The accuracy of soil moisture prediction using an RGB camera on maize and peanut plantation

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Abstract. Forest observation to use soil moisture meters for monitoring soil moisture are still relatively inefficient if done on very large land because it still relies on relatively much energy and requires a long time. This study aims to determine the accuracy of the use of aerial photographs from the Red-Green-Blue (RGB) camera Drone to estimate soil moisture levels. Aerial photographs were analyzed with the ImageJ application to find digital numbers, and actual soil moisture measurements by the gypsum block method. Soil moisture and digital numbers are then analyzed by regression and correlation. The results show that this method has a low accuracy. However, the comparison between the actual soil moisture and the soil moisture from the prediction doesn’t show a significant difference. The accuracy of the estimation depends on the camera settings and the weather, so further calibration and testing are necessary if used under different conditions.

1 Introduction

Water is a vital component of plants. Required by plants in greater numbers than others. Water content in the soil or commonly referred to as soil moisture is a very important factor for plant growth and growth [1]. An efficient tool used today to find out the current soil content is the Soil Moisture Meter. Soil Moisture Meter is useful to indicate the amount of water content from soil samples. This information is very useful for people involved in irrigation system management and for other researchers who need to measure groundwater content [2]. The effort is still relatively inefficient if done on a very large land because it still relies on a relatively large amount of energy and requires a long time so there is a need to find more practical soil moisture.

The use of satellite imagery to determine soil moisture levels has been studied by several researchers in the world. The use of remote sensing with microwaves originating from satellites has succeeded in estimating the dielectric properties of the soil based on ground surface emissivity which leads to the estimation of soil moisture [3]. Access to satellite imagery is quite expensive. Satellite imagery is an image obtained from shooting an area using satellite vehicles operated from space so that access is quite limited and often

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The research was conducted in the Sukosari, Jumantono District, Karanganyar Regency, Central Java, Indonesia with a geographical location of -7° 37’ 49.814” latitude and 110° 56’ 52.408” longitude. The type of soil in this research area is Alfisols, this is following the statement of [10], who previously researched the site. The research began in March to August 2019. Tools used in this research include drone, gypsum blocks, and laptops. The land was designed as an RCGD (Randomized Complete Group Design) with 2 treatment factors. The first treatment factor was the amendment with P0 (control), P1 (manure 5 tons / ha), P2 (biochar 5 tons / ha), and P3 (zeolite 5 tons / ha), and the irrigation volume treatment factor I1 (50% x Evapotranspiration actual), I2 (100% x Evapotranspiration actual), and I3 (150% x Evapotranspiration actual). The Evapotranspiration actual (ETa) value is obtained from the daily evapotranspiration value of maize and peanut plants. Each plot or plot with an area of 2 m x 2 m, within a block of 0.25 m then the distance between the blocks is 0.4 m. The treatment plot aims to obtain soil moisture diversity for observation. Test analysis of this study uses linear and multiple regression statistical analysis. Pearson correlation test and T-test to find out whether there is a significant difference between the measurement of the actual soil moisture with the prediction of soil moisture.

2 Research methodology

2.1 Time and location

The research was conducted in the Sukosari, Jumantono District, Karanganyar Regency, Central Java, Indonesia with a geographical location of -7° 37’ 49.814” latitude and 110° 56’ 52.408” longitude. The type of soil in this research area is Alfisols, this is following the statement of [10], who previously researched the site. The research began in March to August 2019. Tools used in this research include drone, gypsum blocks, and laptops. The land was designed as an RCGD (Randomized Complete Group Design) with 2 treatment factors. The first treatment factor was the amendment with P0 (control), P1 (manure 5 tons / ha), P2 (biochar 5 tons / ha), and P3 (zeolite 5 tons / ha), and the irrigation volume treatment factor I1 (50% x Evapotranspiration actual), I2 (100% x Evapotranspiration actual), and I3 (150% x Evapotranspiration actual). The Evapotranspiration actual (ETa) value is obtained from the daily evapotranspiration value of maize and peanut plants. Each plot or plot with an area of 2 m x 2 m, within a block of 0.25 m then the distance between the blocks is 0.4 m. The treatment plot aims to obtain soil moisture diversity for observation. Test analysis of this study uses linear and multiple regression statistical analysis. Pearson correlation test and T-test to find out whether there is a significant difference between the measurement of the actual soil moisture with the prediction of soil moisture.

