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ASSESSMENT OF ECOSYSTEM SERVICES AND ENVIRONMENTAL DEGRADATION BY USING A LANDSCAPE APPROACH IN THE RIPARIAN AREA OF LAKE RAWAPENING

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ABSTRACT

Lake Rawapening is a unique landscape that naturally provides provisioning, regulatory, cultural, and supporting ecosystem services. On the other side, Rawapening Lake is an open access area that is subject to be vulnerable to any economic activities that lead to environmental degradation. This study aims to identify the spatial distribution of ecosystem services provided in part of the riparian area of Rawapening Lake using a geomorphological approach with detailed scale mapping and identify environmental degradation that occurred in the area in two time periods, 2016 and 2020. Data analysis was carried out using Scoring and Pairwise Comparison techniques to produce Ecosystem Services Index and Ecosystem Services Composite Index values presented in a Spatio-temporal manner. The results of the analysis using the Geographic Information System (GIS) show that the dynamics of the landscape that occurred in 2016 and 2020 caused changes in the provision of ecosystem services in terms of the area. In these two periods, the Landscape Lake Rawapening had the highest Ecosystem Services Composite Index (IKJE). However, the threat of environmental degradation caused by anthropogenic activities is always lurking and can lead to a decrease in the quality and quantity of the provision of ecosystem services from the landscape. Therefore, it is necessary to conduct a study on the physical and socio-economic characteristics of the study area to assist policymakers in formulating the determination of lake riparian area and zoning of related resource use.
Keywords: *Ecosystem Services, Environmental Degradation, Geographic Information System (GIS), Landscape, Lake Riparian Area*

INTRODUCTION

Lake Rawapening is an inter-volcano basin located between Mount Merbabu, Telomoyo, and Ungaran. Lake Rawapening is a semi-natural lake located in Semarang Regency, Central Java, with an altitude between 455 to 465 meters above sea level (masl). The lake body of Rawapening is located in four sub-district administration areas: Bawen District in the North, Tuntang District in the East, Banyubiru District in the South, and Ambarawa District in the West.

Lake Rawapening has nine sub-watersheds that empty directly into the lake's water body, starting from the Rengas sub-watershed, the Kedungringin sub-watershed, the Torong sub-watershed, the Legi sub-watershed, the Parat sub-watershed, the Staten sub-watershed, the Rings sub-watershed, and the Panjang sub-watershed (Mardiatno, 2021).

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The function and utilization of Lake Rawapening are inseparable from the services given by the ecosystem of Lake Rawapening as a seasonal herbaceous wetland. The role of the ecosystem is the ability of the component that makes the ecosystem itself to do the natural process in the provision of materials and services that are particularly needed to fulfill human needs, both directly and indirectly (de Groot, 1992). Ecosystem services are a benefit obtained by humans from the ecosystem. Some of the ecosystem services provided by nature include the provision, regulation, culture, and supporting ecosystem services. As for the ecosystem services class, which are 1) Food Provisioning; 2) Freshwater Provisioning; 3) Flow Regulating and Flood Control; 4) Living Space; 5) Recreation and Ecotourism; and 6) Breeding Habitat (Cahyaningrum, 2020).

Lake Rawapening provides open-access resources which tend to be more vulnerable to exploitative economic activity that points to environmental degradation (Cahyaningrum, 2020). If abandoned, environmental degradation can trigger ecological disaster that adversely impacts and hinders or even stops economic activities. Causes of environmental degradation by activities at Rawapening Catchment Area are: 1) Spatial planning not per the directives of land use functions; 2) erosion and sedimentation; and 3) the absence of environmentally friendly waste treatment for garbage, crop, and livestock that (Tim Pengelolaan Danau Rawapening Provinsi Jawa Tengah, 2019). Some of these trigger the lake to become shallow and increase the trophic level at the lake. Plus, fishery and agricultural activities occurring throughout the lake body of Rawapening will push water hyacinth (*Eichhornia crassipes*) accretion and accelerate shallowing. Environmental problems in Lake Rawapening can also be caused by environmental degradation in the upstream area, riparian area, water pollution, and other forms of degradation in the lake itself (Handoko & Sutrisno, 2021).

Riparian areas support ecosystem services such as biodiversity and are essential for regulating nutrient flow in the waters (Lind *et al*., 2019). The riparian area is effective in reducing contamination from subsurface flows (Vidon *et al*., 2018). Dense vegetation and good management can make the riparian area a natural barrier (Wang *et al*., 2020). The threats cannot separate this area due to the interaction of human activities (Fernandes *et al*., 2011). Proper management is needed according to the various potentials and threats.

The landscape approach is primarily rooted in conservation and the science of the ecological landscape (Lindenmayer *et al*., 2008). It accommodates various interests related to conflicting land uses, i.e., between extractive economic functions and conservative environmental services (Prasetyo, 2017). Landscape's term is related to the spatial and ecological characteristics that help define conservation and development targets or refer to governance and other social interactions and mechanisms minimizing conservation and development tradeoffs (Reed, 2014).

