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Spatial Transformation of Physical Change of Built-up Land in Ambon City Center, Indonesia, Period 1940-2025

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Abstract.
The background of this research focuses on the physical transformation of built-up land in the center of Ambon City from 1940 to 2025, influenced by historical, social, and economic factors, including the impact of riots and population growth. The tools and materials used in this research include thematic maps of land use from various periods, satellite images (Ikonos-2 and Planet Scope), and ArcGIS Pro software for spatial data processing. The method applied is an urban morphology approach with qualitative deductive analysis, which includes geospatial data processing to understand the pattern of urban development. The results of the discussion show that built-up land has increased significantly, although environmental challenges remain a major concern, such as the conversion of green land that impacts the carrying capacity of the environment. The conclusion of this study emphasizes the need for sustainable urban planning strategies to balance urban growth with ecosystem preservation in the future.

Keywords: *Ambon, built-up land, physical change, spatial transformation*

1. Introduction

The development of cities in Indonesia, including Ambon City, has been the focus of research in recent decades. Ambon City, as the capital of Maluku Province, has a long history that dates back to the 16th century as a spice trading center. This trading activity has shaped the early structure of the city, with the Portuguese fort as the center of activity. The physical development of the city is inseparable from the interaction between internal and external factors, such as colonial political policies and regional economic activities (1). Physical changes in urban space, including the transformation of built-up land, are complex phenomena and are influenced by various factors (2),(3). Physical urban development is characterized by population growth, building density, and expansion of settlement areas (4),(5). In Ambon City, this development has occurred since the 17th century, with a relatively stable structure of roads and buildings despite experiencing various physical destruction due to war and social unrest (6),(7). This shows the resilience of the city structure in the face of changing times.

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Population growth and economic activity are the main drivers of land use change in developing cities (8). The urban morphology approach can be used to analyze physical spatial changes in a city (9),(10). In Ambon City, the increase in population and economic activity has led to the expansion of built-up land, with an average of 13.09 hectares per year until 2002 (6). However, social unrest in 1999 slowed this growth rate and changed the direction of the city's development (6). The transformation of built-up land in city centers is often influenced by the availability of infrastructure and ease of access to transportation (11),(10). According to Oliveira, humans as the main actors play an important role in the dynamics of physical changes in urban space (1). In Ambon City, social and economic facilities concentrated in the city center, such as markets and ports, have attracted residents to settle and move (12). This has led to increased demand for residential space and supporting infrastructure (13).

The development of cities is also influenced by interactions with surrounding areas (14), (15). Ambon City, as the center of government and services, has a significant influence on surrounding areas such as Seram, Buru, and Lease Islands (16). This interaction not only drives economic growth but also causes the expansion of built-up areas to the periphery of the city (17). This phenomenon is in line with the theory that limited land in the city center drives activities to the periphery, where land values are cheaper (1). Land use change in Ambon City is also influenced by historical factors and government policies. In the 19th century, the decline of the spice trade led to a decline in economic activity and maintenance of the city's infrastructure. However, since 1950, Ambon City has experienced rapid growth along with increasing population and economic activity. This shows that government policies and economic conditions play an important role in determining the direction of the city's development.

The social unrest in 1999 was a turning point in the physical development of Ambon City (6). Many buildings and settlements were destroyed, causing a change in the direction of urban growth (18). Nevertheless, the city structure that has been formed since the 17th century has survived, showing the physical and social resilience of the city in the face of challenges. This phenomenon is in line with Knowles et al.'s research, which states that physical changes in urban space occur over a long period of time and are influenced by human interaction with the environment (19). Research on the spatial transformation of physical changes in built-up land in the center of Ambon City from 1940 to 2025 is important to understand the dynamics of urban development. The urban morphology approach, as proposed by Oliveira, can be used to analyze patterns of urban spatial development. By considering historical, economic and social factors, this research is expected to provide a comprehensive picture of the physical changes in Ambon City and their implications for future urban planning.

2. Methods

This research was conducted in the central area of Ambon City, Ambon Island, Maluku Province, Indonesia (Figure 1). The limitation of this research area is based on the Detailed Spatial Plan for Ambon City Center Area Year 2021-2041. This research is a deductive research with a qualitative approach. This research focuses on the physical development of built-up land in Ambon City Center in the period 1940-2025. This research uses thematic maps of previous land use in the period 1940-1950, 1950-1960, 1960-1970, 1970-1980, 1980-1990, 1990-1997, 1997-2000 obtained from previous research (6). The use of thematic data was based on the availability of data and important events that occurred in the central area of Ambon City

such as the physical destruction of the city due to war and riots. This research uses Ikonos-2 satellite images in 2002 and 2010 obtained from the USA GeoEye company with a spatial resolution of 0.8 meters, Planet Scope satellite images in 2015 and 2025 obtained from the USA company, Planet with a spatial resolution of 3 meters.

