

Monitoring Urban Sprawl in Ambon City Using Google Earth Engine

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Abstract. Urban sprawl is an increasing problem in many cities around the world including Ambon City. Monitoring urban sprawl is critical to understanding its impact on the environment and quality of life. This study used Landsat 4 Level 2, Collection 2, Tier 1 - Year 1990, 1995, Landsat 5 Level 2, Collection 2, Tier 1 - 2000, 2005, Landsat 7 Level 2, Collection 2, Tier 1 - 2010, Landsat 8 Level 2, Collection 2, Tier 1 - 2015 and Landsat 9 Level 2, Collection 2, Tier 1 Year 2 - Year 2020 satellite image data which were downloaded and analyzed on Google Earth Engine. The results showed that the area of built-up land in Ambon City from year to year experienced an increase in area. In 1990 built-up land in Ambon City was 2,772.78 ha, in 1995 built-up land had an area of 2,237.06 ha, in 2002 built-up land in Ambon City had an area of 1,503.19 ha. In 2000 built-up land in Ambon City experienced a decrease in area, as a result of the 199-1999 riots or social conflicts in Ambon City. In 2005 built-up land had an area of 2,589.57 ha, in 2010 built-up land had an area of 2,340.40 ha, in 2015 built-up land had an area of 3,993.17 ha and in 2020 built-up land continued to experience an increase in area of 4,085.54 ha. Research results enable stakeholders to make evidence-based decisions, plan urban development more efficiently, and involve communities in decision-making. With a data-driven approach and advanced technology, it is expected that cities like Ambon City can develop sustainably and harmonize urban growth with environmental sustainability and people's quality of life.

Keywords: Ambon, Google Earth Engine, Urban Sprawl.

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INTRODUCTION

Urban sprawl, or urban expansion, is a phenomenon that occurs when urban areas expand significantly into rural areas or surrounding regions (Shafia et al., 2018; Salakory & Rakuasa, 2022). Urban sprawl often has a negative impact on the environment and quality

of life of residents in the city (Rakuasa et al., 2022; Latue & Rakuasa, 2023). In general, the actors that influence the occurrence of urban sprawl phenomena include urbanization, population growth, infrastructure development, the need to settle, urban planning policies, economic factors, accessibility and transportation, commercial and trade development, tourism development and geographical factors (Colsaet et al., 2018; Sapena & Ruiz, 2019; Akin & Erdoğan, 2020; Letedara et al., 2023; Rakuasa et al., 2023; Manakane et al., 2023; Latue et al., 2023).

Rapid and uncontrolled urbanization is a global problem faced by many cities around the world (Shafia et al., 2018; Xu et al., 2022; Sugandhi et al., 2022; Latue et al., 2023). According to Somae et al., (2023), Urbanization plays an important role in influencing urban sprawl in Ambon City. Urbanization refers to the movement of people from rural to urban areas (Sapena & Ruiz, 2019). Along with population growth and economic development, urbanization in Ambon City has increased pressure on urban land and led to the expansion of urban areas into surrounding areas (Rakuasa & Somae, 2022). Ambon City in the Maluku Islands, Indonesia, is not an exception to this phenomenon. Rapid population growth and infrastructure development have led to urban sprawl (Pertuack et al., 2023). Urban sprawl in Ambon City is a serious challenge in the face of negative impacts on the environment, natural resources, and quality of life (Latue & Rakuasa, 2023).

Ambon City, as the capital of Maluku Province, has experienced rapid population growth (BPS, 2021). The rapid increase in population, both for urbanization and migration reasons, has increased the demand for housing, commercial facilities, and infrastructure. As a result, peri-urban and rural areas have become targets for new settlements. According to Rakuasa et al., (2022), Urbanization causes an increase in the number of residents in Ambon City, which results in a high demand for housing. The need for a better and more suitable place to live leads to the development of settlements in the areas around the city, resulting in the expansion of urban areas (S. W. Wang et al., 2021). Population growth due to urbanization requires the provision of adequate public infrastructure and facilities, including roads, transportation systems, clean water, and sanitation. To meet these needs, peri-urban areas become the main target for infrastructure development, thus driving urban expansion (Ghosh et al., 2017).

