Detection of Microphytobenthos Using Spectral Unmixing Method in the Saemangeum Tidal Flat, Korea

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Abstract: Microphytobenthos that supply nutrients to the intertidal ecosystem play an important part as a primary producer. If we estimate distribution and density of microphytobenthos, we can possibly calculate a volume of primary product in the tidal flat and its effect to the intertidal ecosystem. To estimate the portion of microphytobenthos, we used a linear spectral unmixing (LSU) method. LSU is a tool for inference the proportions of the pure components (or end-members) in a mixed pixel. The selection of end-members is critical to LSU. The end-members can be selected either from spectral libraries built from field surveys or from a remotely sensed image. We compared the two approaches of end-member selection, and the preliminary results showed end-members from from spectral library are as effective as those from image itself.
Keywords: Linear spectral unmixing, Micophytobenthos

1. Introduction

Field observation in tidal flats is seriously restricted Remote Sensing, combined with in situ surveying, is an effective tool for monitoring the tidal flats. 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 (van der Meer, 2000).

Let Re_{ij} be an end-member to decompose the mixed reflectance spectrum of each pixel, R_i. f_i in Eq. (1) is the fraction of each end-members. The sum of the fractions f_i should be 1.

$$R_i = \sum_{j=1}^{n} f_i \, Re_{ij} + e_i \qquad (1)$$

$$RMS = \sum_{k=1}^{m} \frac{\sqrt{\sum_{j=1}^{n} \left(R_{jk} - R'_{jk}\right)^2 / n}}{m} \qquad (2)$$

In Eq. (a), e_i is a residual error that can be calculated from the difference of modeled (R_{jk}) and measured (R'_{jk}) digital number in band *i*. And *n* is the number of spectral bands and m is the number of pixels within the image. This error should be near zeros and must not show any structure.

Using this method we classified intertidal to microphytobenthos, sediments and water.

2. Test Site and Data

1) Test Site

Wide and two-funnels shaped estuarine zone formed by coastal merging of both Mankyung and Dongjin river mouths is 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) (Chun, 2002). Except the nearby of channel, a mean depth of water is from 0 to 2m.

2) Atmospheric Correction

We acquired a Landsat ETM+ on 14 February 2003 when is the season of blooming.

To estimate the microphytobenthos distribution quantitatively, it is necessary to correct atmospheric effect on satellite image.

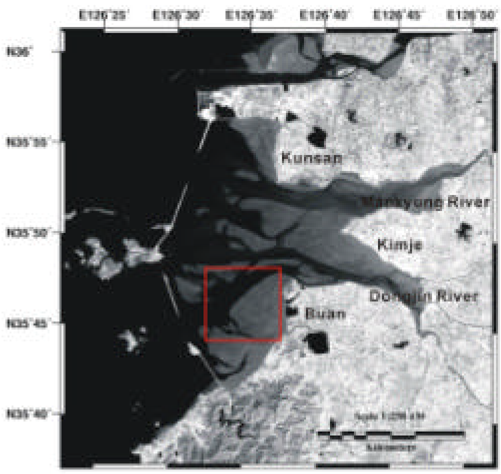

Fig 1. Study area

Using the COST model (improved DOS model), we conducted an atmospheric correction then examined a correlation between satellite image and spectral data acquired from tidal flat.

3) Selection of End-Members for Spectral Unmixing

We unmixed spectral data that could represent water, sediments and microphytobenthos in the tidal flat. To select end-members, we used two methods. The first method was based upon spectral library that measured at field. A Field Spec FR (ASD field spectrometer) was used to measure reflectance in the field. Reflectance data were recorded in the range from 350 to 2500 nm at an interval of 1 nm. We used the spectral range from 450 to 900 nm for comparison. From the several field surveys, we acquired typical spectrum of sediment and microphytobenthos (specifically micro-diatoms). Grain size, moisture content and chlorophyll-a content were measured.

The second method is deriving end-members from the ETM+ image pixels (Asner et al., 2002). In that case, the pixel must present purely an end-member nature, ideally that is not mixed with other end-members. To determine the purest pixels we used Minimum Noise Fraction Transformation (MNF).

