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Analysis of the dynamics of changes in landscape ecological structure using geographic information system (GIS) technology in Badung regency, Bali

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ABSTRACT

The development of land use in Badung Regency in the period 2013-2021 has an impact on changes in the ecological structure of the landscape. Changes in the ecological structure of the landscape occur in the three parameters, namely patch, matrix and corridor, which are indicated by changes in the area and function of the three parameters. The addition of matrix area in the settlement land use class and golf course patches causes changes in the area of the matrix of mixed gardens, rice fields and mangroves as well as corridors of non-volcanic coastal sand that dominantly have ecological functions. The objectives to be achieved in this study are to analyze the dynamics of changes in the ecological structure of the landscape caused by land use development in Badung Regency. The dynamics of changes in the ecological structure of the landscape due to large-scale changes is a driving factor in the deviation of spatial utilization and a decrease in the quality of the environment in Badung Regency. The research concluded that landscape ecology analysis is an important aspect in the development of regional zones in Badung Regency that takes into account the principles of sustainable development. This research found a new formulation in the analysis of ecological zone development that integrates the landscape ecology approach with the spatial approach and regional approach. The ecological zones of Badung Regency are grouped into 4 (four), namely: very high ecological zone, high ecological zone, medium ecological zone and low ecological zone.

1. Introduction

Badung Regency is one of the regions in Bali Province which has an area of 418.52 km2 or about 7.43% of the island of Bali. The Badung Regency area is located at an altitude of 0-2,075 m above sea level (masl) with morphology ranging from lowlands to highlands in the form of hills. The lowland morphology is found in the South Badung area which is dominated by non-agricultural land uses including tourist accommodation, trade and services and settlements. The Central Badung region, with moderate land elevation and good water sources, is very suitable for agricultural activities, so land use is dominated by agricultural land in the form of rice fields, moorlands and rural settlements. North Badung is a plateau, hilly land morphology, high land slope and is a water catchment area dominated by large plants with land use in the form of forests, mixed gardens and moorland.

The more northward the use of built-up land is getting smaller compared to the South Badung area. This shows that the physical development of the South Badung area, which has urban characteristics, is faster than the North Badung area, which has rural characteristics. The development of built-up areas in Badung Regency is driven by population growth and rapid development in the tourism sector. The increasing need for land in Badung Regency to accommodate population growth and

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development has an impact on changes in use and a decrease in environmental quality. Changes in land use are then intervened by the Local Government and accommodated in changes to the spatial pattern plan. In the long term, this approach will have a negative impact on landscape structure and environmental balance, including human life. This is in line with research conducted by Dale et al. (2000) which states that to analyze the impact of land use, it is very important to know that ecological processes occur in temporal settings and change over time.

Landscape ecology often appears and is useful in solving various environmental problems, and its relation to land use (Forman, 1995). Previous research conducted by Wu and Hobbs (2007) investigated the dynamics of land use change in Beijing using Remote Sensing (RS) and Geographic Information System (GIS). They found that the rapid and uneven urban growth trend has led to the loss of farmland and other agricultural land in the metropolitan area. Promoting the development of eco-cities has become an important policy goal in China. Among the many aspects of eco-city planning, promoting sustainable landscape development and green space management are key issues to enhance biodiversity, reduce air pollution and heat island effect, and improve the aesthetic environment and quality of life (Wu, 2015).

In order to solve environmental problems and realize sustainable development goals in Badung Regency, it is appropriate to use a landscape ecology approach in the formulation of spatial policies. The landscape ecology approach accommodates various interests related to conflicting land uses, namely between extractive economic functions and conservative environmental services. Landscape ecological analysis attempts to quantify ecological processes in a landscape that are directly related to humans as the primary managers of the landscape (Leitao and Ahern, 2002). The analysis emphasizes the discussion of structure, function, and dynamics that occur in the landscape (Arifin et al., 2009). Landscape structure is associated with the size, shape, type, and ecosystem configuration of landscape elements, namely patches, matrix, and corridors.

Landscape ecology is the study of patterns and interactions between ecosystems in a region and how these interactions influence ecological processes, especially the effects of spatial heterogeneity (Clark, 2010). The term landscape ecology was first introduced by a German geographer named Carl Troll, who later used the term geo-ecology, which is a combination of geography (landscape) and biology (ecology) which as a whole forms a unity that is influenced by several factors, including: climate, geology, geomorphology, water, soil, vegetation and humans (Soeprobowati, 2011). While Turner et al. (2003) revealed that there are 2 (two) important aspects in landscape ecology that distinguish it from ecological sub-disciplines, namely: (1) landscape ecology is explicitly an important spatial configuration in ecological processes. Landscape ecology discusses the number of constituent components and the shape of their arrangement, (2) landscape ecology often focuses on the expansion of areas larger than the areas traditionally studied in ecology. Then Forman and Godron (1986) defined three basic structural elements of the landscape including: patch, corridor, and matrix.

Based on the problems described above, this study analyzed the dynamics of changes in the ecological structure of the landscape as a result of land use change in Badung Regency, Bali Province in the time period from 2013 to 2021. Furthermore, the results of the landscape ecology analysis become the basis for the preparation of regional ecological zone policies that consider the principles of sustainable development. This research uses variables of land use, land capability, land suitability and landscape ecological structure.

2. Research methods

The analysis of changes in the ecological structure of the landscape in Badung Regency was carried out on the constituent elements of the landscape including: patch, matrix, and corridor, then studied it based on the condition of the structure, function and dynamics of changes in the ecological structure of the landscape. According to Wu (2015), landscape ecology analysis uses spatial analysis of satellite image maps and Geographic Information System (GIS), calculating landscape metrics and land use mapping. Geographic Information System (GIS) technology is used to analyze landscape ecology based on parameters including: climate, geology, geomorphology, water, soil, vegetation and human influence to determine landscape patterns and structures (Samadikun et al., 2012).

