Geospatial approach in determining anthropogenic factors contributed to deforestation of mangrove: A case study in Konawe Selatan, Southeast Sulawesi

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Abstract. Human activities play an important role in ecosystem damage occurrence, particularly located in rapid developing city. Coastal area is one that has high resource potential, but also susceptible to disturbance since most of the population live in these areas. The development of coastal areas is also influenced by rapid development activities on land and sea. Mangrove is one of the dominant coastal ecosystems, highly productive, complex and high-value benefits. Therefore it is important to learn how anthropogenic factors affect the level of disruption to mangrove ecosystem. In this paper, several factors which considered as dominant have been evaluated through a case study in Konawe Selatan, Southeast Sulawesi. Geospatial model was used to mapping zone with disturbance level based on the anthropogenic factors. The result showed areas with highest disturbance level identified in some areas of District Tinangge; Palangga Selatan; Laeya; Lainea; middle of Kolono Bay; along coast area of Moramo and Moramo Utara. It can be concluded that mangrove ecosystem disruption level due model to anthropogenic factors may determine closely to the factual situation involving socio-economic data. This study provide a guide for future studies on mangrove susceptibility mapping and references in determining the strategy of sustainability mangrove management.

1. Introduction

Human activities play an important role in the occurrence of damage to the ecosystem, especially those located in cities with rapid development areas. Human influence on the ecosystem has been increasing worldwide due to rapid population growth, technology and lifestyle, which have resulted a global biodiversity crisis that threatens the world's species and ecosystems. The coastal area is one that has a very high resource potential, but it also susceptible to damage since most of the population live in there.
The development of coastal area is also greatly influenced by the rapid development activities on land and sea.

Mangrove is one of the dominant coastal ecosystem, highly productive, complex and high-value benefits. It is one of the coastal resources of Indonesia which has huge potential and renewable resources. The mangrove ecosystem has several important functions, such as the ecological, social-economic [1], and physical functions [2]. Mangrove ecosystem also has several benefits, both direct and indirect. Direct benefits of mangrove ecosystem are those which directly perceived its usefulness for human life and measurable, either production or services. Indirect benefits are often difficult to feel and measure, but these benefits actually have a strategic value in supporting human life, such benefits in the areas of research and education, germplasm resources, maintain the climate and hydrology [1]. Direct benefits for human are what generally cause high pressure on the mangrove ecosystem. Unfocused utilization and development not consider to the ecological and physical functions causes high levels of mangrove degradation around the world.

Indonesia is country with the largest mangrove ecosystem in the world [3]. Indonesia is also the world’s center of diversity of mangroves [4]. Based on FAO publication [3], in 2003 the estimated area of mangrove in Indonesia about 3.0623 million ha. It covers about 19% of the total area of mangrove in the world. However, it has been significantly degraded. In 1980 the mangrove forests in Indonesia reached 4.2 million ha. There was a decrease of 1.8% in 1990 to 3.5 million ha. Then it continues decreased by 1% in 2000 to 3.15 million ha. In 2005, FAO reported that mangrove forests in Indonesia have only 2.9 million ha remain.

Degradation of mangrove in Konawe Selatan is currently very concerning. In 2009, mangrove area reached 23.195 ha in Distric of Konawe Selatan and approximately 2.940 ha in critical condition [5]. In 2011, Statistical Agency of Konawe Selatan [6] reported that mangrove area is about 15.522 ha, consist of 4.735 ha of forest cultivation area and 10.787 ha of protected forest area. It shows that about 33% mangroves have lost in 2 years.

Mangrove ecosystems are extremely important, but it has been degraded as a result of natural factors and human activities such as urbanization, industrial development, agriculture and aquaculture [7]. Anthropogenic factors identified as the main cause of mangrove degradation in Indonesia. The pressures of human activity on coastal ecosystems are often very high through the competition of land use for aquaculture, agriculture, infrastructure construction and tourism [3]. Mangrove conversions to other uses have recently become very concerning. Rakotomavo and Fromard [8] stated that the mangrove destruction is caused mainly by human activities, therefor it must be controlled to reduce the damages to the environment. Understanding the relationship between human activity and the ecological impact on the mangrove ecosystem, and mapping these impacts could be an important step in the management of mangrove ecosystems. The aims of this study are to identify what are the human activities that most threatening the existence of mangrove ecosystems and develop the spatial model of mangrove disruption level due to anthropogenic factors. Here, we assessed direct human impacts on the mangrove areas using the Human Influence Index (HII) as a proxy [9]. Several factors that are considered as dominant such as access to mangrove area, port activities, aquaculture ponds activities, mining activities, mangrove cover (canopy) density, designation types of forest areas as well as the capacity of local communities have been evaluated through a case study in Coastal Area of Konawe Selatan, Southeast Sulawesi Province.
2. Material and Method

