Assessing the Used of Remotely Sensed Data for Mapping Mangroves Indonesia

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Abstract:- Mangroves is one of important coastal resources in terms of its economical and ecological functions. Those functions have been discussed widely by many experts, so that mangroves data and their changes overtime is highly demanded particularly by planners and decision makers concerning on coastal resources and developments. To fulfill their needs, accurate mapping of mangroves stands and its changes overtime need to be done. Advancement of remote sensing techniques provides great opportunities for mangroves mapping despite its weaknesses. Moreover, mangroves stands are relatively easy to be identified since this type of vegetation is very distinctive compare to other coastal covers, so that it can be easily recognized and delineated from most of satellite imageries. The problems arise when mapping mangroves should be carried out nationally in vast area like Indonesia. Problems span from technical, financial into management of the data. This paper will discussed the opportunities and challenges in applying remote sensing techniques for mangrove mapping in Indonesia based on experience by the Center for Marine Resources Survey, The National Coordinating Agency for Surveys and Mapping (BAKOSURTANAL) in mapping mangroves Indonesia in 2009.

Keywords:- Mangroves, Remote Sensing, Mapping, Indonesia

1. Introduction

Mangroves forest can be found in tropical and sub-tropical inter-tidal area and form a "mangrove belt" that extended in about 230.000 km^2. As the largest archipelago country in the world, mangrove forests Indonesia is the largest in the world comprises about 19% of world's mangroves (FAO 2007). The mangroves growth in Indonesia is supported by its suitable location which in a tropical-equatorial with constant tropical temperature, high rainfall (more than 1,500 mm annually) and salinities ranges from 29-33%o in the inshore waters. Those are important factors to support mangrove development in coastal areas.

World's concern about mangroves ecosystems are very high including Indonesia, particularly because of it is important functions in terms of ecological and economical functions, beside issues and controversy in managing these resources. As subsistence resources, mangrove forests have important role for social-cultural interaction in the local society for a long time.

Mangrove forests in Indonesia have long been appreciated as natural resources with many kinds of benefit can be exploited both commercially and traditionally. Even though there is a growing understanding on the ecological functions of the mangroves, so that mangroves need to be preserved, the exploitation and conversion of mangroves is not deniable. Increased demand of mangrove resources, particularly for timber products and conversion to fish/shrimp ponds have led to degradation of the forest in many areas of the country. The impact of unwise exploitations is reflected on environmental problems such as coastal abrasion and declining fish productions in along the coastal areas.

Along with the growing interest in preserving mangroves forests and general coastal management, demand for accurate mangroves data increased. Several institutions such as the Ministry of Forestry (MOF), Ministry of Fisheries and Marine Affair (MFMA) and Ministry of Environment (MOE) have provided maps for mangroves to fulfill their own purposes, but not necessary useful for other institutions.

BAKOSURTANAL as the coordinating agency for surveys and mapping in Indonesia was nominated to take the responsibility to provide national mangroves map that can be used for all without prejudice the work of other institutions.

Therefore, BAKOSURTA-NAL decided to map existing mangroves compiling the existing mangroves maps that were verified and updated using satellite remotely sensed imageries as the main resources of data. The purpose of this work was to provide data on the mangrove forests distribution along the coast of the 33 provinces in Indonesia. The final result is a map of existing mangroves Indonesia at the scale of 1 : 1.000.000 and (Saputro et al. 2009).

2. Mapping Method

2.1. Mapping approach

Prior to this mapping activity, mangroves maps are already available in several institutions. This is the useful data sources despite the accuracy of the maps. The mapping mangroves conducted by BAKOSURTANAL was not start from scratch but conducted by verifying the existing mangroves maps by using satellite imageries. The existing maps show that mangroves could be found in almost all the provinces except in the Special Province of Yogyakarta (DIY). Those data excludes mangroves in small islands and sometimes the information is not complete. Besides that, irregularities in terms of the number of area often found between provinces and regencies.

The mangroves maps from several institutions were used as references. Those data were organized digitally in Geographic Information Systems (GIS) environment. The mangroves mapping conducted by BAKOSURTANAL developed a more consistent approach, to provide up-to-date mangroves data, and hopefully more accurate by using basemap and used as national standard.

