



Decoding Regional Diversity: Physical and Socio-Economic Development Typology of Sub-Districts in Bogor Regency

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Abstract

Bogor Regency as part of the Jabodetabek Megacity, serves as a satellite area for Jakarta and exhibits significant potential for land cover change. This study aims to: (1) analyze land cover change dynamics; (2) assess regional development levels in 2019 and 2022; (3) classify regions based on physical, social, and economic characteristics; and (4) analyze regional typology using the Sub-District Development Index (SDI), Human Development Index (HDI), and land cover percentage. Data from 2019 and 2022, including land cover maps, administrative maps, village potential, and HDI, were analyzed using overlay techniques, scalogram analysis, Klassen typology, and k-means clustering. Results indicate significant reductions in rice fields and dry agricultural land, primarily converted to built-up areas, especially in Cibinong Sub-district, driven by increased demand for space and economic facilities. Most regions in Bogor Regency exhibit low to very low development levels based on the availability and accessibility of education, health, and economic facilities. Klassen typology reveals a disparity, with some sub-districts progressing while others lag behind. The regional typology identifies three categories: rural areas in the east and west, urban areas in the north, and suburban areas dispersed across sub-districts.

Keywords: *Human Development Index; Klassen Typology; Land-Land cover-Cover changesChanges; subSub-district-District development-Development index; kassen typology*

1. Introduction

Bogor Regency is an integral part of the Jabodetabek Megapolitan area, strategically positioned as a hinterland or satellite region for Jakarta. This geographical position places Bogor Regency within the sphere of Jakarta's development dynamics, significantly influencing its economic, social, and spatial development (Andriamasari et al., 2015). As a supporting region for the nation's capital, Bogor Regency faces substantial pressure on its natural resources and spatial allocation, primarily due to the high demand for land. With a population of 5.6 million, a density of 1,881 people/km², and a population growth rate of 1.32% (BPS, 2024), the regency faces critical challenges in managing sustainable land use. Rapid population growth has become a major driver of land cover changes, driven by the increasing demand for housing, infrastructure, and other supporting facilities.

Urbanization is a dominant phenomenon driving land use changes in Bogor Regency. It leads to substantial transformations in land utilization, where urban areas continue to expand to meet the growing demands for housing and infrastructure, facilitating population mobility (Pravitasari et al., 2024; Anisyaturrobiah, 2021). Empirical data from the Indonesian Statistics Agency (BPS) indicate 15% increase in built-up areas in Bogor Regency over the last decade, predominantly resulting from agricultural land conversion. This trend aligns with Sipayung (2019) findings, which identified heightened pressure on agricultural land due to rising demand from the property and industrial sectors. Furthermore, Latue et al.

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(2023) emphasize that increasingly intensive economic activities, both locally and regionally, have accelerated the dynamics of land use changes.

The commuter phenomenon is another distinctive characteristic of Bogor Regency. Easy accessibility to Jakarta through various transportation modes, such as commuter trains, toll roads, and public transit, has made Bogor Regency a primary residential choice for people working in Jakarta (Sari & Mulyani, 2021; Pravitasari et al., 2018). Data indicate that approximately 40% of the productive population in Bogor Regency [commutes](#) daily to Jakarta (BPS, 2024). This phenomenon not only influences land use patterns but also drives significant changes in socio-economic and institutional dimensions, as highlighted by Fajarini et al. (2015). The conversion of agricultural land into residential areas and built-up zones, including housing complexes and business hubs, is a direct consequence of this [trend](#) (Astuti 2022; Munibah & Widiatmaka, 2019).

Regional development is a complex process, often marked by the expansion of built-up areas as a key [indicator](#) (Rustiadi et al. 2021; Pravitasari et al. 2019). The increasing number and types of facilities, such as housing, shopping centers, and transportation infrastructure, reflect the dynamic growth of a region (Libriyanto et al. 2022; Pravitasari et al. 2019). According to Pravitasari et al. (2018), heightened land demand not only triggers land conversion but also impacts the local economic structure. This is evident in Bogor Regency, where areas like Cibinong, Sentul, and Bojong Gede have experienced rapid growth as emerging economic centers. However, this growth brings challenges, including declining agricultural productivity and heightened environmental risks, such as flooding and groundwater quality degradation, due to uncontrolled land conversion.

In the context of regional autonomy, regional development is expected to drive economic growth, improve community welfare, and maximize the sustainable utilization of local potential (Verburg et al. 2015). However, achieving these goals requires evidence-based planning and in-depth analysis. One relevant approach is regional typology, which aims to identify the unique characteristics of each area and design specific, effective policies. Ghozali and Kautsar (2022) argue that grouping regions based on physical, social, and economic characteristics is crucial for understanding growth dynamics and challenges. For instance, sub-districts in Bogor Regency can be categorized based on urbanization levels, economic activity intensity, and environmental vulnerability (Pielke et al., 2022; Bakri, 2017). Data from land cover change analyses and regional development indices can provide a clearer picture of development trajectories, potentials, and challenges faced by each area.

Moreover, significant land cover changes in Bogor Regency have implications for environmental sustainability. A study by Pravitasari et al. (2020) revealed that the conversion of agricultural land to built-up areas has led to soil quality degradation and biodiversity loss in several regions (Pravitasari et al., 2015). The increase in population and economic activities has also contributed to higher carbon emissions and energy consumption, highlighting the need for improved mitigation policies (Rustiadi et al., 2015). Thus, this research not only focuses on identifying land use change patterns but also examines their impact on sustainable development (Murtadho et al., 2018).

The urgency of this research lies in the pressing need to manage land use changes prudently to support sustainable development. Bogor Regency faces substantial developmental pressures, which, if left unaddressed, could lead to environmental degradation, a decline in community quality of life, and the loss of natural resource potential (Firman, 2009). With increasing urbanization and population growth, it is essential to deeply understand land use change patterns and their implications for regional development (Rustiadi and Nasution, 2017). This research is particularly relevant in supporting regional autonomy policies that require evidence-based approaches for effective and sustainable planning (Firman, 2014).

The novelty of this research lies in its comprehensive and integrative approach, utilizing empirical, data-driven regional typology analysis that incorporates physical, social, and economic variables (Pravitasari et al., 2018). The study focuses on: (i) analyzing the dynamics of land cover change; (ii) evaluating regional development levels in 2019 and 2022; (iii) classifying regions based on their physical, social, and economic characteristics; and (iv) examining regional typologies using the Sub-District Development Index (SDI), Human Development Index (HDI), and land cover percentages. This research introduces an innovative framework for categorizing sub-districts, enabling the formulation of policy recommendations tailored to the specific characteristics of each area (Pravitasari et al., 2018). Furthermore, it provides fresh insights into addressing developmental challenges in megapolitan buffer zones, such as Bogor Regency, while offering practical strategic recommendations for achieving sustainable regional development (Rustiadi et al., 2021).

