Analysing the rate of mangrove forest conversion in South Konawe, Southeast Sulawesi

Dewi Nurhayati Yusuf\(^1\), LB Prasetyo\(^2\), C Kusmana\(^3\), Machfud\(^4\) and Ritabulan\(^5\)

\(^1\)Department of Soil Science, Faculty of Agriculture, Halu Oleo University, Jl. HEA Mokodompit, Anduonohu, Kendari 93232, Indonesia
\(^2\)Department of Forest Resources Conservation and Ecotourism, Faculty of Forestry, Bogor Agricultural University, Jl. Meranti, Dramaga, Bogor 16680, Indonesia
\(^3\)Department of Silviculture, Faculty of Forestry, Bogor Agricultural University, Jl. Meranti, Dramaga, Bogor 16680, Indonesia
\(^4\)Department of Agroindustrial Technology, Faculty of Agricultural Technology, Bogor Agricultural University, Jl. Meranti, Dramaga, Bogor 16680, Indonesia
\(^5\)Department of Forestry, Faculty of Agriculture and Forestry, Sulawesi Barat University, Jl. Prof. Dr. Baharuddin Lopa, Talumung, Majene, Indonesia

E-mail: wafa.yusuf88@gmail.com

Abstract. The degradation of mangrove forests in the Konawe Selatan District has been very rapid over the past three decades. Increases in population growth in coastal areas have been associated with rapid development, including the need for land for housing and livelihood. This development has led to land conversion from mangrove forests to other uses. The aim of the research was to identify the pattern of spatial change of mangrove forests in South Konawe using a geospatial approach from 1984 to 2014. Landuse classification was generated through the processing of Landsat satellite imagery in multiple time series. The research showed that that between 1984 and 1993 in South Konawe District about 9.9% of mangrove forest was converted into open land, 2.3% into aquaculture ponds, and 0.4% into settlements. From 1993 to 2003, the rate of conversion increased rapidly as 13.8% of the remaining mangrove forest was cleared for aquaculture ponds and 1.5% into a settlement. Over the past three decades, 39.9% of mangrove forest in the district has been converted to other uses, and some of this conversion has occurred in protected areas. It’s recommended that the stronger enforcement of regulations pertaining to the protection of mangrove forests in South Konawe.

1. Introduction
In Indonesia, mangrove ecosystems represent a coastal resource that provides numerous natural products to local communities and has high potential for sustainability. Indonesia holds the largest area of mangrove forest in the world at 23% [1], and is the center of the world’s mangrove diversity [2]. Based on data from 2009, the area of mangrove forest in Indonesia is about 3.2 million ha, distributed along the coastlines of Sumatra, Kalimantan, Sulawesi, Java, Bali, East Nusa Tenggara, and Papua. Within Indonesia, the southern coast of West Papua contains the largest continuous expanse of mangrove forest. There are approximately 60 species of trees and shrubs that constitute mangrove forest vegetation and more than 20 additional species that are mangrove associates. In addition, there are also more than 2,000 species of aquatic biota that depend on the existence of mangrove forests, including fish, invertebrates, and epiphytic plants [3]. One of the reasons that...
mangrove ecosystems are so unique is that they represent the connecting boundaries between terrestrial and marine ecosystems, thus strongly influencing biotic life processes in the regions where they occur [3].

The functions and benefits of mangrove forests for both the environment and for human livelihood are so significant that mangrove forests and their conservation are critically important issues being discussed and studied nationally and internationally. Mangrove forests play important roles in the ecology, socio-economics, and physical structure of areas where they occur. Mangrove forests also have several benefits, both direct and indirect. Direct benefits of mangrove forests include those that can be experienced by humans and is measurable, both in the form of products and services. Indirect benefits are often very difficult to measure and perceive, but those benefits actually have strategic value in supporting human life, such as benefits in research and education, germplasm sources, climate and hydrological, and others [4]. Direct benefits to humans provided by mangrove forests is what generally leads to their unsustainable exploitation. Such utilization, including illegal logging, and development for settlements or aquaculture, for example, that not consider the important ecological and physical functions of mangrove forests, lead to high levels of degradation worldwide. In recent decades, the pressure on mangrove forests has been tremendous and continues to increase, resulting in changes in land cover types and land use.

Mangrove has long been exploited in the majority of the countries where it grows. In a report titled "The World’s Mangroves 1980-2005", FAO stated that the world had lost about 3.6 million ha of mangroves since 1980, equivalent to a loss of 20% of the world's total mangrove area. In 1980, the area of mangrove forest in Indonesia totaled 4.2 million ha but decreased by about 17% in 1990 to 3.5 million ha. Declines of another 10% occurred by the year 2000, with only 3.15 million ha of mangrove forest remaining.

