Application of remotely sensed images to the mapping of seagrass in coastal waters

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Contents

- Seagrass mapping in the Korean coastal water
- Tidal flat application
- Coral reef habitat mapping
- Geostationary Ocean Color Imager (GOCI)
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Global seagrass diversity and distribution

- **Zostera marina**, Z. caulescens, Z. japonica, Z. asiatica, Z. caespitosa
- **Phyllospadix iwatensis**, P. japonicus
- **Ruppia maritima**
- **Halophila nipponica**

- 4 genus, 5 species inhabit in Korea

Short et al. 2007
Why seagrass beds are important?

- Provides habitats of a variety of coastal organisms
- Produces organic clasts through photosynthesis
- Dominates substances circulation in the coastal ecosystems by secreting dissolved organic matter
- Provides fields for spawning and growth of the fish of large economic value
- Stabilizes bottom sediment by controlling their movement and suspension

→ very large ecological value in the coastal region
Due to high ecological value of seagrass beds, studies on its distribution, production, etc. have been continuously carried out in Korea. However, seagrass distribution and biomass research has been carried out in some limited areas and depth because it relies on the direct sampling method through scuba diving.
Methods for mapping seagrass

- To overcome the difficulties in the research on the distribution and spatiotemporal changes of seagrass, diverse techniques like underwater photography, underwater acoustics and remote sensing are employed.

- Underwater photography using video camera has an advantage in that it can identify species, density, and plant health status with relatively low cost. However, data collection is limited due to a narrow range of observation, and in particular, the accuracy is influenced by the turbidity of the water, which lead to difficulties in analyzing whole vegetated sites.
Methods for mapping seagrass

- Recently aerial photography is widely used. It can obtain images of wide area, but due to the large cost it is not suitable for repeated temporal analysis for a particular region.
- Remote sensing technique is an effective way for the study on the temporal and spatial distribution of algae that live in the broadband.
Aims of study

Satellite remote sensing method
- Mapping
- Wide area
- Time-series data

Hydroacoustic method
- Height
- Coverage
- Mapping

Direct sampling method
- Height
- Coverage
- Biomass

Application of a satellite image time-series to map changes of seagrass beds

Evaluate the accuracy of satellite image for mapping seagrass beds in turbid and shallow coastal waters
Study area

- Survey area: 16 km²

*Zostera marina*, *Z. caulescens*, *Halophila nipponica*
Hydroacoustic survey

- **Equipment**
  - Digital Echosounder (Biosonics, USA)
    - beam width : 6° (420KHz)
    - pulse width : 0.1 ms
    - pings rates : 5 pings s⁻¹
    - ship speed : 2 m s⁻¹
  - DGPS (horizontal error : ± 5 m)

Accurate positioning of the surveyed location was secured
Hydroacoustic transect

Lines of hydroacoustic survey

Specific area for satellite image analysis
Analysis of satellite image

<table>
<thead>
<tr>
<th>Satellite scene</th>
<th>Date</th>
<th>Time</th>
<th>Low tide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat 5TM</td>
<td>1995.11.27</td>
<td>10:05</td>
<td>07:00 (042) 13:00 (369)</td>
</tr>
<tr>
<td>Landsat 5TM</td>
<td>1999.3.11</td>
<td>10:44</td>
<td>05:00 (250) 11:00 (170)</td>
</tr>
<tr>
<td>Landsat 5TM</td>
<td>2000.3.13</td>
<td>10:39</td>
<td>09:00 (136) 15:00 (256)</td>
</tr>
<tr>
<td>Landsat 5TM</td>
<td>2001.4.1</td>
<td>10:45</td>
<td>09:00 (145) 14:00 (237)</td>
</tr>
<tr>
<td>Landsat 7ETM</td>
<td>2002.2.7</td>
<td>10:54</td>
<td>07:00 (275) 14:00 (146)</td>
</tr>
<tr>
<td>Spot-4</td>
<td>2004.2.27</td>
<td>11:38</td>
<td>09:00 (141) 14:00 (254)</td>
</tr>
<tr>
<td>Kompsat-2</td>
<td>2007.12.20</td>
<td>10:36</td>
<td>07:00 (301) 13:00 (129)</td>
</tr>
<tr>
<td>Aster</td>
<td>2011.3.27</td>
<td>11:24</td>
<td>11:41 (159) 16:46 (206)</td>
</tr>
<tr>
<td>Kompsat-2</td>
<td>2012.1.7</td>
<td>10:30</td>
<td>09:13 (321) 15:42 (108)</td>
</tr>
</tbody>
</table>

- **Image classification**
  - Mahalanobis distance classification (MDC) : one of the cluster analysis
**Field observation & in situ spectral measurement**

- **Field observation**
  - 2012. 1. 17-20
  - 2012. 2. 20

- **Equipment**
  - FieldSpec3 (ASD Inc., USA)

