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Estimating soil moisture content using red-green-blue imagery from digital camera

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Abstract. Soil moisture content is one of the most important soil physical characteristics and very beneficial for plant growth. Instead of employing laboratory analysis, estimating soil moisture in more simple and practical method, such as using a digital camera is very important to improve the efficiency of agricultural productivity. Air and soil temperature, which strongly relate to soil moisture are indicating the climate anomaly. Therefore, it is necessary to observe soil moisture using red green image from camera. This research aimed at estimating soil moisture from several soil types using Red-Green-Blue (RGB) imagery from digital camera. Eight soil samples from several locations of Alfisol soil types were collected, air-dried and sieved. Similar volume of water was applied at each soil sample, then all samples arranged for picture capture. Soon after the picture was captured using RGB digital camera, the soil moisture was investigated using gravimetric method. The image of the captured soil samples then was processed using ENVI software for interpretation. Correlation and regression analysis were applied to obtain the estimation model and accuracy level. The results found that RGB image taken from digital camera can be used to estimate soil moisture with moderate accuracy.

1. Introduction

Soil moisture is a measurement of water contains in the soil pores. The characteristics of soil moisture are closely related to infiltration rates, permeability, and surface runoff [1]. In the practice of agricultural management this will greatly affect yield and crop productivity. In addition, knowledge about soil moisture also greatly affects the need for irrigation water [2]. The method we use is using the gravimetric method. The advantage of this method is more accurate [3].

For the determination of different moisture levels the light reflected by the soil will be read as different red-green-blue (RGB) colors [4]. Thus, the model developed from this study is to predict soil moisture content based on soil response to spectrophotometry from images or by using digital camera images [5][6]. The method commonly used to measure soil moisture using a camera is by placing a thermogravimetric sensor on the camera, the results are very accurate and safe, but unfortunately the cost is very expensive and takes a long time [3].

The color measured is obtained from a digital camera influenced by the water content in the soil [7]. This last approach can produce instant results and use devices that are generally easy to buy, such as commonly used digital cameras. This study aims to determine the equation for estimating soil moisture using variable color space obtained from images of portable digital cameras.

2. Materials and method

The eight samples of Alfisol soil used in this study were taken from Karanganyar District (7° 28' 00" - 7° 46' 00" S, 110° 40' 00"- 110° 70' 00" E), Indonesia. The analysis carried out in the laboratory were physical and chemical soil properties, i.e.: soil texture, gravimetric soil moisture content, soil organic matter and RGB color. The method for soil properties analysis referred to Bouyoucos [8], and Grossman and Reinsch [9], gravimetric soil moisture by oven the soil under temperature 110° C for 24 hours, soil texture using 3 fraction pipette method. Soil organic matter using Walkley and Black method referred to Rayment and Higginson [10]. Linier regression, Pearson correlation were carried out at $\alpha = 0.05$.

The soil was sieved with 2 mm and 0.5 mm sieves. After oven-dried under temperature of 110° C water was added to the soil until the moisture reached 25%, 50%, 75%, and 100% of soil moisture. The soil was then analyzed in the laboratory and photographed using RGB camera (Figure 1). The photo was captured using Samsung digital camera type S5K3L8 with diaphragm opening f/2.1, ISO sensitivity 200, and exposure time 1/30s. The camera lens was positioned vertically at 25 cm above soil samples surface. The geometric resolution was 1280 x 720 pixel.

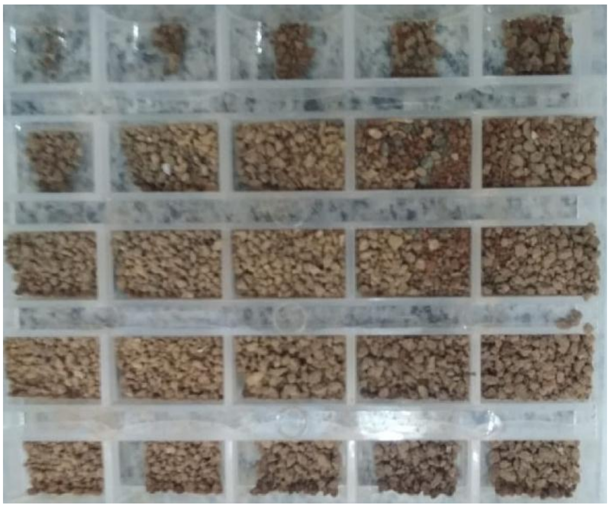

Figure 1. Photograph of soil samples captured for imagery analysis

The value of each band of the RGB color space were extracted to calculate the median. The use of the median is suggested by Persson [11] to overcome the deviations caused by the shading of the micro relief formed on object surface [12].

The Digital Number (DN) values of the monochromatic images were obtained from Equation 1 to convert Red Green Blue band, by adopting the values of National Television System Committee (NTSC) system according to dos Santos et al. [13], as presented in equation (1).

$$DN = 0.2989\,R + 0.5870\,G + 0.1140\,B \qquad (1)$$

Note: DN = Digital Number
R = Red
G = Green
B = Blue

3. Results and discussion

Soil texture analysis using 3 fraction pipette method and textural class with USDA texture triangle and soil organic matter using Walkley and Black method are presented in Table 1. Figure 2 shows the linier regression of digital number of each sample with soil moisture content in percent mass.

