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Increase in Mangrove Area on the North Coast of Central Java Analyzed Using Geospatial Based Approach

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ABSTRACT

Mangrove community has essential benefits to human-beings and other living creatures since it has physical, biological, social and economic functions. Now-a-days, the mangrove area tends to decrease due to land conversion by anthropogenic activities. The purpose of this study was to evaluate the extent of mangrove land on the north coast of Central Java, based on the geospatial analysis approach using Landsat 8 satellite imagery. The results of the measurement of the mangroves community area on the north shore of Central Java in 2014 showed an increase of 2,922.76 ha or 118.89% for three years. A significant increase was due to the absence of detection of mangrove areas in embankment ponds by previous studies. Also, it was due to increasing mangrove vegetation rehabilitation activities on the north coast of Central Java, as well as the natural mangrove development of secondary succession over three years (from 2011-14). The field survey encountered 22 mangrove species growing on the north coast of Central Java, where *Avicennia marina* and *Rhizophora mucronata* dominated all research sites. Based on the rejuvenation category, the mangrove sapling category dominated Brebes Regency, Kendal Regency having the highest density of seedling mangrove, and the tree mangrove category met plentiful in Rembang Regency.

Key words : Mangrove, area, species, density, north coast of Central Java, Landsat 8

INTRODUCTION

Mangrove forests are typical forests along the coast and river estuary and are affected by tides and grow on sheltered or flat beaches. Mangrove swamps have three main functions i. e. physical, biological and economic roles (Lee *et al.*, 2014). They also possess essential values against the community, economy and environment (Li *et al.*, 2019). The physical purpose of mangroves is as a windbreak, protects and stabilizes the shoreline and decreases coastal erosion (Sari and Rosalina, 2016), protects from waves, flood control and prevention of seawater intrusion to the mainland (Hilmi *et al.*, 2017), and filters pollutants (Martuti *et al.*, 2016a, b, 2017). The biological function is as a spawning ground, nursery ground, and as a feeding ground for fish and other marine biotas (Blum and Herr, 2017). The financial service is a producer of wood for raw materials and building materials, food materials and medicines (Sarhan and Tawfik, 2018; Marlianingrum *et al.*, 2019). Also, this function is strategic as a primary producer capable of supporting and stabilizing both marine and terrestrial ecosystems (Lee *et al.*, 2014; Li *et al.*, 2019).

Until now, data on the mangrove area on the north coast of Central Java are still equivocal. Besides, data from several studies generally presented data of the mangrove area partially, from one region to another (Agungguratno and Darwanto, 2016; Nugraha *et al.*, 2018). There were unavailable entire data published for the extent of mangroves community on the north coast of Central Java. Therefore, it was essential to conduct studies to provide data on the mangrove area for the overall region. The present study was done for measuring of mangrove areas on all regencies of the north coast of Central Java by employing geospatial methods as a tool for in-depth mangrove areas analysis so hopefully, the accurate data could be acquired.

The objectives of this study were to provide updated information on the extent of mangrove ecosystems and inventory of mangrove species

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observed in coastal areas at each regency/city on the north coast of Central Java. Data and information from this study were supposed to be able to provide technical input for the government in implementing mangrove rehabilitation in Central Java.

MATERIALS AND METHODS

The extent of the mangrove ecosystem was conducted by using a satellite image of Landsat 8 with a spatial resolution of 15 meters in 2014, which covered the entire north coast area of Central Java. Coastal area of north coast of Central Java was swept away by satellite imagery of Landsat 8 Path/Row : 121/065 on 2 June 2014 for the western region, Path/Row : 120/065 on 10 May 2014 for the central area, Path/Row : 119/065 20 June 2014 for the eastern part, and a small portion of Path/Row : 120/064 26 May 2014 for the Jepara region. Landsat 8 satellite imagery was processed using ER Mapper Ver. 7.0, and the mangrove area was analyzed by a visual digitization method using Arc GIS 10.1 software. A field survey was applied to verify the results of satellite interpretations and to collect primary and secondary data. Arrangement of sampling stations used the transect line plot method, where one plot was 10 x 10 m^2 in size (Sari and Rosalina, 2016). Data were collected from two plot areas, where the first plot started from the mangrove area close to the inland and continued towards the coast. Inventarisation of mangrove species and calculation of the number of trees, saplings and seedlings were by combining the mangrove vegetation in the plot one by one. The grouping was by measuring the diameter and height of each mangrove tree trunk. Furthermore, mangrove plants were categorized into trees, seedlings and saplings. The classification used for mangrove rejuvenation was : *Seedling*, ranging from sprouts to sapling (≤ 1 m); *Sapling*, with a height of > 1 m and a diameter of < 4 cm and *Tree*, with a height of > 1 m and a diameter of > 4 cm. A sampling of leaves, flowers and fruit of mangroves was done for documentation and identification based on BP Berau-IPB (2015) and Tomlinson (2016). All mangrove individuals in the plot were recorded in their species, counted its numbers (trees, saplings and seedlings). The density of mangrove vegetation was calculated as the number of individuals per unit area (Sari and Rosalina, 2016). Data on the extent and density of mangrove were analyzed descriptively.