The BAKOSURTANAL's mangrove mapping in 2009 follows several condition as discussed in focus group discussion (FGD) by the National Mangroves Working Group (KKMN). The conditions are as follows:

- the map should cover the whole area of Indonesia;
- the mapping was a *crash-program* where the map should finish in one fiscal year, with limited budget and human resources.
- the mapping method should use as transparent approach so that can be checked and traced-back by any other parties when required;
- the accuracy is within tolerable accuracy depending on the data sources and mapping method. It should be noted that there were no fieldwork to check the accuracy of the mapping.

With the above conditions, remote sensing technology was selected as the mapping approach. The main consideration was the availability of the data sources, and fortunately that satellite imageries (especially Landsat imageries) were available freely for the whole area of Indonesia, even though should be covered in several years and the quality is not always good especially due to cloud coverage. Therefore budget for data could be repressed.

Another important consideration is that remote sensing is superb in providing data. Since the launching of earth satellite in 1972, satellite imageries are continuously available with better spectral, spatial and temporal resolutions. This is very important for mapping resources such as mangroves where mapping should be conducted in time series to facilitate evaluation and monitoring the development of the resources. This is also means that the continuously of data sources is the key for the sustainability of mangroves management. The stand and distribution of mangroves Indonesia is very vast, making them impossible to be mapped completely in a short time using a ground work. The resources both in human resources and budgeting are the hindrance to do this, especially when mapping should be carried out nationally.

The Indonesia mangroves map produced by BAKOSURTANAL at the scale of 1 : 1.000.000 presents existing mangroves stand as interpreted and delineated from Landsat imageries regardless the mangroves are in the state forest areas (SFA) or in the non-state forest areas (NSFA). A photographic approach was used in the interpretation of the Landsat imageries to map the mangroves cover. This approach is originally developed for landcover mapping including vegetation and mangroves as among the vegetation types (Van Gils et.al 1990 *in* Danoedoro, 2009). Using this approach, interpretation of mangroves cover was conducted using 3 approaches i.e. photo-guided approach, photo-key approach and landscape-ecological approach.

2.2. Material and tools

Data used in the mapping process comprises of :

a) National vegetation map, year 2003
b) Digital topographic map, scale 1 : 1.000.000
c) Landsat satellite imageries (190 scenes, year 2006 – 2009)

The main tools used in the mapping process were sets of Personal Computer with image processing and GIS software. Among the software operated were ArcGIS, ENVI, ER-Mapper.

2.3. Mapping procedure

In general, the mapping procedure can be divided into three steps i.e. preparation, analysis and visualization steps. The description of each steps are as follows:

2.3.1. Preparation step

The preparation includes preparing for the base-maps, image acquisition, image pre-processing and building key-interpretation.

The base-map used for mangroves mapping was extracted from BAKOSURTANAL base-map (Peta Rupabumi Indonesia) database at the scale of 1 : 1.000.000. The map database layers include road network, hydrology (river network), coastline, administrative boundaries and toponyms.

As already mentioned above, the remotely sensed imaged used in the mangroves mapping were Landsat satellite images. All the Landsat images were downloaded from the United States for Geological Survey (USGS) website (http://edcsns17.cr.usgs.gov/EarthExplorer/) covering 190 scenes and ranging from year 2006 - 2009. The images selected were images with best quality with minimum cloud coverage and no or less image stripping. Landsat imageries have spatial resolution of 30 x 30 meters.

The long span of time is actually not ideal for mapping the states of existing mangroves acknowledge for the rapid change in mangroves ecosystems in Indonesia. However, it is the only way that can be done. In fact it is impossible to collect satellite image suitable for mangrove mapping in the particular detail for the whole area of Indonesia in a short time, even by collecting image from different satellites. Besides that, cloud coverage is a prominent problem. As a tropical country, some part of area in Indonesia almost always covered by cloud throughout of the year. To address this problem, several images for the same path/row were downloaded and then image mosaicking was employed to get a free cloud image. The same way was also done for image with striping (Landsat 7 ETM+).