Landscape-scale interventions have been adopted in various sectors, such as Integrated Rural Development, Integrated Natural Resources Management, Integrated Watershed Management, and Integrated Floodplain Management. As landscape-scale management strategies continue to emerge, the sheer number of approaches proposed by many research organizations and practitioners has resulted in a rich but confusing terminology that may hinder progress (Scherr, 2013).

This study aims to identify the ecosystem services provided in the Spatio-temporal perspective of Lake Rawapening Inlet Area (Panjang River Estuary) using a landscape approach with detailed scale geomorphological mapping and identifying environmental degradations in the study area. It is expected to provide input on the formulation of local natural resource utilization policies because it is necessary to maintain the ecosystem services provided and minimize environmental degradation in an area with a narrow coverage area.

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RESEARCH METHOD

Time and Location

The study area is located in a part of the Lake Rawapening Inlet Area, the estuary of the Panjang River in the Panjang sub-watershed. The Estuary of the Panjang River is included in the Administrative Area of Bejalen Village, Ambarawa District, and Semarang Regency. The study area is 1,768,214.02 m2. The researchers chose the inlet area since the condition of the Lake Rawapening ecosystem is inseparable from the influence of the conditions of the rivers flowing into it and the area around its flow. (Hariyati *et al*., 2009). Everything that happens in Lake Rawapening must have started from entering materials, e.g., sedimentary material, water, and destructive materials such as garbage. The estuary of the Panjang River is one of the inlets that become a source of high sedimentation in Lake Rawapening, affected by the increase in erosion rate at the Panjang sub-watershed. (Henny and Handoko, 2016; Apriliyana, 2015). Besides, considering that the inlet area is a transition zone between the lake body and the catchment area (including the lake riparian area), the region is relatively vulnerable to environmental changes, both by fluvial process and anthropogenic activities.

DATA COLLECTING

The first step of data collecting in this research was geospatial data acquisition in the 2016 High-Resolution Satellite Imagery of Research Area and 2020 Aerial Photo of Research Area collected from the Laboratory of Environmental Geomorphology and Disaster Mitigation, Faculty of Geography Universitas Gadjah Mada. The researchers used both geospatial data above to create the 2016 and 2020 Study Area Maps. These maps comprise information about unit analysis in the form of landscape along with the landform elements. The Study Area Maps were then used as a working map during the field validation process. Field validation was performed by field observation and in-depth interviews with informants consisting of the headman, village apparatus, and residents. The maps were then adapted with the actual condition at the field based on the information collected from the field validation process, then processed to be an Ecosystem Services Map.

DATA PROCESSING

The Ecosystem Services map was created by a scoring process involving a team of researchers and experts as assessors based on collected data. In this research, we conducted Pairwise Comparison and Analytical Hierarchy Process (AHP) to minimize result bias from the scoring process due to the subjectiveness of the assessors (Mabrur, 2019).

The relative importance values of each landscape unit for ecosystem service classes are derived from matrix coefficient synthesis using statistical calculations. Those values were then processed to generate Ecosystem Services Index (ESI) and Ecosystem Services Composite Index (ESCI) by the following equations:

$$ESI_{i,x} = \frac{(KJE_{i,a} \, x \, LP_a)+(KJE_{i,b} \, x \, LP_b)+(KJE_{i,c} \, x \, LP_c)+\ldots(KJE_{i,n} \, x \, LP_n)}{LA_{tot}} \ldots(1)$$

For $ESI_{i,x}$is ecosystem service index value class I in region x; $KJE_{i,x}$is ecosystem service coefficient class I in polygon a; LP_a is the area of a polygon a with coefficient a; LA_{tot} is total polygon area.

$$ESCI_{i,x} = \frac{IJE_{i,x}+IJE_{j,x}+IJE_{k,x}+IJE_{n,x}}{\sum \quad IJE} \ldots..(2)$$

For $ESCI_{i,x}$ is ecosystem services composite index I; $ESI_{i,x}$ is ecosystem service index I; ΣESI is the number of ecosystem services.

The identification of environmental degradation was also based on collected data from the field validation process to see how anthropogenic activity and disturbance affect the ecosystem with environmental degradation and ecosystem service.

DATA ANALYSIS

Indexes were analyzed spatially and temporally using Geographic Information System (GIS) and visualized as ecosystem services maps. The ecosystem service classes identified include Food Provisioning Ecosystem Services, Freshwater Provisioning Ecosystem Services, Ecosystem Services for Flow Regulating and Flood Control, Residential and Living Space Ecosystem

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Services, Recreational and Ecotourism Ecosystem Services, and Breeding Habitat Ecosystem Services. The ecosystem services maps provide spatial information on landscape transformation and the impact on the ecosystem services provisioned by each landscape unit. The identified environmental degradation in the study area includes land-use change, erosion and sedimentation, water/soil pollution, monoculture agricultural activity, and waste disposal. The identified environmental degradations mentioned above are described narratively to enrich the analysis of ecosystem services and disservices and ecosystem balance and imbalance and recommend the Lake Rawapening conservation plan

