Overview of National Thematic Data Integration (An Experience on One Map Mangrove Sulawesi)

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Abstract. Playing role as coastal shield with enormous economic value and ecological functions, mangrove forest management is always challenging to be studied. As either the largest archipelagic country or the largest mangrove forest habitat around the globe, Indonesia needs a national mangrove forest baseline data and its updating for coastal management. Many stakeholders and institutions, including Geospatial Information Agency (BIG), had conducted mangrove mapping and updating. However, in order to achieve one mangrove national data, coordination and synergy among stakeholders and institutions such as: the Ministry of Environment and Forestry as mangrove custodian, Indonesian National Institute of Aeronautics and Space, Ministry of Marine and Fisheries, and BIG aligned with the National Mangrove Working Group is needed. A fundamental step for national mangrove forest management is the establishment of National One Map Mangrove Program by means of coordination, synchronization, and integration of mangrove geospatial data from various stakeholders. This paper will discuss the technical process of data integration and field survey in order to produce One Map Mangrove Sulawesi with the same geo-reference, database, and also standard and specification. The result of One Map Mangrove Sulawesi Program comprises of information about mangrove current status, existing area, and its distribution in Sulawesi. Beside the geospatial data from Ministry of Environment and Forestry and other institutions, the primary data used to map mangrove forest in Sulawesi is SPOT 6 and SPOT 7 (year 2014 – 2015) imageries yielded map scale of 1: 25,000. On screen digitization using NIR, Red and Green bands and Normalized Difference Vegetation Index (NDVI) image transformation are applied for the initial canopy density classification. Field survey was done to obtain field data for vegetation analysis, image classification and interpretation. In 2015, the process of producing One Map Mangrove Sulawesi has been carried out. It was preceded by compiling geospatial data from BIG and other stakeholders. The integration process is based on national technical guidelines for mangrove mapping. Ground check also done by the One Map Mangrove team to ensure the accuracy and novelty of data. The result shows that Sulawesi Tenggara has the largest mangrove forest area, it is 62,446.4 ha, with a crown density dominance in rare class. This paper illustrating the process of One Map Mangrove Sulawesi, where data from the local stakeholders are accommodated properly.
1. Backgrounds

Found almost at any type of coastal line and providing a variety of ecological and economic functions, mangrove stands is an interesting subject to be studied. Mangrove also play role on supporting the economy of local communities living in coastal area. Mangrove contribute to environment protection as well as local economic value such as (1) coastal protection from disasters such as tsunami, wind and wave damage[1,2]; (2) a place to live for a variety of aquatic fauna, especially because of its function as spawning area, nursery, living habitat[3,4] and nutrient sources for organisms, and (3) tourism. Provision of seafood [5] as well as timber are those of economic value for the coastal communities[6]. Mangrove-based tourism destination began a lot to be encouraged, such as mangrove tourist areas in North Jakarta or Bali[7]. Mangrove's existence is very important and several of its aspects has been studied and reviewed, yet these have received much less publicity[8].

Polidoro et al. [9] revealed that the highest diversity of mangrove existed in the Indonesia - Malaysia - Philippines areas, which is about 50-60% of all types of mangrove species in the world are found in that region. However, this region also suffered high level of mangrove degradation since the 1980s - 2000s, particularly in Indonesia, with an estimated 25-30% [10,11]. In line with the FAO[12] which reveals that the rate of degradation of mangrove forests Asian region in the period 2005-2010 was 0.56%. Mangrove utilization as a source of timber and land cover change becoming the major cause of degradation[13]. Conversion of mangrove area into shrimp ponds, coastal tourism site, and also the settlements are the most[14]. It has struck the northern coast of Java in the 1990s where land conversion of mangrove often happens for shrimp farming and salt ponds. Other examples of world concern is the declining quality of the lagoon ecosystem Segara Anakan in Cilacap[15].

On 2009, Geospatial Information Agency (BIG) estimated the area of mangrove in Indonesia is to 3.2 million hectares [10]. The tendency to decline every year, where for 25 years (1980-2005) Indonesia has lost 30.1% or 1.3 million hectares of mangrove[11]. Those have made the importance of mangrove monitoring, both in terms of distribution, size, diversity and the current status of mangrove forest itself. In the era of geospatial information, the need for monitoring mangrove can be answered with a mangrove mapping technology that combines remote sensing and field surveys[16]. Remotely sensed data is one of the best source that can show the condition of mangrove forest, with many advantages such as synoptic coverage, provide information for inaccessible area, historical and near real time data [17–19].