2.2 Aerial photoshoot on land

Aerial photographs of the land were taken from May to July 2019. Aerial photo taking was done using a Drone/UAV (Unmanned Aerial Vehicle) model of the DJI Mavic Pro Platinum with camera settings used including ISO 100, Exposure time 1/1000 second, Aperture f/ 2.2, with a flying height of a 10-meter drone. Photos were taken on May 7 May 2019, 14 May 2019, 24 May 2019, 29 May 2019; June 3 June 2019, 12 June 2019, 19 June 2019, 21 June 2019; until July 3 July 2019, 13 July 2019, 21 July 2019, 30 July 2019. Aerial Photography was taken at 10:00 a.m. - 11:30 a.m. to anticipate the shadow of plants that covered the soil. The soil moisture measurements carried out simultaneously while taking aerial photos. The aerial photo is then processed into a digital number with ImageJ software. ImageJ is an image processing application developed by NIH (National Institutes of Health) which is often used in biology to measure cells, bacterial colonies to leaf area. This application can calculate the

d constrained by cloud cover [4]. The use of satellites to take images or images is inefficient if used only in a small area.

According to [5] Unmanned Aerial Vehicle (UAV) is a technology that can conduct data acquisition with low altitude and produce high-resolution images so that it can be a solution in providing data for small island mapping. The camera with a complete sensor has a very expensive price. However, there is a drone with more affordable prices that generally use RGB camera sensors. According to [6], The estimation of soil moisture with an RGB digital camera has moderate accuracy. Supported by research from [7] that digital cameras that compose gray images can estimate soil moisture with high accuracy.

Digital photo analysis can be used as an alternative method of characterization and color quantification that is objective, accurate, and applicable. One of the software to process digital photos is ImageJ software. ImageJ software aids measure and classify some qualitative color quantitatively based on the standard digital value of RGB per pixel [8]. Each pixel is arranged by three color components: R (red), G (green), B (blue). The combination of these three RGB colors produces a distinctive color for each pixel. RGB is a color model consisting of red, green, and blue, combined in a wide array of colors [9]. The purpose of this study is to determine the accuracy of the use of aerial photographs from the RGB camera Drone to estimate soil moisture levels.
statistics of the specified area and pixel values [11]. A digital number is obtained from the number indicated by the pixel in the photographic image (Figure 1).

Fig. 1. The Aerial photo on experimental land (13 July 2019).

2.3 Measurement of actual soil moisture content
The actual soil moisture content is measured by the gypsum block method [12]. The gypsum block is then planted in the field and what is measured is the amount of resistance on the brass plate using a multimeter. Soil moisture is adjusted and selected by groundwater retention to normalize the actual soil moisture value. Soil moisture data obtained in this study after adjusting and selecting with groundwater retention amounted to 236 data (138 in maize land and 98 in peanut land).

3 Result and discussion
3.1 Quantitative data on aerial photographs

Fig. 2. Digital numbers of the aerial photographs of maize and peanut land.

The aerial photographs obtained are then processed into digital numbers consisting of composite RGB, red, green, and blue. Digital numbers of the aerial photos are shown in Figure 2. The results obtained in Figure 2 on both plantations show that the red digital number has the highest value, then the RGB digital number, green digital number, and blue digital number. The digital numbers used this time are the RGB composite (DN RGB = 0.2989·R +
3.2 The actual soil moisture

Soil moisture analysis was measured using gypsum block which was then converted using calibration regression that had been done before observation so that the actual soil moisture value was obtained in maize and peanut land. The moisture data is then correlated with the digital number data to find out the moisture relationship with the digital number (Figure 3).

![Graph: Soil moisture data from May to July on maize and peanut land.]

3.3 Correlation test of digital numbers with actual soil moisture

Table 1. Correlation tests for RGB, Red, Green, and Blue with moisture.

<table>
<thead>
<tr>
<th>Digital Number</th>
<th>R</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RGB</td>
<td>-0.146</td>
<td>0.02</td>
</tr>
<tr>
<td>Red</td>
<td>-0.188</td>
<td>0.00</td>
</tr>
<tr>
<td>Green</td>
<td>-0.137</td>
<td>0.03</td>
</tr>
<tr>
<td>Blue</td>
<td>-0.066</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Test correlation of RGB, red, green, and blue with moisture on the land of maize and peanuts aims to determine the close relationship between digital numbers and moisture. The RGB, red, green, and blue correlation tests with moisture on the planting of maize and peanuts show that the correlation between moisture with digital numbers is negative or inversely proportional which means the greater the value of digital numbers, the smaller the soil moisture, and vice versa, the smaller the value of digital numbers the soil moisture will get bigger (Table 1). The results obtained are following research conducted by [15] which obtained a negative correlation between the value of red, green and blue with the value of soil moisture. The study showed the soil became darker when soil moisture increased.
3.3 Actual moisture regression with digital numbers

