

USING ALOS DATA FOR CLASSIFICATION OF LAND AND WATER USE IN NHA TRANG, VIETNAM

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ABSTRACT

The increasing availability of Earth observing satellites and instrumentation leads to increased image quality and quantity. The Advanced Land Observation Satellite (ALOS) provides three instruments: (1) Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM – 2.5m resolution), (2) Advanced Visible and Near Infrared Radiometer (AVNIR-2 – 10m) and (3) Phased Array type L-band Synthetic Aperture Radar (PALSAR – 2.5-10m). These instruments all provide improved opportunities for systematic land and water-use classification in coastal regions.

This study concentrates on the vicinity of Nha Trang City, Vietnam. We use atmospherically corrected ALOS AVNIR-2 data for supervised classification of land and water use. A hierarchical classification approach is used separating inland and coastal as well open water use types. On the land surface, land cover such as urban, cultivated land and aquaculture represented 10.1, 4.9 and 3.0% of total of land use, respectively. In the coastal and open water regions, eight ports and anchoring sites were located within semi-open waters, river mouths and nearby human settlements on islands. Also 23ha of marine culture was identified around Hon Mieu, northwestern Hon Mot and southern Hon Tre. Even though high spatial resolution ALOS AVNIR-2 data was used, some land cover types such as small houses, were difficult to identify. In addition, spectral similarities were found in marine culture cages and ships. Spectral similarities were resolved using a fusion technique or in-situ identification of these special types of land cover and water use. In general, the typical length scale (spatial, spectral) of ALOS AVNIR-2 data was sufficient to classify land cover and water use in a coastal region of Vietnam.

1. INTRODUCTION

Classification of land and water use, which plays an important role in managing and exploiting natural resources and thus economic development, has been an important field of study to monitor the status and changes of land and water use. The classification is done by in-situ observation and/or estimation from remote sensing images. Remote sensing images have been applied at multiple scales, from molecules to ecosystems and biomes, depending on the objectives of the study (reviewed by Schaepman *et al.*, 2009). Classification of environmental quality in the oceans and offshore waters was applied by low resolution images, whereas land use was often classified with medium or high resolution images. For example, Antoine *et al.* (1996) divided environmental quality of waters based on ocean color images. Images of Envisat, Meris, Landsat and SPOT, in addition, have been used for classification of land use and land cover in agricultural regions, forests, and urban regions (reviewed by Green

et al., 2000; Richardson and LeDrew, 2006). Most studies, however, have only focused on lands or waters separately and did not classify land and water use for coastal zone management at the same time. The Advanced Land Observation Satellite (ALOS) images could meet these needs both in targeted coastal areas and in image quality.

The ALOS satellite, which was launched in 2006, is an earth observation system. Three instruments of ALOS provide high and medium spatial resolution imagery: (1) Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM – 2.5m resolution), (2) Advanced Visible and Near Infrared Radiometer (AVNIR-2 – 10m) and (3) Phased Array type L-band Synthetic Aperture Radar (PALSAR – 2.5-10m). Their products have been applied for estimation of gross primary production (As-syakur *et al.*, 2010), classification of forests as well as estimation of water quality (Giardino *et al.*, 2010) and environmental pollution (Le Minh Hang and Nguyen Dinh Duong, 2007). ALOS images have not widely been applied for the use of land classification. As-syakur *et al.* (2010), however, demonstrated the accuracy ratio of ALOS images analysis was similar with those results of Aster images. Therefore, in this paper, we use ALOS image to classify land and water use in coastal zones in Nha Trang (Vietnam) supporting coastal management.

2. MATERIALS AND METHODS

2.1. Study area

This study was carried out for both the land and water regions in Nha Trang City (Fig. 1). Because of the fast advancement of the city and restructuring its economy, land use in Nha Trang has changed rapidly. Nowadays, the economy of Nha Trang mainly focuses on the development of marine ecotourism and further development of marine resources. This has accelerated after Nha Trang officially became a level I city in 2009. Some regions are used as a marine protected area (MPA). These MPAs cover a region of 16,000 ha, including 3,800 ha of islands. The MPA are divided into three regions: core zones (located around Hon Mun, Hon Vung, Hon Cau, northeastern Hon Tre and a part of B  y lagoon, and some regions were set up as rehabilitation zones), buffer zones (identified as a 300m belt surrounding core zone, Hon Mieu, Hon Tam and Hon Mot, as well as marine regions among Hon Tre, Hon Mot and Hon Mun), and transition zones (the remaining regions).

