ESTIMATION OF SUSPENDED SEDIMENT CONCENTRATION OF WATER BODIES USING LOW COST PORTABLE DIGITAL CAMERA

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ABSTRACT

Quantitative application on remote sensing of suspended sediment is an important aspect of the engineering application of remote sensing study. In this study, image processing technique is used as a method to estimate the amount of sediment concentration to facilitate and increase the speed of measurement. Estimation of fine sediment concentration is important for using water for different domestic, drinking and other purposes, from various sources like rivers, ponds or lakes. Traditional methods for this estimation are time consuming, costly and not easily accessible, especially for rural people in Bangladesh. In this study, it is shown that digital or DSLR camera could be used to estimate the amount of concentration. To accomplish this, a number of experiments had been conducted in two types of water tanks (circular and square) with different background color (white & grey) and with variation of camera height and angle. Sediment samples of brown & grey color were collected from bottom of different water bodies (such as river bed) and had been kept in open space for air drying but instead of it, oven drying cannot be allowed as the internal molecular structural arrangement of soil grain would be damaged. After that special sieve no-63 micron (<63 μm) ASTM no-230 passing very fine sediment samples were separated for the purpose of the experiment to avoid any settlement of sediment particles. Then, a standard correlation between image data (RGB value) & concentration was determined. Using the developed correlation one can easily understand sediment concentration of water bodies, which can be an alternative efficient tool rather than the conventional one.

Keywords: RGB; Fine suspended sediment; Digital image; Concentration

INTRODUCTION

Estimation of suspended sediment concentration is important for using water for different domestic and drinking purposes, from various sources like rivers, ponds, or lakes. High suspended sediment concentrations can affect water resources by damaging turbines of hydroelectric plants, and increasing requirements for water treatment procedures; reducing reservoir and diversion dam storage capacity. However, excessive sedimentation in streams and rivers is considered to be the major cause of surface water pollution.

The traditional method to measure suspended load by direct measuring of sediment samples seems more costly, time consuming and not easily accessible especially for people living in rural areas. Remote Sensing of Suspended Sediment Concentrations in Mekong River and the Red River conducted by Wang *et al*. [2012] aimed to investigate whether suspended sediment concentration (SSC) values could be estimated directly using this technique. The drawback of the study is that the measured reflectance is affected by illumination conditions significantly. Besides, Liew *et al.* [2002] conducted a study in a highly turbid inland river (lower Jinsha River in Yunnan, China) to develop relations between in-situ water reflectance measurement and TSS concentration. It was found that the empirical method established in this study by using a band ratio can only estimate total suspended sediment at lower concentration levels up to 400 g/m^3. This study also lacks in furnishing the impact of sediment properties on the backscattering coefficient. Lodhi *et al.* [1998] used integrated surface reflectance and found that: spectroradiometer data, integrated into the band width of Landsat-TM 4, allowed accurate estimation of suspended sediment concentration. But they failed to compare the findings to actual TM spectral data acquired over lakes and reservoirs.

Furthermore, digital camera is another new technique which can bring many advantages, as it can easily capture data at any time. Pictures are taken very close to the subject and can eliminate any side effect. The most important and difficult part of digital camera technique, is the processing of the captured images. Lim *et al.* [2003] first reported the application of digital camera in the estimation of total suspended sediment. Bejestan and Nouroozpour [2007] also used image processing technique to estimate the amount of sediment concentration which facilitated and increased the speed of measurement. This study was conducted only for the type of sediment available in Karoon banks. The equation established in this study would be varied with the type of sediment changes.

So, after analyzing and taking into account of all these limitations of the previous studies, different tanks, sediment samples and camera were used in this present study. Major purpose of this study is to define the sediment concentration as a function of digital image data in which red (r), green (g) and blue (b) components of color images as well as gray component with different sediment loads were tried to correlate. On the other hand to know the acceptable level of turbidity in streams is the second most important criteria for conducting this study.

The method for the measurement of suspended sediment concentration using digital camera is very cost effective, so only by applying this technique anyone especially rural and general people can get rid of many waterborne diseases, aware of the adverse effects of highly turbid water and be able to know the amount of level of suspended sediment concentration present in any water body.

