Environmental Impacts of Urban Zoning Transformation on Sustainability in Singaraja City

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Abstract. Singaraja City in North Bali faces growing ecological pressures due to uncontrolled land-use conversion and urban zoning transformation. This study aims to identify the dynamics of zoning changes and assess their environmental impacts between 1984 and 2020. A descriptive-quantitative approach was employed using medium-scale satellite imagery from Google Earth, visually interpreted and processed with QGIS. This method was selected for its ability to capture long-term spatio-temporal dynamics of land-use transformation. The results show significant changes: the number of central business districts (CBDs) increased from two to eight, while rural fringe zones disappeared entirely by 2020. Sub-districts were classified into three categories of impact: highly significant (Banyuasri, Banyuning, Kendran), significant (Astina, Banjar Bali, Beratan, etc.), and minimal (Kampung Anyar, Kampung Bugis, etc.). These transformations have contributed to ecological degradation, including the loss of green open space, conversion of agricultural land, increased pressure on water resources, and heightened risks of flooding and seawater intrusion. The findings highlight that urban densification in Singaraja generates considerable ecological risks. Adaptive, ecology-based spatial planning policies are therefore urgently required to mitigate environmental impacts and support sustainable urban development in coastal North Bali.
Keywords: Urban Zoning; Environmental Impacts; Land Use Conversion; Ecological Sustainability

1 Introduction

The Many cities are increasingly sick due to uncontrolled land conversion. Land conversion in big cities occurs along with massive development which has brought unsustainable urban qualities such as high crime, poverty, homelessness, slum settlements, land degradation due to massive groundwater extraction, traffic jams, population movement from villages. to the city has brought various disasters such as the clean water crisis, waste

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management, socio-economic inequality, floods and pollution [1]. Cities have an important role because they are the center of economic activity in the trade and service sectors, but this challenge must be recognized by all stakeholders in creating sustainable communities and cities without gaps and serious damage. Small towns have the opportunity to create a community atmosphere and a sustainable city. However, these cities experience challenges because they are plagued by the same problems as big cities. Identifying changes in a city is important to prepare it so that it does not suffer the same fate as big cities [1]. One city that has the potential to be developed into a sustainable city is Singaraja City in Bali Province, Indonesia, which is geographically located in an small archipelagic region.

Singaraja City, the capital of Buleleng District in North Bali, comprises 18 sub-districts, with 17 in Buleleng District (≈94%) and 1 in Sukasada District (≈6%). According to BPS, the population of Buleleng District grew by more than 9,000 people between 2011 and 2020, placing substantial pressure on land resources. This demographic growth, combined with policy initiatives to expand tourism beyond South Bali, has intensified land conversion in Singaraja. The population has an impact on land conversion because the greater the population, the greater the need for land for residence. The impact of increasing land conversion into built-up land areas such as settlements, housing, public facilities and infrastructure will have an impact on urban zoning classification for the smallest sub-regions of an area such as at the sub-district level of a city [2].

Several similar studies have been conducted on urban zoning in Indonesia. Previous studies on urban zoning in Indonesia have primarily relied on statistical data (e.g., BPS), which lack spatial detail and accuracy. While research in Bandung [3] and Denpasar [4] provides useful insights, no comprehensive study has investigated the long-term dynamics of urban zoning transformation and its environmental impacts in Singaraja City using geospatial approaches.

However, no one has conducted research on changes in the development of urban zoning in the city of Singapore and the magnitude of its environmental impact. This is important because Singaraja is the central axis of activity in North Bali where the development policy initiated by the government will ensure equitable development. The paradigm currently used is to enlarge and increase access and develop new tourist destinations by building facilities and infrastructure such as hotels and villas, which has been carried out in South Bali. The city of Singaraja as a magnet that naturally exists plus development policy intervention from the government will have an indirect effect on land conversion both within the city and in the hinterland of the city itself and so far, several studies have also experienced development of land conversion [2, 5]. According to [6] themselves, they also reveal that the dangers of land conversion, one of which can have consequences for the environment, some of which can even result in flooding.

