An Approach to Measurement of Water Quality Factors and its Application Using NOAA satellite Data

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Abstract

Remotely sensed 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 spectral reflectance by using multi-spectral image of low resolution camera(LRC) which will be loaded in the OSMI multi-purpose satellite(KOMPSAT) scheduled to be launched on 1999 to use the data in analyzing water pollution. We also investigated the possibility of extraction of water quality factors in water bodies by using remotely sensed low resolution data such as NOAA/AVHRR.

In this study, Shiwha-District and Sang-Sam Lake was set up as the subject areas for the study. In this part of the study, we measured the spectral reflectance of the water surface to analyze the radiance of the water bodies in low resolution spectral band and tried to analyze the water quality factors in water bodies by using radiance feature from another remotely sensed data such as NOAA/AVHRR. As the method of this study, first, we measured the spectral reflectance of the water surface by using SFOV(Single Field of View) to measure the reflectance of water quality analysis from every channel in LRC spectral band(0.4～0.9㎛). Second, we investigated the usefulness of ground truth data and the LRC data by measuring every spectral reflectance of water quality factors. Third, we analyzed water quality factors by using the radiance feature from another remotely sensed data such as NOAA/AVHRR. We carried out ratio process of what we selected Chlorophyll-a and suspended sediments as the first factors of the water quality.

The results of the analysis are below. First, the amount of pollutants of Shiwha-Lake has been increasing every year since 1987 by factors of eutrophication. Second, as a result of the reflectance, Chlorophyll-a represented high spectral reflectance mainly around 0.52㎛ of green spectral band, and turbidity represented high spectral reflectance at 0.57㎛. But suspended sediments absorbed high at 0.8㎛. Third, Chlorophyll-a and suspended sediments could have a distribution chart as a result of the water quality analysis by using NOAA/AVHRR data.

1. Introduction

Recently, the range of human activity has become wider with a rapid progress of scientific technique. That caused natural environment destruction and dried up natural resources. Those problems are becoming a big issue through out the world. Especially, water pollution is becoming strained as the modern civilization has industrialized. We suggested several kinds of method to solve the problems.

Generally, the extension and elevation of industrial structure owing to the industrialization caused various pollutants and vicious ones such as 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 inordinate amount of nutrition inflows into the lake, reservoir or the river. Therefore we are subject to restricted 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 mentioned. Indirectly, suspended sediments or transparency can be objects on measurement. In addition, temperature is also one of the factors in terms of eutrophication.

At present, eutrophication in the lakes and marshes is presented as a serious social problem. Hereupon, in order to manage this problem effectively, a large scale and systematic skill for analyzing the quality of water is required. If the water pollution once reveals its serious problem and brings on a change to the natural ecosystem, great effort in financial expense and time are essential to restore to the former condition.

The remote sensing by the satellite data can make an alternative plan to solve those problems. Furthermore, by using advantage of remote sensing, the environmental factor in water body can be analyzed faster and more exactly. Therefore, the measuring method by satellite can help us to observe the place of origin and the whole water body at the same time. Also, it has a big merit of analyzing the polluted area properly and watching it constantly.

The water quality analysis by the satellite data has been used in George(1990), Serwan *et al* (1993), Braga *et al*(1993), Braude *et al*(1995), Huang *et. al*(1998) studies. Most of these studies analyzed the water quality change by an interrelation analysis between the satellite data and the analyzed data of water quality in rivers and water bodies. The water quality factors such as Chlorophyll-a, suspended sediments and turbidity which have much optical characteristics, and water temperature which can be sensed exactly by thermal infrared rays spectrality are usually used. However, the study with a previous analysis method using those factors for the eutrophication of water body is not sufficient.

In this study, we measured the spectral reflectance by using multi-spectral image of low resolution camera(LRC) which will be loaded in the OSMI multi-purpose satellite(KOMPSAT) scheduled to be launched on 1999 to use the data in analyzing water pollution. We also investigated the possibility of extraction of water quality factors in water bodies by using remotely sensed low resolution data such as NOAA/AVHRR. Especially, we emphasized our effort on development of the process technique and the spectral feature of reflectance related with water quality factors.

2. The subject area of the study

In this study, Shiwha-Lake was set up as the study area. The reason that we set up this area as the subject one of study is that it has fluent data which are needed at regression analysis of on-the-spot data. Moreover, euthrophication is rapidly emerging into critical condition. A basin of the Shiwha-Lake was expected to provide Incheon and Ansan with industrial and agricultural water as the source of a stream. However, this Lake is becoming a lake of death, because the foul water and the waste water caused problems.

