Spatial analysis of coastal and marine ecosystem services at Bima Bay, West Nusa Tenggara, Indonesia

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Abstract. Bima Bay, as an ecosystem, is very interesting to understand in its relation between the changes in land use/land cover with ecosystem services. The purpose of this study was to determine the condition of ecosystem services in Bima Bay. The data analysis methods used were: field surveys, independent interviews with stakeholders regarding the direction of development in the Bima Bay area, and spatial information sourced from relevant documents. The results showed that the highest ecological integrity index value was found in West Rasanae Sub-district at 0.5592 and the lowest integrity value was in Soromandi Sub-district at 0.3051. The highest value of the inventory service index was found in West Rasanae Sub-district at 0.1526 and the lowest was Soromandi Sub-district at 0.0981. The highest index value for regulating services was found in West Rasanae Sub-district at 0.3333 and the lowest was Soromandi Sub-district at 0.2119. The highest index value for culture services was 0.5143 and the lowest was Soromandi Sub-district at 0.2143. Meanwhile, the value of the index value of the Bima Bay ecosystem services budgets was -1.8138, this showed that human demand for ecosystem goods and services was greater than the ability to provide them (supply<demand).

Keywords: budgets; culture services; ecological integrity; provisioning services; regulating services

1. Introduction
Bima Bay is a semi-closed water area and is directly connected to the Flores Sea with an area of 169.05 km\textsuperscript{2} and a length of 78 km\textsuperscript{2}. The coastal area of Bima Bay has been experiencing rapid development along with the Bima City development concept as a “Waterfront City” and tourism village through the NTB Governor's Decree Number: 050.13-366 of 2019 concerning the designation of 99 tourist village locations in West Nusa Tenggara Province. It is feared that this concept will put pressure on the preservation of coastal environmental ecosystems, and will have an impact on spatial use such as changes in spatial patterns, either directly or indirectly. These spatial changes are related to the function and distribution of designated areas such as industrial estates, settlements, warehouses, and...
transportation systems, which include changes in the quality and quantity of regional infrastructure and coastal reclamation. Changes in land area, shrinkage of coral reefs, shrinkage of mangrove areas, and sedimentation result in silting which is influenced by environmentally unfriendly spatial use and domestic waste loads [1].

This policy is also expected to stimulate pressure increase in Bima Bay area and to drive the improvement of land utilization, changes in land cover, and raise the quality of the coastal water and ecosystem (mangrove, seagrass and coral reefs). The increased activity that occurs in the bay area will increase land use, so that it effects the quality of the coastal waters and ecosystems (mangroves, seagrass and coral reefs) [2].

Bima Bay coastal area is an area that plays a very important role for the surrounding community, both for socio-economic development and for the ecological (environmental) development of the area. The tendency of increasing human activities is driven by increasing population and per capita consumption, causing changes in coastal ecosystems [3]. Increasing human activities in the Bima Bay area will drive changes in land use; this will reduce the availability of ecosystem services for humans. Land use change is one of the key factors, which drive changes in human activities and the environment [4].

Ecosystem services are benefits that humans obtain from the nature [5-9]. Ecosystem services cannot provide benefits to humans without the role of humans [6]. Burkhard & Maes, [10] stated that ecosystem services are the contribution of ecosystem structure and function (which is combined with other inputs) to human well-being. The Millennium Ecological Assessment (MEA) 2005 agreed that the distribution of ecosystem services can be divided into 4 categories: supporting services, providing services, regulating services, and culture services. Meanwhile, assessment of culture services is very difficult to understand and assess, thus it is reduced to recreational, aesthetic and intrinsic values of biodiversity [11]. Ecosystem service components summarized from various sources can be seen in Table 1.

| Component of Ecosystem Services | [7] | [8] | [9] |
|---------------------------------|-----|-----|-----|
| Supporting Services             | Supporting Services | Habitat Services | Ecological Integrity |
| Regulating Services             | Regulating Services | Regulating Services | Regulating Services |
| Provisioning Services           | Provisioning Services | Provisioning Services | Provisioning Services |
| Culture Services                | Culture Services | Culture Services | Culture Services |

Source: [7-9].