Analysis of the dynamics of changes in the ecological structure of the landscape in Badung Regency was carried out by overlaying using Geographic Information System (GIS) technology supported by the ArcGIS 10.8 application. Overlay is a technique of placing one map graphic over another map graphic and displaying the results on a computer screen or on a plot. Overlaying maps is done with at least 2 (two) different types of maps technically bound; there must be a polygon formed from 2 (two) types of maps that are overlaid. If you look at the attribute data, it will consist of the information of the map that formed it. The stages in analyzing the dynamics of changes in the ecological structure of the landscape in Badung Regency are as follows:

1) Land use map preparation

Land use maps are obtained from on-screen digitization of quickbird satellite image maps and field observations. The land use map prepared is the condition in 2013 and 2021 so that the types of land use, their respective areas and changes occur.

2) Preparation of landscape ecological structure map

Landform ecological structure maps were prepared using Geographic Information System (GIS) technology through on-screen digitization of quickbird satellite image maps in 2013 and 2021. The results of mapping the ecological structure of the landscape are made temporarily based on 3 (three) elements of its formation, namely pacth, matrix, and corridor so that the area and distribution of each element is known.

3) Analysis of landscape ecological index values

The analyzed Badung Regency landscape ecological parameters consist of 6 (six) parameters, which are divided into four groups of landscape ecological indices. The four groups according to Forman & Godron (1986) and Prasetyo (2017) include: (1) area measures, namely Total Class Area (CA) and Largest Patch Index (LPI), (2) density and variability measures, namely Number of Patches (NP) and Patch Density (PD), (3) edge measures, namely Edge Density (ED), and (4) shape measures, namely Landscape Shape Index (LSI). The quantitative value of the landscape ecological index can be used to find similarities and differences in landscape structure and pattern change.

The next stage is the preparation of ecological zones in the Badung Regency area analyzed by overlay techniques using Geographic Information System (GIS) technology on land use maps, land capability maps, land suitability maps and landscape ecological structure maps. Furthermore, the results of the spatial analysis are grouped into several classifications of landscape ecological zones based on delineation in the form of polygons from the results of spatial analysis with overlay techniques.

3. Results and discussion

3.1 Land Use Change

Based on the results of spatial analysis using the Badung Regency land use map interpreted from quickbird imagery in 2013 and 2021, it shows the dynamics of changes in area between land use classes. The cultivated areas that experienced a significant increase in area in the 2013-2021 period consisted of settlements experiencing an increase of 4,810.75 ha (57.50%), then golf courses experienced an increase of 69.80 ha (77, 26%) and freshwater ponds of 5 ha (94.16%). While land use in the 2013-2021 period that experienced the most dominant reduction in area was the use of mixed garden land covering 4,109.54 ha (-21.98%), rice fields covering 736.48 ha (-6.81%), non-volcanic beach sand covering 27.35 ha (-11.60%) and mangroves covering 12.18 ha (-1.93%).

Table 1. Land Use Change of Badung Regency in 2013 and 2021

No	Land Use	Area (ha)		Changes	
		2013	2021	Area (ha)	Percentage
1	Parking Lot and Field	21,42	21,42	-	0,00
2	Residential	8.366,59	13.177,34	4.810,75	57,50
3	Non-volcanic sand beach	235,70	208,35	- 27,35	-11,60
4	Forest	990,78	990,78	-	0,00
5	Mixed Garden	18.699,38	14.589,84	- 4.109,54	-21,98
6	Freshwater Pond	5,31	10,31	5,00	94,16
7	Runway and taxiway	39,55	39,55	-	0,00
8	Mangrove	630,14	617,96	- 12,18	-1,93
9	Golf Course	90,35	160,15	69,80	77,26
10	Rice fields	10.816,61	10.080,13	- 736,48	-6,81
11	River	17,37	17,37	-	0,00
12	Others	1.938,80	1.938,80	-	0,00
Total		**41.852,00**	**41.852,00**		

Source: Results of Land Use Map Analysis, 2022

The trend of land use change is also clearly visible in the area of North Kuta Subdistrict and southern Mengwi Subdistrict as a result of the development of Kuta tourism activities towards the coastal areas of North Kuta Subdistrict to Mengwi Subdistrict. Areas that were once agricultural land (paddy fields) have been converted into residential buildings and buildings supporting tourism facilities, among others: hotels, tourist cottage villas, bars, restaurants, and homestays. The Canggu area has economically become a new growth center whose influence extends to the surrounding villages. This condition is one of the factors accelerating land use change, especially green open space into built-up areas, even though it has been regulated in the Sub-district Detailed Spatial Plan.

Rustiadi (2010) states that basically the use of a good land should be in accordance with the ability of the land so that the carrying capacity of the land is also good, because land has a certain level, ability to support human life, land that is used in accordance with its ability is also able to reduce the level of risk of environmental damage that can occur due to land use so that it can be used sustainably.

