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RESEARCH PAPER

Development of spectral signature curve for the suspended sediment using spectroradiometer

■ **S.S. RAUT AND** B.K. GAVIT

ABSTRACT

Water resources and environment management is important for all living beings on the earth's surface. Capacity of the water resources are reducing due to soil erosion or sedimentation and quality also decreasing due to overflow of the reservoir. The analysis of sedimentation data of Indian reservoirs show that the annual siltation rate has been generally 1.5 to 3 times more than the designed rate and the reservoirs are generally losing capacity at the rate of 0.30 to 0.92 per cent annually (NRSA). Remote sensing is a useful tool for *in-situ* monitoring of suspended sediments in surface water for a variety of reasons such as the multi spectral nature, large area coverage, and temporal data sets. Considering the necessity of the assessment of the sediment as well as advantage of the remote sensing technique. The present study is taken to develop the spectral signature library for different sediment concentration. These results integrating with satellite data yield significant. A controlled experiment was conducted in outdoors condition with a 40 lt water tank (white painted) having natural sunlight condition. A different soil series *viz.*, Gulvanch, Targaon, Rahuri, Pather etc. were added and suspended in the tank filled with water. A total 10 levels of Suspended Sediment Concentration (SSC) (from 1000 ppm to 10000 ppm) were added for each type of treatment. Reflectance was recorded using an HR 1024 Spectroradiometer, and reflectance factor was computed and analyzed. The linearity in the SSC-reflectance relationship increased with wavelength between 400 and 900 nm. For relationship between suspended sediment concentration and reflectance data four different functions, *viz.*, exponential, linear, logarithmic and power were tried. The best fit model was found to be power by regression analysis.

KEY WORDS : Spectral signature, Radiometer, Sediment

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INTRODUCTION

The soil and water are most precious natural resources for sustained economic development in any country. Water resources and environmental management is essential for sustaining quality of life on earth. Modeling and monitoring of suspended matters in water bodies is a difficult task because of many influencing factors. Monitoring of Suspended Sediment Concentration (SSC) in reservoir, river, coastal waters and estuaries is imperative (Gin *et al.*, 2001).

Remote sensing technology holds potential for monitoring and estimating suspended sediments in surface water. Most of these studies focus on the relationships between spectral reflectance and suspended sediment concentrations in surface water.

Several investigators have studied the relationships between suspended sediment concentration (SSC) and spectral reflectance (Han, 1997). Choubey (1994) noted that the correlation between the suspended sediment concentration and the radiance varied with the mineral composition of the sediment. Based on the results obtained, it appears that an algorithm to estimate suspended sediment concentration can be developed from radiance. Lodhi and Rundquist (1998) studied estimation of suspended sediment concentration in water using integrated surface reflectance. Twenty levels of suspended sediment concentration (50 to 1000 ml) were created in large tank filled with 7510 lt of clear water. They found that second order regression models, was the best estimator of SSC with band width TM-4. Karabulut and Ceylan (2005) studied spectral reflectance responses of water with different level of suspended sediment in presence of algae. The results indicate that the suspended sediment causes increasing spectral response in surface water. Bhatti *et al.* (2010), the indoor spectral reflectance was measured 1m above the water surface using hyperspectral Field SpecPro FR Spectroradiometer in the electromagnetic spectrum region of 400 nm to 900 nm. Remotely sensed data made it possible to efficiently monitor the seasonal distribution and concentration of suspended sediment in the water bodies.

Therefore, the purpose of this research is to develop spectral signature library for different concentration of suspended sediment and examine the SSC-reflectance relationship of different soil series, Gulvanch series, Targaon series, Rahuri series and Pather series. The research was based on a controlled experiment conducted outdoors using a large tank and natural sunlight. In future such spectral signature can be integrated with remote sensing data for the reservoir study.

EXPERIMENTAL PROCEDURE

In the present research work four types of soil series *viz.,* Gulvanch, Targaon, Rahuri, Pather were collected from central campus of Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra (India). The soil samples were sieved through 425 μm sieve. From all the soil samples 10 different concentration from 1000 ppm to 10000 ppm were prepared in the 40 lt tank. Fig. A shows the experimental setup. The experiment was conducted in outdoor environment using cylindrical white painted tank filled with clean water during bright sunlight hours. A spectroradiometer HR1024 was used to record the reflectance from the water surface in period 11 to 13 hrs.

