Test Application of KOMPSAT-2 to the Detection of Microphytobenthos in Tidal Flats

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Abstract—Microphytobenthos bloom from late January to early March in Korean tidal flats. KOMPSAT-2 will provide multi-spectral images with a spatial resolution of 4 m comparable with IKONOS. Using IKONOS and Landsat data, algal mat detection was tested in the Saemangeum area. Micro-benthic diatoms are abundant and a major primary product in the tidal flats. A linear spectral unmixing (LSU) method was applied to the test data. LSU was effective to detect algal mat and the classified algal mat fraction well correlated with NDVI image. Fine grained upper tidal flats are generally known to be the best environment for algal mat. Algal mat thriving in coarse grained lower tidal flats as well as upper tidal flats were reported in this study. A high resolution multi-spectral sensor in KOMPSAT-2 will provide useful data for long-term monitoring of microphytobenthos in tidal flats.

Index Terms— Micophytobenthos, tidal flats, KOMPSAT, linear spectral unmixing, benthic algae.

I. INTRODUCTION

Microphytobenthos are principal primary producers that supply nutrients to the intertidal ecosystem. They bloom between late January and early March in Saemangeum tidal flats, Korea. It is called algal mat that microphytobenthos are in full bloom to make a patch when temperature and nutritive salts are in the most suitable for their growing. Algal mat not only provide nutrients but also build extracellular polymeric substance network which prevent erosion of sediments. It is important to monitori the distribution and density of algal mat for evaluating primary product in a tidal flat, its effect to the intertidal ecosystem., and sediment stability. Remote sensing is a useful tool for monitoring micropythobenthos in tidal flats.

High resolution multi-spectral images with a spatial resolution of several meters such as IKONOS and Quickbird become available. In 2005, Korea will launch KOMPSAT-2 equipped with high resolution multi-spectral sensors comparable with IKONOS. It is necessary to test the feasibility of KOMSPAT-2 to micropythobenthos monitoring in tidal flats before launching.

In Korean tidal flats, mirco-benthic diatom is the most common microphytonbentos. Fine grained upper tidal flats are known to be the best for this mirco-benthic diatom. In Saemangeum area (Fig. 1), dikes have been under construction since 1991 and affected ecosystem inside the dikes. Environmental effects of the dikes have not been fully understood. Here we report algal mat in coarse grained lower tidal flats detected by Landsat ETM+ images.

Characteristics of micropythobenthos in the study areas are described in the next section. The results of a

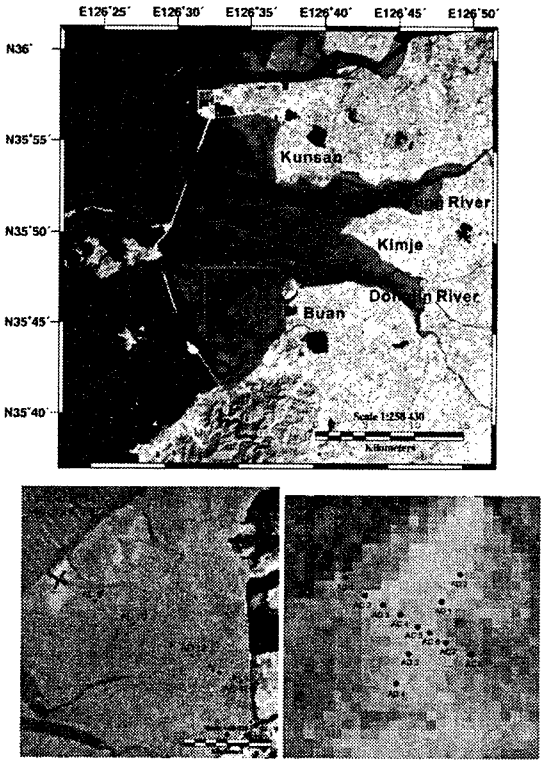

Fig 1. Landsat TM image in the Saemangeum tidal flats (upper) and samplig sites (lower). Algal mat are rendered as green in tasseled cap tranformed images.

linear spectral unmixing (LSU) applied to multi-spectral data are discussed in Section III followed by conclusions.

II. TEST SITES AND ALGAL MAT

Saemangeum tidal flats are located west coast of Korean Peninsula. As in Fig. 1, wide and two-funnel shaped estuarine zone formed by coastal merging of the Mankyung and Dongjin River mouths are called as "Saemangeum Estuary." Buan intertidal is located on the southern part of Saemangeum Estuary. Tides are semidiurnal with a mean tidal rage of 430cm (mean spring tide: 603cm, mean neap tide: 276cm) [1]. Except the nearby of channel, a depth of water is 0 - 2 m.

