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Characterization and spatial distribution of mangrove forest types based on ALOS-PALSAR mosaic 25m-resolution in Southeast Asia

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Abstract. The objective of this research is to investigate characteristics of mangrove forest types and to identify spatial distribution of mangrove forest based on ALOS PALSAR mosaic 25m-resolution in Southeast Asia. Methodology consists of collecting of ALOS PALSAR image for overall Southeast Asia region, preprocessing include converting DN to NRCS and filtering, collecting regions of interest of mangrove forest in Southeast Asia, plotting, characterization and classification. Result on this research we found characteristics of mangrove forest on HH values around -10.88 dB to -6.65 dB and on HV value around -16.49 dB to -13.26 dB. On polarization of HH which the highest backscattering value is mangrove forest in Preak Piphot River Cambodia, Thái Thủy Thai Binh Vietnam, and Vạn Ninh tp. Móng Cái Quảng Ninh Vietnam whereas the lowest backscattering value is mangrove forest in Thailand area. On polarization of HV which the highest backscattering value is mangrove forest in Preak Piphot River Cambodia, Sorong and Teluk Bintuni Indonesia whereas the lowest backscattering value is mangrove forest in Subang Indonesia, Giao Thiện Giao Thuỷ Nam Định, Vietnam and Puyu Mueng Satun Thailand. Based on characterization, we create a rule criteria for classification of mangrove areas and non mangrove area. Finally we found spatial distribution of mangrove forest based on ALOS PALSAR 25m-resolution in Southeast Asia.

1. Introduction
1.1 Background
Mangrove forests can be found along ocean coastlines throughout the tropics area, and provide important products and services [1]. They also provide among the most intense coastal carbon sinks in the world and play a growing and central role in the global carbon cycles [2]. According to Daniel et al. [3] mangroves have five times larger numbers of total carbon storage per unit area basis on average than those typically observed in temperate, boreal and tropical terrestrial forests. High rates of trees and plant growth, coupled with anaerobic, water logged soil that slow decomposition, result in large long term carbon storage [4]. This suggests that mangroves play an important role in global climate change management. In order to gain and build a solid understanding of the global carbon budget and ultimately the effects of diminishing mangrove forests on climate change, it is crucial to obtain an assessment and quantification of the spatial distribution of mangrove forest. As most countries do not have sufficient information to include mangroves in their national reporting to the United Nations [4].

From a global perspective, Southeast Asia is well endowed as it supports the world's largest area of mangroves, originally extending over 6.8 million hectares and representing 34-42 percent of the world's total [1]. Southeast Asia's mangroves are the best developed and probably the most species-diverse in the world [5]. According to Giri et al. [6] the current estimate of mangrove forests of the world is less than half of what it once was and reductions suggest that 30–40% of coastal wetlands and 100% of mangrove forests could be lost in the next 100 years if the present rate of loss continues. Suggested the growing importance of mapping and monitoring of mangrove forest. However, conducting field survey for mangrove forest and its productivity in regional area is proven to be very difficult due to muddy soil condition, heavy weight of the wood [7], the vast area to cover, and tidal influences.

Remote sensing has been widely proven to be essential in monitoring and mapping of land use land cover including mangrove forest. According to Lucas et al. [8] the launch of the Japanese Space Exploration Agency's (JAXA) Advanced Land Observing Satellite (ALOS) Phased Arrayed L-band SAR (PALSAR) represented a milestone in the global observation, characterization, mapping and monitoring or mangroves largely, because these provide more information on the three dimensional structure and biomass of woody vegetation and the presence and extent of (primarily tidal) inundation. As data can be day or night regardless of weather conditions, mangroves can be observed more frequently, even in regions with prevalent cloud cover. The backscattering coefficient depends upon the interactions of microwaves of varying configurations with component of the mangrove (e.g. leaves, branches and trunks) of varying size, dimension, density, orientation and dielectrics constants (moisture contents) [8]. The longer L-band microwaves have a greater likelihood of penetrating the foliage and small branches of the upper canopies of the forest and interacting with woody trunk and larger branch components as well as the underlying surface [9,10]. The objective of this research is to investigate characteristics of mangrove forest types and to identify spatial distribution of mangrove forest based on ALOS PALSAR mosaic 25m-resolution in Southeast Asia. Methodology consists of collecting of ALOS PALSAR image for overall Southeast Asia region, preprocessing include converting DN to NRCS and filtering, collecting regions of interest of mangrove forest in Southeast Asia, plotting, characterization, classification and spatial distribution of mangrove forest.

