DETERMINING SURFACE SOIL MOISTURE STATUS USING DIGITAL IMAGE ANALYSIS

D. M. El Shikha[1], A. M. El-Ghamry[2], A. M. El Shikha[3]

ABSTRACT

Estimating surface soil moisture from soil color using image analysis is evaluated in this paper. The experiment consisted of five samples of natural soil [sandy clay loam (1), clay loam (2), silty clay loam (3), sandy (4) and clayey (5)] with four levels of moisture [applying 0 (a- air dried soils), 100 (b), 150 (c), 200% (d) of field capacity (FC)]. Soil samples were spread in wooden trays (1x1x0.15 m). Soil was wetted to full saturation twice and let to dry before the experiment started. In each tray, the soil surface was leveled and soil depth was measured to be 15 cm.

All soil samples (trays) were wetted to the moisture contents mentioned above then they were photographed. The variations in soil color (red, green, and blue values and their standard deviations) with moisture content were investigated.

Results indicated that all the tested soils had an inverse relation between moisture content and the average of the standard deviation of the green and red values ($ASD_{RG} = \frac{STDEV_{red} + STDEV_{green}}{2}$ *). The average of the green and red values was not as consistent as the ASDRG in separating the soil moisture treatments. Also, the ASDRG was clearer than the average of the blue, green or red values in indicating the presence of standing water.*

Some examples of practical applications of the method used in this study are estimating the runoff, the advance and recession of the water over the field surface, the water ponding on the soil surface, and estimating the application uniformity.

[1] Associate Professor, Agricultural Engineering Department, Fac. of Agric, Mansoura University, Egypt

[2] Associate Professor, Soils Department, Fac. of Agric., Mansoura University, Egypt

[3] Assistant Professor, Agricultural Engineering Department, Fac. of Agric, Damietta branch, Mansoura University, Egypt

1. INTRODUCTION

The most commonly used methods for estimating soil moisture are the gravimetric methods. These methods include the ordinary method of oven drying of soil samples, which is destructive and can only be performed once for the same soil volume. Neutron probes and TDR probes are good nondestructive options; however, to get high spatial resolution, many probes have to be used. Moreover, inserting the probes in the soil will disturb the flow paths. Therefore, there is a need for a method that can measure soil moisture in a nondestructive way at a high spatial and temporal resolution.

The soil color has been related to various physical soil properties. Chen et al. (2000) found an exponential relationship between the red, green and blue (RGB) values of aerial images and soil surface organic matter content. It is also observed that soils become darker when they are wet, so soil color might also be useful for estimating soil moisture content. Persson (2005) concluded that red and green values had better correlation with soil moisture content compared to blue values. The author also stated that the relationship between soil color and soil moisture content was stronger in light colored soils (i.e. with low organic mater content).

Similar to using the standard deviation (Aston and van Bavel, 1972; Ehrler, 1972; Ehrler et al., 1978; and Gardner and Blad, 1981) and the coefficient of variation (Kostrzewski et al, 2002) of canopy temperature as indicators of overall water stress, the standard deviation of the color (blue, green, red) values could be used as an indicator of the variation in soil moisture content. The variability in soil color is expected to increase with the moisture depletion from the soil.

The main objective of the current study is to investigate the possibility of estimating surface soil moisture content from soil color variation using image analysis (i.e. using Image-J x64 2.1.4.5 O software). A secondary objective is to model the relationship between soil color and surface moisture content.

2. MATERIALS AND METHODS

2.1.Experimental Set-Up and Camera Settings:

The experiment consisted of five samples of natural soil [sandy clay loam (1), clay loam (2), silty clay loam (3), sandy (4) and clayey (5)] with four moisture levels [applying no water to air dried soils (a), and applying water to soils to attain 100 (b), 150 (c), 200% (d) of field capacity (FC)]. Soil properties for the soil samples are listed in table 1. The soils were shoveled in 1x1 m wooden trays with 0.15 m height. Soil trays were wetted to full saturation then they were air dried twice before the experiment started, which is a way to emulate the soil condition in the real field (in terms of particle agglutination). In each tray, the soil surface was leveled and soil depth was measured to be at least 0.10 m. The trays were placed outdoors at The College of Agriculture Farm, Mansoura University, Mansoura, Dakahlia, Egypt. All twenty trays were in direct sun (not shaded) during the experiment. Soils were then wetted to 100, 150, and 200% of the field capacity (treatments b, c, and d, respectively). The soils in treatment (a) were air dried (i.e., they had the hygroscopic moisture contents).

Properties of the soils under study were listed in table 1. Particle size distribution for soil was carried out using the pipette method as described by Dewis and Fertias (1970). Total carbonate was estimated gasometrically using Collins Calcimeter and calculated as calcium carbonate according to Dewis and Fertias (1970). Soil reaction (pH) was measured in saturated soil paste using combined electrode pH meter as mentioned by Richards (1954). Total soluble salts were determined by measuring the electrical conductivity in the extraction of saturated soil paste in dS m-1 as explained by Jackson (1967). Amounts of water soluble cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and anions (CO_3^{-2}, HCO_3^{-} and Cl^{-}) were determined in the extraction of saturated soil paste by the methods described by Hesse (1971), whereas (SO_4^{-}) ions were calculated as the difference between total cations and anions. Soluble Ca^{2+} and Mg^{2+} were determined by titration with standardized versenate solution.

Soluble Na^+ and K^+ ions were determined by using flame photometer. Soluble $CO_3^=$ and HCO_3^- ions were determined by titration with standardized H_2SO_4 solution. Soluble Cl^- ions were determined by titration with standardized silver nitrate solution. Soil available nitrogen was extracted using KCl (2.0 M) and determined by using macro-Kjeldahl method according to Hesse (1971). Soil available phosphorus was extracted with $NaHCO_3$ (0.5 M) at pH 8.5 and determined colorimetrically after treating with ammonium molybdate and stannous chloride at a wavelength of 660 nm, according to Jackson (1967). Available potassium was determined by extracting soil with ammonium acetate (1.0 M) at pH 7.0 using flame photometer as described by Hesse (1971).