Spectral reflectance readings were taken with HR1024 spectroradiometer during the clear sunshine hours. The HR-1024 covers the UV, visible, and NIR wavelengths from 350 nm to 2500 nm. From these recorded data spectral

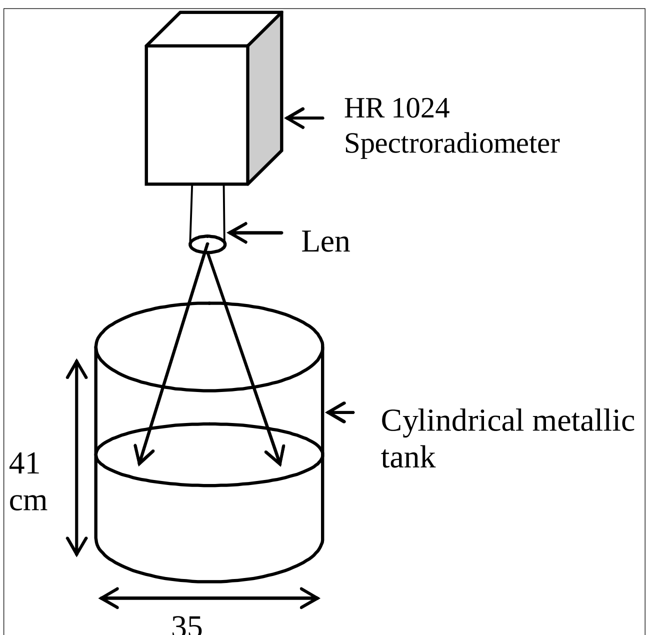

Fig. A : Experimental setup

library were developed with use of SVC HR 1024 software.

Water tank filled with 40 lt of clear water, Initially spectral reflectance readings of the clear water was taken prior to the addition of any suspended sediments and sediments, Latter on the SSC of suspended sediment was prepared in the tank with adding desired quantity, 1000 ppm to 10,000 ppm in clear water-filled tank. To get better result the three readings were recorded of each SSC and then mean observation was used for analysis. The soil sediments were kept in suspension by manually stirring at regular intervals.

The water tank was scanned within 15 seconds of addition of sediments in order to minimize settling of suspended sediments. The sensor of spectroradiometer was positioned perpendicular at the center of the tank to achieve nadir view. The distance of the sensor from the water surface was kept fixed at the height of 1 meter above the sample.

Reflectance is calculated as a simple ratio between target and reference panel using following equation :

$$R\% = \frac{L(\lambda)}{S(\lambda)} \quad (1)$$

where,

L (λ)-Target radiance, S (λ)- Reference radiance.

EXPERIMENTAL FINDINGS AND ANALYSIS

The spectral response of various concentrations observed with Spectroradiometer were plotted. For getting the clear reflectance of each concentration it is plotted by series wise. All soil series are shown in Fig. 1 to 4. In order to investigate the concentration and type of suspended sediments in surface water, series of reflectance measurements in the spectral range between 350 to 2500 nm with 1 nm resampling interval was carried out in a cylindrical white painted tank. The reflectance curves shows increasing trends with SSC, expect in few minor exceptions. At wavelength shorter than 400 nm, visual separation of spectral curves is more difficult. Similarly for wavelength longer than 900 nm the spectral curve tends to merge. The spectral range 400 to 900 nm is good for the discriminating the suspended concentration of all soil series.

The reflectance of all soil series shows clear discrimination of Gulvanch series (0 to 11 %) (Table 1), Targaon series (0.90 to 18 %), Rahuri series (0.25 to 17 %) and Pather series (0.90 to 12 %) in 350 to 2500 nm ranges. As the concentration of suspended sediment increases the reflectance also increases and vice versa *i.e.* there is direct relationship between sediment concentration and reflectance (Fig. 1 to 4) up to 900 nm wavelength.

In all the four soil series the visual separation was very difficult in wavelengths shorter than 400 nm and longer than 900 nm. The most useful range range for differentiation of SSC is 400 to 900 nm which falls in visible and infrared range as shown in Fig. 5.

In case of all soil series the two prominent peaks occurred at 705 to 710 nm and 810 to 818 nm. In any water body, sediments as a result of water erosion are not from one type of soil series, its mixture of more than one soil in water bodies. Hence the mixture of four series *i.e.* Gulvanch series, Targaon series, Rahuri series and Pather series was used in equal proportion for preparing concentration ranging from 1000 ppm to 10000 ppm. The result showed that the reflectance ranged from 0.90 to 15 per cent and the reflectance increased with increase in sediment concentration. The spectral curve for the range of 350 to 2500 nm wavelengths as shown in Fig. 6 showed similar trend as seen in different series and when the spectral curve in the range of 400 to 900 nm was prepared.

