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The Analysis of Spectral characteristics of Water Quality Factors Using Airborne MSS Data

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Airborne MSS 자료를 이용한 수질인자의 분광특성 분석

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Abstract

Airborne MSS data is regarded as a potentially effective data source for the measurement of water quality and for the environmental change of water bodies. In this study, we measured the radiance reflectance by using multi-spectral image of low resolution camera(LRC) which will be reached in the multi-purpose satellite(KOMPSAT) to use the data in analyzing water pollution. We also investigated the possibility of extraction of water quality factors in water bodies by using high resolution remote sensing data such as Airborne MSS. Especially, we tried to extract environmental factors related with eutrophication such as chlorophyll-a, suspended sediments and turbidity, and also tried to develop the process technique and the radiance feature of reflectance related with eutrophication. Although it was difficult to explicitly correlate Airborne MSS data with water quality factors due to the insufficient number of ground truth data. The results were summarized as follows: First, the spectrum of sun's rays which reaches the surface of the earth was consistent with visible bands of 0.4μm~0.7μm and about 50% of total quantity of radiation could be found. The spectrum was reached highest at around 0.5μm of green spectral band in visible bands. Second, as a result of the radiance reflectance Chlorophyll-a represented high mainly around 0.52μm of green spectral band, and suspended sediments and turbidity represented high at 0.8μm and at 0.57μm, respectively. Finally, as a result of the water quality analysis by using Airborne MSS, Chlorophyll-a could have a distribution image after carrying out ratio of B3 and B5 to B7. Band 7 was useful for making the distribution image of suspended sediments. When we carried out PCA, suspended sediments and turbidity had distributions at PC 1 and PC 4 which are

similar to the ground data. Above results can be changed according to the change of season and time. Therefore, in order to analyze the environmental factors of water quality by using LRC data more exactly, we need to investigate the ground data and the radiance feature of reflectance of water bodies constantly. For further studies, we will constantly analyze the radiance feature of the surface of water in water bodies by measuring the on-the-spot radiance reflectance and using low resolution satellite image(SeaWiFS). We will also gather the data of water quality analysis in water bodies and analyze the pattern of water pollution.

요 약

Airborne MSS 자료는 수질오염을 효과적으로 감시하고 분석할 수 있는 자료이다. 본 연구에서는 다목적 실용위성(KOMPSAT)에 탑재될 저해상도카메라(LRC)의 다중분광 영상자료를 수질오염 분석에 활용할 목적으로 수질인자의 분광반사도를 측정하였으며, 고해상도 원격탐사 자료인 Airborne MSS 자료를 이용하여 수역에서의 수질인자 추출 가능성을 조사하였다. 특히 부영양화와 관련된 환경인자 추출을 시도하였다. 수질인자는 클로로필-a, 부유물질, 탁도 등을 선정하여 분광반사 특성 및 처리기법을 개발하였다. 그 결과는 다음과 같다. 첫째, 수면에 도달하는 태양광 스펙트럼은 가시광 영역인 0.4~0.7μm에서 전체 복사량의 50% 정도가 반사되며, 0.50μm 부근에서 가장 높다. 둘째, 클로로필-a는 녹색파장대인 0.52μm, 부유물질의 반사도는 0.8μm, 탁도는 0.57μm에서 높은 반사율을 보였다. 셋째, Airborne MSS자료를 이용하여 수질인자 분석결과, 클로로필-a는 Band 3과 Band 7을 비연산처리를 하여 분포도를 작성하였다. 부유물질은 Band 7에서 분포도를 작성할 수 있었으며, PCA를 수행하였을 때 PC 1에서 유용함을 알 수 있었다. 탁도는 PCA 분석시 PC 4에서 현장자료와 유사한 분포패턴을 나타내었다. 이상의 결과들은 계절적, 시간적 변화에 따라 파장대역이 달라질 수 있으므로, LRC 자료를 이용하여 보다 정확한 수질환경 인자를 분석하기 위해서는 현장실측 자료 및 수역의 분광반사 특성 등을 지속적으로 조사할 필요가 있다. 추후 본 연구에서는 저해상도 위성영상 및 현장 분광반사도 측정을 통한 수역의 분광반사 특성을 지속적으로 분석하고, 수역의 수질분석자료 확보 및 수질오염 유형을 분석할 것이다.

