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COMPARISON OF CARBON STOCK BASED ON EXISTING LAND COVER AND SPATIAL PATTERN PLANS IN GILI MATRA

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ABSTRACT

As a mainstay destination on Lombok Island, Gili Matra has many strategic issues for which appropriate and effective solutions still need to be found. Massive changes in land use for tourism activities, land use conflicts, land sales on small islands to foreign nationals, environmental damage, and pollution. This condition will gradually lead to land use outside its intended use. Through the North Lombok PUPR (Public Work and Public Housing) Department Service and various related stakeholders, the government prepared the Detailed Spatial Plan (RDTR) for the Gili Tramena Tourism Area to anticipate land use different from sustainable spatial planning principles. This research compares the potential carbon stored in existing land cover and the polar money plan in Gili Matra (Meno, Trawangan, and Air) based on the RDTR for the Gili Tramena Tourism Area. The method used is gap analysis or deviation of existing land cover with spatial pattern plans on Gili Matra using overlay techniques. It also uses a conversion method for carbon stock estimates between existing land use and planned spatial patterns on Gili Matra. The results of this research are a decrease in carbon stocks in the spatial pattern plan (2,616.75 tons C) compared to carbon stocks based on existing land use classes on Gili Matra (12,571.24 tons C). This research shows that there is a difference of 9,954.49-ton C. Therefore, appropriate recommendations include: 1) provide a minimum of 30% of the land for Green Open Space (RTH); 2) maximizing protected zones; 3) carry out supervision and control in zones designated as protected zones; and 4) developing the concept of sustainable tourism.

Keywords: *carbon stock, gili matra, spatial pattern planning*

INTRODUCTION

Gili Matra is a group of islands whose economic activities are dominated by tourism (Selvia et al., 2024). The development of the tourism sector has shaped each island's structure and spatial patterns, where open land has been converted into tourism-supporting facilities and infrastructure such as accommodation, restaurants, cafes, food stalls, tourism service providers, and other public facilities. Gili Trawangan, Gili Meno, and Gili Air developed in the 1980s, when tourists first visited Gili Matra to enjoy various underwater

beauties such as snorkeling, diving, sunset points, and enjoying the beach atmosphere and other natural beauty (Septiani & Santoso, 2019). Initially, only a few accommodations were available in the form of guest houses, which residents rented out for tourists who wanted to stay overnight. In line with policy developments such as the designation of the Gili Matra Area as a Marine Nature Tourism Park Area through the Decree of the Minister of Forestry No. 85/Kpts-II/1993, this started the development of several other policies that made the name Gili Matra increasingly known to both domestic and non-domestic tourists (Tisna et al., 2019). In **Figure 1**, several policies related to determining land use functions on Gili Matra are explained. That condition illustrates the fluctuating dynamics of land use. Policies related to tourism development attract investors to develop tourism-supporting infrastructure on Gili Matra, thereby causing significant land conversion (Kurniawan et al., 2016).