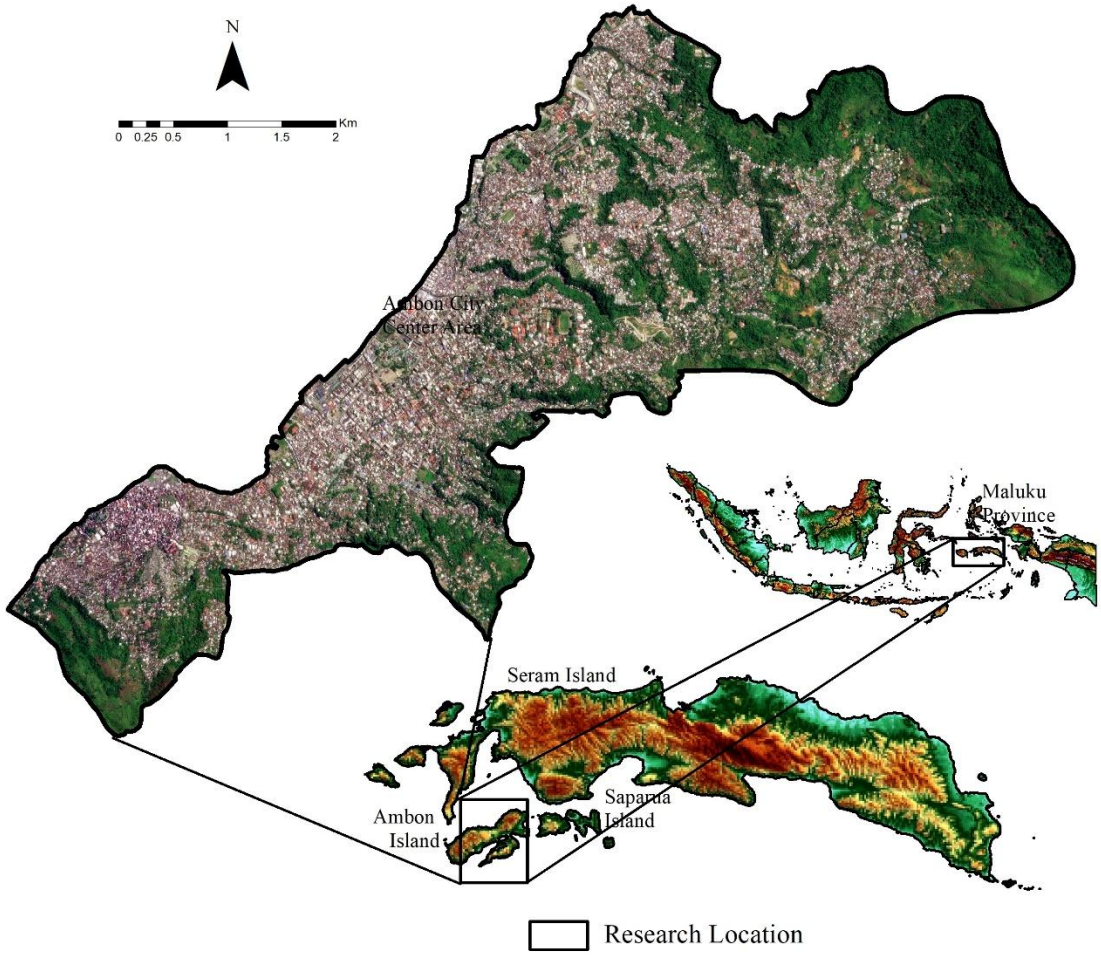


Figure 1. Research location, Ambon City Center, Ambon Island, Indonesia

Spatial data processing was conducted in ArcGIS Pro and Microsoft 365 software. Data processing starts from performing geometric correction or Georeferencing on thematic maps of land use in the central area of Ambon City in the period 1940-1997 obtained from the results of research (6), then on-screen interpretation and digitization with ArcGIS Pro software. Ikonos-2 satellite images (2002 and 2010) and Planet Scope satellite images (2015 and 2025) obtained were then subjected to radiometric correction, geometric correction, and image cropping according to the boundaries of the research area before the built-up land digitization process was carried out. The results of the built-up land digitization were then calculated to see the development of built-up land in the central area of Ambon City for the period 1940-2025.

3. Results and Discussion

3.1. Direction of Physical Development of Built-up Land 1940-1950 Period

The physical spatial development of the center of Ambon City in the period 1940-1950 was marked by major destruction due to aerial bombing by the Japanese (1941), Allies (1945), and APRIS - (Indonesian Armed Forces of the Republic of

Indonesia) (1950), which led to a reduction in built-up area by 7.46 ha, including a decrease in settlements (15.16 ha), offices and social facilities (4.35 ha), as well as the conversion of 149.91 ha of forest into mixed gardens.