(A) Seagrass beds & unvegetated area
(B) Unvegetated seawater
(C) Seagrass beds
(D) Seaweed aquaculture
Optical data measurement

- Total water leaving radiance (LwT)
- Sky radiance (Lsky)
- Down-welling irradiance (Ed)
- Radiance from white reference plate (Lwhite) for data calibration
- Instrument: dual field spectroradiometer (ASD Inc.)
Accuracy evaluation of satellite image classification

1. Field observation for error matrix

- 50% of in-situ measurement was used for the validation (error matrix)

2. Correlation map

Kompasat-2 classification

Hydroacoustic mapping
Results from hydroacoustic survey

- Seagrass area from hydroacoustic survey: 4.5 km²
- Seagrass were mainly distributed within 0-2 m depth based on the lowest low water level
- No seagrass in the area of 7-9 m depth
Field spectrum

- Seawater
- Seagrass
- Aquaculture
Spatial & spectral resolution

<table>
<thead>
<tr>
<th>Band</th>
<th>Kompsat-2</th>
<th>Spot-4</th>
<th>Aster</th>
<th>Landsat-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>0.45-0.52</td>
<td>-</td>
<td>-</td>
<td>0.45-0.52</td>
</tr>
<tr>
<td>Green</td>
<td>0.52-0.60</td>
<td>0.50-0.59</td>
<td>0.52-0.60</td>
<td>0.52-0.60</td>
</tr>
<tr>
<td>Red</td>
<td>0.63-0.69</td>
<td>0.61-0.68</td>
<td>0.63-0.69</td>
<td>0.63-0.69</td>
</tr>
<tr>
<td>NIR</td>
<td>0.76-0.90</td>
<td>0.78-0.89</td>
<td>0.78-0.86</td>
<td>0.76-0.90</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>4 m</td>
<td>10 m</td>
<td>15 m</td>
<td>30 m</td>
</tr>
</tbody>
</table>
Reflectance correction using spectral response function

Kapsat-2

Landsat-5

Aster

Spot-4

Seagrass

Seawater
**Accuracy assessment of satellite classification**

![Map A](image1.png)

**In situ data**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Seagrass</th>
<th>Seawater</th>
<th>Aquaculture</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seagrass</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>Seawater</td>
<td>4</td>
<td>13</td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>4</td>
<td>0</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>18</td>
<td>15</td>
<td>15</td>
<td>48</td>
</tr>
</tbody>
</table>

**Producer’s accuracy**: 55.5%  Seagrass (satellite)  86.6%  Aquaculture (satellite)  80%  Seagrass (echosounder)

**User’s accuracy**

- Seagrass: 71.4%
- Seawater: 72.2%
- Aquaculture: 75.0%
- **Total**: 72.9%
Spatial distribution of seagrass beds
Spatial distribution of seagrass beds

1999 (Maximum) 2011 (Minimum)
Long term changes of seagrass distribution
Contents

- Seagrass mapping in the Korean coastal water
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Seagrass in tidal flats

- Geunso-Bay tidal flat
  - semi-diurnal tides (mean tidal range = 6 m)
  - 70% of the flat is exposed during low tide and water depth is 2-4 m at high tide
Seagrass in tidal flats

d) NDVI (NIR-R / NIR+R): clear pattern of seagrass, diatom

c) NIR+Red+Green of Landsat ETM+ (February 20, 2004)
   → red area: chlorophyll dominant (seagrass at the bay mouth, Fig. a)
   → widely reddish area: algal mat (Fig. b)
Diatom blooming in tidal flat surface

- Overall concentration of Chlorophyll a
  - 88.0 ~ 222.1 mg·m⁻² (February, 2007)
  - 43.2 ~ 115.9 mg·m⁻² (May, 2007)

- Algal mat, which has been formed by diatom blooming, is well developed at some sampling locations in February
Diatom blooming in tidal flat surface

- Seasonal variations in diatom distribution Landsat ETM+
  - clear pattern of diatom blooming in tidal surface was identified in the image from October to February
  - decrease until September and increase again
  - specific blooming in the center part of study area from the image of February
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Coral reef habitat in Weno Island, FSM

Weno island in the Chuuk lagoon of Federated States of Micronesia
- biodiversity: Mangrove forest, Seagrass, Coral reef communities
Seagrass in Weno Island, FSM

Long Seagrass

Short Seagrass

Coral
Coral reef habitat mapping

← WorldView-2 image at Feb, 3rd, 2010

KOMPSAT-2 : 2010. 09
Field data : 2011. 09

- Large Seagrass
- Short Seagrass
- Sand+Seagrass
- Sand
- Coral
- Rubble
- Rock
## Habitat mapping & Change monitoring