2. Methods

This research was conducted in Bogor Regency, West Java Province, a region geographically situated between 6°18'0" - 6°47'10" South latitude and 106°23'45" - 107°13'30" East longitude. Strategically located adjacent to the national capital, Jakarta, Bogor Regency serves as a vital hinterland supporting the center of government, services, and trade, characterized by high levels of developmental activity. Covering an area of 294,666.1 hectares, the regency is administratively divided into 40 sub-districts and 435 villages, with its government center located in Cibinong Sub-district.

Population dynamics play a crucial role in regional development. According to Muta'ali (2015), population refers to the total number of individuals living in a specific area at any given time. Data from BPS Bogor Regency (2023) indicate that the population grew from 5,489,530 in 2021 to 5,566,840 in 2022. Kusuma and Sukendra (2016) define population density as the number of people per unit area,

measured in people per square kilometer (km²). In 2022, the average population density of Bogor Regency was 1,865 people/km². Bojong Gede Sub-district recorded the highest population density at 10,535 people/km², reflecting its urban characteristics, while Cariu Sub-district had the lowest density at 310 people/km², indicative of its rural nature.

The Human Development Index (HDI) serves as a comprehensive metric to evaluate the success of improving human quality, offering insights into the social conditions, quality of life, and welfare of the population in a region (Ningrum et al., 2020). An HDI analysis of the 40 sub-districts in Bogor Regency (2023) revealed that three sub-districts: Gunung Putri (83.25), Cibinong (80.8), and Bojong Gede (78.99), achieved the highest HDI values. These areas reflect significant progress in human development, underpinned by better access to education, healthcare, and economic opportunities. Collectively, the demographic, spatial, and human development characteristics underscore the strategic importance and diverse challenges of Bogor Regency as a focus of this study.

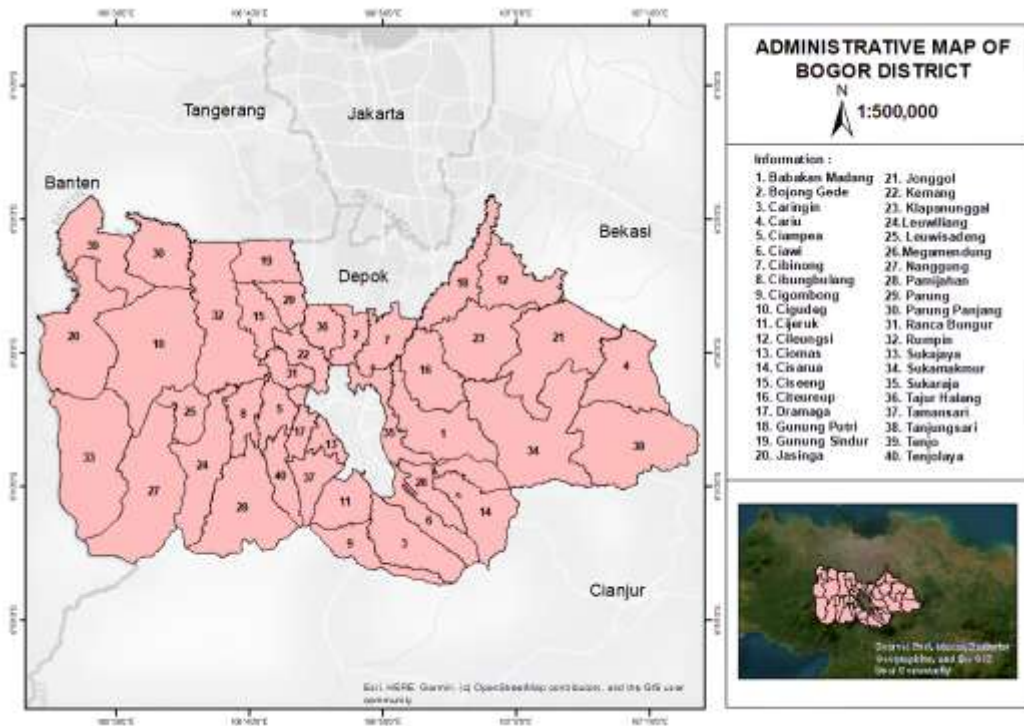


Figure 1. Study Location Map
(Author's Analysis, 2025)

2.1 Land Use and Cover Changes Analysis

The overlay process was chosen for this study due to its ability to effectively analyze spatial changes over time by integrating multiple datasets (Pravitasari et al. 2019). This method was selected because it provides a precise, visual, and quantifiable approach to examining land cover change, which is essential for understanding the dynamics of land use in a given region. The overlay technique allows for the integration of different layers of spatial data, such as land cover maps from different years (2019 and 2022) and regional administrative boundaries, into a unified spatial model. This makes it possible to track and visualize land cover changes within a defined geographical area, offering insights into temporal shifts in land use patterns (Pravitasari et al. 2015).

The choice of overlay as a method improves upon previous research by providing a more comprehensive and layered approach to analyzing land use change. Many studies on land cover change rely on a comparison of land cover maps from different years, but they often overlook the administrative and policy boundaries that influence land use decisions (Rosandi et al. 2024). By integrating these maps with regional administrative boundaries, this method enables a more nuanced understanding of the factors driving land cover changes. For instance, the overlay process allows researchers to directly link land use changes to specific regions, highlighting how different administrative areas are experiencing varying rates and types of change (Rosandi et al. 2024). This level of detail enables more targeted policy recommendations and regional planning interventions.

Moreover, the overlay method facilitates the identification of specific hotspots where land use changes are most pronounced (Wang, 2016; Tobias, 2016). By analyzing the spatial extent of land cover change within these areas, the study can pinpoint regions where the conversion of agricultural land to urban areas, for example, is most significant (Liu, 2018). This method also improves on previous research by enhancing the ability to analyze land use changes in the context of broader socio-economic and environmental factors (Copernicus, 2020). While many studies focus solely on the physical changes in land cover, the overlay process allows for the integration of external variables, such as demographic shifts

or changes in government policies, which are often critical drivers of land use changes (Xiangping, 2020). By mapping these changes over time, the study can not only quantify the extent of land use change but also assess the underlying forces shaping these transformations, such as population growth, urbanization, or shifts in agricultural practices (Copeland, 2017). This deeper understanding helps clarify the relationship between land cover changes and regional development, offering insights into the potential long-term impacts of these changes on environmental sustainability.

2.2 Sub-District Development Index (SDI) with Scalogram Analysis

The scalogram method was chosen for this study due to its ability to provide a comprehensive, data-driven analysis of sub-district development levels, which is essential for understanding the socio-economic dynamics in regions with significant disparities. The Sub-District Development Index (SDI), derived from the scalogram method, aggregates key variables such as accessibility, education, healthcare, and economic facilities, offering a multidimensional approach to assessing development (Pravitasari et al., 2019). This is especially valuable in regions like Indonesia, where regional disparities in terms of infrastructure, education, healthcare, and economic opportunities are pronounced. The SDI method enables a more nuanced understanding of development, taking into account factors that directly impact the quality of life for residents, rather than relying solely on traditional economic measures like Gross Regional Domestic Product (GRDP), which primarily captures economic output (Pravitasari et al., 2020).