3. Results

1) End-Member from Spectral Library

82 spectra points were investigated between April 2002 and March 2003. We found typical spectra by not only continuum removal but also analysis of grain size, moisture content, chlorophyll-a content and spectral data. Fig 2 shows the reflectance from spectral library and image for the typical sediments (sand) and microphytobenthos. Microphytobethos have a typical absorption at 670nm and a typical reflection at 720nm by chlorophyll-a. Water absorbed at the visible and near infrared range. Because of difficulty of approach to sea water, we could gain pure water's spectra in the field. Instead of measuring from water in the sea, we derived from the image.

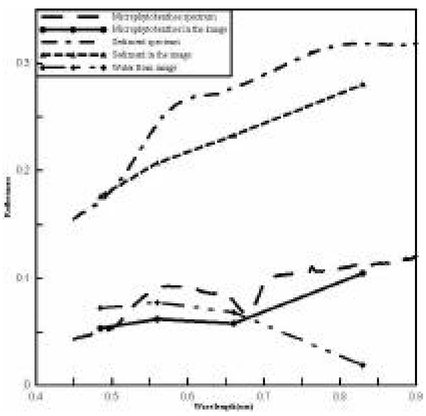

Fig 2. Reflectance from spectral library and from image for the typical sediments (sand) and microphytobenthos.

The trend of spectra from the library generally agrees with that from Landsat ETM+ image.

2) End-Members from Images

End-members are the purest pixel spectra in the dataset and are often located at the extremities of the scatterplot when two MNFs are plotted against each other. Each end-member located at the extreme corner of each part.

Fig. 4 shows end-members derived from an image. It has slightly lower reflectance than end-members from spectral library. Sediment spectral has light absorption at the band 3.

3) Linear Spectral Unmixing

Study area is heterogeneous in its fraction distribution and very complicated area. Sediment, microphytobethos and water are mixed in the intertidal flats. Especially microphytobenthos exist all over the intertidal (Our main target was microphytobenthos patch). But Chlorophyll-a from the patches in the uppermost sediment surface can better be detected and estimated by image (Riethmuller et al., 2000). We applied LSU to Landsat ETM+ band 1 to band 4 to comparing the results of LSU using different end-member selection approaches.

One can verify the result of LSU using Error matrix. Error matrix should be near zero and must not show any

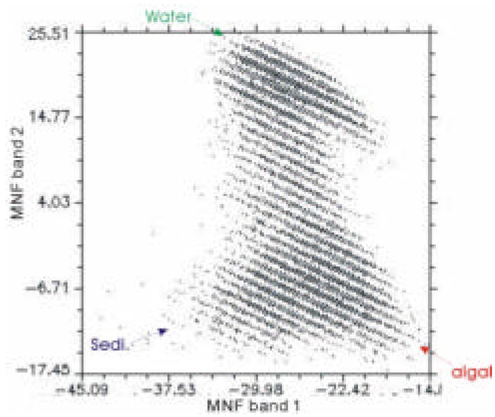

Fig 3. Scatterplot of MNF band 1 and MNF band 2.