Explain that the availability of ecosystem services depends on biophysical conditions and changes in space and time of land cover, land use and human-caused climate change [9]. The spatial patterns in land cover and land cover change can be linked to a larger area to provide direct measurements of human activities. The use of spatial units in mapping ecosystem services is necessary to understand supply and demand services that may differ based on geographic conditions, thus a supply and demand map of ecosystem services is needed [12]. Mapping between supply and demand providers is needed as a basis for calculating that demand does not exceed supply, so mapping is a useful tool for describing and measuring the spatial mismatch between supply and demand for ecosystem services that can be used for communication and support policy making [13].

Ecosystem service mapping is very useful for increasing public awareness regarding ecosystem goods and service providers, environmental education about the influence of humans and the function of natural resources in providing information. This shows that mapping ecosystem services is very important to understand how ecosystems contribute to human well-being and support policies that impact natural resources [10].

Based on the characteristics mentioned above, it is very necessary to have a proper bay management for sustainable use. Sustainable use efforts require management and understanding of the role of ecosystems in providing benefits to humans around the area. This is in line with the development of
Bima Bay as an important area for improving the economy and welfare of the people around the area. Therefore, this study aimed to map the characteristics of ecosystem services in Bima Bay.

2. Method

2.1. Description of the study sites
The research was conducted in Bima Bay, West Nusa Tenggara Province (figure 1), located at coordinates 118°41′33,265″E 8°28′40,732″ S. Research data were taken in December 2019. The approach used in this study was by adopting Ecosystem Services Approach developed with an ecosystem services matrix [9]. The matrix built was integration between ecosystem services and land cover / land use (LULC) which was then outlined in a spatial form (table 2).

![Figure 1. Research location.](image-url)
### Table 2. Ecosystem services matrix by type and coastal sub-district at Bima Bay (Asakota Sub-District).

| Land cover/ Land use | Ecological Integrity | Regulating services | Provisioning services | Culture services |
|----------------------|----------------------|---------------------|-----------------------|-----------------|
|                      | μ | λ | μ | λ | μ | λ | μ | λ | μ | λ | μ | λ | μ | λ | μ | λ | μ | λ | μ | λ | μ | λ |
| Port area            | 3 | 2 | 3 | 4 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Apari                | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lembeh               | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Warehouse            | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Hotel                | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Min market           | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Restaurant           | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Natural capital      | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Green open space (RTH) | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| TRPPP                | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Market               | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Jetty                | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Road infrastructure  | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Settlement           | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Tourism location     | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Pentaeris deposit    | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| PTU Buho             | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| PLTU Nibb             | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| PLTU Nibb             | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Mangrove area        | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Farm area            | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Cultivation area     | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Agricultural area    | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| School building      | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Road terminal        | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Sport and recreation facilities | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Grassland            | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Watersheds          | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |

Scale for assessing:
0: no relevant Capacity
1: low relevant Capacity
2: medium relevant Capacity
3: high relevant Capacity
4: very high relevant Capacity
| Land cover/ Land use          | Ecological Integrity | Regulating services | Provisioning services | Culture ser |
|------------------------------|----------------------|---------------------|-----------------------|-------------|
|                              | 1                    | 2                   | 3                     | 4           |
| Port area                    | 30                   | 32                  | 32                    | 3           |
| Apartment                    | 0                    | 0                   | 0                     | 0           |
| Landfills                    | 4                    | 2                   | 0                     | 0           |
| Warehousing                  | 4                    | 3                   | 2                     | 0           |
| Hotel                        | 3                    | 3                   | 3                     | 0           |
| Mini market                  | 3                    | 0                   | 0                     | 0           |
| Restaurant                   | 3                    | 2                   | 2                     | 0           |
| SPONISERU                    | 0                    | 0                   | 0                     | 0           |
| Green open space (RTH)       | 5                    | 5                   | 5                     | 5           |
| TRF/PR                       | 4                    | 4                   | 4                     | 4           |
| Market                       | 5                    | 5                   | 5                     | 5           |
| Jetty                        | 5                    | 5                   | 5                     | 5           |
| Road infrastructure          | 5                    | 5                   | 5                     | 5           |
| Settlement                   | 3                    | 4                   | 4                     | 2           |
| Tourism location             | 5                    | 5                   | 5                     | 5           |
| Portema depo                 | 3                    | 3                   | 3                     | 3           |
| LTLD Ntu                     | 5                    | 5                   | 5                     | 5           |
| Ice factory                  | 4                    | 4                   | 4                     | 4           |
| Mangrove area                | 5                    | 5                   | 5                     | 5           |
| Farm area                    | 5                    | 5                   | 5                     | 5           |
| Cultivation area             | 3                    | 5                   | 5                     | 5           |
| Agricultural area            | 0                    | 0                   | 0                     | 0           |
| School building              | 0                    | 0                   | 0                     | 0           |
| Bus terminal                 | 5                    | 5                   | 5                     | 5           |
| Sport and recreation facilities| 3                    | 5                   | 5                     | 5           |
| Grassland                    | 3                    | 5                   | 5                     | 5           |
| Watersheds                   | 5                    | 5                   | 5                     | 5           |