Unlike GRDP, which may fail to reflect the socio-economic realities of a region, the SDI provides a more holistic picture by considering the ratio of facilities to population (Rustiadi, 2011). This is crucial for understanding how economic growth translates into tangible improvements in residents' daily lives. For example, a sub-district with a high GRDP may still lack adequate healthcare or education services, leading to a disconnect between economic growth and social welfare (Panuju, 2013). The SDI bridges this gap by incorporating critical social and infrastructural factors into the analysis, making it a more comprehensive indicator of development. By focusing not just on economic performance, but also on the availability and accessibility of essential services, the SDI captures a broader scope of development that is more aligned with residents' actual living conditions.

The inclusion of education and healthcare facilities as variables in the analysis ensures that the SDI not only reflects economic conditions but also addresses human development factors that are crucial for long-term sustainability (Pravitasari et al., 2022). These variables are essential for fostering human capital, which is a key driver of regional growth. Furthermore, accessibility the ease with which populations can reach services and opportunities is a fundamental component of the SDI. Access to education, healthcare, and economic services influences how well populations can benefit from available resources, and thus is vital for ensuring that growth is inclusive and equitable. By integrating these factors, the SDI provides valuable insights into areas where investments are needed most, particularly in underdeveloped sub-districts (Pravitasari et al., 2022).

The scalogram method's ability to use village-level data across multiple years enhances its effectiveness by capturing temporal changes in development (Pravitasari et al., 2017). This is particularly important in rapidly urbanizing or demographically shifting regions, where development may not be uniform across all areas. By tracking changes over time, the method highlights areas where growth has been uneven or where existing infrastructure is struggling to meet the needs of a growing population. This temporal aspect of the SDI is crucial for identifying regions where development interventions are required to ensure that growth is balanced and that infrastructure and services can keep pace with population changes (Pratomo, 2019; Pravitasari et al., 2018).

In comparison to previous research that may have relied heavily on static or economic-focused metrics, the scalogram method and SDI improve upon earlier studies by offering a dynamic, multidimensional framework for assessing regional development. Traditional indicators like GRDP often fail to capture the complexities of regional development, particularly when disparities in access to basic services are significant. The SDI offers a more comprehensive view by accounting for factors such as education, healthcare, and accessibility, which are essential for fostering sustainable and inclusive growth. This method enhances our understanding of the regional development process, moving beyond economic output to encompass the broader social infrastructure that supports long-term growth.

Table 1: Dimension and Variable that influence Sub-district Development Index (SDI).

Code	Dimension and Variable to Identifying Sub-district Development Index	Unit
Education		
V1	Number of kindergarten	Unit
V2	Number of elementary school	Unit
V3	Number of junior high school	Unit
V4	Number of senior high school	Unit
V5	Number of vocational high school	Unit
V6	Distance to kindergarten	Kilometers (Km)
V7	Distance to elementary school	Kilometers (Km)
V8	Distance to junior high school	Kilometers (Km)
V9	Distance to senior high school	Kilometers (Km)
V10	Distance to vocational high school	Kilometers (Km)
Health		
V11	Number of pharmacy	Unit

Code	Dimension and Variable to Identifying Sub-district Development Index	Unit
V12	Number of doctor's office	Unit
V13	Number of midwife practice	Unit
V14	Distance to pharmacy	Kilometers (Km)
V15	Distance to doctor's office	Kilometers (Km)
V16	Distance to midwife practice	Kilometers (Km)
Economy		
V17	Number of inns	Unit
V18	Number of bank	Unit
V19	Number of convenience store	Unit
V20	Number of shop group	Unit
V21	Distance to lodging	Kilometers (Km)
V22	Distance to Minimarket	Kilometers (Km)
V23	Distance to group of shop	Kilometers (Km)

Source: Author's Analysis, 2025

The analysis of the sub-district development level was done in one go by combining two years' worth of data through the following steps:

1. Calculating the inverse distance on each inverse variable, where a larger distance (after inversion) indicates a greater similarity between objects using the equation:

$$Y_{ij} = \frac{1}{X_{ij}}$$

Where:

Y_{ij} = Index of the j-th data

X_{ij} = j data value

2. Calculating the weight of the characterization index using the equation:

$$I_{ij} = \frac{X_{ijn}}{X_{ijp}}$$

Where:

I_{ij} = Characterization index weight

X_{ij} = Data value of the i-th region of the j-th variable

i = Sub-district area

j = Characteristic variable

n = Number of sub-district areas

p = Number of characterizing variables

3. Determine the standardized value of the index (standardization) with the equation:

$$K_{ij} = \frac{I_{ij} - (\min I_j)}{S_j}$$

Information :

K_{ij} = Standardized index value

I_{ij} = Weighted value of the characterization index

$\min I_j$ = The minimum value of the index at the j-th feature

S_j = Standard deviation value

4. Determine the value of the Sub-district Development Index (SDI) with the equation:

$$SDI = \sum_{i=1}^P K_{ij}$$

Information :

SDI = Sub-district development indeks

K_{ij} = Number of standardized index values

2.4 Klassen Typology

The choice of using Klassen typology analysis in this study is driven by its ability to categorize sub-districts based on levels of development, land use, and human development, providing a clear and actionable framework for understanding regional disparities (Pravitasari et al., 2024; Misbah, 2019). This method was selected for its simplicity, flexibility, and capacity to capture complex relationships between

various socio-economic and spatial variables, which is crucial in regions like Bogor Regency, where there are significant variations in development, land use patterns, and human development (Bernaciak, 2014).

Klassen typology is particularly useful for this study because it enables the integration of multiple variables specifically the percentage of built-up area, Sub-District Development Index (SDI), and Human Development Index (HDI) into a straightforward analytical model (Pravitasari et al., 2024). By plotting these variables on a scatterplot, Klassen typology creates four quadrants that categorize each sub-district based on urbanization levels (built-up area), socio-economic development (SDI), and human development (HDI) (Pravitasari et al., 2024). This approach provides a clear spatial overview of the development landscape in Bogor Regency, allowing the study to identify and visualize the position of each sub-district in relation to both development and human welfare.

The four quadrants created through the scatterplot serve as a basis for comparing and categorizing sub-districts, providing valuable insights into the extent to which land use changes and developing activities contribute to or hinder overall socio-economic well-being (Pravitasari et al., 2024). This typology is an essential tool for identifying areas where infrastructure and services are outpacing human development or where, conversely, social welfare is advancing without sufficient physical or economic growth (Pravitasari et al., 2024; Misbah, 2019). Such analysis is crucial for policymaking, as it provides a clearer understanding of the relationship between land use changes, human development, and regional disparities, enabling more focused interventions.

Compared to previous research, which may have relied solely on economic or demographic data, the use of Klassen typology in this study improves upon traditional approaches by integrating both land use (built-up area) and human development (SDI, HDI) into a unified framework (Munandar, 2016). Many studies have typically focused on economic output or population growth as development indicators, often overlooking the complexities of social welfare and infrastructure access (OECD, 2011). By incorporating SDI and HDI alongside land cover data, this method provides a more comprehensive assessment of development that better reflects the actual living conditions of residents (OECD, 2011).

