# Mangrove mapping analysis on: Optical and Synthetic Aperture Radar data using

# ALOS/PLASAR and ALOS/ AVNIR-2

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**Abstract:** The Klias Peninsula also known as the last largest remaining wetland area of Sabah is located within the district of Beaufort, Kuala Penyu and Membakut. It covers approximately 130,000 ha with dense mangrove, nipah forest and peat forest. Grassland, scrub and small scale mixed horticulture also observed throughout the peninsula. It is important to track the land use change in the area to monitor the mangrove forest growth. Mangrove forests have been affected by illegal shrimp farming with in the area. This study is to analyze mangrove mapping using Optical and Synthetic Aperture Radar (SAR) data. Both full Polarimetric SAR and Optical data for the year 2010, from ALOS/PALSAR and ALOS/AVNIR-2 sensors were used to produce the year 2010 land use for the study area. The importance of microwave images was felt as finding cloud free optical images of the study area was a difficult task. Combination of field data and Unsupervised classification was used to classify the images. ALOS/PALSAR PLR 1.1 product level data was used to apply Wishart classification algorithm for the SAR data. Optical image classification was carried out using maximum likelihood algorithm. Initially it failed to distinguish forest and mangrove area accurately. Thus to improve the accuracy of the classification Principal Component Analysis was carried out, this resulted in accurately distinguishing the forest and the mangrove. Comparison of the results showed SAR data is more suited for mangrove mapping compared to Optical data from ALSO/AVNIR-2. The lack of Short Wave Infra-Red band in ALSO/AVNIR-2, made it difficult to apply ALOS/AVNIR-2 data for mangrove mapping compared to sensors with SWIR band. Biomass based mangrove area extraction using SAR data also showed very promising method for mangrove mapping using SAR data.

## Intorduction

Mangrove forest growing in saline coastal area in the tropics and subtropics region plays a major part in the costal ecosystem and sea coast conservation. There are more than 100 Mangrove species each specially adapted saline, tide and wave condition of the area. Specialized root system enables them to grow in this saline environment where other plant species have failed. Mangrove forest also contributes in reducing the global carbon foot print. Been able to thrive in salt water it proved solutions to un-usable land area due to salification with the increasing sea-level. Mangrove forest has its own unique ecosystem and is the breeding ground for verity of sea species.

The demand for seafood has led to the destruction mangrove forest, large mangrove areas have been cut down for shrimp farming, and other aquaculture activities. The land is abandoned after few years due to the build-up of toxicity in the area, which make is even unsuitable for mangrove. Thus it's very important to map and monitor mangrove forest to protect its ecosystem.

Remote Sensing Optical data has been widely used for land cover classification and have proven to be very efficient. Landsat TM and Landsat ETM are most widely used sensors; ALOS/AVNIR-2 has also become widely used due to its 10m spatial resolution, compared to 30m spatial resolution in Landsat TM. Maximum likelihood and K-Mean are most commonly used Supervised and Unsupervised image classification algorithms used in optical RS and have been proven to be effective in land cover mapping applications.

With the improvement of full polarimetric SAR (Synthetic Aperture Radar )satellite data, use of SAR data for land cover classification has grown. R.Cloude & E.Pottier;1997 has introduced new SAR decomposition for supervised as well as unsupervised algorithms to accurately classify the SAR data.

Tree biomass calculation provides various benefits, including habitats, food, timber, forest growth and in reducing the carbon footprint (Nagelkerken et al., 2008). Biomass estimation of mangrove forest using filed work is a difficult due to the muddy soil condition and weight of the trees. To overcome this problem researchers have developed various kinds of allometric algorithms to calculate the Dry Weight of mangrove tree species. (*C. Proisy , 2000* ) has shown that it's possible to use SAR data to calculate the mangrove biomass with only few sample point.

The study was undertaken to study mangrove forest mapping using ALOS/PALSAR and ALOS/AVNIR-2 data the results were compared to see how effective the technology is for mangrove mapping. The SAR data proved to be more effective to distinguish mangrove compared to four band AVNIR data. The lack of short wave infrared band proved ALOS/AVNIR-2 is ineffective for mapping mangrove. Approximate biomass estimation was done using SAR backscatter coefficient. To map the mangrove area using back scatter coefficient.