RESULT AND DISCUSSION

Landscape Dynamic

The identification results show thirteen landscapes with five components of landform elements in the Panjang River Estuary and its surroundings. Landscape dynamics happened significantly for four years, observed in the 2016 and 2020 Landscape Map (Figure 1). 2016 was dominated by lake bodies, tidal rice fields, and water hyacinth colonies. Meanwhile, in 2020 dominated by lake bodies and water hyacinth colonies. The shifting among both periods was affected by factors, including the increased water level of Lake Rawapening and human activities in the vicinity. Human activity meant including the development and the effort to clean water hyacinth colonies as a part of Lake Rawapening revitalization.

The most massive change is the increase in the lake body by 26.81% of the study area or about 472.88 hectares (Figure 2). The high rainfall that falls in various areas in the Rawapening catchment area adds to the water supply in Lake Rawapening. In addition, the lake revitalization plan is one of the closures of several Tuntang sluices as Lake Rawapening outlets. Thus the volume and height of the lake water increase, increasing the area of the lake water body. Meanwhile, tidal rice fields were submerged and comprehensively decreased by 21.87% or about 386.7 hectares.

Water hyacinth colonies also decreased by 6.42% of the study area caused by the water weed cleanup efforts. It shows that the cleanup efforts were made effective enough to control the growth rate of water hyacinth in the study area. While other landscapes also experienced changes in the area with different magnitudes. Extensive changes to the landscape have implications for the ability of the landscape to provide ecosystem services in a specific quantity and quality.

Identifying Ecosystem Services

Food Provisioning

The provision of food is crucial for the survival of creatures that live in a particular ecosystem. Unfortunately, food as a source of energy to live life (especially for humans) does not develop in harmony with human development. Several indicators show that a landscape is considered to be of high value for its food supply. It starts from the scale of production that has met the population's needs to the landscape's ability to produce food products that can be distributed outside the region.

Two landscapes that play an essential role in providing food in this area are Irrigated Rice Fields and Lake Bodies. Both of them can be classified as very high in the ability to provide food because these two landscapes are a source of food for the people around Rawapening. The Irrigated Rice Field Landscape plays a role as a producer of rice, which is the primary commodity in meeting the population's carbohydrate needs. Meanwhile, the Lake Body acts as a breeding location for fish such as Toman fish which is the primary source of protein in this area.

Freshwater Provisioning

The availability of freshwater is essential for human needs in addition to the availability of food. Ecologically, freshwater is one of the benefits derived from ecosystem functions. Naturally, freshwater is obtained from surface water, lakes, and groundwater (Febriarta *et al*., 2020). Lake Body Landscape has a very high classification, but basically, it is still a qualitative assessment. Another study revealed that the possibility of water in Lake

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Rawapening being used as a source of freshwater is quite tricky. It is because the water quality in Lake Rawapening is categorized as very heavily polluted.

For this reason, other processes are still needed to treat the water so that it is included in the first-class water category to be used as a source of drinking water (Piranti *et al*., 2019).

Although the condition of the lake area has increased, it does not highly affect the need for freshwater for residents. Based on resident narratives, they use water from PDAM and wells for their daily needs, such as eating and drinking. Residents only use the Panjang River and Lake Rawapening water bodies for domestic activities such as washing clothes, usually done in irrigation canals. Overall, the Lake Rawapening riparian area has a proper condition to be used as a source of freshwater supply. However, its utilization is not very practical for residents because the quality is categorized as heavily polluted. Most residents use water from PDAM and wells to meet their daily needs. The restoration of Lake Rawapening is expected to positively impact residents, especially by providing freshwater to replace groundwater. According to some residents, it has experienced a decrease in water quality, and the well may dry up during the dry season.

Flow Regulating and Food Control

Regulating water flow and flood control are services provided by the environment to regulate the hydrologic cycle, such as water movement, water storage, flood control, and water maintenance that can be used to consider environmental management (Setyawan *et al*., 2019). The analysis result shows that there is such distinction among every landscape in the inlet area of Lake Rawapening. Three landscapes have high value in ecosystem services: pond water body, river water body, and lake body as the highest value of ecosystem services of freshwater provisioning. The three landscapes have a high potency because they have an essential role in controlling the water movement and saving water, so there is no surface runoff in this area. Swamp has ecosystem services of water storage and controlling the flood (Obiefuna *et al*., 2013). Besides, nine landscapes have very low value in ecosystem services: branjang, fish cage, water hyacinth colony, tidal rice field, irrigated rice field, vacant land, mixed plantation, and settlements. All of that has a very low value of ecosystem services because of its limited role in controlling water movement and inability to be water storage. According to Barth & Döll (2016), intensive agricultural land and settlement can produce relatively high surface runoff that can be causing the flood.