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

![Figure 1. Study area and ground control point.](image)

2.2. Tools and Materials
The tools used in this research include NIKON Digital Camera, Garmin GPS V+, Global Mapper, ESRI ArcGIS 10.1 and ERDAS ER Mapper 9.1 and a set of HP laptop Core i3 RAM 2 GB. The materials used in this research include interview and focus group discussion (FGD) guideline; Ground Control Point (GCP); Landsat-8 raw data full band 15m resolution in panchromatic and 30m resolution in multispectral, path 112 row 63, recorded on October 9th, 2014 in GeoTIFF format; thematic data such as road, river and coastline year 2009 in shape file format obtained from Geospatial Information Agency of Indonesia; port, mining and designation types of forest areas year 2013 in shape file format obtained from Planning and Regional Development Agency of Konawe Selatan Region; population growth and majority type of worker per district year 2014 in tabular data obtained from Statistical Agency of Konawe Selatan Region; and literature.

2.3. Research Procedure

2.3.1. Literature study, FGD and interview
Literature study was obtained from various sources, such as book reports, theses, journals, internet and other documents related to the research subject. Literature study aims to obtain secondary data that can be used in completing the research data. Data and information related to the condition of the coastal environment and public perception obtained through FGD method. Discussions were held by stakeholders, consists of community groups, fishing ponds, entrepreneurs, researchers, government and social/environmental organizations. Interview with the expert aims to get more specific and in-depth information.
2.3.2. Initial processing of satellite imagery
In this step include radiometric correction, geometric correction, composites, fusion and sharpening image contrast. Histogram adjustment method used in radiometric correction, based on several considerations: (1) The process does not use a complicated algorithms and processes can be performed quickly and easily; and (2) The method does not change the value of imagery data pixels, because the authenticity of the pixel values is very important to produce a high accuracy in the spatial information extraction process based on spectral approach, such as digital classification and image transformation process conducted in this research. The nearest neighbour method used in rectification process based on considerations: (1) The process does not use complex mathematical models; (2) Computational process is faster; and (3) Does not change the value of pixel image produced [10].

The colour composite used in image analysis was the original true colour composite RGB channel 321 and false color composite RGB channel 432. Pan sharpened image process conducted on satellite images Landsat-8 multispectral channel which have a 30m spatial resolution with panchromatic channel which has a 15m spatial resolution. The fusion process carried out with the aim to improve the quality of visual display of imagery for the purposes of interpretation and digital classification. Contrast enhancement used to increase the contrast difference between objects on the mainland, coastal and waters. Linear Transformation Method with auto clip of 99% used for contrast enhancement process.

2.3.3. Land cover mapping
Land cover data generated through the processing of Landsat-8 satellite imagery and field survey. At first, supervised classification digital feature extraction method used for land cover classification mapping. These procedure based on the spatial pattern recognition. Based on field knowledge, reclassify the results of the initial land cover classes were not as expected. These procedure also using land use map year 2009 from Geospatial Information Agency as the class reference. Classes of land cover mapped in this research were forest, crop, mangrove, settlement, bush, aquaculture ponds, open land and farm-field. Furthermore, the class of mangrove, settlement and aquaculture ponds thematic layer were used as input parameters in the preparation of the spatial model of mangrove disruption level due to anthropogenic factors.

2.3.4. Survey
Field verification aims to correct the results of remote sensing data processing carried out in the laboratory. Field verification done by the number of survey points (GCP) that correspond to the field conditions using purposive sampling method.

2.3.5. Accuracy assessment
Accuracy assessment aims to measure the validity of the thematic layer data to be accepted as an input parameters in the preparation of model, which were delivered from land cover map. We tested the accuracy of the land cover map resulted from image processing compared with the factual data in the field, through a set of GCP. Accuracy assessment was done using both Confusion Matrix [11] and Kappa Index Method [10].