2.2. Study materials

The ALOS AVNIR-2 data were collected on July 17, 2007, and were used to classify land and water use in Nha Trang (Fig. 1). The ALOS image has 4 spectral bands: Band 1 - blue (420-500nm), band 2 - green (520-600nm), band 3 - red (610-690nm) and band 4 - near-infrared (NIR: 760-890nm) all with a spatial resolution of 10m. Geolocation of ALOS data was performed using available digital maps from Vietnam. All satellite data were reprojected into UTM with the WGS84 datum in zone 49N.

2.2. Classification method

The classification processing of ALOS image was carried out in twelve steps (Fig. 2). These steps had 2 parts: preliminary analysis and classification. An important step was the atmospheric correction to prepare the image for the classification. To achieve this, pixel digital numbers of each image band were converted to sensor radian by the approach of Bouvet *et al.* (2007). In the common process of atmospheric correction, the dark objective

value, an important parameter to identify the aerosol optical depth (AOD) for atmospheric correction, was estimated from the pixel value of short-wave infrared (SWIR, around 2.2 μm), blue (480 nm) and red (660 nm) bands. However, ALOS images do not have bands at SWIR. Thus, the AOD was estimated from the red and near-infrared (NIR) bands following Richter et al. (2006). Then, the image would be corrected by using their method with the rural model in ENVI's ATCOR tool.

In the subsequent classification, land and water uses were classified separately because some land and water use types had similar reflectance value. For land regions, the image was divided into twenty-four classes, but after field trips and ground truthing, the number of classes was reduced to twelve. For water regions, the ports and anchor areas were also identified during the field trips. Water use was initially divided into twelve classes but later they were combined in just three classes: marine culture, anchoring sites and unused water.

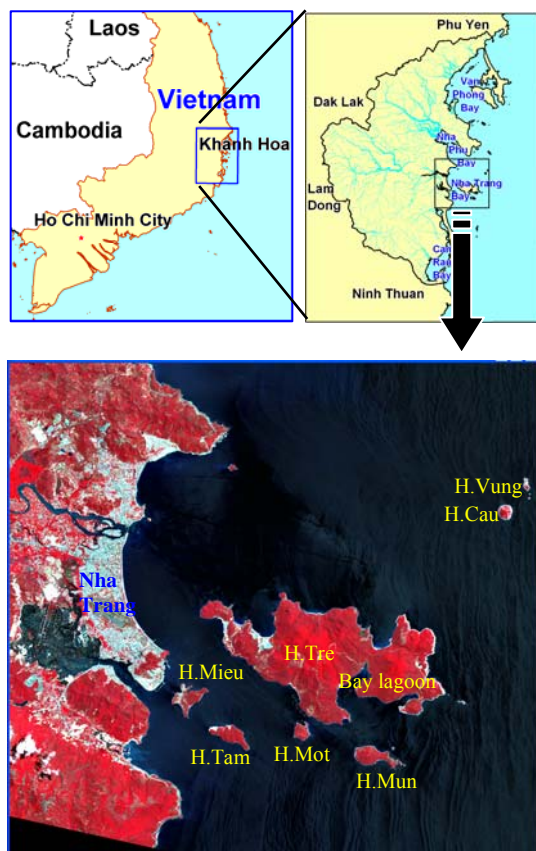


Figure 1. Study area located within ALOS AVNIR-2 data acquired on July 17, 2007 (false color).

3. RESULTS AND DISCUSSIONS

3.1. Land use classification

Land use in Nha Trang was abundant (Fig. 3). That contributed mainly to natural land (including forests, a major part of rock/hard covered and bare land areas), urban (settlements) regions, cultivated lands and aquaculture (Fig. 3). Urban, cultivated land and aquaculture represented 10.1%, 4.9% and 3.0% of total of land use, respectively (Fig. 3b).