Living Space

Ecosystems are formed as spaces for living things (especially by humans as intelligent entities inhabit them). Earth is the main object of human habitation. Items that need to exist in a place to live and proper living space are not owned by all places on Earth. The measurement of living and living space ecosystem services is then also influenced by social and geographical environmental conditions and wide-area development opportunities (Pusat Pengendalian Pembangunan Ekoregion Sumatera, 2018).

Of the 13 landscapes around the Rawapening inlet (Panjang River Estuary), only one landscape is suitable for human habitation and living space: the Settlements with a Very High class, far above other landscapes such as vacant land and mixed plantations. Settlements can get a high score in the Living Space Ecosystem Services class because of the house's capability as a component located on land, referred to as a residential area. The role of the house that can become a place as a living space for humans then makes the value of Ecosystem Services in this landscape high.

Recreation and Ecotourism

Lake Rawapening is a tourist attraction that attracts many tourists. The tourism potential in the Rawapening area is quite significant because apart from being a natural tourist attraction, the Rawapening area happens to be a cultural tourist attraction, too. This kind of potential needs more management and development so that Rawapening could be more beneficial to local society. One of the tourism management strategies applicable to

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this case is identifying ecosystem services of recreation and ecotourism. Ecosystem services of recreation and ecotourism can show how the environment (ecosystem) plays a role in an area's recreation and ecotourism sector.

The result of recreation and ecotourism ecosystem services shows that lake bodies have a most significant value than other landscapes. There is a considerable gap between lake body ecosystem services value and other landscapes. This indicates that the Lake Body landscape has the most significant role in recreation and ecotourism activities in Rawapening's riparian area and vice versa. It is undeniable that the lake body landscape has the most significant value compared to other landscapes because the lake body has great tourism potential, namely nature tourism and cultural tourism. Rawapening's area has a suitable character with the requirement of an ecotourism area, which has unspoiled natural conditions, rural characteristics in the surrounding area, and has many tourism potentials that can be developed (Tanaya & Rudiarto, 2014).

Breeding Habitat

Ecosystem services of breeding habitat are related to the role of the Lake Rawapening ecosystem as the place for the life cycle of various species of flora and fauna. The landscape of the lake body has a very high-class potential as a supporter of this ecosystem service. Another landscape that has the potential to support a breeding habitat is the water body of the Panjang River with a high class, and at the same time, others have a very low class. The very high potential class' area has increased from 2016 to 2020 by 26.74%. It is caused by primarily tidal rice fields being drowned. According to Palomo *et al*. (2013), habitat ecosystem services are declining due to land-use changes related to intensive agriculture. The service provider lands that experience these changes will be degraded and have intensive water contamination.

Good water quality supports the growth of aquatic organisms, both animals and plants. According to Handoko & Sutrisno (2021), the lake body around Bejalen Village from September to November (2020) has DO levels fluctuating between 3-6 mg/L with good grades for maintaining various forms of biological life in water such as fish and shrimp. The most dominant fish species are Nile, Snakehead, and Green barb, endemic to the lake. The high potential for habitat and breeding in the lake body is also supported by a large number of several types of plankton (zooplankton and phytoplankton) as a food source for fish. Several populations of aquatic plants other than water hyacinth are also found in this area, i.e., Hydrilla verticillata and Najas indica, serving as places to hide and breed fish (Tim Pengelolaan Danau Rawapening, 2019).

Ecosystem Services Composite Index

Ecosystem Services Composite Index acts as the description of how landscape's role to ecosystem existence at all, where specific at this research about six ecosystem services that has been calculated previously. Every landscape has its role. For example, irrigated rice fields have very high value in food provisioning ecosystem services or settlements with very high value in living space ecosystem services. Besides, they have their roles. Every landscape cannot give the optimal ecosystem services at every kind of ecosystem service that is measured. For example, water hyacinth colonies were valued as very low in every ecosystem service that the researchers calculated. These things are then described in Table 1, where the water hyacinth colonies have close to 0 value of ecosystem services composite index (0.08).