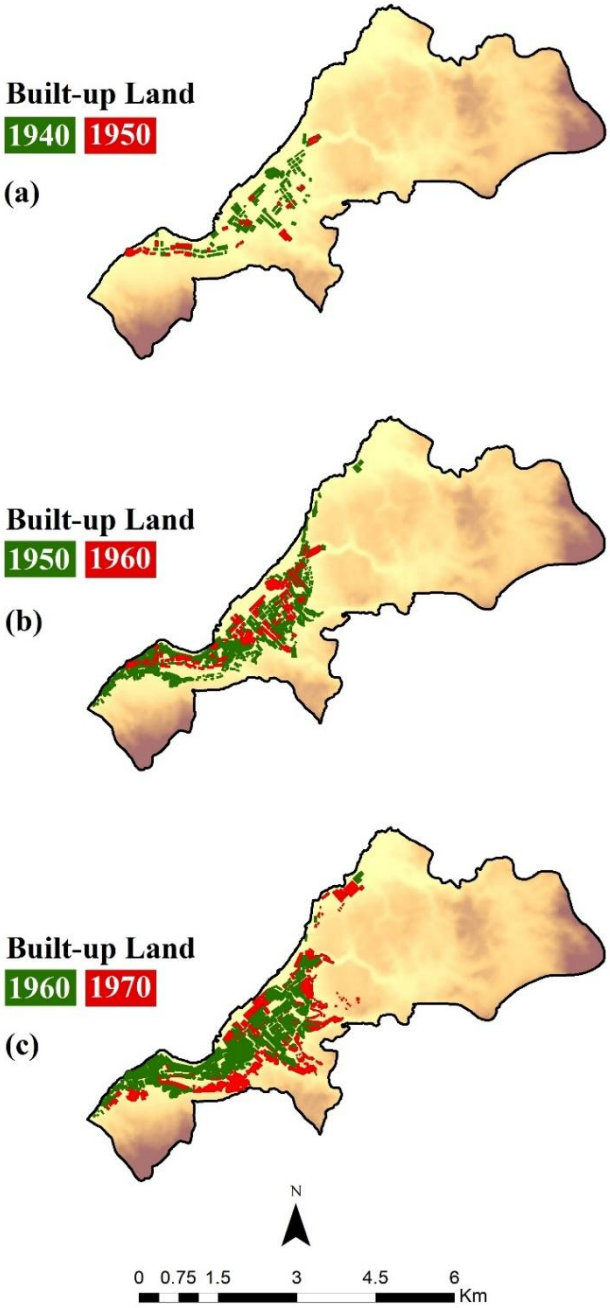


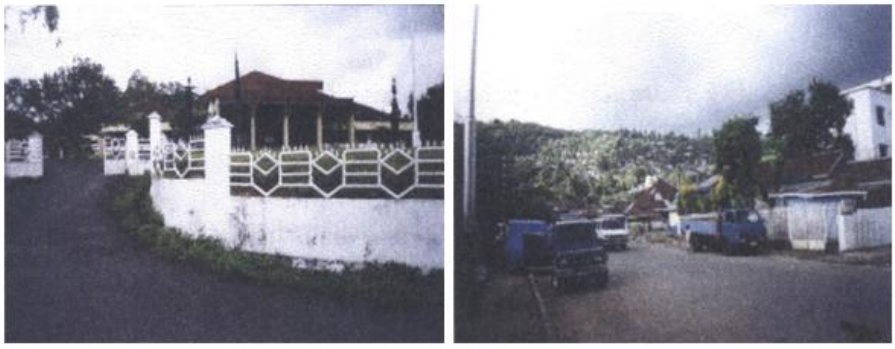
Figure 2. Development of Built-up land period: (a) 1940-1950, (b) 1950-1960, (c) 1960-1970

The worst damage occurred in the central part of the city, such as in the villages of Urimessing, Waihaong, Silale, Ahusen, Honipopu and Rijali, while the southwestern area, which is outside the city's administrative boundary, was relatively unaffected. Nonetheless, new settlement growth occurred along the route to Gudang Arang Port, which served as a center for charcoal unloading during the Japanese occupation. Research results from Maiil, (2003), showed that built-up land in 1940 was 44.67 ha and in 1950 it was 37.21 ha, a change in area of -7.46 ha. The pattern of physical development of the city in this period tends to be

linear, following the main road to the southwest, creating a form of development centered on the outskirts of the city. The spatial map of the direction of physical development of built-up land for the period 1940-1950 can be seen in Figure 2 (a).

3.2. Direction of Physical Development of Built-Up Land 1950-1960 Period

In the period 1950-1960, Ambon City experienced rapid physical development after the destruction caused by the war, with an additional built-up area of 166.29 ha, including settlements (157.32 ha), offices, social and military facilities. Land use change was driven by the efforts of the Maluku Regional and Provincial Governments in rebuilding the city, especially in central areas such as Waihaong, Ahusen, Honipopu, and Rijali, and in the southwest such as Nusaniwe, Benteng, and Wainitu. The development of public and employee housing, educational facilities such as Pattimura University, and road infrastructure encouraged the growth of new settlements. The physical development pattern of the city is concentric in the center and linear following the main road to the southwest, with flat topography (0-2%) in most areas, except in Kudamati which has a slope of 15-30%. The results of Maiil's research show that the built-up land in 1950 was 37.21 ha and in 1960 was 203.50 ha, with a change in area of 166.29 ha. The spatial map of the direction of physical development of built-up land for the period 1950-1960 can be seen in Figure 2 (b).