Anthropogenic factors have been identified as the main cause of mangrove forest degradation. Mangrove is a very important ecosystem but has been degraded due to natural factors and human activities such as urbanization, industrial development, agriculture, and aquaculture. The pressures of human activity on coastal ecosystems are often very high through land use conversion for aquaculture, agriculture, infrastructure and tourism development [1]. The change of mangrove forests to other uses has recently become a critical issue. The destruction of mangrove forests is mainly caused by human activities, so it must be controlled to minimize environmental damage.

Similar to trends worldwide, chronic degradation of mangrove forests in Southeast Sulawesi Province of Indonesia has occurred over decades and currently remains very high. Approximately 60-70% of the total historical area of mangrove forest in two districts in the province have been lost or severely degraded. The degradation of mangrove forests includes conversion into aquaculture ponds and human settlements, and extraction for firewood, industry, raw materials for furniture, and development of roads and ports [5].

Approximately 30% of mangrove forest in one district in Southeast Sulawesi, South Konawe, was degraded between 2009 and 2011 BPDAS Sampara (2009) BPS of Southeast Sulawesi Province (2011). Human population size of coastal areas of this district increased by 2.2–3.4% from 2011 to 2014. I was demonstrating the rapid development in this coastal area. As a result of increased human populations, the need for land for housing and livelihood will increase as well. The change of mangrove forests into human settlements and aquaculture ponds has been identified as the main cause of mangrove forest degradation in this part of Indonesia. The aim of this research was to quantify the pattern of spatial change of mangrove forests over three decades in this area.

2. Methodology

2.1. Study area
This research was conducted in Coastal Area of Konawe Selatan District (4° – 4°31’ S and 122° – 122°55’ E), Southeast Sulawesi Province, on March to July 2015. This area consists of 8 sub-districts,
namely Sub-district Tinanggea, Palangga Selatan, Laeya, Lainea, Kolono, Laonti, Moramo and Moramo Utara.

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 Ground Control Point (GCP); time series of Landsat imagery data such as Landsat-8 raw data full band 15m resolution in panchromatic and 30m resolution in multispectral recorded in the year 2014, Landsat7 ETM raw data full band 15m resolution in panchromatic and 30m resolution in multispectral recorded in the year 2003, Landsat5 TM raw data full band 15m resolution in panchromatic and 30m resolution in multispectral recorded in year 1993, and Landsat5 MSS raw data full band 30m resolution in multispectral recorded in year 1984, all imagery data series in path 112 row 63 and GeoTIFF format; thematic data such as road, river and coastline year 2009 in shapefile format obtained from Geospatial Information Agency of Indonesia; and literature.

2.3. Research procedures

2.3.1. Initial processing of satellite imagery. In this step included 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 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 approaches, such as digital classification and image transformation process conducted in this research. The nearest neighbor method used in the rectification process is 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 [6].

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 and Landsat-7 ETM multispectral channel which has a 30m spatial resolution with the panchromatic channel which has a 15m spatial resolution. The fusion process carried out with the aim to improve the quality of the 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.

2.3.2. Landuse mapping. Landuse data was generated through the processing of Landsat-8 satellite imagery and field survey. At first, the supervised classification digital feature extraction method used for landuse classification mapping. These procedures based on the spatial pattern recognition. Based on field knowledge, reclassified the results of the initial landuse classes were not as expected. These procedures also using landuse map year 2009 from Geospatial Information Agency as the class reference. Classes of landuse mapped in this research were forest, crop, mangrove, settlement, bush, aquaculture-ponds, open land and farm-field. Furthermore, the result used to be a reference of digital feature extraction for Landsat imagery in the previous year.

2.3.3. Survey. Field verification aims to correct the results of remote sensing data processing carried out in the laboratory. Field verification was done by the number of survey points (GCP) that correspond to the field conditions using the purposive sampling method (Figure. 1).
2.3.4. **Accuracy assessment.** Accuracy assessment aims to measure the validity of the thematic layer data to be accepted as an input parameter 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 GCPs. Accuracy assessment was done using both Confusion Matrix [7] and Kappa Index Method [6].

2.3.5. **Study the pattern of changes in mangrove forest.** Detection of changes was done by separating each class of landuse classification in different years, layer per layer. ESRI ArcMap software supports steps in this processing. This step is done to monitor changes that occur in mangrove forests at different times. Furthermore, the overlay technique is used to determine the area and extent of mangrove forest changes that occur and the pattern of mangrove conversion becomes another type of land use.