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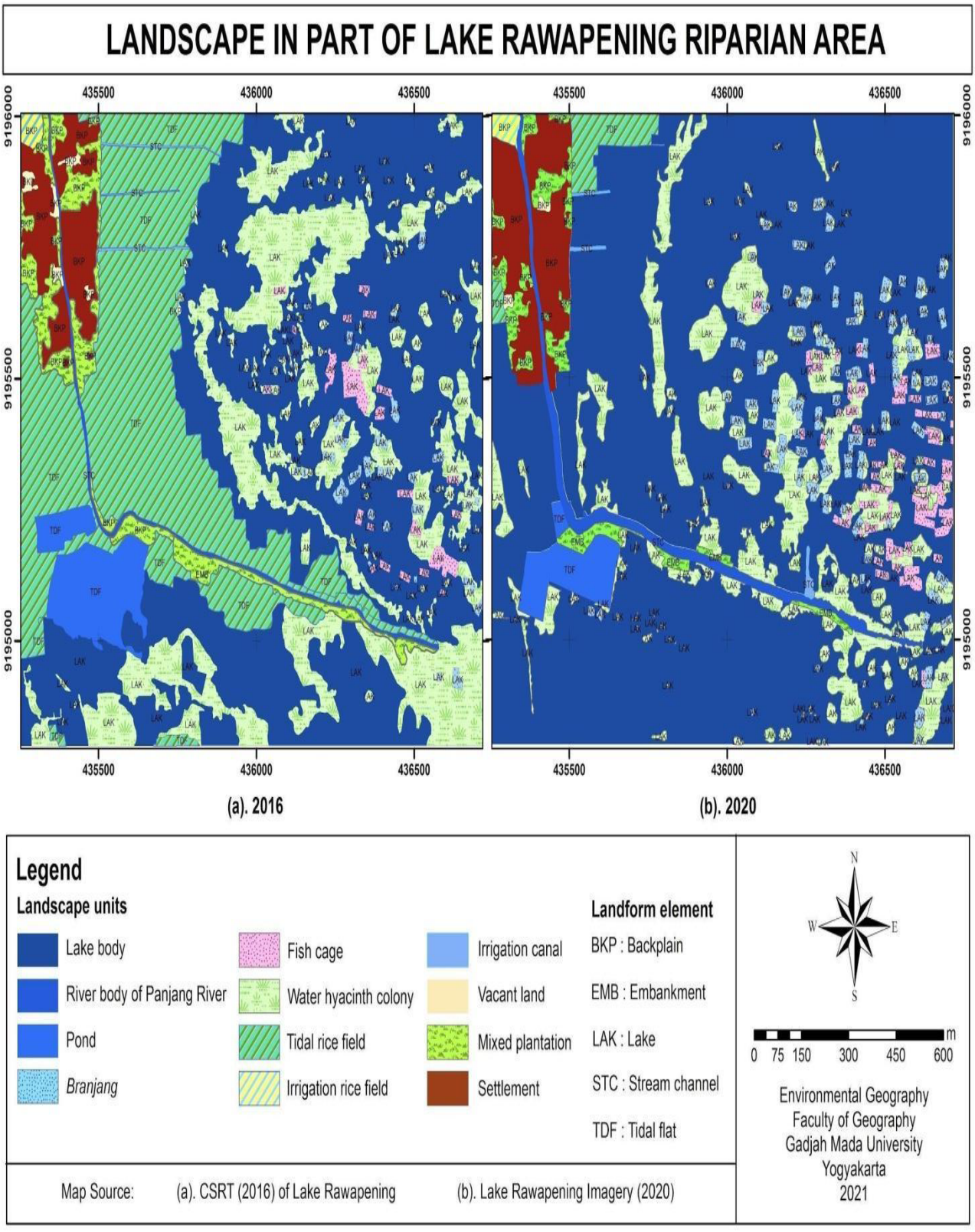

Figure 1. Landscape Map

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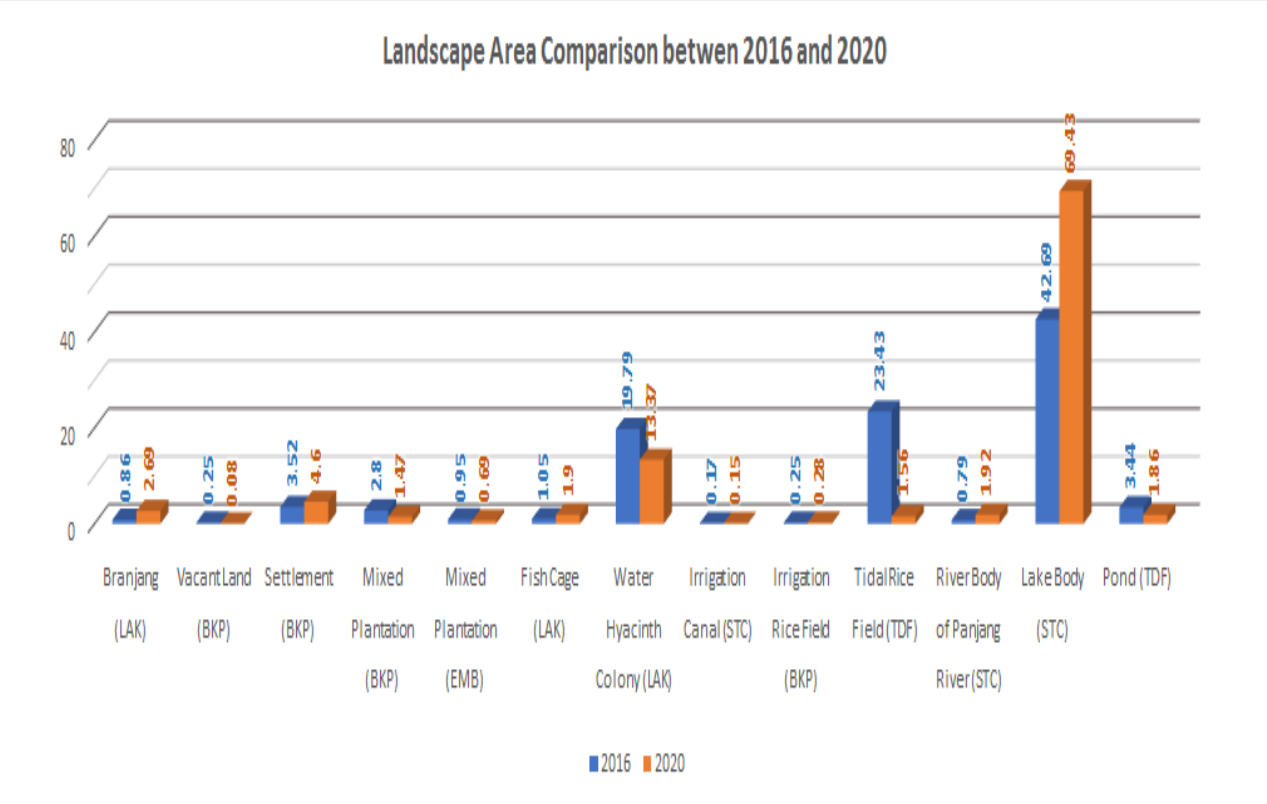

