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The Challenges of Land Conversion in Realizing a Livable and Sustainable City, Case Study: Depok City

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Abstract - Jakarta, the business-center of Indonesia, has experienced significant changes due to urbanization. The outward expansion of the urban area has affected surrounding areas, including Depok City. Depok, situated to the south of Jakarta, serves as a buffer zone. The impact of urbanization has resulted in a rise in the number of people working in Jakarta but residing in Depok City. This trend has caused an increase in land conversion in Depok to satisfy the housing demand. Not only has the amount of undeveloped land decreased, but household waste and garbage have also increased due to population-growth. If this situation is not addressed promptly, creating a livable and sustainable city will become challenging. The involvement of multiple parties is crucial in developing sustainable and livable urban planning, which can enhance the welfare of its residents. This study employs a quantitative research method with a descriptive format. The land conversion will be measured using NDVI spatial analysis and then correlated with the analysis of changes in built-up land use. The results of this analysis are expected to identify land conversion areas in Depok City, which can be utilized as a consideration in urban planning to create a livable and sustainable urban space.

Keywords: land conversion, livable city, NDVI, land-use, urban planning.

1 Introduction

The city of Jakarta, as the capital of Indonesia, has experienced rapid development, leading to urban expansion beyond its administrative boundaries. This growth has significantly influenced the surrounding regions, prompting their development and enabling them to absorb some of the functional and spatial burdens of the capital city. The areas directly impacted by Jakarta's urban expansion have collectively formed a metropolitan region commonly referred to as the JABODETABEK mega-urban area. This region comprises five major cities: Jakarta, Bogor, Depok, Tangerang, and Bekasi.

The status of Depok City as part of Jakarta's mega-urban area has significantly influenced its transformation and development (see Fig. 1). As a buffer city, Depok plays a role in providing residential areas to accommodate Jakarta's population surge [1]. This role has led the government to

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direct Depok's city planning toward residential functions. Residential growth continues to increase each year [2]. ndirectly impacting the conversion of non-built land.

Fig. 1. Area of Interest

Data from Depok's Central Bureau of Statistics indicates that built-up land has increased by 47% from 2010 to 2024. Additionally, residential development has grown at an average rate of 12% per year, reflecting significant land-use changes within the city. Since residential growth continues to rise annually, it suggests that the conversion of land is largely for residential purposes, consistent with Depok's planning as a residential city.

Currently, there is no longer any Protected Rice Field (LSD) available in Depok City. In 2023, the Depok Land Office confirmed that the Mayor of Depok signed a declaration confirming that the amount of LSD is now zero. Despite West Java Province's plan (LP2B) to designate 268.79 hectares of rice fields, the ongoing increase in built-up areas could hinder the achievement of this plan [3]. Regarding green open spaces, data from Depok City's government shows that only 2,015.53 hectares are available, which falls short of the 30% green space standard; currently, Depok meets only 10% of this target [4].

The data above presents a concerning picture, particularly regarding sustainability in an environmental context [5]. As Depok is directed towards a residential function, careful planning is needed to ensure environmental preservation and support a sustainable city. Although the government has implemented policies to control rice field conversion, these measures appear ineffective as rice field areas continue to decrease. Thus, a policy revitalization is needed to support future agricultural development [6]. The ongoing decline in environmental function affects not only urban sustainability but also the city's livability, potentially making it uninhabitable [7].

Previous research suggests that urban social sustainability is a strong predictor of a city's livability over time. However, the relationship between economic and environmental sustainability and urban livability is more complex, as it depends on the quality of business regulation. Economic and environmental sustainability have a stronger positive effect on livability in cities with effective business regulatory frameworks. Conversely, with low regulatory quality, the impact of economic sustainability weakens, and environmental sustainability negatively affects livability [7][8].

Research conducted in Venice shows that urban morphology influences urban sustainability. The study found that various urban landscape types help identify areas with different morpho-functional patterns, which may require distinct policies and plans. Urban morphological patterns are also influenced by the expansion of built-up land, indirectly affecting urban sustainability [5][9].