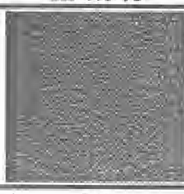
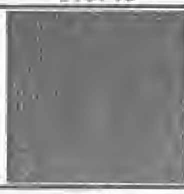
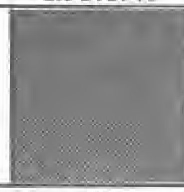
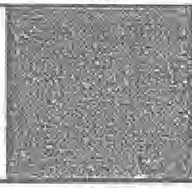
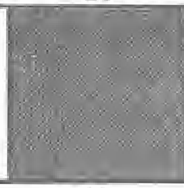
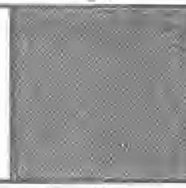
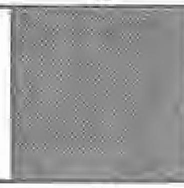
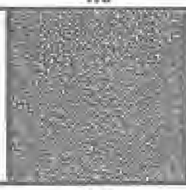
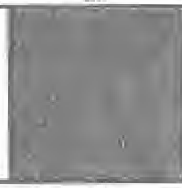
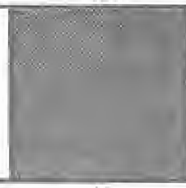
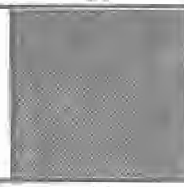
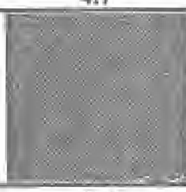
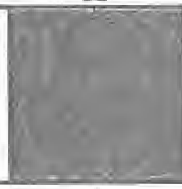
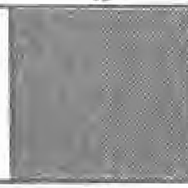
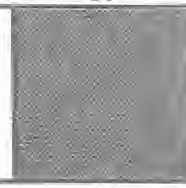
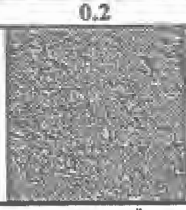
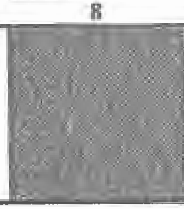
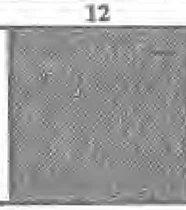
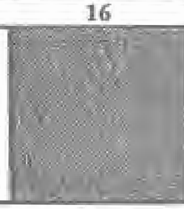
Soil trays were wetted to 100, 150, and 200% of the field capacity (treatments b, c, and d, respectively). The soil of treatment a was air dried (i.e., they had the hygroscopic moisture contents). All the trays were photographed once a week (at noon) using sunlight only (no artificial light) from April 28 until May 27, 2009, which resulted in five weekly data sets. Photographs were taken at three heights (0.30, 0.60 and 0.90 m) using a Kodak EasyShare-C340 digital camera (Eastman Kodak Company, Rochester, NY, USA) with 35 mm lens [f/2.7–4.6 (34–102 mm, equivalent 35 mm)]. Because they were taken in a short time, shifts in solar illumination were minimal. Photographs taken on April 28 for the soils with different moisture contents are shown in figure 1.The camera has 2576 × 1932 effective pixels (i.e. 5.0 megapixel). Photographs were taken with the camera pointed vertically downward at 30 cm (pixel size), 60 cm (pixel size) and 90 cm (pixel size) above the soil surface. Three shots were taken at each height. To guarantee that pictures were taken vertically at the specified height, a camera holder consisting of a telescopic pole with water bubble level was developed and used for this purpose.

Table 1: Some properties of the studied soils

Soil Properties		Soil 1	Soil 2	Soil 3	Soil 4	Soil 5
Particle size distribution	Sand %	51.88	41.55	19.41	94.31	17.17
	Silt %	21.15	30.20	42.19	4.12	22.70
	Clay %	26.97	28.25	38.40	1.57	60.13
Soil Texture		Sandy clay loam	Clay loam	Silty clay loam	Sandy	Clayey
Water holding capacity (mm/cm depth of soil)	S. P.	4.8	5.6	6.4	1.6	7.6
	F. C.	2.4	2.8	3.2	0.8	3.8
	W. P.	1.1	1.2	1.4	0.3	2.4
	A. W.	1.3	1.4	1.8	0.5	1.5
Chemical analysis	pH	7.9	7.8	7.8	8.6	7.6
	EC dS/m	3.64	1.85	2.19	0.45	2.12
	OM%	0.89	1.78	2.36	0.25	2.94
	CaCO3	6.23	3.10	1.40	4.26	4.52
Soluble cation meq/l	Ca^{++}	12.56	5.89	8.21	0.62	6.21
	Mg^{++}	9.81	6.70	6.83	0.42	2.45
	Na^{+}	10.54	4.50	5.64	2.14	1.64
	K^{+}	3.51	1.27	1.25	1.31	10.9
	HCO_3^-	10.27	4.48	5.42	1.28	6.45
	Cl^-	12.54	8.10	9.67	1.34	9.34
	SO_4^{--}	13.61	5.78	6.84	1.87	5.41
Available nutrient (ppm)	N	37.2	60.0	67.1	15.3	29.4
	P	6.9	15.4	6.4	4.6	15.8
	K	375	295	423	60.5	414

F.C. = field capacity W.P. = wilting point A.W. = available water S. P. = Saturation Percent

The images, were imported to Image-J x64 2.1.4.5 O, image analysis software, which was used for determining digital numbers (0-255) in the blue, green and red channels. Also it provided the standard deviation of the values in a selected area of interest. The area of interest in this case was the whole tray, excluding any shade resulting from the camera or its holder.

Soil Type	A H. W. %	B F.C. %	C 1.5 F.C. %	D 2.0 F.C. %
Soil (1) Sand clay loam				
MC %	3.7	24	36	48
Soil (2) Clay loam				
MC %	4.6	28	42	56
Soil (3) Silty clay loam				
MC %	4.7	32	48	64
Soil (4) Sandy				
MC %	0.2	8	12	16
Soil (5) Clayey				
MC%	5.5	38	57	76

H.W. = air dried soil (hygroscopic water), F.C. = field capacity, MC = moisture content

Figure 1: Photographs of the five soil types 1, 2, 3, 4, and 5 at the 4 moisture contents (a, b, c, and d) at 30-cm camera height (on April 28, 2009).