1.2 Site description
Southeast Asia or Southeastern Asia is a subregion of Asia, consisting of the countries such as Myanmar, Thailand, Cambodia, Laos, Vietnam, Malaysia, Singapore, Brunei, Philippines, East Timor and Indonesia. According to Giesen et al. [1] Mangroves occur throughout Southeast Asia, from the Irrawaddy delta in Myanmar in the Northwest, through the more than 17 000 scattered islands of the Indonesian and Philippines archipelagos to Papua Island in the East, spanning a distance of more than 6000 kilometres from east to West and 3500 kilometres from North to South. We choice 46 samples, their location is representative of all mangrove forest in Southeast Asia. Distribution of sample site on study areas can be seen on figure 1.

2. Methodology
For this study, methodology consists of collecting of ALOS-PALSAR data and some references data such as land cover maps, Landsat data and information from Google earth, preprocessing focus on converting Digital Number to Normalize Radar Cross Sections (NRCS) and filtering. Delineation of samples of mangrove forest based on some references, characterization for knowing mean and standard deviation, profiling and statistics, and classification. The Methodology will follow on figure 2.

2.1 Data collection
ALOS PALSAR L-band with 1.27 GHz center frequency and 14 or 28 MHz bandwidths and dual polarization HH and HV developed by Japan Aerospace Exploration Agency (JAXA). The ALOS PALSAR was developed by JAXA and launched in January 2006. ALOS PALSAR data was collected

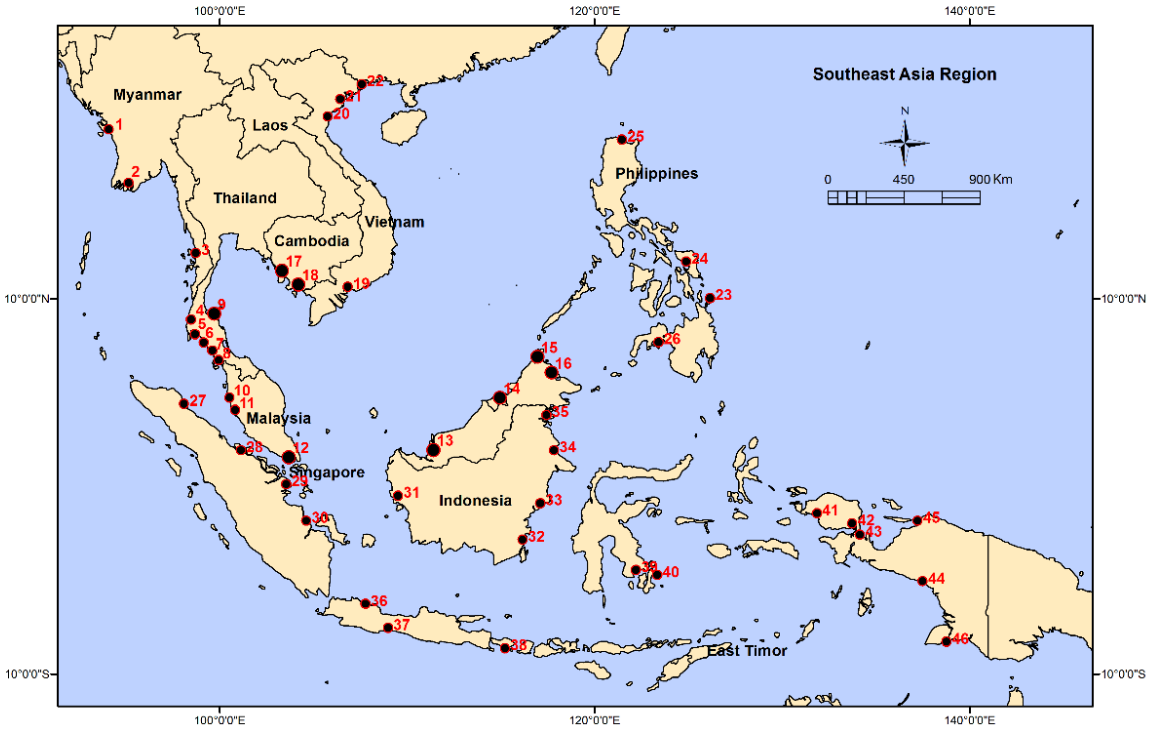


Figure 1. Study area and distribution of 46 samples.