1. Introduction

Recently, the range of human activity has become wider with a rapid progress of scientific technique. That resulted in natural environment destruction and dried up natural resources. Those problems are raising in a great factor through out the world. Especially, water pollution is becoming strained as the modern civilization has industrialized. Several kinds of methods are suggested to solve the problems. Generally, the extension and elevation of industrial structure owing to the industrialization caused various pollutants and vicious effects such as the exhaust of heavy metal. Particularly, the flow of all sorts of nutriment that are exhausted from the sewage or

waste water generates eutrophication phenomenon.

Eutrophication can be defined as a case that plant plankton grows excessively as the large amount of nutrition inflows into the lake or the river. Therefore we are subject to restriction in using water. When we comment on eutrophication, items related to the quality of water such as BOD, COD, T-N, T-P and Chlorophyll-a are considered. Indirectly, suspended sediments or transparency can be object on measurement. In addition, temperature is also one of factors of eutrophication.

At present, eutrophication in rivers and water bodies is presented as a serious social problem. Hereupon, a large scale and systematic skill for analyzing the water quality is required in order to manage this problem effectively. However, the present analysis method of water quality in river and water bodies is difficult to inspect the constant distribution status, movement and spread of pollutants because the method is being used to analyze some specific chosen spots for their characteristics of water flowing.

The remote sensing by the satellite data can make an alternative approach to solve those problems. Furthermore, by using strong points of remote sensing, the environmental factors in water bodies can be analyzed faster and more precisely. Therefore, the measuring method by satellite can help us observe the place of origin and the whole water bodies at the same time. Also, it has the merit of analyzing the polluted area properly and observing it constantly.

The water quality analysis by the satellite data has been used in Kim Kwang-Eun(1994), Yoshifumi,(1982) Forster *et al.*,(1985) George, D.G.,(1990) Serwan and M.J. Baban(1993)' s studies. Most of these studies analyzed the water quality change by an interrelation analysis between the satellite data and the observed data of water quality in water bodies. The water quality factors such as Chlorophyll-a, suspended sediments and turbidity have much optical characteristics, and water temperature can be sensed exactly by thermal infrared rays spectrality. However, the study with a new analysis method using those factors for the eutrophication of rivers and water bodies is not sufficient.

In this study, we measured the radiance reflectance using multi-spectral image of low resolution camera(LRC) which will be loaded in the multi-purpose satellite(KOMPSAT) to use the data in analyzing water pollution. Moreover, we investigated the abstraction possibility of water quality factors in water bodies using high resolution satellite data such as Airborne MSS. Especially, we tried to extract the environmental factors related with eutrophication. We also tried to develop the processing technique and the radiance feature of reflectance related with eutrophication.

