J.Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 6 (5): 591 - 601, 2015

CENTER-PIVOT IRRIGATION WATER MANAGEMENT BASED ON SOIL SPECTRAL REFLECTANCE TECHNIQUE

Elmarsafy, M. A. ; H. A. Farag ; H. S. Mohawed and K. Allam
Agric. Eng. Res. Inst. ARC, Egypt

ABSTRACT

Center pivot irrigation system has the potentiality for economically net return of various crop patterns, although it's higher fixed cost's inputs. Therefore, water management under the specified center pivot irrigation system can play a crucial role in maximizing water unit productivity and enhancing physical agricultural resources sustainability. Hereby, the aim of this research was to evaluate the optional of a general reflectance model based solely on soil moisture distribution pattern as a key for a farm irrigation management under center pivot irrigation system. Data revealed that the relative reflectance was strongly correlated with soil moisture contents. However, the best correlation was found act high soil moisture level between the reflectance values of 700 nm (Red-NIR) wave length and the volumetric water content (R^2=0.9) at the short time (one hour). Moreover, the results of this study help to appear the strong in influence of soil moisture on spectral reflectance and absorption features and should aid in the development operational and management algorithms of on-farm irrigation systems.

INTRODUCTION

Egypt launched a mega project to reclaim four million feddans for increasing cultivation area from 8.3 to 12 million feddans. This new reclamation area need an irrigation water which it should be supplied throw irrigation beast management. Shortage of water resources and *Researchers at Agricultural Engineering Research Institute (AEnRI), ARC, Dokki, GIZA, Egypt* growing competition for water will reduce water availability for irrigation, while the need to meet growing food demands will require more food within adequate less water amount. A more effective water use and greater water productivity will be primary challenge for future development. However, water productivity in terms of output of food per cubic meter of irrigation water used needs to be increased in both irrigated and rain fed agriculture (FAO, 2000). Due to excess or deficient levels of water or nutrients can result in yield reductions. Proper design and management of micro irrigation system is essential for successful crop production. System must integrate soil-physical properties, crop root distribution characteristics, water requirements related to crop growth stage and environmental condition and irrigation delivery system hydraulic characteristics (El-Raie and Abdel- wahed, 2005 and Replogle, 2000). Knowledge of soil hydraulic properties is crucial for the solution of equations describing the water flow in unsaturated soils. However, the accurate estimated of water flux and therefore water availability is of importance environmental issues. Water retention curves describe the relationship between the pressure head and the volumetric water content .Particle size distribution data have been widely used as a basis for estimating soil hydraulic properties and consequently irrigation water scheduling .Hydraulic conductivity of unsaturated soil is one of the most important soil properties controlling infiltration and surface runoff, as well as leaching of the applied agro-chemicals. Hydraulic conductivity depends strongly on soil texture, structure and therefore can vary widely space. Soil moisture is an important factor across a range of environmental processes, including plant growth, soil biogeochemistry, land –atmosphere heat and water –exchange (Wignecon *et al.*, 2007).Therefore timely and accurate measurements of soil moisture are highly describe for the management of irrigation. However, on-farm irrigation water management had been simply clarified by (Arafa, 2010) as shown in Figure (1). Monitoring of soil moisture distribution uniformity under center pivot irrigation system is highly required for understanding and modeling irrigation systems and maximizing on - farm irrigation water unit net return .The uniformity of water application under a center pivot is determined by setting out cans or rain gauges along the length of pivot, bringing the irrigation system up to proper operating pressure, and letting the system pass over them (Record the distance from the center of the pivot and the amount of water collected for each can or gauge. From this information, a coefficient of uniformity can be calculated. The coefficient of uniformity is usually expressed as a percentage (Foley and Raine., 2001).