The digital Landsat images downloaded consisted of 7 or 8 bands that are separated in each band. The pre-processing images include image stacking and mosaic in order to have image ready to be displayed in color. This process was very challenging because of the size of images is very big so that take up lots of computer memory and the process becomes slower and slower as the number of scenes increases. Therefore, the mosaic was done part by part, depending on the capacity of computer to handle. Image enhancement was also done during this pre-processing step.

The other important step in this preparation is building key-interpretation. The key-interpretation is a set of samples of definite mangroves in the satellite image.

2.3.2. Analysis step

In general, objects on image are identified based on their spectral and spatial characteristics. Parameter used for defining mangroves boundary was the environmental setting of the mangroves growth which can be identified spatially and spectrally from the image i.e. inundation class. Using photographic approach, mangroves were identified from image by their color, texture, sites and association.

During the interpretation and delineation of mangroves cover, the available mangroves maps were overlaid on top of the image and used as a reference. There is no field check for the delineation of the mangroves cover, so that the accuracy of the delineation has not been proved in the field. However, the delineation was guided by a very high image resolution available in Google Earth such as Quickbird with spatial resolution 0.6 meter. Through this image elongated mangroves trees can be identified and delineated clearly, including ‘relict’ of mangroves.

2.3.3. Visualization steps

Following the completion of the interpretation and delineation of mangroves cover, the mangroves map was composed by combining the mangroves layer with the basemap layers. The visualization process follows general rules of cartography, such as minimum mapping unit, grid systems and legend.

The minimum mapping unit (mmu) is the smallest size of objects that can be presented on a map in a particular scale. In regard to mmu, one should bear in mind that map visualization incurs a generalization process as reflected by the denomination of the scale of the map. This means that the smaller the scale, the greater the generalization, the less detail of objects presented on a map and vise versa. The mmu is generally assumed as big as 2 x 2 mm size of object in paper-base map. Therefore for the mangroves map at the scale of 1 : 1.000.000, the smallest size of mangroves cover is 400 hectares. Using Landsat satellite image with spatial resolution of 30 x 30 meter (0.09 hectare), this mmu is equal to 4.444 pixels. This size if far exceeded the minimum size of object that can be delineated in the image which is 3 x 3 pixels (0.8 hectare). Should the mapping procedure is completely followed, then the mangrove map will loss a great detail of information. This is not inline with the aim of the mapping which is to calculate the area of existing mangroves Indonesia therefore the generalization is not executed. The other consideration is that the map is actually in digital format, and displaying or visualizing data in digital basis is more flexible unlike the paper base mapping.

The grid systems used for the mangroves map is Geographic and UTM. The map then presented in three different forms, those are based on sheet or tile (36 sheets), in provincial based (33 province), and a seamless national based. The map composed was completed with annotation and legend. The title of the map is 'Peta Mangroves Indonesia' or Indonesia Mangroves Map.

3. Result and Discussion

The Indonesia Mangroves Map shows that mangroves ca be found along the coasts of 33 provinces. The estimates of total mangrove cover by the provinces varies because of differences in mapping techniques and the used of mangrove term.

The result of the mapping by BAKOSURTANAL shows that the area existing mangroves Indonesia is 3,244,018.46 hectares. Meanwhile, the mangroves map produced by the Ministry of Forestry in 2007 shows that the area of mangroves was 7,758,410.595 hectares (see Table 1). Comparing the two numbers, the area of mangroves seems to be declining more than a half only within 2 years. This conclusion could be misleading since the mapping approach used for the two mapping process was not the same. The mangroves mapping conducted by Directorate of Land and Forest Rehabilitation (RLPS) of MOF was prepared for rehabilitation purposes, so that the area that assigned as mangroves area does not always covered by mangroves, but mostly the area possible for mangroves to grow on the state-forest area.

Regardless the accuracy of the mapping done by BAKOSURTANAL, one thing that should be appreciated is the advancement of remote sensing technology. Without this technology, we cannot obtain an objective source of data, even though the mapping process particularly during the interpretation and delineation process is also subjective based on skill of the operators. More over, the free image such as that provided by the USGS as well as Google Earth gives significant contribution to the success of the mapping especially by repressing the budget. Besides that, the continuity services of remote sensing technology in providing earth imageries enable the sustainable environmental monitoring, including mangrove ecosystem.