One way to identify urban zoning is with land cover/land use data as in the research from [4, 5]. Google Earth has the availability of satellite image data in the form of images at different times so that it can detect changes in land cover/land use by delineating manually through visual interpretation. Apart from that, the platform is also easy to use and utilize. Meanwhile, in Google Earth there is medium-scale satellite imagery data, namely Landsat [7] from 1984 to 2020 so that the dynamics of change can be seen in a massive overview over this period of almost half a century. This study therefore addresses this gap by (1) identifying changes in urban zoning in Singaraja City from 1984 to 2020, and (2) analyzing the associated environmental impacts. By combining satellite imagery analysis with environmental interpretation, the study contributes both empirically and methodologically to the understanding of medium-sized city transformation in Indonesia.

2. Methods

This research uses a descriptive research design with a quantitative and qualitative approach. This research focuses on changes in land cover, changes in Urban Zoning, and the magnitude of environmental impacts. The location of this research is in Singaraja City which is determined based on the status of the sub-district area which is the scope of the study. The consideration in selecting the location is because Singaraja City is the largest city in North Bali and has a history of being the center of all activities in Bali, namely the capital of Lesser Sunda Province. However, it does not experience urban sprawl as badly as Denpasar [8, 9], which shows the same big city problems as other big cities, namely Jakarta [10] and Semarang.

The analysis was carried out in three stages. First, visual interpretation of Landsat imagery was conducted using Google Earth, and the delineated maps were processed with QGIS 3.34.5 Prizren to calculate land-use area. Second, urban zoning was classified following Yunus' typology: (a) urban/CBD zone (100% non-agricultural land), (b) urban fringe zone (≥75% non-agricultural land), (c) rural–urban fringe (50–75%), (d) urban–rural fringe (25–50%), and (e) rural fringe (≤25%). Third, the magnitude of change was categorized as class-3 (very significant), class-2 (significant), or class-1 (not significant). To complement the quantitative results, qualitative interpretation was conducted to identify environmental impacts such as the loss of agricultural land, green space reduction, food insecurity, water stress, seawater intrusion, and flood vulnerability.

A key limitation of this study lies in the use of medium-resolution Landsat imagery and visual interpretation, which may reduce accuracy at the micro-spatial level. More advanced methods, such as multispectral analysis via ENVI or Google Earth Engine, could provide more detailed insights [11, 12].

3.Result and Discussion

3.1 Changes in Urban Zoning in Singaraja City in 1984-2020

The results of data processing on the area of land cover obtained are shown and visualized through a percentage bar diagram which contains information on regions or sub-districts in Singaraja City with the area of each land cover and the total area of land in a sub-district. More details can be seen in Figure 1.

Fig. 1. Percentage of land cover in Singaraja City in (a) 1984 and (b) 2020.

The analysis of Landsat imagery reveals substantial transformations in the urban zoning of Singaraja City between 1984 and 2020. In 1984, only two sub-districts (Kampung Bugis and Kampung Singaraja) were classified as urban/CBD zones, while seven were urban fringe zones, two were rural–urban fringe, three were urban–rural fringe, and four remained rural fringe

By 2020, the number of urban/CBD zones had quadrupled to eight sub-districts, while rural fringe zones had completely disappeared. Four sub-districts were categorized as urban fringe, two as rural–urban fringe, and four as urban–rural fringe. This indicates that the city has expanded significantly, with formerly rural areas transformed into predominantly urban landscapes.

Based on these results, during the 36 years from 1984 to 2020 in Singaraja City there have been massive changes in urban zoning. The increase in the number of Urban zones/CBDs from initially only 2 to 8 in 2020 and the absence of Rural fringe zones in 2020 shows the transformation of Singaraja City itself into a more dense city in line with the development of population and the need for land. The complete results of the overall urban zoning classification for Singaraja City from 1984 to 2020 can be seen in Table 1.