The values, digital numbers, and their standard deviations for the three channels were averaged for the five data sets then those averages were plotted for comparison. Regression analysis was performed using Microsoft Excel-2010 software. The relationship of soil surface moisture content and the average standard deviation of the green(G) and the red(R) channels (ASD_{RG}) [$ASD_{RG} = \frac{STDEV_{red} + STDEV_{green}}{2}$] was of interest as well.

3. RESULTS AND DISCUSSION

3.1. Using mean digital number and standard deviation to detect difference in soil moisture content

Average digital numbers-ADN (value) from the red and green channels (bands), denoted by ADN_{RG}, increased with increasing moisture content for especially for soil type 1(sand clay loam). However, for soil types 2 (clay loam), 3 (silty clay loam), 4 (sandy), and 5 (clayey), the trend of the AND_{RG} was not very clear (Figue 2).

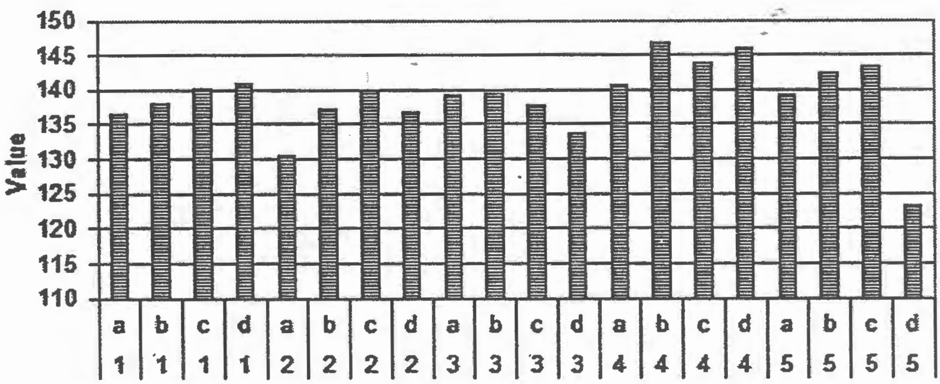


Figure 2. Average of the green and red values (digital numbers) for the five soil types 1 (sand clay loam), 2 (clay loam), 3 (silty clay loam), 4 (sandy), and 5 (clayey) at the four moisture contents [air dried (a), FC (b), 1.5FC (c), and 2.0FC (d)] at 30-cm camera height.

The average standard deviation of the green and red values (ASD_{RG}), from images taken at 30-cm camera height, and soil moisture content were plotted in figure 3. The ASD_{RG} values and soil moisture content was inversely related. In other words, the lower the soil moisture content, the higher the ASD_{RG} values. This relation was clearer for sand clay loam. The ASD_{RG} of the different soil types were plotted versus soil moisture content in figure 4. Linear regression models between STD_{RG} and soil moisture content were developed and posted in the same figure. The models indicated a reliable inverse relation between the soil moisture content and STD_{RG}, which was reflected by the high R^2 values. The R^2 values ranged from 0.92-0.99 except for the sandy soil which had a relatively low R^2 value (0.57). The lower R^2 value was associated with the sandy soil. Using the standard deviation to detect changes in soil moisture content is based on changes in soil color, which should be minimal for the sandy compared to the clay soil. Therefore the sandy soil had lower R^2 values than the clay soil.

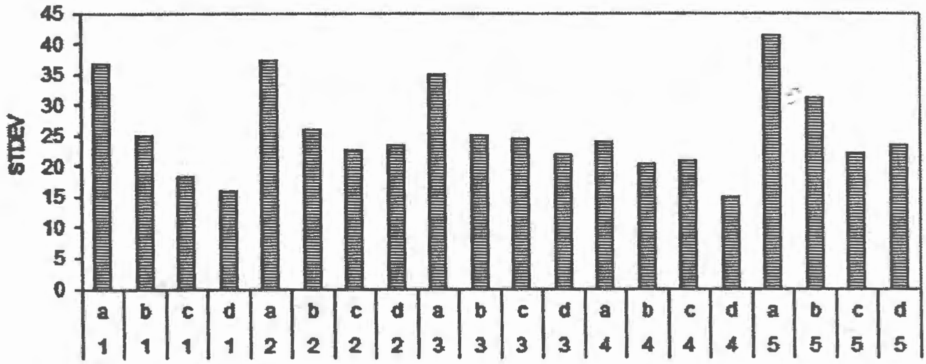


Figure 3. Average of the green and red standard deviations (ASD_{RG}) for the five soil types 1 (sand clay loam), 2 (clay loam), 3 (silty clay loam), 4 (sandy), and 5 (clayey) at the four moisture contents [air dried (a), FC (b), 1.5FC (c), and 2.0FC (d)] at 30-cm camera height.

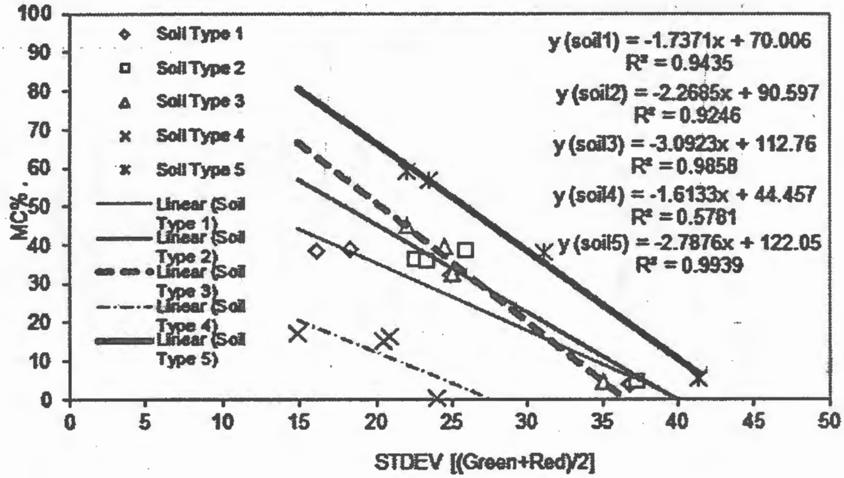


Figure 4. Moisture content (MC %) vs. average standard deviation of the green and red bands for the five soil types 1 (sand clay loam), 2 (clay loam), 3 (silty clay loam), 4 (sandy), and 5 (clayey) at the four moisture contents [air dried (a), FC (b), 1.5FC (c), and 2.0FC (d)] at 30-cm camera height.