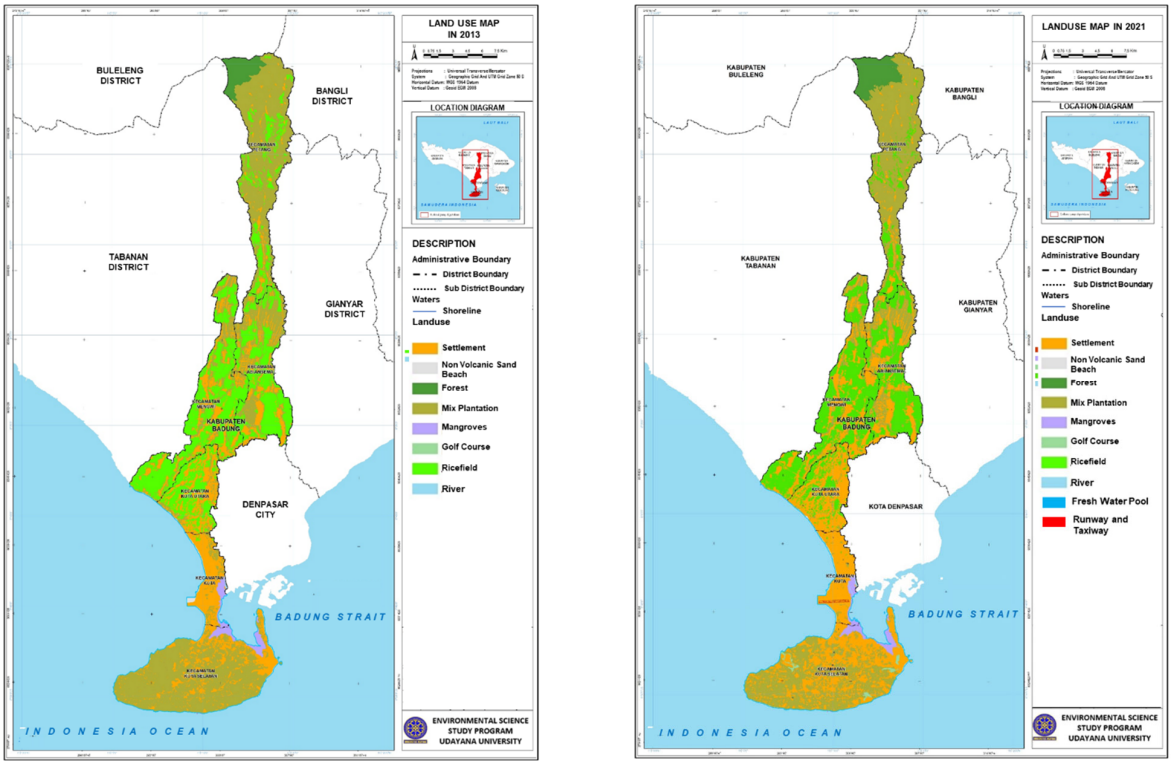


Fig. 1. Land Use Map of Badung Regency in 2013 and 2021

The forest area in Badung Regency in 2021 is 990.78 ha (2.37%) and mangroves are 617.96 ha (1.48%) of the total area, which has not reached the ideal condition for optimizing environmental benefits according to Law Number 41 of 1999 concerning Forestry, which is at least 30% of the total area. Forests that have a function as a catchment area experience land conversion due to the pressure of cultivation activities including housing, accommodation, and trade and services. If land use change is not controlled with strategic efforts, it will be increasingly difficult to obtain ideal conditions in terms of environmental benefits from the existence of forests in Badung Regency. Land use change has a significant impact on the physical and social environment as well as food reserves to fulfill the needs of local communities. In addition to land use change, pressure on the environment also occurs in the Tahura Ngurah Rai conservation area. This area was identified as having severe damage reaching 22.83%. Mangrove forest points in Prapat Benoa that are severely damaged are Tanjung Benoa, Benoa and Serangan (Dinas Pekerjaan Umum dan Penataan Ruang Kabupaten Badung, 2021). The threat of pollution and damage to mangrove forests in Badung Regency comes from various community activities around the forest and from the watershed that empties into Tahura Ngurah Rai. Along with development and population growth, the production of garbage and waste, coastal reclamation, and logging are serious threats to the sustainability of mangrove forest ecosystems.

3.2 Changes in the Landscape Ecological Structure of Badung Regency

In landscape ecology, processes occur that result in changes to the landscape structure within it. To justify the situation in a landscape and the dynamics of structural changes that occur in its constituent components, measurements of the ecological structure of the landscape are made based on spatial modeling data (Wu & Hobbs, 2007).

Based on the analysis of the ecological structure of the landscape, 4 (four) types of patches were identified in Badung Regency with a total area of 156.63 ha in 2013, then increased to 231.43 ha in 2021 or an increase in area of 74.80 ha (47.76%). The largest patch is the golf course which reached 90.35 ha in 2013 and increased to 160.15 ha in 2021 or an increase in area of 69.80 ha (77.26%) and the smallest is the freshwater pond patch of 5.31 ha in 2013 and increased to 10.31 ha in 2021 or an increase in area of 5.00 ha (94.08%). Meanwhile, the parking area and field patches as well as runways and taxiways have not changed in the area.

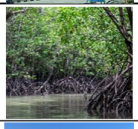
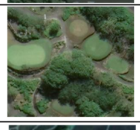
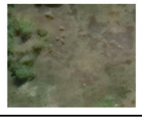
No	Type of Land Use	Code	Image of Satellite Imagery	Field Condition	Area (Acres)	Persentage (%)
1	Parking area and field	PL			21,42	0,05
2	Settlement	R			13.177,34	31,49
3	Non-volcanic stretch of beach sand	PP			208,35	0,50
4	Forest	HL			990,78	2,37
5	Mixed plantation	P-3			14.589,84	34,86
6	Fresh water pool	KL			10,31	0,02
7	Runway and *Taxyway*	LP			39,55	0,09
8	Mangroves	EM			617,96	1,48
9	Golf Course	PG			160,15	0,38
10	Ricefield	P-1			10.080,13	24,09
11	River	S			17,37	0,04
12	Other land use	L			1.938,80	4,63
TOTAL					**41.852,00**	**100,00**

Fig. 2. Quickbird Image Land Use and Field Conditions in 2022

.