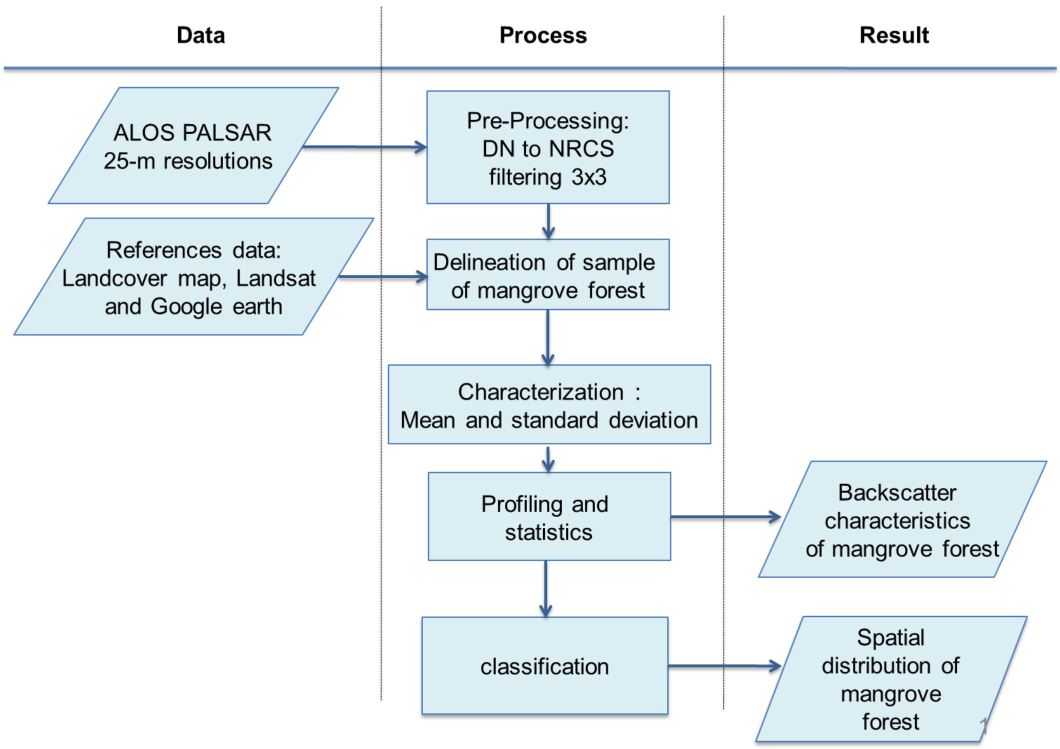


Figure 2. Methodology.

as part of Kyoto and Carbon Initiative project. We collected ALOS PALSAR from http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm. We used ALOS PALSAR mosaics on 2010 that total 60 tiles for covering Southeast Asia regions. All data were acquired in fine beam dual mode at a viewing angle of 34.4 and delivered in single-look complex (SLC) as the normalized backscattering coefficient in slant-range geometry by JAXA. PALSAR product is geometry and radiometric corrected and normalized for topography at 25 meter pixel spacing. PALSAR radiometric and geometric calibration is given in Shimada et al. [11]. We collected all scenes to cover Southeast Asia region. For secondary data we used land cover maps from each country and Landsat data also Google earth for supporting identification of mangrove area.

2.2 Pre-processing

All images were projected into geographical latitude and longitude coordinates. The digital number (DN) value of HH (DN_{HH}) and HV (DN_{HV}) backscatter intensities were converted to a normalized radar cross section (NRCS) in decibel (dB), (i.e., $\sigma°_{HH}$ and $\sigma°_{HV}$) by the following equations [12] :

$$\sigma°_{HH} = 10 \text{ x } \log_{10}(DN^2_{HH}) - CF \quad (1)$$

$$\sigma°_{HV} = 10 \text{ x } \log_{10}(DN^2_{Hv}) - CF \quad (2)$$

Where, σ° is backscattering coefficient and CF is the calibration factor. The CF is dependent on the processing date, in this study CF is equal to -83 both for HH and HV.

All images were mosaicked into one continuing images to cover overall Southeast Asia region using the image analysis software. For visualization we used image composites with R=HH, G=HV and B=HH/HV. We also use Enhanced Lee filtering with windows size 3x3 to reduce speckle noise.

2.3 Characterization and profiling

We have collected samples of mangrove forest as Region of Interest (ROI) on ALOS PALSAR data based on references data. We collected 46 ROI of mangrove forest dispersion on Southeast Asia region. The size of ROI different for each mangrove forest. This condition because large of mangrove forest areas is different on each region. After that calculating of mean and standard deviation for each sample. For visualization we create profiling of mean and standard deviation for each sample.

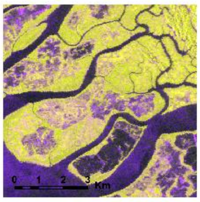
2.4 Classification of mangrove forest area

Classification of mangrove forest based on backscattering characteristics of mangrove forest on each location and also based on topography data. We used rule based classification method based on characteristics of mangrove for classification of mangrove and non mangrove in study area. Parameter that was used on rule based classification is HH, HV and topography data.