The geographical position of this study area is in Latitude 37° 12′ ~ 37° 22′ and Longitude 126° 48′ ~127° 28′ . And it's about 45km from Seoul to the direction of southwest. Geographical feature of Shihwa-Lake consists of a tideland, a plain, a cultivated land, slope of the foot of a mountain and a low hill. Slope is composed of the wide tidal flat with slope within 2 percent, plain and low hill of 2 to 15 percent.

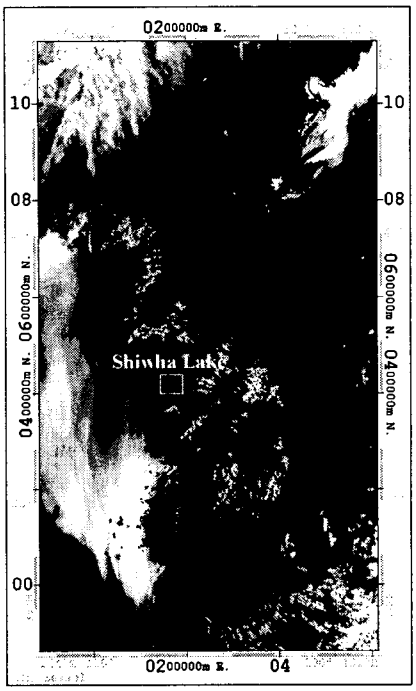

Fig 1. NOAA/AVHRR image of study area

3. The method of the study

In this study, we measured the spectral reflectance to analyze the radiance feature of the water bodies in low resolution spectral band and tried to analyze the water quality factors in water bodies by using radiance feature from another remotely sensed data such as NOAA/AVHRR.

This study is composed of four parts. First, we measured the spectral reflectance of the surface by using SFOV to measure the reflectance of water quality analysis on every channel in LRC spectral band.

Second, we investigated the usefulness of ground truth data and the LRC data from by measuring every spectral reflectance of water quality factors.

Third, we analyzed water quality factors by using the spectral feature from another remotely sensed data which is similar to the LRC data. By using NOAA/AVHRR data, we carried out ratio algorithm process.

Finally, we analyzed chlorophyll-a and suspended sediments from the remotely sensed data among the water quality factors related with the eutrophication of water body.

4. Analysis of spectral reflectance in water bodies

In this study, we measured the spectral reflectance in water bodies to analyze the water surface of radiance feature from LRC sensor. Spectral reflectance were measured once for each of the two lakes on cloudless days between 29 March and 22 June 1998. Water Samples for laboratory analysis were collected at the same time. Analysis items were Chlorophyll-a and suspended sediments among the water quality factors related with eutrophication. And the method of this study was Standard Method.

Generally, The spectral reflectance chart of water bodies differs according to mainly the flux and the speed

of a current, density of water quality. As a result of the spectral reflectance analysis of every factor of the water quality in water bodies, among the water surface, where the density of Chlorophyll-a is low since the spectral reflectance was absorbed mostly around the 0.4 to 0.5㎛ of blue spectral band, but high where the spectral reflectance was high mainly around the 0.57㎛ of green spectral band. When comparing the surface of the highly dense water and the surface of the lowly dense water of suspended sediments, the reflectance of suspended sediments was relatively low at 0.8㎛. The infrared rays are considered to be very useful in plants or agriculture for its strong reflection characteristic, while they are used in dividing water and land for its strong absorption in water.