2.3.6. Mangrove cover (canopy) density
One of the input parameter is the mangrove cover (canopy) density. Layer of canopy density obtained from the polynomial regression correlation between NDVI values with the calculated mangrove canopy density (%) in the field using a measuring instrument canopy density [12]. The calculation formula is as follows (equation 1):
Mangrove cover density (%) = 99.739x² + 44.942x + 7.4204; Where x = NDVI (1)

2.3.7. Spatial model of mangrove disruption level due to anthropogenic factor.

Spatial model of mangrove disruption level due to anthropogenic factor structured through 7 (seven) input parameters with different weight capacities based on the level of influence as the main driver of mangrove disruption. The process of identification and weighting the parameters based on the study of literature, focus group discussion (FGD), expert’s comparative judgement and factual condition in the field. First, literature study listed any of parameters as a driven of disturbance on mangrove ecosystem through human activities. FGD aims to assess what parameters are happening on the site and to get any information from stakeholders about the condition of mangrove ecosystem on the site. Expert’s comparative judgement aims to get the information of which parameters considered the most influential among all others, then weighting of each parameter based on the level of disruption through pairwise comparison method [13]. List of 7 parameters representing human disturbance on site and result of weighting of each parameter by the experts presented in table 1.

Table 1. Weight and value of variables in mangrove disruption level due to anthropogenic factor model.

| No. | Parameters / Variables                  | Weight | Value                        |
|-----|---------------------------------------|--------|------------------------------|
| 1   | Access to the mangrove area (Lgi.Ak)  | 0.2500 |                              |
|     | A Distance from settlement (Lgi.Akm)  | 0.1125 | 4 - 19.9 km, 2 - 4 km, 0 - 2 km |
|     | B Distance from main road (Lgi.Akj)   | 0.0625 | 2 - 10.5 km, 1 - 2 km, 0 - 1 km |
|     | C Distance from river (Lgi.Aks)       | 0.0375 | 500m - 2.5 km, 250 - 500 m, 0 - 250 m |
|     | D Distance from coastline (Lgi.Akp)   | 0.0375 | 500m - 2.5 km, 250 - 500 m, 0 - 250 m |
| 2   | Port activities (Lgi.Plb)             | 0.1000 | 2 - 15.5 km, 1 - 2 km, 0 - 1 km |
|     | Distance from port                    |        |                              |
| 3   | Aquaculture ponds activities (Lgi.Plb) |        |                              |
|     | Distance from aquaculture ponds       | 0.2000 | 4 - 26.9 km, 2 - 4 km, 0 - 2 km |
| 4   | Mining activities (Lgi.Apt)           | 0.1000 | > 2 km, 1 - 2 km, 0 - 1 km |
| 5   | Mangrove cover (canopy) density (Lgi.Tjm) | 0.1000 | > 60%, 30 – 60%, 0 – 30% |
| 6   | Conservation Area (Lgi.Kkv)           | 0.1500 | HSA* & HL**, APL***         |
|     | Types of designation forest areas     |        |                              |
| 7   | The capacity of local communities (Lgi.Km) | 0.1000 |                              |
|     | a Population growth (Lgi.Kml)         | 0.0500 | 0 - 3 %, 3 - 6 %, > 6 %     |
|     | b Community work in sector: farming, fishing, hunting, forestry, plantation, mining and quarrying (Lgi.Kmu) | 0.0500 | 0 - 30 %, 30 - 60 %, > 60 % |

*HSA = preserves forest; **HL = protected forest; ***APL = another area of use

There were 3 different units in the parameters; distance, percentage and class type. Each layer of input parameter reclassified based on the range value of parameter. The range of each value of parameter

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defined through study of literature and factual condition on the site. The aims of these step was to get 
the same unit of each parameter. We were working on cell based to process the spatial data. Geospatial 
model approach was used to map the zone with the various level of disturbance (high, medium and low),
based on the anthropogenic factors. It aims to represent direct human influence over the mangrove area 
as a gradient ranging from 0 (safest area) to the highest value (highest disturbance area). We used the 
30x30m pixel raster map based on the source of the land cover thematic map, Landsat-8, which has 30m 
spatial resolution. Mangrove disruption level due to anthropogenic factors defined as the total 
cumulative of value multiplied by weight from each parameter. Based on the table 1, the spatial model 
of mangrove disruption level due to anthropogenic factor compiled through the following equation 2:

\[
\text{Mangrove disruption level (Lgi) = (Lgi.Ak x 0.25) + (Lgi.Plb x 0.1) + (Lgi.Ptb x 0.2) + (Lgi.Apt x 0.1) + (Lgi.Tjm x 0.1) + (Lgi.Kkv x 0.15) + (Lgi.Km x 0.1)}
\]