Table 1. Singaraja City Urban Zoning Classification in 1984 and 2020

District	Sub-district	1984	2020
Buleleng	Astina	Urban fringe zone	Urban zone/CBD
	Banjar Bali	Urban fringe zone	Urban zone/CBD
	Banjar Jawa	Urban fringe zone	Urban zone/CBD
	Banjartegal	Rural-Urban fringe zone	Urban fringe zone
	Banyuasri	Urban-Rural fringe zone	Urban fringe zone
	Banyuning	Rural fringe zone	Rural-Urban fringe zone
	Beratan	Rural fringe zone	Urban-Rural fringe zone
	Kaliuntu	Urban fringe zone	Urban zone/CBD
	Kampung Anyar	Urban fringe zone	Urban fringe zone
	Kampung Bugis	Urban zone/CBD	Urban zone/CBD
	Kampung Kajanan	Urban fringe zone	Urban zone/CBD
	Kampung Singaraja	Urban zone/CBD	Urban zone/CBD
	Kampungbaru	Urban fringe zone	Urban fringe zone
	Kendran	Rural-Urban fringe zone	Urban zone/CBD
	Liligundi	Urban-Rural fringe zone	Rural-Urban fringe zone
	Paket Agung	Rural fringe zone	Urban-Rural fringe zone
	Penarukan	Urban-Rural fringe zone	Urban-Rural fringe zone
Sukasada	Sukasada	Rural fringe zone	Urban-Rural fringe zone

The expansion was spatially concentrated in the central area of Singaraja (including Kaliuntu, Banjar Jawa, Banjar Bali, Kampung Kajanan, Astina, and Kendran), while western (Banyuasri, Banjartegal), southern (Paket Agung, Sukasada, Beratan), and eastern (Banyuning) sub-districts also experienced significant conversion. The distribution of changes Zoning can be seen in Figure 2.

