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Development of on-the-go soil organic matter sensor

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ABSTRACT

Soil organic matter (OM) greatly influences soil quality and productivity. Conventional soil OM analysis is expensive, time consuming and laborious. To practice precision farming, one important step is to describe the variability of a farm and the conventional analysis is always delayed. Quick ground sensor or on-the-go sensor can help to achieve this need. With the development of a new technology, the soil OM information can be gathered in a real time basis by using Soil Organic Matter Sense (SOMSENSE) with the integration of software developed using MATLAB. A model of soil OM estimation based on Red, Green, and Blue (RGB) scales showed significant findings when plotting on 1:1 line. This technique will help farmers or farm managers to determine their field variability quickly to practice precision farming based on OM variability map.

Key words: Ground sensor, Organic matter, Precision farming, SOMSENSE, Variability map.

Plant productivity is linked closely to soil organic matter (OM) (National Research Council, 1993). There are many ways in determining the soil OM content. Conventionally, it is determined by laboratory analysis methods known as back titration method or ignition loss method. From the physical color properties of soil, a dark soil color is associated with high OM concentrations. Attempts were made to quantify organic matter concentrations by soil color by Brown and O'Neal in the 1920's (Schulze *et al.* 1993). While, Coleman *et al.* (1990) used the Thematic Mapper (TM) to differentiate surface soils and found significant correlations between radiance data and OM. The Munsell color chart was later used to describe the relationship between OM and color. Steinhardt and Franzmeier (1979) used the Munsell color book to correlate moist soil color with OM in 262 soil samples from Indiana.

On-the-go soil sensors can be a part of either "map-based" or "real-time" systems (Adamchuk *et al.* 2004). Another important issue is the usefulness of on-the-go sensors is the economic value of the soil maps obtained. For example, data from soil Electrical Conductivity (EC) sensors were initially correlated to other soil properties (Searcy 2003). The sensor with a smart camera device and light radiation insides to scan the surface of the soil is known as Soil Organic Matter Sense (SOMSENSE). This system can retrieve and display soil OM content based on Red, Green, and Blue (RGB) color interpretation in a real time basis using a sensor. A digital camera can be used to measure soil color, and when using an appropriate color space model, these measurements may be used to derive accurate pedotransfer functions for soil Organic Carbon (OC) (Coleman *et al.* 1990). It was earlier developed by Advance Technology Institute (ITMA), Universiti Putra Malaysia (UPM) based on Besler Vision Technology for the camera used. Based on the previous study, Shonk *et al.* (1991) has developed an on-the-go sensor that used reflectance of light at 660 nm to obtain correlations with soil OM. While Sudduth and Hummel (1993) used a full-spectrum Near Infrared (NIR) sensor and averaged the data into 26 wider wavelengths between 1640 nm and 2640 nm for predictions of soil OM.

Unfortunately, there was no suitable program built for this equipment. Hence, there is a need to SOMSENSE to build an integrated program by create a network between Global Positioning System (GPS) and SOMSENSE with the Matlab software. With this network, the soil OM can be determined from the image analysis with their latitude and longitude on the real time. Selecting the threshold to detect only grey levels or RGB values within specific ranges enables selective detection of features. Jain and Dorai (1997) state that detection is the process which extracts a simplified, binary image from the original image.

MATERIALS AND METHODS

About 112 soil samples from Tanjung Karang Rice Irrigation Scheme located on a flat coastal plain in the district of Kuala Selangor, Sabak Berbam, Malaysia, were used for this study. The soil analysis was conducted by previous study and OM value from the sample analysis was taken to compare with the OM obtained by the image

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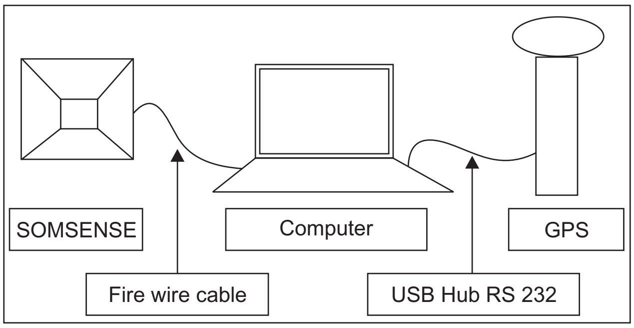


Fig 1 Roughly sketching for connecting both devices with the computer

Fig 2 The SOMSENSE and GPS are installed both devices with the computer at the back of this tractor

captured by SOMSENSE later.

Based on Fig 1, the computer was connected to the smart camera SOMSENSE and the GPS for the images and the location of the soil. It was placed on the tractor for on-the-go sensor (SOMSENSE) (Fig 2). The picture of the soil was snapped while the tractor moved through the predetermined path. The soil has been plowed before the experiment run.

The coding has been build based on the output that we aimed to be performed. The program was completed by neatly arrangement of the value of RGB from the image, latitude, longitude and lastly percentage of the soil OM.

