Mapping typology of mangrove based on the level of damage and anthropogenic disruption in forest designation areas

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Abstract. Indonesia is an archipelagic country, becoming one of the countries that have the largest area of mangrove forests in the world. Mangrove forests have a significant role, and its functions are perfect both directly and indirectly for the surrounding environment, especially for coastal residents, including preventing seawater intrusion, erosion, and coastal abrasion, as well as providing foodstuffs and becoming a nursery area for fish and invertebrates that live around it. However, mangrove forests throughout the world continue to experience pressure. The conversion of the function of mangrove forest land to other land uses to increase, for example, the conversion of mangrove forest land to ponds and residential areas, or the use of wood used as raw material for furniture and housing. In this case, human activities are considered to be the main cause of damage to mangrove forests. Therefore, it is essential to protect mangrove forests under pressure and rehabilitate mangrove forests that have been damaged. Budget limitations in the implementation of mangrove forest protection and rehabilitation programs cause the need to determine zones, which are work priorities in the implementation of the program. This study aims to determine the priority zones of work through the preparation of mangrove forest typologies based on the level of damage and the level of anthropogenic disruption in the area of forest designation through spatial analysis methods.

1. Introduction

Indonesia is a country with the largest area of mangrove forests in the world [1]. Indonesia is also the center of world mangrove diversity [2]. Based on 2009 data, the total area of mangrove forests in Indonesia is about 3,244,018,46 ha, spread across Sumatra, Kalimantan, Sulawesi, Java, Bali and East Nusa Tenggara and Papua. This covers 23% of the total mangrove area in the world. The southern coast of West Papua is the largest mangrove forest area in the world [3].

Mangrove ecosystem is a system that consists of organisms that interact with environmental factors and others within a mangrove habitat. Thus, the mangrove ecosystem is a living alliance between the
mangrove community (flora and fauna) with the environment, which is a unified whole where there is a process of exchanging the substances needed to maintain its life. One reason that makes the mangrove ecosystem to be unique is that the mangrove ecosystem is the boundary that connects between terrestrial and marine ecosystems. Therefore it can affect the life processes of biota in the region [4,5].

The very high functions and benefits of mangrove forests make mangrove forests a hot issue that is discussed and researched not only on a national scale but also on an international scale. The pressure on mangrove forests is tremendous and continues to increase so that it has implications for changes in the area and land use [6,7]. Factors that encourage the degradation of mangrove forests are economic growth, conversion of mangrove forests, inappropriate planning and implementation of regulations, lack of human resources, and low awareness among stakeholders [8].

The high degradation of mangrove forests in the West Konawe District was around 30% within two years, 2009 amounting to 23,195 ha [9] and 15,522 ha in 2011 [10]. This shows that the conversion of mangrove forests has become a land for other needs. Conversion of mangrove forest into settlement areas and ponds is identified as the cause of mangrove forest degradation. The condition of this mangrove forest can get worse due to the absence of regional regulations that specifically regulate mangrove forest management policies in the area of the West Konawe District. The percentage of the population working in the agriculture, plantation, forestry, hunting, and fisheries sectors in the West Konawe District is about 55.96% [11]. These sectors are the types of work that can be in direct contact with forest areas, including mangrove forests.

In the management of natural resources, it has been agreed to pay attention to three important aspects that are the basis of sustainability, namely economic, ecological and social aspects, so that their achievements can meet both human welfare and environmental welfare. Sustainable management of mangrove forests is a part of holistic coastal development. Spatial information on the condition of mangrove forests, the distribution of mangrove forests, the level of damage and disruption, and patterns of change are important things to know. Information on the current condition of mangrove forests based on the class of damage and the level of disruption of mangrove ecosystems due to anthropogenic factors can be a strong foundation in determining priority zones in implementing rehabilitation and protection programs for mangrove forests. The purpose of this study was to determine the typology of mangrove forests based on the level of anthropogenic damage and disturbance in the area of forest designation.

2. Methods

2.1. Study area

This research was conducted in the Coastal Area of West Konawe Region (4° – 4°31’ S and 122° – 122°55’ E), Southeast Sulawesi Province, in March 2015 to July 2016. This area consists of 8 districts, namely District Tinanggea, West Palangga, Laeya, Lainea, Kolono, Laonti, Moramo, and Moramo Utara. Figure 1 shows the location of the study area.