Additionally, Klassen typology enhances previous research by offering a dynamic and comprehensive model that considers temporal changes (comparing data from 2019 and 2022) and spatial relationships between sub-districts. This longitudinal approach allows for the identification of development trends over time, helping to discern whether specific areas are progressing or regressing in terms of both economic and human development (Pravitasari et al., 2024; Misbah, 2019).

Table 2: Klassen Typology.

Klassen Typology		Percentage of Built-up Area (BuA)	
		Percentage of Built-up Area i is lower than average Percentage of Built-up Area in Bogor Regency ($BuA_i < BuA$)	Percentage of Built-up Area i is higher than average Percentage of Built-up Area in Bogor Regency ($BuA_i > BuA$)
Sub-district Development Index (SDI) & Human Development Index (HDI)	SDI and HDI sub-district i is higher than average SDI and HDI in Bogor Regency $\overline{SDI_i \& HDI_i} > \overline{SDI \& HDI}$	QUADRANT 2 (low percentage of BuA, high SDI & HDI) $\overline{BuA_i} < \overline{BuA}$ $\overline{SDI_i \& HDI_i} > \overline{SDI \& HDI}$	QUADRANT 1 (high percentage of BuA, high SDI & HDI) $\overline{BuA_i} > \overline{BuA}$ $\overline{SDI_i \& HDI_i} > \overline{SDI \& HDI}$
	SDI and HDI sub-district i is lower than average SDI and HDI in Bogor Regency $\overline{SDI_i \& HDI_i} < \overline{SDI \& HDI}$	QUADRANT 3 (low percentage of BuA, low SDI & HDI) $\overline{BuA_i} < \overline{BuA}$ $\overline{SDI_i \& HDI_i} < \overline{SDI \& HDI}$	QUADRANT 4 (high percentage of BuA, low SDI & HDI) $\overline{BuA_i} > \overline{BuA}$ $\overline{SDI_i \& HDI_i} < \overline{SDI \& HDI}$

Source: Author's Analysis, 2025

Note:

*Percentage of Built-up Area (BuA) => (total built-up area in t1 - total of built-up area in t0)/total of built-up area in t0/t1-t0

**Sub-District Development Index (SDI) => number of sub-district development index

***Human Development Index (HDI) => number of Human development index

The four quadrants in Klassen's Typology consist of:

1. Quadrant 1: Sub-districts in quadrant 1 are categorized as areas with a higher percentage of built-up area than the average percentage of built-up area in Bogor District, and a SDI and HDI greater than the average SDI and HDI in Bogor District.

2. Quadrant 2: Sub-districts in quadrant 2 are categorized as areas with a lower percentage of built-up area than the average percentage of built-up area in Bogor District, but the SDI and HDI in the area are greater than the average SDI and HDI in Bogor District.
3. Quadrant 3: Sub-districts in quadrant 3 are categorized as areas with a lower percentage of built-up area than the average percentage of built-up area in Bogor District, and the SDI and HDI in the area are also smaller than the average SDI and HDI in Bogor District.
4. Quadrant 4: Sub-districts in quadrant 4 are categorized as areas with a higher percentage of built-up area than the average percentage of built-up area in Bogor District, but the SDI and HDI in the area are smaller than the average SDI and HDI in Bogor District.

3. Result and Discussion

3.1 Land Cover Change Analysis in Bogor Regency

Land cover in Bogor Regency is categorized into nine distinct types: water bodies, forests, developed land, plantations, mining, dry land farming, rice fields, shrubs, and open land. To identify changes in land cover, a comparative analysis was conducted using spatial data from two time points: 2019 and 2022. Figure 2 presents a land cover map, supplemented by a pie chart reflecting the highest land cover area distribution. Over the three-year period from 2019 to 2022, Bogor Regency experienced notable land use transformations, as detailed in Table 4. Forested areas slightly decreased from 64,015.2 hectares in 2019 to 63,875.6 hectares in 2022. In contrast, the built-up area increased from 47,721.9 hectares to 49,580.3 hectares, indicating significant urban expansion. Similarly, plantation areas grew from 11,882.6 hectares to 12,077.0 hectares, while mining areas slightly contracted from 1,866.7 hectares to 1,811.1 hectares. Dry land farming decreased from 119,756.7 hectares to 118,600.4 hectares, and rice fields also saw a reduction from 45,643.0 hectares to 44,428.5 hectares. Shrub areas expanded from 2,162.1 hectares to 2,371.3 hectares, and open land increased notably from 501.0 hectares to 805.1 hectares. It is important to note that the water bodies category remained unchanged during this period, indicating no significant alteration in these areas. These findings reflect a dynamic shift in land use in the region, with urbanization and agricultural expansion driving the most substantial changes (Mulya, 2022; Ariyani, 2023; Merlina 2023).

