Characterization of mangrove species using ALOS-2 PALSAR in Hai Phong city, Vietnam

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Abstract. Hai Phong city is located in the Northern coast of Vietnam where the mangroves are distributed between zone I and zone II among the four mangrove zones in Vietnam. This city is vulnerable to rising sea levels associated with climate change and tropical cyclones, which are forecasted to become more severe due to the impact of climate change. In the past, mangrove forests in this city have decreased markedly because of over expansion of shrimp farming. Thus, identification of mangrove forests is important to monitor and support mangrove conservation and management in the coastal zone. The objectives of this research were to identify the locations of mangrove and characterize mangrove species in Hai Phong using HH and HV backscatters of the Advanced Land Observing Satellite 2 (ALOS-2) with enhanced Phased Array L-band Synthetic Aperture Radar (PALSAR). Image segmentation was used to identify the locations of mangrove forests. Moreover, Geographic Information System (GIS) was applied to update current status of mangrove species in 2015. The results showed that the means of HH and HV backscatter coefficients of K. obovata are lower than S. caseolaris. K. obovata has HH value around -13.9 dB until -10.3 dB and HV value around -20.6 dB until -16.2 dB. Higher HH values between about -14.9 dB and -6.8 dB and HV values between roughly -20.6 dB and -14.3 dB have observed by S. caseolaris. The total area of mangrove forest in Hai Phong in the year 2015 was around 4084 hectares, of which S. caseolaris occupied over 68% and mixed mangrove species was approximately 25.6%. This research indicates the potential for the use of L-band ALOS-2 PALSAR in characterizing mangrove forest species in the coastal zone.

1. Introduction
Mangrove forests are productive and the most important ecosystems which appear in the inter-tidal zones along the coast in most tropical and semi-tropical climates. They play an important role in protecting land from erosion, mitigate the effects of tropical cyclones [1], and reduce damage from the effects of tsunamis [2]. Moreover, their ecosystems could stabilize coastlines, clean water, and act as highly efficient carbon sinks in the tropics [3]. For centuries, mangroves have contributed significantly to the socio-economic lives of coastal dwellers since they could provide building materials, charcoal, tannin, food, honey, herbal medicines, and other forest products [4].

Nevertheless, mangroves are under severe threat due to high population growth, aquaculture expansion and migration into coastal areas. Globally more than 3.6 million hectares of mangroves have been lost since 1980. Asia has suffered the greatest loss of 1.9 million hectares [5]. The mangrove areas...
in Vietnam have decreased dramatically over the last 50 years [6]. In northern coast of Vietnam, throughout the periods 1964-1997, mangrove area decreased by 17,094 ha. This loss of mangrove forests in the Northern coast of Vietnam due to over expansion of shrimp aquaculture [7]. Therefore, it is necessary to monitor mangroves, and map their locations in order to support coastal zone management and planning programs.

Satellite remote sensing data can be used for large areas and over time and thus represents an alternative tool for monitoring mangrove forests. Throughout the world, many researchers have utilized various satellite remote sensing data for mapping mangrove forests including optical imagery [8-12] and SAR data [9, 13]. However, in Vietnam few studies have used remotely sensed data to characterize mangrove forest types. There is a lack of available and updated data on the current status of mangrove area in Vietnam [14]. Mangrove mapping and change detection have been done only in some specific regions of Vietnam such as Ca Mau Peninsula in the South [15-17], Hai Phong and Quang Ninh in the North [18-20].

The Advanced Land Observing Satellite 2 (ALOS-2) was successfully launched in May 2014 equipped with an enhanced Phased Array L-band Synthetic Aperture Radar (PALSAR-2). ALOS-2 PALSAR provides higher resolution mode and wider area observation compared to ALOS PALSAR. As a result, disaster and environmental monitoring at local, regional and global scales will continue by ALOS-2 [21]. The objectives of this study are to map the locations of mangrove forest types and to investigate characteristics of mangrove species in Hai Phong using ALOS-2 PALSAR. In this study, an object-based method was used for ALOS-2 PALSAR image processing. In addition, Geographic Information System (GIS) was also utilized update information of different mangrove species.

2. Materials and methods

2.1. Materials

2.1.1. ALOS-2 PALSAR. ALOS-2 PALSAR imagery level 2.1 with high sensitive polarimetric mode was used to map the locations of mangrove forest types and characterize distribution of dominant mangrove species in Hai Phong. Data acquisition is shown in Table 1.

| Satellite sensor | Date of acquisition | Level of process | Pixel Spacing | Polarizations |
|------------------|---------------------|------------------|---------------|---------------|
| ALOS-2 PALSAR    | 2015/7/31           | 2.1              | 6.25 m        | L band (HH, HV) |

*Source: JAXA, Japan*

2.1.2. Field survey data. The field data was collected during several field trips carried out during the period of this research (September 2014, July & August 2015). The foundation for these field trips was the collection of land cover information in particular mangrove forest types. Five coastal districts (Fig. 1) were visited in Hai Phong and we collected ground-truth points (GTPs) using GPS (Global Positioning Systems) to characterize dominant mangrove species which are present in Hai Phong. In total, 157 GTPs were collected during field survey, of which 57 locations were recorded for mangrove species.