Ambon City as the center of trade and industry in the Maluku Islands region offers employment opportunities and economic growth (Rakuasa et al., 2023). People from surrounding areas seeking employment opportunities will migrate to the city, leading to population growth and urban sprawl. According to Fallati et al. (2017), urbanization leads to increased demand for commercial and industrial land. The construction of shopping complexes, offices, and industries will lead to the expansion of urban areas to peripheral areas. Urbanization can lead to increased accessibility and transportation infrastructure. Good transportation facilities and easy accessibility to the city center can encourage people to live in urban areas and surrounding areas, resulting in urban sprawl.

The phenomenon of urban sprawl in Ambon City, as in many other large cities, brings negative impacts that need to be watched out for, including community displacement and relocation, traffic congestion and pollution, ecosystem damage, lack of green open space, increased land demand, decreased quality of life, increased infrastructure and public service costs and low environmental quality (Fahad et al., 2021). According to Al-Hameedi

et al. (2021), uncontrolled urban growth leads to the expansion of urban areas into rural areas or land used by local communities. This often results in forced evictions and relocations of local communities, impacting their social, economic and welfare lives. Urban sprawl increases population mobility and the need for transportation infrastructure (Ghosh et al., 2017).

According to Sihasale & Rakuasa, (2023), the expansion of urban areas results in the loss of green land and forests. Damage to natural ecosystems can lead to decreased biodiversity, soil erosion, and increased risk of floods and landslides (Rakuasa et al., 2022; Rakuasa et al., 2022; Latue et al., 2023). Urban sprawl reduces the availability of green open spaces in cities (Latue et al., 2023). The lack of parks and recreational areas leads to fewer opportunities for city residents to exercise and relax in nature (Latue & Rakuasa, 2023). Urban sprawl results in inefficient land use, as urban areas require more land for housing, infrastructure and commerce. This can lead to reduced agricultural land and loss of valuable natural resources (Latue et al., 2023). Urban sprawl can lead to a decline in the quality of life of city residents. Traffic congestion, air pollution, and loss of access to green spaces can affect people's physical and mental health. Urban sprawl requires the development of additional infrastructure and public services, which is costly for the government. This can lead to a heavy fiscal burden and reduce resources for other social and development programs. Urban sprawl leads to reduced quality of the urban environment (Latue & Rakuasa, 2023). Lack of green open space, increased pollution, and changes in land use can lead to an unhealthy environment for city residents (Rakuasa & Latue, 2022).

To address this issue, remote sensing technology and satellite image analysis from Google Earth Engine are effective tools to monitor and inform sustainable urban management (Ermida et al., 2020). Google Earth Engine is a cloud-based platform that provides access to a wide range of satellite imagery data from various sources, such as Landsat, Sentinel and MODIS (Muntaga, 2019). It offers scalable and efficient imagery analysis, which enables monitoring of urban development with high accuracy and at a larger scale (Zarro et al., 2022). Google Earth Engine also offers the ability to monitor land use changes over time, providing a better understanding of the changes taking place in Ambon City (Xue et al., 2021). The use of Google Earth Engine in monitoring urban sprawl can be an important step in realizing a sustainable and quality city for the citizens of Ambon City. Based on the description above, this research aims to monitor the development of Urban Sprawl in Ambon City using Google Earth Engine.