RESULTS AND DISCUSSION

Mapping the condition of mangroves used four scenes of Landsat satellite imagery in 2014, which covered the entire north coast region of Central Java with a spatial resolution of 15 meters, and the cloud cover less than 5%. The coverage of the Landsat 8 satellite imagery is shown in Fig. 1. Mangroves can be well recognized visually on RGB 564 composites on Landsat 8 images due to the SWIR wavelength, reflecting values will be lower in wetter soil areas caused by tidal inundation, which was, in fact, a habitat for mangrove vegetation. Reflection differences were discerned visually in channel 5, where the mangrove area had a lower value than the non-mangrove vegetation area. In contrast, the reflection on channel 4, which was associated with leaf chlorophyll content, was not much different. It was due to the tidal effect in the intertidal region, which characterized the typical soil types affecting the reflectance of the plant community spectral.

Fig. 1. Landsat 8 satellite images of 2014 covered the entire north coast region of Central Java.

By utilizing the display of False Colour in a combination of channels (5, 6 and 4) Landsat 8 with the application of RGB (Red Green Blue), clearly visible differences in mangrove vegetation with other non-mangrove objects, making it easier to carry out visual analysis (digitization on screen) by using Arc GIS 10.1. The visual appearance of mangrove vegetation on Landsat 8 by utilizing a combination of RGB 564 channels is visible in Fig. 2.

Fig. 2 shows the differences between mangrove vegetation on the coast as well as in pond embankments. Based on this appearance, the digitization of mangrove distribution on the

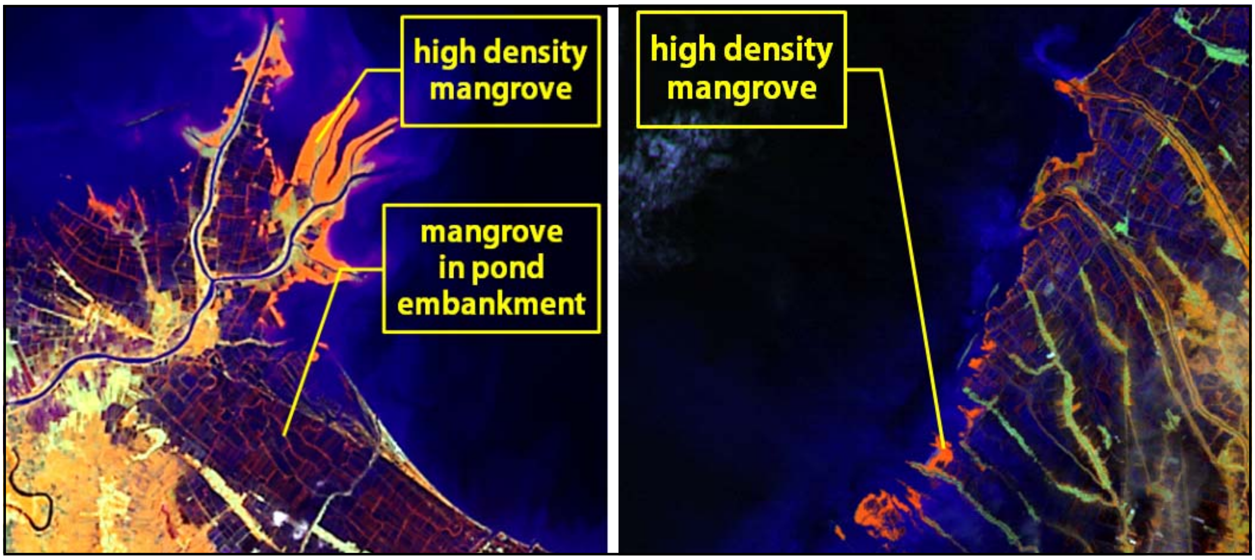

Fig. 2. Mangrove display on RGB 5-6-4 Landsat 8 differentiates among mangroves community and non-mangrove vegetation so that the mangrove area can be measured.

north shore of Central Java was then done on-screen digitation by using Arc GIS 10.1. A ground check was carried out to verify the existing condition of the mangroves at selected locations. The selected survey sites were Rembang Regency (Eastern region), Demak and Kendal Regency (Middle region), and Brebes Regency (Western part). Identification and processing of Landsat 8 satellite imagery in May and June 2014, as well as field surveys in selected locations, resulted in measuring the width of mangrove ecosystems on the north coast of Central Java.