The average values of the green and red for soil types 1 through 5 from images taken at 60 cm camera height were plotted in figure 5. The figure indicated clear separation of the different soil moisture treatments especially for silty clay loam. For the rest of the soil types, there was separation among treatments, however, the difference was not that significant and the trend was not consistent.

The average standard deviation of the green and red bands, for images taken at 60-cm camera height, was plotted in figure 6. It indicated very consistent separation among soil moisture treatments for all soil types under investigation. There was an inverse relation between the soil moisture content and the ASD_{RG}. The ASD_{RG} from images taken at 60 cm height were better in separating the treatments than those taken at 30 cm camera height.

Plotting the ASD_{RG} versus the soil moisture content for the five soil types resulted in linear regression models with R^2 values that ranged from 0.71-0.99 (figure 7).

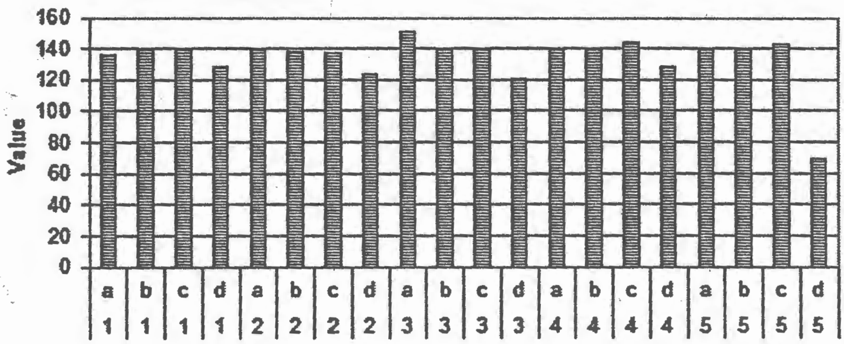


Figure 5. Average of the green and red values (digital numbers) for the five soil types 1, 2, 3, 4, and 5 at the 4 moisture contents (a, b, c, and d) at five soil types 1 (sand clay loam), 2 (clay loam), 3 (silty clay loam), 4 (sandy), and 5 (clayey) at the four moisture contents [air dried (a), FC (b), 1.5FC (c), and 2.0FC (d)] at 60-cm camera height.

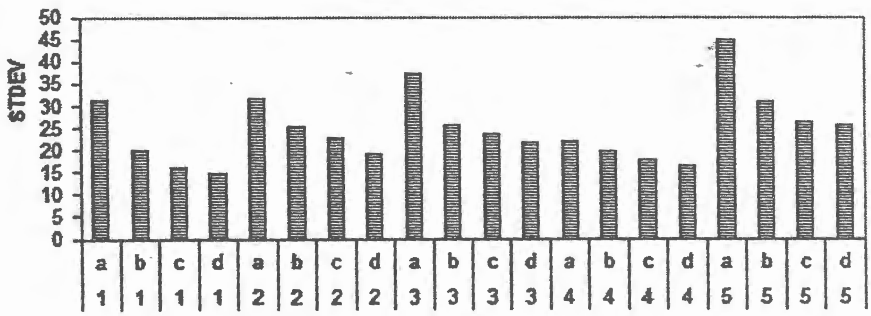


Figure 6. Average of the green and red standard deviations (ASD_{RG}) for the five soil types 1 (sand clay loam), 2 (clay loam), 3 (silty clay loam), 4 (sandy), and 5 (clayey) at the four moisture contents [air dried (a), FC (b), 1.5FC (c), and 2.0FC (d)] at 60-cm camera height.

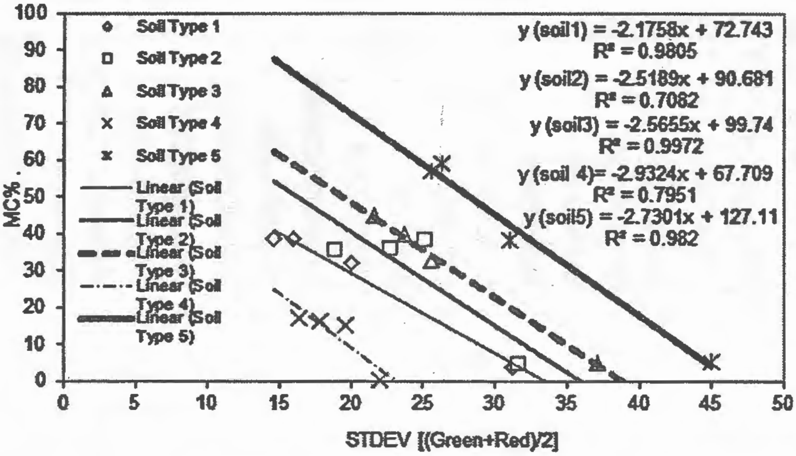


Figure 7. Moisture content (MC %) vs. average standard deviation of the green and red bands for the five soil types 1 (sand clay loam), 2 (clay loam), 3 (silty clay loam), 4 (sandy), and 5 (clayey) at the four moisture contents [air dried (a), FC (b), 1.5FC (c), and 2.0FC (d)] at 60-cm camera height.

The average values of the green and red for the five soil types, 1 (sand clay loam), 2 (clay loam), 3 (silty clay loam), 4 (sandy), and 5 (clayey), from images taken at 90 cm height were plotted in figure 8. The difference in soil moisture treatment was not very clear when the average value of green and red was used. Reasonable separation among soil treatments only with silty clay loam (the higher the soil moisture content, the higher the average of green and red values was seen). The ASD_{RG} values for images taken at 90-cm camera height were plotted in figure 9. Similar to figure 7, figure 9 indicated a steady separation among soil moisture treatments for all soil types (1-5). There was an inverse relation between the soil moisture content and the ASD_{RG} (Figure 9). Linear regression models were obtained when ASD_{RG} was plotted versus soil moisture content for the soil types under study (figure 10). The models had high R^2 values (0.77-0.98) for all soil types.