![Figure 1. Study area.](image-url)
2.2. Tools and materials
The tools used in this research include NIKON Digital Camera, Garmin GPS, ESRI ArcGIS Software, and a set of DELL laptop Core i7 RAM 8 GB.

The materials used in this research include a map of the level of mangrove damage from the previous studies; map of mangrove disruption due to anthropogenic factors from the previous studies; thematic maps obtained from West Konawe local government such as road, river, forest designation areas, and administration boundary maps; thematic maps created from processing Landsat satellite imagery such as mangrove, ponds and settlement maps; and literature.

2.3. Research procedure

2.3.1. Literature study. A literature study was obtained from various sources, such as book reports, theses, journals, internet, and other documents related to the research subject. A literature study aims to obtain secondary data that can be used in completing the research data. Discussions were held by stakeholders, consists of community groups, fishing ponds, entrepreneurs, researchers, government, and social/environmental organizations.

2.3.2. Mapping typology of mangrove forests based on the level of damage and anthropogenic disruption. From the results of the analysis of the level of damage and anthropogenic disruption of mangrove forests obtained from previous studies, the overlay was carried out to obtain a typology of mangrove forests in the study area. The preparation of this typology levels was based on the fact that there have been differences in the level of damage to mangrove forests in the field, as well as differences in the level of disruption that threatens the remaining mangrove forests. The typology levels of mangrove forests will be beneficial in determining priority zones for an emergency response to formulate appropriate management strategies according to factual conditions in the field. The mangrove forest typology class was then overlaid with a thematic map of the type of designation of the forest area to obtain a work area that becomes the main priority of the programs, which was a mangrove forest with a high level of damage and disruption within the nature reserve forest, protected forest, water bodies, and production forest.

![Figure 2. Quadrant level of damage and anthropogenic disruption of mangrove forests.](image-url)
3. Results and discussion

3.1. Mapping the level of damage to the mangrove forest
Mapping the level of damage to mangrove forests was compiled based on three criteria, namely, the type of land cover, soil type, and the percentage of mangrove canopy density [12]. In this study, the land cover used was forest land cover. Mangrove ecosystems that mapped in the land cover class were mangrove ecosystems that identified into the forest category. Mangrove vegetation, which scattered within the location of ponds, settlements, or other land cover classes was not categorized as mangrove forests. Soil types that common in mangrove growing sites are Sulfaquents and Troposaprist. The most dominant type of soil overgrown with mangroves is the Sulfaquents soil type. Figure 3 shows the distribution of the level of damage to mangrove forests in the study area.

![Figure 3. Level of damage to mangrove forests in the West Konawe district.](image)

3.2. Mapping the level of disruption due to anthropogenic factors in the mangrove forest
Mapping the level of disruption of mangrove forests due to anthropogenic factors was arranged through 9 parameters that were considered to be related to human activities and have a real impact on mangrove forests, namely access to mangrove areas, pond cultivation activities, types of the designation of forest areas, mining activities, the social and economic capacity of the community, port activities, agricultural cultivation activities, traditional fishing activities, and mining permit areas. Each parameter has a specific distribution of values and weights that were arranged into an index. The distribution of values for each parameter was determined through the results of distance analysis (Euclidean distance), in-depth discussions with the expert team, and referring to factual conditions in the field. The weight of each parameter was determined through the assessment of 5 experts (expert judgment) using the pairwise comparison method with a consistency value of 0.079 [13]. The results obtained are shown in figure 4.
Figure 4. Level of anthropogenic disruption to mangrove forests in the West Konawe district.

Access to the mangrove area indicated as the main factor of anthropogenic disruption, especially the main road. Infrastructure building is one of the essential things in development, but also become a bridge that could threaten the natural ecosystems. Aquaculture ponds activities also indicate the critical factor causing the damage of the mangrove. Mostly, aquaculture ponds were opened by illegal cutting of mangrove forests. Once this area cleared, then the mangrove area around it becomes more vulnerable to damage. Port activities, mining activities, mangrove cover (canopy) density, and the capacity of local communities, also contributing as the factor causing the damage of mangrove ecosystems. A conservation area is supposed to be a barrier of mangroves destruction, but in this case, designation as protected forest or preserves forest does not help a lot. This shows the weaknesses of the monitoring system and existing law enforcement. Table 2 shows the area and percentage of the level of anthropogenic disruption to mangrove forests.