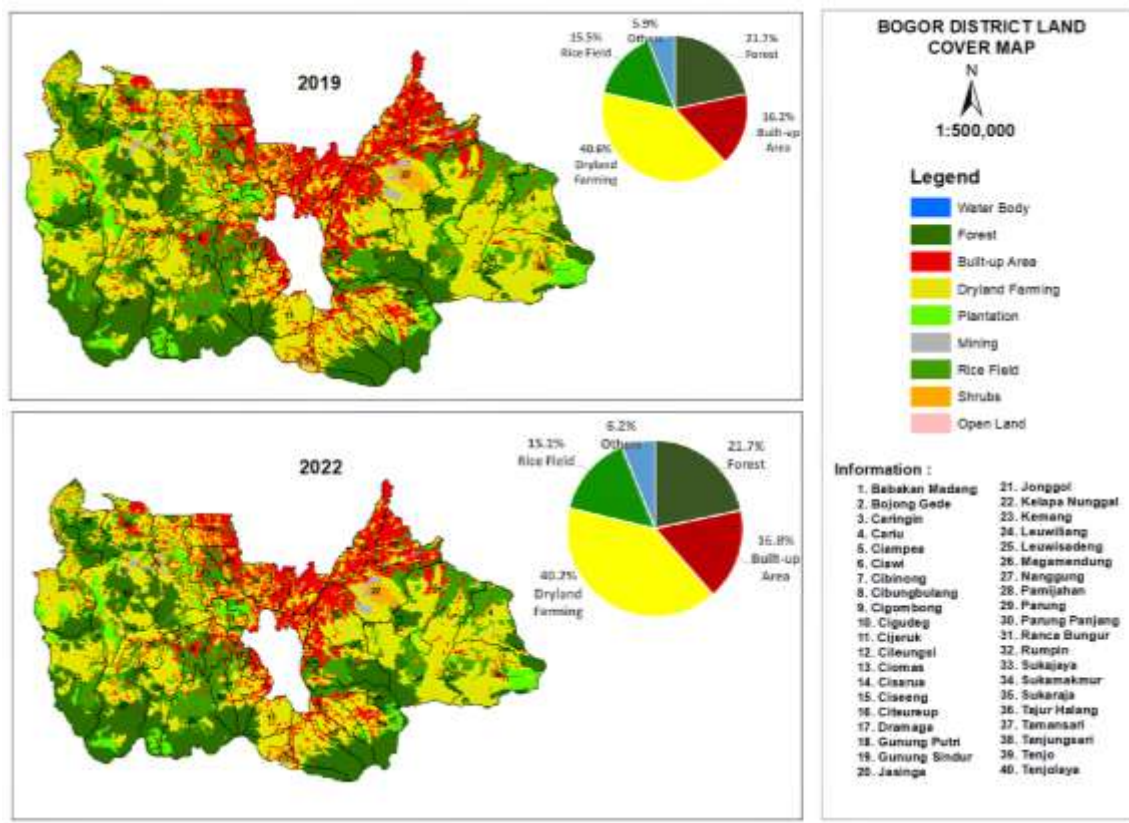


Figure 2. Land Cover Changes in 2019 and 2022
Author's Analysis, 2025

The observed changes in land use patterns in Bogor Regency align with broader trends of urbanization and land conversion in the region. Research by Mulya et al. (2022) and Ariyani et al. (2023) highlights the transformation of agricultural land into settlements, restaurants, cafes, and other buildings in Bogor Regency, driven by economic factors and changing land use preferences. Similarly, Merlina et al. (2023) report on the growth of settlement areas in East Cilebut Village, Sukaraja District, Bogor Regency,

between 2015 and 2020, reflecting the increasing demand for housing in suburban areas. Furthermore, a study on the border area of Bogor Regency and Bogor City found a significant increase in settlement areas between 2010 and 2020, emphasizing the ongoing urbanization process in the region.

Table 3: Land Cover Change in Bogor Regency (2019 and 2022)

Land Cover	2019 (ha)	2022 (ha)	2019-2022 (ha)
Water Body	1.116,9	1.116,9	0
Forest	64.015,2	63.875,6	-139,6
Built-up Area	47.721,9	49.580,3	1.858,4
Plantation	11.882,6	12.077,0	194,4
Mining	1.866,7	1.811,1	-55,7
Dryland Farming	119.756,7	118.600,4	-1.156,3
Rice Field	45.643,0	44.428,5	-1.214,4
Shrubs	2.162,1	2.371,3	209,2
Open Land	501,0	805,1	304,1

Source: Author's Analysis, 2025

This conversion from agricultural to non-agricultural land can be triggered by increasing population growth (Ricky et al., 2017). This is in accordance with BPS data (2023) which shows 4,699,282 people in 2019 experienced a significant increase in 2022 to 5,566,840 people with a population growth rate per year 2010-2022 of 1.25%. This population growth causes changes in land use patterns, so that built-up area increasingly dominates and urges natural spaces to change function (Tulenan et al., 2014). According to Pravitasari et al. (2020), this population growth increases the demand for space, which leads to the conversion of paddy fields into built-up area, especially for settlements.

The changes in land cover, particularly the conversion of paddy fields and dryland farming (PLK) into developed land, are most prominently observed in the northern and western parts of Bogor Regency, including areas such as Gunung Sindur, Parung Panjang, Tenjo, and Jasinga. This trend can be attributed to the role of Bogor Regency as a buffer zone for DKI Jakarta and its surrounding areas, which are undergoing significant land use transformations. The increased pressure for land use changes in these areas is further compounded by the spatial policies outlined in the 2005-2025 Bogor Regency Regional Spatial Plan (RTRW), particularly the designation of industrial estates, which has contributed to the expansion of built-up areas (Fajarini et al., 2015).

Bogor Regency's high accessibility, due to its strategic location, has made it a focal point for urban settlement development and a hub for various economic activities. These activities include agricultural production, trade, services (such as nature and culinary tourism), and industrial operations (particularly small and medium industries) (Trimarmanti, 2014). The proximity to major transportation networks has fostered the growth of urban settlements and commercial areas, further accelerating the conversion of vegetated land into built-up areas, such as residential zones, industrial areas, trade centers, and transportation corridors.

As noted by Djalante (2019), improved and more extensive road infrastructure often leads to the formation of activity centers along transportation routes. This creates a feedback loop where increased connectivity drives further urbanization, leading to the conversion of natural land cover into urban spaces. According to Aklile et al. (2014), land use changes are influenced by a combination of human needs and environmental factors. As the population grows and the demand for land increases, the balance between these two forces—human needs for space and infrastructure, and environmental processes—becomes a driving factor in land use transformation.

3.2 Sub-district Development Index

The results of the scalogram analysis are illustrated on the map of regional development levels, which shows the spatial distribution of Sub-District Development Index (SDI) values across Bogor Regency in Figure 3. The level of regional development is categorized into five groups based on SDI values: very low (5-17), low (17-29), medium (29-41), high (41-53), and very high (53-65). These SDI values are influenced by the availability of facilities and their accessibility within each sub-district.

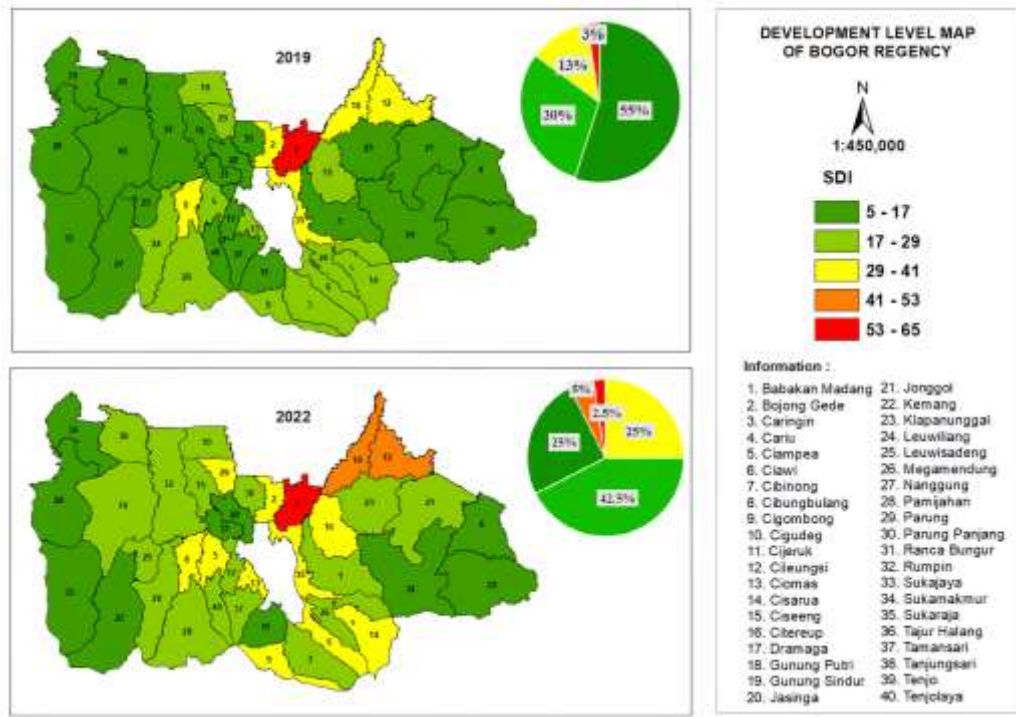


Figure 3. Map of Sub-district Development Index (SDI) in 2019 and 2022
Author's Analysis, 2025

Sub-District Cibinong, with SDI values of 56.08 in 2019 and 62.84 in 2022, falls into the very high development category in both years. This indicates that Cibinong is a highly developed area with significant potential to become a service center due to its high population density, well established infrastructure, and excellent accessibility. These findings align with the research by Utami (2014), which also highlights Cibinong as the area with the highest score for facilities in the regency, given its role as the economic development center in Bogor Regency.

