F-2.1 Monitoring and mapping of wetland with remote sensing (Final Report)

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Abstract: This project investigates new techniques for wetland monitoring using remotely sensed images, with a special emphasis on wetland vegetation mapping. There are 3 major original contributions in this thesis: First is the development of new spectral indices, such as Perpendicular Vegetation Index, Water Turbidity Index, and Vegetation-Soil-Water Index. Second is the development of a new unmixing method called the subspace method. Third is the development of a new classification method using multi-temporal satellite images.

Key Words: Remote Sensing, Wetland, Classification, Multi-temporal, Unmixing

1. Introduction

New satellite sensors are now providing a huge number of time series of remotely sensed images of the earth's surface. There is an increasing need for improved techniques to extract information about the earth ecosystems from these remotely sensed data, because remote sensing is the only comprehensive approach to monitor the global environment. However, until recently, there have been few studies on the techniques for monitoring complex natural ecosystems such as wetlands. In this project we have investigated new techniques for wetland environmental monitoring using remotely sensed images, with a special emphasis on wetland vegetation monitoring.

2. Research Objective

The 3 major research objectives in this project are:

1) The development of new spectral indices, such as PVI (Perpendicular Vegetation Index), WTI (Water Turbidity Index), and VSWI (Vegetation-Soil-Water Index), that can be used to monitor the vegetation, water, and soil conditions in wetland areas. These indices allow assessment of the states of wetland environments and changes in them.

2) The development of a new unmixing method called the subspace method. This new unmixing method is effective for delineating continuous vegetation distribution using spectral image data.
3) The development of a new classification method using multi-temporal satellite images.

In the following, methods and results for these 3 research objectives are discussed, respectively.

3. Research Method

1) PVI was further developed to the VSWI that can monitor vegetation, soil and water at the same time. An algorithm to determine automatically the end-member spectral points for vegetation, soil and water was developed by fitting a triangle to the scatter plot instead of finding the soil line. The distances between the spectrum point and the triangle edges were used as the new index. In conventional unmixing approaches, end-member points are often determined manually and arbitrarily from the image data or from a scatter plot of the data. The new algorithm automatically determines the end-member points. The VSWI was applied to wetland monitoring using multitemporal Landsat TM image data. Vegetation, soil, and water conditions and changes were successfully delineated.

2) New approach to the unmixing problem, the subspace method, was developed and applied to wetland vegetation using hyperspectral image data. Unmixing by the subspace method was superior to conventional methods for hyperspectral imagery in numerical stability and computational speed. The results of an unmixing application showed that unmixing by subspace is accurate except for classes that are spectrally very similar.

3) We established a way to classify wetland vegetation types using multitemporal remotely sensed image data. Because seasonal changes in the wetland vegetation happen rapidly, it is difficult to classify using a scene obtained on a single date. In an experiment, we used multitemporal Landsat TM data acquired over the Kushiro wetland in June, August, and November, to classify the major vegetation types--reeds, sedges, alder trees, and Sphagnum moss. Distinct temporal growth patterns of wetland vegetation both in biomass and spectral signatures were apparent from measurements of biomass and spectral reflectance of several vegetation types. By using this temporal information for the vegetation types, it was possible to classify them with a high degree of accuracy.

4. Research Results

1) The new spectral index called a Vegetation-Soil-Water (VSW) index can be used to monitor wetland conditions. The VSW index is defined as a natural extension of PVI for monitoring not only vegetation conditions but also soil and water conditions as well. VSW

index is defined using a triangle on a NIR–Red scatter plot. The PVI measures only vegetation parameters, whereas the VSW index monitors vegetation, soil and water parameters simultaneously by measuring the distances in the scatter plot. Landsat Thematic Mapper (TM) scenes were used for the analyses. Wetland plants in Kushiro Mire were in the beginning of their growing season in June, and in their maximum growth stage in August. All the vegetation was dead in October. These scenes show how the vegetation changes seasonally and year by year for 5 years. We determined the end member spectral points for vegetation, soil and water (VSW) with an algorithm to fit a triangle to the spectral distribution. This automatic end member determination also standardizes the spectral responses of scenes. Scatter plots of the TM scenes on NIR–red axes were overlaid with the determined VSW end member points. The VSW index was used to monitor land cover change in the Kushiro wetland with Landsat TM images to evaluate the effectiveness of our approach for wetland monitoring. Changes in the vegetative components of the Kushiro wetland, both seasonally and over the full 5 year period we examined, could be easily resolved from these color composite images.

2) A new approach of unmixing with the subspace method is proposed and an experiment using hyperspectral image was conducted. In stead of using conventional statistical unmixing procedures which incorporate all channel data to perform unmixing, the proposed approach assigns subspace for each unmixing class. In this method, unmixing is calculated by the projection of observed pixel vector on the class subspaces. This method is more stable than conventional methods against noises and works effectively as a feature extraction and data reduction procedure at the same time. Owing to these advantages, this approach is suitable for the unmixing of hyper spectral image which has high correlation between channels. The performance of this method is tested by an experimented using a hyper spectral CASI image acquired over a wetland area. Unmixing of 7 wetland vegetation classes were calculated using least square, quadratic programming, orthogonal subspace projection and subspace method. Finally, the results of unmixing experiment were compared and evaluated for the use of wetland vegetation monitoring.

3) In order to improve the accuracy of vegetation classification, we have investigated the wetland vegetation classification using multi–temporal Landsat TM images. Because the growth pattern of a wetland vegetation changes according to the vegetation type, we can used this difference of temporal growth pattern which appear in the multitemporal images for classifying the vegetation types. In order to clarify this temporal growth pattern of wetland vegetation types, we have conducted sampling experiments to measure the biomass growth during the growing season. And also spectral reflectance measurements were conducted to see the spectral difference between the vegetation types as well. As the result of supervised classifications using the multitemporal Landsat TM image, an accurate wetland vegetation classification map has been produced.

5. Discussion

The advanced remote sensing techniques developed in this thesis can be applied to the actual wetland monitoring in several ways:

1) The Vegetation–Soil–Water Index (VSWI) is useful for monitoring the wetland complex using Satellite–borne optical sensors. Because the wetland area is composed of vegetation, soil (or sediment), and water, this three indices are most natural for evaluating the state of the wetland. This index is applicable not only the high resolution sensors such as Landsat, but also to the global coverage image such as NOAA. Although the Normalized Difference Vegetation Index (NDVI) has been used unanimously as the spectral index using NOAA data, VSWI will be anlernative index that is more suitable for imaging the wetland area. Once the VSWI is calculated we can proceed to quantitative studies like vegetation amount estimation or to classification of the image using VSWI as the new signature space.

2) Unmixing using hyperspectral data is a promising approach for monitoring wetland area. Because the wetland is one of the most complicated ecosystems in the world, to extract the information on the each constituent of wetland is the ideal approach for studying the wetland ecosystems. Especially in bog area, wetland ecosystem is very sensitive to the environmental change. Even a subtle vegetational difference, which reflect the water flows underneath, might be an ecologically important factor for managing the area. Moreover the extracted spatial distribution of each vegetation type tell us the history of the vegetational succession in the past.

3) In the near future, huge amounts of new types of remotely sensed data will become available with the launching of the Japanese ADEOS II platform and the American EOS platform. These new data will provide us with global coverage as well as high–dimensional optical and radar band information. The potential of the new classification approach using multi–temporal satellite images will be challenged by these data.

Reference

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