Table 2. Ecosystem services matrix by type and coastal sub-district at Bima Bay (Rasanae Barat Sub-District) (continued).
Table 2. Ecosystem services matrix by type and coastal sub-district at Bima Bay (Palibelo Sub-District) (continued).

| Land cover/ Land use | Agriculture | Aquaculture | Biodiversity | Conservation | Cultural | Environmental | Infrastructure | Recreational | Resilience | Resource Extraction | Sustainable Use |
|----------------------|-------------|-------------|--------------|--------------|----------|---------------|----------------|--------------|------------|-------------------|-----------------|
| Areas                |             |             |              |              |          |               |                |              |           |                   |                 |
| Palibelo Sub-District |             |             |              |              |          |               |                |              |           |                   |                 |

Note: The matrix above represents the ecosystem services matrix by type and coastal sub-district at Bima Bay (Palibelo Sub-District) (continued). The values indicate the level of service provision, with higher values indicating greater service provision.
Table 2. Ecosystem services matrix by type and coastal sub-district at Bima Bay (Woha Sub-District) (continued).

| Land cover/ Land use | I Ecological integrity | II Regulating services | III Provisioning services | IV Culture services |
|----------------------|------------------------|------------------------|--------------------------|--------------------|
|                      | Abiotic biodiversity    | Access to biodiversity | Food availability       | Recreation          |
|                      | Basic services          | Ecosystem services     | Fish availability       | Wild foods          |
|                      | Metabolism efficiency   | Ecosystem services     | Crop availability       | Timber              |
|                      | Energy capture          | Ecosystem services     | Fishery availability   | Wood fuel            |
|                      | Catchment control       | Ecosystem services     | Energy availability     | Energy              |
|                      | Flood protection         | Ecosystem services     | Energy availability     | Biodegradable and   |
|                      | Local climate control    | Ecosystem services     | Energy availability     | Non-biodegradable   |
|                      | Nutrient regulation     | Ecosystem services     | Energy availability     | Waste                 |
|                      | Water purification      | Ecosystem services     | Energy availability     | Forestry             |
|                      | Nutrient regulation     | Ecosystem services     | Energy availability     | Janitor              |
|                      | Water purification      | Ecosystem services     | Energy availability     | Janitor              |
|                      | Nutrient regulation     | Ecosystem services     | Energy availability     | Janitor              |
|                      | Ecosystem services     | Ecosystem services     | Energy availability     | Janitor              |

Scale for assessing
0 no relevant capacity
1 low relevant capacity
2 relevant capacity
3 medium relevant capacity
4 high relevant capacity
5 very high relevant capacity
Table 2. Ecosystem services matrix by type and coastal sub-district at Bima Bay (Bolo Sub-District) (continued).