Prior to the enactment of Act No. 4 of 2011 of Geospatial Information, various mangrove stakeholders in Indonesia issued the information of mangrove forest extent, causing on data discrepancies. This is describing on the difficulties on calculate the mangrove forests area accurately and could be agreed by all stakeholders. Referring to the national regulations on one spatial data, the entire mangrove stakeholders involved in KKMN initiate the process of unifying the mangrove thematic geospatial information. Both of central and local governments were also involved. Ministries or government agencies involved to perform these activities are Geospatial Information Agency (BIG), Ministry of Environment and Forestry, Ministry of Maritime Affairs and Fisheries. Also private stakeholders are involved, such as Wetlands International Indonesia and the Center for International Forestry Research (CIFOR).

The main purpose of this study is to describe the process of mangrove mapping and integration resulted in One Map Mangrove Sulawesi. Mapping method used in this paper is following the national regulation: Head of Indonesia Geospatial Information Agency Regulation No. 3 2014. This study used mid-resolution imagery and Normalized Difference Vegetation Index (NDVI) for mangrove canopy density interpretation. NDVI and simple image ratio between NIR and Red wavelengths can also be used to extract vegetation parameter and condition of the mangrove ecosystem[20]. There are several studies related to the delineation of mangrove area by using different imagery in Sulawesi[21–24]. Sulawesi is selected as one of islands that enriched by mangrove forest which is needed to be defined either per region or entirely. Furthermore, some mangrove areas in Sulawesi are belong to protected area, and
many of mangroves areas has been threatened by human[13], so that it needs to be monitored. In addition, One Map Mangrove Sulawesi is a significant way to support land management, spatial planning, rehabilitation, and monitoring of coastal area especially on mangrove forests existence.

2. Methodology
This study focused on the two processes of mangrove data integration. The main process of this study is mangrove mapping using remote sensing technology assisted with ground truth or mangrove validation. Second, data integration comprised of geospatial data compilation and synchronization. Geospatial mangrove data were collected from stakeholders, mainly from Ministry of Environment and Forestry and Geospatial Information Agency. Image interpretation method occupied in this study were varied depend on the image datasets condition. In general, there are two major image interpretation methods: visual and digital interpretation. Brief and clear workflow of the mangrove mapping in Sulawesi was depicted in Figure 1.

![Figure 1. Flowchart of Mangrove Mapping](image)

2.1. Study Area
Crossing the equatorial line, Sulawesi extends between the Wallace and Weber line that made it has several endemic flora and fauna. Administratively, Sulawesi divided into 6 provinces: Sulawesi Utara, Sulawesi Tengah, Gorontalo, Sulawesi Barat, Sulawesi Selatan and Sulawesi Tenggara (Figure 2). BIG has completed mangrove mapping process from 2014 to 2015.

Figure 2 shows the study area of mangrove mapping 2014 – 2015, scale of 1:25,000. Tan-yellow box revealed index where mapping has been done. It was based on the small-scale mangrove mapping for whole Indonesia in 2009[10]. The first phase of mid-scale mapping in 2014, it was completed northern part of Sulawesi (Sulawesi Selatan, Gorontalo, and Sulawesi Tengah province), while the rest were done in 2015.
2.2 Materials and Methods
Base map used for image geo-rectification was Indonesia topographic map scale of 1:25,000. Satellite images used in this study are (Table 1):

Table 1. Imagery for Mangrove Mapping

| Year | Images                  | Acquisition date | Spatial Resolution | Analysis         |
|------|-------------------------|-------------------|--------------------|------------------|
| 2014 | SPOT 5/6                | October – December 2013 | 10 m; 5 m        | Visual interpretation |
|      | RGB Composite          |                   |                   |                  |
|      | ALOS RGB Composite     | 2011 - 2013       | 6 m; 1.5 m        |                  |
|      | Landsat 8               |                   | 10 m              | NDVI             |
|      |                        |                   |                   |                  |
| 2015 | SPOT 5                 | June 2014         | 30 m; 15 m        | NDVI             |
|      | SPOT 6/7               | November 2013     | 6 m; 1.5 m        | Visual interpretation |
|      | ALOS RGB Composite     | Early 2015        | 10 m              | NDVI             |
|      | Landsat 8               | 2011 – 2013       |                   | Visual interpretation |
|      |                        | August 2015       | 30 m; 15 m        | NDVI             |

2.3 Image interpretation
Various data were used to complete the task (Table 1). Satellite imageries used based respectively on priority are: ALOS, SPOT 5/6/7, and Landsat 8. They are considered based on acquisition date, spatial resolution, cloud coverage, condition, and the availability of each image. This step was done to maintain...
the output scale of 1:25,000. However, from all the data, there were some drawbacks found, so that each type of image is used to cover up the shortcomings from another image.