3. Results and discussion

3.1 Backscatter characteristics of mangrove forest in Southeast Asia

We processed all ALOS-PALSAR image include mosaicking, converting DN to NRCS, filtering and then create image composites with R=HH, G=HV and B=HH/HV. The image cover overall Southeast Asia region. Based on ALOS-PALSAR composite and also land cover maps from each country, Landsat data and Google earth, we can identify mangrove forest. In the figure 3 we show dispersion of mangrove forest from ROI in Southeast Asia region. Based on references data we can identify mangrove forest and non-mangrove forest on study area.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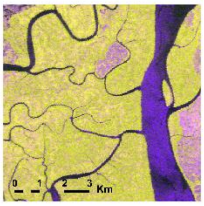
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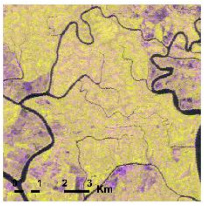
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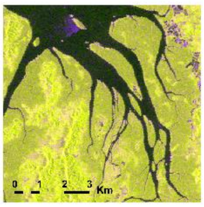
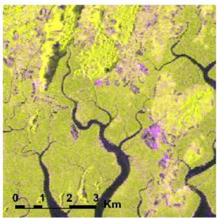
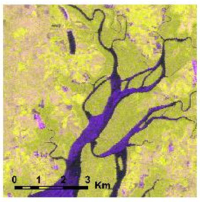

4. Shi Phangnga National Park, Thailand


5. Bang Toei Mueang Phangnga, Thailand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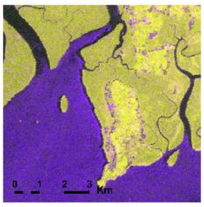
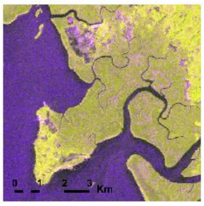
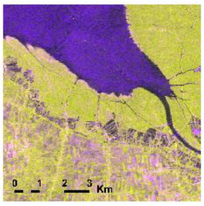
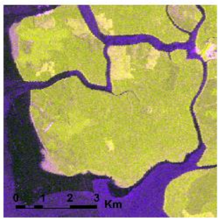
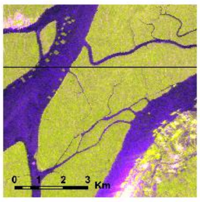
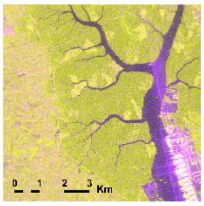