METHODOLOGY

A number of experiments were conducted to develop a correlation between suspended sediment concentration and digital image with variation of water tank and sediment sample. The experiment was conducted during the day time when sunlight was available. Photos were taken vertically, at an angle of 45° as well. Two types of tank were used- one circular (2' dia) and the other square (2' X 2 'X 2') in shape. The circular one (Fig-1) was of plastic material and the square one (Fig-2) was of perspex material. Bottom and side walls of the square tank was kept gray and that of circular one was kept white which was later changed to gray. Brown colour and gray colour clayey soils were used as suspended sediment. The soil samples were collected (Fig-6) from the bottom of two lakes in Mirpur Cantonment. The soil samples were air dried (Fig-7), pulverized and sieved through non-standard (special) sieve of 63 micron (Fig-5). The sieved material (Fig-8) was weighted and mixed with a known volume of water in different concentration. Suspended sediment concentration was produced by consecutive addition of 5mg/l, 10mg/l, 20mg/l, 30mg/l, 40mg/l, 50mg/l, 75mg/l, 100mg/l, 150mg/l, 200mg/l, 250mg/l, 300mg/l, 400mg/l and finally 500mg/l of the soil sample. During the experiment, sediments were kept in suspension by manual stirring. During higher concentration quick settlement of the sediment was observed. Photos (Fig-9, 10, 11...) were taken after each addition from a height of one foot by using NIKON D3000 DSLR camera with 10.2 megapixels as well as with Canon S110 with 10 megapixels normal digital camera (Fig-3) to check if different camera, pixel capacity and resolution have any effect on the image quality. In order to establish a relationship between turbidity and suspended sediment HANNA turbidity meter HI93703 (Fig-4) was used for the experiment which can measure turbidity within (0-1000) FTU range. Average of R (red), G (green), B (blue), their mean value and gray value were calculated from 9 pixel values (3 X 3) by using Adobe Photoshop version 8.0. Separate graphs (Fig-12) were generated for R, G, B, gray and average of RGB against concentration. Graphs for turbidity against concentration were also developed.



Fig-1: Circular tank Fig-2: Square tank Fig-3: Digital Camera Fig-4: Turbidity




Fig-5: 63 µm sieve Fig-6: Wet sediment Fig-7: Dry sediment Fig-8: Sieved brown


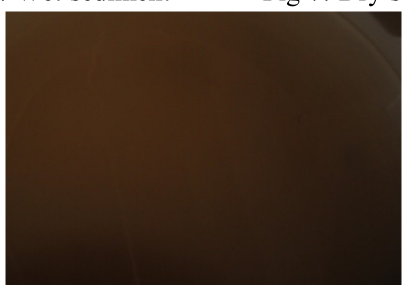
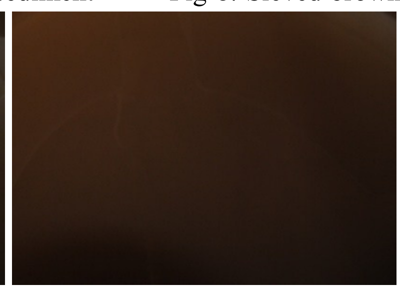

Fig-9, 10 and 11: Water with concentration (a) 5mg/l; (b) 100mg/l; (c) 500mg/l (images taken during experiment conducted in white circular tank using brown sediment)

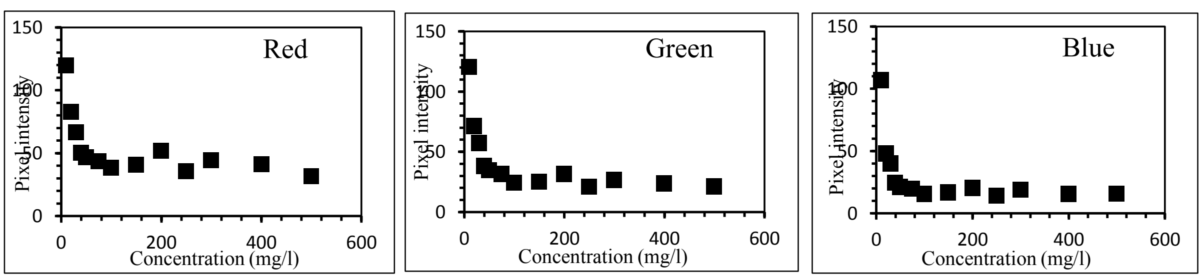

Fig- 12: Correlation between pixel intensity and sediment concentration for experiment conducted in circular white tank using brown sediment (concentration up to 500mg/l).