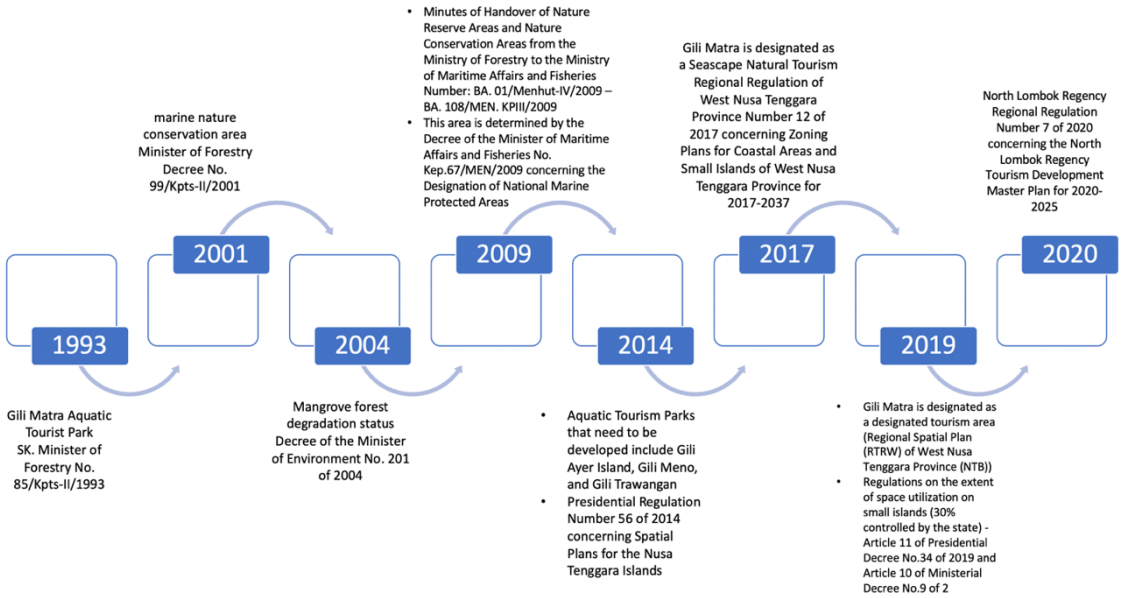

Figure 1. Development of policies that influence the use of space on Gili Matra

After enacting a policy related to establishing the Gili Matra water tourism park in 1993, it led to an increase in the number of tourists and supporting facilities. Based on data from report document of the North Lombok Regency Tourism Office, it is known that the number of Jasmine hotels in 2010 was 91 units and increased to 144 units in 2014. In 4 years, there has been an increase of 67 units. Moreover, in 2014, it was supported by a Policy in the form of Presidential Regulation Number 56 of 2014 concerning the Spatial Plan for the

Nusa Tenggara Islands, which determined Gili Matra as a Marine Tourism Park. The number of tourists also grew from 2011 (291,143 tourists) to 2017 (886,703 tourists). In 2018, an earthquake occurred on Lombok Island, which caused a decrease in the number of tourists that is 575,602 tourists (Report Document of The North Lombok Regency Tourism Office, 2011-2018). This condition was exacerbated by the Covid-19 pandemic in 2020-2022. In 2022, states will begin to recover, and tourists will start arriving on Gili Matra (255,701 tourists). Star hotels, up to jasmine hotels and bungalows, have grown and caused several changes in land use from open land, shrubs, and local protection (beach borders and lake borders) to supporting infrastructure for tourism.

Land use change is an effort continuously by humans to the availability of land resources, primarily vacant land not built up to meet daily needs (Sodikin et al., 2023). Changes in land use in an area can cause changes in the local ecosystem, especially the species composition found in that environment (Meyfroidt et al., 2018). Changes in land use in Gili Matra occur due to the local population's need for land for housing, investors to develop undeveloped land into tourism-supporting infrastructure, and the government's need to build tourism-supporting infrastructure. This increasing need for land resources is a logical consequence of the phenomenon of land conversion in the development of an area, including Gili Matra (Paul & Rashid, 2017). Based on research (Bakti et al., 2023) which compared land cover changes in the Gili Matra archipelago consisting of Gili Meno, Gili Trawangan and Gili Air, it was explained that the highest land conversion occurred on Gili Trawangan. From 2013 to 2022, there was a change of 48.14% from undeveloped land cover to built-up land used for tourism support facilities. This massive transfer of land use results in uncontrolled land use and is also different from the spatial planning rules. The lack of spatial control causes many impacts, such as a misalignment of space use with the principles of sustainable development (Pinuji et al., 2018), a misalignment of the land's carrying capacity with various activities on Gili Matra, and environmental impacts that occur, such as environmental degradation, which results in an imbalance in the ecosystem. According to (Kurniawan, 2017), Gili Matra, therefore, requires a planning

aspect in carrying out land conversion so that it is by the zoning plan in an area (Rahmadi et al., 2023).