Micro-benthic diatoms are the most common primary product in Korean tidal flats. They are observed in multi-spectral remotely sensed images. Optical reflectance from micro-benthic diatoms at near infrared is relatively low compared with that from land vegetation. Fine grained upper tidal flats are known to be the best habitat for this mirco-benthic diatom. After the tidal flat bottom surface is exposed to air, algal mat begins to emerge from below the surface. Microphytobenthos prefer longer exposure time to the Sun. Upper tidal flat has longer exposure time with low tidal energy and the best conditions for most microphytobenthos. Fine grain size is also preferred by micro-benthic diatoms. However, we found strong algal mat signatures in coarse-grained lower tidal flats. The microphytobentos residing in coarse grained lower tidal flats are very unusual and characterized by a very strong reflectance at near infrared band. It was suspected that the species residing in the lower tidal flats might be different species from common micro-benthic diatom. Fig. 2 is a microscopic photo of the microphytobenthos bloomed in coarse grained Buan lower tidal flat. Fig. 3 displays the chlorophyll-a content along the sampling line from AC1 to AC17 in Fig. 1. Chlorophyll-a content was specially high from sampling site AC2 to AC 8 in which sediments were composed mainly of fine sand. The location is characterized as lower tidal flats and fine sand dominant composition. Fig. 4 is a QuickBird image in the Buan lower tidal flat in which a new species of microphytobenthos was found.

Fig. 2 Microscopic photo of the observed microphytobenthos in coarse grained Buan lower tidal flats.

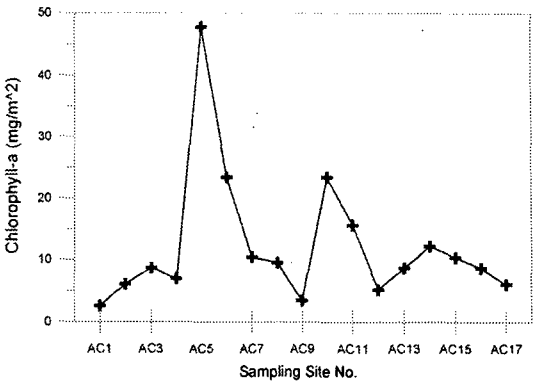

Fig. 3. Chlorophyll-a content along a sampling line AC1-17 in Figigure 1.

Saemangeum dikes have been under construction since 1991. When Landsat images in early 1990s were reviewed, the chlorophyll features in the Buan tidal flat were not detected. The microphytobenthos residing in coarse grained lower tidal flats was confirmed as not a diatom but algae. The cause of emergence of this species is yet to be studied. The construction of dikes has apparently affected the ecosystem inside the dikes and might be related to cause of the new microphytobenthos.

III. RESULTS OF LINEAR SPECTRAL UNMIXING

Spectral unmixing is a deconvolution technique that aims estimating the surface abundances of a number of spectral components or together causing the observed mixed spectral signature of a pixel [2].

A. Spectral Library

Eighty two spectra points were measured between April 2002 and March 2003. We obtained typical spectra through analysis of grain size, moisture content, chlorophyll-a content and spectral data. Field Spec FR

Fig. 4 QuickBird image of the algal mat in the Buan lower tidal flat. Algal mat is rendered by red.

(ASD field spectrometer) recorded in the range from 350 to 2500 nm at an interval of 1 nm. Sand and mud have similar spectral patterns but they are distinguishable with continuum removal. Microphytobethos showed a typical absorption band at 670nm and strong reflection at 720nm.

B. *Atmospheric Correction*

We acquired a Landsat ETM+ on 16 January and 14 February 2003 before and during algal mat blooming period. COST model was applied for an atmospheric correction and then examined a correlation between satellite image and spectral data acquired from tidal flat. Atmospheric correction model for IKONOS was not open to public. Since there was a strong linear correlation, R^2 of 0.984, between Landsat ETM+ data and IKONOS corresponding, the same COST model was applied to IKONOS data.

C. *Determination of End-Members*

Water, sediments, and microphytobenthos were selected as end-members in the tidal flats. To determine the value of end-members, we used two methods. The first method was based upon spectral library that measured at field. The spectral range of 450 - 900 nm was used for comparison. Second method was deriving end-members from the ETM+ image pixels. The pixels presenting purely an end-member nature, ideally that is not mixed with other end-members, must be selected [3]. Minimum Noise Fraction Transformation (MNF) was used to determine the purest pixels.