7. Suso Palian, Thailand

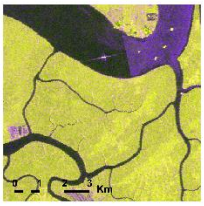

8. Puyu Mueng Satun, Thailand

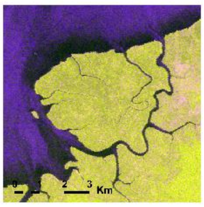

9. Pak Phanang Fangtawanok, Thailand

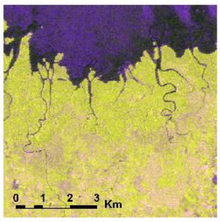

10. Jebong Perak, Malaysia

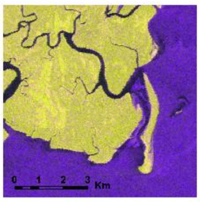

11. Pulau Kelang, Malaysia

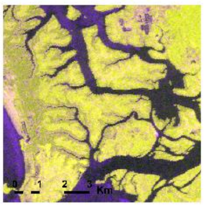

12. Serkat Johor, Malaysia

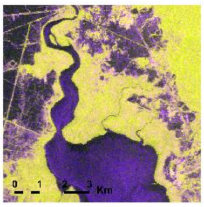

13. Sarikei Sarawak, Malaysia

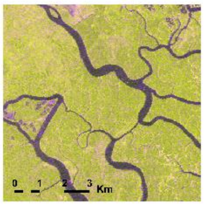

14. Pulau Selirong, Brunei

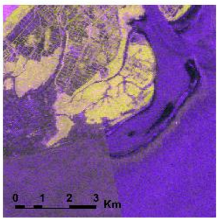

15. Kota Marudu Sabah, Malaysia

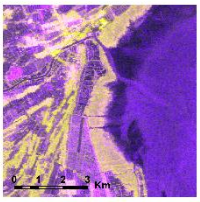

16. Beluran Sabah, Malaysia

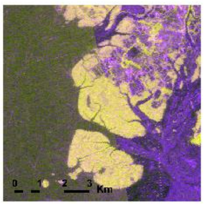

17. Peam Krasaop Wildlife Sanctuary, Cambodia

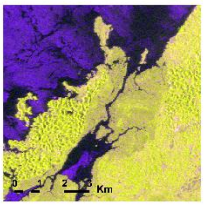

18. Preak Piphot River, Cambodia

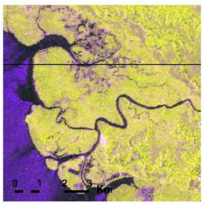

19. Thạnh An, Cần Giờ, Vietnam

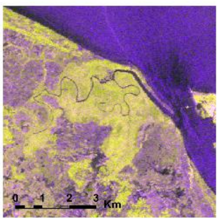