(a) (b)

Figure 3. Built-up area of Ambon city center 1970-1980, (a) Maluku provincial legislature building in the hills of Karang Panjang (Kelurahan Amantelu), (b) Gantung stone settlement with the hills of Kampung Ganemo (Kelurahan Kudamati) in the background. Source: (Maiil, 2003)

3.3. Direction of Physical Development of Built-Up Land 1960-1970 Period

In 1970, the spatial use of Ambon City consisted of a built-up area of 332.10 ha, including settlements (261.35 ha), trade (10.97 ha), military (32.33 ha), offices and services (8.69 ha), and social facilities (18.76 ha), while the non-built-up area was dominated by mixed gardens and forests. Compared to 1960, there was an increase in the area of settlements (104.03 ha), trade (9.55 ha), military (8.04 ha), offices and services (4.76 ha), and social facilities (2.23 ha), which led to a reduction in the area of forests and mixed gardens. The development of built-up areas leads to the southwest, south, southeast and northeast, triggered by the construction of housing, infrastructure and facilities such as Pattimura University, Army housing and settlements along riverbanks such as Wai Batu Gantung, Wai Gajah and Wai Tomu. The physical development pattern of the city is concentric in the center and linear

following the main road, with new settlements emerging on flat land along the riverbanks and hilly areas, supported by good accessibility and a cheap land rental system. The results of research from Maiil, (2003), showed that the built-up land in 1960 was 203.50 ha and in 1970, 332.10 ha, there was a change in area of 128.60 ha. The spatial map of the direction of physical development of built-up land for the period 1960-1970 can be seen in Figure 2 (c).

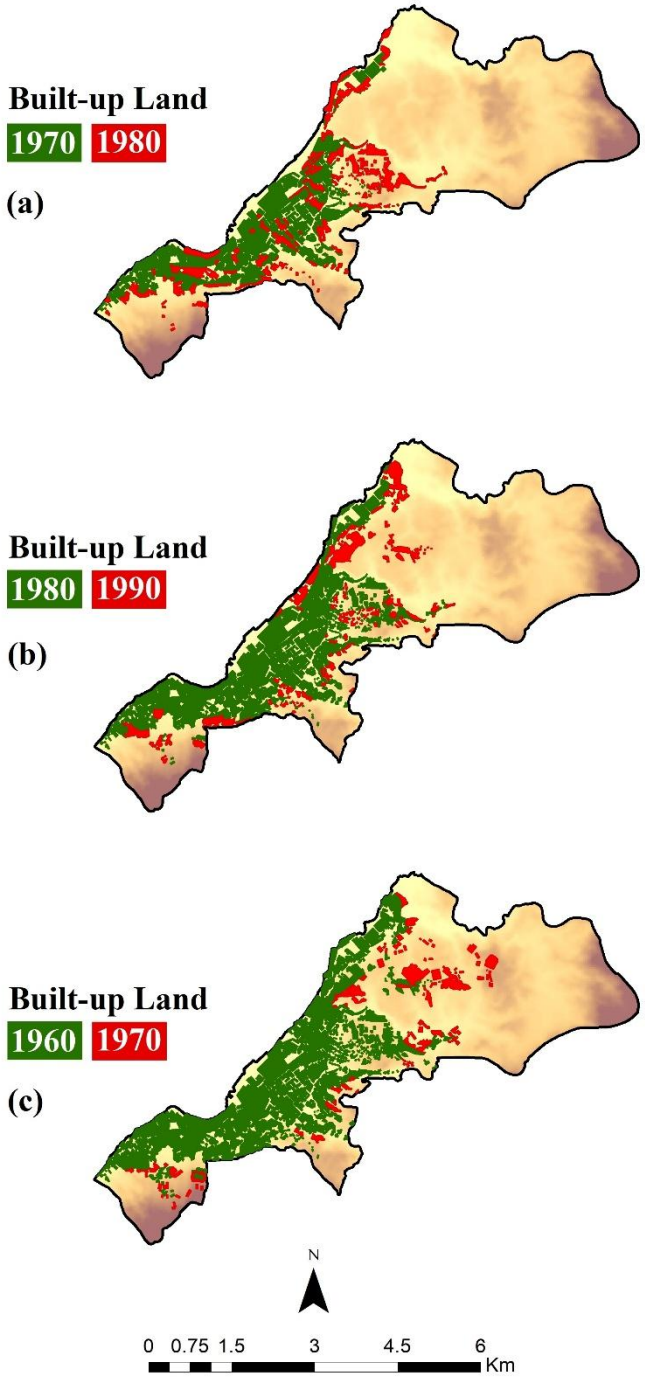


Figure 4. Development of Built-up Land Period: (a) 1970-1980, (b) 1980-1990, (c) 1990-1997