To develop the relationship between suspended sediment concentration and reflectance data four different

Table 1 : Relationship between SSC and reflectance for Gulvanch series

Function	Equation	R^2	MS	RMSE	$\chi 2$
Exponential	$Y=75.984e^{0.6635x}$	0.955	0.871	0.933	0.012
Linear	Y=2621.5x-10650	0.873	72078914	8489.93	2514.95
Logarithmic	Y=14573ln(x)-20771	0.843	69555386	8339.99	5974.16
Power	$Y=5.1409x^{3.7615}$	0.958	0.874	0.935	0.011

* X- Reflectance (%), Y- Concentration (ppm)

functions, *viz.*, exponential, linear, logarithmic and power were tried. Fig. 7 shows the relationship developed for the Gulvanch series. Similarly the relationships are developed for all soil series.

The best fit model found as power function. The results obtained for all soil series as tabulated below.

Summary :

Spectral reflectance for different types and concentration of suspended sediments are unique. Magnitude and spectral shape of reflectance curve varies with type, texture and concentration of suspended sediment. In result general trend of all spectral reflectance curve as the SSC increases reflectance also increases in the wavelengths between 400 and 900 nm. Power model was best fit for develop relationship between SSC and reflectance by regression analysis. The power model gives R^2 0.958 for Gulvanch series, 0.792 for Targaon series, 0.921 for Rahuri series and 0.942 for Pather series and 0.913 for composition of four series. Also in this spectrum, for both treatments,