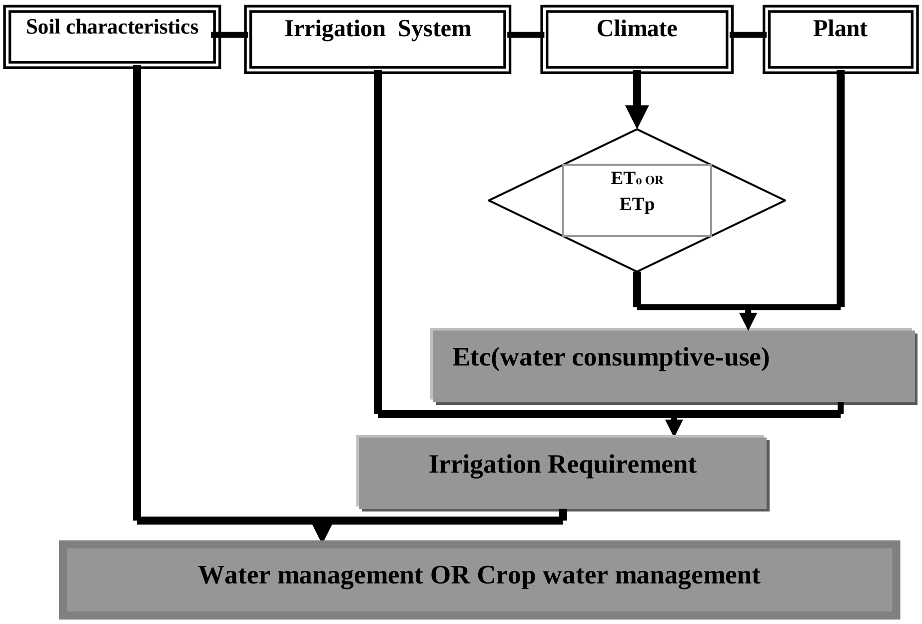

Fig. (1): Characterization of crop water management

Remote sensing approaches have primarily focused on microwave wavelength, where moisture exerts strong control over soil dielectric properties, and where measurements are not impeded by clouds or darkness (Lobell and Asner 2002., Njoku and Entekhabib, 1996 and Ulaby *et al.*, 1996). On the other hand, moisture influences the reflection of shortwave radiation from soil surfaces in the VNIR (400-1100 nm) and SWIR (1100-2500 nm) region of the spectrum (Skidmore *et al.*, 1975). However, quantification of moisture using this wavelength remains difficult because of significant variability from other soil chemical and physical properties, such as organic matter and mineralogy, as well as vegetation cover (Asner, 1998). Kaleita *et al*. (2005) investigated the relationship between soil moisture content and soil surface reflectance and indicated that it is feasible to estimate surface (0-to 7.6 cm) soil moisture from visible to near infrared reflectance.

The main objective of this study is to monitor temporal and spatial changes, in the field water application uniformities along radial and circular lines under center-pivot systems using soil reflectance as a soil proceeded from wet to dry states and to determine the dependence of these changes on wavelength.

MATERIALS AND METHODS

Experimental Layouts and site description

Field experiments were carried out in the Experimental Farm of Faculty of Agriculture, Ain Shams University, El-Kanater city, Kalubia Governorate. Soil physical and Hdro-physical characteristics of the investigated illustrated in Table (1).

Table (1): Physical properties of the farm soil

Sample depth (cm)	H.C (cm/h)	particle size distribution (%)				Ө % at			BD (g/cm^3)	
		Coarse sand	Fine sand	Clay	Texture class	F.C (33 kPa)	P.W.P (1500kPa)	A.W		
0-5	0.9	25.8	41.5	30.8	SCL	31.46	15.10	16.36	1.25	3.12
5-10	1.0	25.5	40.2	33.3	SCL	31.21	15.42	15.97	1.28	2.36

***According to the standard soil texture triangle**

Some chemical properties of soil were measured as follows;

Soil pH and EC were measured in 1: 2.5 soil : water suspension in soil paste extract, respectively. Some soluble cations and anions were determined by titration methods and flame photometer according to ASAE, Standard some chemical properties of the soil are presented in Table (2).

Table (2): Some chemical properties of the studied soil

Semple depth (cm)	pH	E.C. (dS/m)	Cations, (meq/l)				Anions, (meq/l)			
			Ca++	Mg ++	Na+	K +	CO_3 - -	SO_4 - -	Cl -	HCO_3 -
0-5	7.7	0.26	0.40	0.48	0.41	0.19	0.00	0.63	0.49	0.36
5-10	7.6	0.23	0.46	0.46	0.51	0.18	0.00	0.76	0.51	0.23

Chemical analysis of irrigation water was carried out by using the standard methods and presented in Table (3)

Table (3): Some chemical properties of irrigation water

pH	EC (dS/m)	Cations, (meq/l)				Anions, (meq/l)				SAR
		Ca++	Mg ++	Na+	K+	CO3 - -	HCO_3- -	Cl -	SO_4- -	
7.3	0.38	2.74	1.42	2.19	0.21	0.00	2.41	2.55	1.36	1.52