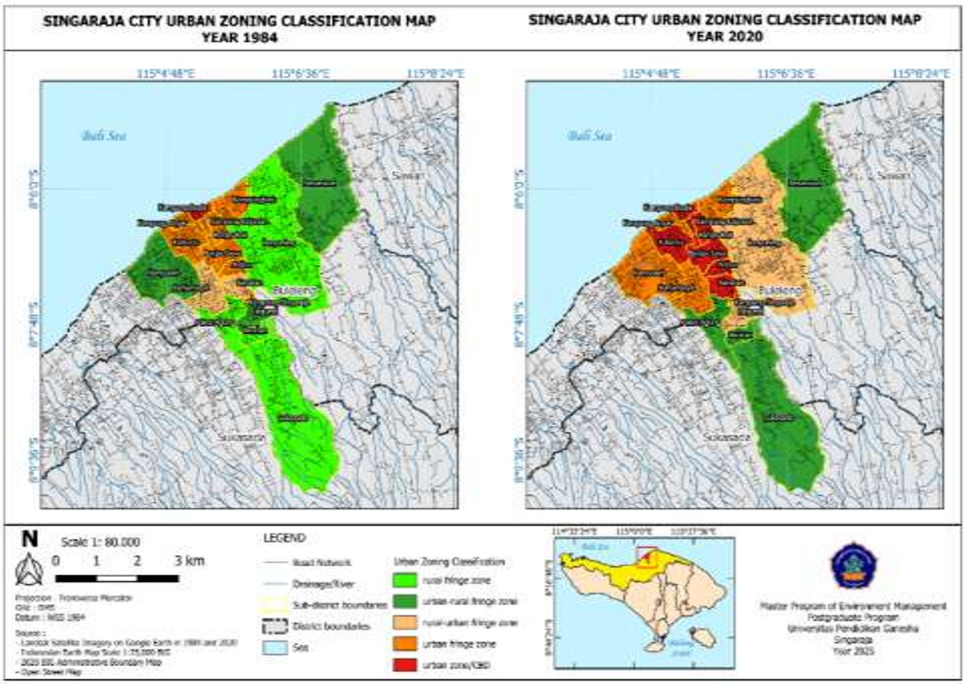

Fig 2. Singaraja City Urban Zoning Classification Map for 1984 and 2020

3.2 Identified the Magnitude of the Environmental Impact of the Change

The results of the urban zoning classification that have been obtained are analyzed further to identify the magnitude of the environmental impact of changes which are divided into three classes. Based on the analysis carried out, it was found that from 1984 to 2020, many sub-districts in Singaraja City experienced changes based on the changing urban zoning. Classification of environmental impact levels shows that three sub-districts (Banyuasri, Banyuning, Kendran) experienced class-3 or very significant changes, ten sub-districts were categorized as class-2 (significant changes), and five sub-districts remained in class-1 (minor changes).

Overall, the results demonstrate that Singaraja has undergone a fundamental transition from a mixed urban–rural system into a predominantly urbanized city. This process has reshaped the spatial structure of the city and created new environmental pressures. The results of the classification of the magnitude of the impact resulting from changes in urban zoning in Singaraja City can be seen in Table 2.

Table 2. Classification of the Impact of Urban Zoning Changes in Singaraja City

District	Sub-District	Class	Rate of changes
Buleleng	Astina	Class-2	There have been significant changes
	Banjar Bali	Class-2	There have been significant changes
	Banjar Jawa	Class-2	There have been significant changes
	Banjartegal	Class-2	There have been significant changes
	Banyuasri	Class-3	There has been a very significant change
	Banyuning	Class-3	There has been a very significant change

District	Sub-District	Class	Rate of changes
	Beratan	Class-2	There have been significant changes
	Kaliuntu	Class-2	There have been significant changes
	Kampung Anyar	Class-1	No significant changes occurred
	Kampung Bugis	Class-1	No significant changes occurred
	Kampung Kajanan	Class-2	There have been significant changes
	Kampung Singaraja	Class-1	No significant changes occurred
	Kampungbaru	Class-1	No significant changes occurred
	Kendran	Class-3	There has been a very significant change
	Liligundi	Class-2	There have been significant changes
	Paket Agung	Class-2	There have been significant changes
	Penarukan	Class-1	No significant changes occurred
Sukasada	Sukasada	Class-2	There have been significant changes

Source: Results of data processing

The distribution of the respective impacts of urban zoning changes in Singaraja City is very intensive in the west and east of the city, while in the center and south there are also significant changes. In the middle of the Singaraja City area, many changes have occurred in the sub-districts of Kampung Kajanan, Banjar Bali, Banjar Jawa, and Astina, which are included in the class-2 change areas, there have been significant changes and Kendran, which is included in the class-3 change areas, has seen very significant changes. In the west of Singaraja City, Banyuasri sub-district is the only area that is included in class 3, there has been a very significant change, while Banjartegal and Kaliuntu are included in class 2, there has been a significant change. In the south of Singaraja City, the sub-districts of Paket Agung, Liligundi, Beratan, and Sukasada all fell under the impact of class-2 changes, experiencing significant changes. Finally, in the east of Singaraja City, the Banyuning sub-district area itself is also an area that has experienced very significant changes in class-3. The distribution of the results of this impact classification can be seen in Figure 3.