Combination of Green – Red – NIR bands were used for on-screen digitation to determine the polygon of mangrove areas, carried out by referring to the result of preliminary study. In addition, delineation of mangrove extent and canopy density classes takes the advantages of hi-res imagery such as: SPOT 6/7. Using enhanced true and false color composite, canopy density classes can be easily differentiated. On the other hand, in order to classify canopy density using medium resolution imageries such as: Landsat and ALOS, digital interpretation using NDVI transformation (Eq. 1) were implemented[25].

Classification of canopy density referred to the national standard for Mangrove Surveying and Mapping (SNI 7717: 2011) scale of 1:25,000. The canopy density classes would be: high density, dense, medium, rare, and very rare. The result from image interpretation process becomes the main information to organize field survey, combined with the previous information from local people collected in pre-survey.

NDVI image transformation:

\[
NDVI = \frac{\text{Band (NIR)} - \text{Band (R)}}{\text{Band (NIR)} + \text{Band (R)}}
\]  

(1)

Where:
- NIR : Near Infrared
- R : (visible) Red
- Range of NDVI : -1 to 1

2.4 Field survey
The field survey was conducted for data retrieval in the sample points/ polygons that have been determined. To-do-list in field survey consists of first; validation form of existing mangrove. It is needed to verify the results of image interpretation especially in not-so-good image quality due to cloud existence or other disturbance. Second, inventory of mangrove stand parameters to determine: canopy density, density of trees, value index and mangrove species (dominance). Third, fish eye lens were used to get 180° view of canopy. Lastly, secondary data collection to complete the information of mangrove areas.

Each sampling plot size of 10 x 10 m² were carried out along the coastal line (Figure 1), distributed up to 2 PS in each index box, resulted in 615 PS for total 438 mapping index at Sulawesi (Table 2). The number of PS was determined by considering the mangrove extent and canopy density classification, occupying stratified random sampling method. For canopy density and species dominancy also acquired in TS. It also used to test the accuracy mapping result.

Table 2. Mapping index and number of samples

| Year | Σ Index | Areas/ Province                  | Number of PS | Number of TS |
|------|---------|----------------------------------|--------------|--------------|
| 2014 | 209 NLP | Sulawesi Selatan, Gorontalo,     | 315          | 210          |
|      |         | Sulawesi Tengah                  |              |              |
| 2015 | 229 NLP | Sulawesi Barat, Sulawesi Selatan,| 300          | 200          |
|      |         | Sulawesi Tenggara                |              |              |
Two sampling types were held in every index, Plot Sample (PS) and Point Sample (TS). Inside the Plot Sample box, data inventory for trees (10 x 10 m), saplings (5 x 5 m), and seedlings (1 x 1m) were conducted while land use/land cover was observed in TS sampling type. Illustration of sampling types design was presented on Figure 3 below:

![Figure 3. Plot Sample (left) and Point Sample (right)](image)

2.5 Accuracy assessment

Image interpretation process resulted in two kind of maps. Firstly, land cover map which shows land cover class around mangrove forest area. This map explained that there are always other land cover existed surrounding mangrove forest area. In addition, interpreting mangrove will not always result in high classification accuracy in mangrove class, there are miss interpretations caused by the old image acquisition dates which is not relevant with the actual land cover condition. Second, canopy density map that shows classification of mangrove canopy density. After land cover map near mangrove forest area had been yielded, mangrove canopy density map was produced. Accuracy assessment of image interpretation was done using matrix accuracy developed by Short in 1982. Based on it, the overall accuracy can be calculated using a simple formula as follows:

$$Overall\ Accuracy = \left( \frac{\sum_{i=1}^{r} X_{ii}}{N} \right) \times 100\%$$  \hspace{1cm} (2)

Where:

$$X_{ii} =\text{diagonal matrix}$$

$$N = \text{sample}$$

2.6 One Map Preparation

It started with many mangrove mapping activities organized by institutions, one map is aimed to integrate mangrove maps so that there is a single dataset that can be used by all institutions in mangrove resource management\cite{26}. First step on one map preparation started with data compilation from various institutions in a National Working Group of Mangrove (KKMN). Data that use to produce one map mangrove are form Geospatial Information Agency (BIG), Ministry of Environment and Forestry Affairs, Ministry of Marine and Fisheries Affairs, and other institutions such as Wetlands.