Table 2
Land Cover Patches in Badung Regency in 2013 and 2021

No	*Patch*	Area(ha)		Changes	
		Tahun 2013	Tahun 2021	Area (ha)	Percentage (%)
1	Parking Area and Field	21,42	21,42	0,00	0
2	Freshwater Pond	5,31	10,31	5,00	94,08
3	Runway and Taxiway	39,55	39,55	0,00	0,00
4	Golf Course	90,35	160,15	69,80	77,26
	Total	**156,63**	**231,43**	**74,80**	**47,76**

Source: Analysis Result, 2022

Corridor is a homogeneous surface area that is elongated and continuous (connectivity). The results of the interpretation of quickbird imagery and the Rupa Bumi Indonesia (RBI) map, there are 2 (two) main types of corridors in Badung Regency, namely rivers and non-volcanic coastal sand with a total area of 253.07 ha in 2013, then reduced to 225.71 ha in 2021. The river corridor tends not to change in area compared to other landscape ecological structures, while the non-volcanic coastal sand corridor with a function as a coastal border experiences dynamic changes as a result of the development of tourism activities. The dynamics of change are indicated by the reduction in the area of coastal sand corridor from an area of 235.70 ha in 2013 to an area of 208.35 ha in 2021 or a reduction of 27.35 ha (-11.60%).

Table 3
Land Cover Corridor of Badung Regency in 2013 and 2021

No	*Corridor*	Area (Ha)		Changes	
		Tahun 2013	Tahun 2021	Area (Ha)	Percentage (%)
1	Non-Volcanic Sand Beach	235,70	208,35	-27,35	-11,60
2	River	17,37	17,37	0,00	0,00
	Total	**253,07**	**225,71**	**-27,35**	**-11,60**

Source: Analysis Result, 2022

Matrix is the most dominant surface area of a landscape mosaic that eventually becomes a type of landscape element and plays a dominant functional role in the landscape (Forman & Godron, 1986; Arifin et al., 2009). The matrix in Badung Regency is reflected in the composition of land cover which includes: North Badung and Central Badung areas have a dominant land cover composition of agricultural land, forests, and settlements. South Badung area, given the basic physical conditions that are difficult to develop food crop agriculture, the land use is more dominant for built-up land including settlements, tourism, and trade and services.

Based on the results of the analysis, the total area of land cover matrix in Badung Regency in 2013 was 39,503.49 ha, reduced to 39,456.05 ha in 2021 or a reduction in area of 47.45 ha (-0.12%). Changes in the form of additional area occurred in the settlement land cover matrix reaching an area of 4,810.76 ha (57.50%). While changes in the form of area reduction occurred in the mixed garden land cover matrix reaching an area of 4,109.55 ha (21.98%), rice fields covering an area of 736.47 ha (-6.81%), and mangroves covering an area of 12.19 ha (-1.93%). While the forest land cover matrix has no change in area.

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Table 4
Land Cover Matrix of Badung Regency in 2013 and 2021

No	*Matrix*	Area (Ha)		Changes	
		Tahun 2013	Tahun 2021	Area (Ha)	Percentage (%)
1	Settlement	8.366,59	13.177,34	4.810,76	57,50
2	Mixed Garden	18.699,38	14.589,84	-4.109,55	-21,98
3	Rice Fields	10.816,61	10.080,13	-736,47	-6,81
4	Forest	990,78	990,78	0	0,00
5	Mangrove	630,14	617,96	-12,19	-1,93
	Total	**39.503,49**	**39.456,05**	**-47,45**	**-0,12**

Source: Analysis Result, 2022

The landscape ecological structure of Badung Regency based on its land cover has different landscape configurations in each part of Badung Regency. Based on the landscape ecological structure map, in the South Badung section, the landscape ecological structure is dominated by artificial structures (residential buildings, runways and taxiways, golf courses, and parking areas and fields, while the natural structures include non-volcanic beach sand, mixed gardens, and mangroves. While the condition of the ecological structure of the landscape in the Central Badung section is still dominated by natural structures in the form of rice fields and mixed gardens, the artificial structures show development and fragmentation. In contrast, the ecological structure of the landscape in the North Badung area has natural characteristics that dominate compared to artificial structures. North Badung landscape conditions are dominantly formed from mixed garden land cover and protected forests. This condition according to Arifin et al. (2009) illustrates that the landscape ecology of Badung Regency has been occupied by artificial structures (built-up land), as a form of human intervention in the landscape to meet their needs.

The dynamics of a landscape indicate that the landscape in general is not permanent, but undergoes changes in terms of quality, configuration, size, shape, function, and others. Understanding landscape dynamics has major implications for landscape management and planning. Landscape change is change caused by alteration/disturbance to the structure and/or function of the landscape, either in the form of natural events or human disturbance. Disturbance to function does not necessarily change structure, but disturbance to structure will definitely change landscape function. Landscapes change all the time due to the influence of various driving factors including physical, social and economic factors. Predicting the direction of landscape change and estimating its future consequences is important information. This information can be used as a basis for appropriate management and policy interventions.

Table 4
Changes in Landscape Ecological Structure of Badung Regency in 2013-2021

No	Ecological Components of Landscapes	Area (Ha)		Changes	
		2013	2021	Area (Ha)	Percentage (%)
1	*Patch*	156,63	231,43	74,80	47,76
2	*Matrix*	39.503,49	39.456,05	-47,45	-0,12
3	*Corridor*	253,07	225,71	-27,35	-11,6