LITERATURE REVIEW

1. Urban Sprawl

Urban sprawl is the phenomenon of urban expansion into rural areas or open land around cities (Abu Hatab et al., 2019). It results from rapid and uncontrolled urban growth, where human settlements, infrastructure, and commercial activities spread continuously into surrounding areas (Rubiera-Morollón & Garrido-Yserte, 2020). Urban sprawl often occurs due to rapid urbanization, economic growth, and increased demand for residential land and commercial facilities (X. Wang et al., 2020). The phenomenon of urban sprawl can cause a variety of negative impacts, including displacement and forced relocation of local

communities, traffic congestion, air and water pollution, ecosystem damage, and lack of green open space (Shao et al., 2021). In addition, urban sprawl can also lead to inefficient land use, increase the cost of infrastructure and public services, and degrade the quality of the urban environment (X. Wang et al., 2020).

Urban sprawl is a serious challenge for sustainable urban management (Chen et al., 2021). Therefore, prudent urban planning, efficient land use regulation, and sustainable infrastructure development are required to overcome the negative impacts of urban sprawl and maintain the quality of life of city residents (Pratami et al., 2019). Collaborative efforts between the government, stakeholders, and communities are important in dealing with the urban sprawl phenomenon and achieving balanced and sustainable urban development.

2. Google Earth Engine

Google Earth Engine is a cloud-based platform developed by Google for highly scalable remote sensing data analysis (Zhao et al., 2021). The platform provides access to a wide range of satellite imagery datasets and remote sensing data from various sources, including Landsat, Sentinel, MODIS, and more (Ermida et al., 2020). With Google Earth Engine, researchers, scientists, and policy makers can perform large-scale and rapid analysis and processing of imagery data (Rakuasa et al., 2023).

Google Earth Engine provides various tools and functions for image analysis, mapping, and visualization, making it easy for users to monitor environmental change, land use, and urban development over time (Pertuack & Latue, 2023). An advantage of Google Earth Engine is its ability to quickly manage large datasets, enabling accurate and efficient monitoring of regional development (Liwan & Latue, 2023). With access to continuous and up-to-date satellite imagery data, Google Earth Engine is also an important tool for identifying trends and patterns in the natural environment, agriculture, forestry, and urban areas. The utilization of Google Earth Engine helps in informed decision-making and sustainable management of natural resources (Muntaga, 2019).

Google Earth Engine also supports collaboration and data sharing between users, enabling collaborative research and analysis to address various environmental and urban challenges. Overall, Google Earth Engine is a powerful tool for remote sensing data analysis and area development monitoring, allowing users to extract important insights into environmental and urban changes to achieve more sustainable management (Ermida et al., 2020).

METHOD

This research was conducted in Ambon City, Maluku Province, Indonesia. This research uses Landsat 4 Level 2, Collection 2, Tier 1 - Year 1990, 1995, Landsat 5 Level 2, Collection 2, Tier 1 - 2000, 2005, Landsat 7 Level 2, Collection 2, Tier 1 - 2010, Landsat 8 Level 2, Collection 2, Tier 1 - 2015 and Landsat 9 Level 2, Collection 2, Tier 1 Year 2 - Year 2020 satellite image data which were downloaded and analyzed on Google Earth Engine. Monitoring urban sprawl in Ambon City using Google Earth Engine starts from the process of selecting the satellite image data used, the year of recording, cutting the image data based on the administrative boundaries of Ambon City, performing the Cloud mask process, Generate image per year, Create an image composite, Normalized Difference Built-up Index,

Modified Normalized Difference Water Index, Built up, Image area for calculation, Create dictionary for each year expansion for visualization, Create expansion image and Create table to show the urban area change. The complete research workflow can be seen in Figure 1.

To monitor urban sprawl in Ambon City on the Google Earth engine, researchers used the NDBI and MNDWI algorithms. NDBI stands for "Normalized Difference Built-up Index" or Building Standardized Difference Index. NDBI is one of the satellite image indices used in remote sensing analysis to map and identify urban areas or built-up areas (Rahnama et al., 2020). The NDBI index is calculated using the difference between two bands of near infrared (NIR) and red (Red) satellite imagery (Rahnama et al., 2020). Typically, the NDBI calculation formula is as follows:

$$\text{NDBI} = (\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red})$$

In this formula, NIR is the pixel value of the near infrared band, and Red is the pixel value of the red band. The NDBI index yields a value between -1 to 1, where positive values indicate urban or built-up areas, while negative values indicate non-urban or open land areas. Using the NDBI index, researchers and stakeholders can conduct analysis to map urban areas, identify urban sprawl, monitor land use change, and understand urban growth over time. The NDBI index is a useful tool in remote sensing analysis to support sustainable urban planning and efficient management of urban areas (Rahnama et al., 2020).