Determining standard and specification becoming the next phase to achieve One Map. Referred to standard Act 4/2011 about Geospatial Information, where thematic geospatial information must refer to base geospatial information, base geospatial information are vertical and horizontal geodetic control, bathymetric maps and topographic maps. Standard DGN-95/WGS-84 also implemented. Standard DGN-95 is single reference in organize geospatial information in Indonesia, this standard used ellipsoid World Geodetic System 1984 (WGS-84).
Continued with integration spatial and attribute data, where these must be synchronized in order to join. Data integration stage is the stage of aggregation of data multiple data sources to produce a similar information of completeness, accuracy, scale and format data. The data which has integrated later verified. After joining the data, maps compiled become temporary one map for verification and ground check. Areas that reveal doubts, uncertainties and possibility of land changing into one of the groundcheck target, still local institutions were involved. Steps of one map mangrove depicted in Figure 4.

3. Result and Discussion

3.1 Mangrove map of Sulawesi

Unlike mangrove forest ecosystem in Java Island, mangrove forest ecosystem in Sulawesi is featured by narrow habitat area. In addition, geomorphologic condition of river and coastal area in Sulawesi support mangrove grow even denser than in Java Island. However, the important thing influencing mangrove forest condition in Sulawesi is population and development growth which is not as faster as Java. However, indication of mangrove degradation and deforestation in Sulawesi caused by population and local development growth also caught many researchers’ attentions. One thing characterizes mangrove Sulawesi is there are many of mangrove forest grows well in small islands.

Figure 9 (a) showed the mapping results throughout the years 2014 - 2015, mangrove’s extents sequentially to the six provinces are 10,182.38 ha in Sulawesi Utara, 26,235.67 ha in Sulawesi Tengah, 7,918.58 ha in Gorontalo, 3,717.72 ha in Sulawesi Barat, 10,403.70 ha in Sulawesi Selatan, and which has the largest area that is 62,426.42 ha in Sulawesi Tenggara (Table 4). Digital image interpretation using NDVI for obtaining themangrove canopy density classification were carried out, mostly in 2014 using Landsat 8, and for 2015 using SPOT 6/7 and Landsat 8. Both results were crosschecked with the real condition at field. The rare canopy density class was dominantly appeared in Sulawesi. Sequentially it was dominated in Sulawesi Tenggara (25,990.77 ha), Sulawesi Utara (6,065.39 ha), and Sulawesi Selatan (3,063.30 ha). Medium canopy density class (4,661.16 ha) dominated in Gorontalo and Sulawesi Tengah (10,416.87 ha), while dense canopy density dominated in Sulawesi Barat (1,786.06 ha). In general, Rhizophora and Bruguiera dominated almost throughout mangrove areas of Sulawesi. Overall accuracy both for land cover near mangrove forest area and mangrove canopy density are shown in Table 3. Overall accuracy for both results are above 85%.
Table 3. Overall accuracy (%) for land cover and canopy density interpretation

|                  | Land cover | Canopy Density |
|------------------|------------|----------------|
| Sulawesi Utara   | 88-95.83%  | 86-88.07%      |
| Sulawesi Tengah  |            |                |
| Gorontalo        |            |                |
| Sulawesi Barat   | 98.81%     | 86.93%         |
| Sulawesi Selatan |            |                |
| Sulawesi Tenggara|            |                |

The overall accuracy both for coverage area and to NDVI interpretation are above 85%. Several reasons based on the steps on mapping process could probably be the reason.

1. Variations of imagery. Interpretation of land cover in 2014-2015 used the medium-to-high resolution imagery, so the appearance is quite clear to distinguish mangrove and non-mangrove. The average image used for the delineation of the boundaries (or class mangrove NDVI) has fairly good resolution as SPOT 6/7, SPOT 5 or ALOS, and the lowest was Landsat 8 (as complementary), so that the delineation of the boundary can be corrected through visual interpretation from the image.

2. The imagery used was relatively new. As seen in Table 2 that averagely the data were obtained in less than one year from the time of mapping process. In particular Landsat 8 acquisition date was the closest.