3.3. Mapping typology of mangrove forest based on the level of damage and anthropogenic disruption in forest designation areas

This typological analysis was intended to see areas of mangrove forests that have high and medium levels of damage so that more specific programs can be made in those areas to combine land rehabilitation programs and more targeted supervision programs. Figure 5 shows areas that are indicated to have high disturbance, both with moderate and undamaged conditions. The mangrove forest area with the green category is an area with a low level of disturbance and mangrove conditions that are still quite good. However, there is a distribution of mangrove forest spots with red and orange categories in them that indicate damage on a medium scale and high disturbance in the area. The blue category is an area with good mangrove forest conditions but has a high level of disturbance due to human activities. The composition of the area of the typology of mangrove forests based on the level of damage and disturbance due to anthropogenic factors is presented in table 1.
From the results of spatial analysis, the percentage of mangrove forest areas with good condition and low disturbance level was about 48.62%. Mangrove forest area with good condition but experiencing high disturbance by 50.13%. The rest, around 1%, are in moderate damage condition and are at low or high interference levels.

To develop a sustainable mangrove management program, in addition to priority areas, information on areas that are bound by legal status or regional regulations is very important to facilitate the implementation of rehabilitation and supervision programs and other programs related to their use by local communities. Priority areas that enter into protected areas according to government regulations are an excellent first step as a basis for program preparation so that program evaluations can be more targeted. Figure 6 shows the typology of mangrove forests according to the type of designation of the forest area.

Table 1. Area composition (ha) of mangrove forest typology based on the level of damage and anthropogenic disruption.

| Typology       | Level of Damage | Level of Disruption | Area (ha) | Percentage (%) |
|----------------|-----------------|---------------------|-----------|----------------|
| 1              | Undamaged       | Low                 | 5,646.48  | 48.62          |
| 2              | Undamaged       | High                | 5,289.63  | 50.13          |
| 3              | Moderate Damage | Low                 | 472.02    | 0.68           |
| 4              | Moderate Damage | High                | 444.44    | 0.56           |
| Total          |                  |                     | 11,852.57 | 100.00         |
Figure 6. Typology of mangrove based on the level of damage and anthropogenic disruption in forest designation areas.

Mangrove forest area with red gradation shows the area of mangrove forest in the nature reserve forest area. The bright red color indicates the area of mangrove forest experiencing high disturbance and moderate damage. Green gradation is a mangrove forest that is inside a protected forest area. The dark green color shows the mangrove forest area that experienced high disturbance and moderate damage. Blue gradation is a mangrove forest that is inside another area of use. The dark blue color shows mangrove forests experiencing high disturbance and moderate damage. The composition of the area and location of mangrove forest typologies based on the type of forest designation area can be seen in table 2.

Table 2. The composition of the area (ha) of the typology of mangrove forests based on the type of forest area designation.

| Forest Designation Type | Typology | Sub District | Area (Ha) | Percentage (%) |
|------------------------|----------|--------------|-----------|----------------|
| Nature Reserve Forest  | 4        | Tinanggea    | 1.90      |                |
|                        | 3        | Tinanggea    | 133.19    | 0.02           |
|                        | 2        | Tinanggea    | 77.46     | 1.12           |
|                        | 1        | Kolono       | 2,228.74  | 21.91          |
|                        |          | Laonti       | 66.05     |                |
|                        |          | Tinanggea    | 50.73     |                |
|                        |          | West Palangga| 51.56     |                |
|                        | 4        | Laeya        | 45.67     | 2.01           |
|                        |          | Laina        | 70.59     |                |
|                        |          | Kolono       | 20.17     |                |
|                        |          | Tinanggea    | 57.48     |                |
| Protected Forest       | 3        | West Palangga| 1.06      | 1.57           |
|                        |          | Laeya        | 20.11     |                |
|                        |          | Laina        | 107.15    |                |
|                        |          | Tinanggea    | 317.58    |                |
|                        |          | West Palangga| 573.01    |                |
|                        | 2        | Laeya        | 397.18    | 24.26          |
|                        |          | Laina        | 1,573.66  |                |
|                        |          | Kolono       | 36.28     |                |
Spatial analysis results show that 23.7% of mangrove forests are within natural reserve forest areas, most of which are in the Tinanggea Subdistrict, which is directly adjacent to the area of Rawa Aopa.
Watumohai National Park. Most are in typology 1, but there is a total of 210 ha of mangrove forests, which are in a high level of disturbance and moderate damage in the nature reserve forest area. The largest mangrove forest is in the protected forest area of 44.43%, mostly in the typology 1 and 2. The mangrove forest in the largest protected forest area is in Lainea District, the rest is spread in the Tinanggea, West Palangga, and Laeya Districts, and a small portion is in the Districts of Kolono and Moramo. About 22% of mangrove forests are in other use areas, and production forests spread throughout the coastal districts. There are about 9.88% of the mangrove forests scattered in the area of water bodies, mostly in the Districts of Tinanggea and Kolono.