According to Table 1, Demak Regency had the largest mangrove ecosystem (2,176.78 ha) or about 40.45% of the total mangrove area on the north coast of Central Java. Subsequently, it was followed by Brebes Regency with mangrove area 1,179.01 ha (21.91%), Kendal Regency with area 385.38 ha (7.16%), Pati Regency with area 348.18 ha (6.57%), Jepara Regency with area 346.05 ha (6.43%), Pemalang Regency with area 314.5 ha (5.84%), Semarang City with 242 ha (4.5%), Rembang Regency with an area of 112.71 ha (2.09%), Pekalongan Regency with an area of 74.44 ha (1.38%), Batang Regency with an area of 68.3 ha (1.27%), Tegal City with an area of 53.39 ha (0.99%), Tegal Regency with an area of 48.75 ha (0.91%), and Pekalongan city with an area of 31.66 ha (0.59%).

Based on the reports of the identification of damage and rehabilitation plan of mangrove forest on the north coast of Central Java 2011, the mangrove area in this region was 2,458.39 ha (Marine Affairs and Fisheries Agency of Central Java Province, 2011). While the result of the geospatial analysis in 2014 (present study) was 5,381.15 ha. Thus, there was an increase in mangrove ecosystem area of 2,922.76 ha or 118.89%. The lower mangrove extent reported by the previous study was due to many mangrove areas in the embankment ponds that were not detected by digital processing in 2011. Moreover, the period from 2011 to 2014 had been encouraging the rehabilitation mangrove areas by the Government and some communities. Also, there was growth and development of mangrove seedlings during secondary succession in the north of Central Java during this period.

Following the Law of the Republic of Indonesia Number 1 of 2014, concerning the coastal green belt; it was at least 100 meters wide from the highest tide point, perpendicular towards the land. Based on geospatial analysis, the area of the coastal border on the north coast of Central Java was 4,552.78 ha. Meanwhile, the extent of mangrove ecosystems in that region was 5,381.15 ha. Regardless of the spacious distribution at each location, the mangrove ecosystem area on the north coast of Central Java was still adequate to serve as a beach belt. However, the majority of mangrove ecosystems on the north shore of Central Java grew in embankment ponds. Hence, it was necessary to rehabilitate mangroves with priority replanting on the shoreline area so it functioned

Table 1. Area of mangrove ecosystems in the north coast of Central Java in 2014 based on processing of Landsat Satellite Imagery 8 in May and June 2014

S. No.	Regency	Prefecture	Mangrove area (ha)	Percentage
1.	Brebes	1. Brebes	717.90	13.34
		2. Bulakamba	94.12	1.75
		3. Losari	210.28	3.91
		4. Tanjung	73.97	1.37
		5. Wanasari	82.74	1.54
	Amount		**1,179.02**	**21.91**
2.	Tegal City	1. Tegal Barat	26.43	0.49
		2. Tegal Timur	26.96	0.50
	Amount		**53.39**	**0.99**
3.	Tegal	1. Kramat	48.75	0.91
4.	Pemalang	1. Ulujami	309.97	5.76
		2. Petarukan	4.53	0.08
	Amount		**314.60**	**5.84**
5.	Pekalongan	1. Sragi	1.16	0.02
		2. Tirto	5.23	0.10
		3. Wiradesa	68.05	1.26
	Amount		**74.44**	**1.38**
6.	Pekalongan City	1. Pekalongan	31.66	0.59
7.	Batang	1. Batang	3.4	0.06
		2. Gringsing	20.1	0.37
		3. Rowosari	31.3	0.58
		4. Tulis	13.5	0.25
	Amount		**68.31**	**1.27**
8.	Kendal	1. Brangsong	9.75	0.18
		2. Cepiring	41.40	0.77
		3. Kaliwungu	119.33	2.22
		4. Kota Kendal	39.93	0.74
		5. Patebon	174.97	3.25
	Amount		**384.59**	**7.16**
9.	Kota Semarang	1. Genuk	41.23	0.77
		2. West Semarang	16.96	0.32
		3. Tugu	183.81	3.42
	Amount		**241.99**	**4.50**
10.	Demak	1. Bonang	314.06	5.84
		2. Karang Tengah	164.14	3.05
		3. Sayung	478.38	8.89
		4. Wedung	1220.20	22.68
	Amount		**2,176.79**	**40.45**
11.	Jepara	1. Bangsri	43.49	0.81
		2. Jepara	51.07	0.95
		3. Kedung	131.16	2.44
		4. Donorojo	12.06	0.22
		5. Mlonggo	76.72	1.43
		6. Tahunan	31.55	0.59
	Amount		**346.05**	**6.43**
12.	Pati	1. Batangan	49.59	0.92
		2. Dukuhseti	67.43	1.25
		3. Juwana	79.17	1.47
		4. Margoyoso	67.19	1.25
		5. Tayu	65.26	1.21
		6. Trangkil	18.94	0.34
		7. Wedarijaksa	0.50	0.009
		8. Dukuhseti	0.10	0.001
	Amount		**348.18**	**6.47**
13.	Rembang	1. Kaliori	18.12	0.34
		2. Lasem	45.01	0.84
		3. Rembang	46.85	0.87
		4. Sluke	2.73	0.05
	Amount	**112.71**	**2.09**	
	Total		**5,381.15**	**100**