| Land cover/land use | Sport and recreation facilities | Watershed conservation | Ecological integrity | Regulating services | Provisioning services | Cultural services | Social services | Economic services |
|---------------------|--------------------------------|------------------------|---------------------|---------------------|----------------------|------------------|-----------------|------------------|
| Port area            | 20                             | 20                     | 20                  | 20                  | 20                   | 20               | 20              | 20               |
| Roads and paths      | 20                             | 20                     | 20                  | 20                  | 20                   | 20               | 20              | 20               |
| Building area        | 20                             | 20                     | 20                  | 20                  | 20                   | 20               | 20              | 20               |
| Recreation area      | 20                             | 20                     | 20                  | 20                  | 20                   | 20               | 20              | 20               |
| Agriculture area     | 20                             | 20                     | 20                  | 20                  | 20                   | 20               | 20              | 20               |
| Forest area          | 20                             | 20                     | 20                  | 20                  | 20                   | 20               | 20              | 20               |
| Fishing area         | 20                             | 20                     | 20                  | 20                  | 20                   | 20               | 20              | 20               |
| Tourism area         | 20                             | 20                     | 20                  | 20                  | 20                   | 20               | 20              | 20               |
| Land-use controls    | 20                             | 20                     | 20                  | 20                  | 20                   | 20               | 20              | 20               |
| Land-use planning    | 20                             | 20                     | 20                  | 20                  | 20                   | 20               | 20              | 20               |
| Land-use management  | 20                             | 20                     | 20                  | 20                  | 20                   | 20               | 20              | 20               |
| Land-use regulation  | 20                             | 20                     | 20                  | 20                  | 20                   | 20               | 20              | 20               |

Scale for assessing: 0 = None, 1 = Low relevant, 2 = Medium relevant, 3 = High relevant, 4 = Very high relevant.
Table 2. Ecosystem services matrix by type and coastal sub-district at Bima Bay (Soromandi Sub-District) (continued).

| Land cover/ Land use                  | Ecological Integrity | Regulating services | Provisioning services | Culture service |
|---------------------------------------|----------------------|---------------------|-----------------------|-----------------|
|                                       | 1                    | 2                   | 3                     | 4               |
| Port area                             | 0                    | 0                   | 0                     | 0               |
| Airport                               | 0                    | 0                   | 0                     | 0               |
| Landfill                              | 4                    | 2                   | 0                     | 0               |
| Warehousing                           | 0                    | 0                   | 0                     | 0               |
| Hotel                                 | 0                    | 0                   | 0                     | 0               |
| Mini market                           | 0                    | 0                   | 0                     | 0               |
| Restaurant                            | 2                    | 2                   | 0                     | 0               |
| Green open space (RT/9)               | 35                   | 4                   | 2                     | 4               |
| TPI/PPI                               | 0                    | 0                   | 0                     | 0               |
| Market                                | 0                    | 0                   | 0                     | 0               |
| Road infrastructure                   | 3                    | 2                   | 3                     | 2               |
| Settlement                            | 3                    | 3                   | 4                     | 5               |
| Tourism location                      | 4                    | 4                   | 4                     | 4               |
| Perhannia depot                       | 0                    | 0                   | 0                     | 0               |
| PLTD Nu                               | 0                    | 0                   | 0                     | 0               |
| Hotel factory                         | 0                    | 0                   | 0                     | 0               |
| PLTU Borelo                           | 0                    | 0                   | 0                     | 0               |
| Mangrove area                         | 1                    | 2                   | 3                     | 4               |
| Farm area                             | 0                    | 0                   | 0                     | 0               |
| Cultivation area                      | 0                    | 0                   | 0                     | 0               |
| Agricultural area                     | 0                    | 0                   | 0                     | 0               |
| School building                       | 0                    | 0                   | 0                     | 0               |
| Sport and recreation facilities       | 0                    | 0                   | 0                     | 0               |
| Grassland                             | 2                    | 3                   | 4                     | 5               |
| Watershed                             | 0                    | 0                   | 0                     | 0               |

Scale for assessing:

0: no relevant Capacity
1: low relevant Capacity
2: medium relevant Capacity
3: high relevant Capacity
4: very high relevant Capacity