From the program developed, there was an equation to model the percentage OM for the on-the-go measurement.

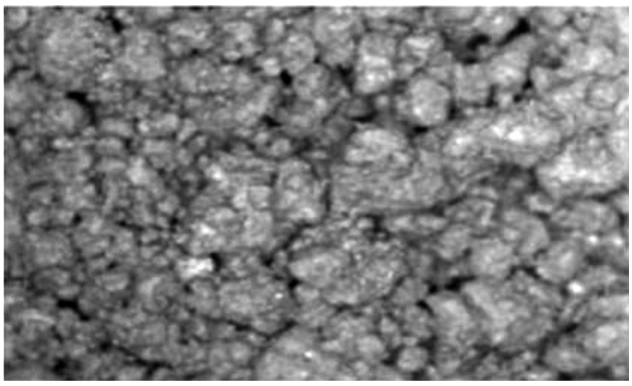


Fig 3 An image of the soil sample captured by SOMSENSE

This was the new model for OM that has been developed by regression analysis from SPSS software. The analysis was done by using the value of soil OM from the conventional laboratory analysis method and the RGB value captured by SOMSENSE.

The soil samples were captured by SOMSENSE for their image to be analyzed (Fig 3). The images which come out from SOMSENSE were separated into 3 bands, Red, Green, and Blue (RGB). In getting the relationship between RGB and organic matter, SPSS software was used.

RESULTS AND DISCUSSION

Programming result

Connecting the GPS with Matlab software

```
tic
for i = 1:10;
if i = = 1
   vdoobj = videoinput ('winvideo', 1);
   start (vdoobj)
   preview (vdoobj)
   gps = serial ('COM12','BaudRate', 4800);
   fopen (gps);
   k = 1;
else
   pause (1);
   coor = fscanf (gps);
   coor1= str2mat (coor);
if coor1(1,1) = = '$' && coor1 (1,2) = = 'G' && coor1 (1,6) = = 'A'
   coorbetul = coor;

lat = coorbetul (1,18:19);
long = coorbetul (1,32:34);
latt = coorbetul (1,20:29);
longg = coorbetul (1,35:44);

coordinate1 = [lat];
coordinate2 = [long];
coordinate3 = [latt];
coordinate4 = [longg];
```

Connecting the SOMSENSE and Matlab software

```
snapshot = getsnapshot (vdoobj);
rgbimage = ycbcr2rgb (snapshot);
gambar {k} = snapshot;
imagesc (snapshot)

rgbimage = ycbcr2rgb (snapshot);
gambar {k} = rgbimage;
imagesc (rgbimage)
imshow (rgbimage);

red = rgbimage (:, :, 1);
green = rgbimage (:, :, 2);
blue = rgbimage (:, :, 3);
```

```
mean Red = mat2str (mean 2 (red));
mean Green = mat2str (mean 2 (green));
mean Blue = mat2str (mean 2 (blue));
```

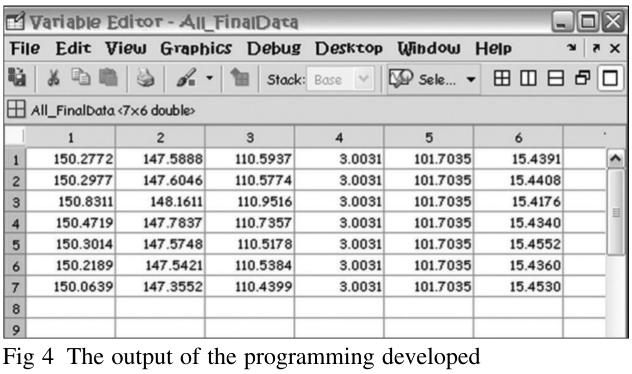
Integrating the SOMSENSE and GPS with Matlab software

```
a = 18.253; r = 0.394; g = 0.412; b = 0.011;
all Mean = {mean Red mean Green mean Blue coordinate1 coordinate3 coordinate2 coordinate4};
All Data (:,k) = {all Mean};
K = k+1;

end
end
end

toc
[m n] = size (All Data);
for i = 1:n

Susun (i,:) = All Data {1,i};
Mean Red Semua (i,1) = str 2 num (Susun {i,1});
Mean Green Semua (i,1) = str 2 num (Susun {i,2});
Mean Blue Semua (i,1) = str 2 num (Susun {i,3});
coordinate 1 Semua (i,1) = str 2 num (Susun {i,4});
coordinate 3 Semua (i,1) = str 2 num (Susun {i,5});
coordinate 2 Semua (i,1) = str 2 num (Susun {i,6});
coordinate 4 Semua (i,1) = str 2 num (Susun {i,7});
coordinate 5 Semua (i,1) = coordinate 3 Semua (i,1)/60 + coordinate 1 Semua (i,1);
coordinate 6 Semua (i,1) = coordinate 4 Semua (i,1)/60 + coordinate 2 Semua (i,1);

organic Matter (i,1) = a + r* Mean Red Semua (i,:) - g* Mean Green Semua (i,:)- b* Mean Blue Semua (i,:);

end

All_Final Data = [Mean Red Semua Mean Green Semua Mean Blue Semua coordinate 5 Semua coordinate 6 Semua organic Matter];
```

Programming output

One of the soil samples was picked to determine the percentage of OM content. After the Matlab completed run the program, the program output is displayed (Fig 4). From the result, columns 1, 2 and 3 represent the RGB of image captured by the SOMSENSE. While columns 4 and 5 represent the value of latitude and longitude of the soil's location. The reading is 3.0031° N and 101.7035° E. The last column, which is column 6, represents the percentage of OM, 15.4391% for the first reading.