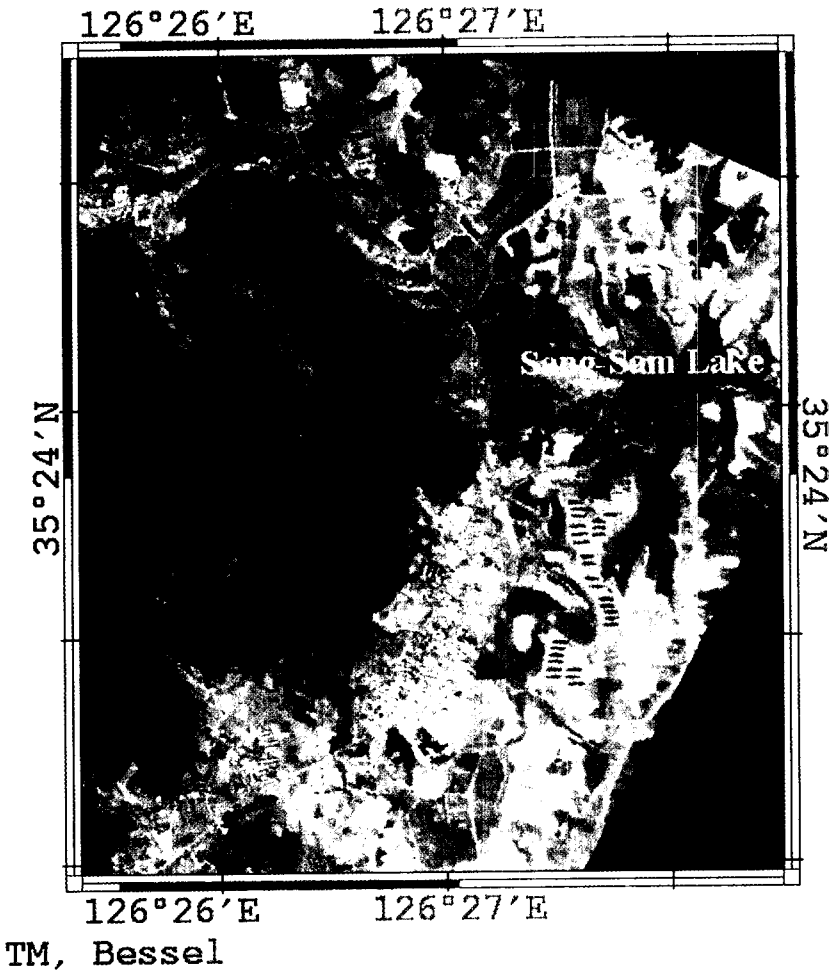


Fig. 1. False color composite image of Sang-Sam Lake site

2. The extent and the methods of this study

1) The subject area of this study

In this study, Sang-Sam Lake was set up as the study area, and Sang-Sam Lake locates at Yong-Gwang County, Chon-Nam Province(Fig. 1). The geographical position of this study area is in Latitude 35° 24′, Longitude 126° 27′, and it's about 45km southwest from Chonju.

The reason that we chose this area as the subject of study is that it has abundant data which

are needed at regression analysis of ground truth data when the materials of Airborne MSS image analyze the water quality.

2) Methods and data used

In this study, we measured the radiance reflectance of the water surface to analyze the radiation reflectance of the water bodies in low resolution spectral band and tried to analyze the water quality factors in river and water bodies by using radiance feature from another remotely sensed data. Airborne MSS was used as the remotely sensed data.

As the method of this study, firstly, we measured the reflectance of the water surface by using SFOV(Single Field of View) to measure the radiance reflectance of water quality analysis every item in LRC spectral band(0.4 ~ 0.9μm).

Secondly, we investigated the usefulness of ground truth data and the LRC data by measuring every radiance reflectance of water quality factors.

Thirdly, we analyzed water quality factors by using the radiance feature from another remotely sensed data, which is similar to the LRC spectral band. By using Airborne MSS, we carried out ratio process and principal component analysis(PCA).

Finally, we analyzed Chlorophyll-a, suspended sediments and turbidity from the Airborne MSS data among the water quality factors related with the eutrophication of water bodies.

3. Analysis of radiance reflectance in water bodies

First of all, LRC represents the feature of spectral band which is needed to be examined to sample the factors in the environment of the water bodies. The practical measures of water quality factors among LRC spectral bands are four visible bands which are all short spectral bands. Also spectral bands from B1 to B3 are most suitable for analyzing both Chlorophyll and eutrophication. Besides, spectral band B4 is suitable for analyzing turbidity and for abstraction with the environmental factors related to eutrophication. The rest two spectral bands are important as the previous process in abstracting the environmental factors of the water quality.

In this study, we measured the radiance reflectance in water bodies to analyze the water surface radiance feature of reflectance from LRC sensor. As a spectroradiometer which was used to collect data was SFOV of GER(Geophysical Environmental Research), an American company, which has 875 channels at 0.31 ~ 2.50μm spectral bands.

From the beginning, we found out the quantity of optical energy by measuring the white

plate of approximately 25cm × 25cm which was spread over Barium sulfate. Then, we changed the quantity of the reflected energy from the water bodies into a percentage to use as a reflectance by using that as a standard.

As the subject area of this study, we selected Sang-sam lake which locates at Yong-gwang County, Chon-Nam Province. Sampling was carried out at around 10 A.M., 29 March 1998, according to the measuring time of the Airborne MSS. Analysis items were Chlorophyll-a, suspended sediments and turbidity among the water quality factors related with eutrophication. The analysis method of water quality used Standard Method.