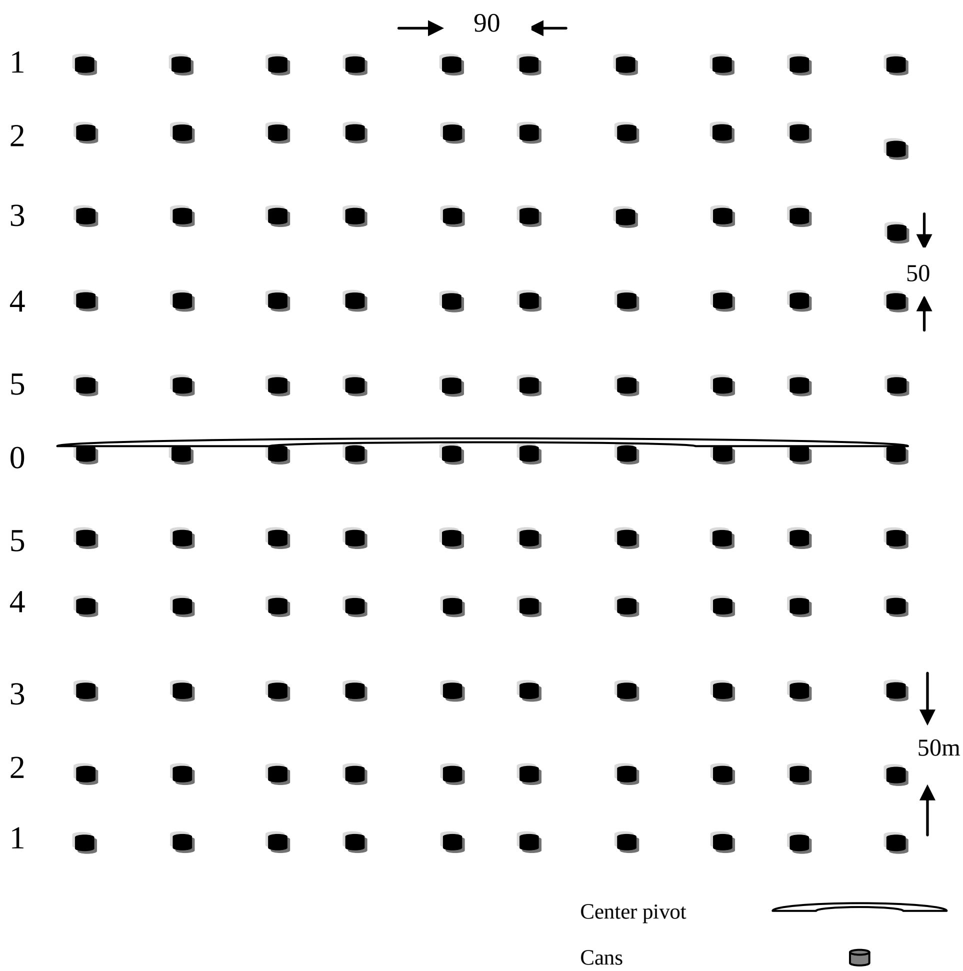

Fig. (2): Schematic diagram of the investigated points under the center pivot

Soil water uniformity distribution under center pivot irrigation system had been measured in order to evaluate the efficiency of the portable reflectance spectrometer in detecting water content of the surface layer for the soil within different times of soil depletion 1hr up to 96 hr after shut down of the irrigation events. Investigated points under center pivot shown in Fig. 2.

Calibration of reflectance spectrometer

Because of variations in the manufacture of the electrical components such as lamps and light sensors which use to measure and read the wave and light movement a laboratory calibration was done before start the field experiment instrument to correct these differences between instruments and to move the measurement closer to what happens to the light. Measurement of light reflectance is given as the percentage or proportion of light (for each wavelength or color) that reflects from the soil. The display number measurements indicate how much light (of each color) has reflected from the soil, but how much light hit the soil to start with. One way to measure how much light hits the soil and how much is reflected, is to take reflectance measurements of a standard material to know how much light is reflected. Standards for this experiment are heavy white paper or white poster board, which reflect almost all of the light that hits them, about 85%. White photocopy paper was used to measure the reflectance standard, where the spectrometer was put on the piece of white photocopy paper and again measure the spectrometer's output voltage for each lamp. The reading was recorded and written in the worksheet in the column labeled "Standard White Paper, table 4.

