VII−16 **Optimum Hyper-spectral Band Selection for Monitoring Algae with Different Turbidity Levels in Ishizuchi Storm Water Reservoir in Kochi Prefecture, Japan.**

Kochi University of Technology ○Abdoul Nasser IBRAHIM*
Kochi University of Technology Yasushi MABUCHI*
Kochi University of Technology Masahiro MURAKAMI*

## Introduction

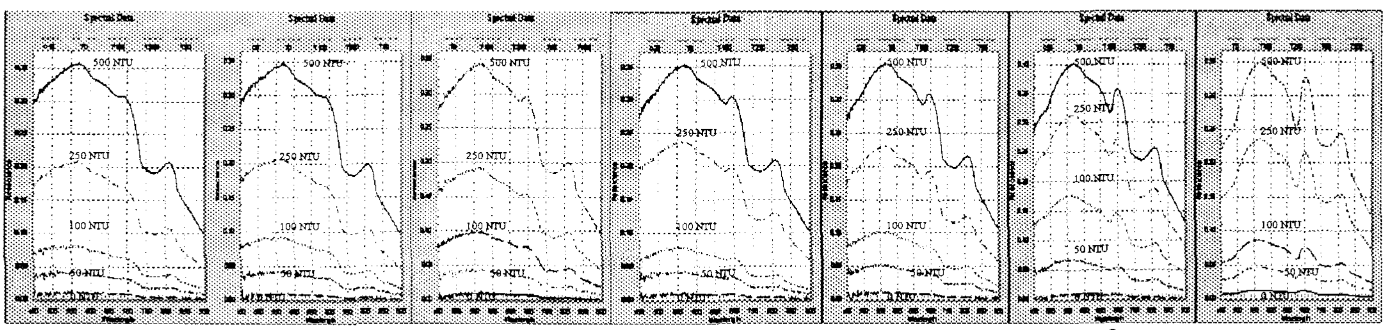
The possibility of using hyper-spectral data to develop a remote sensing model for monitoring the algae pollution level in Ishizuchi storm water reservoir in Kochi Prefecture is explored in this paper.

## Materials and Methods

Laboratory experiments have been carried out to understand the effects of chlorophyll pigment and turbidity on Ishizuchi water reflectance spectra. The measurements are carried out in a blackened interior sides glass batch to minimize side reflectance (Bhargava and Mariam, 1990; Han and Rundquist, 1994). Reflectance data are collected under controlled illumination, within the spectral range between 450 and 2,350nm, using a handy hyperspectral spectroradiometer. Five different levels of SSC (50 to 500NTU) using standard Kaolin are prepared in the batch filled with reservoir water at different chlorophyll concentrations ranging from 5 to 100ug/L. To simulate satellite bands, the spectral data are integrated in the bandwidths of Landsat-7/ETM. Each band is further split into 5nm sub-bands to obtain in total 135 simple bands. Reflectance values (%) are computed as simple ratio between the target and the BaSO4 pannel (Han and Rundquist, 1994; Gitelson et al., 1993). Band ratios are calculated for each of the 135 sub-bands, and regression techniques are used to examine the relationship between reflectance values ratios and chlorophyll concentrations as well as the correlation between reflectance values ratios and turbidity (NTU) levels. The correlation coefficients between Chlorophyll concentrations and sub-bands ratios, and those between Turbidity (NTU) and sub-bands ratios are calculated. The optimum chlorophyll monitoring wavebands are selected by simple comparison of the correlation coefficients.

## Results and discussion

The spectral responses of Ishizuchi storm water reservoir within the wavelength 450 to 900nm is shown on figure 1; each curve represents a given level of turbidity. The reflectance values increase with increasing level of turbidity.



a) b) c) d) e) f) g)

**Figure 1**: Spectral response of Ishizuchi storm water reservoir showing increase in reflectance values with increasing levels of turbidity (0.5NTU; 50NTU; 100NTU; 250NTU and 500NTU) **a)** fixed chlorophyll content 5ug/L; **b)** fixed chlorophyll content 10ug/L **c)** fixed chlorophyll concentration 15ug/L **d)** fixed chlorophyll concentration 20ug/L **e)** fixed chlorophyll concentration 25ug/L; **f)** fixed chlorophyll concentration 50ug/L; **g)** fixed chlorophyll concentration 100ug/L

In the range 450 to 900 nm (visible to NIR), the reflectance spectra shows different interesting feature:
A peak in the green domain between 550 and 600 nm representing a minimal absorption by chlorophyll-a; the magnitude of this peak as seen on figure 1 is closely related to the scattering by inorganic suspended particulate matter.
A trough around 625 nm representing a decline in reflectance values as shown in figure 1; the decreasing in reflectance is caused by chlorophyll absorption. The depth of this trough is tightly related to the amount of Chlorophyll as shown clearly by figure 1 from a) to g).