Based on the Regulation of the Minister of Maritime Affairs and Fisheries Number 8/Permen-KP/2019 Concerning Administration of Permits for the Utilization of Small Islands and Surrounding Waters in the Context of Foreign Investment and Recommendations for the Utilization of Small Islands. In this regulation, Article 5 paragraph (1) stipulates that in land use on small islands and waters, it is obligatory to pay attention to ecological, social, and economic aspects of the land area of these small islands. Furthermore, Article 10, paragraph (1) states that the state controls at least 30% of the island's area. This percentage is intended to allocate protected zones so that they do not change their function into built-up land and maintain the balance of the ecosystem. However, there are still obstacles, including the ownership status of land on Gili Trawangan that existed before the regulation was made.

Another problem is that the Detailed Spatial Plan (RDTR) on Gili Matra was compiled after the land conversion had already taken place massively. As a result, the existence of protected zones that function as ecosystem balancers and carbon stores is reduced. The zones designated as protected zones have various stands of vegetation that absorb CO2 in the atmosphere (Rawung, 2015). If land conversion continues, the ability of a land cover to absorb carbon will also decrease. This has an impact on increasing greenhouse gases. The increase in carbon emission production is also caused by the dynamics of land use changes(Solomon et al., 2018).

The increase in the amount of carbon released into the atmosphere is the cause of climate change. As a group of small islands, Gili Matra has a high vulnerability to climate change. The impacts of climate change that can be directly felt by the people and tourists who live on small islands include rising sea levels, abrasion, increasing temperatures, and the tsunami disaster. The role of spatial planning through the RDTR Document for the Gili Matra Tourism Area in balancing the ecosystem, which is closely related to reducing carbon emissions, is to create spatial pattern plans that pay attention to environmental sustainability. In previous research conducted by (Selvia, Taufiqurrahman, et al., 2023) regarding the comparison of carbon stocks based on

existing land use and spatial pattern plans in detailed spatial planning documents (RDTR) in planning area III of Singkawang City, it showed that there was a decrease in carbon stocks of 1.3% of the spatial pattern plan. This shows that the spatial plan that is made cannot describe sustainable planning because it will change or convert areas that have vegetation cover into built-up areas. This research will also compare carbon stocks on Gili Matra, a small island that is very vulnerable to climate change. Spatial planning, especially on small islands, should be more detailed and consider various aspects to ensure environmental sustainability. This is due to the impact of climate change, which has a multiplier effect that is felt more on small islands such as Gili Matra. Therefore, this research will examine comparative carbon estimates based on existing land cover conditions and spatial pattern plans. The more detailed objectives of this study include: 1) knowing the classification of land use on each island in Gili Matra; 2) Identify the spatial pattern plan in Gili Matra based on RDTR WP Tramena; 3) converting carbon stocks based on existing land use and money polar plans; 4) evaluating gaps in the utilization of existing space and spatial pattern plans.

MATERIALS AND METHODS

This research is located on three dykes consisting of Gili Meno, Gili Trawangan, and Gili Air. This group of islands is often referred to as Gili Matra by the Decree of the Minister of Maritime Affairs and Fisheries Number 57/KEPMEN-KP/2014 of 2014 concerning Management and Zoning Plans for Aquatic Tourism Parks of Gili Ayer, Gili Meno, and Gili Trawangan Islands in West Nusa Tenggara Province 2014-2034. This research was conducted in March-June 2023. Geographically, Gili Matra is located at coordinates 116°01′34″ - 116°12′11″ East Longitude and 8°20′02" - 8°22′16" Latitude South.
The research location be seen in **Figure 2**