3. The plot sample (PS) position on field survey. The accuracy of canopy density could be affected by sampling. As has been done, the determination of the sample taken at the middle of the polygons interpreted as mangrove where the NDVI values tend to be homogeneous.

4. Delineation process shall refer to a lot of the imagery available. The process is carried back and forth between the main image and the supporting image. For the NDVI, the result was crosschecked with the green band.

3.2 One Map Mangrove Sulawesi

One Map is needed due to problems found in mangrove maps from institutions. Remotely sensed data as the common data for mangrove mapping have many resolutions. From mid-resolution imagery such as Landsat 8, which is adequate to give information of mangrove area and also canopy density, to high resolution imagery from SPOT 6 or SPOT 7[28,29]. Therefore, map with various scale were produced depending on the imagery. Difference georeferenced system also evokes data discrepancies. Last but not least, area coverage in mapping of mangrove. Figure 5 displays the problems found at the compilation stage of One Map Mangrove Sulawesi. In the first step, Mangrove map from BIG were compiled with other mangrove map from Ministry of Environment and Forestry Affairs, Ministry of Marine and Fisheries Affairs, and BPDAAS as representation of local institution. Compiled data were crosscheck with the information from local knowledge. Not only the spatial aspects but also attribute data must be synchronized in order to enable join process. As it seen at Figure 5(b), where attribute tables from different institutions different fields.
Figure 5. Data discrepancies due to differences of (a) mapping area coverage and (b) imagery.

Figure 6. Distribution of survey plot by BIG (2014 – 2015) and ground check position by National Working Group of Mangrove (2015). Ground check for One Map Mangrove Sulawesi was done at October - November 2015, while field survey conducted by BIG was on October – November 2015 and September 2014.
Areas with uncertainty of mangrove availability become a priority as ground check location. Further, areas where found only on one source of map need to validate, so that it was considered as ground check location. In spite of the time of mangrove mapping by BIG were organized in 2014 – 2015, survey did not cover all area and imagery that used as primary data for mapping were coming from various years between 2011-2015. Therefore, some of them need to be validated. On One Map Mangrove Sulawesi, ground check location carried out in different position with survey plot conducted by BIG in 2014-2015, but several locations was nearby (Figure 6). All processes in composing One Map Mangrove Sulawesi were depicted in Figure 7.

![Figure 7. Scheme on composing One Map Mangrove Sulawesi](image)

Ground check were done not only to verify the data that have been collected, but also to check the delineation area as mangrove from the satellite image, since land conversion still becoming the main issues happened at mangrove areas. Groundcheck results diversify the condition of mangroves, particularly related community activities. In Buloa, Tallo–Sulawesi Selatan, the mangrove area has been slowly switching its function into garbage dump. Different from the area of Takalar - Jeneponto and Ujung Loe - Bulukumba, where mangrove exist as border from shoreline and river. At these locations, people have been aware of the importance of mangroves for coastal protection from abrasion. The presence of mangroves in addition to natural growth, also planted by civil society and through the rehabilitation program lead by Ministry of Environment and Forestry named Kebun Bibit Rakyat in 2014 (Figure 8). Information collected from ground check were used as guidance in data editing, as well as newest imagery available for such area.
Figure 8. Ground check in 2015, located in Sulawesi Selatan

BIG and other institutions have different area coverage on mapping, therefore One Map accommodate new information from other institution especially from local knowledge. Result in Figure 9 showed the differences area coverage of mangrove mapping. Mangrove areas from small islands such as Banggai and Sangihe – Talaud Islands were added into One Map Mangrove. In mainland, information of mangrove areas around Donggala – Palu region were also added. Addition of mangrove areas on hectares from each province as result of one map process revealed in Table 4. It showed that mangrove map from BIG is accommodated as part of One Map Mangrove Sulawesi, and involvement of many stakeholders completed the information.
4. Conclusions
In 2014 and 2015, BIG has completed mangrove mapping project at scale of 1:25.000. Field survey was carried out not only in the coastal of Sulawesi mainland, but also several small islands surround it. Using combination of ALOS – SPOT 5/6/7 – Landsat 8 imagery, mangrove extent was obtained for all parts of Sulawesi. Mangrove area in Sulawesi Barat, Gorontalo, Sulawesi Utara, Sulawesi Selatan, Sulawesi Tengah, and Sulawesi Tenggara yielded sequentially from the smallest to the largest between 3,717.72 and 62,426.42 ha. *Bruguiera sp.* and *Rhizophora sp.* becoming dominant species in Sulawesi. Rare canopy density of mangrove dominated in Sulawesi Utara (59.57%), Sulawesi Tenggara (41.63%), and Sulawesi Selatan (29.44%). Sulawesi Barat was dominated with dense canopy density area of mangrove (48.04%), while medium canopy density dominated in Sulawesi Tengah (39.71%) and Gorontalo (58.86%).