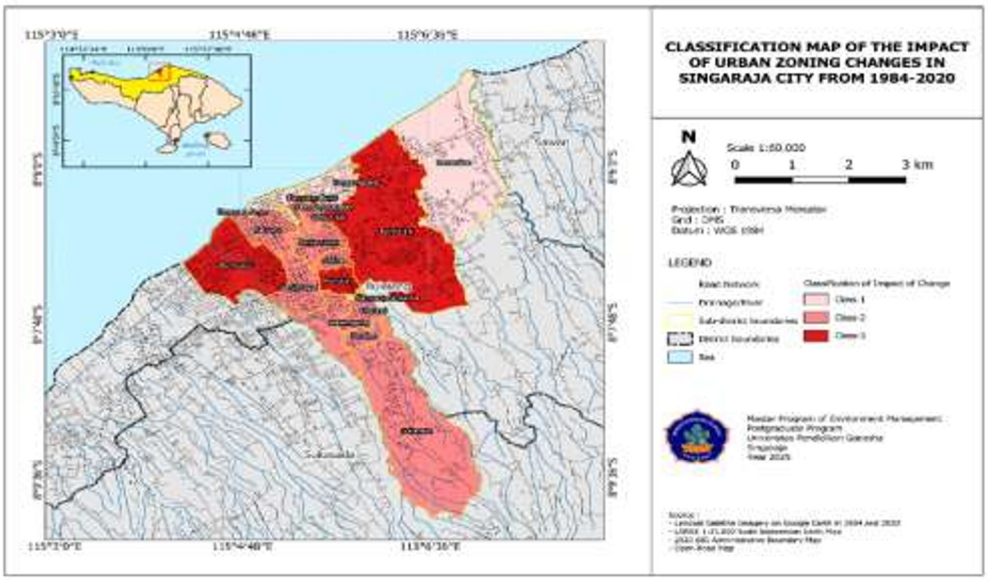

Fig 3. Classification Map of the Impact of Urban Zoning Changes in Singaraja City

In the existing research from various studies such as those conducted by [2] shows the massive increase in built-up land such as settlements, housing, public facilities and infrastructure in Singaraja City and the surrounding area. Bharata & Rahman revealed through high-resolution satellite imagery data on Google Earth itself that land such as rice fields and plantations have been transformed into organizational land. Land such as rice fields and plantations have a better coefficient of air runoff compared to built-up land such as organizations which will worsen air runoff in Singaraja City. Research conducted by [2] revealed that areas such as Banyuning and Kendran are included in class-3 where very significant changes have occurred, which are areas that are less comfortable based on their green open spaces, even for the Banyuasri area itself which is also included in class-3 where very significant changes have occurred, it is an area that is uncomfortable or bad for its green open spaces. From this study, only Sukasada holds comfortable conditions in the research of [2].

The impact of urban zoning changes in Singaraja City has been recorded from several studies that have been conducted. Research conducted by [2] through data from the 1:25,000 scale RBI map acquired in 1999 to predict the physical development of Singaraja City showed that 39% of the land in Singaraja City had been converted into housing, public facilities, and infrastructure. Research conducted by [2] using ALOS AVNIR-2 satellite imagery also showed that the outskirts of Singaraja City experienced changes, from 2010, 2015 and 2020 which were dominated by agricultural land which then changed into housing. The study also revealed that the largest expansion of settlements in the western part is Banyuasri Village/Sub-district which based on research conducted by researchers is included in the impact of class-3 changes, there have been very significant changes, while in the southern part is Beratan Village/Sub-district which is included in the impact of class-2 changes, there have been significant changes and in the eastern part is Banyuning Village/Sub-district which is included in the impact of class-3 changes, there have been very significant changes. Research conducted by Bharata & Rahman using high-resolution imagery from Google Earth in Singaraja City itself as a Sub-Downstream Watershed of the Buleleng Watershed shows massive changes during the period 2004 - 2020 related to the land cover of Wetland Seasonal Crops (Rice Fields) to Residential/Mixed Buildings in the eastern part of the location which is administratively included in the Banyuning sub-district area which is included in the impact of class-3 changes, there have been very significant changes. In addition, there are changes, especially from Gardens and Mixed Crops to Residential/Mixed Buildings and Non-Residential Buildings in the western, northern and southern parts of the location.