3.4. Direction of Physical Development of Built-Up Land 1970-1980 Period

In 1980, the spatial use of Ambon City consisted of a built-up area of 494.71 ha, including settlements (393.25 ha), trade (10.99 ha), military (32.33 ha), offices and services (23.25 ha), and social facilities (34.90 ha), while the non-built-up area was dominated by mixed

gardens and forests. Compared to 1970, there was an increase in the area of settlements (131.90 ha), offices and services (14.56 ha), and social facilities (16.13 ha), which led to a reduction in the area of forests and mixed gardens. The development of built-up areas towards the southwest, east, and northeast was triggered by national development in PELITA I, the function of Ambon City as the center of government, trade, and education, as well as infrastructure development such as Army housing, offices, worship, and sports facilities in the Karang Panjang hills. Settlements also extended along the riverbanks and hillsides, supported by the cheap Tanah Dati rental system and limited land in the city center. The pattern of physical development of the city is linear following the main road, concentric in the center with the opening of new areas on the Karang Panjang hills. The results of research from Maiil, (2003), showed that the built-up land in 1970 was 332.10 ha and in 1980 was 494.71 ha experiencing a change in area of 162.62 ha. The spatial map of the direction of physical development of built-up land for the period 1960-1970 can be seen in Figure 4 (a). The physical condition of the built-up area of Ambon City center in 1970-1980 can be seen in Figure 4.

3.5. Direction of Physical Development of Ambon City Center in 1980-1990

In 1990, the spatial use of Ambon City consisted of a built-up area of 654.44 ha, including settlements (522.71 ha), trade (31.45 ha), military (32.35 ha), offices and services (28.98 ha), and social facilities (38.97 ha), while the non-built-up area was dominated by mixed gardens and forests. Compared to 1980, there was an increase in the area of settlements (129.46 ha), trade (20.46 ha), offices and services (5.73 ha), and social facilities (4.07 ha), which led to a reduction in the area of forests and mixed gardens.

(a) (b)

Figure 5. Built-up area of Ambon city center 1980-1990, (a) Settlement in Kebun Cengkeh village, seen from the hills (Batu Merah village). (b) Mardika shops (Kelurahan Rijali). Source: (Maiil, 2003)

The development of built-up areas is toward the southwest, southeast, east and northeast, with the fastest changes in Batu Merah and Hative Kecil villages. Driving factors include the construction of a ring road, beach reclamation for markets and terminals, and the attraction of an affordable location close to the city center. The pattern of physical development of the city is linear following the main road, concentric in the center, and jumping with the opening of new areas in Batu Merah Atas and Kebun Cengkeh. The results of research from Maiil, (2003), show that built-up land in 1980 was 494.71 ha and in 1990 was 654.44 and experienced a change in area of 159.72 ha. The spatial map of the direction of physical development of built-up land for the period 1980-1990 can be seen in Figure 4 (b).

The physical condition of the built-up area of Ambon City center in 1970-1980 can be seen in Figure 5.

(a) (b)

Figure 6. Built-up area of Ambon city center 1990-1997, (a) STAIN campus in Air Besar (Batu Merah village). (b) Cengkih Housing Estate (Batu Merah Village). Source: (Maiil, 2003)

3.6. Direction of Physical Development of Ambon City Center in 1990-1997

In 1990, the spatial use of Ambon City consisted of a built-up area of 654.44 ha, including settlements (522.71 ha), trade (31.45 ha), military (32.35 ha), offices and services (28.98 ha), and social facilities (38.97 ha), while the non-built-up area was dominated by mixed gardens and forests. Compared to 1980, there was an increase in the area of settlements (129.46 ha), trade (20.46 ha), offices and services (5.73 ha), and social facilities (4.07 ha), which led to a reduction in the area of forests and mixed gardens.

(a) (b)

Figure 7. Built-up Area of Ambon City center 1997-2002, (a) Refugee Relocation Housing in Air Besar (Batu Merah Village). (b) Settlement in the protected area at Gunung Nona (Benteng Village) Source: (Maiil, 2003)

The development of built-up areas is toward the southwest, southeast, east and northeast, with the fastest changes in Batu Merah and Hative Kecil villages. Driving factors include the construction of a ring road, reclamation of the coast for markets and terminals, and the attraction of an affordable location close to the city center. Physical development to Batu Merah village was influenced by the construction of the 24 ha campus of the Alaudin State Islamic College (STAIN) in Air Besar in 1991 (Figure 4). The pattern of physical development of the city is linear following the main road, concentric in the center, and jumping with the opening of new areas in Batu Merah Atas and Kebun Cengkeh. The results of research from Maiil, (2003), showed that built-up land in 1990 was 654.44 and in 1997 was

803.26 and experienced a change in area of 148.83 ha. The spatial map of the direction of physical development of built-up land for the period 1980-1990 can be seen in Figure 4 (c). The physical condition of the built-up area of Ambon City center in 1970-1980 can be seen in Figure 6.