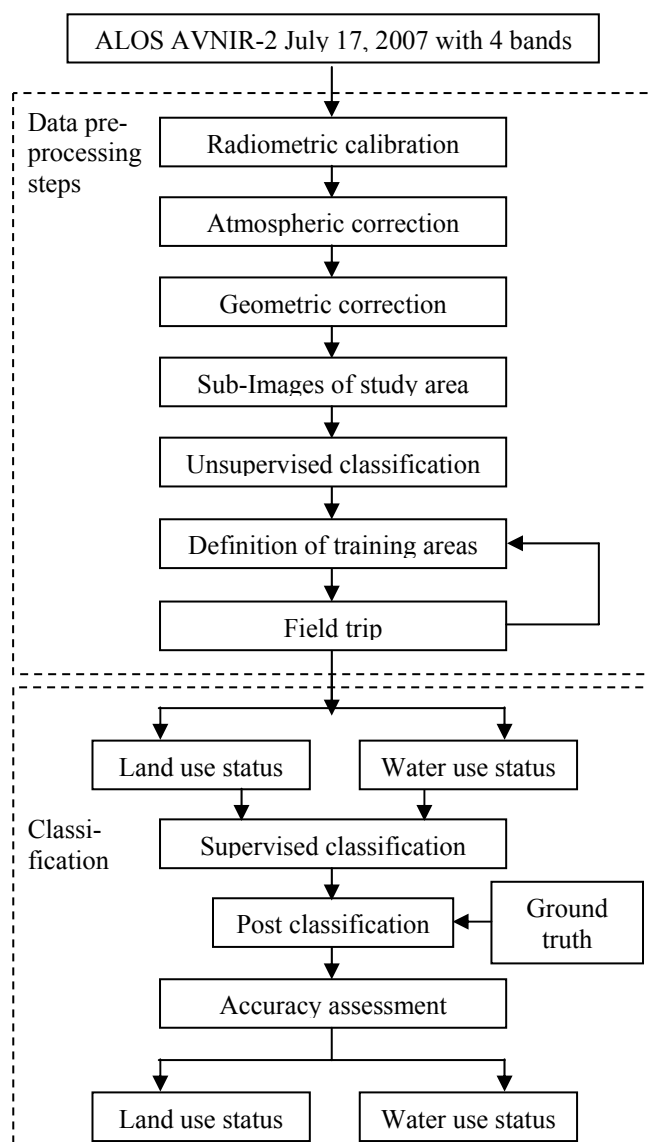


Figure 2. Flowchart of classification for land and water use with ALOS image in ENVI

These types were distributed in the centre of the Nha Trang region. A large part of the area consisted of natural land (Fig. 3). This type dominated mainly in mountains, islands and changing-land-use. In addition, the accuracy ratio of vegetable, cultivated and aquaculture regions was more than 83%, whereas that ratio of urban region (e.g. settlements) was about 61%. Urban regions were defined as the complex landscapes which combined houses, roads, soil, water, garden/vegetation and other infrastructures (Melesse *et al.*, 2007), but in our study, the high resolution imagery allowed to limit urban regions to solely classify houses, buildings and roads. Thus, the estimated urban area was less than the actual urban area.