Generally, the spectrum of sun's rays which reaches the surface of earth is known as 0.3μm ~3.0μm. Among them, 0.4μm~0.7μm was consistent with visible bands and about 50% of total quantity of radiation were there. And at around 0.5μm of green spectral band in visible bands, the spectrum was the highest(Fig. 2).

The radiance reflectance image of water bodies differs according to mainly the flux and the speed of a current, Chlorophyll-a, suspended sediments and turbidity. A result of the radiance reflectance analysis of every factor of the water quality in water bodies where the density of Chlorophyll-a is high outcome that the spectral reflectance was extremely high around the 0.52μm of green spectral band. When comparing the surface of the highly densed water with the surface of the lowly densed water of suspended sediments, the reflectance of suspended sediments was

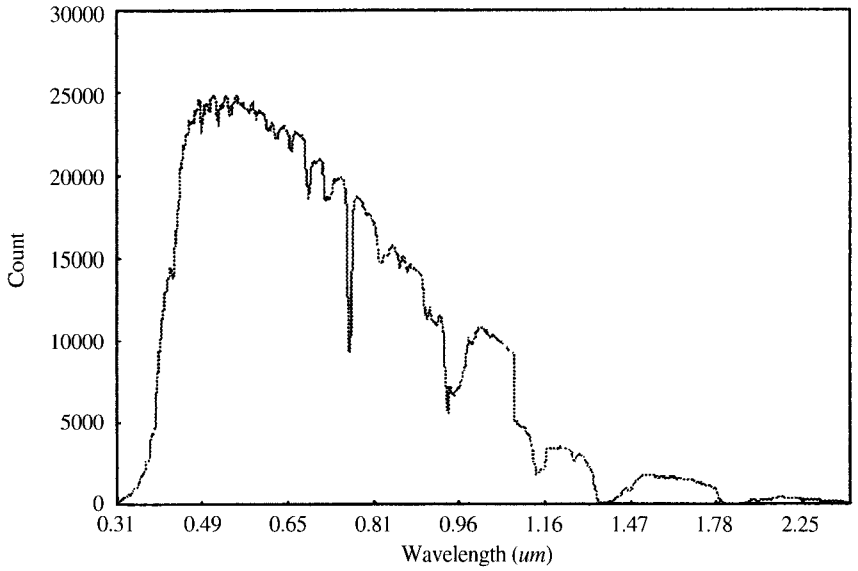
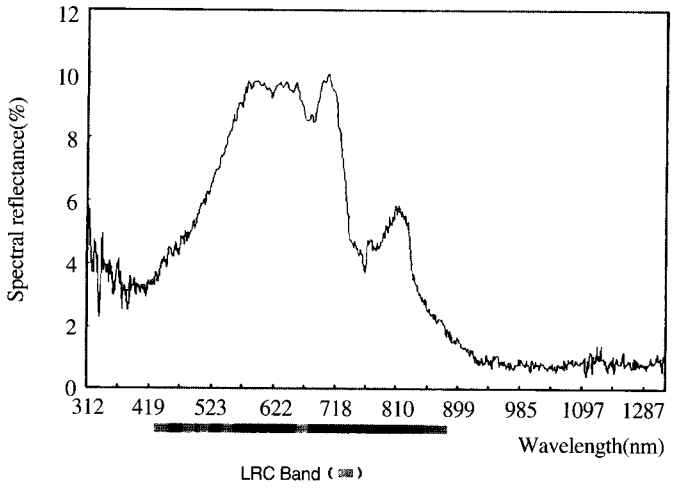
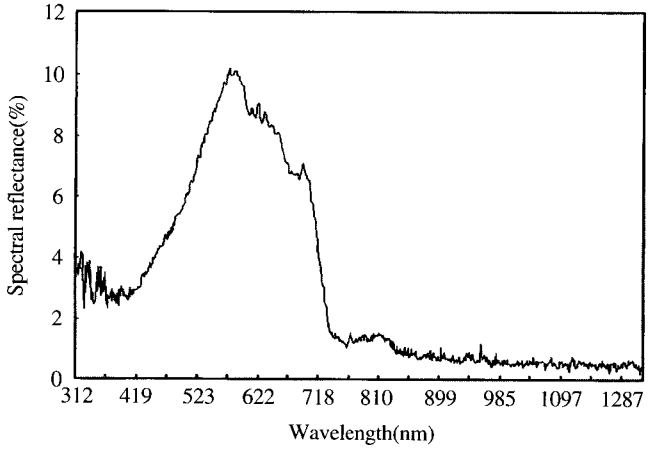