3.7. Direction of Physical Development of Ambon City Center 1997-2002

At the beginning of 2002, the spatial use of Ambon City consisted of a built-up area of 855.99 ha, including settlements (677.89 ha), trade (35.95 ha), military (32.33 ha), offices and services (41.28 ha), and social facilities (68.54 ha), while the non-built-up area was dominated by mixed gardens and forests. Compared to 1997, there was an increase in the area of settlements (42.20 ha), offices and services (5.93 ha), and social facilities (4.60 ha), which led to a reduction in the area of forests and mixed gardens. The development of built-up area slowed down due to the economic crisis in 1997 and social unrest in 1999, with growth of only 1.28% per year. The physical development of the town is concentrated in the east and northeast, especially in Batu Merah village, and in the southwest and southeast, influenced by the post-riot religious segregation of settlements.

(a) (b)

Figure 8. Built-up Area of Ambon City center 2002-2015, (a) Pattimura University Campus B (Batu Merah Village). (b) Shopping Center at Mardika Market (Benteng Village)

The pattern of development is linear following the road and concentric around existing built-up areas, with negative impacts such as reduced spring water discharge due to conversion of forests and mixed gardens. The results of research from Maiil, (2003), showed that the built-up land in 1997 was 803.26 ha and in 2002 was 855.99 ha and experienced a change in area of 57.73 ha. The spatial map of the direction of physical development of built-up land for the period 1997-2002 can be seen in Figure 9 (a). The physical condition of the built-up area of Ambon City center in 1997-2000 can be seen in Figure 7.

3.8. Direction of Physical Development of Ambon City Center in 2002-2015

In the period 2002-2015, the spatial use of Ambon City experienced a growth in built-up land of 84.46 ha, from 855.99 ha to 940.45 ha. This development was dominated by the expansion of settlements (677.89 ha to approximately 760 ha), trade, and social facilities, triggered by post-riot recovery in 1999 and increased economic stability. Infrastructure development such as road improvements, the development of educational areas, and port

expansion drove growth to the northeast and southwest, particularly in the Batu Merah area and its surroundings.

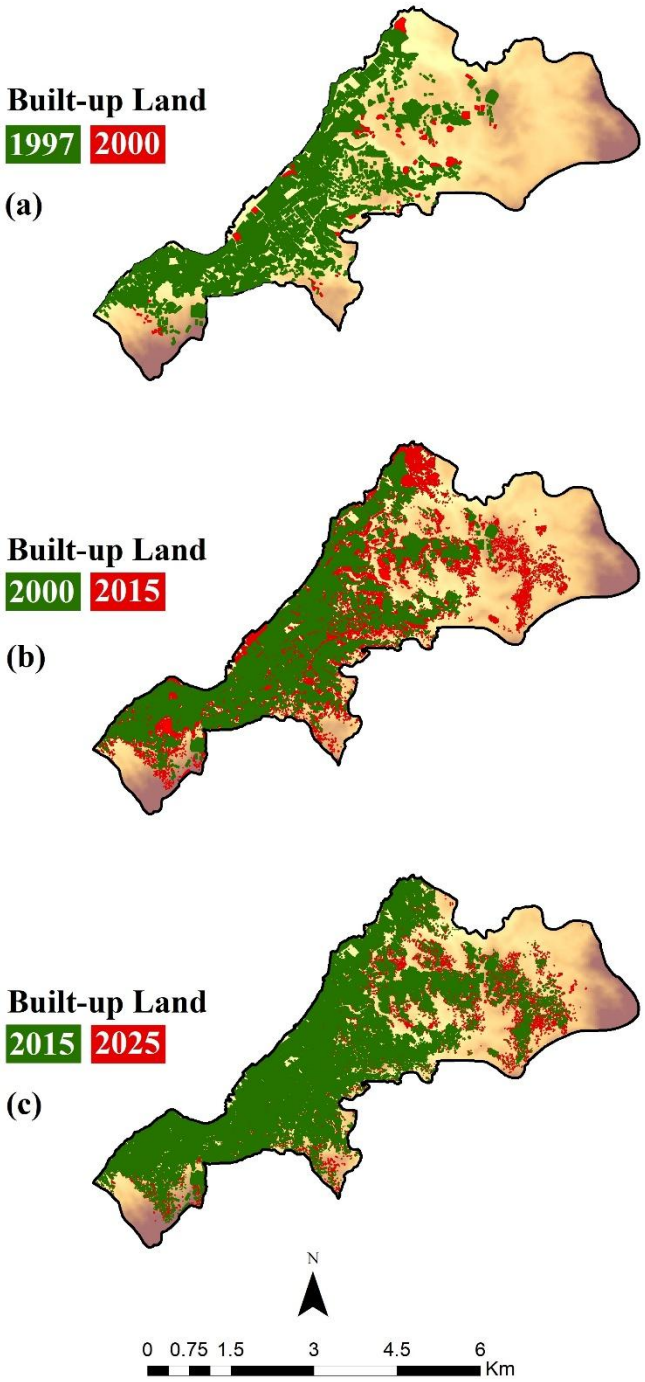


Figure 9. Development of Built-up Land Period: (a) 1997-2000, (b) 2002-2015, (c) 2015-2025

However, conversion of forests and mixed plantations continues to occur, reducing the carrying capacity of the environment. Development patterns tend to be linear following the main transportation corridors and concentric around the city center, with limited land encouraging the use of marginal land. The spatial map of the direction of physical development of built-up land for the period 2002-2015 can be seen in Figure 9 (b). The physical condition of the built-up area of Ambon City center in 2002-2015 can be seen in Figure 8.