20. Giao Thiện, Giao Thuỷ Nam Định, Vietnam

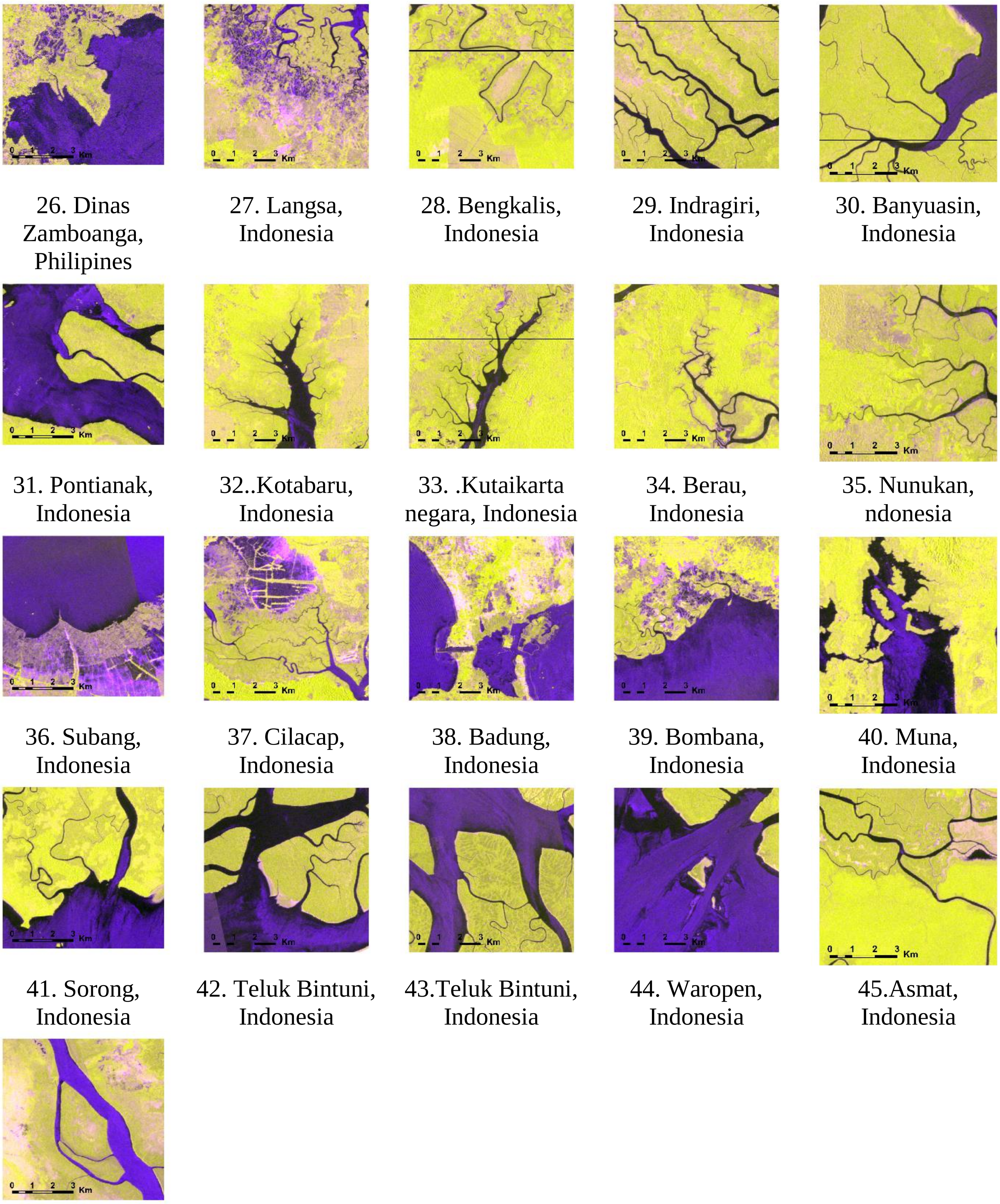

21. Thái Thủy Thai Binh, Vietnam


22. Vạn Ninh, tp. Móng Cái Quảng Ninh, Vietnam


23. Siargao island, Philipines


24. Santa Margarita, Philipines

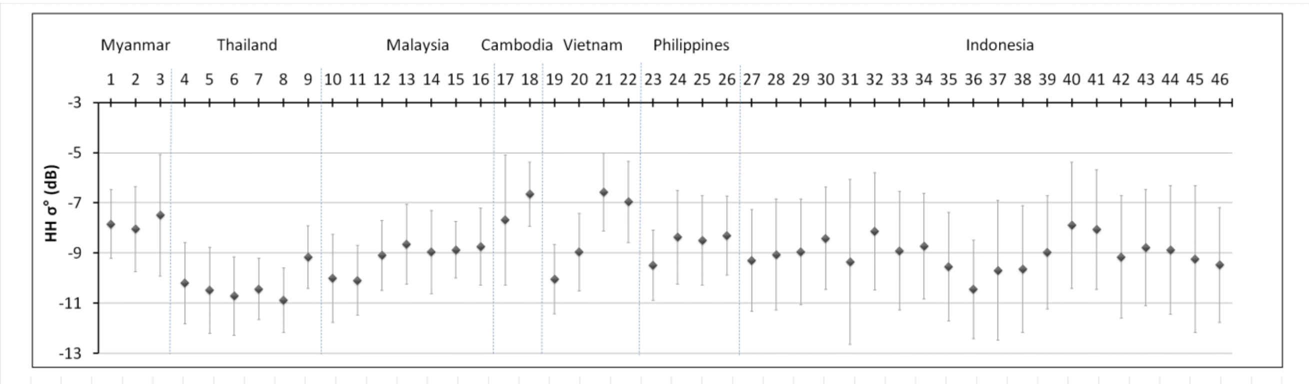

25. Abulug Cagayan, Philipines



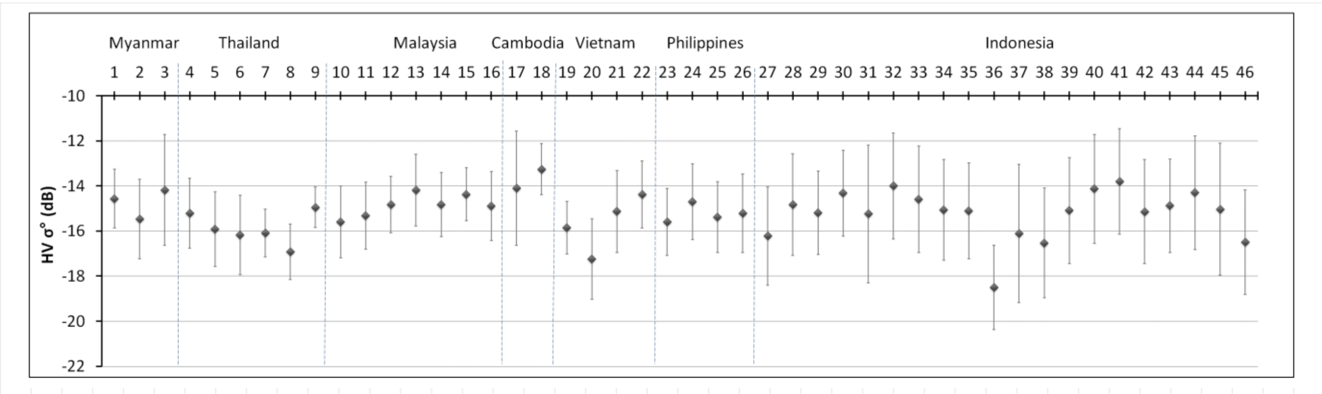
26. Dinas Zamboanga, Philipines
27. Langsa, Indonesia
28. Bengkalis, Indonesia
29. Indragiri, Indonesia
30. Banyuasin, Indonesia
31. Pontianak, Indonesia
32..Kotabaru, Indonesia
33. .Kutaikarta negara, Indonesia
34. Berau, Indonesia
35. Nunukan, ndonesia
36. Subang, Indonesia
37. Cilacap, Indonesia
38. Badung, Indonesia
39. Bombana, Indonesia
40. Muna, Indonesia
41. Sorong, Indonesia
42. Teluk Bintuni, Indonesia
43.Teluk Bintuni, Indonesia
44. Waropen, Indonesia
45.Asmat, Indonesia
46. Merauke, Indonesia

Figure 3. Visualization of mangrove forest on ALOS PALSAR composite R=HH, G=HV, B=HH/HV.