Table 1. Soil texture and organic matter

Sample number	Texture (%)			Texture class	Soil Organic Matter (%)
	Sand	Silt	Clay		
1	36.017	12.414	51.568	Clay	1.32
2	31.621	18.021	50.358	Clay	1.24
3	32.399	20.021	47.579	Clay	1.33
4	37.190	12.017	50.793	Clay	1.22
5	44.891	12.803	42.306	Sandy Clay	1.17
6	47.169	16.819	36.012	Sandy Clay	1.31
7	13.138	20.425	66.436	Clay	1.03
8	21.683	19.223	59.094	Clay	1.19

Table 1 shows Alfisols soil samples were dominated by clay, sandy clay and clay. The highest Soil organic matter was 1.33%, and the lowest was 1.03%, with textural class similarly clay. The sand, silt and clay fractions ranged from 13.138 to 47.169%, 12.414 to 20.425% and 36.012 to 66.436%, respectively.

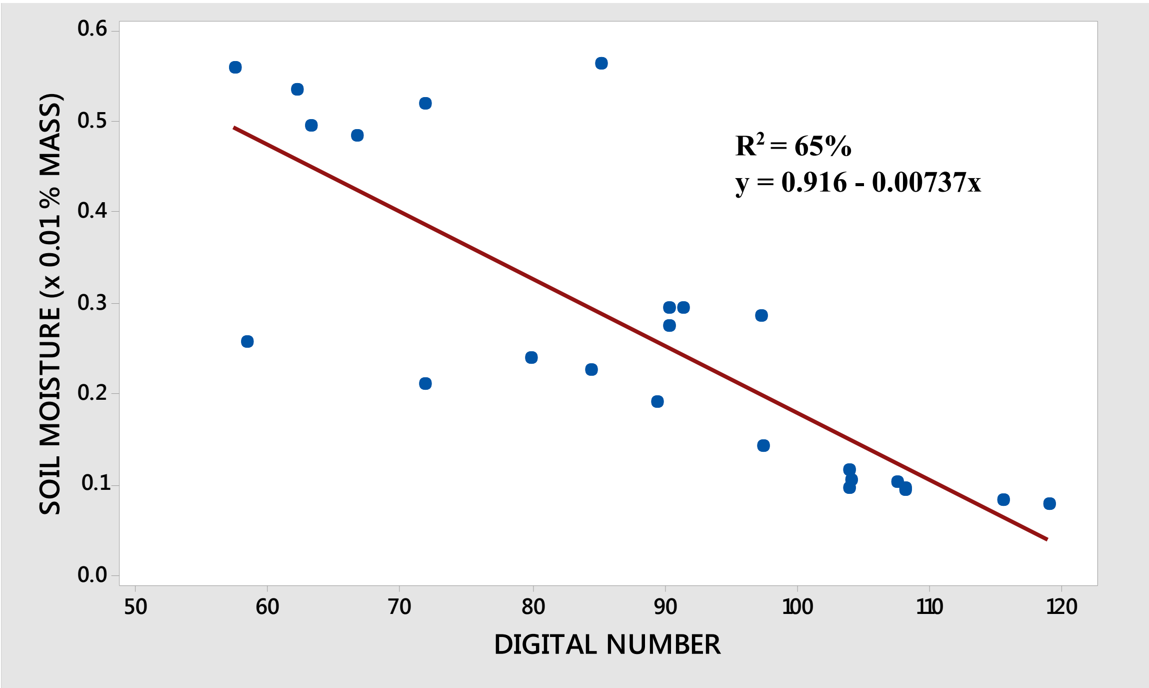

Figure 2. Linier regression between soil real moisture and digital number (DN)

Figure 2 shows the coefficient of determination (R^2) of soil moisture and Digital Number is 0.65. This means estimating Soil Moisture Content with Red Green Blue Imagery from digital camera is moderately accurate. From this statistical analysis, it can be said that soil moisture determined 65% of digital number of the captured soil photograph. Meanwhile, 35% of the digital number may had been determined by another soil properties such as soil organic matter and soil texture as presented in Table 1. This result agrees with [6] regarding estimating soil water content from surface using image analysis with gray level resulted moderate to high accuracy. However, a significance of soil moisture with color parameters produced from camera capture should be identified. The correlation between soil moisture and color parameter is showed in Table 2.

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Table 2. Pearson's correlations between soil moisture with selected soil color parameters (α = 0.05)

Soil moisture vs. soil color parameters	R (correlation coeff.)	P-value (Significance)
Red	-0.841**	0.000
Green	-0.790**	0.000
Blue	-0.738**	0.000
Digital Number	-0.806**	0.000

Note: ** highly significant

Table 3 indicates all the soil color parameters (Red, Green and Blue) significantly correlated with soil moisture, as well as the digital number. Since all the color parameters significantly correlated with soil moisture with rather high R^2 (Figure 1), so the equation produced from the linier regression analysis (equation 2) can be recommended to predict soil moisture of Alfisol soil using RGB camera. However, another factors of soil properties would be better to be taken into consideration for higher accuracy in further research.

$$\text{SOIL MOISTURE} = 0.916 - (0.002203\ \text{RED} + 0.004326\ \text{GREEN} + 0.00084\ \text{BLUE}) \qquad (2)$$

4. Conclusion

Estimating Soil Moisture Content using Red Green Blue Imagery from Digital Camera is moderately accurate. Predicting soil moisture of Alfisol soils in Karanganyar Regency, Indonesia using RGB camera can be carried out with the following equation: Soil Moisture = 0.916 - (0.002203 red + 0.004326 green + 0.00084 blue)

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