Source: Analysis Result, 2022

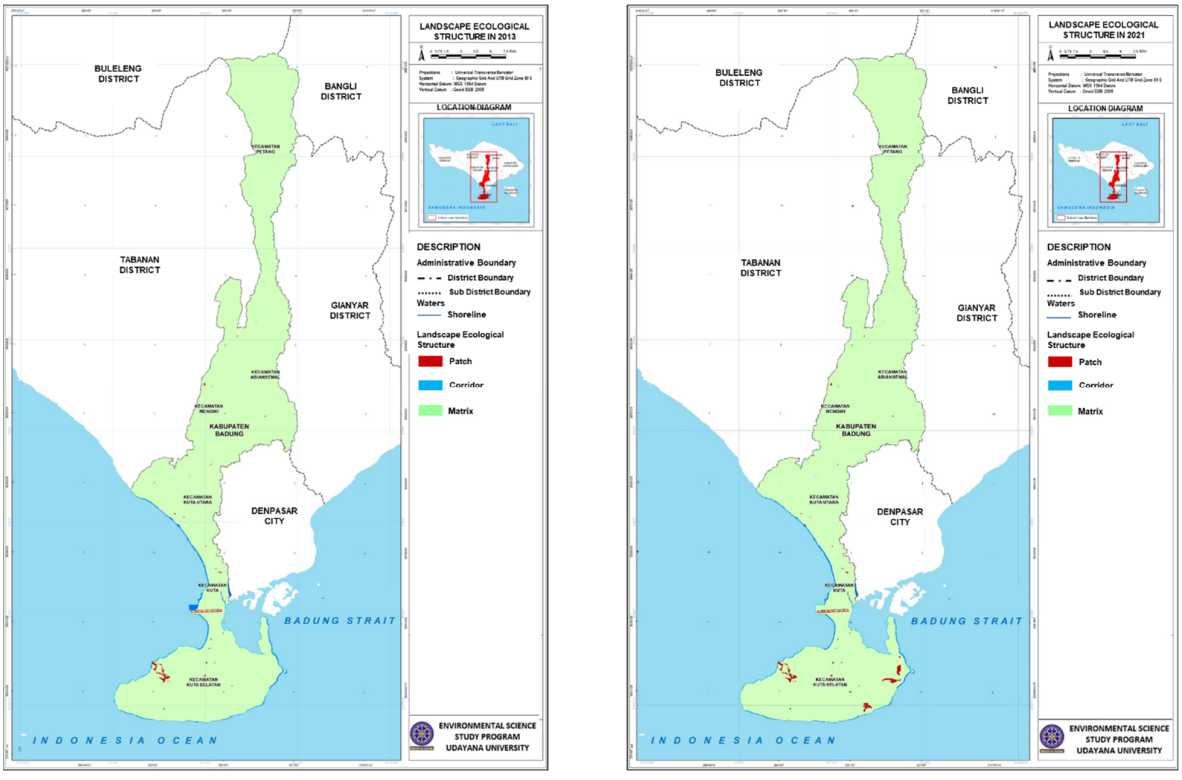

Fig. 4. Landscape Ecological Structure of Badung Regency in 2013 and 2021

The availability of multi-time spatial data allows long-term landscape changes to be compiled and when combined with

spatial data on driving factors, allows spatially explicit models of landscape change to be created. Changes in the ecological structure of the landscape that occur in Badung Regency tend to be exploratory and do not pay attention to the ecological conditions of the landscape, especially in areas that are related to tourism. Ecological conditions that naturally have the character of buffers and/or limitations to development, have actually changed into areas with massive development. In fact, this condition results in the balance of spatial balance being in favor of economic aspects only and at the expense of ecological aspects, so that the goal of sustainable development is increasingly difficult to implement.

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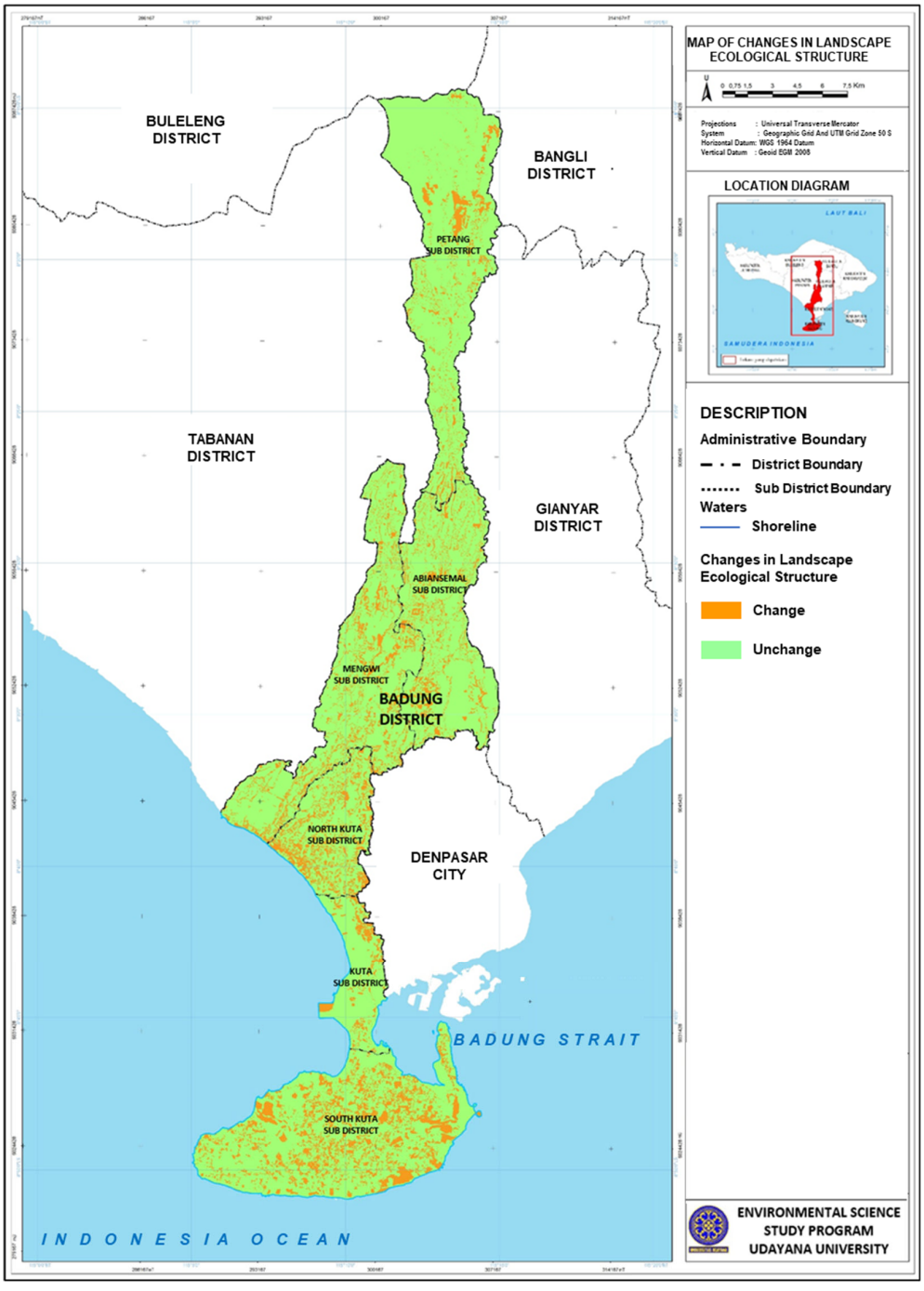