We collected ROI to know characteristics of mangrove forest based ALOS-PALSAR. ROI spread overall Southeast Asia region from (**1**) Lay Taung, Myanmar until (**46**) Merauke Papua, Indonesia. After that calculate mean and standard deviation from each ROI. Mean and standard deviation value for each ROI can see in the figure 4. In figure 4, we can see characterization of backscatter coefficient of mangrove forest on polarization of HH and HV. The “HH” modes indicates the combination of a horizontally (H) polarized transmitted signal and a horizontally (H) polarized received signal. Similarly, “HV” stands for the combination of a horizontally polarized (H) transmitted signal and a vertically polarized (V) received signal. Based on figure 4, characterization of mangrove forest for average of HH value around -10.88 dB to -6.65 dB and average of HV values around -16.49 dB to -13.26 dB. On polarization of HH, the highest backscattering value is mangrove forest in Preak Piphot River, Cambodia (18), Thái Thủy Thai Binh, Vietnam (21), and Vạn Ninh, tp. Móng Cái Quảng Ninh Vietnam (22) dan whereas the lowest backscattering value is mangrove forest in Thailand area. On polarization of HV, the highest backscattering value is mangrove forest Preak Piphot River, Cambodia (18), Sorong (41) and Teluk Bintuni (32) Indonesia whereas the lowest backscattering value is mangrove forest in Subang, Indonesia (36), Giao Thiện, Giao Thuỷ Nam Định, Vietnam (20) and Puyu Mueng Satun, Thailand (8).



(a)



(b)

Figure 4. Backscatter characteristics of mangrove forest
based on ALOS PALSAR polarization on (a) HH and (b) HV.

The sensitivity of the backscatter to mangrove forest parameters and the saturation level is rather sites-dependent, since mangrove forest structure influences the relative contribution of the scattering mechanism [10,13]. In addition, the individual contribution to the total mangrove forest backscatter is also dependent on environmental conditions (i.e. weather conditions, moisture conditions, and weather dynamics) and also topography and tidal height [14] which can affect the dielectric properties of the vegetation and ground surface. The interactions between the radiation and the plant's internal properties (e.g. moisture content influencing the dielectric constant of a material and cell structure) and external components (e.g. size, geometry and orientation of leaves, trunks, branches, and aerials or stilt roots) also result in a specific backscatter signal (e.g. radar calibration and orthorectification) [15,16].

Scatter graphs for visualization both HH and HV value can be seen in figure 5. Based on figure 5 correlation of HH and HV value not exactly linear. Generally, the sensitivity of the backscatter intensity to the biophysical parameters of land surface vegetation is examined in different combinations of polarized modes [17]. The HV polarization has more the stable relationship revealed between the SAR backscatter and above-ground forest biomass rather than HH polarization [18] and HV is much less influenced by soil and vegetation moisture [19]. Based on visual interpretation from scatter graphs in figure 5, backscatter value of mangrove forest on polarization HH and HV can be classified on three classes. First class which has higher value of HH and HV, second class which middles values of HH and HV and third class which has lower value of HH and HV. If compared with previous research [19] about characteristics of mangrove types based on ALOS PALSAR 50m-resolution in 2008, the results are similar.

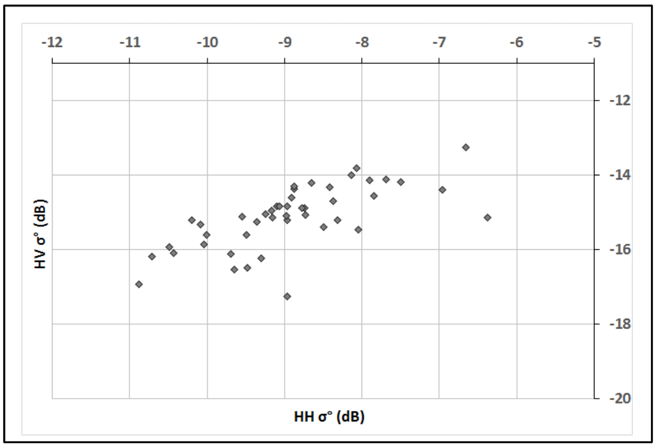


Figure 5. Scatter graph on HH and HV backscatter value of mangrove forest.

3.2 Spatial distribution of mangrove forest in Southeast Asia

We classify mangrove forest based on backscattering characteristics of mangrove forest and also based on topography data. On this case the method that was used is rule based classification method. Parameter that was used on rule based classification is HH, HV and topography data derived from SRTM 90. The threshold based on lowest and highest of HH and HV value on study area (figure 4) and average of topography data derived from SRTM 90m. Based on characterization, we found the lowest HH value of -10.88 to -6.65 dB and HV value of -16.49 to -13.26 dB also average of height of topography is 9.92 m. Based on that criteria we have found spatial distribution of mangrove forest based on ALOS PALSAR. Spatial distribution of mangrove forest in Southeast Asia can be seen on figure 6. Basically for getting mapping of mangrove forest on regional areas with high accuration we suggest classifying smaller areas by smaller areas. This condition because of mangrove forest has unique characteristics on each area. However for classification of smaller areas by smaller areas on whole Southeast Asia need big effort and time.