Fig. 2. Spectral distribution of sun's rays by the white plate

relatively high at 0.8μm. Then Band 6 which is mainly infrared rays was in there. The infrared rays are used usefully in plants or agriculture for its strong characteristic of reflection. Besides, they are used in dividing water and land for its strong absorption in water. Turbidity changes according to the water quality factors such as suspended sediments and Chlorophyll-a in water. In this study, we compared the reflectance of that with clear water. By increasing the density of the turbidity artificially then the reflectance reached high at 0.57μm(Fig. 3).



(a) Low Density



(b) High Density

Fig. 3. Spectral response characteristic of suspended sediments

4. Analysis of the water quality factors by using Airborne MSS data

1) Process of Airborne MSS

Airborne MSS is the data which can inspect and analyze water pollution effectively. In this study, we tried to find out the radiance feature of reflectance in water bodies, and to analyze the water quality by using remotely sensed data and the ground truth data related with water pollution. The sampling was carried out at around 10 A.M., 29 March 1998, according to the measuring time of the Airborne MSS. We selected the Sang-Sam Lake that has the same date of measurement with remote sensing data as the subject region. To select the spectral bands of water quality factors such as Chlorophyll-a, suspended sediments and turbidity, we investigated the fundamental data for analysis of correlation between ground truth data and remotely sensed data.

To sample the feature of radiance of the water environment, which is the purpose of this study, masking, filtering, ratioing and PCA had been done from Airborne MSS data.

First of all, we converted the cor-ordinates on the topographical map of scale 1/5,000 by using the Affine convertible formula in order to correct the geometric distortion of Airborne MSS image which was used in this study, and we corrected RMS error less than 0.5pixel. In addition, masking had been done to sample the factors of water environment of the Sang-Sam Lake from the corrected geometrical data. To make a definite contrast between water bodies and land bodies, MSS Band 5 was used in the process of masking. Then, we selected the suitable spectral band for analyzing water pollution after understanding the radiance feature of each band. We used Band 1, Band 2, Band 3, Band 5, and Band 7 for utilizing data which are mostly used is factor analysis of the environment of water bodies similar to LRC spectral band such as plant plankton, red tide, impurity degree and movement of suspended sediment. The non-operation process had been done to analyze the radiance feature of the quality of water in the Sang-Sam Lake. Among MSS Band 2, Band 3 and band 5 were used in the ratioing process. Using this processed image, we analyzed the correlation of ground truth data with doing Density Slice. With that analysis, we analyzed the radiance feature of the water quality such as Chlorophyll-a, suspended sediment and turbidity in the Sang-Sam Lake.

2) Analysis of Airborne MSS

Generally, water is represented as a blue color, it is presented as green color in satellite image when water contains Chlorophyll-a. Therefore, we analyzed the distribution pattern of Chlorophyll-a using the green band and the near infrared bands. In this way, we carried out ratio

of Band 3(0.52~0.60μm) and Band 5(0.63~0.69μm) which is useful for analyzing Chlorophyll-a to Band 7 of near infrared bands. We processed non-operated image to be ratioing with following.

$$Chlorophyll\text{-}a = [(Band\ 3)\text{-}(Band\ 7)]\text{-}[(Band\ 5)\text{-}(Band\ 7)] \quad \text{..... formula 1.}$$

When we compared this result of image process with the real measured distribution of Chlorophyll-a, we obtained a relatively similar result(Fig. 4).

Band 7 among ten bands of Airborne MSS is suitable for investigating the distribution of suspended sediments which exist in the water surface layer because Band 7 is sensitive the density change of suspended sediment. In this study, we analyzed the density distribution of suspended sediments in two methods. First, we made a distribution image using Band 7. As a result, the distribution pattern was similar to the ground data. Second, we carried out PCA(principal component analysis) using Band 1, Band 2, Band 3, Band 5 and Band 7. PCA in remote sensing is an algorithm to compress all of the information contained in an original n-channel data set into fewer than n component(Lillesand and Kiefer, 1994). The concepts involved in PCA may be expressed simply and graphically be consideration a two-channel image data set. For channels of multispectral data, the first principal component (PC1) includes the largest percentage of the total scene variance and succeeding component (PC2, PC3, ···, PCn) each contain a decreasing percentage of the scene variance. As a result of PCA, we found out PC1 is suitable for making a distribution image of suspended sediments(Fig. 4).