This study aims to examine the challenges of achieving a sustainable city, focusing on environmental aspects, especially land conversion. If sustainability is achieved, it is expected to support Depok's goal of becoming a livable city. This analysis will assess whether converting land for residential purposes is a suitable response to housing demand or if it compromises environmental functionality, potentially leading to uninhabitable conditions and increasing the number of slums.

The green area analysis in this study will employ NDVI analysis to spatially monitor these changes. By identifying the extent of green land conversion, we can assess the urgency of the situation and determine appropriate solutions. This study will also reveal the direction of Depok's development, informing future planning efforts.

2 Materials and methods

This study focuses on the mission of creating sustainable urban areas, ultimately contributing to a livable city. One of the indicators of a livable city is its status as a sustainable city [10]. with a focus on environmental variables, particularly the presence of green spaces. This research primarily employs a quantitative method with a descriptive format, identifying green areas in Depok City by examining land conversion, observed through NDVI (Normalized Difference Vegetation Index) analysis.

Land conversion calculations can be analyzed using vegetation indices, which measure vegetation greenness by processing digital signals from satellite sensor brightness data across various channels. These channels capture data based on spectral bands available on the satellite. The chlorophyll in plant leaves absorbs red light and reflects near-infrared light, leading to significant differences in brightness values detected by satellite sensors on these channels. In non-vegetative areas such as water bodies, residential zones, bare land, or damaged vegetation areas, the ratio values tend to be low. Conversely, areas with dense, healthy vegetation display a high ratio between the two channels, with maximum values in the near-infrared range and a decrease in reflected red light. The spectral reflectance pattern of water shows a reduction in both infrared and red light. NDVI, the Normalized Difference Vegetation Index, represents the "greenness" level or photosynthetic activity of vegetation and can be used to estimate parameters such as green leaf biomass within the vegetation cover [11][12].

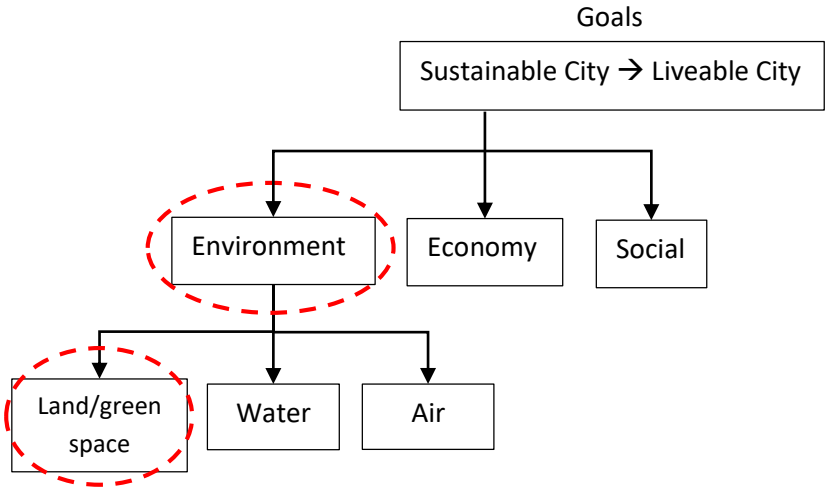


Fig. 2. Scope of this research

The scope of this research is illustrated in Fig. 2. This diagram indicates that this study will focus on a single aspect and a single indicator within the urban sustainability concept. Specifically, it will focus on the environmental aspect, examining only green space availability as the research focus.

To analyze green space availability, this study will incorporate not only vegetation density analysis using NDVI but also land-use data, which will be cross-analyzed with NDVI results. This analysis will further reveal patterns in land conversion. For a clearer understanding of the research flow and methods employed, refer to the Fig. 3.