## Study area

The Klias Peninsula, Malaysia (5º21’57.77”N 115º 33’53.38”E) also referred to as the last largest remaining wetland area of Sabah is located within the district of Beaufort, Kuala Penyu and Membakut which is about 80 km southeast of Kota Kinabalu. It is a large area approxiately 130,000 ha covered with dense areas of mangrove, Nipah forest and Peat forest. Grassland, scrub and small scale mixed horticulture also observed throughout the peninsula (Scott, 1989). There are six Forest Reserves within the Peninsula which include the Binsuluk, Klias, padas Damit, Kampung Hindian and Menumbok which covered and area of 31,053 ha (Vas, Justin. 1998; Maryati Mohamed et al., 1999). These areas are classified as class one forest reserves and not allowed to log within the areas. The Peninsula are connected with several extensive river channel which include the Padas Damit, Klias river flows from southern part of Binsuluk Forest Reserve towards the Brunei Bay and the Api-Api and Bukau river flows from Southern part of Klias Forest Reserve towards Weston.

## Land cover classification for Optical data

Images from Landsat TM 30m spatial resolution and ALOS/AVNIR-2 with 10m spatial resolution were used to for the classification. For the Landsat classification six bands from the Landsat TM was selected band 6 was omitted because of the 120m resolution. Initial unsupervised classification was done on the 1995 Landsat image to get a general idea of the land cover in 1995. Created 25 classes in the unsupervised classification were merged to create 8 classes. By combining results from the unsupervised classification and the land use map of 1999 the image was re-classified using training data base on the maximum likelihood algorithm into 8 land use class. Coefficient matrix was generated to check the accuracy of the classification. The overall accuracy was 95.7794% and Kappa coefficient of 0.9460.

ALOS/AVINR-2 was fist classified using ground truth data collected from field work using maximum likelihood algorithm but algorithm failed to distinguish between forest and mangrove. Thus Principle component analysis was performed on the AVINR-2 data set and the first 4 components were stacked. Unsupervised K-mean algorithm was applied with initially 30 classes and merged in to the final 8 class to create the 2010 land cover map Figure 2(a). The results were accurate than using the raw optical bands, but was not accurate enough to use the technique for mangrove mapping. In the post processing stage the classified image were cleaned and generalized using Sieve and Clump applied to remove isolated pixels and to add spatial coherency to the classes, for both 1995 and 2010 images.