3.7. Direction of Physical Development of Ambon City Center in 2015-2025

From the analysis of Planet Scope satellite imagery, it is known that between 2015-2025, built-up land in Ambon City is projected to increase by 97 ha, from 940.45 ha to 1,037.45 ha. This development is driven by population growth, the expansion of dense residential areas in the northeast (such as Batu Merah Atas), and the construction of new government and commercial centers in the southeast. Improved accessibility through the ring road and revitalization of the coastal area also accelerated land use change, especially in low-lying areas and former mixed gardens. The pattern of physical development follows a linear combination along transportation routes and into hilly areas, although it is balanced by environmental mitigation efforts due to reduced green cover. The spatial map of the direction of physical development of built-up land for the 2015-2025 period can be seen in Figure 9 (c). The physical condition of the built-up area of Ambon City center in 2015-2025 can be seen in Figure 10.

(a) (b)

Figure 10. Built-up Area of Ambon City center 2015-2025, (a) Port Area (b) Ambon City Center (Peace Gong Area) Source: (Kele Projet)

3.8 Physical Development Rate of Ambon City Center 1940-2025

The physical spatial development of Ambon City center from 1940 to 2025 reflects the dynamics influenced by various historical, social, economic, and development policy factors. In the period 1940-1950, the city experienced a decrease in built-up land of 7.46 hectares (ha) due to the destruction caused by the war. However, rapid recovery occurred post-1950, with built-up land growth reaching 166.29 ha in the 1950-1960 period and 128.60 ha in 1960-1970. The highest growth occurred in the decades 1970-1980 (162.62 ha) and 1980-1990 (159.72 ha), driven by national programs such as PELITA I, infrastructure development, and the expansion of settlements and public facilities. However, the rate of growth slowed down during the period 1997-2002 (57.73 ha) due to the economic crisis and social unrest, before picking up again in 2002-2015 (84.46 ha) as stability was restored and the ring road was built. Projections for the period 2015-2025 estimate an additional 97 ha of built-up land, reflecting continued urbanization pressures. Cumulatively, built-up land increases from 44.67 ha in 1940 to 1,037.45 ha in 2025, with an average growth of ±14.3 ha per year, signifying a significant transformation from a small post-war town to a complex urban center.

The physical development pattern of Ambon City spatially follows the southwest, northeast, and southeast directions, with the dominance of linear forms along the main transportation routes and concentric in the city center. Key factors driving this development include the development of infrastructure such as ports, ring roads, and campuses, as well as

cheap land rental policies that attract investors and residents (20). In addition, the attraction of being close to the center of economic and governmental activity has also encouraged urban expansion. However, this expansion has not been without consequences, as it has led to the conversion of forest land and mixed gardens, with approximately 1,000 ha lost over 85 years. This has resulted in a decline in environmental carrying capacity, such as reduced spring discharge and green cover, threatening the sustainability of local ecosystems. The spatial transformation of built-up land development for the period 1940-2025 can be seen in Figure 11 and the area graph can be seen in Figure 12.