2.2. Methods

2.2.1. Study site. This study was conducted in mangrove forests of Hai Phong city, which is located between 20°30’ to 20°01’ N latitude and 106°23’ to 107°08’ E Longitude. This city belong to the Northern coast of Vietnam which is about 120 km from the capital Hanoi. The length of sea coast of Hai Phong is about 125 km including the length of coast surrounding the offshore islands. A vast
majority of mangrove forests in the North is distributed in Hai Phong and surrounding provinces [18]. Mangrove forests in this city are under severe threats due to over shrimp aquaculture [7]. Five coastal districts were visited during this research (Fig. 1). Regarding to mangrove species, about 57 different locations were recorded during July and August 2015.

Figure 1. Location map of the study area.

2.2.2. ALOS-2 PALSAR imagery processing. ALOS-2 PALSAR data level 2.1 was acquired from the Remote Sensing Technology Centre (RESTEC) of Japan. The DN (Digital Number) was converted to normalized radar sigma-zero by the equation 1

\[ \sigma^0 [\text{dB}] = 10 \cdot \log_{10} (\text{DN})^2 + \text{CF} \]  

(Eq. 1)

Where \( \sigma^0 \): backscattering coefficient,

\( \text{DN} \): digital number of the amplitude image

\( \text{CF} \) (Calibration Factor) = -83 dB for both HH and HV polarizations [22]. The CF used to process ALOS-2 PALSAR is similar to ALOS PALSAR [23].

The digital number of each pixel was transformed into backscattering sigma naught (\( \sigma^0 \)) in decibel (dB) after applying Forst filters with moving windows of 5 x 5 in order to reduce speckle noise of SAR data.

ALOS-2 PALSAR imagery was classified using a supervised training method by applying maximum livelihood algorithms. The ENVI 5.2 software was also employed for SAR imagery processing. The details of the whole image processing of ALOS-2 PALSAR for 2015 could be similar to image processing for ALOS PALSAR which can be found in [19].

Figure 2 shows an example of image segmentation created from image composite of ALOS-2 PALSAR (RGB = HH, HV, and HH/HV) for land-cover types of Hai Phong city in 2015.

2.2.3. Characterization of mangrove species. In order to characterize mangrove species, a total of 57 sampling plots with size 30 m x 30 m were randomly selected in the study site during field survey in July and August 2015. The species composition of each plot were recorded using GPS. In fact, two dominant mangrove species including: Kandelia obovata and Sonneratia caseolaris were recorded in the study area. All information on mangrove species which are presented in Hai Phong during the year 2015 was updated and stored in ArcGIS 10.3.1 geodatabase.
3. Results and discussion

3.1. Spatial distribution of mangrove forests
Figure 3 displays spatial distribution of mangrove forest types in Hai Phong in the year 2015. Mangroves are presented mostly on the exterior of sea dykes or in the river mouths of Hai Phong. It is quite clear because mangrove could defend against tropical cyclones during stormy season [7].

Figure 2. Image segmentation of land cover types of Hai Phong in 2015.

Figure 3. Mangrove distribution in five coastal districts of Hai Phong in 2015.
Mangrove forests appear in tidal regions of 5 coastal districts of Hai Phong city. Based on the image segmentation from ALOS-2 PALSAR composite, it can be identified different mangrove forest types among other land cover types.

In order to identify the locations of mangrove forests, we collected Ground Truth Points (GTPs) for different land cover types. Then each GTP was extracted HH, HV backscatters values. Finally, all GTPs of each land cover type were calculated min, max, mean and standard deviation for HH and HV backscatters values. Table 2 shows the characterization of backscatter coefficients (HH, HV) for land-cover types of Hai Phong in 2015.