A trough between 650 and 700 nm in the red band represent a maximal absorption by chlorophyll a in the red range of the spectrum. However this trough depends as well on the amount of turbidity specially for chlorophyll concentrations more than 20ug/L (Gitelson et al., 1993).
A peak around 700 nm at the red-NIR boundary known as chlorophyll fluorescence peak.

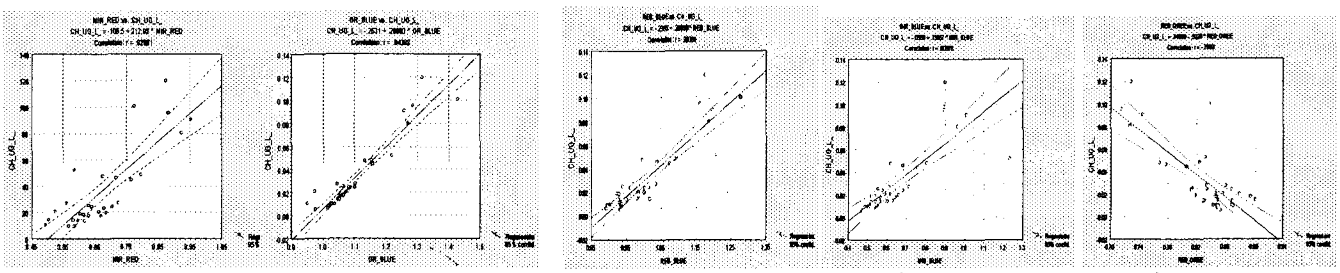
Ratios of reflectance values of each band to the sub-bands of other spectral bands are computed and compared in order to select the bands that have the best correlations with chlorophyll concentrations and are less influenced by turbidity contents. The best values of r are shown in table1.

**Table 1**: Correlation coefficients of the selected optimum band ratios

| **Band ratio** | **R (chlorophyll)** | **R (turbidity)** |
|---|---|---|
| NIR(812)/Red(672) | 0.83 | 0.47 |
| Green(537)/Blue(497) | 0.94 | 0.08 |
| Red(637)/Blue(497) | 0.90 | 0.14 |
| NIR(797)/Blue(472) | 0.81 | 0.19 |
| Red(677)/Green(597) | -0.77 | 0.19 |

Assuming a mean of zero and a normal distribution of the residuals, the band ratio values can be used to develop a linear regression model of the following form for the estimation of chlorophyll concentration in the case of Ishizuchi storm water reservoir:

$$Chlorophyll\text{-}a\ (ug/L) = b_0 + b_1 * x_{(bandi/bandj)} + e(x)$$



a) b) c) d) e)

**Figure 2**: Correlation between the actual chlorophyll concentration and the band reflectance values ratio a) NIR(812)/Red(672); b) Green(537)/Blue(497); c) Red(637)/Blue(497); d) NIR(797)/Blue(472); e) Red(677)/Green(597)

$$\textbf{Chlorophyll-a } [ug/l] = \begin{cases} -106.5 + 212.02 * x, & x = NIR(812)/Red(672), \quad r = 0.83 \\ -0.2631 + 0.26893 * x, & x = Green(537)/Blue(497), \quad r = 0.94 \\ -0.2366 + 0.26659 * x, & x = Red(637)/Blue(497), \quad r = 0.90 \\ -0.0588 + 0.13867 * x, & x = NIR(797)/Blue(472), \quad r = 0.81 \\ -0.44909 + 0.5028 * x, & x = Red(677)/Green(597), \quad r = -0.77 \end{cases}$$

**Conclusion**

Ratios of 5nm narrow bands in the visible to NIR domain of the spectra between 450 and 900nm are found useful for chlorophyll-a levels estimation in the case of Ishizuchi storm water reservoir in Kochi Prefecture. The best correlations are found with the ratios Green(537)/Blue(497) and Red(637)/Blue(497) which have best coefficients of determination respectively r=0.88 and r=0.81, and best standard error of estimate. Future work is needed to check the suitability of the algorithms in estimating chlorophyll levels in the reservoir from actual TM spectral data of the reservoir.

**Acknowledgements**

The authors acknowledge all the water management laboratory students for their help in sampling and assistance in laboratory work.

**Reference**

Bhargava, D. S. and Mariam, D. W., 1990. Spectral reflectance relationships to turbidity generated by different clay minerals. Photogrammetric Engineering and Remote Sensing, 56: 225-229.
Han, L. and Rundquist, D. C., 1994. The response of both surface reflectance and underwater light field to various level of suspended sediments: preliminary results. Photogrammetric Engineering and Remote Sensing, 60: 1463-1471.
Gitelson, A. A., Schalles, J. F., Rundquist, D. C., Schiebe, F. R., Yacobi, Y. Z., 1999. Comparative reflectance properties of algal cultures with manipulated densities. Journal of Phycology, 4: 345-354.