|                | BIG (ha)     | One Map (ha) |
|----------------|--------------|--------------|
| Sulawesi Utara | 10,182.38    | 11,884.75    |
| Sulawesi Tengah| 26,235.67    | 33,538.95    |
| Gorontalo      | 7,918.58     | 8,006.31     |
| Sulawesi Barat | 3,717.72     | 3,720.00     |
| Sulawesi Selatan | 10,403.70 | 10,412.00    |
| Sulawesi Tenggara | 62,426.42 | 62,446.83    |

Table 4. Increasing of mangrove areas in Sulawesi as result of One Map Mangrove Sulawesi
The result of mangrove mapping 2014 - 2015 became the primary data on composing One Map Mangrove in 2015. In the process of composing, local and central institutions giving contribution on spatial data of mangrove from previous activity. Two steps of ground check were implemented for this study for validation. First, field survey was held for validation based on information from remote sensing data and interpreter, and the second was based on local knowledge. However, without prejudicing the advantages from the first field survey, ground check for One Map Mangrove are more reliable for yielding the updated information by involving local knowledge.

Mangrove mapping in Sulawesi which performed by BIG still relatively new, but through the process of One Map, by merging data and groundcheck, mapping results can be further refined, it can be seen from the addition of mangrove area in all provinces of Sulawesi around 2.28 – 7,303.28 ha. The largest one is for Central Sulawesi. Based on the survey results and groundcheck by KKMN team, found the tendency of mangrove land conversion into the pond, despite there also found the initiation of mangrove planting activities through local government and community.

One Map Mangrove resulted from collaborative works between governmental institutions (both central and local) and non-government organization. One map is an action to avoid ambiguity among users about the data. Technically to avoid redundancy and also increasing the contribution among stakeholders in composing one spatial information.

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References
[1] Danielsen F, Sørensen MK, Olwig MF, Selvam V, Parish F, Burgess ND, et al. 2005 The Asian Tsunami: A Protective Role for Coastal Vegetation Science 310 643. Available from: www.sciencemag.org/cgi/content/full/310/5748/643/ DC1
[2] Yanagisawa H, Koshimura S, Miyag T, Imamura F 2010 Tsunami damage reduction performance of a mangrove forest in Banda Aceh, Indonesia inferred from field data and a numerical model J Geophys. Res. Ocean 115(6) 1–11.
[3] Kuenzer C, Bluemel A, Gebhardt S, Quoc TV, Dech S 2011 Remote sensing of mangrove ecosystems: A review Remote Sens.3(5) 878–928.
[4] Nagelkerken I, Blaber SJM, Bouillon S, Green P, Haywood M, Kirton LG, et al. 2008 The habitat function of mangroves for terrestrial and marine fauna: A review Aquatic Botany 89:155–85.
[5] Rönnbäck P 1999 The ecological basis for economic value of seafood production supported by mangrove ecosystems. Ecol Econ 29(2)235–52.
[6] Walters BB 2005 Ecological effects of small-scale cutting of Philippine mangrove forests. For Ecol Manage206(1–3)331–48.
[7] Fitriana YR 2005 Diversity and abundance of macrozoobenthos in mangrove rehabilitation forest in Great Garden Forest Ngurah Rai Bali Biodiversitas7(1)67–72.Available from: http://biodiversitas.mipa.uns.ac.id/D/D0701/D070117.pdf
[8] Valiela I, Bowen JL, York JK 2001 Mangrove Forests: One of the World’s Threatened Major Tropical Environments Bioscience 51(10) 807-15. Available from:http://bioscience.oxfordjournals.org/
[9] Polidoro BA, Carpenter KE, Collins L, Duke NC, Ellison AM, Ellison JC, et al 2010 The loss of species: Mangrove extinction risk and geographic areas of global concern. *PLoS One* **5**(4) e10095

[10] Hartini S, Saputro GB, Yulianto M, Suprajaka 2010 Assessing the used of remotely sensed data for mapping mangroves Indonesia 10th WSEAS/IASME Int. Conf. on Electric Power Systems, *High Voltages, Electric Machines* p 210–5.