In the 2019 analysis, no sub-districts in Bogor Regency were classified as having high SDI values. However, by 2022, two sub-districts Cileungsi and Gunung Putri experienced an increase in their SDI scores, reaching 45.23 and 49.67, respectively. The growth in SDI in these sub-districts is likely attributed to their strategic proximity to government and economic centers, which has fostered the development of supporting infrastructure and facilities. The addition of these new facilities has contributed to the increase in SDI, consistent with the findings of Nurhasanah et al. (2018), who noted that Cileungsi and Gunung Putri, with relatively strong economic structures and GRDP per capita above the regency average, show characteristics of more developed areas.

Additionally, the number of sub-districts classified within the medium SDI category increased from 5 sub-districts in 2019 to 10 sub-districts in 2022. These include Bojong Gede, Ciamepa, Ciawi, Cibungbulang, Cigombong, Ciomas, Cisarua, Citeureup, Parung, and Sukaraja. According to Sitepu and Rahmawati (2022), the availability of more facilities in these areas has facilitated their emergence as growth centers, thus driving regional development. The increasing number of sub-districts in this category suggests a broader and more inclusive regional development, with growing infrastructure and services contributing to the overall improvement in the region's socio-economic conditions.

Number of sub-districts in the low SDI category increased from 12 in 2019 to 17 in 2022. These sub-districts include Babakan Madang, Caringin, Cigudeg, Cijeruk, Ciseeng, Dramaga, Gunung Sindur, Jonggol, Kemang, Leuwiliang, Leuwisadeng, Megamendung, Pamijahan, Parung Panjang, Tajur Halang, Tamansari, and Tenjolaya. As shown in the pie chart in Figure 3, the SDI values in Bogor Regency are primarily dominated by the low and very low categories. These categories suggest that many sub-districts in the region face significant challenges in terms of the availability of facilities and access to essential services such as education, healthcare, and economic infrastructure.

Prevalence of sub-districts in the low to very low SDI categories indicates that these areas are struggling with limited access to the services and resources necessary to foster development. Areas located farther from service centers typically experience slower development, as they face higher barriers to accessing essential services and infrastructure. This observation aligns with the findings of Noviyanti et al. (2020), who argue that regions with limited facilities and poor accessibility are often hindered in their development efforts. The lack of adequate infrastructure and services significantly impedes socio-economic growth and exacerbates regional disparities.

The results of the Klassen typology analysis, based on the Sub-District Development Index (SDI) and the percentage of built-up area in 2019, show distinct patterns of development across Bogor Regency. Sub-districts in the Quadrant 1 (15%) category, which include Cileungsi, Gunung Putri, Cibinong, Citeureup, Bojong Gede, and Sukaraja, have high percentages of built-up area and SDI values. These areas are located in the northern part of the regency, close to Jakarta, and exhibit a high level of educational and economic facilities, signifying that they are developed and fast-growing regions. The high built-up area percentage coupled with high SDI values reflects the strong infrastructure and development dynamics in these sub-districts.

Quadrant 2 (10%) category, which includes Cibungbulang, Ciampea, Ciawi, and Ciomas, contains sub-districts with low percentages of built-up area but high SDI values. This indicates that, despite having less urbanization, these areas are fast-growing and have the potential for further development. The relatively high SDI values suggest improvements in social and economic infrastructure, even if these sub-districts are not yet fully urbanized.

In contrast, the Quadrant 3 (50%) category, which includes sub-districts such as Cijeruk, Leuwisadeng, Jasinga, Tenjo, and others, represents underdeveloped areas where both the percentage of built-up area and SDI values are lower than the average for Bogor Regency. These sub-districts show the lowest development levels in terms of infrastructure and facilities, pointing to challenges in improving living conditions and access to services.

Quadrant 4 (25%) category, which includes sub-districts such as Tajur Halang, Babakan Madang, and Gunung Sindur, represents developed areas that are experiencing stagnation or decline. These sub-districts have a high percentage of built-up area but relatively low SDI values, indicating that while the areas have seen urbanization, they face challenges in providing adequate facilities and services, which hampers overall development.

The 2022 analysis reveals a shift in the regional development landscape compared to 2019. The shift is particularly notable as Q4 sub-districts, such as Parung, Cisarua, and Jonggol, moved to Q1. This suggests that these areas have experienced significant improvements in SDI, which could be attributed to the development of infrastructure and services in education, healthcare, and economic sectors, as reflected in the BPS data for 2022. The improvements in service capacity in these sub-districts have enhanced their overall development, aligning with Sultani's (2016) assertion that the increase in facilities leads to better service delivery and higher development levels.

Another shift occurred from Q3 to Q2, involving sub-districts like Megamendung, Leuwiliang, Pamijahan, Dramaga, Caringin, Ciseeng, and Cigombong. This shift indicates that these areas experienced an above-average increase in SDI scores, suggesting rapid development in terms of infrastructure and service provision. This aligns with the BPS data showing that these sub-districts saw a rise in educational, health, and economic facilities, which contributed to their improved development rankings. In contrast, Kemang Sub-district shifted from Q4 to Q3, indicating a decrease in the percentage of built-up area. This could be due to more rapid urban expansion in other sub-districts compared to Kemang, which lowered its relative position in terms of built-up area. As the average values for the built-up area and SDI increase, sub-districts can shift into different quadrants with distinct characteristics, as noted by Rajab and Rusli (2019). This further emphasizes the dynamic nature of regional development and highlights the influence of infrastructure expansion on the overall development trajectory.

Table 5: Klassen Typology of Percentage of Built-up Area and HDI in Bogor Regency (2019 and 2022).