<table>
<thead>
<tr>
<th>Class Names</th>
<th>Color</th>
<th>Pixels</th>
<th>Area (m²)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 seagrass (1)</td>
<td></td>
<td>78557</td>
<td>78557</td>
<td>15.26</td>
</tr>
<tr>
<td>2 seagrass (2)</td>
<td></td>
<td>24794</td>
<td>24794</td>
<td>4.82</td>
</tr>
<tr>
<td>3 Sand</td>
<td></td>
<td>85416</td>
<td>85416</td>
<td>16.60</td>
</tr>
<tr>
<td>4 sand + short grass</td>
<td></td>
<td>86134</td>
<td>86134</td>
<td>16.74</td>
</tr>
<tr>
<td>5 sand + long grass</td>
<td></td>
<td>16286</td>
<td>16286</td>
<td>3.16</td>
</tr>
<tr>
<td>6 coral (1)</td>
<td></td>
<td>51790</td>
<td>51790</td>
<td>10.06</td>
</tr>
<tr>
<td>7 coral (2)</td>
<td></td>
<td>70603</td>
<td>70603</td>
<td>13.72</td>
</tr>
<tr>
<td>8 coral (3)</td>
<td></td>
<td>94248</td>
<td>94248</td>
<td>18.31</td>
</tr>
<tr>
<td>9 rock</td>
<td></td>
<td>3261</td>
<td>3261</td>
<td>0.63</td>
</tr>
<tr>
<td>10 deep sea</td>
<td></td>
<td>3570</td>
<td>3570</td>
<td>0.69</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>514659</td>
<td>514659</td>
<td>100</td>
</tr>
</tbody>
</table>

### Results

- **Area of seagrass**: increased 8%
- **Total area of coral reef habitat**: decreased 6.28% from 42.09% to 35.82%
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Technical Specification of GOCI

- **GOCI**
  - GSD(Ground Sampling Distance) : 500m * 500m
  - Target Area : 2,500km * 2,500km (Center : 130°E 36°N)
  - Included Nations : Korea, China, Japan, Russia, etc.
  - Temporal Resolution : 1hour (8 times at 1 day)

Spectral Bands Characteristic and Requirements of GOCI

<table>
<thead>
<tr>
<th>Band</th>
<th>Central wavelengths</th>
<th>Band Width</th>
<th>SNR</th>
<th>Type</th>
<th>Primary Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>412 nm</td>
<td>20 nm</td>
<td>1,000</td>
<td>Visible</td>
<td>Yellow substance and turbidity</td>
</tr>
<tr>
<td>B2</td>
<td>443 nm</td>
<td>20 nm</td>
<td>1,090</td>
<td>Visible</td>
<td>Chlorophyll absorption maximum</td>
</tr>
<tr>
<td>B3</td>
<td>490 nm</td>
<td>20 nm</td>
<td>1,170</td>
<td>Visible</td>
<td>Chlorophyll and other pigments</td>
</tr>
<tr>
<td>B4</td>
<td>555 nm</td>
<td>20 nm</td>
<td>1,070</td>
<td>Visible</td>
<td>Turbidity, suspended sediment</td>
</tr>
<tr>
<td>B5</td>
<td>660 nm</td>
<td>20 nm</td>
<td>1,010</td>
<td>Visible</td>
<td>Baseline of fluorescence signal, Chlorophyll, suspended sediment</td>
</tr>
<tr>
<td>B6</td>
<td>680 nm</td>
<td>10 nm</td>
<td>870</td>
<td>Visible</td>
<td>Atmospheric correction and fluorescence signal</td>
</tr>
<tr>
<td>B7</td>
<td>745 nm</td>
<td>20 nm</td>
<td>860</td>
<td>NIR</td>
<td>Atmospheric correction and baseline of fluorescence signal</td>
</tr>
<tr>
<td>B8</td>
<td>865 nm</td>
<td>40 nm</td>
<td>750</td>
<td>NIR</td>
<td>Aerosol optical thickness, vegetation, water vapor reference over the ocean</td>
</tr>
</tbody>
</table>
Time-series variations in GOCl-derived turbidity

areas of relatively high turbidity (in red) gradually decreased over time
- clear water from open sea suppressed turbidity during flood tide
around the time of high tide, turbidity was remarkably lower
- settlement of suspended particulates during the transition from flood to ebb tide
and resulting lull in the tidal current
GOCI-based CHL-a 1-h interval image (2012.4.17)
GOCI-based TSM
daily composite
(2011.9.1-
2013.12.31)
Summary

- Seagrass beds was spectrally distinct from unvegetated seawater and aquaculture in the high spatial resolution satellite images.
- Remotely sensed images can be applied to the mapping of seagrass distribution with relatively high accuracy (73%).
- Annual variability in spatial change of seagrass distribution was observed between 1995 and 2012.

→ Remote sensing technique is effective for long-term monitoring of seagrass beds distribution combined with in-situ observation.
Thank you

jkchoi@kio.st.ac

http://www.divephotoguide.com/user/stevedeneef/gallery/gallery/photo/12361/