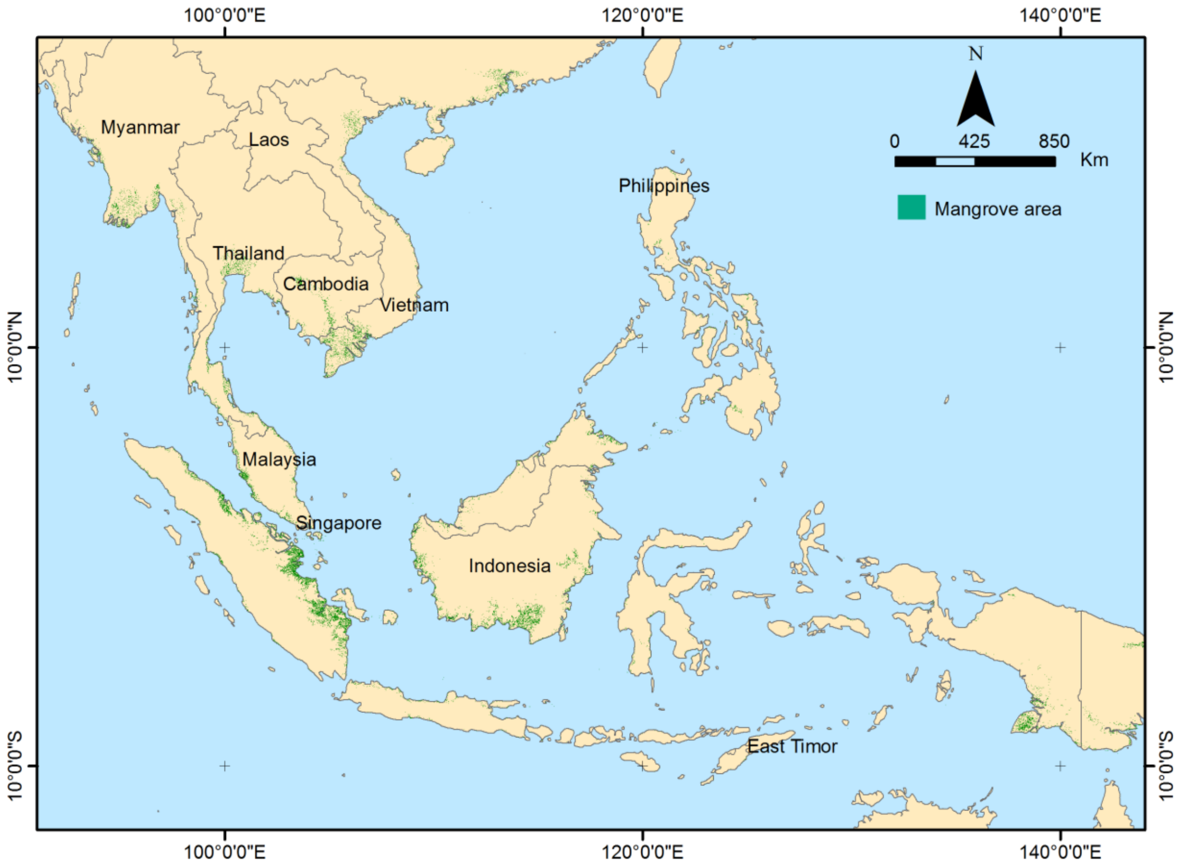


Figure 6. Spatial distribution of mangrove forest in Southeast Asia.

4. Conclusion

We showed backscattering characteristics of mangrove forest in Southeast Asia based on ALOS PALSAR mosaic 25m-resolution with polarization on HH and HV. We found characteristics of mangrove forest on HH value around -10.88 dB to -6.65 dB and on HV value around -16.49 dB to -13.26 dB. Also we found backscatter value of mangrove forest on polarization HH and HV can be classified on three classes. First class which has higher value of HH and HV, second class which has middles values of HH and HV and third class which has lower value of HH and HV. On polarization of HH which the highest backscattering value is mangrove forest in Preak Piphot River Cambodia, Thái Thủy Thai Binh Vietnam, and Vạn Ninh tp. Móng Cái Quảng Ninh Vietnam whereas the lowest backscattering value is mangrove forest in Thailand area. On polarization of HV which the highest backscattering value is mangrove forest Preak Piphot River Cambodia, Sorong and Teluk Bintuni Indonesia whereas the lowest backscattering value is mangrove forest in Subang Indonesia, Giao Thiện Giao Thuỷ Nam Định Vietnam and Puyu Mueng Satun Thailand. Based on characterization, we create a rule criteria for classification of mangrove areas. Finally we found spatial distribution of mangrove forest based on ALOS PALSAR 25m-resolution in Southeast Asia. Actually mangrove forest has unique characteristics on each area, needed some specific criteria to identify mangrove with the highest accuration result, for next step we will verify and validate our result and also for enhancement our results we try to find more rule criteria for classification of mangrove forest on regional area.

Acknowledgement
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