3. **Result and discussion**

3.1. **Accuracy assessment of landsat-8 image classification**

The accuracy test in this research used the distribution of 102 observation points of land cover in the field. In this identification and analysis, the suitability between observation points corresponding to on-site conditions and unsuitable observation points and falling on other land cover classes is shown in the Table 1.
Table 1. Confusion matrix of land use class interpretation from Landsat-8 imagery and Groud Control Points (GCPs)

| Landuse Class Interpretation from Landsat-8 Imagery Year 2014 | Ope n Land | Far m Field | Tota l |
|---------------------------------------------------------------|------------|-------------|--------|
| Ground Control Points                                         | 4          | 11          | 24     |
| Forest                                                        | 1          | 19          | 1      |
| Crop                                                         | 9          | 1           | 10     |
| Mangrove                                                     | 23         | 1           | 24     |
| Settlement                                                   | 1          | 1           | 1      |
| Bush                                                        | 6          | 1           | 7      |
| Aquaculture Ponds                                            | 14         | 1           | 15     |
| Open Land                                                    | 1          | 8           | 10     |
| Farm Field                                                   | 1          |             | 9      |
| Total                                                        | 4          | 11          | 24     |

The calculation of user accuracy of land cover in the overall category of land cover class was above the minimum acceptable tolerance of 80%. Therefore, the mapping result of this land cover can be accepted and in accordance with the conditions in the field. Kappa Index analysis result was in the range of values close to 1 with a positive value, indicating that the accuracy value obtained did not occur by chance (Table 2).

Table 2. The accuracy of landuse classification

| No. | Landuse Class | Producer Accuracy (%) | User Accuracy (%) |
|-----|---------------|-----------------------|-------------------|
| 1   | Forest        | 100.00                | 100.00            |
| 2   | Crop          | 81.82                 | 90.00             |
| 3   | Mangrove      | 95.83                 | 95.83             |
| 4   | Settlement    | 95.00                 | 82.61             |
| 5   | Bush          | 85.71                 | 85.71             |
| 6   | Aquaculture Ponds | 87.50            | 93.33             |
| 7   | Open Land     | 80.00                 | 80.00             |
| 8   | Farm Field    | 80.00                 | 88.89             |

| Overall Accuracy (%) | 89.22 |
| Kappa Index          | 0.87  |

3.2. Landuse class composition
The Analysis of the composition of land cover area in South Konawe Regency showed a decline of mangrove forest area by 15.47% per 10 years, characterized by mangrove forest degradation of 11.81% in between 1984 to 1993, then degradation increased by 22.51% in between 1993 to 2003 and although not as large as before but mangrove forest degradation persisted in the period 2003 to 2014 of 12.1%. Another land cover that also declined was forests, at 7.02% on average every 10 years from 1984 to 2014. In contrast, the composition of land cover for crop, settlement, aquaculture ponds and open land were identified having a significant increase, whereas the land cover area for the farm field only increased in between 1993 to 2003, and tended to remain within 2003 to 2014.
3.3. Pattern of Changes in Mangrove Forest

The average increase in land cover composition for mixed farms is 12.06% per 10 years. This is demonstrated by the increase in the area of farm field by 23.56% in between 1984 to 1993, further increasing in between 1993 to 2014 but not as big as 10 years earlier.

The settlement is also one of the land classes that experienced a significant increase of 81.58% per 10 years in the period of 1984 to 2014. The increase of settlement land in between 1984 to 1993 was 67% then increased very rapidly in the period of 1993 up to 2003 at 164%.

Land cover that also shows a major change is an aquaculture ponds area that has increased significantly by 568.29% per 10 years in the period of 1984 to 2014. The opening of a very large aquaculture ponds area occurred in the period of 1984 to 2003. Entering the year 2014, an increase reduces to about 45.34%.

Open land is included in one of the increasing land covers. In the period of 1984 to 1993 there has been an increase in open land area of 39.02% and increased rapidly between the years 1993 to 2003 of 60.9%.

In the beginning of the 1990s was a period of growth in the area of South Konawe District, it was the early process of expansion of the region, separated from Konawe Regency into the definitive region of South Konawe Regency. This condition led to rapid growth in the region in between 1990 to 2005. The rapidly growing residential area in between 1993 to 2003 showed this. Similarly, changes of land use from vegetation to open land also increased rapidly during the same period. The area of farm field and aquaculture ponds began to increase in the period of 1984 to 1993. This shows the large number of inhabitants entering the area. Human efforts to meet food needs encourage the opening of aquaculture ponds, crops and farm fields. This is reasonable given the enormous potential of natural resources owned by the newly developing areas at the time.