D. *Results of Linear Spectral Unmixing (LSU)*

Study area is heterogeneous in its fraction distribution and very complicated area. Sediment, microphytobethos and water are mixed in the intertidal flats. Especially micro-benthic diatoms exist all over the intertidal. But Chlorophyll-a from the patches in the uppermost sediment surface can better be detected and estimated by image [4]. LSU by exploiting spectral library was applied to Landsat ETM+ band 1 to band 4 to obtain the results in Fig. 6. Microphytobenthos residing in lower tidal flats are well detectable rendered as high values (or bright) in algal mat fractions (upper right image of Fig. 5) while lower (or dark) in sediment fractions (lower left image of Fig. 5). But the error matrix shows a structure, which implies errors are not random.

The accuracy of the linear spectral unmixing model may be evaluated by comparing the estimated values with actual ground observations. The correlation between the in-situ sampled data and the estimated algal mat fraction was very poor. Microphytobenthos fraction images were also compared with NDVI that is highly sensitivity to microphytobenthos. The correlation coefficient of Fig. 5 with NDVI was R=0.86. Reference end-members from spectral library were slightly more effective than image end-members.

The newly detected algal mat in the Buan flat was plotted on a tidal flat DEM in Fig. 6. Lower tidal flats

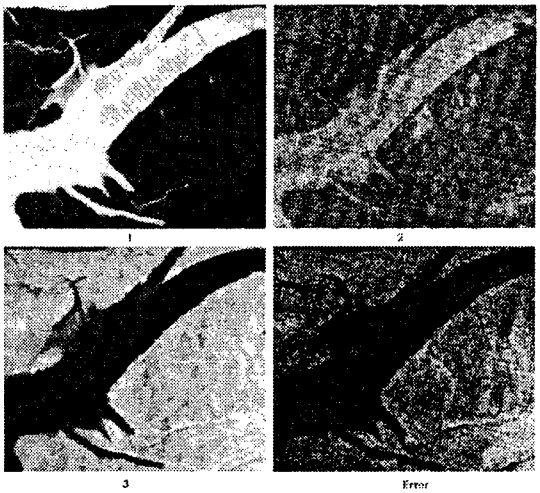

Fig. 5 Results of LSU by using end-members estimated from spectral libtray: water (upper left), microphytobenthos (upper right), sediments (lower left), and error fraction (lower right).

with fine sand composition provided a rich habitat for this microphytobenthos.

E. *Effectiveness of High-resolution Image and KOMPSAT-2*

High resolution multi-spectral data become available and popular to use. KOMPSAT-2 will be launched in late 2005, and will provide data comparable with IKONOS. Although medium resolution multi-spectral data such as Landsat TM are very useful to detect and monitor microphythobenthos in tidal flats, it is very difficult to delineate blooming and non-blooming areas of algal mat. In the future, the area of algae should be measured to monitor consistently. Fig. 4 is a QuickBird image showing the target algae (red). The total algal mat area in this region has increased since its first appearance. To understand the relationship between the growth of this unusual algae and changes in environmental conditions, it is necessary to delineate the boundary of

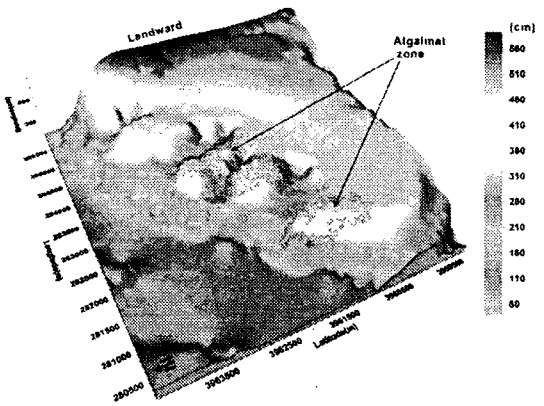

Fig. 6 Algal mat habitat detected by this study. Note that coarse-grained lower tidal flats provide a rich habitat for a certain microphytobenthos.

algal mat blooming by using high resolution multi-spectral data.

IV. CONCLUSIONS

Microphytobenthos are primary product in tidal flats, and required to continuously monitor their distribution for understanding tidal flat ecosystem. Algae bloomed in coarse grained lower tidal flats is first reported in this study.

A linear spectral unmixing using Landsat ETM+ images was very effective to detect algal mat in the Saemangeum tidal flats. LSU results showed that the classified layer of algal mat relatively well correlated with NDVI image. Reference end-members from the spectral library were slightly more effective than that of image end-member for discriminating algal mat from sediments. It was not possible to do volumetric estimation of algal mat in tidal flats by remotely sensed data alone.

High resolution multi-spectral data are important to delineate the boundary of algal mat, and KOMSPAT-2 will provide very valuable data for microphytobenthos in tidal flats.

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