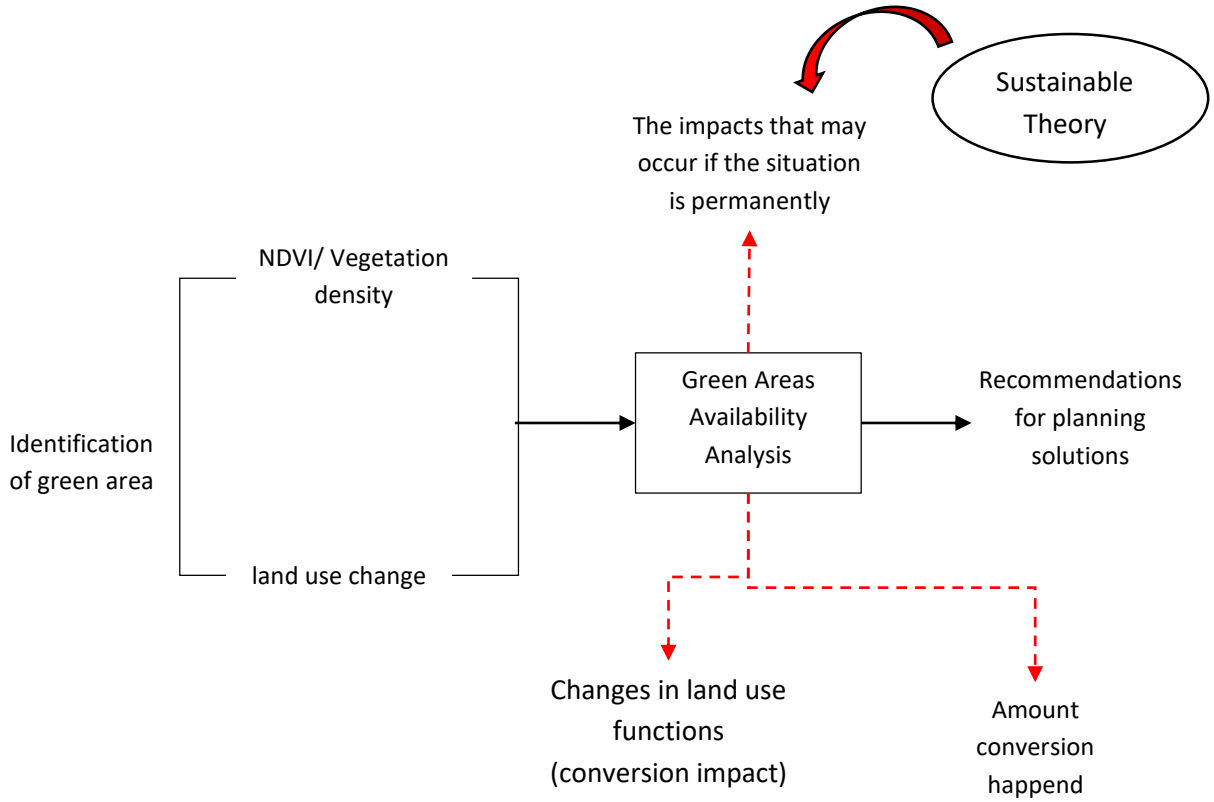


Fig. 3. The Research Flow

As illustrated in the diagram, green space identification involves two data sources: NDVI and land-use change data (TGL). After analyzing these two datasets, a comprehensive assessment of green space availability is produced. This analysis provides information on land-use changes, such as the extent and impacts of land conversion, and projects potential consequences if such conversions continue unchecked. The study also seeks to connect these findings to sustainability theories, aiming to offer spatial planning recommendations and solutions as key outcomes.