Quadrant	2019		2022	
	Number of Sub-Districts	%	Number of Sub-Districts	%
Q1	15	37,5	12	30
Q2	9	22,5	7	17,5
Q3	15	37,5	18	45
Q4	1	2,5	3	7,5
Total	40	100	40	100

Source: Author's Analysis, 2025

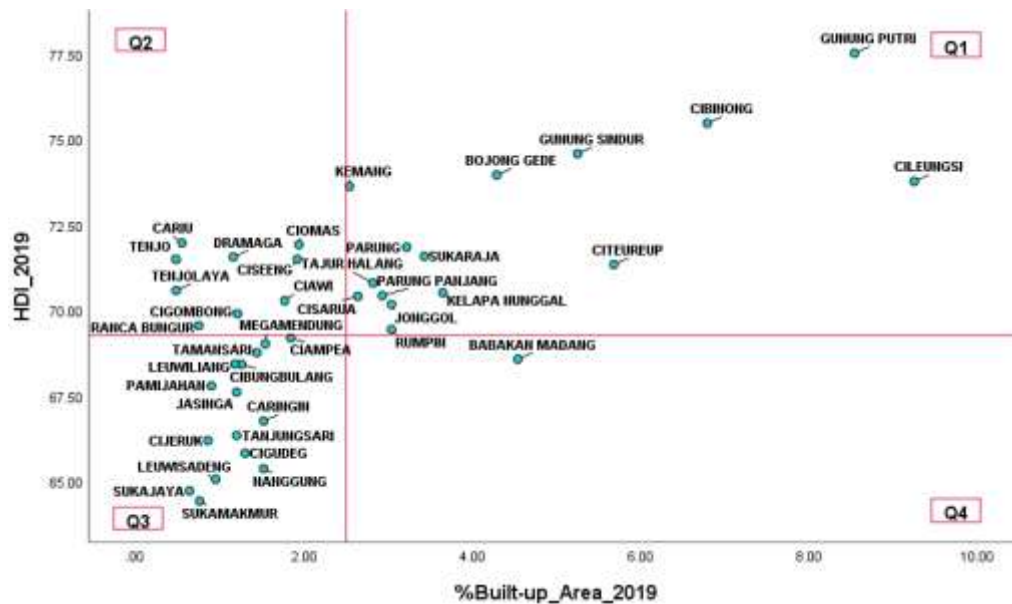


Figure 6. *Klassen Typology of Percentage BuA and HDI in Bogor Regency 2019*
Author's Analysis, 2025

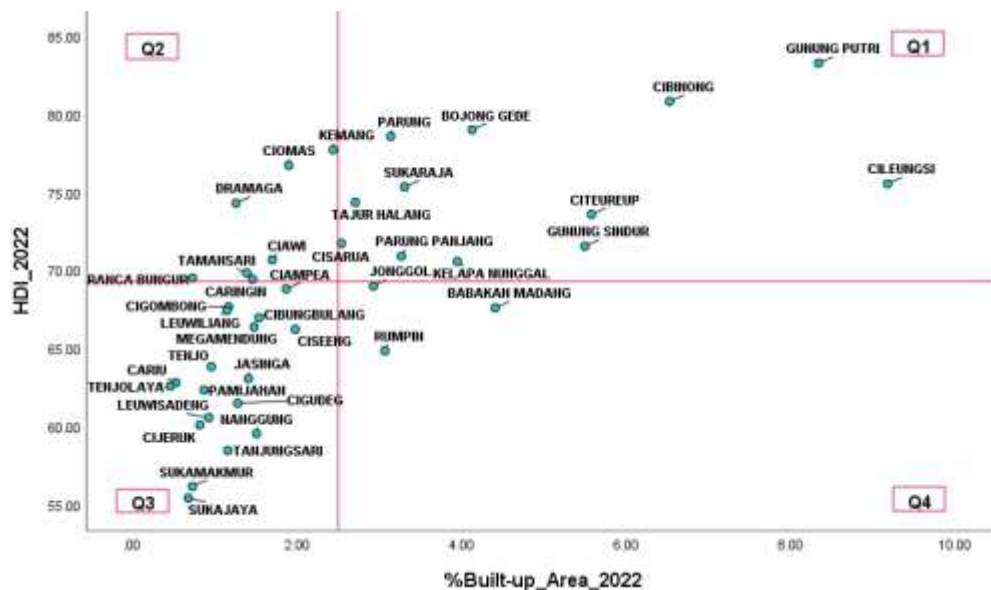


Figure 7. *Klassen Typology of Percentage BuA and HDI in Bogor Regency 2022*
Author's Analysis, 2025

The Klassen typology analysis for 2019 reveals distinct regional development patterns in Bogor Regency, based on the relationship between the percentage of built-up area and the Human Development Index (HDI). Sub-districts classified in the Q1 category (37.5%), characterized by both high built-up area and high HDI, are considered developed and rapidly growing regions. These sub-districts include Gunung Putri, Cileungsi, Cibinong, Gunung Sindur, Citeureup, Bojong Gede, Kelapa Nunggal, Sukaraja, Parung, Tajur Halang, Parung Panjang, Cisarua, Kemang, Rumpin, and Jonggol. The Q2 category (22.5%) includes areas with low built-up area but high HDI, signaling that they are developing quickly, even though urbanization has yet to fully take hold. This category includes Ciomas, Dramaga, Ciawi, Rancabungur, Tenjo, Tenjolaya, Cigombong, Ciseeng, and Cariu. Sub-districts in the Q3 category (37.5%) are considered underdeveloped, with both low built-up area and low HDI values, reflecting significant gaps in infrastructure and socio-economic development. These sub-districts include Megamendung, Cibungbulang, Leuwiliang, Pamijahan, Jasinga, Tanjungsari, Cigudeg, Cijeruk, Leuwisadeng, Nanggung, Sukajaya, Sukamakmur, Ciampea, Tamansari, and Caringin. Finally, the Q4 category (2.5%) represents a developed but underperforming area, specifically Babakan Madang. In the 2022 analysis, a shift occurred, with Q1 decreasing to 30%, Q2 to 17.5%, Q3 rising to 45%, and Q4 increasing to 7.5%.

The observed shifts between built-up area percentage and HDI suggest significant changes in regional development. Notably, certain sub-districts in Q1, such as Rumpin and Jonggol, moved to Q4, while sub-districts in Q2, including Tenjo, Tenjolaya, Cigombong, Ciseeng, and Cariu, shifted to Q3. These

transitions were primarily driven by a decline in HDI from 2019 to 2022, likely exacerbated by the socio-economic impacts of the Covid-19 pandemic. The pandemic resulted in increased mortality rates and reduced life expectancy, negatively influencing HDI scores. According to Fajri (2021), a decrease in life expectancy is indicative of unsuccessful health development, which can have long-term repercussions on human development.

Conversely, sub-districts like Tamansari and Caringin shifted from Q3 to Q2, reflecting improvements in HDI. This suggests that these areas experienced positive developments in healthcare, education, and economic services, leading to an overall enhancement in their socio-economic conditions. As noted by Lumbantoruan (2014), HDI serves as a key indicator of regional development performance, encompassing both physical dimensions (such as life expectancy) and non-physical dimensions (such as educational attainment). The increase in HDI for these sub-districts signals progress in both these areas, demonstrating the positive impact of targeted development policies.

An additional shift occurred in Kecamatan Kemang, which moved from Q1 to Q2. This shift can be attributed to slower urban growth in Kemang relative to other sub-districts, where built-up areas expanded more rapidly. As a result, Kemang's percentage of built-up area became lower than the average for the region, leading to its transition from Q1 to Q2. This highlights how the pace of urbanization in neighboring sub-districts can influence the relative position of a given sub-district in the typology, even when it experiences some level of growth.

The regional typology analysis of Bogor Regency in 2022 was conducted using several key variables: the percentage of forest area, percentage of built-up area, percentage of paddy fields, Sub-district Development Index (SDI) value, and Human Development Index (HDI). This typology analysis employs a clustering method to group sub-districts based on similar or identical characteristics. One of the most commonly used clustering methods is the k-means algorithm, known for its simplicity and efficiency in categorizing data (Kusumah et al., 2017).