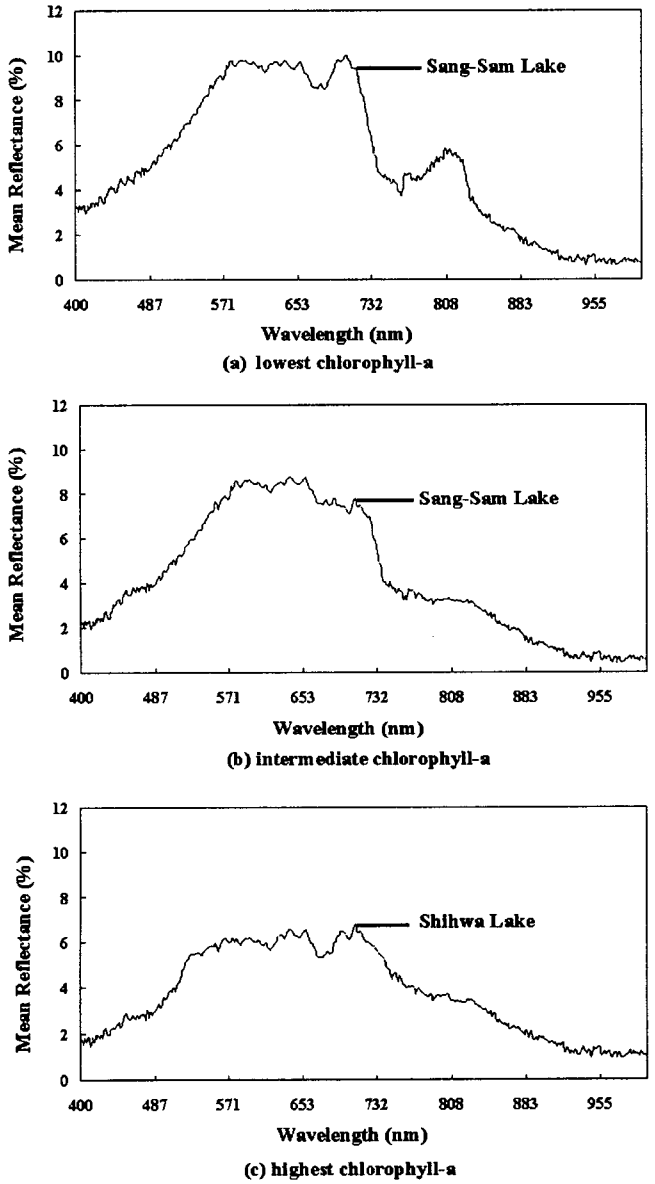

Fig 2. Mean reflectance for Shiwha-Lake and Sangsam-Lake

Reflectance ranged between 1 and 12 per cent across the spectrum for the two lakes(fig. 2). The spectral reflectance showed several common features. All had, as expected, a peak in the green range(o.57㎛) corresponding to the spectral minimum for chlorophyll-a absorption. Peaks in the green spectral range typically rose gradually to a maximum at about 0.57㎛ and fell sharply to about 0.65㎛. The reservoirs with least chlorophyll-a had the most sudden drop. With increasing amounts of algal biomass, reflectance generally decreased from blue to green spectral region, and increased in the 0.7㎛ of red to infrared range. For the lakes rich in phytoplankton, a single peak of reflectance occurred near the red-infrared boundary, it shifted toward longer wavelengths with increasing concentrations of chlorophyll-a.

4. Analysis of the water quality factors of shiwha by using NOAA/AVHRR data

NOAA/AVHRR is the data which can inspect and analyze water pollution effectively. In this study, we tried to find out the spectral feature of reflectance in water bodies, and to analyze the water quality by using remote sensing data and the every on-the-spot measured data related with water pollution. Sampling was carried out at around 11 A.M. Analysis items were Chlorophyll-a, suspended sediments.

The western sea adjoin the Shiwha lake is very muddy because the inflow of suspended sediments from big rivers like the Han River in Korea and the Yellow River in China. The movement of suspended sediments is remarkable especially in the summer, because we have much amount of rainfall in the summer. There are three measuring points in the basin of the Shiwha lake. The amount of pollutants has increased since 1987. The change of factors of the quality of water related to eutrophication from 1987 to 1998 shows that the eutrophication in the Shiwha-basin has been rapidly increased. For example, BOD has increased by 376%, COD has increased by 381%, T-N has increased by 266%, T-P has increased by 336%, Chlorophyll-a has increased 352% and suspended sediment has increased by 287%.

<Table 1> represents the numerical value of COD and T-N at each measuring point of the water quality within the subject region in 1998. As a result of the analysis, we found out that the Shihwa lake had the numerical value of measurement. Pollutants decreased expeditiously at the inner estuary barrage. Nevertheless, upper stream of the Shiwha lake was polluted more severely of the inflow of sewage and waste water, we could analyze that Shuhwa-lake discharged polluted water to the ocean.