Figure 2. Landscape Area Comparison Chart Between 2016 and 2020

Table 1. Ecosystem Composite Index (ESCI)

No.	Landscape	*ESCI**	Classification	Areas 2016 (m^2)	Areas 2020 (m^2)
1.	*Branjang* (LAK)	0.39	Very Low	15,248.36	47,510.51
2.	Vacant Land (BKP)	0.46	Very Low	4,451.11	1,486.71
3.	Settlement (BKP)	3.55	Medium	62,160.45	81,344.86
4.	Mixed Plantation (BKP)	0.88	Very Low	49,579.59	25,907.28
5.	Mixed Plantation (EMB)	0.65	Very Low	16,823.18	12,194.47
6.	Fish Cage (LAK)	0.73	Very Low	18,646.81	33,528.54
7.	Water Hyacinth Colony (LAK)	0.08	Very Low	349,991.10	236,448.00
8.	Irrigation Canal (STC)	1.18	Very Low	3,008.48	2,655.14
9.	Irrigation Rice Field (BKP)	1.22	Very Low	4,438.62	4,981.06
10.	Tidal Rice Field (TDF)	1.15	Very Low	414,278.00	27,510.54
11.	River Body of Panjang River (STC)	2.27	Low	13,926.99	33,956.54
12.	Lake Body (LAK)	6.16	Very High	754,847.60	1,227,723.00
13.	Pond (TDF)	2.29	Low	60,813.76	32,967.37

**ESCI Values For 2016 and 2020 are the same*
Source: Data Processing (2021)

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The low ecosystem value in the water hyacinth colony shows that the water hyacinth colony has almost no positive impact on the ecosystem. Instead, it disturbs and destroys the ecosystem. Several water hyacinth colony impacts include reducing fishery sector yields, making it difficult for water to flow, silting processes, etc. (Soemarwoto, 1979). Water hyacinth appears as a weed, one of which is the eutrophication process around the lake (Haloho, 2005) (in this case, in Rawapening, there has been a eutrophication process).

Table 1 shows that the Lake Body is the area with the Highest Ecosystem Services Composite Index (ESCI) in this region. It indicates that of the six calculated ecosystem services, it is a meticulously calculated landscape with a very high role and benefit for the existence of the existing ecosystem. Besides having the highest ESCI value, the Lake Body landscape will also become the largest landscape in 2020 due to submerging the area around the lake for efforts to revitalize the area around Rawapening. The Settlement Area then owns the landscape with the highest ESCI value. The cause of the high value of ESCI in residential areas is primarily due to the lofty role of Settlement Areas in ecosystem services for residence and living space. In contrast to the water bodies of lake bodies, this area dominates the other five ecosystem services as a very high-class landscape.

Table 2 shows significant changes in terms of area per class of ecosystem services. Significantly there was a decrease of 484,243 m^2 in the very low class and an increase of 472,875 m^2 in the very high class.

Table 2. Changes in terms of area per class of ecosystem services

No.	Classification	Areas 2016 (m^2)	Areas 2020 (m^2)
1.	Very Low	876,465.25	392,222.26
2.	Low	74,740.75	66,923.91
3.	Medium	62,160.45	81,344.86
4.	High	0.00	0.00
5.	Very High	754,847.60	1,227,723,00

Source: Data Processing (2021)

The class shift from very low to very high in 2016 to 2020 shows a positive trend in the previously calculated ecosystem values. Figure 3 shows a striking difference in gradation between the two time periods. We can see that in 2016 the landscape between the Settlement Area and the Lake Body still looks like a separator, namely the Tidal Rice Field landscape with a very low ESCI class. However, due to drowning the surrounding land, the Tidal Rice Fields sank, which resulted in the ESCI value in this area shifting to a very high value due to the increase in the size of the Lake Body.