The values of RGB, latitude, longitude and OM content were automatically displayed right after the program run was completed. The output will display the results until the set loop in the programming code finish.



	1	2	3	4	5	6
1	150.2772	147.5888	110.5937	3.0031	101.7035	15.4391
2	150.2977	147.6046	110.5774	3.0031	101.7035	15.4408
3	150.8311	148.1611	110.9516	3.0031	101.7035	15.4176
4	150.4719	147.7837	110.7357	3.0031	101.7035	15.4340
5	150.3014	147.5748	110.5178	3.0031	101.7035	15.4552
6	150.2189	147.5421	110.5384	3.0031	101.7035	15.4360
7	150.0639	147.3552	110.4399	3.0031	101.7035	15.4530
8						
9						

Fig 4 The output of the programming developed

Organic matter and RGB relationship

The color of each pixel in an RGB digital image is determined by the binary numbers (0-255) assigned to each color channel red, green and blue for each pixel. Every single RGB image is interpreted in means of red, green and blue for the final output.

Table 1 shows the correlation of the OM with RGB for light no 8. There are correlated with the negative values which indicate strength and direction of the correlation. The significant level is very small which is less than 0.01, so the correlation is significant and these variables are linearly related. From the regression analysis, a new model of OM content in the soil was performed (Table 2). The equation derived is as follows:

$$OM = 18.253 + 0.394R – 0.412G – 0.011B$$

Organic matter linear relationship

The graph of OM measured versus obtained has been plotted (Fig 5). The estimate regression line at zero intercept is y = 1.1967x – 2.2823 while the coefficient of determination, R^2 is 0.2183. However, using another type of algorithm to predict Organic Carbon (OC) such as CIELa*b* tristimuli algorithm, the adjusted R^2 may be increased up to 0.91 (Viscarra Rossel *et al.* 2008).

The result of OM shows a significant between OM measured and OM obtained from SOMSENSE. The coefficient of determination for line measured versus obtained is R^2 = 0.2183, compared to the straight line which intercept at 0, is 0.2143. The percentage of difference between these two values is 1.87%. Both values are

Table 1 Correlation of OM with RGB using light no. 8

	Red	Green	Blue
OM Pearson correlation	–0.258**	0.006	–0.297**
Significant (2-tailed)	0.001	–0.315**	0.001

**Correlation is significant at the 0.01 level (2-tailed).

Table 2 The regression analysis of the organic matter with RGB values

Parameter	r	R^2	Sig	Coefficients			
				Constant	Red	Green	Blue
OM	0.436	0.191	0.000	18.253	0.394	–0.412	–0.011

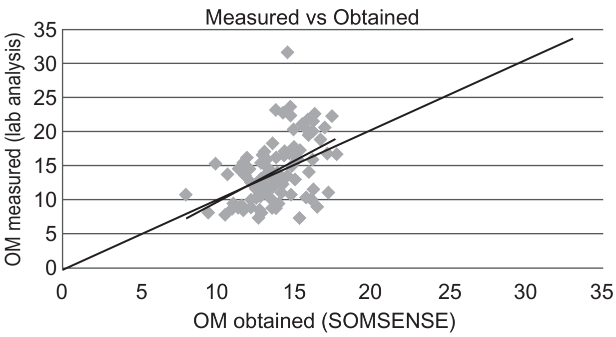


Fig 5 The predicted OM values plotted against the obtained OM values

approximate to 22% of variation in measuring the OM value. Maybe there are some experimental errors occur while the experiment run. The ambient light interference might affect the OM reading. Furthermore, the soil sample used was kept more than 6 months also affects the result of the OM obtained.

As a conclusion, the SOMSENSE and GPS were successfully integrated by the Matlab software in determining the soil organic matter with the specific location based on their latitude and longitude. As a new approach, the SOMSENSE can be used to measure the soil color with the image produce based on color interpretation in a real time basis compared to conventional soil analysis which is expensive, time consuming and laborious. The objective in finding the relationship of soil organic matter with RGB approach was achieved. A new model for determining organic matter was successfully derived by regression analysis method. This model is only use to test the soil paddy for cultivation area at Tanjung Karang. In order to test the various types of soil, the improvements must be done on the existing model. So it can be used by on-the-go the SOMSENSE everywhere around Malaysia.

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