| Land Cover Type | HH Max | HH Min | HH Mean | HV Max | HV Min | HV Mean |
|----------------|--------|--------|---------|--------|--------|---------|
| Mangrove       | -10.9  | -12.1  | -11.5   | -22.8  | -30.1  | -26.8   |
| Water bodies   | -22.8  | -24.1  | -23.4   | -30.1  | -41.4  | -36.4   |
| Settlement     | -8.4   | -1.5   | -13.5   | -24.1  | -35.7  | -29.3   |
| Forest         | -11.9  | -20.0  | -19.2   | -31.2  | -47.5  | -36.4   |
| Bare land      | -12.8  | -29.3  | -24.3   | -47.5  | -74.2  | -58.2   |
| Aquaculture    | -18.6  | -31.2  | -20.5   | -26.4  | -54.6  | -40.4   |
| Rice Paddy     | -21.8  | -28.6  | -17.8   | -24.5  | -41.9  | -31.6   |

It can be seen from table 2 that HH and HV backscattering coefficients of water bodies and aquaculture are lowest among various land cover types, followed by the corresponding figures of rice paddy. The means of backscattering coefficients are about -20 dB at HH and roughly -26 dB at HV for water bodies and aquaculture. In contrast, the means of backscattering coefficients of settlement are lowest among seven land cover types. These numbers are approximately -8.4 dB at HH and around -15.4 dB at HV. Interestingly, the means of backscattering coefficients of forest and mangrove are almost similar at HH whilst the mean of HV for forest cover type is slightly higher than that of mangrove.

3.2. Characteristics of mangrove species in Hai Phong

We compared characterizations of dominant mangrove species in Hai Phong based on backscattering coefficients values at HH and HV polarizations. The result is shown in table 3.

| Species         | HH Max | HH Min | HH Mean | HV Max | HV Min | HV Mean |
|-----------------|--------|--------|---------|--------|--------|---------|
| K. obovata      | -10.3  | -13.9  | -12.0   | -16.2  | -20.6  | -18.2   |
| S. caseolaris   | -6.8   | -14.9  | -9.8    | -14.3  | -20.6  | -16.4   |
| Mixed species   | -7.8   | -15.3  | -11.4   | -13.4  | -22.7  | -17.9   |

The result indicates that the means of HH and HV backscatter coefficients of K. obovata are lower than S. caseolaris. In fact, K. obovata has HH value around -13.9 dB until -10.3 dB and HV value around -20.6 dB until -16.2 dB. Higher HH values between about -14.9 dB and -6.8 dB and HV values between roughly -20.6 dB and -14.3 dB have observed by S. caseolaris. These numbers are slightly lower than those of mangrove forest types in Indonesia due to the significant differences in mangrove species. In
Indonesia, three dominant species accounted for majority of mangrove forests are *Rhizophora*, *Bruguiera* and *Ceriops* [24]. Figure 4 depicts three kinds of mangrove forests in the study sites.

![K. obovata](image1.jpg) ![S. caseolaris](image2.jpg) ![Mixed mangrove forest](image3.jpg)

**Figure 4.** Mangrove forests communities in the study area.

3.3. Mangrove area statistics of Hai Phong in 2015.  
Table 4 indicates the area in hectares and in percentage of each mangrove forest type. As table 4 showed, the largest area is occupied by *S. caseolaris*. The mangrove forest area covered by *S. caseolaris* is approximately 2781 hectares accounting for about over 68% while the area of *K. obovata* is just around 256 hectares. The total mangrove forests area of Hai Phong in the year 2015 is about 4084 hectares.

| Mangrove type  | Area (ha) | Area (%) |
|----------------|-----------|----------|
| *K. obovata*   | 256.05    | 6.27     |
| *S. caseolaris*| 2781.07   | 68.09    |
| Mixed species  | 1046.83   | 25.64    |
| Total          | 4083.95   | 100      |

It is quite clear because *S. caseolaris* could grow well in the high level of tidal due to their pneumatophores while *K. obovata* could not survive from high tidal inundation. Therefore, *K. obovata* often plants together with *S. caseolaris* [4]. From 2001 to 2013, mangrove forests increased slightly in Hai Phong then continued its upward trend in 2015 thanks to community-based forest management in cooperation with local authorities [25].

4. Conclusion  
This research demonstrates that L-band ALOS-2 PALSAR data could be used to characterize the spatial distribution of mangrove species in the coastal zone. The results of this research indicated that *K. obovata* has HH value around -13.9 dB until -10.3 dB and HV value around -20.6 dB until -16.2 dB. Higher HH values between about -14.9 dB and -6.8 dB and HV values between roughly -20.6 dB and -14.3 dB have observed by *S. caseolaris*. The total area of mangrove forest in Hai Phong during the year 2015 is around 4084 hectares, of which *S. caseolaris* occupied over 68% and mixed mangrove species is approximately 25.6%. This research indicates the potential for the use of ALOS-2 PALSAR in characterizing mangrove forest species in the coastal zones. For future works, we will estimate above ground biomass and carbon storage of mangrove species using ALOS-2 PALSAR and field survey measurements.
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