The results of the typology analysis reveal that 32.5% of the area in Bogor Regency falls into cluster 1, 55% into cluster 2, and 12.5% into cluster 3. Each cluster was categorized based on its index level, which is classified into three categories: low, medium, and high. These categories were determined through the plot of means for each cluster, as presented in Figure 8. This method provides a clear understanding of the spatial distribution of development levels across the sub-districts, allowing for more targeted interventions based on the characteristics of each cluster.

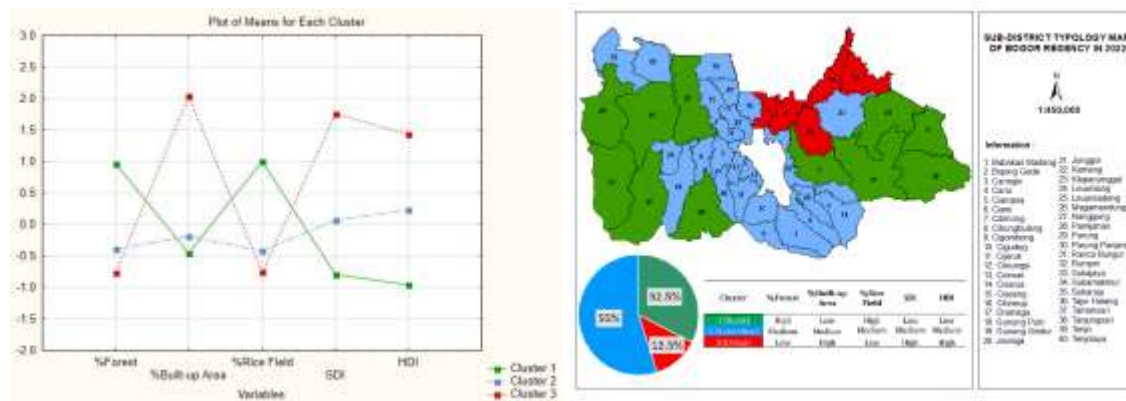


Figure 8. Plot Graph for Each Cluster and Sub-district Cluster Typology Map of Bogor Regency in 2022
Author's Analysis, 2025

Cluster 1, represented in green, consists of sub-districts characterized by a high percentage of forests and rice fields relative to the other clusters, but a low percentage of built-up areas, SDI, and HDI. This cluster, which includes 13 sub-districts—Babakan Madang, Cariu, Cigudeg, Jasinga, Jonggol, Nanggung, Pamijahan, Rumpin, Sukajaya, Sukamakmur, Tanjungsari, Tenjo, and Tenjolaya—is predominantly located in the eastern and western parts of Bogor Regency. The characteristics of this cluster reflect rural areas, largely attributed to the extensive forests and rice fields in these regions, as shown in the 2019 and 2022 land cover maps. Consequently, the availability of built-up areas remains relatively low. According to Firdaus (2020), the slow pace of rural development is often due to limited access to infrastructure and the inadequate quantity and quality of agricultural facilities, which in turn impacts the socio-economic welfare of rural communities.

Cluster 2, marked in blue, spans across various regions of Bogor Regency and consists of 22 sub-districts: Caringin, Ciampea, Ciawi, Cibungbulang, Cigombong, Cijeruk, Ciomas, Cisarua, Ciseeng, Dramaga, Gunung Sindur, Kelapa Nunggal, Kemang, Leuwiliang, Leuwisadeng, Megamendung, Parung, Parung Panjang, Ranca Bungur, Sukaraja, Tajur Halang, and Tamansari. Sub-districts in this cluster exhibit moderate characteristics across all variables. While they possess higher proportions of paddy fields and forests compared to urban areas, these areas remain less rural than those in Cluster 1, marking them as suburban areas. This cluster's characteristics align with findings from Kalsum & Jinca (2017), who argue that population growth leads to increased demand for housing, industry, warehousing, and other

facilities. The limited availability of land in city centers encourages migration to suburban areas, driving suburbanization processes.

Cluster 3, represented in red, consists of sub-districts with a low percentage of forests and rice fields but a high percentage of built-up area, SDI, and HDI. This cluster is primarily located in the northern part of Bogor Regency, encompassing five sub-districts: Bojong Gede, Cibinong, Cileungsi, Citeureup, and Gunung Putri. These sub-districts, characterized by their dominance of built-up areas, reflect urban environments where the development of infrastructure and settlements surpasses agricultural land use. The low percentage of rice fields and forests further corroborates the urban nature of this cluster. Prasetyo (2017) supports this observation, explaining that urban areas are typically characterized by a lack of agricultural activity as the main economic driver, with urban settlements dominating the landscape.

4. Conclusions

This study reveals significant land cover changes in Bogor Regency between 2019 and 2022, particularly the reduction of rice fields and dryland farming due to their conversion into built-up areas. This transformation, most prominently occurring in sub-districts such as Cibinong, reflects rapid urbanization and increasing spatial demand driven by population growth and economic activities. The intensification of built-up areas underscores spatial development pressures and environmental challenges, raising concerns regarding sustainable land use management in the region. In terms of socio-economic development, the Sub-District Development Index (SDI) shows general improvement between 2019 and 2022, especially in strategically located sub-districts that have benefitted from better infrastructure provision. Nevertheless, a majority of sub-districts remain categorized under low to very low development levels, indicating persistent disparities in access to basic services such as education, healthcare, and economic facilities. These findings highlight the uneven distribution of development outcomes across the regency.

The Klassen typology analysis further affirms these disparities. A small number of sub-districts primarily those situated in the northern part of Bogor Regency fall into the most developed quadrant, characterized by high percentages of built-up land, high SDI scores, and elevated Human Development Index (HDI) values. In contrast, a large proportion of sub-districts remain in the underdeveloped quadrant, where both the extent of built-up land and development indicators are below the regency average. This indicates that land urbanization does not automatically translate into improved human development or infrastructure access for all regions.

Using k-means clustering, the study identifies three distinct regional typologies: rural, suburban, and urban clusters. Rural areas, located predominantly in the eastern and western parts of the regency, exhibit high proportions of agricultural and forest land, low development indices, and limited built-up areas. Suburban clusters scattered throughout the regency represent transitional areas with moderate values in all key variables, signaling ongoing but uneven development. Urban clusters, concentrated in the northern region, are defined by high degrees of urbanization and relatively high SDI and HDI scores, making them regional growth poles.

These findings have important implications for spatial planning and sustainable development in metropolitan hinterlands such as Bogor Regency. The identified typologies underscore the need for place based and differentiated development strategies. Rural regions require targeted investments in basic infrastructure and service access, suburban areas need controlled urban expansion with balanced infrastructure provision, and urban zones demand improved livability and environmental safeguards. This nuanced approach aligns with sustainable development principles and supports Bogor Regency's strategic role as a buffer zone to Jakarta, balancing economic growth with environmental conservation in the long term.

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