<table>
<thead>
<tr>
<th>Regression</th>
<th>Digital number</th>
<th>$R^2$</th>
<th>$Y$</th>
</tr>
</thead>
<tbody>
<tr>
<td>linear regression</td>
<td>Composite RGB</td>
<td>0.021</td>
<td>51.949 - 0.0569 RGB</td>
</tr>
<tr>
<td>linear regression</td>
<td>Red</td>
<td>0.035</td>
<td>59.026 - 0.0781 Red</td>
</tr>
<tr>
<td>linear regression</td>
<td>Green</td>
<td>0.018</td>
<td>50.046 - 0.0491 Green</td>
</tr>
<tr>
<td>linear regression</td>
<td>Blue</td>
<td>0.004</td>
<td>46.35 - 0.0278 Blue</td>
</tr>
<tr>
<td>multiple regression</td>
<td>Composite RGB, Red, Green, and Blue</td>
<td>0.073</td>
<td>57.2 + 1.69 RGB - 0.54 Red - 1.27 Green + 0.12 Blue</td>
</tr>
</tbody>
</table>

The regression in moisture with the RGB digital number yields $R^2 = 0.021$; moisture with a red digital number of yields $R^2 = 0.035$; moisture with a green digital number of yields $R^2 = 0.018$; moisture with a blue digital number of yields $R^2 = 0.004$; and Multiple regression between RGB, red, green, and blue composites with soil moisture yields $R^2 = 0.073$ (Table 2). The regression with the highest $R^2$ to the lowest is soil moisture multiple regression with the RGB, red, and green; linear regression soil moisture with red digital numbers; soil moisture with RGB digital number; soil moisture with green digital number; soil moisture with blue digital numbers. The results of the analysis of these data prove that the multiple regression formula between moisture with the composite digital numbers RGB, red, green, and blue is the most accurate among the other regressions with $R^2 = 0.073$. According to [6], the regression results between moisture and digital numbers have moderate to high accuracy by identifying the camera and settings used, but the results of this study indicate that the use of outdoor camera RGB is less accurate in terms of a very low $R^2$ value. The use of a drone with RGB cameras is greatly influenced by outside factors such as light and weather. Besides, differences in soil moisture on Figure 3, which is very volatile also cause low $R^2$ values. The next highest-accuracy regression formula is a linear regression between moisture with digital red numbers. The red color has the longest wavelength in visible light which is around 620 - 750 nm. Supported by research [16], states that the spectral reflection in the soil tends to increase with increasing wavelengths of light so that the red color which incidentally has a high wavelength following the spectral reflection of the soil.

3.4 Comparison of actual soil moisture value and digital number prediction soil moisture

Digital number data obtained on observations, then used in the multiple regression formula with the highest $R^2$ value. The multiple regression formula produces a predictive value of the digital number of aerial photographs. The predictive value of the digital aerial photograph number is then compared with the actual value of the soil moisture on the land.

Multiple Regression between soil moisture with digital composite numbers RGB, red, green, and blue has a low $R^2$ but it is expected that the soil moisture values from the regression and the actual are not much different (Table 2). The experiment compared with the Correlation, T-test, and linear regression between the actual soil moisture obtained from measurements in the field with the predicted soil moisture obtained by the multiple regression formula, yielding T-value = 0.00 and P-value = 1. These results can be concluded that there is no difference between the soil moisture when the measurement is on the field and the soil moisture is predicted from aerial photographs. According to [17] states that multi-spectral imagery which has a high resolution, then combined with soil sampling, is sufficient to provide information on modelling approaches to accurately estimate spatially distributed surface soil moisture. This statement supports the results of this study which states that there
is no difference between actual soil moisture measurements and predicted soil moisture measurements.

4 Conclusion
The conclusion that can be drawn from this research is the method of estimating soil moisture by using aerial photography of RGB on maize and peanut plantations have low accuracy. However, the comparison between actual soil moisture on the soil and soil moisture from the prediction of aerial photographs does not show a significant difference so this method still needs to be increased and improved. The accuracy of the estimation is very dependent on the camera settings and the weather so that further calibration and testing is necessary if used under different conditions.

References
4. R. Shofiyanti, 20, 58 (2011)