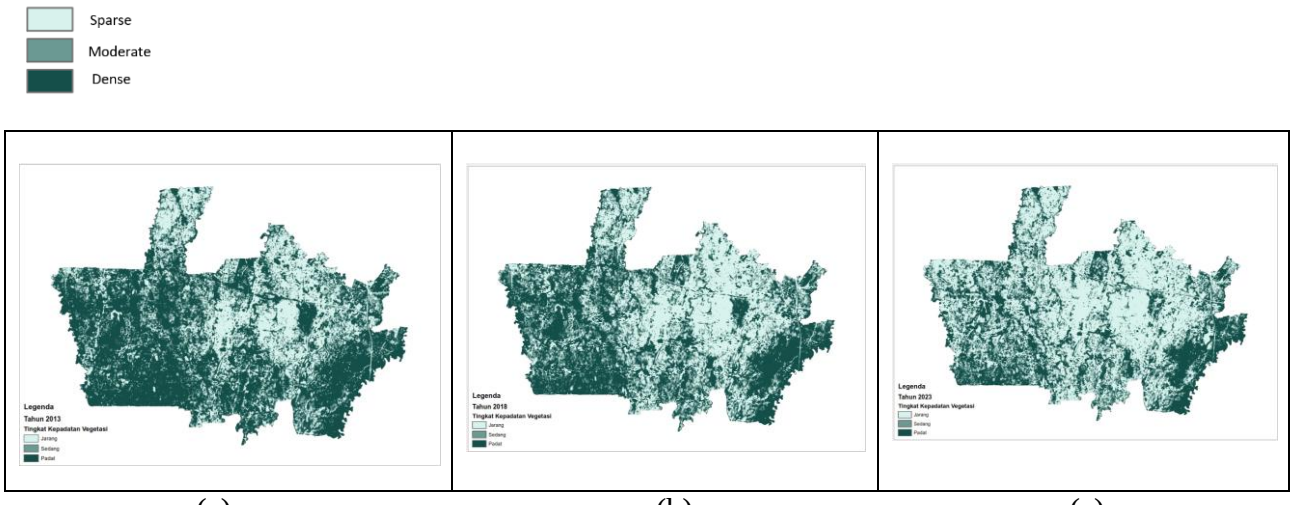
3 Results and discussion

3.1 Green Space Availability Analysis

This study's analysis of green space availability employs two data sources: NDVI (Vegetation Density) and Land-Use Change (LULC). The analysis results are obtained by evaluating vegetation density and land-use changes, with each analysis serving a distinct purpose. The NDVI analysis aims not only to detect vegetation density changes but also to measure the extent of those changes. Meanwhile, the land-use change analysis focuses on identifying shifts in land functions resulting from conversions. Each analysis is further detailed in the following subsections.

3.1.1 Vegetation Density Index

The Vegetation Density Index represents the density of vegetation greenness, derived from brightness values in satellite sensor data. Satellite channels consist of various bands; in this analysis, two bands are used—band 5 and band 4. The NDVI formula applied in this study is as follows: NDVI= NIR-RED NIR + RED [11].



(a) (b) (c)

Fig. 4. The NDVI analysis results for the years: a) 2013, b) 2018, and c)2023

Based on the NDVI analysis results in Fig. 4, observations of vegetation density were obtained for the years 2013, 2018, and 2023. It is evident that significant changes in vegetation density have occurred from 2013 to 2023. In several areas that previously exhibited dense vegetation, there has been a shift to sparse density levels. This indicates that the rate of land conversion has been quite high.