as green belt vegetation along the northern coast of Central Java.

The identification of mangrove vegetation, in four regencies (Rembang, Demak, Kendal and Brebes) discovered 22 species. Details of the names of mangrove species are discerned visually in Table 2. Rembang had the most mangrove species (with 16 species). While Brebes regency with eight species mangrove found in its peninsula, Kendal Regency with six species, and Demak Regency with seven species. *Avicennia marina* and *Rhizophora mucronata* were the dominant species that were encountered in all of the study locations, followed by *Sesuvium portulacastrum*, which settled at Brebes, Kendal and Rembang Regency (Table 2). Rembang Regency contributed to high mangrove biodiversity, although the mangrove area was only 112.71 ha. The high number of mangrove species met in Rembang was due to the high awareness of several Rembang people concerning the importance of mangrove ecosystem functions and benefits. They rehabilitated mangroves in the Kaliori, Lasem, Rembang and Sluke areas since 1970. Renta *et al.* (2016) found only three mangrove species in Ulujami, Pemalang Regency (north coast of Central Java), consisting of *Avicennia marina*, *Avicennia alba*, and *Rhizophora mucronata*. The low number of mangrove species found in Ulujami, Pemalang, Central Java was due to the mangrove ecosystem as a result of replanting by groups of shrimp farmers who simultaneously managed mangroves-replanting aimed at protecting the farmer's ponds from the onslaught of the ocean waves.

Tomlinson (2016) grouped mangrove vegetation into two groups, namely, the 'true mangrove' and the 'mangrove associate'. The results of field observations in the present study found 10 species 'true mangroves' and 11 species 'mangrove associates' (Table 2). Moreover, Wang *et al.* (2011) had proven the existence of significant differences in leaf characteristics and osmotic properties of both the categories. From the results of his study Wang *et al.* (2011), based on cluster analysis using leaf character data and osmotic systems, showed that 33 representative species of mangroves could be classified into two groups, 'true mangrove' and 'mangrove associates' groups.

The calculation of mangrove resulted in the average density of mangrove vegetation (tree category) in the four regencies ranging from 1,500 to 4,283 individuals/ha (Fig. 3). By comparison, Rembang Regency ranked first with the density of its tree category, while the lowest was in Brebes Regency. The density of mangrove sapling in four regencies ranged from 700-5,733 individuals/ha (Fig. 3), with the smallest amount in Rembang Regency. The lowest density of sapling in Rembang Regency was inversely proportional to the tree category; this was due to in Rembang, mangrove replanting started since 1970 so that the tree category currently dominated the vegetation community. The seedling category in the mangrove community of the north coast of Central Java ranged from 10,000 to 433,333 individuals/ha (Fig. 3) with the highest value encountered in the Kendal Regency. At the same time, the lowest density was observed in Demak Regency. Renta *et al.* (2016) obtained the abundance of mangrove in the Pemalang Regency, north coast of Central Java with 3,133.33 individuals/ha (tree category), 966.67 individuals/ha (sapling category) and the mangrove seedling was not found. Those values of density were comparable with what was encountered in the present study. The high amount of seedling phase mangrove indicated that mangrove replanting activities in Kendal regency were under the implementation period. Replanting was practised as a way the applicability of mangrove ecosystem restoration method when alternative after the natural seedling recruitment during secondary succession was inadequate to drive mangrove rejuvenation (Lewis and Brown, 2014).