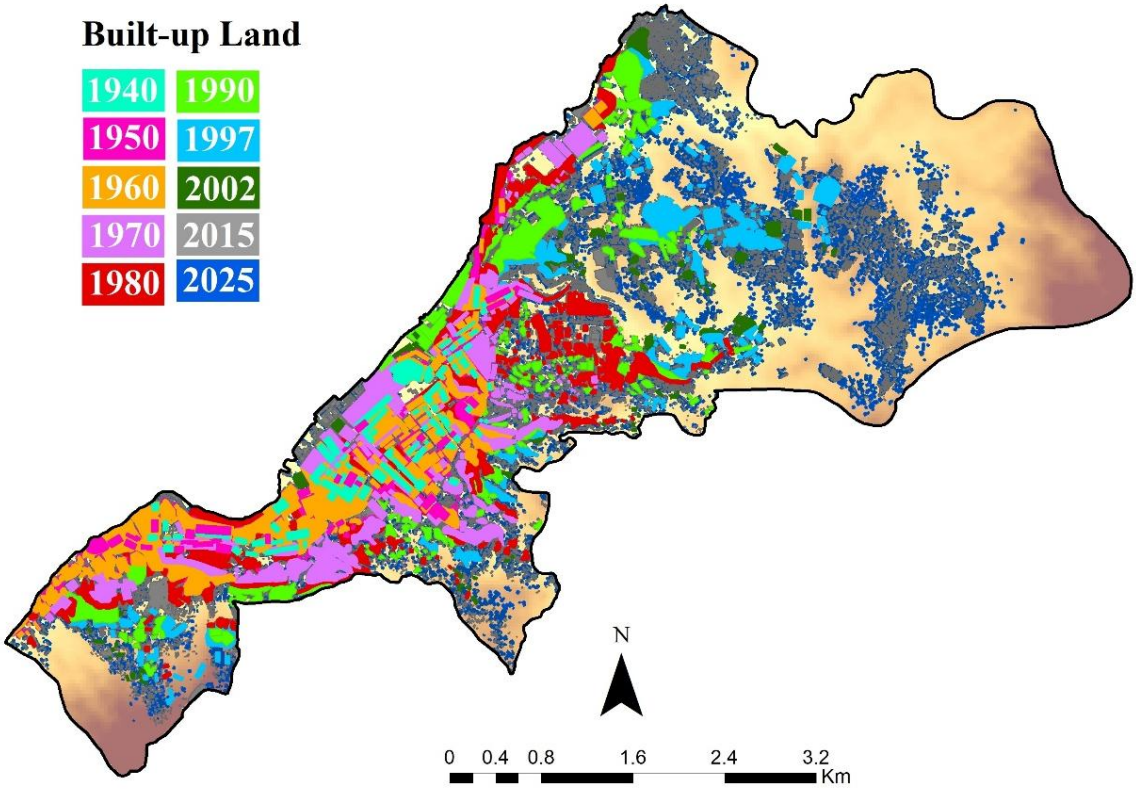


Figure 11. Built-up Land Development Period: 1940-2025

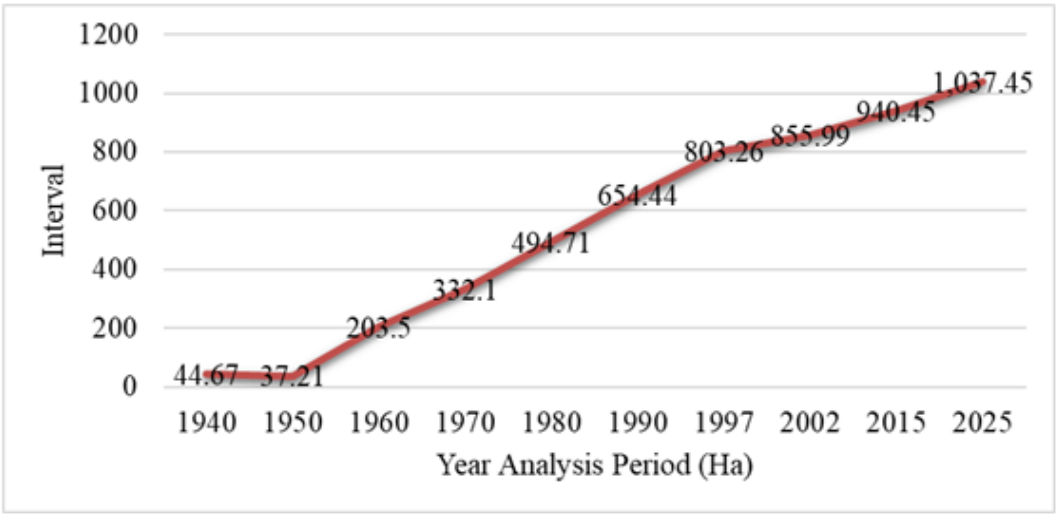


Figure 12. Increase in built-up land area for the period 1940-2025

The period from the 1990s to 2025 also saw development "jump" to hilly areas, such as Karang Panjang and Batu Merah Atas, due to limited flat land in the city center. This development, although balanced with environmental mitigation efforts, still poses its own challenges in terms of land conservation and management. This development into hilly areas shows adaptation to geographical limitations, but also indicates the need for more careful spatial planning to minimize negative impacts on the environment. This finding underscores the importance of sustainable spatial policies, which consider not only economic growth and settlement needs, but also ecosystem preservation and environmental balance. Overall, the transformation of Ambon City from a small post-war town to a complex urban center reflects the dynamic interaction between development factors, policies, and socio-economic pressures. However, this rapid growth also poses serious challenges, particularly in relation to land conversion and the decline in environmental carrying capacity (13). Therefore, in the future, a more holistic and sustainable spatial policy is needed, which is able to balance the needs of economic development, settlements, and environmental preservation. Thus, Ambon City can continue to develop without sacrificing ecological sustainability and the quality of life of its people.

Conclusions

The results of this study show that the physical transformation of built-up land in Ambon City center from 1940 to 2025 was driven by historical, social, economic, and development policy factors that have significantly influenced urban growth. Although the city experienced a decline in built-up area due to war devastation in the 1940-1950 period, rapid recovery occurred in the following decades with substantial additions to residential areas. It was found that built-up land is projected to continue to increase along with population growth and infrastructure development. However, this expansion also poses a challenge to the carrying capacity of the environment, given the conversion of forest and plantation land that could potentially threaten ecosystem balance and food security. Therefore, this research emphasizes the importance of sustainable spatial planning to address such issues in the future.

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Conflicts of Interest

The authors declare no conflict of interest

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