Fig. 5. Map of Changes in Landscape Ecological Structure of Badung Regency 2013-2021

3.3 Landscape Ecological Index of Badung Regency

Based on the results of the landscape ecological index analysis in Badung Regency in 2013 and 2021, it shows that there is an increase in Total Class Area (CA) which is dominated by the residential land use class with the Largest Patch Index (LSI) reaching 33.02% followed by an increase in the Number of Patches (NA) of settlements by 38 units. On the other hand, the plantation land use class increased in number of patches but decreased in area, illustrating the fragmentation of plantation land. Greater pressure occurred on paddy fields where both the area and number of patches decreased. Another indicator, Patch Density (PD), for both residential and mixed farmland increased, which means there is pressure on the land. The increasing Landscape Shape Index (LSI) value of residential land use has a correlation with a decrease in the LSI value of mixed plantation land use by -0.078 and paddy fields by -0.011 with landform changes tending to be fragmented.

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Table 5
Recapitulation of Landscape Ecological Index of Badung Regency in 2013

No	*Landform Matrix*	Code	Landscape Ecological Index Value					
			CA (ha)	LPI (%)	NP (unit)	PD (unit)	ED (m/ha)	LSI (-)
1	Settlement	R	8.366,59	20,97	596	1,49	98,13	0,123
2	Mixed Garden	P-3	18.699,38	46,86	329	0,82	146,36	0,183
3	Rice Fields	P-1	10.816,61	27,11	367	0,92	79,17	0,099
4	Forest	HL	990,78	2,48	2	0,01	0,71	0,001
5	Mangrove	EM	630,14	1,58	6	0,02	2,15	0,003

Source: Analysis Result, 2022

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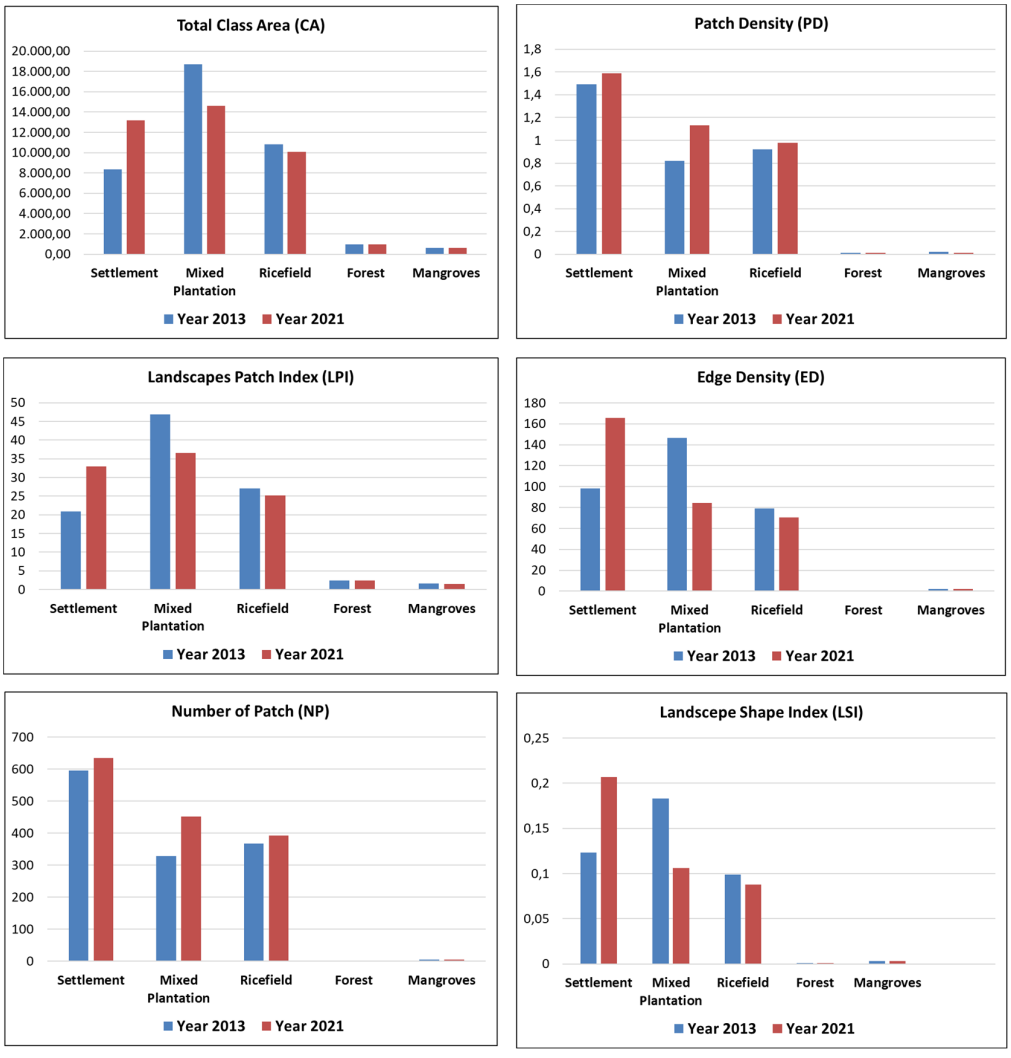