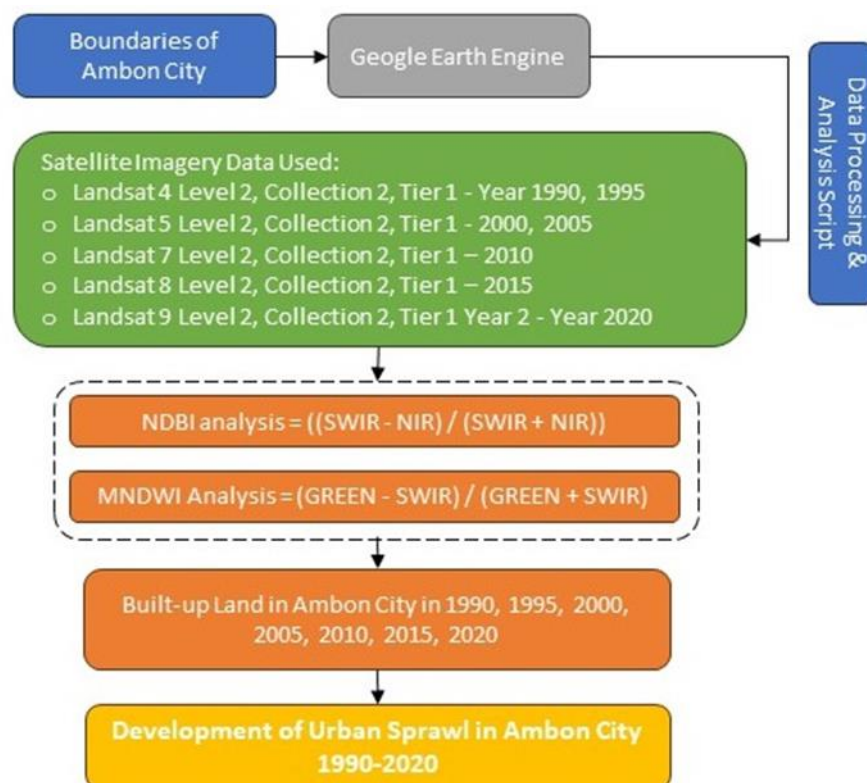


Figure 1. Workflow

In addition to the NDBI algorithm, researchers also use the MNDWI algorithm. MNDWI stands for "Modified Normalized Difference Water Index". MNDWI is one of the

satellite image indices used in remote sensing analysis to map and identify water areas or flooded areas. The MNDWI index is calculated using the difference between two satellite image bands, namely the green and near infrared (NIR) bands (Krishnaveni & Anilkumar, 2020). Typically, the MNDWI calculation formula is as follows:

$$\text{MNDWI} = (\text{Green} - \text{NIR}) / (\text{Green} + \text{NIR})$$

In this formula, Green is the pixel value of the green band, and NIR is the pixel value of the near infrared band. The MNDWI index yields values between -1 to 1, where positive values indicate water areas or inundated areas, while negative values indicate non-water areas or non-inundated areas (M. & M., 2019). The utilization of MNDWI is to identify and map water areas, such as rivers, lakes, reservoirs, or areas that are inundated due to flooding. The index can also be used to monitor changes in water area over time, making it an important tool in remote sensing analysis to support water resources management and flood disaster mitigation. In addition, MNDWI can also be used in environmental sustainability mapping and water-related environmental quality monitoring in urban and rural areas. The results of NDBI and MNDWI analysis were then analyzed to determine the distribution and extent of built-up land in Ambon City in 1990, 1995, 2000, 2005, 2010, 2015 and 2020.