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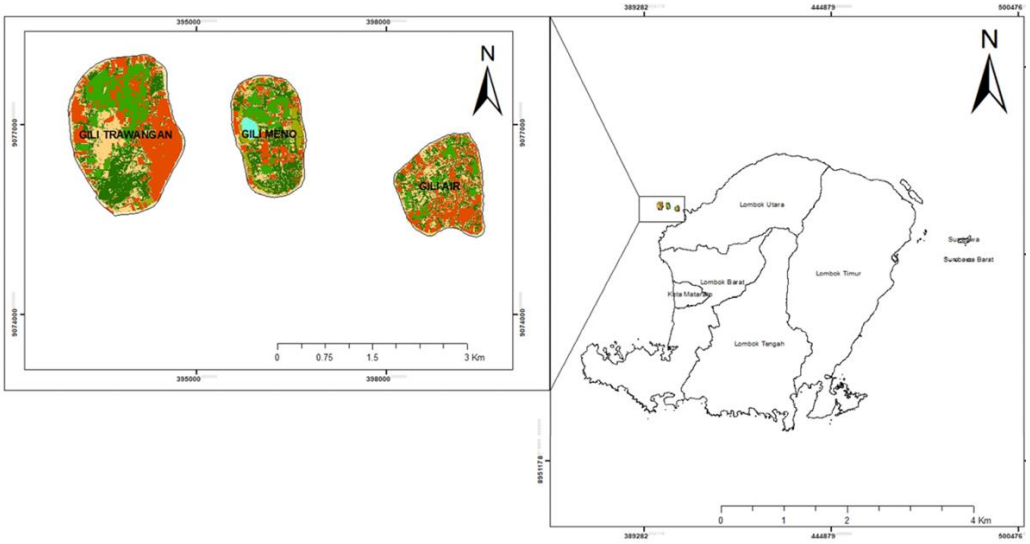

Figure 2. Research Location

This research uses secondary data and primary data. Secondary data is a Spatial Pattern Plan Map and Technical Material, which are part of the Detailed Spatial Plan (RDTR) document for the Gili Tramena Tourism Area and its Surroundings. Primary data was obtained from field survey activities in the form of documentation of various land covers and locations that experienced changes in land cover and ground checks to conduct accuracy tests.

The equipment used is GPS, a handphone camera, and a laptop equipped with Arc.Gis, Google Earth Pro, MS Word, and MS Excel. **Figure 3** shows a research flow chart that includes the analysis stages carried out in this research, including: 1) classification analysis of existing land use on Gili Matra; 2) analysis of gaps or deviations in existing land use with the spatial pattern plan in Gili Matra; 3) comparative analysis of carbon stock estimates between existing land use and the spatial pattern plan in Gili Matra.

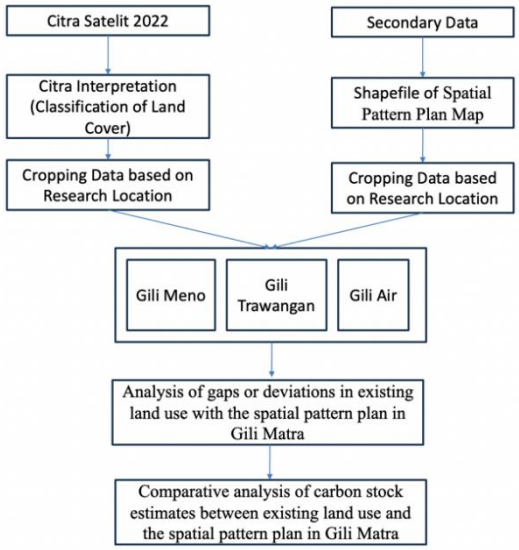

Figure 3. Research Flow Chart

RESULTS AND DISCUSSION

Land use classification in Gili Matra consists of tourism/art/cultural buildings, residential buildings, stretches of beach

sand, lakes, swamps, fields/fields, shrubs, grasslands, and plantations. Land use in Gili Matra is divided into built-up land and undeveloped land. Built-up land consists of residential and tourism buildings such as hotels, bungalows, other accommodations, restaurants, cafes, etc. Meanwhile, undeveloped land consists of expanses of land designated for green land, bodies of water such as lakes, shrubs, and other expanses of land that can absorb water. The proportion of built-up land is 32.47%, and undeveloped land is 67.53%. Existing land use on Gili Matra is dominated by built-up land with an area of 223.55 ha. The development of land use for built-up land on Gili Trawangan is higher than Gili Air and Gili Meno. This can be seen from the more significant proportion of land used for building infrastructure.

The development of the tourism sector in Gili Matra has caused pressure on the environment, where every year, land conversion occurs, which causes the loss of vegetated areas to become built-up lands. Shrubs, swamps, mangroves, plantations that have the potential to absorb carbon, and water catchment areas are decreasing. **Figure 4**. shows land use changes in Gili Matra over the past ten years.