Source: Analysis Results, 2022

Fig. 6. Graph of Changes in the Badung Regency Landscape Ecological Index in 2013 and 2021

Table 6
Recapitulation of Landscape Ecological Index of Badung Regency in 2021

No	*Landform Matrix*	Kode	Landscape Ecological Index Value					
			CA (ha)	LPI (%)	NP (unit)	PD (unit)	ED (m/ha)	LSI (-)
1	Settlement	R	13.177,34	33,02	634	1,59	165,67	0,207
2	Mixed Garden	P-3	14.589,84	36,56	452	1,13	84,33	0,106
3	Rice Fields	P-1	10.080,13	25,26	392	0,98	70,57	0,088
4	Forest	HL	990,78	2,48	2	0,01	0,71	0,001
5	Mangrove	EM	617,96	1,55	5	0,01	2,13	0,003

Source: Analysis Result, 2022

Changes in the landscape ecology index of Badung Regency in the graph above show changes in the orange delineated area. The insistence on the development of residential areas in non-built areas such as rice fields and in mixed garden areas, creates a condition of crowded development due to development plans that do not pay attention to natural landscape ecology.

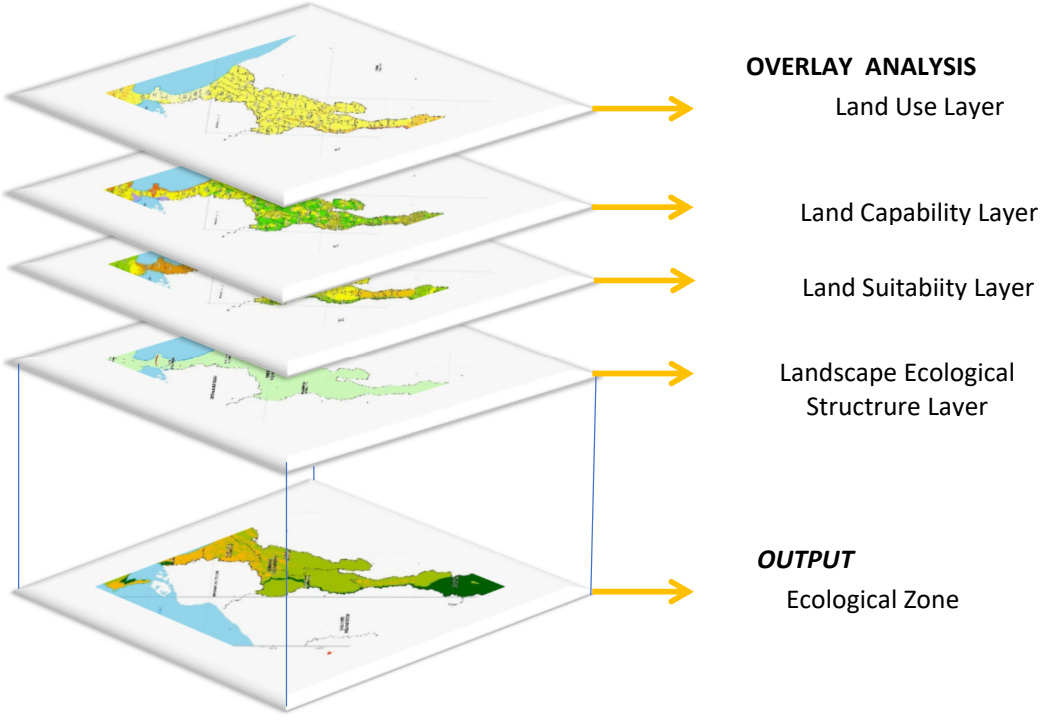

Fig. 7. Schematic Overlay Analysis of Ecological Landscape Zones of Badung Regency

Based on the results of spatial analysis with overlay techniques, the Badung Regency area is classified into 4 (four) benthic ecological zones, namely very high ecological zones, high ecological zones, medium ecological zones and low ecological zones..

a. Very high ecological zone is a zone that has natural conditions that function as conservation and high limitations to development. The very high ecological zone has an area of 8,629.76 ha, covering part of Abiansemal sub-district, part of Kuta sub-district, part of South Kuta sub-district and part of Petang sub-district.
b. A high ecological zone is a zone in the form of green areas as a counterweight to urban areas and has development limitations so that massive development does not occur. The high ecological zone has an area of 24,149.48 ha, covering part of the Abiansemal District, part of the Kuta District, part of the South Kuta District, part of the North Kuta District, part of the Mengwi District and part of the Petang District.
c. Medium ecological zone is a zone that functions as a built-up and productive cultivation area as an urban area. The medium ecological zone has an area of 7,094.40 ha, covering part of Abiansemal Subdistrict, part of Kuta Subdistrict, part of South Kuta Subdistrict, part of North Kuta Subdistrict, part of Mengwi Subdistrict and part of Petang Subdistrict.
d. Low ecological zone is a zone that functions as a built-up cultivation area with a high density. The low ecological zone has an area of 7,094.40 ha, covering parts of Kuta Sub-district.