RESULTS AND DISCUSSION

Monitoring urban sprawl in Ambon City using Google Earth Engine is an effective and efficient method to understand changes in urban areas and address urban sprawl issues (Mosammam et al., 2017). With access to high-resolution satellite imagery data, sophisticated analysis algorithms, and large-scale data processing capabilities, Google Earth Engine is an important tool in meeting the challenges of sustainable urban development in Ambon City and other cities in Indonesia. Using the information obtained from this platform, stakeholders can take appropriate policies and actions to achieve a balance between urban development and environmental preservation (Zarro et al., 2022).

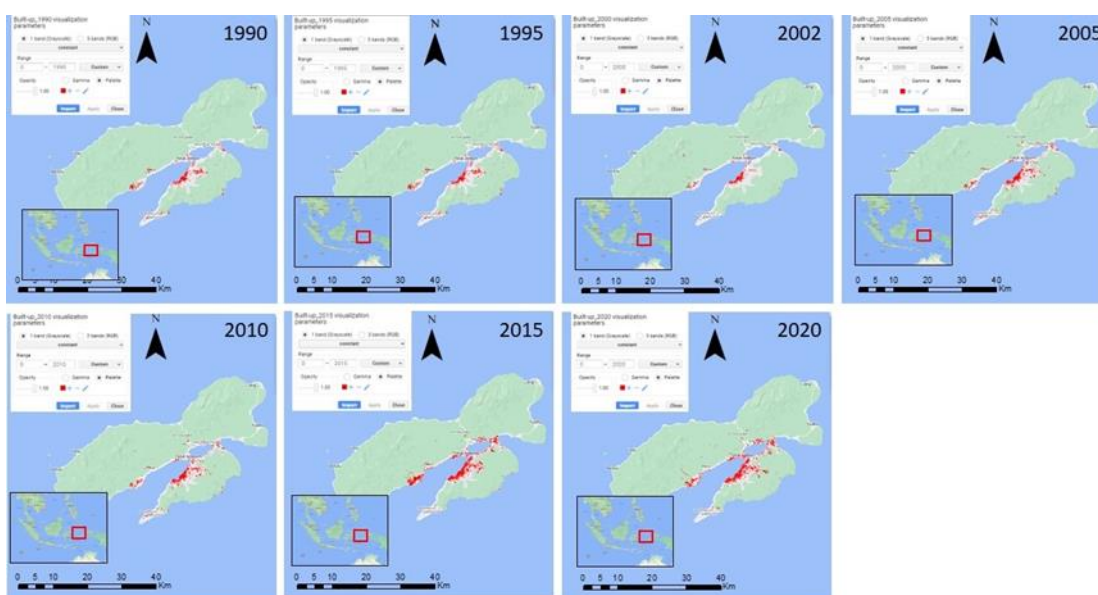


Figure 2. Development of built-up land in Ambon City in 1990, 1995, 2000, 2005, 2010, 2015 and 2020.