RESULTS AND DISCUSSIONS

It is seen that the values of pixel intensity decreases for increasing amount of concentration. But for higher concentration the values of pixel intensity remains almost constant. So values for higher concentration were discarded later.

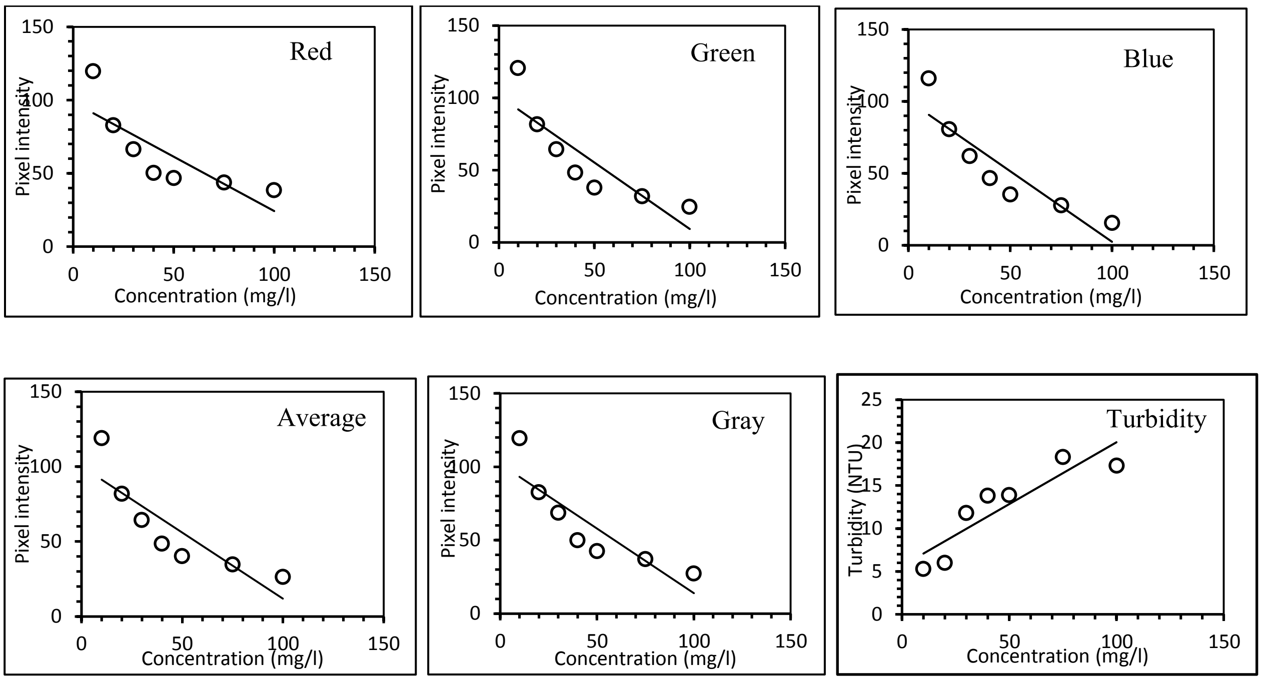

Fig-13: Correlation between pixel intensity and sediment concentration for experiment conducted in circular white tank using brown sediment (concentration up to 100mg/l)

Validation

For the validity purpose or comparison of the experimental results with the actual field data, two samples of water were collected from the Gulshan Lake (one from the bank and the other one from the middle of the lake) in two different containers and the average turbidity of these two samples were found as 22 NTU with the help of turbidity meter. Then the laboratory measurement of concentration by the process of filtration was conducted using 45 micron filter papers and the actual concentration values had been found as 59.9mg/l and 44.67mg/l, where 51.84 mg/l is the mean of these two values.

Fig -14: Pictures captured at Gulshan Lake for the purpose of Validation

Verification of Experimental Result

After observing all the graphs which was developed through the evaluation of the value of three bands of Red, Green, Blue; their mean and gray for each image with their respective concentration, it has been found that the Blue value always follows a decreasing linear trend line and gives a better result in comparison with actual field concentration which have been developed by analysing data by Excel. Though the red values shows a fairly good result of concentrations in comparison with the actual field result but dual nature of the linear trend line (y= mx+c); increasing (m=+ve) for white or decreasing (m= -ve) for grey background color of the tank makes the red value unfit or inappropriate for the measurement of SSC. The equations obtained from the green vs. concentration graphs do not produce results fair enough to compare it with the actual field results. As green and red band values are discarded, for this the equations obtained from graphs of average values of the RGB band against the concentrations are not taken into account. Grey values of the image data which was found from the grayscale by using the Adobe Photoshop software shows an almost or nearly equal values & graphs in accordance with the average values of the RGB band and that is the reason for which gray values are not also being accepted.