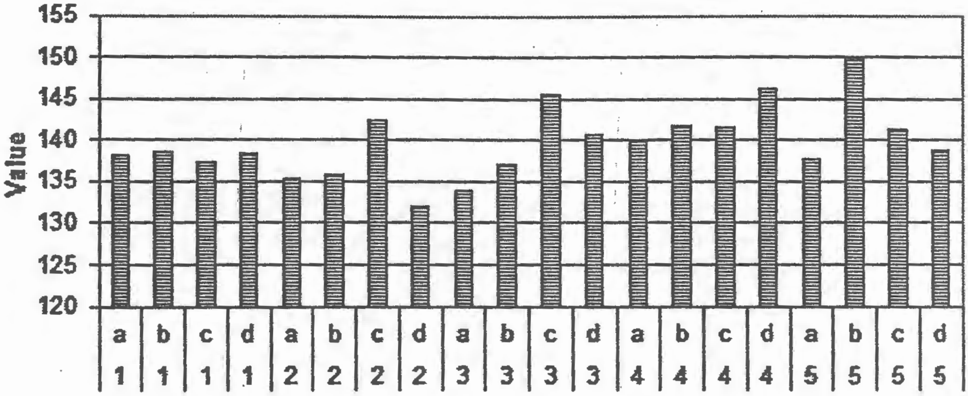


Figure 8. Average of the green and red values (digital numbers) for the five soil types 1 (sand clay loam), 2 (clay loam), 3 (silty clay loam), 4 (sandy), and 5 (clayey) at the four moisture contents [air dried (a), FC (b), 1.5FC (c), and 2.0FC (d)] at 90-cm camera height.

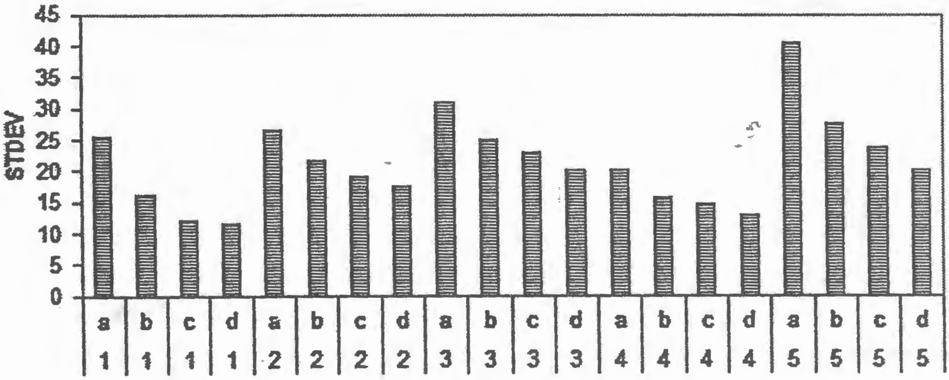


Figure 9. Average of the green and red standard deviations (ASD_{RG}) for the five soil types 1 (sand clay loam), 2 (clay loam), 3 (silty clay loam), 4 (sandy), and 5 (clayey) at the four moisture contents [air dried (a), FC (b), 1.5FC (c), and 2.0FC (d)] at 90-cm camera height.

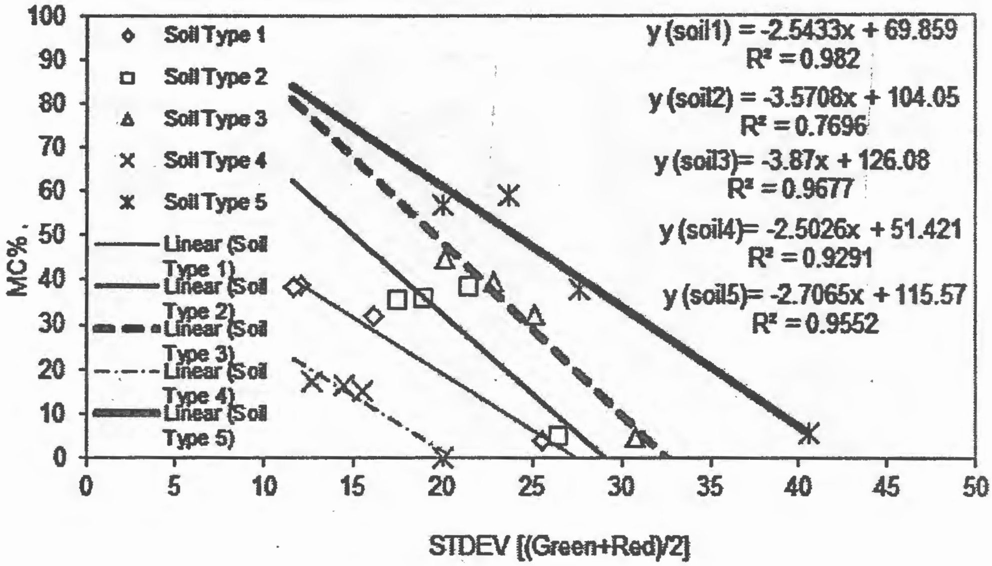


Figure 10. Moisture content (MC %) vs. average standard deviation of the green and red bands for the five soil types 1 (sand clay loam), 2 (clay loam), 3 (silty clay loam), 4 (sandy), and 5 (clayey) at the four moisture contents [air dried (a), FC (b), 1.5FC (c), and 2.0FC (d)] at 90-cm camera height.

3.2. Wet soil with standing water vs. no standing water

Mean, mode and standard deviation of the blue green and red bands (average of the three heights) for sand clay loam were plotted in figure 11. The mean and the standard deviation of the blue band indicated the difference between treatments (standing vs. no-standing) but the standard deviation was clearer in showing the presence of standing water. The standard deviation of the blue green and red values was inversely related to the presence of standing water.