(Continued)
2.2. Raw material and data analysis

The methods used in this study were field surveys, independent interviews with stakeholders regarding the direction of development of the Bima Bay area, spatial information, and other sources such as urban planning documents for Bima Regency and Bima City, documents on zoning plans for coastal areas and small islands in NTB Province and other relevant documents that supported this research. This study adopted the ecosystem services matrix by making some modifications [9]. Several steps were taken: 1) identifying land cover or land use in the Bima Bay area; 2) creating a matrix of relationships between ecosystem services and land cover or land use. Then, the coverage broad of ecosystem services include 6 sub-district around of Bima Bay is Asakota, Rasanae Barat, Palibelo, Woha, Bolo and Soromandi sub-district or 66491 ha and the results of the ecosystem services matrix were then expressed in spatial form using GIS. Calculating the aggregate index value of coastal ecosystem services using the following formula:

\[
ES_i = \frac{\sum_{m=1}^{n} \sum_{o=1}^{L_{max}} I_{mo}}{\sum_{m=1}^{n} \sum_{o=1}^{L_{max}} I_{mo} \ max}
\]

Description:
- \( I \) = Ecosystem services: ecological integrity, regulating services, provisioning services and culture services
- \( M \) = land use/land cover
- \( o \) = supply and demand parameters

Meanwhile, to determine the value of the ecosystem services budgeting index, the following formula is used:

\[
ES_B = EI - (RS + PS + CS)
\]

Description:
- \( EI \) = ecological integrity
- \( RS \) = regulating services
- \( PS \) = provisioning services
- \( CS \) = culture services
- \( L_{max} = 5 \)

3. Result and discussion

3.1. Analysis of the supply capacity of ecosystem services

Mapping of supply ecosystem services is closely related to the condition of the natural resources. Mapping of ecosystem services supply is related to the land use / land cover (LULC) capacity of the coastal area of Bima Bay. Based on the value of the ecological integrity index in the research unit (coastal sub-districts) which was classified according to class intervals, it was known that the value of ecological integrity for the Asakota Sub-district was 0.416327; Rasanae Barat Sub-district at 0.559184; Bolo Sub-district at 0.413265, and Palibelo Sub-district at 0.495591. This shows that the relationship between ecological integrity and changes in LULC is included in the medium capacity class. Changes in LULC in coastal areas through the conversion of land use functions in coastal areas will have an impact on changes in the availability of supply ecosystem services.

Meanwhile, Woha Sub-district has an ecological integrity index value of 0.320408 and Soromandi Sub-district of 0.305100. This indicates that the availability of supply ecosystem services associated with LULC has a low capacity relationship. The relationship between the capacities of the Woha and Soromandi Sub-district shows that the impact of human activities on changes in land cover / land use is still low.
3.2. Analysis of the capacity of demand ecosystem services

The results of the mapping of demand ecosystem services (regulating services, provisioning services and culture services) based on index values and class intervals showed that all coastal Sub-district in the Bima Bay area were included in the low capacity relationship category class even with different regulating service index values, with details as follows: Asakota Sub-district with an index value of 0.253175; Rasanae Sub-district at 0.333333; Palibelo Sub-district at 0.301587; Woha Sub-district at 0.227778; Bolo Sub-district at 0.259524; and Soromandi Sub-district at 0.211905. The highest index value related to the capacity of demand ecosystem services is found in West Rasanae Sub-district. This shows that the increase in land cover change will have a huge impact on changes in demand ecosystem services. These changes are greatly influenced by the increasing human activity in the Bima Bay area.

The provisioning services for the Bima Bay area associated with the LULC capacity show that all the coastal Sub-district of Bima Bay with low capacity class classifications have different index values. Details of the index value for each Sub-district are Asakota Sub-district of 0.1247; West Rasanae Sub-district of 0.152597; Palibelo Sub-district of 0.146104; Woha Sub-district of 0.12013; Bolo Sub-district of 0.134416; and Soromandi Sub-district of 0.098052.

Based on the value of the provisioning service index, it shows that the West Rasanae Sub-district has a greater index value than other coastal Sub-district in the Bima Bay area. This is because the West Rasanae Sub-district is an area that has a high land cover change activity with an area that is smaller than the other Sub-district around the area, and as the center of trade and services in the area of Bima City. Meanwhile, the Soromandi sub-district is the region with the smallest supply service index value, this shows that the change in LULC is very small because it is a sub-district with the widest area compared to other coastal sub-districts. Most of the area of Soromandi sub-district is hilly and overgrown with grasslands and is directly connected to the Flores sea area. The ecosystem service map of Bima Bay can be seen in figure 2.