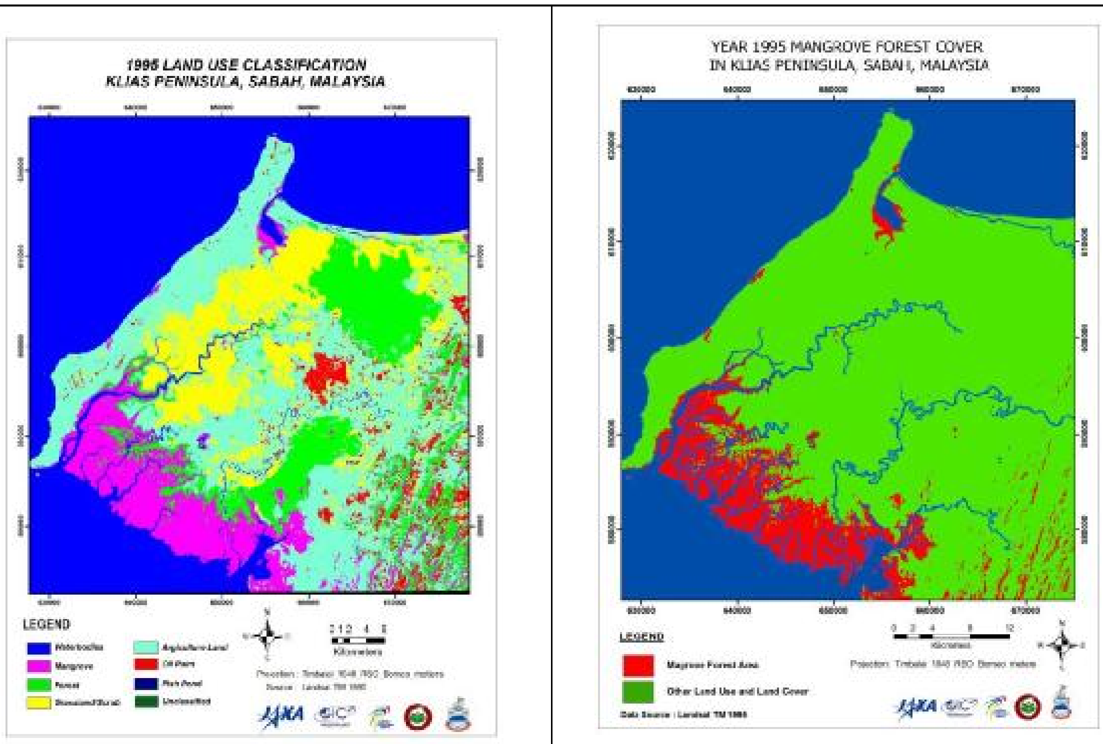



**Figure 1 1995 Landsat TM image classfication (a) Extracted mangrove area (b)**

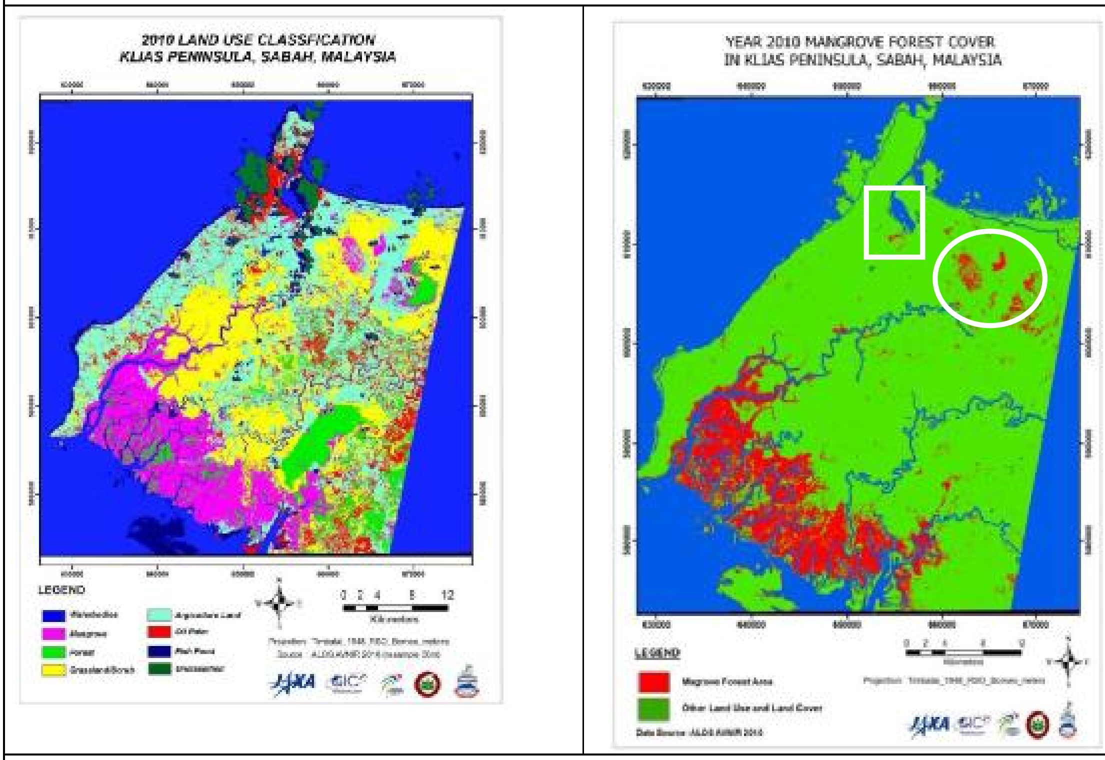



**Figure 2 (a) ALSO/AVNIR-2 2010 image classification (b) Extracted mangrove area showing miss classification**

Combination of unsupervised and supervised classification for 1995 landst5 TM image had an overall accuracy of 95.7794% but the initial supervised classification of the 2010 ALOS/AVNIR-2 was 67.2342% with forest and mangrove classified as forest. PCA was applied with K-mean algorithm to increase the accuracy of the result, which gave an better result but the result still had miss classified mangrove as shown in Figure-2 (b) the area circled by white circle is an non mangrove are but misclassified as mangrove and the area marked by an white square should have mangrove but was classified as oil palm and agriculture. It proved that it's difficult to use ALSO AVNIR-2 data for mangrove forest mapping. This is due to the lack of SWIR band in the sensor ( *Masayuki, 2010* ). Thus Landsat and other sensors with SWIR wave observation should be used if mangrove mapping is to be done using optical data. *Masayuki, 2010 also has* shown it's possible to use a combination of AVNIR -2 data and DEM (Digital Elevation Model ) with decision tree technique to increase the accuracy of the AVNIR-2 based mangrove mapping. Figure 3 below shows the significant difference in the spectral signature in the SWIR region compared to the four bands used by ALOS/AVNIR-2.

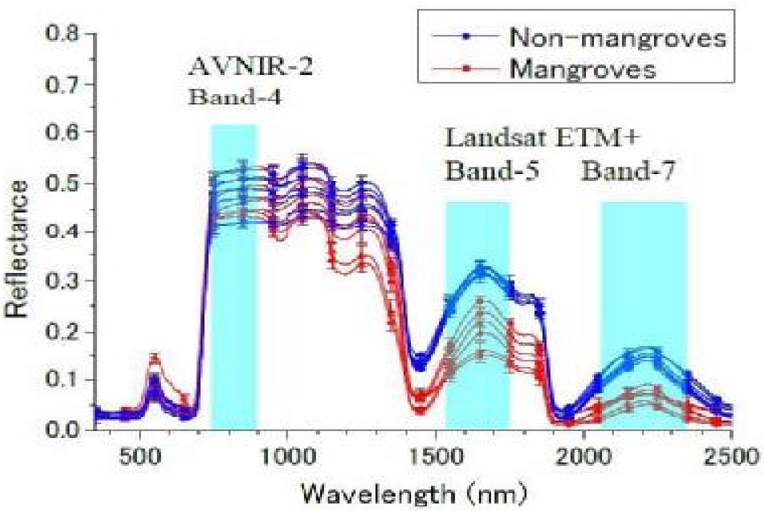