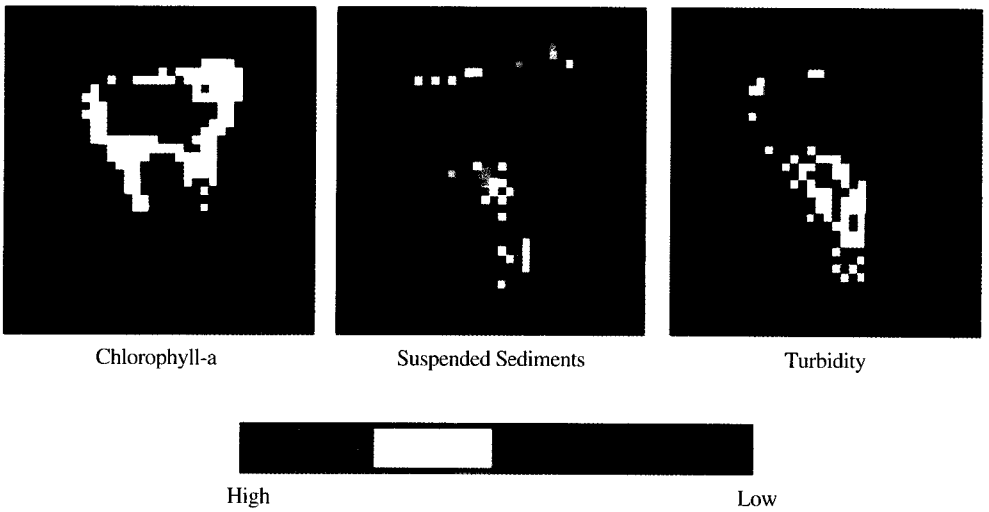


Fig. 4. Distribution image of water quality factors in the Sang-sam lake

Turbidity depends on more suspended sediments than Chlorophyll-a, and the water of high turbidity has a high reflectance at 0.55μm. Thus, we made a distribution image using Band 3. As a result of that, when we compared it with the ground data, there was no relativity. Therefore, in this study, we carried out PCA and as a result of that we could make a distribution image of turbidity at PC 4 which is similar to the ground truth data(Fig. 4)

5. Results and Discussion

In this study, we measured the water quality radiance reflectance of water bodies to practically apply the water quality analysis spectral band of LRC sensor, and analyzed the water quality factors by using Airborne MSS data. The results are mentioned below.

First, the spectrum of sun's rays which reaches the surface of earth was consistent with visible bands of 0.4μm~0.7μm and about 50% of total quantity of radiation could be found. The spectrum was reached the highest at around 0.5μm of green spectral band in visible bands.

Second, examining the radiance reflectance, Chlorophyll-a represented high spectral reflectance mainly around 0.52μm of green spectral band, and suspended sediments and turbidity represented high spectral reflectance at 0.8μm and at 0.57μm, respectively.

Finally, as a result of the water quality analysis by using Airborne MSS, Chlorophyll-a could have a distribution image when carried out ratio of B3(0.52~0.60μm) and B5(0.63~0.69μm) to B7(0.76~0.90μm). Band 7 was useful for making the distribution image of suspended sediments. A result of PCA show that PC 1 was suitable for making a distribution image of suspended sediments, and we could make a distribution image of turbidity at PC 4 which is similar to the ground data.

For further studies, we will constantly analyze the radiance feature of the water surface in water bodies by measuring the on-the-spot radiance reflectance and using low resolution satellite image. Besides, we will gather the data of the water quality analysis in water bodies into database and analyze the pattern of water pollution. Also, we will survey the usefulness of the ground measurement data and the LRC data. And we will carry out the study related with radiometric correction in terms of air because we faced many problems with analyzing the exact radiance feature of the water surface for noises such as cloud and fog.

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