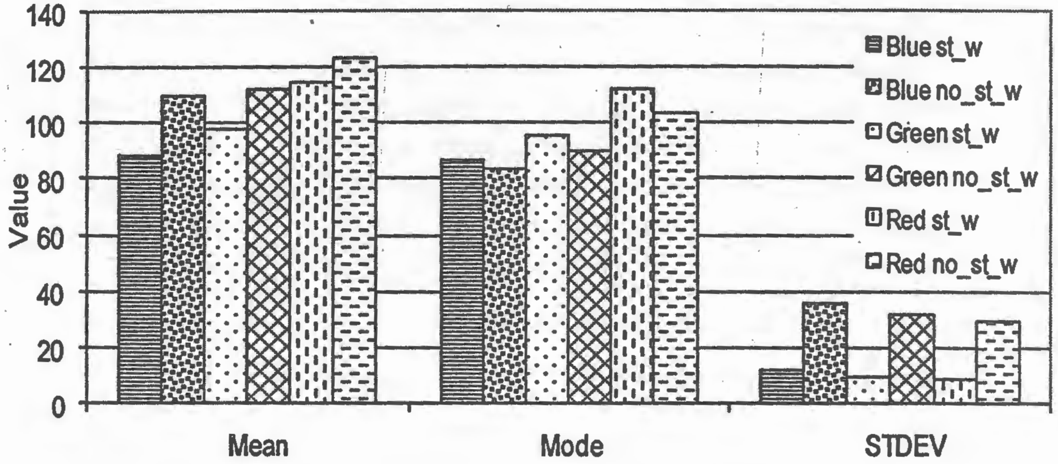


Figure 12. Mean value, mode and standard deviation (STDEV) (average of the three camera heights 30, 60 and 90 cm) for wet soil with standing vs. no standing water (clay loam) with blue, green and red channels.

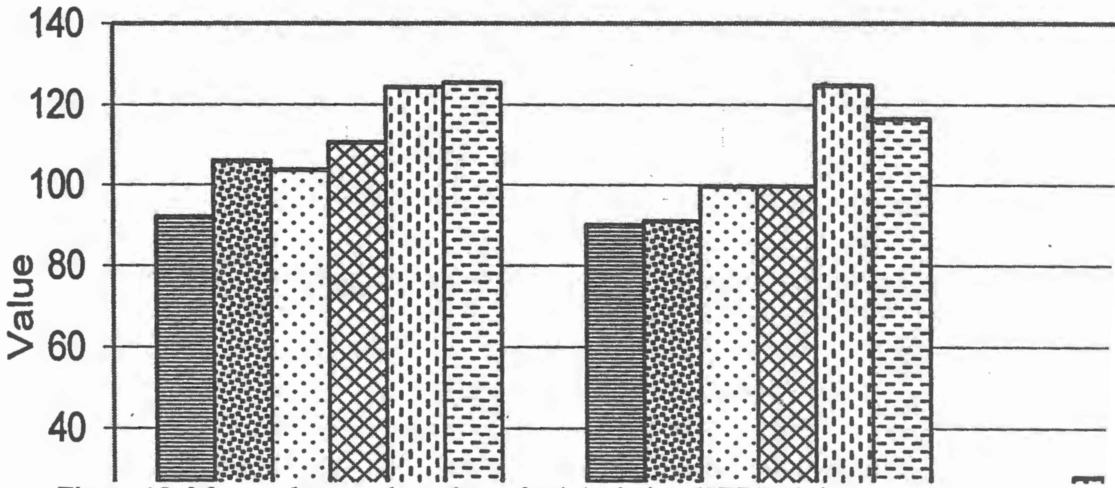


Figure 13. Mean value, mode and standard deviation (STDEV) (average of the three camera heights 30, 60 and 90 cm) for wet soil with standing vs. no standing water (silty clay loam) with blue, green and red channels.

For sandy soil, mean, mode and standard deviation of the blue green and red bands (average of the three camera heights) were plotted in figure 14. Unlike the previously discussed soil types, the mode was able to detect the presence of standing water. Similar to soil types 1, 2 and 3, the mean and standard deviation of all bands (blue green and red) showed the difference between standing and no-standing water. The mean, mode and standard deviation values were inversely related to the presence of standing water (higher values when there is no standing water).

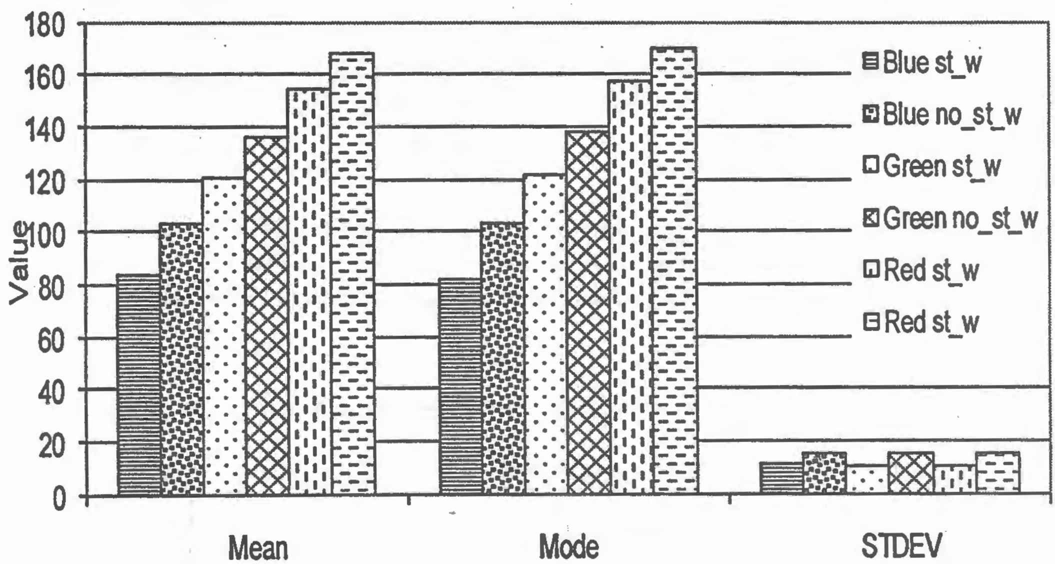


Figure 14. Mean value, mode and standard deviation (STDEV) (average of the three camera heights 30, 60 and 90 cm) for wet soil with standing vs. no standing water (sandy) with blue, green and red channels.

Mean, mode and standard deviation of the blue green and red bands (average of the three camera heights) for the clayey soil were plotted in figure 15. The mean and the standard deviation of the blue band indicated the difference between standing and no-standing water conditions; on the other hand, the standard deviation was better in showing the standing water. Both the mean and standard deviation values were inversely related to the presence of water.