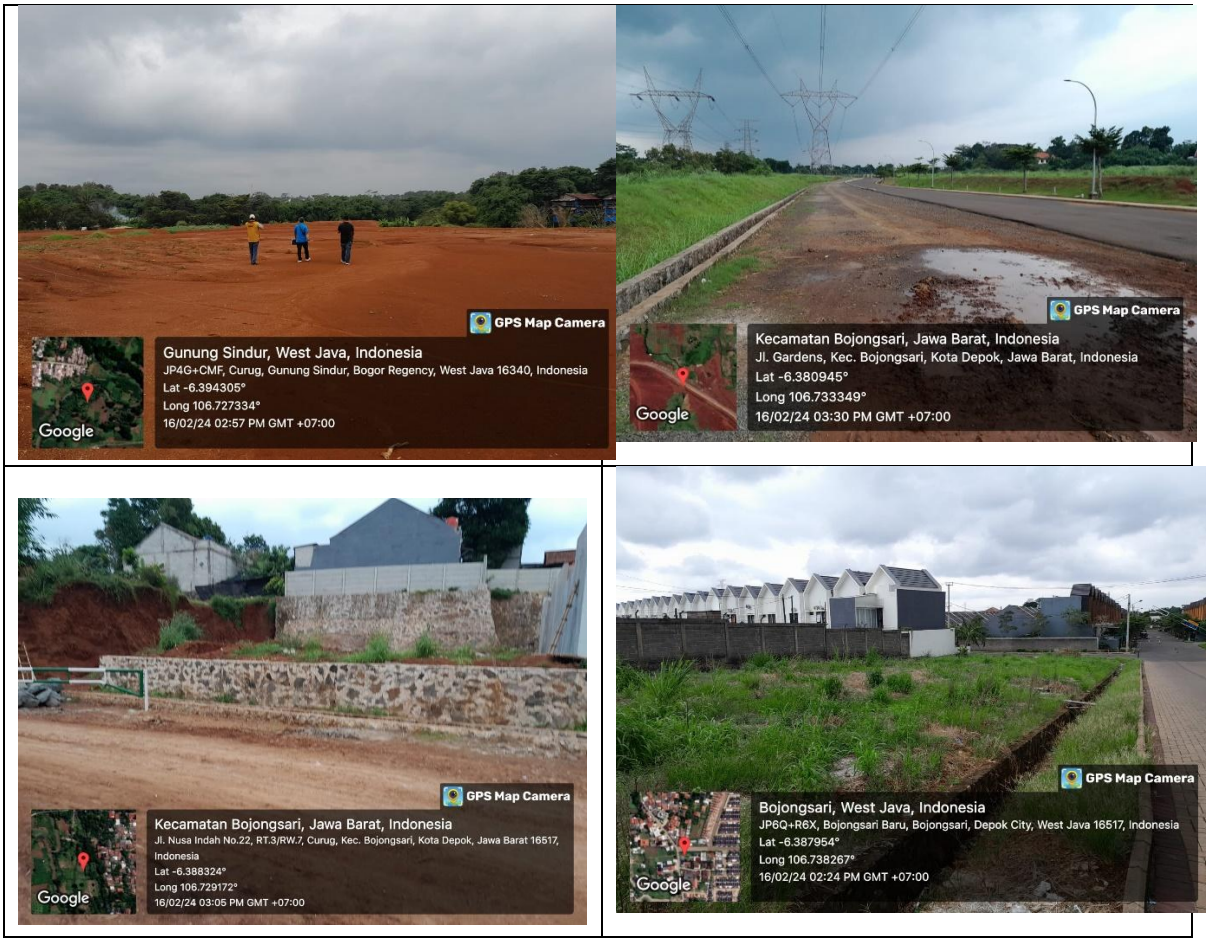
Table 1. The Area of NDVI

Classification	Area		
	2013	2018	2023
Sparse	51.087.500	70.617.000	97.605.900
Moderate	42.198.600	48.864.200	46.588.500
Dense	106.614.000	80.418.900	55.705.700
Total	199.900.100	199.900.100	199.900.100

Based on the analysis conducted through spatial data and field surveys, the following factors have been identified as the causes of high land conversion in Depok City:

a. Surge in Housing Demand

As a buffer city, Depok experiences an influx of residents from DKI Jakarta. Many of these individuals reside in Depok despite not holding Depok ID cards. Nevertheless, the city must meet the housing needs of these residents, as Depok's role within the Jakarta Mega Urban area is primarily as a residential function. This is further corroborated by field observations in 2024, where it was found that in one housing development in the Bojongsari District of Depok, the majority (65%) of residents do not possess Depok ID cards and work outside the city.



Source: Field Survey, 2024

Fig. 5. Land Clearing for Housing

b. Planning Direction of Depok City Emphasizes Residential Function.

This focus is reflected in the 2021-2032 Spatial Planning Regulation of Depok City, which states that the development direction of Depok will prioritize residential functions along with supporting facilities. While this approach may be beneficial, it is essential that environmental considerations are also taken into account. Providing alternatives for environmental management that balance the rampant conversion of green land could serve as a solution to these issues.

c. Increase in Economic Value of Non-Built Land

The high demand for housing has led landowners with non-built green areas, such as rice fields and gardens, to convert their land into ready-to-build plots due to changes in market value. This trend is also influenced by a diminishing interest in agricultural activities, prompting individuals to opt for converting their productive green land into built-up areas to achieve higher profits.

3.1.2 Land Use Change

Supporting the statement in subsection 3.1.1, significant conversion of green land has occurred in Depok City, as evidenced by NDVI results showing vegetation density from the years 2010, 2018, and 2023. While it is known that green land conversion has taken place, not all conversions have shifted toward residential use. Therefore, further analysis is needed to understand these changes.