The identified land cover decreased during that time was forests and bush/shrubs, as well as mangrove forests. Those three types of land cover area are the most eligible land for settlement land and for business land such as crops, aquaculture ponds and farm fields. Some of the areas that had been cleared but not yet been processed were identified as an open land. In addition to the need for residential and business land, clearing of forest land and mangroves also aims to obtain raw materials in the manufacture of dwellings (houses), furniture and boats as one of the needs for marine fisheries business.

The pattern of changes in mangrove forest to another land cover classes can be seen in Table 3. In the period of 1984 to 1993, the area of mangrove forest converted to open land shows a very large value. There was a large of mangrove forest clearance reached 1.948.2 ha, but had not been processed for other uses. Mangrove forests converted into aquaculture ponds were about 458.43 ha, farm field 530.45 ha, bush/shrubs 384.82 ha and some 70.57 ha of mangrove forests converted into settlements.
However, there was a large additional area of new mangrove forest it was about 1,062.23 ha. In the period of 1993 to 2003, conversion of mangrove forests into aquaculture ponds increased very rapidly, equal to 2,394.20 ha. In the same period, conversion of mangrove forest into open land amounted to 556.21 ha, farm field 405.3 ha and settlement 252.9 ha.

| No. | Landuse Class | Area of Mangrove Change (ha) |
|-----|---------------|-----------------------------|
|     | Mangrove 1984 | Other Uses 1993 | Mangrove 1993 | Other Uses 2003 | Mangrove 2003 | Other Uses 2014 | Mangrove 2014 |
| 1   | 19,726.2      | 16,333.7       | 13,471.3       | 11,802.9       |
| 2   | 458.4         | 2,394.2        | 1,311.1        |
| 3   | 1,948.2       | 556.2          | 115.7          |
| 4   | 384.8         | 316.0          | 30.0           |
| 5   | 530.5         | 405.3          | 44.3           |
| 6   | 70.6          | 252.9          | 177.1          |
| 7   | 1,062.2       | 9.6            | 49.7           |

In the period of 2003 to 2014, the intensity of mangrove forest conversion began to show a declining trend. Nevertheless, the opening of aquaculture ponds through the conversion of mangrove forests was still high at about 1,311.07 ha, some of which were converted into settlement and open land. Currently, the issue is growing more towards land tenure conflicts. The data of Kecamatan in Figures 2014 published by National Land Agency mentioned the high area of unproductive land. In Moramo Sub-district, unproductive land was around 2,476 ha whereas the productive aquaculture ponds were only 87 ha. In Lainea Sub-district, the productive aquaculture ponds were about 21 ha whereas the unproductive land was about 3,430 ha. This indicated the condition of unproductive aquaculture ponds was very high, therefore the opening of aquaculture ponds was allegedly only a reason for the community to claim land ownership.

4. Conclusion
The pattern of spatial changes of mangrove forest in coastal area of South Konawe District in between 1980 to 1990 mostly converted to open land followed by farm-field and ponds cultivation. In 1990 to 2014 the change of mangrove forest increased very rapidly towards ponds cultivation, settlement and open land. Eventhough converted mangrove to open land become less, but ponds cultivation still high. We suggest that government should take action to increased enforcement of regulation and developing programs based on community around mangrove forest to protect the remaining population of mangrove.
References

[1] FAO 2017 *The World’s of Mangroves (1980 – 2005). A Thematic Study Prepared in the Framework of the Global Forest Resources Assessment 2005* (Food and Agriculture Organization)

[2] Spalding M, Blasco F and Field 1997 *World Mangrove Atlas. West Yorkshire: The International Society for Mangrove Ecosystems, The World Conservation Monitoring Centre, The International Timber Organization*. (Paris: UNEP)

[3] 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.)

[4] Kustanti 2011 *Manajemen Hutan Mangrove* (Bogor: IPB Press)

[5] Tenggara P P S 2014 *Rencana Strategis Wilayah Pesisir dan Pulau-Pulau Kecil Provinsi Sulawesi Tenggara Tahun 2014 – 2034* (Sulawesi Tenggara: Pemerintah Provinsi Sulawesi tenggara)

[6] Lillesand T M and Kiefer R . 1979 *Remote sensing and image interpretation. Remote sensing and image interpretation*. (Amerika serikat)

[7] Sutanto 2013 *Metode Penelitian Penginderaan Jauh* (Yogyakarta: Badan Penerbit Fakultas Geografi (BPFG))