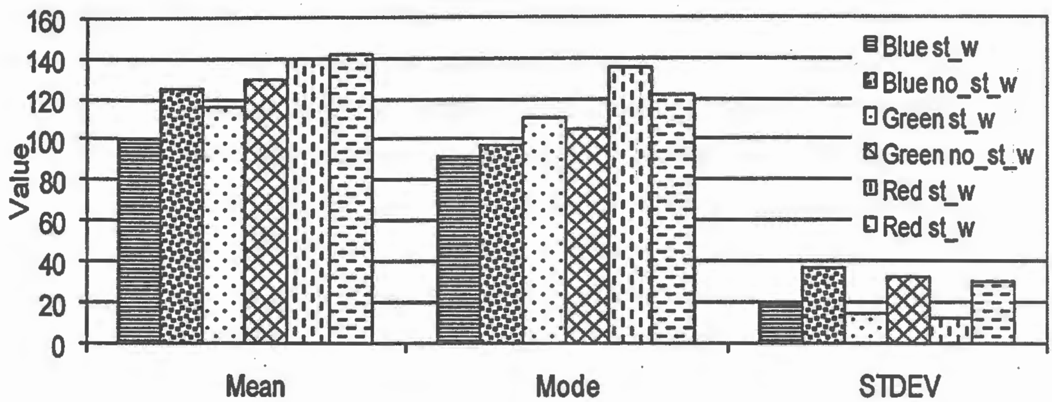


Figure 15. Mean value, mode and standard deviation (STDEV) (average of the three camera heights 30, 60 and 90 cm) for wet soil with standing vs. no standing water (clayey) with blue, green and red channels.

The average standard deviation of the green and red (ASD_{RG}) for the five soil types in this study, recoded from images taken at 30, 60 and 90 cm camera heights, was plotted in figure 16. Similar to the standard deviation of the blue green and red, the ASD_{RG} was able to indicate the existence of standing water on the surface of the five soil types under investigation. Higher ASD_{RG} was detected with no standing water condition.

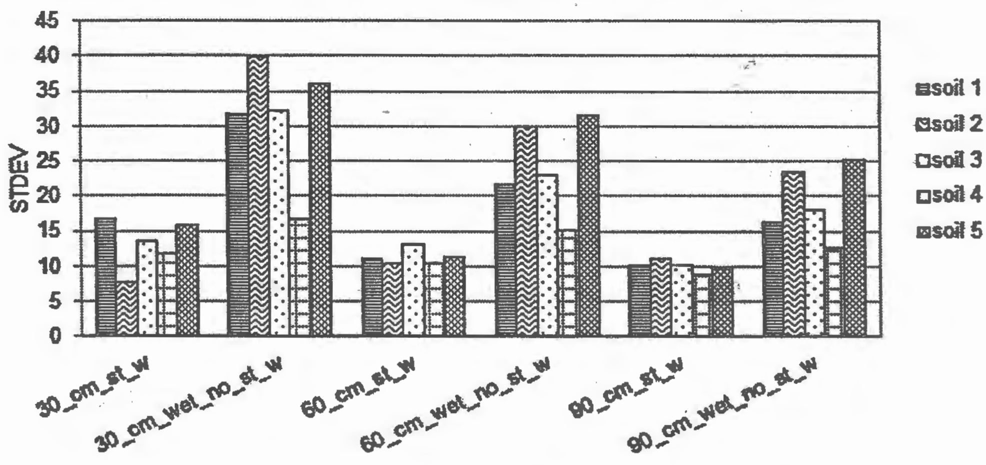


Figure 16. Using average standard deviation (STDEV of green and red channels) to distinguish between wet soil with standing water (st_w) vs. no standing water (no_st_w) for soil types 1 (sand clay loam), 2 (clay loam), 3 (silty clay loam), 4 (sandy), and 5 (clayey).

4. CONCLUSIONS

The relationship between soil moisture content and soil color expressed in blue green and red values and their standard deviation was investigated. It was shown that the average standard deviation of the green and red values (ASD_{RG}) was a good indicator of soil moisture content for all the soil types under investigation when images are taken at heights that ranged from 30-90 cm. Unlike the ASD_{RG}, the average value of the green and red bands was not consistent in showing the difference in soil moisture contents. Both the mean and standard deviation of the blue green and red values were able to detect the presence of standing water on the surface of soil (types 1-5) but the standard deviation was clearer. Also, the ASD_{RG} was able to separate the soil with standing water from that with no standing water. In general, data extracted from images taken at 60-90 cm camera heights were better than those taken at 30 cm camera height.

The lower blue green and red values associated with the presence of standing water was mainly explained by high absorption and less reflection in the blue green and red by the water. Furthermore, the standard deviation had higher values when no standing water was present because of the relatively rougher soil surface, which might have resulted in shadow effects. The ASD_{RG} values had high correlation with soil moisture content for tested soils with relatively high R^2 values (0.71-0.99). The developed linear models can be used to predict soil moisture content.

Our research demonstrates how digital color images/pictures along with a simple image processing software can be used to predict soil moisture content. Also, these digital pictures would be useful in showing water distribution in the field after irrigation.

Estimation of soil surface moisture content using digital photographs can be useful for estimating the runoff, the advance and recession of the water over the field surface, the water ponding on the soil surface, and the application uniformity. Consequently, digital photographs can be used for defining irrigation performance.

5. REFERENCES

Aston, A. R. and C. H. M. Van Bavel. 1972. Surface Soil Water Depletion and Leaf Temperatures. Agron Journal 64, 368-373.

Chen, F.; D.E. Kissel; L.T. West, and W. Adkins. 2000. Field-scale mapping of surface soil organic carbon using remotely sensed imagery. Soil Sci. Soc. Am. J. 64:746-753.

Dewis, J. and F. Fertias. 1970. Physical and Chemical Methods of Soil and Water Analysis. Soils Bulletin No. 10. Rome, FAO.

Ehrler, W. L. 1972. Cotton leaf temperatures as related to soil water depletion and meteorological factors. Agron. J. 65: 404-409.

Ehrler, W.L.; S.B. Idso; R.D. Jackson; and R.J. Reginato. 1978. Wheat canopy temperature: Relation to plant water potential. Agron. J.70: 251-256.

Gardner, B.R. and B. L. Blad. 1981. Relationships between Crop Temperature, Grain Yield, Evapotranspiration and Phenological Development in two Hybrids of Moisture Stressed Sorghum. Irrigation Science, 2: 213-224.