**Figure 3 Leaf spectral reflectance of 6 species of mangorves and 7 species of non-mangorve trees, with AVNIR-2 band 4 range , and landsat TM band 5 and band 7 ranges (source : Masayuki, 2010 )**

## SAR data based mangrove mapping

ALOS/PALSAR Full Polarimetric data was used to analyse feasibility of SAR data for mangrove mapping as well as overall land cover classification. Two PALSAR scenes were used to cover the study area. The scenes were classified separately and mosaicked to create the full map. ALOS/PALSAR product level 1.1 was used, which is single look complex (SLC) data in slant range, data file contains 32 bit real and 32 bit imagery components. The data will reduce its resolution from 12m to 30m after multi-looking process.

Coherency matrix [T3] matrix was generated which is needed to identify incoherent objects (object having distributed scatter) such as natural and man-made object. Lee refined filter was used to remove the speckle in the image, first run was done using 3X3 kernel, for the second run 5X5 kernel was used on the already filter image which resulted in an smooth image. Coherency matrix was geo referenced using sensor parameters contained in the "LED" file provided by with the data. The H/A/α polarimetric decomposition theorem by *Cloude and E.Pottier, 1997* was used to decompose the [T3] matrix into Entropy, Ansitropy and Alpha Eigen vector components. Using Wishart supervised classification algorithm the SAR images was classified in to 8 land cover classes. Due to the limitation of the software it was not possible to create the error matrix to carryout accuracy assessment of the results. Thus quantitative analysis was done comparing results from AVNIR-2 and PALSAR data.