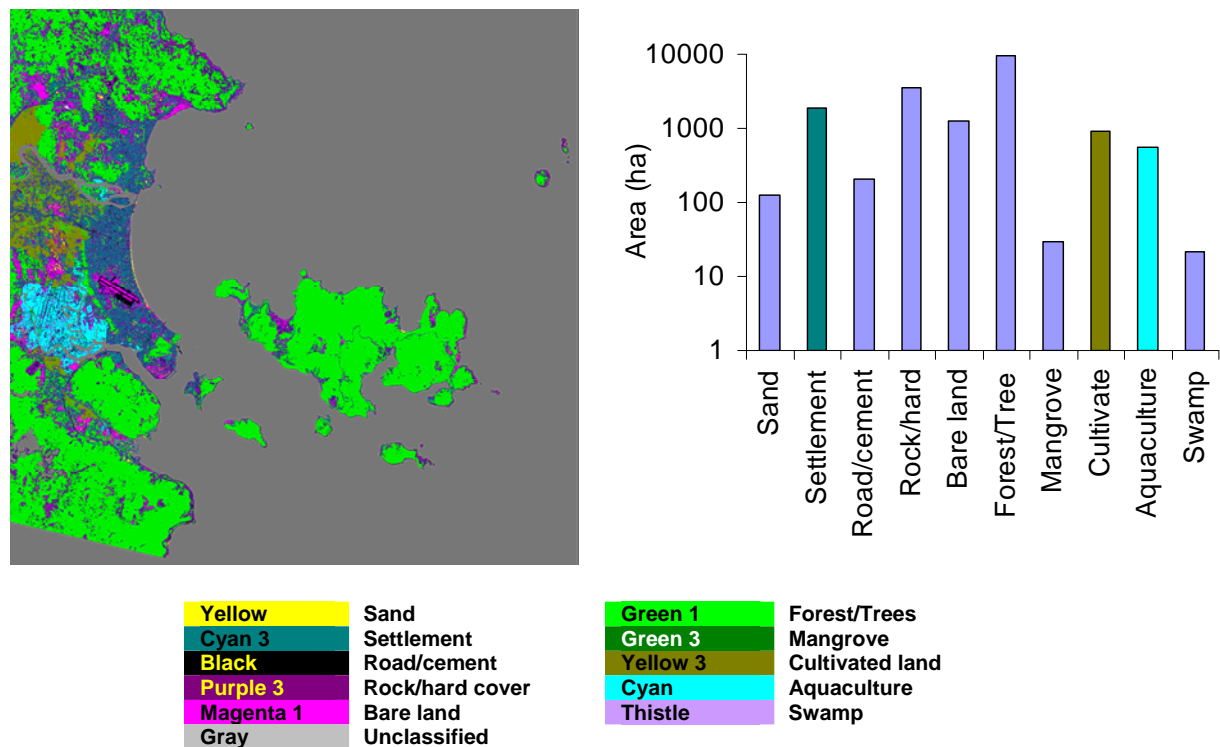


Figure 3. Land use classes (left) and their spatial coverage (right) in Nha Trang estimated from ALOS data in 2007. Legend colors are selected according to water quality impact.

However, the low accuracy ratio for urban areas was still caused by mixed pixels. Nha Trang has emerged from small towns and agricultural areas, with many small buildings (size < 5x5 m). These buildings in rural and sub-urban regions were part of the mixed pixels. Further, the increased dust from roads and construction sites caused changed the normal reflections. Therefore, these small-scale land use types in complex landscapes lead to an increasing the number of mixed pixels and this reduced the accuracy of the land use estimation. This was also observed by others (e.g. Melesse *et al.*, 2007).

This classification, however, aimed to increase the accuracy ratio. On the one hand, a “hard classification” could help increasing the ratio up to 80% by accomplishing a pixel-by-pixel classification. On the other hand, a “soft method” (e.g. a fuzzy classification approach with other higher resolution images) assesses the relationship between pixels in each land-use type. Fortunately, the ALOS satellite not only provides AVNIR-2 images but also the pan band of PRISM at 2.5m resolution. Thus, it is possible to increase the resolution of ALOS AVNIR-2 images by fusion the images with the pan band (Fig. 4). Consequently, the analysis complimented with at a 2.5 m resolution is more accuracy and display many more details.

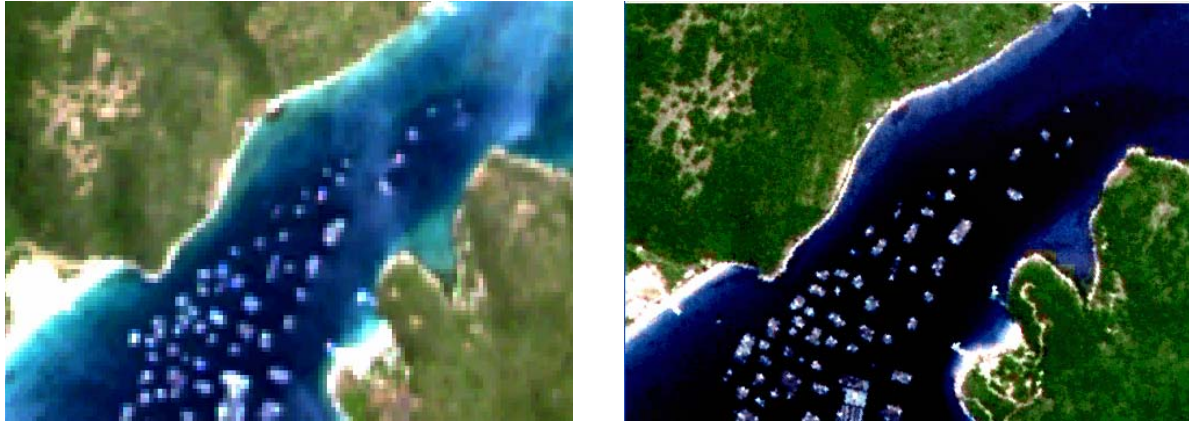


Figure 4. Application of PAN fusion method for ALOS data. Left: AVNIR-2 (10m resolution) data and right: PAN fused images (2.5 m resolution).