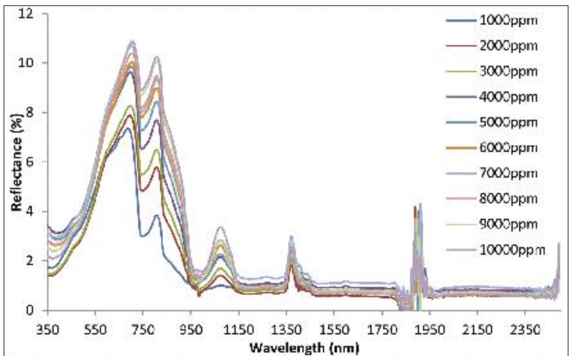

Fig. 1 : Spectral reflectance curve for Gulvanch series

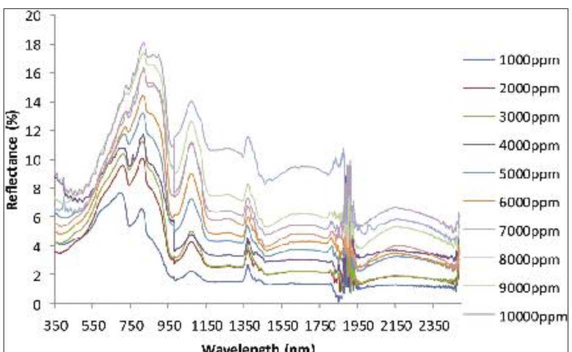

Fig. 2 : Spectral reflectance curve for Targaon series

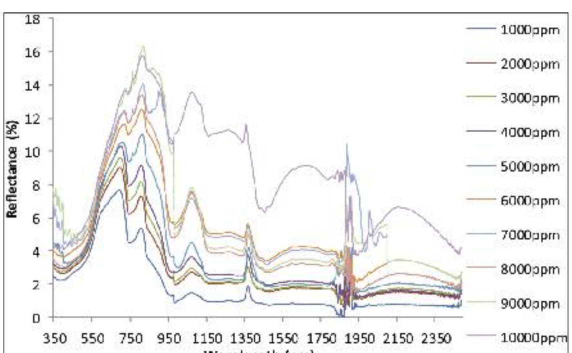

Fig. 3 : Spectral reflectance curve for Rahuri series

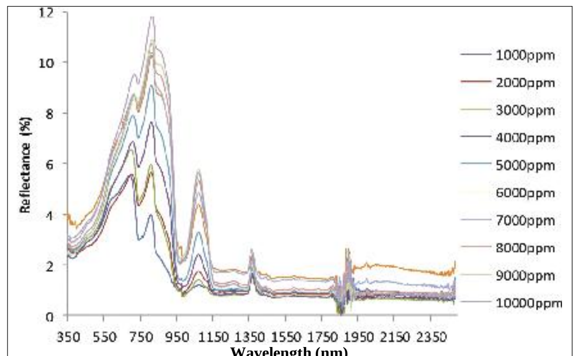

Fig. 4 : Spectral reflectance curve for Pather series

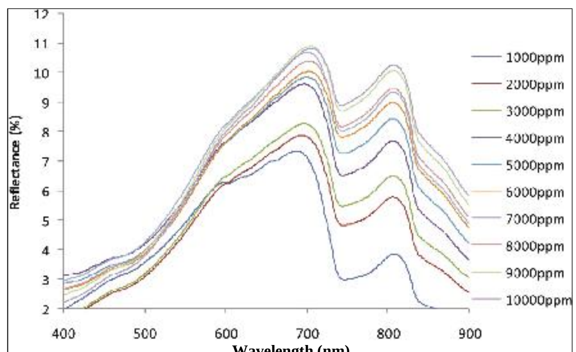

Fig. 5 : Spectral reflectance curve for Gulvanch series

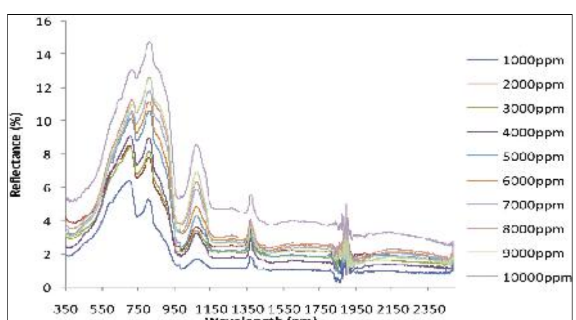

Fig. 6 : Spectral reflectance curve for composition of four series

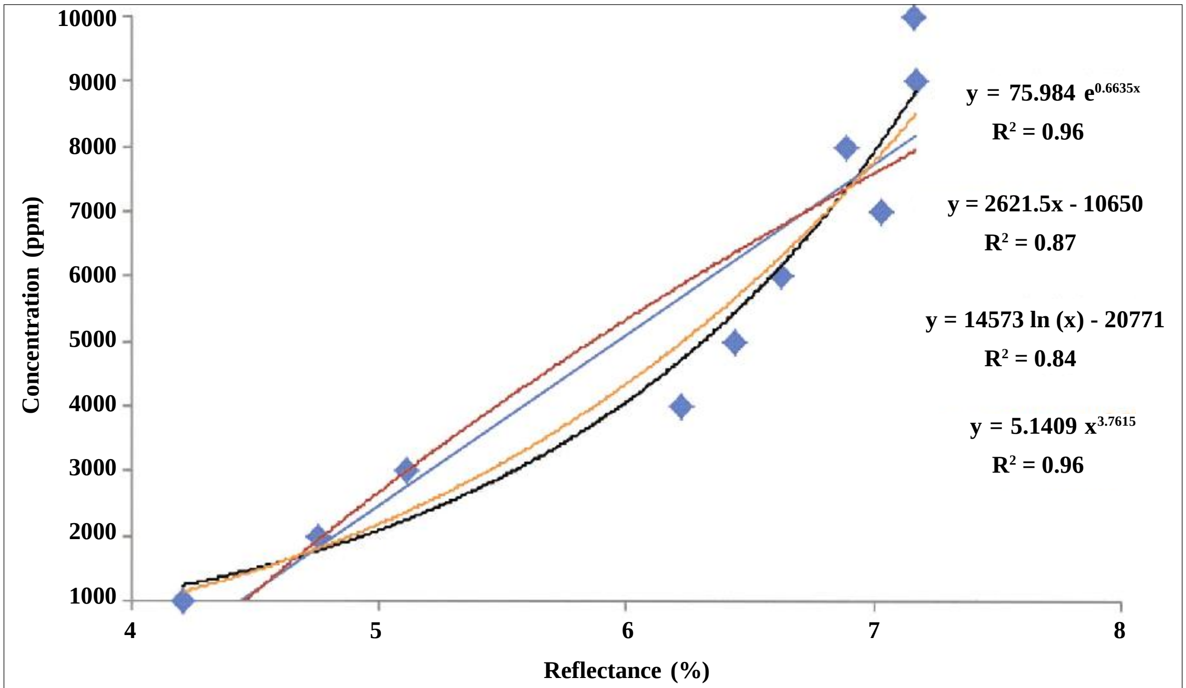

Fig. 7 : Suspended sediment concentration and reflectance relation for Gulvanch series

higher the SSC, the smaller the rate of change between reflectance and SSC. However, a trend in increasing reflected radiance with increasing suspended sediment concentration is observed. The analysis at ten levels of SSC, ranging from 1000 to 10,000 ppm and 4 types of soil series sediment applied.

Conclusion :

All soil series shows that the 400 to 900 nm wavelength is most useful for the study of suspended sediment. Such spectral library can be developed for many soil series and which can be used with the combination of the remotely sensed data for the assessment of suspended sediment concentration.

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MEMBERS OF RESEARCH FORUM

AUTHOR FOR CORRESPONDENCE :

S.S. Raut,
Department of Soil and Water Conservation Engineering,
K.K.W. College of Agricultural Engineering and Technology,
NASHIK (M.S.) INDIA

CO-OPTED AUTHORS :

B.K. Gavit, Department of Soil and Water Conservation Engineering,
Dr. A.S. College of Agricultural Engineering,
Mahatma Phule Krishi Vidyapeeth, Rahuri,
AHMEDNAGAR (M.S.) INDIA