(2)

3. Result and Discussion

3.1. Land Cover Mapping and Accuracy

Based on classification of Landsat satellite imagery-8 multiband, the total forest area is about 
131,695,449 ha, crop 75,322,070 ha, mangrove 11,849,992 ha, settlement 5,979,207 ha, bush 
25,074,413 ha, aquaculture ponds 4,202,614 ha, open land 49,536,326 ha and farm-field 22,978,604 ha. 
The result of land cover mapping in 8 districts of coastal area in Konawe Selatan presented in table 2.

| No. | Land cover Year 2014 | Area (ha) | Producer Accuracy (%) | User Accuracy (%) |
|-----|----------------------|-----------|-----------------------|------------------|
| 1   | Forest               | 131,695,449 | 100.00                | 100.00           |
| 2   | Crop                 | 75,322,070  | 81.82                 | 90.00            |
| 3   | Mangrove             | 11,849,992  | 95.83                 | 95.83            |
| 4   | Settlement           | 5,979,207   | 95.00                 | 82.61            |
| 5   | Bush                 | 25,074,413  | 85.71                 | 85.71            |
| 6   | Aquaculture Ponds    | 4,202,614   | 87.50                 | 93.33            |
| 7   | Open Land            | 49,536,326  | 80.00                 | 80.00            |
| 8   | farm-field           | 22,978,604  | 80.00                 | 88.89            |

| Amount                      | 326,638,675 | Overall Accuracy (%) | 89.22 |
|-----------------------------|------------|----------------------|-------|
| Kappa Index                 |            |                      | 0.87  |

Accuracy assessment conducted on land cover map shows that the value of overall accuracy about 
89.22%, that’s above the minimum tolerance value of 80%. It means the land cover map in accordance 
with the existing conditions in the field and acceptable validity. In user accuracy assessment of each 
classes of land cover show that the value range between 80 to 100%, correspond the minimum 
acceptable value of 80%. This indicates that each layer of land cover assessed has a good accuracy and 
can be used for analysis. It’s very important because some layers such as mangrove, settlement and
aquaculture ponds used as an input parameters for the preparation of mangrove disruption level due to anthropogenic factor model. In Kappa Index assessment, the accuracy value is 0.87. Kappa accuracy value is in the range 0-1. Closer to 1 means the accuracy value occurred by chance is 0, or means that the accuracy resulted not by accident.

3.2. Mangrove Cover (Canopy) Density

NDVI is an index measuring the level of greenness of a plant, ranging from -1 (which is generally water) to +1 (heavy vegetation). The NDVI value is defining characteristics of the vegetation, but it does not show the detail part of the vegetation. To get the value of mangrove cover (canopy) density, we proceed the NDVI formula to get the detail value of canopy density. Canopy is the cover of branches and foliage formed by the crown of trees. The percentage area of land covered by the canopy of trees is called canopy density. Vegetation density shows the health status of the forest which depends on the percentage of the canopy cover of the mangrove forest in the area. Dense mangrove shows good health status of mangroves which indicates tall trees, fine distribution, diversity extent and excellent local habitat for the mangrove growth [14]. NDVI was performed for estimating the vegetation cover of the mangrove canopy, this indicates biomass of forest. The NDVI data derived from satellite images was used to compute percentage of canopy closure from 0% to100% [15]. The distribution of mangrove cover (canopy) density can be seen in figure 2.

3.3. Ecological Function of Mangrove

Mangrove usually located in the estuarine areas, which as the final destination of organic particles or silt washed from upstream areas due to erosion. Thus, the mangrove area is a fertile area, both land and waters, caused by the transport of nutrients due to tides [16]. Mangrove forests are communities of tropical and subtropical coastal vegetation consisting of several types of species that can grow and thrive in the muddy coastal tidal areas [17]. Based on the types of trees that making up the formation of mangrove forests from the sea to the mainland, then mangrove can be divided into several zones, namely: Zone *Avicennia sp.*, the area closest to the sea, with a little sandy substrate, often covered by *Avicennia sp.*, the usual association with *Sonneratia sp.* which is dominant to grow on mud rich in organic material; Zone *Rhizophora sp.*, more landward, mangrove forests are generally dominated by *Rhizophora sp.* In this zone also encountered *Bruguiera sp.* and *Xylocarpus sp.*; Zone *Bruguiera sp.*, dominated by *Bruguiera sp.* and *Nypah sp.*, the transition zone between mangrove forest with the usual lowland forest overgrown by Nypah fructicans and some other palm species [17].