CONCLUSION

Geospatial analysis of mangrove areas on the north coast of Central Java concluded that the area of mangrove vegetation increased from 2,458.39 ha (in 2011) to 5,381.15 ha (in 2014) or an increase in 2,922.76 ha (or 118.89%). The increase in mangrove area in 2014 caused by an analysis of mangrove area in 2011 did not detect mangrove vegetation that grew on embankment ponds; and mangrove replanting carried out between 2011 and 2014; as well as growth and development of natural mangrove seedling during secondary succession. The ground check survey conducted in four regencies (Rembang, Demak, Kendal and Brebes) encountered 21

Table 2. Results of the field survey for inventorying mangrove species found on the north coast of Central Java and the grouping it into the category of 'true mangrove 'and 'mangrove associates'

Regency	Species	Category
Rembang	1. *Avicennia alba*	True mangrove
	2. *Avicennia marina*	True mangrove
	3. *Excoecaria agallocha*	True mangrove
	4. *Rhizophora mucronata*	True mangrove
	5. *Rhizophora stylosa*	True mangrove
	6. *Rhizophora apiculata*	True mangrove
	7. *Sonneratia alba*	True mangrove
	8. *Sonneratia caseolaris*	True mangrove
	9. *Acanthus ilicifolius*	Mangrove associate
	10. *Acanthus ebracteatus*	Mangrove associate
	11. *Calotropis gigantea*	Mangrove associate
	12. *Hibiscus tiliaceus*	Mangrove associate
	13. *Sesuvium portulacastrum*	Mangrove associate
	14. *Spinifex littoreus*	Mangrove associate
	15. *Terminalia catappa*	Mangrove associate
	16. *Thespesia populnea*	Mangrove associate
Demak	1. *Avicennia alba*	True mangrove
	2. *Avicennia marina*	True mangrove
	3. *Bruguiera cylindrica*	True mangrove
	4. *Rhizophora mucronata*	True mangrove
	5. *Rhizophora stylosa*	True mangrove
	6. *Rhizophora apiculata*	True mangrove
	7. *Xylocarpus granatum*	True mangrove
Kendal	1. *Avicennia marina*	True mangrove
	2. *Bruguiera gymnorrhiza*	True mangrove
	3. *Rhizophora mucronata*	True mangrove
	4. *Xylocarpus granatum*	True mangrove
	5. *Sesuvium portulacastrum*	Mangrove associate
	6. *Hibiscus tiliaceus*	Mangrove associate
Brebes	1. *Avicennia marina*	True mangrove
	2. *Rhizophora mucronata*	True mangrove
	3. *Calotropis gigantea*	Mangrove associate
	4. *Hibiscus tiliaceus*	Mangrove associate
	5. *Ipomoea gracilis*	Mangrove associate
	6. *Ipomoea pescaprae*	Mangrove associate
	7. *Casuarina equisetifolia*	Mangrove associate
	8. *Sesuvium portulacastrum*	Mangrove associate

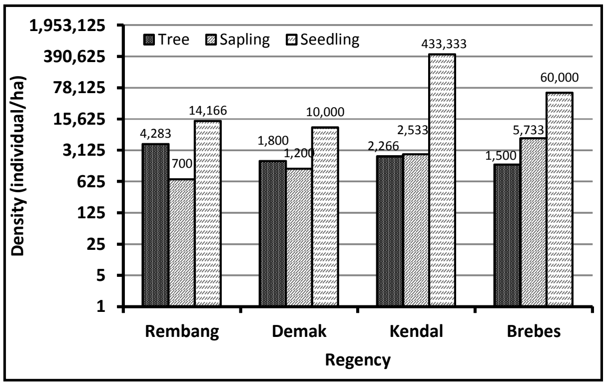

Fig. 3. The density of mangrove vegetation (based on tree, sapling and seedling category) (in individuals/ha) on the north coast of Central Java. Mangrove inventory was observed at four representative locations (Rembang, Demak, Kendal and Brebes Regencies).

mangrove species with the dominant species *Avicennia marina* and *Rhizophora mucronata*. Analysis of abundance based on the mangrove category showed that Rembang Regency had a stable mangrove community where the composition of the tree category dominated the mangrove area. Meanwhile, Brebes Regency elapsed the rehabilitation period, shown by the structure of vegetation dominated by the mangrove sapling category. And, Kendal Regency was in the stages of implementing mangrove rejuvenation, demonstrated by a high mangrove amount in the seedling category. An exceptional case occurred in the Demak Regency, where the mangrove replanting process run continuously, as indicated by the equal number of seedling, sapling and tree categories.

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