別紙様式８

研　究　主　論　文　抄　録

論文題目　**Applications of remote sensing and geostatistics to monitoring of intertidal sediments with a case study of Ba Lat estuary, Northern Vietnam**
（リモートセンシングと地球統計学を用いた潮間帯堆積物のモニタリング，およびその北部ベトナム Ba Lat 河口への応用）

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主論文要旨

Vietnam coastline stretches from north to south about 3,260 km and there are over 100 large and small estuaries, as well as about 3,000 near shore islands, along the coastline. The Ba Lat Estuary (BLE) located in Northern Vietnam is one of the biggest river mouths and the most representative deltas in Vietnam. Like tropical estuaries in the world, the BLE is characterized by a wide variety of tidal flats including intertidal mudflats, sand flats, shoals, sand dunes, sandy islands, mangroves which play significant roles as nesting, feeding and spawning grounds for wildlife, especially migratory birds. However, tidal flats have been changed in quantity and quality by environmental and ecological degradation associated with shoreline erosion, climate change, and economic development pressure. Monitoring tidal flats hence becomes a great need and effective way for coastal sustainable management. Especially, intertidal sediments have been paid attention to monitor because the exhibiting heterogeneously in spatial - temporal of intertidal sediments contribute to understand the hydro-dynamic condition, biogeochemical cycle, morphological change and contaminated process in the estuary.

Remote sensing provides an adequate tool for monitoring tidal flats with low cost consumption and rapid update on quantitative synoptic view of tidal flats. Microwave remote sensing and airborne remote sensing have gained an advantage over optical remote sensing in application for the tidal flat monitoring due to their sensors are independent on acquisition time and weather condition but more expensive. On the

contrary, an extreme difficulty in applying optical remote sensing for monitoring tidal flats is to collect satellite image at the same time as collecting ground truth data under the fine weather condition and low tide level. However, some optical remote sensing data are free or low price with high spatial resolution. An alternative approach is using the multi images that have smallest time gap with ground truth data. This study attempts to map intertidal sediments by regression analysis between the multi image and ground truth data. The resultant intertidal sediment maps obtained from remote sensing data are evaluated by comparing with each other and with the map created from ground truth data using geostatistic modeling.

Field and laboratory measured data of sediment samples taken in the BLE were used to calibrate relationships between the reflectance and sediment properties. Sediment grain size is key sediment property selected for mapping intertidal sediment types. Other sediment properties such as water content, organic matter content and mineral composition were considered to evaluate their effects on the reflectance of sediments. ALOS and ASTER imagery were used because of high spatial resolution, high quality (cloudlessness, small time gap with ground truth data) and availability of ASTER time series images.

Firstly, grain size distribution of intertidal sediments in the BLE was estimated by applying ordinary kriging method for laboratory measured grain size data. The results show that intertidal sediments in the study area exhibited heterogeneity in spatial distribution with the sand content (fraction > 0.063 mm) increased with an increase distance from mainland. Four sediment types could be recognized: sand, muddy sand, sandy mud and mud. The sandy sediment types are dominant from the near sea shoals (Con Mo, Con Vanh, Con Thu) to centre of study area. The muddy sediment types concentrate on from inner edge to centre of study area, where mangroves cover partly these tidal flats. Such trend in intertidal sediment distribution in Ba Lat estuary corresponded with the sediment exhibition rule of tidal flats as a result of wave, currents and tide actions.

In order to validate and improve accuracy of mapping intertidal sediment distribution using remote sensing, it requires a comprehensive understanding of spectral characteristics of sediments under the laboratory condition. Therefore, effect of sedimentary properties on the laboratory measured reflectance of intertidal sediments was investigated separately and simultaneously. The reflectance varied inversely with sand content showing clearly in both the case of four sediment types (mud, sandy mud, muddy sand and sand) and overall sediment samples at the ALOS band 1 to band 4 and had slightly stronger correlation under the dry condition than the wet condition (r =-0.78 and -0.71, respectively). The reflectance increasing with loss of water content

observed in the mud, sandy mud, muddy sand and sand types. However, the reflectance had positive correlations with both the water content (r=0.55) of overall wet sediment samples and organic matter content (r=0.76) for wet sediment samples contain >0.20% organic matter content, because it could be derived from the dominant influence of grain size on the reflectance attributed to interrelation of the reflectance and sediment parameters. The reflectance showed no significant correlation with the mineralogical compositions. The ALOS band 4 presented the strongest correlation with the sand content, it therefore was suggested the ALOS band 4 to be the most suitable wave length range for distinguish intertidal sediments in the next work.

Maps of intertidal sediment distribution were generated by using ALOS and ASTER imagery combine with sediment grain size data via regression analysis. Between the sediment grain size and both reflectance data extracted from ALOS band 4 and ASTER band 3 showed negative correlations (r=-0.75, -0,78, respectively) which agree with the correlation found between the sediment grain size and the laboratory measured reflectance at simulated ALOS band 4 as mentioned in previously. Intertidal sediment distribution pattern estimated from ASTER data exhibited general trend as grain size increases toward the sea that similar as the intertidal sediment distribution on the map modeled by ordinary kriging method. Some sand domains located on the sandy shoals in the northeast and southwest parts of the study area were estimated to be sandy mud domains on the map created from ALOS image. Misclassification of sediment grain size observed on the ALOS image based map could be attributed to the water surface covering the tidal flats at the incoming tide. Additionally, the intertidal sediment map based on ASTER image was obtained from single band (band 3). Consequently, further study should consider other image classification techniques such as maximum likelihood, factor analysis, and spectral unmixing to verify this regression model.