This study employs land use change analysis to examine the types of changes that have occurred. Due to data limitations, the analysis is constrained to changes between the years 2013 and 2017. It is anticipated that these data limitations will not significantly impact the analysis conducted. The land changes observed during this time frame adequately represent the types of land transformation occurring in Depok City. The changes are illustrated in the figures and tables below.

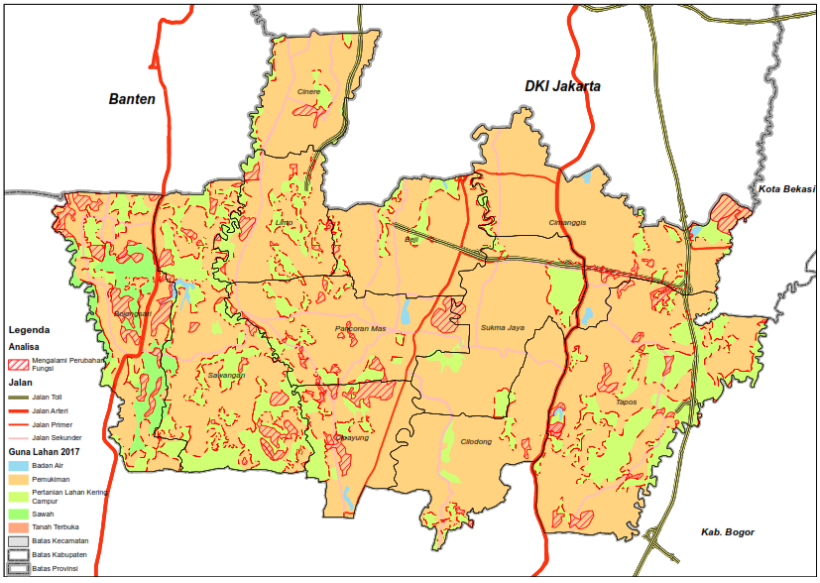


Fig. 6. Land Use Change in Depok City in 2017

Table 2. The Area of Land Use Change in Depok City in 2017

No	Land Use	Areas (m^2)
1	Change to residents	10.425.908
2	Change to dryland agriculture	25,99
3	Change vacant land	156.592
Total		10.582.525,99

Based on the data analysis presented above, it is evident that 98.5% of the land converted has changed into residential areas. This demonstrates that the predominant land transformation has been towards housing development. Field observations further support this finding, indicating a significant conversion of green land for residential purposes. In fact, the LP2B rice field program is no longer a prominent topic, as evidenced by the declaration of zero Protected Rice Land (Lahan Sawah Dilindungi) in Depok City, signed by the mayor. The area of land change from 2013 to 2017 amounts to 10.6 km² compared to the total area of Depok City, which is 200.3 km². Unfortunately, this data is only available for the year 2017, and there is no corresponding data from 2017 to 2023. However, as observed in the NDVI results (subsection 1.1.1), there has been a significant change in vegetation density from dense to sparse. Despite these limitations, the findings adequately address the nature of land changes occurring, which are predominantly driven by residential development.

3.2 Long-term Impacts and Relationship to Sustainability Theory

After conducting the analysis in the previous subsection, data has been obtained that addresses the research questions, namely:

a. What is the extent of green land conversion that has occurred?
b. What type of land use change has predominantly occurred?

The first question can be explained by stating that there has been a 54% conversion of green land in Depok City, as evidenced by the NDVI values from 2013 to 2023. In response to the second question, the changes that have occurred are predominantly toward residential use. The conclusion drawn is that the conversion of land into residential areas has been quite significant in Depok City. This situation may not have an immediate effect that can be felt by its residents, but it is likely to lead to long-term impacts, particularly from an environmental perspective. This relates to sustainability theory.

If this condition persists, and green land continues to diminish while being entirely converted into residential areas, will environmental balance still be achievable? Will a city constructed at the expense of the environment become a livable and comfortable place to reside? Questions like these will arise if these issues are not addressed comprehensively.

The increasing population also exacerbates environmental problems. In addition to threatening the availability of green land, it contributes to the growing amount of domestic waste generated daily, as well as water and air pollution, water availability issues, and public health concerns. There is a pressing need for effective environmental management scenarios so that Depok City, as a buffer city, can meet housing demands while preserving environmental sustainability. The long-term impacts of these changes can be illustrated in the Fig. 7.

