authors declare no conflict of interest.

Data availability

Data is available upon Request.

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