3.2. Water use classification

Like the land-use classification method, three water use classes were used in Nha Trang waters (Fig. 5). Eight ports and anchoring sites, which were identified by field trips, were used to separate the regions of marine culture. These sites were located at semi-opening waters (army, goods and tourism ports), river mouths (fishing boats anchoring sites) and nearby human settlement in islands (fishing boats anchoring sites). In addition, our estimates show that marine aquaculture covered 23ha of water. These marine cultures can lead to nutrient enrichment of the marine environment (Borja *et al.*, 2009) and this impacts was considerably up to 50m from the actual sites. Therefore, these 23ha of aquaculture should be complemented with a buffer zone of 50m. Using the ENVI software, this results in an area of marine culture of 121ha.

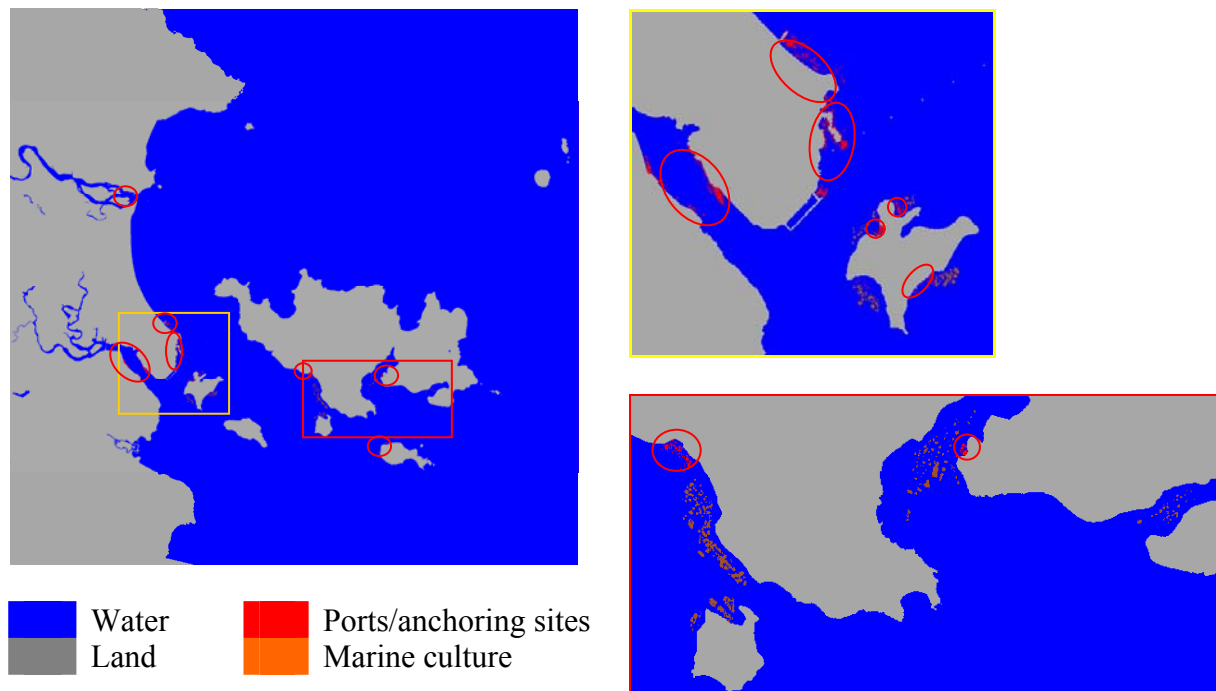


Figure 5. Water use classes in Nha Trang derived from ALOS data in 2007. Left: Full area, Right top and bottom: Zoomed to sensitive areas. Ports and anchoring sites are marked using red ellipsoids.

4. CONCLUSIONS

We applied a supervised classification approach to corrected ALOS AVNIR-2 images to identify land and water use. The urban regions, cultivated lands, aquaculture (both, inland and in open waters) and ports/anchoring sites could be distinguished. Activities in these areas contribute considerably to the Nha Trang's economy but also threaten the environmental quality. Spectral confusion increased particularly in more complex landscapes and too small size of specific land and water uses, which when compared with the pixel size, negatively impacted the accuracy of the classification. However, these problems were minimized by using a PAN fusion approach with high resolution data from PRISM, and by classifying land use and water use separately. In conclusion, the ALOS AVNIR-2 and PRISM fused images added noticeably a promising innovative opportunity to study land and water with appropriate level of detail. This is urgently needed for integrated coastal zone management together with making progress in the economic, social and environmental aspects of sustainable development.

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