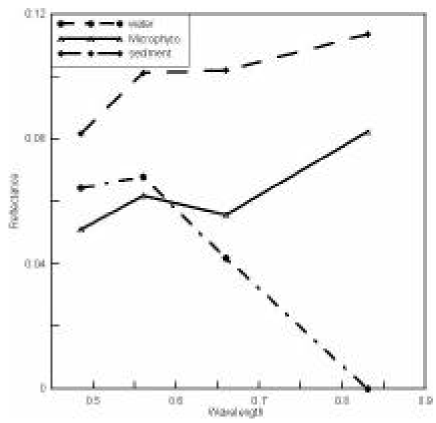

Fig 4. Relfectance from images

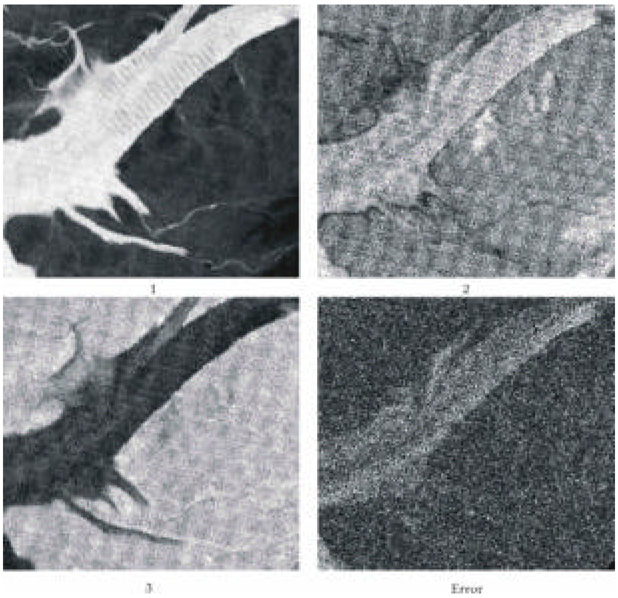

Fig 5. LSU using end-members from the image. 1) water fraction, 2) microphytobenthos fraction, 3) sediment fraction, and 4) error fraction.

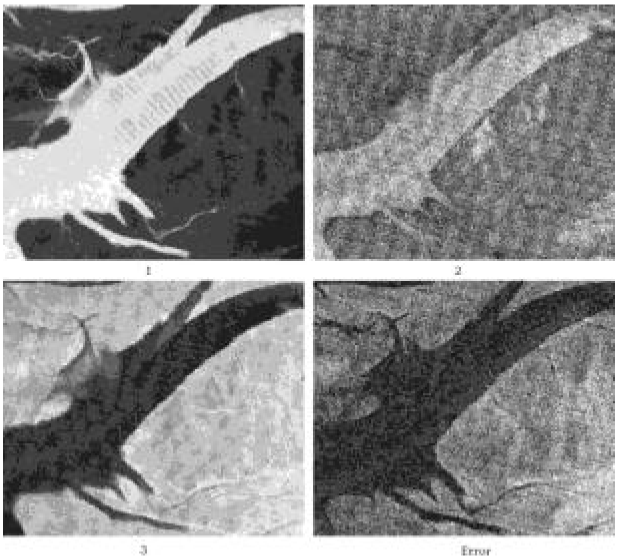

Fig 6. LSU using end-members from the spectral library. 1) water fraction, 2) microphytobenthos fraction, 3) sediment fraction, and 4) error fraction.

structure. Figs. 5 and 6 show results of LSU. Fig. 5 is the result of LSU using end-members from image. Sediment is better detected than Fig. 6, and the error matrix Fig. 5(4) does not show structure. Fig. 6 is the result of LSU using end-members from the spectral library. It can detect certain area like microphytobenthos, but do not well represent the spectral properties of the entire area. So it has a structure in the error matrix.

The proportion of end-members derived from two methods are to be validated. The accuracy of the linear spectral unmixing model may be evaluated by comparing the estimated values with actual ground observations. When such ground-truth is absent, alternate methods for validating the unmixing model are to be used. Lack of real time ground data at the time of data acquisition, microphytobenthos fraction images were compared with

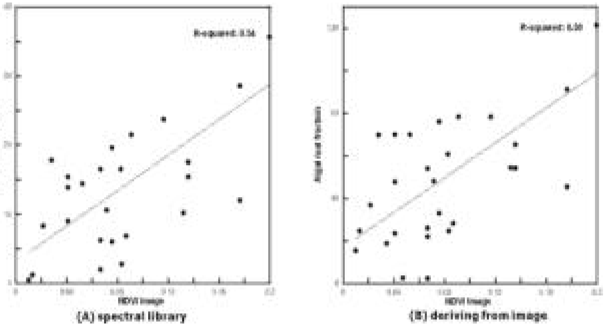

Fig 7. Relationship of image NDVI and microphytobenthos fraction of LSU. (A) end-members from spectral library, (B) end-members from image

NDVI. NDVI is highly sensitivity to microphytobenthos. If a microphytobenthos fraction image is positively correlated with the NDVI image, then it may be presumed that the vegetation fractions derived by spectral unmixing are correct (Shanmugam, 2002). Fig. 7 shows the correlation between NDVI from image and microphytobenthos fraction from LSU. The end-members estimated from the spectral library as effective and correlated to NDVI as those from image itself.

4. Conclusions

End-members were selected from image and spectral library. LSU results show that the classified layer of microphytobenthos relatively well correlates with NDVI image. Application of spectral library turned out to be effective. According to the fraction images, we can estimate amount of microphytobenthos in the uppermost sediment surface. However, it is still far from the exact volumetric estimation of microphytobenthos.

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