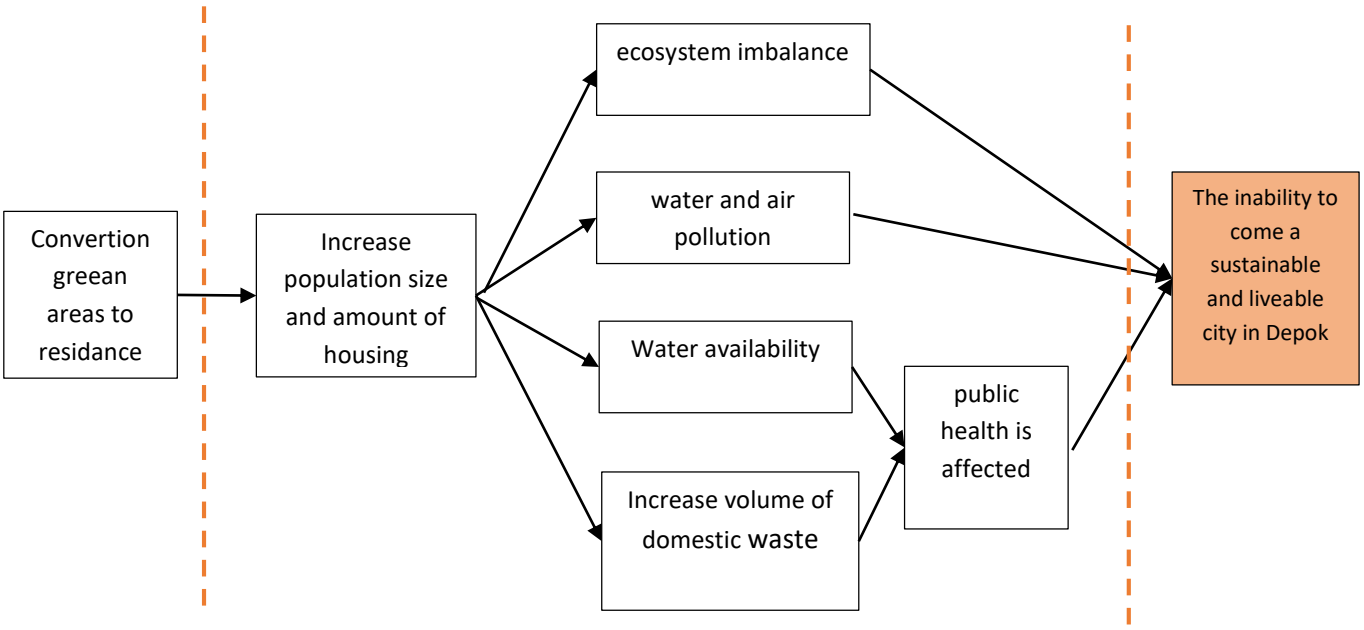


Fig. 7. The Long-Term Impacts of Land Use Change

3.3 Recommendations and Planning Directions

Based on the analysis of NDVI (Normalized Difference Vegetation Index) and land-use changes, the proposed planning concept will primarily focus on identifying the potential green spaces that can be preserved. Furthermore, to guide the development of residential areas and to balance environmental sustainability, a pilot project will be planned in the form of an urban farming development concept in Bojongsari District. This decision is motivated by the significant land conversion observed in the district. Additionally, field survey results indicate that there are numerous opportunities for urban farming initiatives in the area. The figure 8 is a conceptual map outlining the planning directions.