Mangrove ecosystem support the conservation of biodiversity, by providing shelter, breeding grounds, nursery and feeding sites of various animal species. Including several endangered animal
groups, ranging from the class of reptiles, amphibians, aves and mammals. Mangrove ecosystems can also protect coral reef and sea grass. Various types of fish whether commercial or non-commercial also depend on the existence of mangrove ecosystems [3]. It has been estimated that nearly 90% of all marine animals spend some part of their life cycle within a mangrove ecosystem [18]. Mangroves play an important role within these areas as they guard the low-lying coastal land by forming a protective barrier. This biological barrier reduces damaged caused by storms by limiting wave energy and preventing the land from being flooded. This has become even more apparent after the 2004 Asian tsunami [19]. Mangroves also provide various ecological and economical ecosystem services contributing to coastal erosion protection, provision of building material and medicinal ingredients, and the attraction of tourists [20].

3.4. Human Activities
The influences of human activities are the main drivers of global ecosystem damage [21]. Changes in the size, composition, and distribution of human populations affect coastal regions by changing land use and land cover. Fishing or harvesting, the destruction of mangroves, and pollution and sedimentation from human activities all can affect the coastal environment [22]. Aquaculture, the world’s fastest growing food production activity, can lead to the destruction of mangroves and may lead to irreversible damage to both estuarine and offshore fisheries and by modifying habitats [22]. Unconventional mining activity damages of the mangrove forest. Mining activity causes loss and reduces the mangrove area. This condition makes the mangrove lost its function, in ecological, physical, and economical benefit [14]. In Southeast Sulawesi, mangrove mostly converted into fishponds and settlements, the use of firewood, industrial, raw materials household furniture, as well as roads and ports [23].

3.5. Mangrove Disruption Level Due to Anthropogenic Factor
From Landsat satellite year 2014, BPDAS Sampara [5] and Statistic Agency of Konawe Selatan Region [6], show that a degradation of mangrove in Konawe Selatan Region around 48% from 2009 to 2014. Access to the mangrove area indicated as the main factor with highest weight (0.25), especially main road. Infrastructure building is one of the important things in development, but also become a bridge that could threaten the natural ecosystems. Aquaculture ponds activities also indicate as the important factor causing the damage of the mangrove with weight of 0.20. Mostly, aquaculture ponds were opened by illegal-cutting of mangrove forest. Once this area cleared, then 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 with weight of 0.1. Conservation area is supposed to be a barrier of mangroves destruction, but in this case, designation as protected forest or preserves forest is not help a lot. This shows the weaknesses of the monitoring system and existing of law enforcement. Spatial model of mangrove disruption level due to anthropogenic factor is presented in figure 3.

The result shows the distribution of most and less effected level of disruption. The red colour showing the area with high level of disruption, the middle and low level of disruption showing in yellow to green colours. Areas in circle from figure 3 showing the highest to middle level disruption of mangrove. From the study, the high level identified in some areas, such as most of District Tinangge to the areas bordering the Palangga Selatan District; District Palangga Selatan and Laeya that abut each other; in the middle of coast area of District Lainea; in the middle of Kolono Bay; and along coast area of District Moramo and Moramo Utara.

The shape and nature of the human activities, the distance range to the location and ecological impacts from human activities are important information for the preparation of strategic management
and oversight priorities for ecosystem management [24]. This study can be used to meet the priority area of working for the management programmes purpose.

Figure 3. Spatial model of mangrove disruption level due to anthropogenic factor.

4. Conclusion
From the study, it can be concluded that:
1. Human activities that most threatening the existence of mangrove ecosystems are access to the mangrove, specially distance from the settlement and main road; aquaculture ponds activities; and types of designation forest areas.
2. The high level of mangrove disruption identified mostly in District Tinangge to the areas bordering the Palangga Selatan District; District Palangga Selatan and Laeya that abut each other; in the middle of coast area of District Lainea; in the middle of Kolono Bay; and along coast area of District Moramo and Moramo Utara.

5. Suggestion
From the study, we suggest that:
1. The spatial model with cell-based data analysis gives result for preparing zoning system of the mangrove area for management purposes.
2. Spatial model of mangrove ecosystem disruption level due to anthropogenic factors may be determined more closely to the factual situation by involving more recently socio-economic data such as the educational degree of local communities and other human activities spatial layer such as fishing ground and agricultural area.

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