Hesse, P.R., 1971. A Text Book of Soil Chemical Analysis. Juan Murry (Publisher) Ltd., London.

Jackson, M.L., 1967. Soil Chemical Analysis. Printice-Hall of India, New Delhi.

Kostrzewski, M.; P. Waller; P. Guertin; J. Haberland; P. Colaizzi; E. Barnes; T. Thompson; T. Clarke; E. Riley, and C Choi. 2002. Ground-based remote sensing of water and nitrogen stress. Transactions of the ASAE 46(1): 29-38.

Persson, M. 2005. Estimating surface soil moisture from soil color using image analysis. Vadose Zone J., 4 (November), 1119-1122.

Richards, L.A., 1954. Diagnosis and Improving of Saline and Alkaline Soils. U.S., Salinity Laboratory Staff. Agric. Handbook, No. 60.

الملخص العربي

تقدير رطوبة التربة السطحية بإستخدام تحليل الصور الرقمية

ضياء الدين محمد الشيخة[1] _ أيمن محمد الغمري[2] _ أحمد محمد الشيخة[3]

نظرا لأهمية تقدير المحتوي الرطوبي للتربة وذلك لتحديد مواعيد الري وباقي العمليات الزراعية حتي لا يتم اجراء تلك العمليات عند رطوبة غير مناسبة للتربة فيحدث هدم لبناء التربة.فكان لابد من ايجاد طريقة سهلة وسريعة لتحديد رطوبة سطح التربة وتم ذلك عن طريق تحليل الصور الرقمية المأخوذة لسطح التربة والوصول الي العلاقة التي تربط المحتوي الرطوبي لسطح التربة مع لون التربة. ومع تغير رطوبة التربة يتغير اللون الخارجي لسطح التربة وبالتالي يمكن تبين هذا الفرق في تحليل الصور الرقمية المأخوذة للتربة عن طريق نسب الألوان الأساسية (أحمر، أخضر ،أزرق)(RGB).

---

[1] أستاذ مساعد ـ قسم الهندسة الزراعية ـ كلية الزراعة ـ جامعة المنصورة.
[2] أستاذ مساعد ـ قسم الأراضي ـ كلية الزراعة ـ جامعة المنصورة.
[3] مدرس ـ قسم الهندسة الزراعية ـ كلية الزراعة بدمياط ـ جامعة المنصورة.

وقد أجريت التجربة في كلية الزراعة جامعة المنصورة الدقهلية لخمس أنواع من التربة [رملية طينية طميية (١)،طينية طميية (٢)، سلتية طينية طميية (٣)، رملية (٤)، طينية (٥)] معدة في صواني خشبية ١×١م بعمق ٠.١٥ م. رويت تلك العينات بالماء للوصول بها الي ضعف السعة الحقلية (درجة التشبع) مرتين قبل اجراء عملية التصوير مع تسوية سطح التربة لكي لا يقل العمق عن ٠.١م. وكانت تلك الصواني معرضة للشمس مباشرة (دون وجود ظل) وأخذت معاملات ري (١٠٠، ١٥٠، ٢٠٠%) من السعة الحقلية وأخذت المعاملة الرابعة للتعبير عن التربة الجافة هوائياً.

صورت تلك الصواني مرة واحدة اسبوعيا بعد الظهيرة من ٢٨ ابريل حتي ٢٧ مايو ٢٠٠٩ بواسطة كاميرا Kodak EasyShare-c340 مثبتة علي حامل رأسي. واخذت الصور علي ثلاث ارتفاعات (٠.٣، ٠.٦، ٠.٩م) أعلي سطح التربة وأخذت ثلاث لقطات عند كل ارتفاع .ولضمان رأسية وضع الكاميرا أعلي سطح التربة ثبت حامل الكاميرا أعلي عمود تليسكوبي بميزان مياه لضمان الأفقية.

حللت الصور بواسطة Image Analysis Software والذي يستخدم لحساب القيم الرقمية (صفر- ٢٥٥) للأزرق والاصفر و الاحمر ويعطي أيضا الانحراف المعياري للقيم في المساحة المختارة . واخذت متوسطات القيم لكل من الألوان الثلاثة والانحراف المعياري للخمس صواني للمقارنة.

وقد تحققت العلاقة الجيدة بين المحتوي الرطوبي لسطح التربة ومتوسط الانحراف المعياري للأخضر والأحمر [$ASD_{RG} = (STDEV_{red} + STDEV_{green})/2$] .

وقد تحققت قابلية استخدام الصور الرقمية لبيان المياه الراكدة فوق سطح التربة للخمس أنواع من الترب المختلفة. وتحققت تلك العلاقة بين المحتوي الرطوبي للتربة ولون التربة معبرا عنه بقيم الازرق والاخضر والاحمر وانحرافهم المعياري وقد كان متوسط الانحراف المعياري لقيم الاخضر والاحمر ASD_{RG} مؤشر جيد للمحتوي الرطوبي للتربة لجميع أنواع التربة المستخدمة مع الصور المأخوذة من ارتفاع ٠.٦- ٠.٩ م .

وكان متوسط قيم الأخضر والاحمر لا يظهر الفرق في محتويات الرطوبة المختلفة .

وكان كل من المتوسط والانحراف المعياري لقيم الازرق والاخضر والاحمر لهم القدرة علي كشف وجودالماء الثابت علي سطح التربة للأنواع المختلفة ولكن الانحراف المعياري كان أكثر

وضوحا . وايضا متوسط الانحراف المعياري لقيم الاخضر والاحمر كان قادرا علي الفصل بين التربة مع المياه الراكدة والتربة مع عدم وجود مياه راكدة.

فبشكل عام البيانات المستنتجة من الصور علي ارتفاع ٠.٦ ، ٠.٩م كانت أفضل من المأخوذة علي ارتفاع ٠.٣م.

وقد أظهر هذا البحث مدي امكانية استخدام الصور الرقمية مع برامج معالجتها البسيطة للتنبؤ بالمحتوي الرطوبي للتربة وتكون هذه الصور مفيدة في تبيين توزيع المياه علي طول الحقل بعد الري و في تقدير الجريان السطحي والتقدم والإنحسار للمياه علي سطح التربة وتحديد اماكن برك المياه علي سطح التربة . وبالتالي يمكن استخدام الصور الرقمية لبيان آداء الري الحقلي.