Changes in land conversion also make Singaraja City a city that is less comfortable to uncomfortable based on green open space [13] Other studies also show that population pressure on agricultural land in several areas of Singaraja City also includes a deficit or pressured status [12]. Although areas such as Kampung Bugis and Kampungbaru are areas in Singaraja City that are included in class-1, there have been no significant changes, this does not mean that this area has no problems with the impact of urban zoning which is the Urban zone/CBD. Research conducted by revealed that there is a fairly wide distribution of slum settlements in the two sub-districts. Research by revealed that in Kampung Anyar, which actually did not experience significant changes in urban zoning, it also fell into the moderate slum level. Research conducted by revealed that in the coastal areas of Singaraja City, there is still a community behavior of dumping waste directly onto the beach, which is also known based on the positive and significant relationship between environmental knowledge and the behavior of coastal communities in maintaining environmental cleanliness.

Banyuning as a sub-district included in class-3 has experienced very significant changes not only in terms of land conversion to built-up land or settlements but also waste

problems in the housing environment. Research conducted by revealed that in the BTN Banyuning Indah and Multi Banyuning Lestari housing complexes there are various types of waste and tend to increase both organic and non-organic with the largest burden being on the organic waste itself, even in its follow-up by it was seen that the waste was mixed. Research conducted by revealed that the markets in Singaraja City, namely many centered in Banyuasri, Singaraja Village, Kajanan Village, are also inseparable from the problem of mixed waste.

In addition, population growth in the Singaraja City area, especially seen from data from Buleleng District, puts pressure on agricultural land. A study conducted by [13] revealed that most areas in Buleleng District are not self-sufficient in food. Although in general the population pressure that has existed so far has not been experienced by most of Singaraja City, areas such as Banyuning Village have experienced population pressure. Several studies have shown that the Singaraja City area as a whole is already in a food deficit as shown by the research of and a study conducted by the Bali and Nusa Tenggara Ecoregion Development Control Center through the 2021 Bali Island food carrying capacity status document which shows that the Singaraja City area also stated that its food status is not sustainable except for Sukasada Village which is included in Sukasada District

Judging from the data on the condition of its water resources, the results of the Bali Water Protection (BWP) study itself revealed that the Buleleng District area, which is 94% of the Singaraja City area, is one of the areas experiencing seawater intrusion and is an area with high groundwater exploitation. A study by BWP also revealed that the Singaraja City area, which is 94% of which is included in the Buleleng District, is an area with a water status based on the natural ecosystem of its water supply on the island of Bali which is already in deficit and also has an unsustainable status. Research by [6] revealed that some areas in Singaraja City were flooded, some of which actually occurred in Banyuning Village and Kampung Anyar. However, research from revealed that the related agencies in this case the Public Works and Spatial Planning (PUTR) Office of Buleleng Regency had worked well in terms of planning, organizing, directing, and supervising flood management in Singaraja City. In the midst of Singaraja City which continues to develop, although in terms of organization and implementation of tasks it was good, resources such as finances were one of the obstacles in flood management.

The various impact conditions that actually occur due to massive land conversion have provided various challenges to Singaraja as a city. In the midst of the conditions being faced, the environmental conditions that occur in Singaraja City can be seen in full in Table 3.

Table 3. The environmental conditions considered as impact of urban zoning development which occur in Singaraja City are characterized by (X)

District	Sub-district	Class	Environment conditions considered as impact of urban zoning development in Singaraja City										
			1	2	3	4	5	6	7	8	9	10	11
Buleleng	Astina	Class-2	X				X	X	X	X	X	X	
	Banjar Bali	Class-2	X				X	X	X	X	X	X	
	Banjar Jawa	Class-2	X				X	X	X	X	X	X	
	Banjartegal	Class-2	X				X	X	X	X	X	X	
	Banyuasri	Class-3	X		X		X	X	X	X	X	X	
	Banyuning	Class-3	X		X	X	X	X	X	X	X	X	X
	Beratan	Class-2	X				X	X	X	X	X	X	
	Kaliuntu	Class-2	X				X	X	X	X	X	X	
	Kampung Anyar	Class-1					X	X	X	X	X	X	X