From Figure 3, it can be seen that there is indeed a shift in the composite class of ecosystem services in the area around the Rawapening inlet (Panjang River) in the period 2016 to 2020. Most of the area around the Rawapening inlet in 2020 is classified as a very high service class on the ecosystem services composite index. This condition occurs due to the submergence process in the area around the Rawapening inlet. With the broader area with a very high class, the area around the Rawapening inlet will have a better role in providing ecosystem services, from food to ecotourism.

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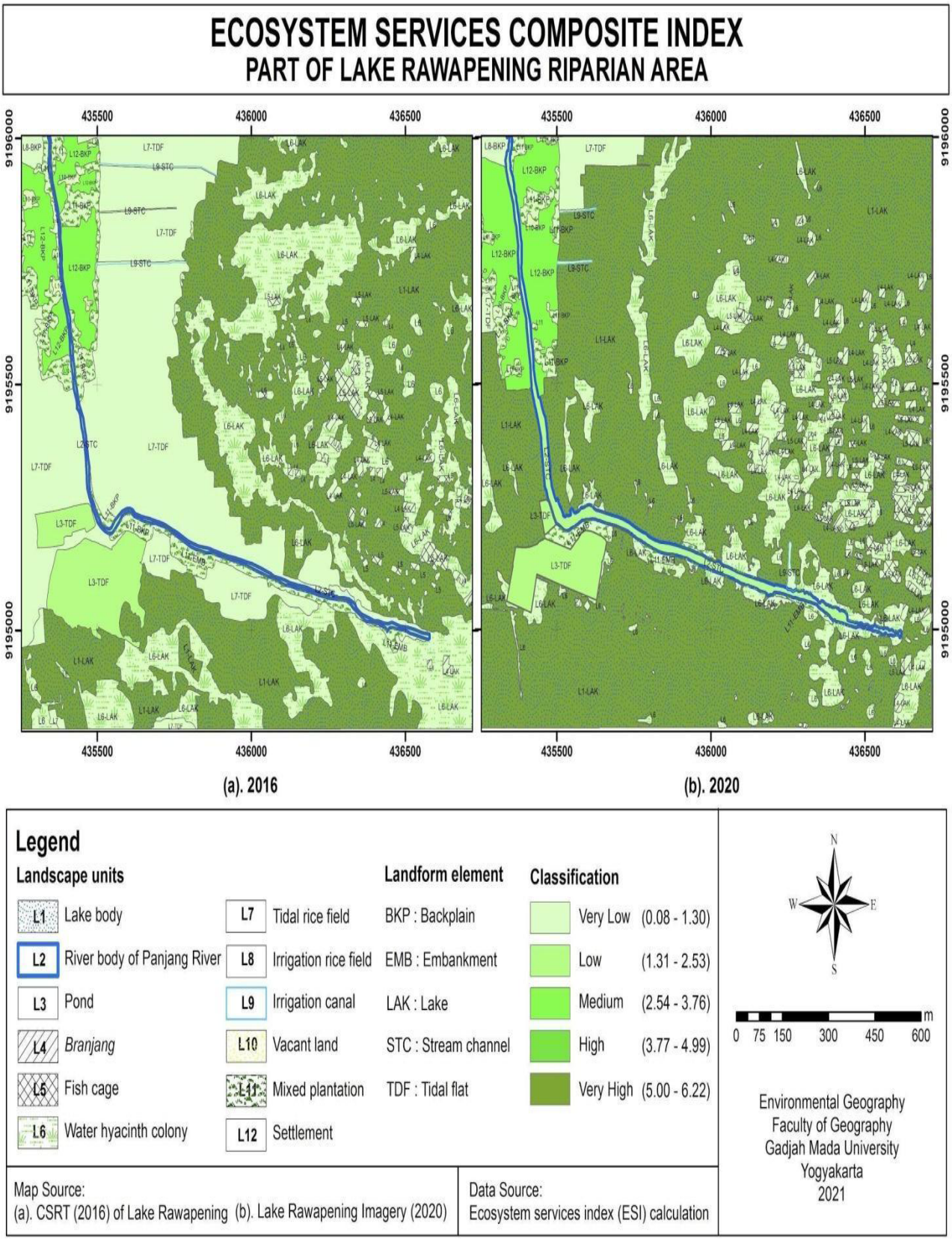

Figure 3. Ecosystem Services Composite Index Map

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Environmental Degradation

Environmental degradation occurs due to uncontrolled and inappropriate use of its function (Nadjib, 2016). Environmental degradation is often associated with human activities and natural disasters (Olanipekun *et al*., 2019). We identified potential environmental degradation problems in the inlet area of Lake Rawapening from observations and interviews with local communities who have benefited from Lake Rawapening. The land use around the Panjang River estuary is quite diverse, ranging from settlements, agricultural land, fish ponds, fish cages, and tourism. Each of these uses can trigger environmental degradation if it is not under its capabilities. Potential environmental degradation is caused by human activities such as agricultural activities, fisheries, and domestic activities. In addition, flooding and garbage are also problems at the study site.