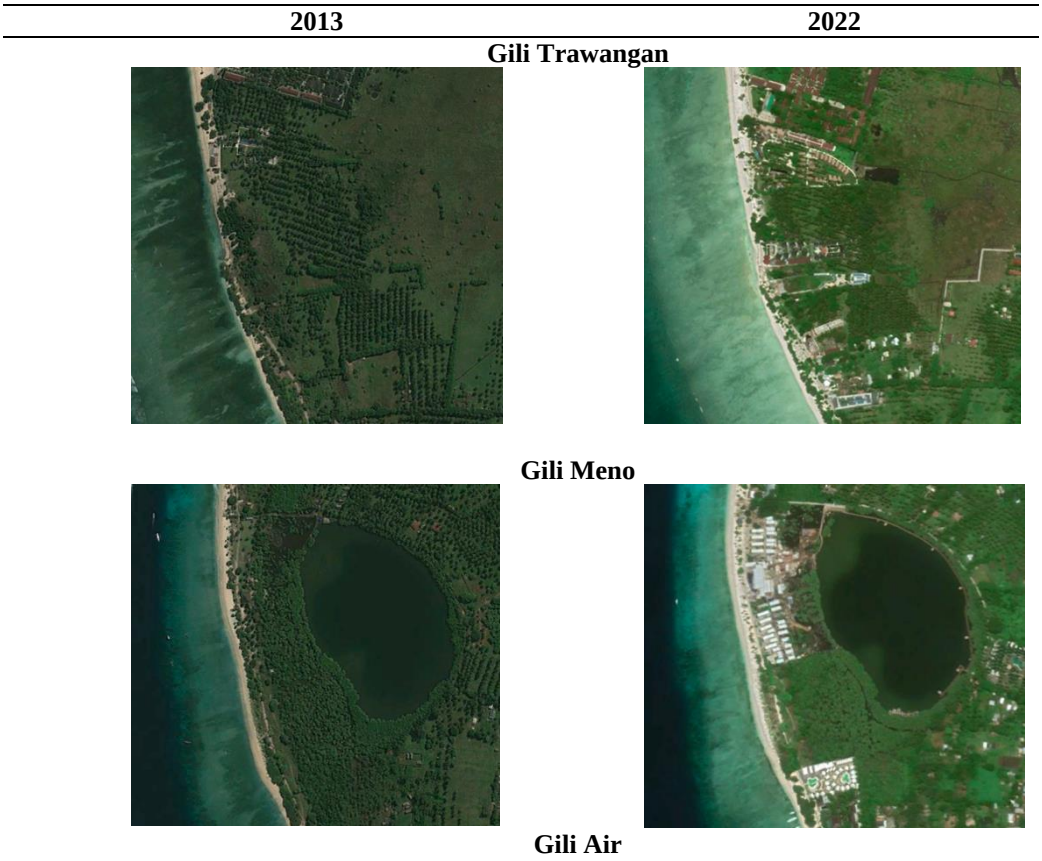

Figure 4. Land Cover Change in Gili Matra

Land conversion that needs to be balanced with continuous environmental conservation will cause environmental degradation, one of which is the unavoidable impact of climate change on small islands. Many parties have yet to focus on preventing the impacts of climate change on Small Islands. Some concrete steps taken in conservation efforts for Small Islands include greening movements from academics in Real Work Lecture (KKN) activities, academic activities in carrying out community service related to reforestation to increase carbon uptake through vegetation such as trembesi trees and several non-profit institutions such as the Gili Eco Trust which is carrying out a beach clean-up movement to reduce waste on Small Islands (Selvia, Sukartono, et al., 2023). Meanwhile, efforts made by the government include preparing spatial planning documents as a control measure over space utilization in Gili Matra. In 2022, a Detailed Spatial Planning Plan (RDTR) for the Tramena Tourism Area, which consists of Selamat District and Tanjung District, has been prepared. The document is in the process of substance approval at the central level. In most cases in Indonesia, there are areas for improvement in the stages of controlling space utilization, where spatial planning documents are prepared after a lot of neglect and environmental degradation. The Tramena/ Gili Matra Planning Area (RDTR) is here to carry out zoning planning per the mandate of Law Number (26) of 2007 concerning Spatial Planning, where 20% of the area is designated for protected zones. However, the obstacle experienced is that private land ownership in Gili Matra is very dominating. 85.10 ha of the total area is owned, building use rights are 102.17 ha, use rights are 0.84 ha, and 143,079 ha have not been identified.