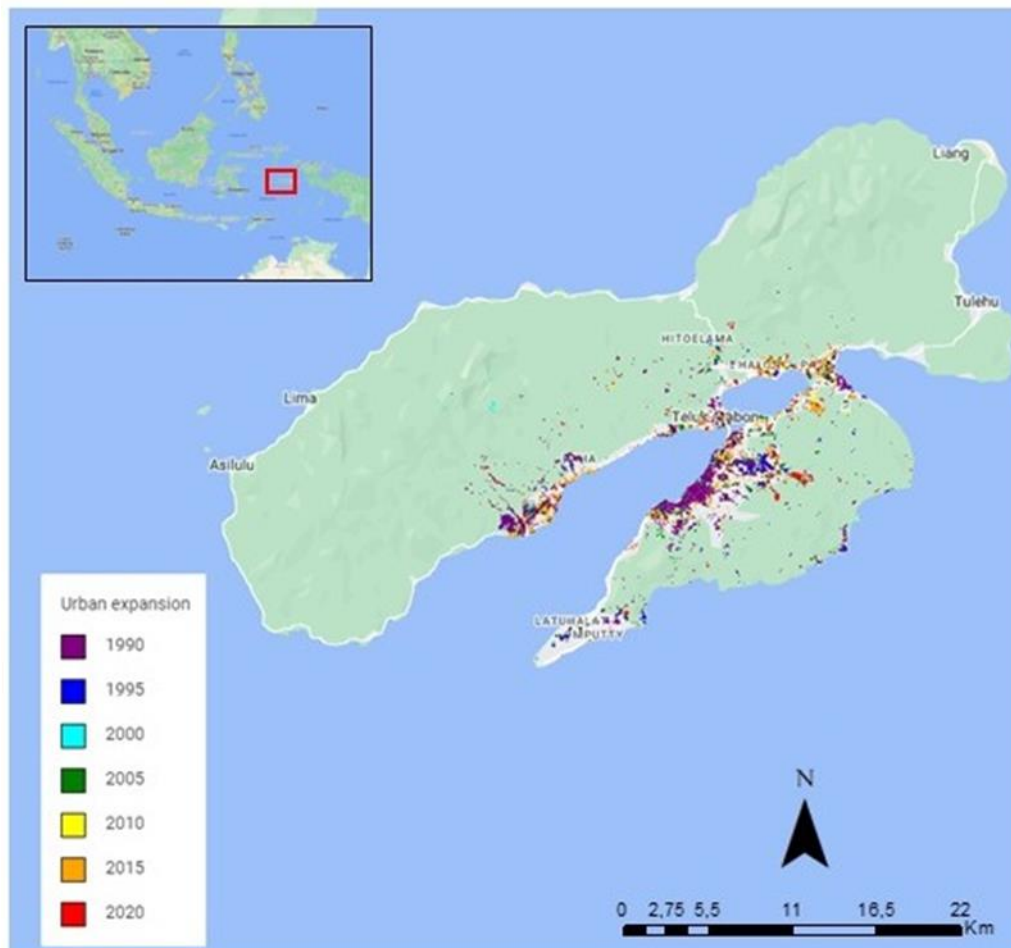


Figure 3. Urban Sprawl in Ambon City

The results of the analysis show that the area of built-up land in Ambon City has increased from year to year. In 1990 built-up land in Ambon City was 2,772.78 ha, in 1995 built-up land had an area of 2,237.06 ha, in 2002 built-up land in Ambon City had an area of 1,503.19 ha. In 2000 built-up land in Ambon City experienced a decrease in area, as a result of the 199-1999 riots or social conflicts in Ambon City. In 2005 built-up land had an area of 2,589.57 ha, in 2010 built-up land had an area of 2,340.40 ha, in 2015 built-up land had an area of 3,993.17 ha and in 2020 built-up land continued to experience an increase in area, namely 4,085.54 ha. Further development of built-up land in Ambon City in 1990, 1995, 2000, 2005, 2010, 2015 and 2020 can be seen in Figures 2 and 3.

Based on Figure 3, it can be concluded that the development of built-up land in Ambon City reflects a phenomenon common to many cities in Indonesia and the world. Population growth, urbanization, and economic growth are the main factors influencing land use. However, it is important for the government and the community to work together to manage the development of built-up land wisely. With good planning and a sustainable approach, Ambon City can experience balanced growth, maintain environmental quality, and improve the quality of life of its citizens. The development of built-up land in Ambon City has various impacts, both positive and negative, which can affect the environment,

social, and economy. The following are some of the impacts that can occur due to the development of built-up land in the city:

- a) **Reduction of Green Land and Open Space:** The development of built-up land means a reduction in green open space in the city. This can reduce air quality, increase surface temperatures, and reduce the environmental quality of the city. Loss of green space can also reduce opportunities for recreation and increase pressure on natural ecosystems.
- b) **Ecosystem Change:** By changing land use from agricultural or forest land to residential or industrial areas, built-up land development can disrupt natural ecosystems. As a result, biodiversity may be threatened, wildlife habitats fragmented, and groundwater systems may be disrupted.
- c) **Population Density:** The development of built-up land leads to high population density in urban areas. This can result in traffic congestion, increased pollution levels, and pressure on public facilities such as clean water and sanitation
- d) **Flooding and Drainage:** Irregular and unplanned land development can disrupt water flow and drainage systems. As a result, areas that were prone to flooding become more prone to this disaster during the rainy season
- e) **Social and Cultural Changes:** The development of built-up land often also means social and cultural changes for local communities. Increased urbanization can result in changes in lifestyles, cultural values and social interactions that can have both positive and negative impacts.
- f) **Infrastructure Improvement:** The development of built-up land is usually accompanied by the construction of infrastructure such as roads, bridges, and other public facilities. While these infrastructures are important to support the growth of the city, construction may cause temporary environmental disruptions and impacts.
- g) **Increased Economic Opportunities:** The development of built-up land can create new economic opportunities for residents, such as employment in the construction, trade and industrial sectors. This can increase residents' income and purchasing power, and have a positive impact on the city's economic growth.
- h) **Increase in Property Value:** Developments of built-up land can increase property values in the area. While this can be beneficial for property owners, it can also cause land prices and rents to become unaffordable for low-income earners.

It is important to note that the impacts of built-up land development in Ambon City may vary depending on how the development is planned, managed and supervised by the government and stakeholders. To achieve sustainable growth and reduce negative impacts, it is important to integrate sustainable development principles in the planning and implementation of built-up land development in the city. Research on Monitoring Urban Sprawl in Ambon City Using Google Earth Engine has various benefits that are very meaningful for city management and development. Some of the benefits include:

- a) **Evidence-based Decision Making:** Satellite imagery data and analysis using Google Earth Engine provide objective and evidence-based information on urban change in Ambon City. This enables stakeholders, including local government, to make more informed decisions in urban development planning.

- b) identification of Urban Development Patterns and Trends: By monitoring urban sprawl over time, this research enables the identification of patterns and trends of urban development in Ambon City. This information can help in formulating sustainable urban development strategies and policies
- c) More Effective Urban Sprawl Control: The data and analysis obtained from this research enables the local government to identify areas prone to urban sprawl. Thus, more effective development planning and control measures can be taken to prevent the negative impacts of urban sprawl.
- d) Public Awareness and Participation: The results of this research can be used as a communication tool to sensitize the public on the importance of controlling urban development. Interactive maps and visualization of the analysis results can help engage the public in the decision-making process and urban planning.
- e) Evaluation of Development Policy: This research can serve as a tool to evaluate the success of previous urban development policies and strategies. Data on changes in urban areas over time can be used to assess the impact of policies that have been implemented.
- f) Environmental and Resource Conservation: By monitoring urban sprawl, this research can help identify areas that need to be protected and preserved to maintain environmental sustainability and the availability of natural resources in Ambon City.
- g) Efficient Use of Resources: Through the analysis of land classification and use, this research can help local governments to allocate resources more efficiently and sustainably for the benefit of urban development.
- h) Database for Further Research: This research can serve as a valuable database for further research on urban development, environmental quality, and socio-economic impacts of urban sprawl in Ambon City.

CONCLUSION

Research on Monitoring Urban Sprawl in Ambon City Using Google Earth Engine has significant benefits in sustainable urban development. The data and analysis obtained from this platform allow stakeholders to make decisions based on solid evidence, plan urban development more efficiently, and involve the community in decision-making. With a data-driven approach and advanced technology, it is hoped that cities like Ambon City can develop sustainably and harmonize urban growth with environmental sustainability and people's quality of life.

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