The result has shown it's possible to use the SAR data for land cover mapping. It was able to distinguish forest and mangrove without difficulty, the forest and mangrove which were difficult distinguish in ALOS/AVINR -2 data was easily distinguished. SAR results were compared with the AVNIR-2 results as a qualitative analysis. The area shown in red on Figure 6(a) is classified as mangrove in SAR data but classified as some other land use in AVNIR-2. Field data confirms this area to be mangrove. The SAR data has also has identified the missing mangrove area in the ALSO/AVINIR-2 classification (Marked by White Square in Figure-2 (b)). In Figure 6 (b) Red spots indicates scrubs area in according to AVNIR-2 but classified as mangrove in the SAR data. There has been some miss classification in the SAR data, but the result has to verify through field verification. Figure 6 (c) shows area of agriculture in the AVNIR-2 data but misclassified as mangrove in the SAR data. There is considerable amount of error in the west costal area, where there is lots of coconut trees and other agriculture. This can be explained by lack of agricultural training area for SAR classification in the second SAR image, as the field work was collected only considering ALOS/AVNIR-2 images.

Figure 5 shows the area extent of each land cover in ALSO/PALSAR and ALOS/AVNIR-2 images. Most significant different is between forest and agriculture land use. This is due to the miss classification in the SAR image in the southern west costal area of the study area. The results show the SAR classification has more mangrove area and less forest area compared to the ALOS AVINIR-2 this is due to the miss classification in the data.