Table 7
Landscape Ecological Zone of Badung Regency in 2022

No	Classification Ecological Zone	Criteria			Area (Ha)
		Analysis Land Suitability	Analysis Land Capability	Analysis Land Use	
1	Very High Ecological Zone	• Protected Area	Low Development Capability	• Forest • Mangrove	8.629,76
2	High Ecological Zone	• Annual Crop Cultivation Area • Buffer Area	Medium Development Capability	• Rice Field • Mixed Garden	24.149,48
3	Medium Ecological Zone	• Annual Annual Crop Cultivation Area	Somewhat High Development Capability	• Mixed Garden • Settlement	7.094,40
4	Low Ecological Zone	• Residential Area	Very High Development Capability	• Settlement	39,54

Source: Analysis Result, 2022

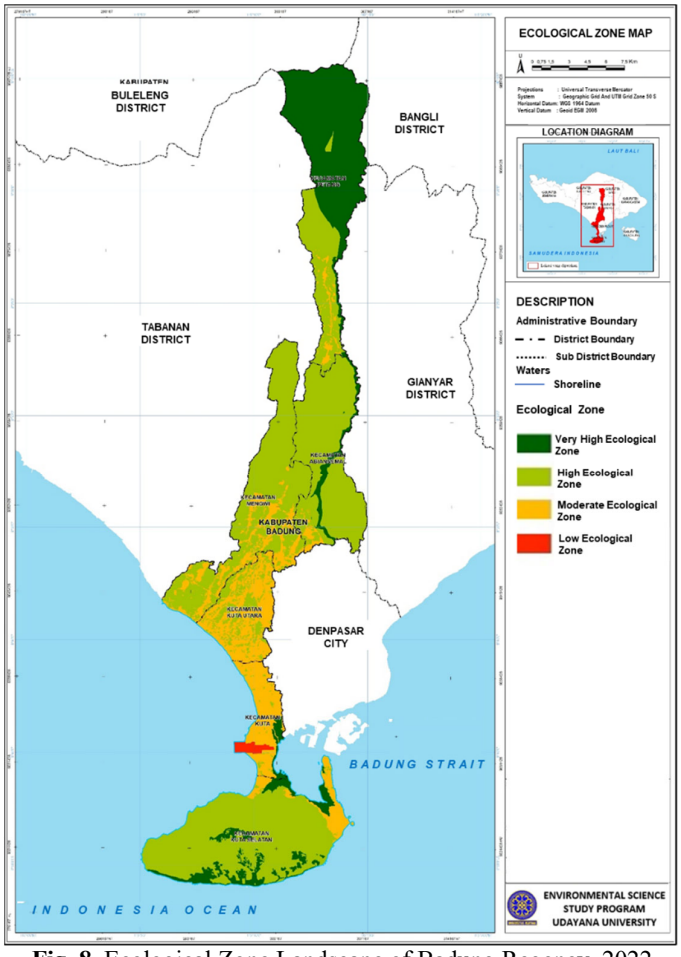

Fig. 8. Ecological Zone Landscape of Badung Regency, 2022

4. Conclusions and Suggestions

Based on the results of research conducted in the Regency, it can be concluded as follows: changes in the ecological structure of the landscape in Badung Regency occurred in the three parameters, namely pacth, matrix and corridor, as shown by changes in the area of the three parameters of landscape structure in the 2013-2021 period. The addition of matrix area in the residential land use class and golf course patches causes changes in the area of the matrix of mixed gardens, rice fields and mangroves and corridors of non-volcanic coastal sand that dominantly have ecological functions. Total Pacth in Badung Regency in 2013 was 156.63 ha, then in 2021 it was 231.43 ha, or an increase in area of 74.80 ha (47.76%). Total Corridor in Badung Regency in 2013 was 253.07 ha, then in 2021 it will be 225.71 ha, or a reduction in area of 27.35 ha (-11.60%). Total

Matrix in Badung Regency in 2013 was 39,503.49 ha, then in 2021 it will be 39,456.05 ha, or a reduction in area of 47.45 ha (-0.12%).

Based on the results of the analysis of the parameters and supporting components of the implementation capacity of the landscape ecology-based land use system in Badung Regency between 2013 and 2021 conditions, it shows that the addition of Total Class Area (CA) is dominated by the residential land use class with the Largest Patch Index (LSI) reaching 33.02% followed by an increase in the Number of Patch (NA) settlements by 38 units. On the other hand, the plantation land use class increased in number of patches but decreased in area, illustrating the fragmentation of plantation land. Greater pressure occurs on paddy fields where both the area and number of patches decrease. Another indicator, Patch Density (PD), for both residential and mixed farmland increased, which means there is pressure on the land. The increase in the Landscape Shape Index (LSI) value of residential land use has a correlation with a decrease in the LSI value of mixed plantation land use by -0.078 and paddy fields by -0.011 with changes in landform tending to be fragmented.

The formulation of the development of the Badung Regency regional system based on landscape ecology is grouped into 4 (four) zones including first, a very high ecological zone with the direction of land use as a very high conservation / limitation zone. Second, high ecological zone with the direction of land use as agricultural areas, plantations, livestock, rural settlements, ecotourism, agro-tourism, regional scale trade and services and agricultural infrastructure. Third, medium ecological zones with land use directions as urban residential areas, small industries, regional-scale trade and services, tourism, and urban infrastructure. Fourth, the low ecological zone with the direction of land use as urban residential areas, tourism areas, regional-scale trade and service areas and regional infrastructure.

Based on the results of research conducted in the Badung Regency, suggestions can be made for further research to be developed until the economic and social analysis of human influence on the occurrence of changes in the ecological structure of the landscape so that it becomes more comprehensive, and the results of the analysis of landscape ecological parameters become an important consideration in the preparation of the regional system and the concept of spatial pattern direction of Badung Regency. The development of built-up land use in Badung Regency has the consequence of reducing green open space. To anticipate the impact of massive changes, it is recommended that the results of the analysis of landscape ecological parameters be taken into consideration in the preparation of regional development plans for Badung Regency, both spatial and non-spatial.

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