Land ownership, especially property rights on Small Islands, will make it challenging to allocate protected zones for environmental conservation efforts, such as reforestation of degraded land, conservation of mangrove areas, and other efforts, especially in increasing the carbon absorption capacity of various vegetation in the area. Small Islands. Ideally, the spatial pattern plan that is part of the Tramena WP RDTR can be a strategic effort to control massive land use for tourism infrastructure on the three dykes. Based on the RDTR WP Tramena spatial pattern plan, it is stated that the proportion of protected zones is 10.44%, consisting of local protection subzones (lake and beach borders).

Table 1. Carbon Estimation Based on Existing Land Cover on Gili Matra

Land Cover	Area (ha)	Koef. Carbon Stock (ton C)	Amount of Carbon Stock (ton C)
Water Bodies	6,70	0	-
Sand Beach	30,97	0	-
Mangrove	16,89	142,6	2408,514
Shrubs	139,19	15	2087,85
Open Land	166,19	3,4	565,046
Plantations	105,01	63	6615,63
Built-Up Area	223,55	4	894,2
Total			**12.571,24**

Source: Research Analysis, 2023

Based on the results of the conversion of carbon stocks to existing land use on Gili Matra, carbon stocks are 12,571.24 tons C (**Table 1**). The highest carbon stocks come from mangrove land use, which is equal to a coefficient of 142.6 tons C. Overall, the amount of carbon stocks is known that the least amount is open land with little vegetation with a carbon stock coefficient of 3.4 and a total carbon stock of 565.05 tons C.

Based on the spatial pattern plan map in Gili Matra, it is known that there are two zones, including the marine tourism park zone and the natural tourism park zone, which has a total of 21 sub-zones (see **Table 2**). Conversion of carbon stocks is carried out by multiplying the area of each zone by the coefficient of carbon stocks. Overall, carbon stocks based on existing land use are more than based on spatial pattern plans, namely 12,571.24 tons C and 2,616.75 tons C, respectively. There is a reduction in carbon stocks in spatial pattern plans because the proportion of green land is decreased due to the allotment of built-up lands in the spatial pattern plan.

Table 2. Carbon Stock Analysis (Spatial Pattern Plan) Gili Tramena Area and Surroundings

Spatial Pattern Plan	Area (ha)	Koef. Carbon Stock (ton C)	Amount of Carbon Stock (ton C)
Local Protection Zone	0,69	2	1,39
Marine Tourism Park / Coastline	2,43	2	4,86
Nature Tourism Park/ Lake Protection Zone	41,15	2	82,31
Nature Tourism Park / Mangrove Ecosystem	7,07	142,6	1.008,14
Nature Tourism Park / Water Bodies	6,87	2	13,75
Nature Tourism Park / Sub-District Park	20,33	2	40,66
Nature Tourism Park /Cemetry	0,21	2	0,42
Nature Tourism Park /Plantations	25,56	2	51,12
Marine Tourism Park / Road	0,01	0	-
Nature Tourism Park / Road	19,99	0	-
Marine Tourism Park / Tourism	0,00	4	0,02
Nature Tourism Park / Tourism	408,45	2	816,90
Nature Tourism Park /Electric Power Generation	4,86	0	-
Nature Tourism Park / Solid Waste Disposal	1,44	0	-
Nature Tourism Park / Trade and Services at the Sub-Planning Area Scale	17,83	4	71,30
Nature Tourism Park / Office	0,58	4	2,30
Nature Tourism Park / Low Density Housing	125,38	4	501,51
Nature Tourism Park / Medium Density Housing	0,27	2	0,54
Nature Tourism Park /Distric Scale - Public Service Facilities	1,46	4	5,85
Nature Tourism Park / Sub-District Scale - Public Service Facilities	3,69	4	14,77
Nature Tourism Park /Hamlet Scale – Public Services Facilities	0,23	4	0,92
Total	**688,50**		**2.616,75**