![Ecosystem services map of Bima Bay](image)
The highest culture services index value was found in West Rasanae Sub-district of 0.5143, which was then followed by Palibelo Sub-district with an index value of 0.3786, and the lowest value of culture services index was Soromandi Sub-district of 0.2143. This shows that the relationship between culture service capacity and LULC is due to the fact that West Rasanae and Palibelo Sub-districts are icons of Bima Bay as a location for tourism development and a service trade center which has an impact on increasing human activity. Increasing human activity in the 2 (two) Sub-districts will directly increase the LULC around the Bima Bay area. The value of the ecosystem services index per component and the Bima Bay Sub-district can be seen in figure 3.

3.3. Analysis of the supply and demand ecosystem services budget

The results of the calculation of the value of the ecosystem services budget index per coastal Sub-district in the coastal area of Bima Bay can be seen in figure 4.

The value of the budgets for ecosystem services in the Bima Bay area is -1.8138. The negative value in the availability matrix (budget) shows that human demand is higher than the availability of resources (demand > supply) in supporting human activities in the region, thus management breakthroughs are needed, especially in providing support for the availability of supply ecosystem services. The results of the mapping of ecosystem services for each coastal Sub-district in the Bima Bay area which are connected to the LULC capacity can be seen in figure 5.

![Figure 3. Ecosystem services index value by types and coastal sub-district at Bima Bay.](image)

![Figure 4. Ecosystem services budget value of Bima Bay.](image)
3.4. Discussion

The availability of ecosystem services supply (ecological integrity) in coastal Sub-district in the Bima Bay area which is connected to LULC shows different aggregate index values. The assessment of availability, regulation and culture appears to be a challenging aggregation strategy in applying the concept of ecosystem-based environmental analysis [14]. The index value for the availability of ecological integrity, this indicates that changes in land use cover and high land use in supporting human activities in the Bima Bay have an effect on the sustainability of natural resources.

Riegels et al. [15] explain that quantifying ecosystem services provision requires understanding how ecosystem and human inputs work together to make contributions to human welfare. Meanwhile, the lowest index value found in some Sub-district in the Bima Bay shows that the availability of natural resources in meeting human demand for goods and services is still very low so that the room for its development is still open. The ecosystem service is understood as contributing to sustainability through sustainability strategies rather than assessing all forms of natural resource use in aggregated assessments [16]. Furthermore, Burkhard et al. [9], the main impact of human activities on the environment is the use of land which results in land changes that have an impact on the ability of ecosystems to provide goods and services for humans.

The maximum index value for regulating services shows that increased human activity on land use and land change will have an impact on the availability of regulating services as an effort to maintain the sustainability of the ecosystem in the Bima Bay area. Ecosystems provide a variety of goods and services for the welfare of coastal communities that directly contribute to economic welfare and wealth [13]. The land use and changes in land cover have an impact on the availability of ecosystem services in the coastal area of Bima Bay. According to Ronchi [17], changes in LULC will affect the provision of ecosystem services because it determines the decline in global environmental conditions and loss of biodiversity, hence, information on ecosystem services is fundamental to support spatial planning processes and strategic environmental assessment can be the tool used to integrate in planning for sustainable land use management.

![Diagram ecosystem services per coastal sub-district of Bima Bay](image_url)

**Figure 5.** Diagram ecosystem services per coastal sub-district of Bima Bay.
4. Conclusions

Based on the result research about ecosystem services index of Bima Bay is necessary to make sustainable management decisions makers local governments or related stakeholder. Some important things to note are:

1) There is a need for changes in zoning policies, especially those that are directly related to coastal Sub-district as stated in the spatial planning document (RTRW) related to the direction of utilization policies;

2) As an area that is important in supporting the lives of coastal communities and its surroundings, it is necessary to have integrated planning should be for all Sub-district in Bima Bay including the use of coastal land as road infrastructure and residential buildings as well as replacing mangrove forests into fish farming pond and settlements.

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