4. Conclusion
From the study, it can be concluded that the remaining mangrove forests in the coastal area of West Konawe District, 7.73% have been identified as experiencing moderate damage, 5.5% of them are within the nature reserve forest, protected forest and water bodies area. Also, 48.38% experienced high pressure due to human activities, 35.49% of which were located in the nature reserve forest, protected forest, and water bodies area.

References
[1] Lobovikov M, Ball L, Paudel S, Guardia M, Piazza M, Wu J, Ren H and Russo L 2007 World bamboo resources: a thematic study prepared in the framework of the global forest resources assessment 2005 (Food & Agriculture Org.)
[2] Spalding M D, Blasco F and Field C D 1997 World Mangrove Atlas (Okinawa: The International Society for Mangrove Ecosystems)
[3] Veron J E N, Hoegh-Guldberg O, Lenton T M, Lough J M, Obura D O, Pearce-Kelly P, Sheppard C R C, Spalding M, Stafford-Smith M G and Rogers A D 2009 The coral reef crisis: The critical importance of < 350 ppm CO2 Mar. Pollut. Bull. 58 1428–36
[4] Kusmana C, Wilarso S, Hilwan I, Pamoengkas P, Wibowo C, Tiryana T, Triswanto A, Yunasfi and Hamzah 2003 Teknik Rehabilitasi Mangrove (Bogor: Fakultas Kehutanan IPB)
[5] Susanto A H, Soedarti T and Purnobasuki H 2018 Mangrove community structure of Surabaya east coast An Int. J. Plant Res. Biotechnol. 31 51–6
[6] Pattimahu D V 2010 Kebijakan Pengelolaan Hutan Mangrove Berkelanjutan di Kabupaten Seram Bagian Barat, Maluku (IPB Post Graduate)
[7] Fauzi A, Sakti A, Yayusman L, Harto A, Prasetyo L, Irawan B, Kamal M and Wikantika K 2019 Contextualizing mangrove forest deforestation in southeast asia using environmental and socio-economic data products Forests 10 1–18
[8] Kustanti A 2011 Manajemen Hutan Mangrove (Bogor: IPB Press)
[9] Balai Pengelola Daerah Aliran Sungai Sampara 2009 Laporan Akhir Kegiatan BPDA Sampa: Inventarisasi dan Identifikasi Lahan Kritis Mangrove di Sulawesi Tenggara (Kendari: Kementerian Lingkungan Hidup dan Keheutanan)
[10] Pemerintah Daerah Provinsi Sulawesi Tenggara 2017 Rencana Strategis Wilayah Pesisir dan Pulau-Pulau Kecil Provinsi Sulawesi Tenggara (Kendari: Pemerintah Daerah Provinsi Sulawesi Tenggara)
[11] Badan Pusat Statistik Kabupaten Konawe Selatan 2013 Kabupaten Konawe Selatan Dalam Angka (Konawe Selatan: Badan Pusat Statistik (BPS))
[12] Yusuf D N, Prasetyo L B and Kusmana C 2017 Detection of Mangrove Disruption due to Anthropogenic Factor in Protected Area using GIS Model: A Case Study in Konawe Selatan, Southeast Sulawesi Int. J. Sci. Basic Appl. Res. IJSBAR) 31 31–42
[13] Yusuf D N, Prasetyo L B and Kusmana C 2017 Geospatial approach in determining anthropogenic factors contributed to deforestation of mangrove: A case study in Konawe Selatan, Southeast Sulawesi IOP Conf. Ser. Earth Environ. Sci. 54 12049