Table 1. Amount of water quality factors in the Shiwha Lake

Date	site	Temp	DO	pH	COD	Chla	PO4-P	T-P	T-N
1998.4.18	Site 1	16.0	9.4	8.8	12.6	56.9	0.181	0.322	4.9
	Site 2	14.5	10.2	8.5	9.6	62.4	0.367	0.256	3.5
	Site 3	14.0	12.3	8.2	8.7	52.8	0.161	0.243	2.9
1998.5.20	Site 1	22.1	12.2	9.0	13.2	47.0	0.093	0.311	4.3
	Site 2	21.5	15.4	9.0	12.0	52.6	0.209	0.215	3.2
	Site 3	18.6	13.6	8.6	8.5	62.5	0.133	0.251	2.5
1998.6.12	Site 1	23.5	9.0	8.5	7.2	26.5	0.085	0.285	4.0
	Site 2	20.2	8.1	8.2	5.5	28.1	0.112	0.244	3.4
	Site 3	21.0	9.3	8.4	4.5	22.5	0.092	0.162	2.1

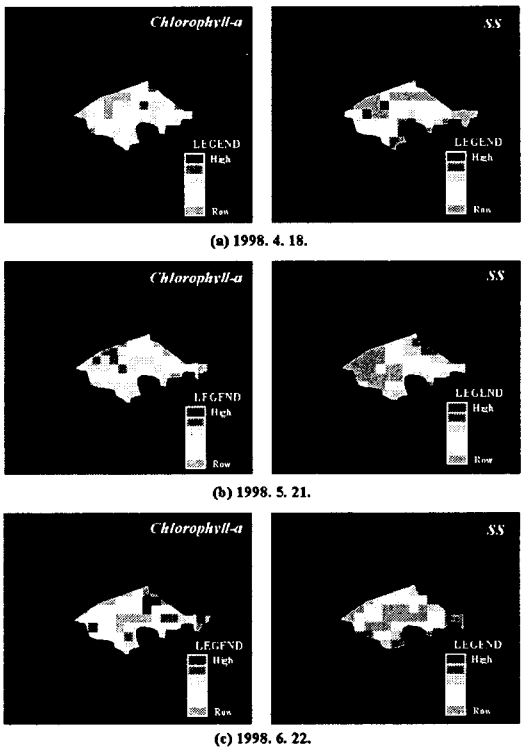

Fig 3. Distribution chart of water quality factors in the Shiwha-Lake

Generally, water represents as a blue color, however, when water contains Chlorophyll-a it is represented as a green color in satellite image. So, we analyzed the distribution pattern of Chlorophyll-a by using the green band and the near infrared rays band. In this way, we carried out ratio of Band 1(0.58~0.68㎛) and Band 2(0.73~1.10㎛). We processed again non-operated image to be ratioing. That is like formula 1.

$$Chlorophyll\text{-}a = [(R\ 2) - (R\ 1)] / [(R\ 2) + (R\ 1)]$$

When we compared this result of image process with the real measured distribution of Chlorophyll-a, we obtained a relatively similar result(Fig. 3).

Band 1 among five bands of NOAA/AVHRR data is suitable for investigating the distribution of suspended sediments which exist in the surface layer of water because Band 1 is sensitive at the density change of suspended sediments. And the surface of the loosely dense water of suspended sediments, the reflectance was relatively low at 0.8㎛. Therefore, In this study, we analyzed the density distribution of suspended sediments that we carried out ratioing, and as a result of that we could made a distribution chart of suspended sediments at output data which is similar to the ground truth data(Fig. 4).

$$Suspended\ sediments = (R\ 1) - (R\ 2)$$

5. Results and Discussion

In this study, we measured the water quality spectral reflectance of water bodies to practically apply spectral characteristics of LRC sensor. And we analyzed the water quality factors by using NOAA/AVHRR data. The results are below.

First, the spectral reflectance showed the green range(o.57㎛) corresponding to the spectral minimum for chlorophyll-a absorption. Peaks in the green spectral range typically rose gradually to a maximum at about 0.57㎛ and fell sharply to about 0.65㎛.

Second, The reservoirs with least chlorophyll-a had the most sudden drop. With increasing amounts of algal biomass, reflectance generally decreased from the blue to green spectral region, and increased in the 0.7㎛ of red to infrared range.

Third, as a result of the water quality analysis by using NOAA/AVHRR, chlorophyll-a and suspended sediments could have a distribution chart when carried out ratioing of R1 and R2.

Furthermore, we will constantly analyze the reflectance feature of the water surface in water bodies by measuring the on-the-spot spectral reflectance and using KOMPSAT data. Besides, we will gather the data of the water quality analysis in water bodies into database and analyze the pattern of water pollution along with survey the usefulness of the ground measurement data and the LRC data.

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