This condition is in line with research (Agus et al., 2014), which states that the dynamics of changes in land use also cause an increase in carbon emission production. Apart from that, the impact of changes in land use on stock size has also been studied by (Kurniawati, 2021), who classified land use in the city of Surabaya between 2000 and 2020 and then converted it to the carbon stock coefficient per each land use classification. However, this research was different from the spatial pattern plan. Meanwhile, this research compares carbon stock conversion based on existing land use and planned spatial patterns. This research shows that spatial pattern planning in spatial planning, especially for small islands, also influences carbon stocks in the future.

Research on carbon dynamics from changes in land cover and use over ten

years was also carried out by (Permata & Rahayu, 2016) located in Kendal Regency. This research was carried out over a series of 3 years, namely 2008, 2013, and 2018. The results were significant changes in land use in the types of primary and secondary dry land forest land use, which indicated a change of function into residential and mixed dry land agriculture. Gili Matra, one of the small islands in the West Nusa Tenggara Province, has several agroforestry areas that combine plantation crops such as coconut and other horticultural crops such as pineapple. This agroforestry system provides benefits apart from improving the ecosystem and storing carbon reserves; it also increases people's income from using coconuts and pineapples for sale to hotels, restaurants, and cafes. However, this method is rarely known and realized by the public. If developed massively, especially in bushlands, to plant wood trees with large canopies, it will be able to increase carbon reserves.

The decline in carbon reserves on Gili Matra is due to the use of space for tourism-supporting facilities and infrastructure, as the direction of the spatial pattern plan for the next 20 years to be designated as a tourism zone. According to (Selvia & Iemaaniah, 2024) the establishment of Gili Matra as a tourism function is like two swords: on the one hand, wanting to make Gili Matra a conservation area, but on the other hand, also developing the economy through the tourism sector.

According to (Massetti & Gil, 2020) apart from the potential loss of carbon stocks due to changes in land cover, it is also observed to be related to the loss of biodiversity. It can strengthen the study's results that the phenomenon of land conversion not only impacts reducing spaces that have a protective function but also causes a decline in ecosystem balance, including on small islands such as Gili Matra. As a small island with many limitations in carrying capacity and environmental capacity, Gili Matra requires stricter spatial utilization regulations and sustainable spatial pattern plans.

CONCLUSIONS

Based on a comparison between the existing land cover and the spatial pattern plan in Gili Matra, it is known that there has been a decrease in carbon reserves, namely 12,571.24 tons C and 2,616.75 tons C respectively. This significant

decrease is caused by the allocation of space in the spatial pattern plan, which is dominated by natural tourism park zones and tourism sub-zones. Meanwhile, existing land cover is dominated by potential protected zones such as local protection or lake borders, coastal borders, and mangrove ecosystem areas. The dilemma in planning spatial patterns on small islands such as Gili Matra is the status of land ownership in the form of property rights, which are challenging to acquire or plan as protected zones because they conflict with the interests or needs of individuals or groups in making changes to the use of the land they own. The results of this research show that planning spatial patterns in an area can reduce carbon stocks. This research will have implications for environmental change, where the proportion of built-up land will increase so that the vegetation that functions to absorb carbon will decrease. Therefore, so that the spatial pattern plan that has been prepared can maintain environmental sustainability, several recommendations are needed, including:

1. making arrangements for minimum infrastructure requirements for both community housing zones and tourism zones, trade services, and public service facilities to provide a minimum of 10% of the land for Green Open Space (RTH);
2. Maximizing protected zones such as local protection (lake borders), mangrove ecosystem areas, and sub-district parks with various vegetation that has high carbon absorption capacity;
3. Carry out supervision and control in zones designated as protected zones so that they do not change their function to built-up land;
4. They were developing the concept of sustainable tourism, where the zones designated as tourism zones maintain carrying capacity and dampening capacity for the environment.

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