However, there are also difficulties encountered during the mapping process in order to achieve the goal of the mapping. The first problem is data acquisition and handling. Due to the large area of Indonesia, there is no single satellite image provider that can cover the whole area in a short time to provide data of the state of existing mangroves stand is a particular time and particular detail. Geo-synchronous system based satellite such as NOAA-AVHRR can provide image for the whole area of Indonesia, however we cannot rely on this for mapping existing mangroves. In facts, there is always trade-off in using satellite images, the higher the spatial resolution the lower the temporal resolution. A new breakthrough is needed to solve this problem, probably by using images with almost at the same characteristics. But, this will raise a budget problem since the price of images is not always cheap.

In the case of images used in the mangroves mapping, even though the Landsat images are provided freely by USGS, the quality is not always good. Cloud cover and image striping are the main problems. Creating a mosaic of several images could help but not necessary solve all of the problems. Cloud cover is almost always problem encountered in mapping using passive system of remote sensing data. The cloud cover and image striping is the main source of inaccuracy of the mapping since objects under clouds and stripe cannot be defined. Active remote sensing system could resolve this problem but none of them available in free basis besides problem in the objects identification and geometric. Besides that, when processing a big size image, the display become slow, result in a longer time for interpretation and delineation of the mangroves.

The mapping conducted by BAKOSURTANAL employed people with background in geography with sufficient training in remote sensing and GIS. Therefore, problem of human resources were not clearly apparent during the mapping process. However, there is always chance for inaccuracy in delineation since this is a very subjective process. This issue was already addressed by supervising by developing a set of key interpretations and used the previous mangroves maps as references. Ideally, the map should be checked in the field to enhance the accuracy of the mangroves map.

4. Conclusion

The used of remotely sensed data has been fundamental in the quantification of existing mangroves Indonesia. The ease of its integration with other geographical digital data within a Geographic Information System (GIS) presents an ideal platform to advance study of the bio-complexity of mangrove forests in Indonesia.

Lesson learned from the mangroves mapping in Indonesia, standardize of mapping techniques is needed so that the mapping could be done effectively and accurately. A well plan of mapping process should be developed, discussed and agreed among the stakeholders of the mangrove particularly the member of the national mangrove working group.

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Table 1. Comparation between BAKOSURTANAL and RLPS-MOF mangroves area in each province in Indonesia.

No.	Province	Area of Mangroves (ha)	
		Bakosurtanal 2009	RLPS –MOF 2007
1	Nanggroe Aceh Darussalam	22,950.321	422,703.000
2	North Sumatera	50,369.793	364,581.150
3	Bengkulu	2,321.870	0.000
4	Jambi	12,528.323	52,566.880
5	Riau	206,292.642	261,285.327
6	Kepulauan Riau	54,681.915	178,417.549
7	West Sumatera	3,002.689	61,534.000
8	Bangka Belitung	64,567.396	273,692.820
9	South Sumatera	149,707.431	1,693,112.110
10	Lampung	10,533.676	866,149.000
11	DKI Jakarta	500.675	259.930
12	Banten	2,936.188	1,180.484
13	West Java	7,932.953	13,883.195
14	Central Java	4,857.939	50,690.000
15	East Java	18,253.871	272,230.300
16	D.I. Yogyakarta	0	0
17	Bali	1,925.046	2,215.500
18	West Nusa Tenggara	11,921.179	18,356.880
19	East Nusa Tenggara	20,678.450	40,640.850
20	West Kalimantan	149,344.189	342,600.120
21	Central Kalimantan	68,132.451	30,497.710
22	South Kalimantan	56,552.064	116,824.000
23	East Kalimantan	364,254.989	883,379.000
24	North Sulawesi	7,348.676	32,384.490
25	Gorontalo	12,315.465	32,934.620
26	Central Sulawesi	67,320.130	29,621.560
27	South Sulawesi	12,821.497	28,978.300
28	South East Sulawesi	44,030.338	74,348.820
29	West Sulawesi	3,182.201	3,000.000
30	North Maluku	39,659.729	43,887.000
31	Maluku	139,090.920	128,035.000
32,33	Papua and West Papua	1,634,003.454	1,438,421.000
Total		**3,244,018.460**	**7,758,410.595**