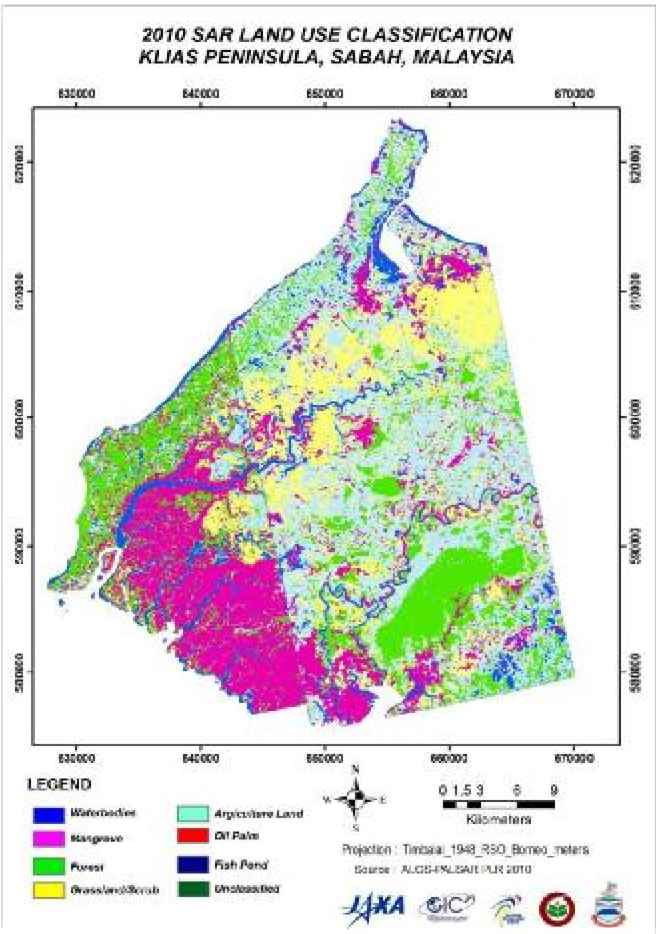



**Figure 5 ALOS/PALSAR SAR based land use classification**

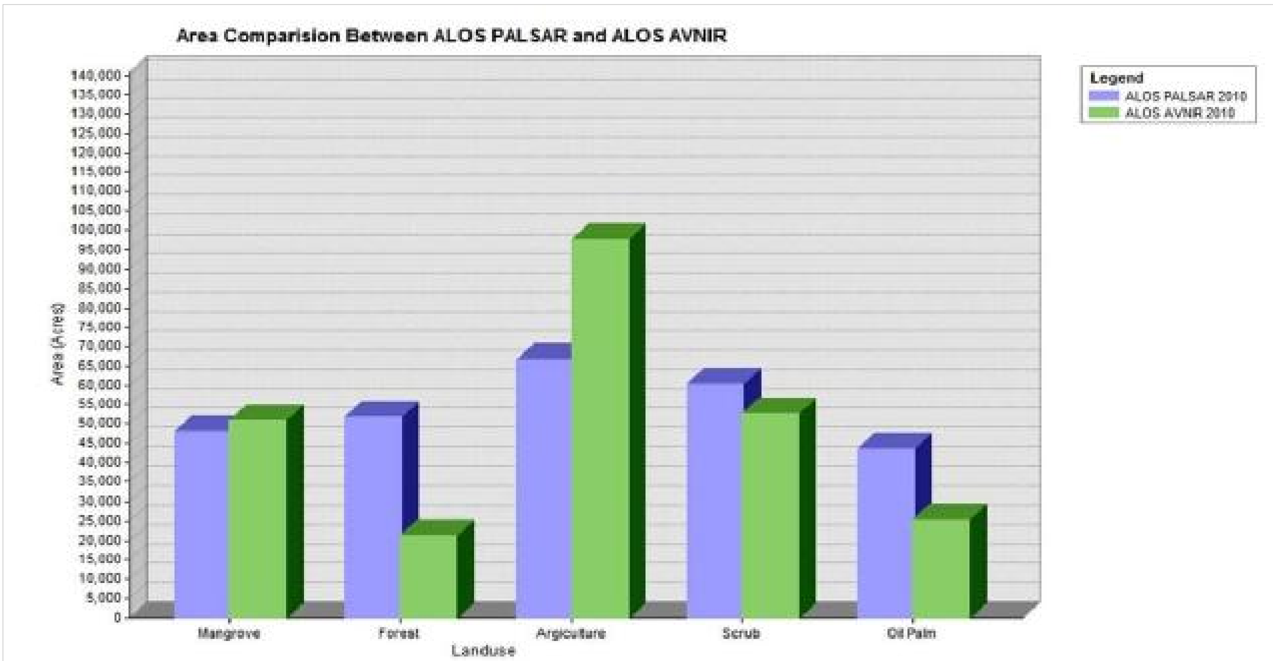
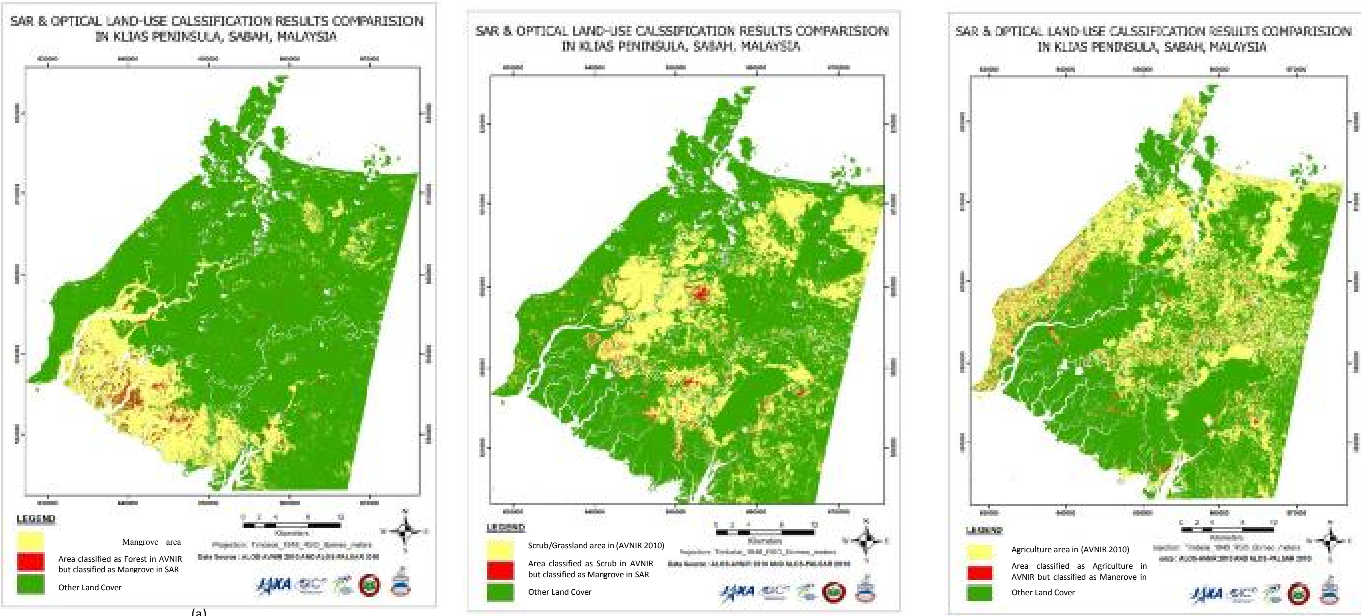