[11] FAO 2007 The world’s mangroves 1980-2005. FAO *For Pap*;153 89.

[12] Giri C, Ochieng E, Tieszen LL, Zhu Z, Singh A, Loveland T, et al 2011 Status and distribution of mangrove forests of the world using earth observation satellite data. *Glob. Ecol. Biogeogr.* **20**(1)154–9.

[13] Nurkin B 1994. Degradation of mangrove forests in South Sulawesi, Indonesia. *Hydrobiologia* **285**(1–3)271–6.

[14] Thu PM, Populus J 2007. Status and changes of mangrove forest in Mekong Delta: Case study in Tra Vinh, Vietnam. *Estuar. Coast. Shelf Sci.* **71**(1–2)98–109.

[15] Jennerjahn TC, Yuwono E 2009. Segara Anakan, Java, Indonesia, a mangrove-fringed coastal lagoon affected by human activities. *Reg. Environ. Chang.* **9**(4)231–3.

[16] Satyanarayana B, Idris IF, Mohamad KA, Husain ML, Shazili NAM, Dahdouh-Guebas F 2010. Mangrove species distribution and abundance in relation to local environmental settings: A case-study at Tumpat, Kelantan Delta, east coast of peninsular Malaysia. *Bot Mar* **53**(1)79–88.

[17] Ibharim NA, Mustapha MA, Lihan T, Mazlan AG 2015 Mapping mangrove changes in the Matang Mangrove Forest using multi temporal satellite imageries. *Ocean Coast Manag.* **114**64–76.

[18] Long JB, Giri C 2011 Mapping the Philippines’ mangrove forests using Landsat imagery. *Sensors* **11**(3)2972–81.

[19] Agris RAALM, Arreto RAB 2010. Mapping and assessment of protection of mangrove habitats in Brazil *PANAMJAS* **5**(Ong 1995)546–56.

[20] Sari SP, Rosalina D. Mapping and monitoring of mangrove density changes on tin mining area. 2016;33:436–42.

[21] AS Akbar M, Saleh B, Nurdin N, Sofian I 2015 Cellular automata-markov model of vegetation cover changes on a small island spemeronde archipelago , *Indonesia 36th Asian Conf. on Remote Sensing 2015 (ACRS 2015): Fostering Resilient Growth in Asia* p 451- 64

[22] Laremba S 2014 Sebaran dan kerapatan mangrove di teluk Kota Kendari, Sulawesi Tenggara[Undergarduate theses of Hasanuddin University, Makasar]

[23] Jamili, Setiadi D, Qayim I, Guhardja E 2009 Struktur dan komposisi mangrove di Pulau Kaledupa Taman Nasional Wakatobi , Sulawesi Tenggara *Ilmu Kelautan* **14**(4)197–206.

[24] Arfan A, Toriman ME, Maru R, Nyompa S, Uca 2015 Reflectance Characteristic of Mangrove Species using Spectroradiometer HR-1024 in Suppa Coast , Pinrang , South Sulawesi , Indonesia *Asian J. of App. Sci.* **3**(5)642–8.

[25] Pastor-Guzman J, Atkinson PM, Dash J, Rioja-Nieto R 2015 Spatiotemporal variation in mangrove chlorophyll concentration using Landsat 8 *Remote Sens* **7**(11)14530–58.

[26] Pramono GH, Wijaya W S, Nurwadjedi 2014. Analisis Sebaran dan Kerapatan Mangrove Menggunakan Citra Landsat 8 di Segara Anakan, Cilacap *Semin. Nas. Penginderaan Jauh* p 232–41.

[27] Jhonnerie, R 2015 Klasifikasi Mangrove Berbasis Objek dan Pikscl Menggunakan Citra Satelit Multispektal di Sungai Kembung, Provinsi Riau [Theses of Institut Pertanian Bogor] 86p.

[28] Vetrita Y, Suwarsono SP 2014 Pemanfaatan penginderaan jauh untuk pemantauan lingkungan...
mangrove Bunga Rampai Pemanfaatan Penginderaan Jauh untuk Pemantauan, Deteksi, dan Kajian Lingkungan. edB Hasyim et al (Bogor: Crestpent Press) page 77-86.