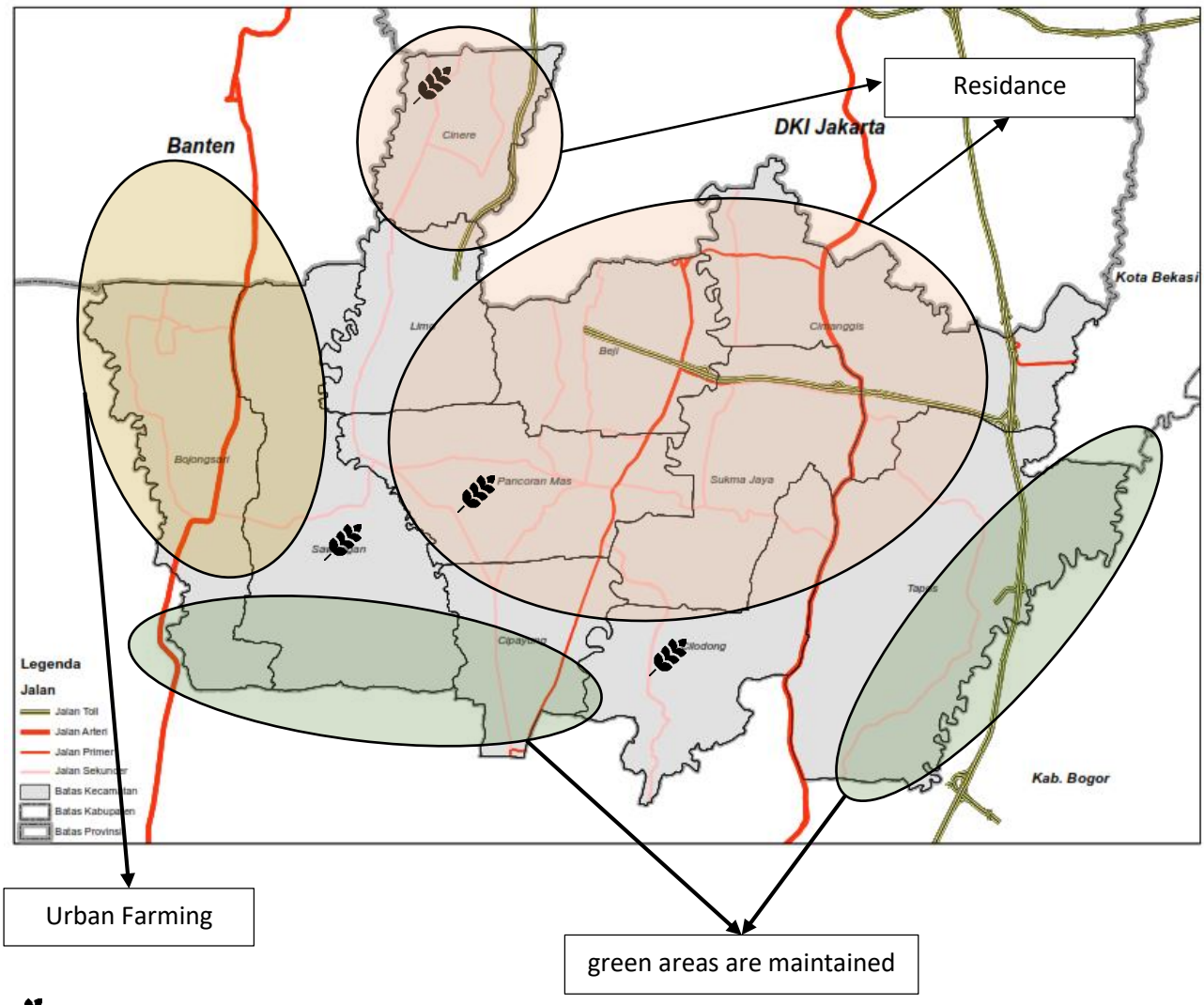


Fig. 8. The Planning Directions

It is acknowledged by the researchers that this study has several limitations:

a. The scope of the research on sustainability pertains solely to the environmental aspect, without a comprehensive examination of the other two indicators (economic and social).

b. The environmental component focuses exclusively on the indicator of green space availability and does not consider other indicators such as water, air, waste, etc.

4 Conclusion

Based on the NDVI analysis results, it is indicated that there has been a conversion of green land in Depok City amounting to 30%. Of the total land use area that changed from 2013 to 2017, 98.5% has been converted to residential areas. In terms of planning direction, efforts will focus on preserving the potential of green land in the southern part of Depok City, while the central to northern areas will be designated for residential development. Additionally, in the western region, specifically in Bojongsari District, a pilot project for urban farming will be developed.

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