Final Result

From the observation of the experimental results, it is clearly visible that the experimental value for the circular shaped white background colour of the tank with brown sediment provides better result of 49.69 mg/l in comparison with the actual field result of 51.84mg/l for the determination of suspended sediment concentration. So, the standard equation of the graph (Blue value of the RGB band against concentration) for the measurement of SSC after the final analysis is, $y = -0.9812x + 100.46$; [Here, $m = -0.9812$ and $c = 100.46$]. A general equation as well as for the turbidity has been developed for the determination of the suspended sediment concentration after averaging m and c values found from different experimental results and after finishing final analysis the standard equation stands as, $y = 0.340x + 4.499$; [Here, $m = 0.340$ and $c = 4.499$].

The user of this equation should realize that because different technologies and different models of the same technology of turbidity meters can produce significantly different outputs for the same environmental sample, only one manufacturer and model of the turbidity meter can be used to develop the relationship between the SSC and turbidity readings at a site. If a different manufacturer or a different model type of turbidity meter is used, a new relationship will need to be developed for the site. The relationship of SSC and transparency to turbidity across many streams and lakes indicates that 22 NTU is approximately equal to 51.5 mg/L for SSC. However, the relationship between turbidity and SSC can vary greatly in individual streams or even locations within a stream.

MODIFICATIONS

- Only static condition of water was considered.
- All the images were taken from a height of 1 foot. Variations were there only for angular position.
- More correctness would be acquired if light intensity could be maintained constant.
- Settlement occurs as sediments were mixed manually but settlement of sediment can be avoided by the application of mechanical stirrer.

CONCLUDING REMARKS

The conducted study showed that there exists a strong correlation between suspended sediment concentrations with pixel intensity variation of different color components. The developed camera based method of sediment concentration determination produces fairly good comparison with actual concentration measured by mass balance method. The developed technique is very efficient and cost effective compared to the traditional method, hence can be used as a first approximation for suspended sediment concentration.

Table 1: Summary table for experimental result: Equations developed from graphs with variation of camera, tank shape and background color as well as sediment type and color

Tank Shape	Back-ground color	Sediment color	Camera used	Equation for 'Red' Vs. conc.	Equation for 'Green' Vs. conc.	Equation for 'Blue' Vs. conc.	Equation for Gray Vs. conc.	Equation for Avg. Vs. conc.
Circular	White	Brown	DSLR	Y=-0.742x + 98.55	Y=-0.920x + 101.1	Y= -0.981x + 100.4	Y=-0.879x + 101.9	Y=-0.881x + 100.0
Circular	Gray	Gray	DSLR	Y= 1.048x + 83.25	Y=0.507x + 141.8	Y= -0.505x + 130.4	Y= 0.415x + 129.4	Y= 0.350x + 118.5
Circular	Gray	Brown	DSLR	Y=0.479x + 124.5	Y= -0.304x + 146.2	Y= -0.678x + 128.1	Y=-0.139x + 132.7	Y= -0.166x + 132.9
Circular	White	Gray	DSLR	Y=-0.617x + 175.1	Y= -0.686x + 188.5	Y= -0.632x + 168.1	Y=-1.140x + 188.6	Y= -0.678x + 177.8
Square	Gray	Gray	DSLR	Y=1.048x + 83.25	Y=0.507x + 141.8	Y= -0.505x + 130.4	Y= 0.415x + 129.4	Y= 0.350x + 118.5
Square	Gray	Brown	DSLR	Y= 0.471x + 125.3	Y= -0.154x + 152.5	Y= -0.940x + 113.4	Y= 0.061x + 155.3	Y= -0.229x + 131.3
Circular	Gray	Gray	Digital camera	Y= 0.286x + 143.2	Y= -0.068x + 156.2	Y= -0.519x + 132.1	Y=-0.090x + 147.2	Y=-0.101x + 143.9

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