	Kampung Bugis	Class-1		X			X	X	X	X	X	X	
	Kampung Kajanan	Class-2	X		X		X	X	X	X	X	X	
	Kampung Singaraja	Class-1			X		X	X	X	X	X	X	
	Kampungbaru	Class-1		X			X	X	X	X	X	X	
	Kendran	Class-3	X				X	X	X	X	X	X	
	Liligundi	Class-2	X				X	X	X	X	X	X	
	Paket Agung	Class-2	X				X	X	X	X	X	X	
	Penarukan	Class-1					X	X	X	X	X	X	
Sukasada	Sukasada	Class-2	X										

Description: 1. Change of land use, 2 Slums, 3. Waste problem, 4 Population pressure on agricultural land, 5. Not self-sufficient in food. 6. Food Deficit. 7. High category of groundwater exploitation. 8. Seawater Intrusion. 9. Deficit Water status based on the natural ecosystem that provides the water. 10. Water reserve status is not sustainable, 11. Flood

The results demonstrate that Singaraja has undergone significant spatial restructuring, resembling urban sprawl processes observed in other Indonesian cities. The shift from rural to urban zones, coupled with the complete disappearance of rural fringe areas, reflects rapid and uneven urbanization. This pattern is consistent with findings from Bandung [3], where suburban zoning indicated accelerated rural-to-urban transitions, and with studies in Denpasar [4], which showed similar outward expansion from the city center.

The environmental consequences are considerable. Agricultural land conversion and the loss of rural fringe zones threaten food security, aligning with, who documented the impact of farmland loss on local food resilience in Buleleng. Water-related challenges, including groundwater overexploitation and seawater intrusion, also echo concerns raised in Bali Water Protection studies, which emphasize aquifer depletion as a long-term risk. In addition, flood vulnerability in Singaraja, particularly in Banyuning and Kampung Anyar, corroborates the flood hazard mapping conducted by [6], which identified these areas as highly exposed.

The findings further reveal that zoning transformation alone cannot fully explain environmental problems. Even sub-districts with relatively minor spatial changes (class-1) still experience slum proliferation and poor waste management, as seen in Kampung Anyar and Kampung Bugis. This supports [5], who highlighted how socio-cultural and governance factors influence environmental outcomes in coastal communities of Singaraja.

Theoretically, these results contribute to the understanding that medium-sized cities are not immune to unsustainable growth trajectories often associated with megacities. As [10] argue for the Jakarta–Bandung conurbation, unmanaged land conversion leads to conurbation pressures and environmental degradation [4]. Practically, this study underscores the urgency of implementing stricter land-use controls, expanding green space protection, regulating groundwater use, improving flood mitigation infrastructure, and promoting community-based waste management in Singaraja.

A limitation of this study lies in the use of medium-resolution Landsat imagery and reliance on visual interpretation. While sufficient for detecting broad zoning dynamics, this method lacks micro-scale precision. Future studies could adopt high-resolution imagery and advanced geospatial techniques such as ENVI or Google Earth Engine to provide more detailed insights.

4 Conclussion

This study concludes that Singaraja has experienced substantial urban zoning transformation between 1984 and 2020. The number of CBD zones increased from 2 to 8, while rural fringe zones disappeared entirely, indicating a clear shift toward urban dominance. These spatial changes have generated significant environmental consequences, including the loss of agricultural land and green open space, food insecurity, groundwater overexploitation, seawater intrusion, water stress, flood risks, and the emergence of slum settlements. The findings confirm that medium-sized cities such as Singaraja are vulnerable to unsustainable growth trajectories similar to those observed in larger metropolitan areas if land conversion is not effectively managed. Based on these findings, several policy recommendations are proposed: (1) stricter control of land conversion through enforcement of spatial planning regulations; (2) expansion and protection of urban green open spaces; (3) sustainable groundwater management and alternative water supply strategies; (4) improved flood mitigation through integrated spatial planning and drainage systems; (5) revitalization of slum areas and strengthening of community-based waste management; and (6) reinforcement of local food security by protecting remaining agricultural zones. These measures are essential to ensure that Singaraja evolves into a sustainable city capable of balancing urban growth with environmental resilience and social well-being.

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