The tidal plain landform is part of the Lake Rawapening border around the Panjang River inlet, which is often used by the community as paddy fields. The utilization of land as agricultural land can potentially result in environmental degradation, which impacts the destruction of soil fertility and water pollution. The existence of intensive agrarian activities often affects border areas (Lind *et al*., 2019). Agricultural land that uses excessive and intensive nitrogen and phosphorus fertilizers will cause the release of chemicals into the environment so that it pollutes the soil and water (Harizanova-Bartos & Stoyanova, 2019). According to local farmers, they usually use 15 kg of fertilizer per 100 square meters. In 2020 the tidal rice field landscape changed a lot into a lake body. This change occurs due to an increase in the lake's water level, which causes agricultural land to be unable to produce.

The inlet water of the Panjang River and Lake Rawapening are also widely used by local communities as recreation locations, cages, beds, and supporting domestic activities. One activity that has the potential to cause environmental degradation is fish cages. Based on interviews with local fishers, fish cages at the Panjang River inlet are cultivated using the feed in the form of pellets. The utilization of fish cages in Lake Rawapening can cause environmental degradation from fish feed and fish waste. The impact of excessive fish feed and manure will cause sedimentation and an increase in nitrogen and phosphorus in the water (Wisnu *et al*., 2021). It needs to be avoided to reduce pollution and damage to water quality in Lake Rawapening. In water, nitrogen and phosphorus can also be caused by erosion, use of fertilizers, and domestic waste carried into lakes through rivers (Mardiatno *et al*., 2021). Excessive nitrogen and phosphorus content can trigger eutrophication which causes massive growth of water hyacinth (Piranti, 2019).

Exploitative land use in watersheds reduces the watershed's carrying capacity and environmental functions, which can trigger land degradation, one of which is flooding (Miardini, 2016). The existence of the Panjang River in Bejalen Village sometimes causes flooding in surrounding settlements due to the increased volume of the river. Soon, there have been two floods. One of the causes of the overflow of river water is the high rainfall in this area which increases the volume of river water and makes the river unable to accommodate the existing water. One of the major floods that hit the village also brought new problems—namely the existence of a lot of garbage carried away by the flood. There was so much garbage that the Balai Besar Wilayah Sungai (BBWS) sent four tools for four days to clean up the trash. The height of the trash itself reaches 1 meter above the water level. Even though the flood they faced was relatively large, the houses built around the river were already so high that water rarely entered the house. Unfortunately, according to the people from the government, there has been no flooding disaster mitigation effort made to minimize the potential flood risk for the community.

CONCLUSIONS

The role of the landscape analysis unit in the provision of ecosystem services as stated in the Ecosystem Services Composite Index shows that the lake water body plays a crucial role in the provision of ecosystem services in

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the study area. This applies to the 2016 and 2020 periods, where the Lake Body is classified as a "Very High" class. The high role of the Lake Body in ecosystem services is seen through the increased contribution of that landscape that plays a crucial role in providing all of the ecosystem services stated before, excluding living space ecosystem services. This is in contrast to other landscapes, which only contribute significantly to one or two ecosystem services classes or do not contribute considerably at all.

Land clearing or land conversion occurs mainly in Settlements, where houses are built on vacant lands and/or mixed plantations to meet the needs of residents' housing. The same thing also happened in wetlands (tidal plains) which functioned as monoculture agricultural land. Land clearing activity, settlements, and monocultural agriculture trigger water/soil contamination that in the future can trigger erosion and sedimentation across the lake body. This led to silting that lasted for years. Disposal of household and agricultural waste that is not appropriately managed can trigger changes in water/soil characteristics in the study area. The resulting modifications will usually harm the sustainability of the ecosystem and the services it provides. However, environmental problems in the study area are also inseparable from human activities in the Rawapening Catchment Area (RCA), especially the Panjang sub-watershed. Land conversion, settlement activities, agriculture, and other cultivation activities will ultimately affect environmental conditions in the study area, which is the estuary of the Panjang River.

RECOMMENDATION

The absence of regulations governing the determination of lake riparian areas has implications for the lack of clarity regarding the zoning of the utilization of the lake body and the surrounding area. The lake riparian area protects the lake from activities that interfere with preserving the lake's function. In addition, lake riparian areas also have an essential role in producing and providing ecosystem services under management objectives. Lake Rawapening is an open economic zone. This means that the community can take advantage of the available resources and gain prosperity from them. Therefore, it is necessary to regulate the lake riparian area so that the utilization zoning of the Lake Rawapening water body and the surrounding area can be controlled and easily monitored.

Determining the lake riparian area can be done by selecting the utilization zoning of water boundaries and closely with the spatial layout around the lake. Physical and environmental aspects (such as geomorphology, hydrology, and meteorology-climatology) must be identified to determine the ideal lake riparian area. Furthermore, social and economic factors also need to be studied to formulate uses that the community can carry out to meet the needs of life without disturbing the sustainability of the lake ecosystem.

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