**Figure 4 ALOS/PALSAR & ALOS/AVNIR land cover area comparison**




(a) (b) (c)

**Figure 6 Shows the comparison of mangrove cover comparing 2010 PALSAR & AVNIR results**

## Mangrove mapping using SAR backscatter coefficient

Due to low above ground biomass value in mangrove it's possible to accurately calculate the biomass using SAR backscatter coefficient (*Proisy,*C. *et al.,* 2000 ). Biomass estimations from allometric method using the sample data from field work was used to calculate the biomass values of mangrove the study area. Sample points were only spread along the river due to the difficulty of field data collection inside the mangrove forest. Mangrove in the river bank and the near the coast line showed low biomass but increase to the level of saturation point reaching the 100tDMha$^{-1}$ value when moving in land. Using the calculated values the mangrove biomass was categorized in to 3 class as 40 t DM ha$^{-1}$ , 40-80 t DM ha$^{-1}$ And 81-100 t DM ha$^{-1}$ . Using the field data backscatter coefficient ranges were estimated for the three biomass classes. This range was then use to identify the mangrove area from the SAR image. To improve the accuracy a buffer zone of 700m was created around water bodies as the most suitable area for mangroves. Table 2 contains the SAR backscatter based calculated biomass and biomass calculated from allometric methods for field data points(Komiyama, Eong, & Poungparn, 2008). It can be observed the SAR base method is accurate for biomass estimation. The SAR data was only calculated as three ranges to get a homogenous area of pixels. Thus this method can be used to approximately extract the mangrove forest by building the relationship between the biomass and the backscatter coefficient of the SAR image. The method has to be improved to get an accurate map.

*Rhizophora apiculata*

$$w_{top} = 0.235DBH^{2.42} \qquad \text{(Komiyama, Eong, \& } Poungparn\text{, 2008)}$$

$$w_{top} = Above\ Ground\ Tree\ Weight\ in\ Kg$$

**Table 1 Relationship between calculated Biomass and Backscatter Coef.**

| Tree Name | DBH (cm) | Calculated (t DM ha$^{-1}$) | Backscatter Coef. | Biomass class |
|---|---|---|---|---|
| R. Apiculata | 49 | 54.30708 | -17 | 41-80 |
| R. Apiculata | 51 | 56.43706 | -17 | 41-80 |
| R. Apiculata | 32 | 36.20225 | -19 | 41-80 |
| R. Apiculata | 52 | 57.50205 | -18 | 41-80 |
| R. Apiculata | 49 | 54.30708 | -17 | 41-80 |
| R. Apiculata | 47 | 52.1771 | -18 | 41-80 |

| | | | | |
|---|---|---|---|---|
| R. Apiculata | 51 | 56.43706 | -14 | 81-100 |
| R. Apiculata | 65 | 71.34692 | -12 | 81-100 |

**Table 2 Backscatter coef. range value for biomass classes**

| Class | Back scatter coefficient range Sigma ∂ |
|---|---|
| Class 1 (40 t DM $ha^{-1}$) | < -20 |
| Class 2 (40-80 t DM $ha^{-1}$) | -19 ~ -13 |
| Class 3 (81-100 t DM $ha^{-1}$) | -13 ~ -12 |

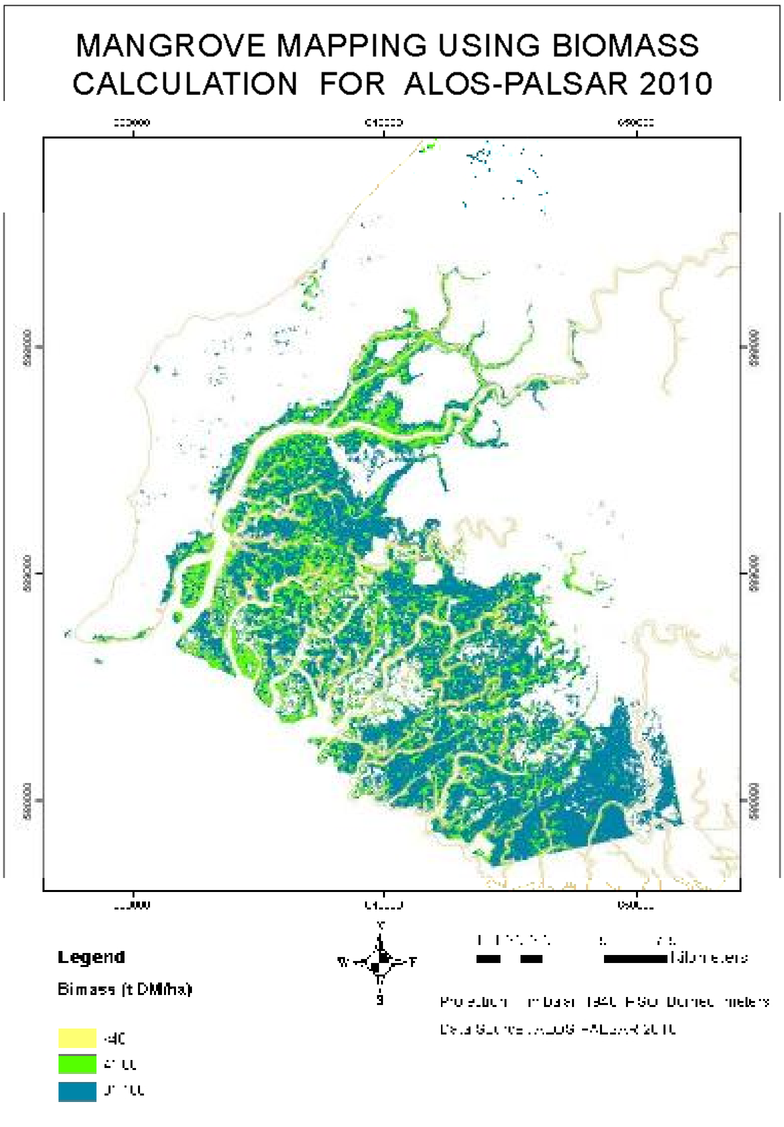



**Figure 7 SAR Mangrove area map using Backscatter coef.**

## Conclusions and Recommendations

The study has shown that it's difficult to use AVNIR-2 for mangrove mapping due to the lack of SWIR band in the sensor. Thus carrying mangrove forest change detection using AVNIR-2 results is not suitable due to the inaccuracy of the classification results. Good alternative would be to use the ALOS/PALSAR sensor for mangrove mapping which has shown good results in the study. Any other optical sensor with SWIR band will also be good for mangrove forest identification.

It's important to use the proper decomposition algorithm when classifying SAR data. Decomposition technique will extract more meaning full information from the raw SAR data, thus different decomposition technique will have different result in the classification. Accurate speckle removal technique applied without using too much data will ensure there will be less misclassified isolated pixels in the image. Application of SAR data is new for land cover mapping; the result of the classification showed good accuracy from visual interpretation. Accurate analysis of SAR base classifications should be done involving more intensive field data collection. Different decomposition techniques should be tested to see which technique is most suitable for mangrove mapping. Improvements in the spatial resolution of SAR full polarimetric data and in the algorithms will ensure that the SAR data will be widely used for land cover mapping in the coming years.

Use of SAR backscatter coefficient for mangrove biomass calculation and mapping is a very easy procedure, for biomass estimation and approximate the mangrove forest cover. Thus this method can easily be used for monitoring of mangrove forest growth and productivity. Allometric method used for mangrove dry weight calculation is a simple less field intensive method which can be adopted for nearly all kinds of mangrove forest. The drawback of this technique is that it can only be adopted in the pioneer and mature stages forests with biomass less than 100 t DM $ha^{-1}$ and the area should not contain other vegetation cover with similar biomass density in the area.

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