Table (4): The record of the spectrometer output

wave lengths nm	The reading was recorded with white paper
470	646
525	796
560	800
585	825
600	790
645	858
700	836

With the "Standard" data, we can now calculate the proportion (or percentage) of light reflected by the soil. For each color, simply divide the display voltage number for the soil by the display voltage number for the white paper. This value is called the reflectance.

Reflectance = (Display number for sample) / (Display number for white paper).

Displayed numbers for white paper using different wave lengths are 646, 800, 790, and 836 for 470, 560, 600, and 700 Aº, respectively. The aim of this study is to water uniformities along radial and circular lines under center-pivot systems depending of the soil reflectance.

RESULTS & DISCUSSION

The relationship between the wavelength and reflectance at different progress time

Figure (3) show that for all the wavelengths the reflectance increased with time progress. With time progress the soil moisture decreases witch reflects on the % reflectance in all studied wavelengths. The familiar darkening of soil upon wetting is because of a change in the real part of the refractive index (n) of the immersion medium from air (n = 1) to water (n = 1.33) (Twomey *et al.*, 1987). According to Lobell and Asnar (2002) this decreases the contrast between soil particles (n ~ 1.5) and their surrounding medium, resulting in an increase in the average degree of forward scattering and, thus, an increased probability of absorption before reemerging from the medium. Numerous studies have investigated the relationships between wet and dry soil reflectance, noting an overall decrease in reflectance upon wetting.

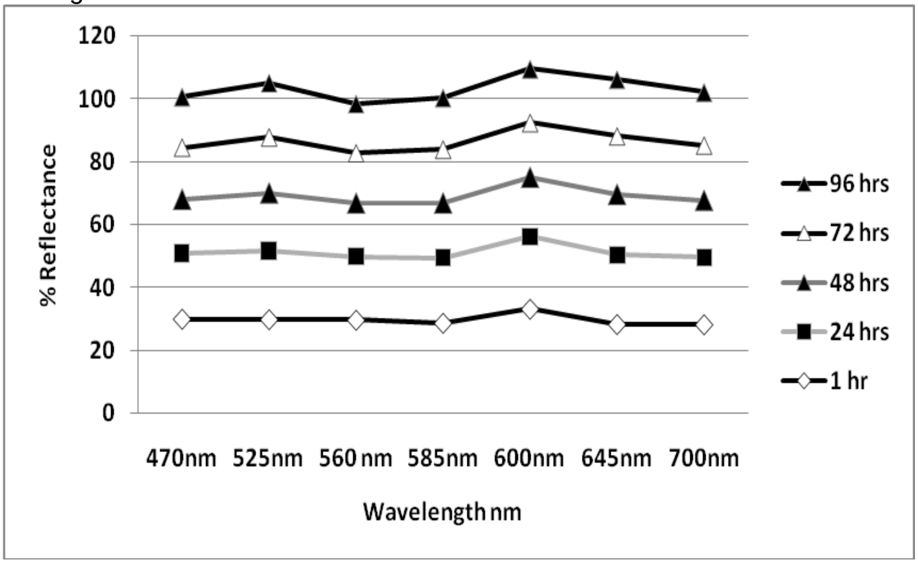

Figure 3: Soil reflectance in different wavelengths as affected by the time.

The effect of time period on water distribution

Figure (4) shows the volumetric water content distribution under the center pivot irrigation system as affected by either time; five different periods, one, 24, 48, 72 and 96 hours the distance from the center pivot. For the five different study periods the moister content in the middle distance point, 50 m, was highest compared to the nearestand farthest points; 0 and 100 m, from the center pivot. The effect of soil moisture on reflectance was summarized for each sample points by determining the best-fit coefficients of linearrelationship relating moisture and reflectance.

The relationship between the soil moisture and reflectance at different progress time

Figure (5) show the relationship between the soil moisture content and the light reflectance in different wavelengths (470 to 700 nm) and different time series, one hour to 96 hr. The data show that the reflectance values in the four studied wavelengths were linearly coordinated with the soil moister content after one hour. This relationship gradually disappeared with time progress till we reached 96 hr. Starting from 48 hrs the data showed that there is no correlation between reflectance values and the soil moisture content.

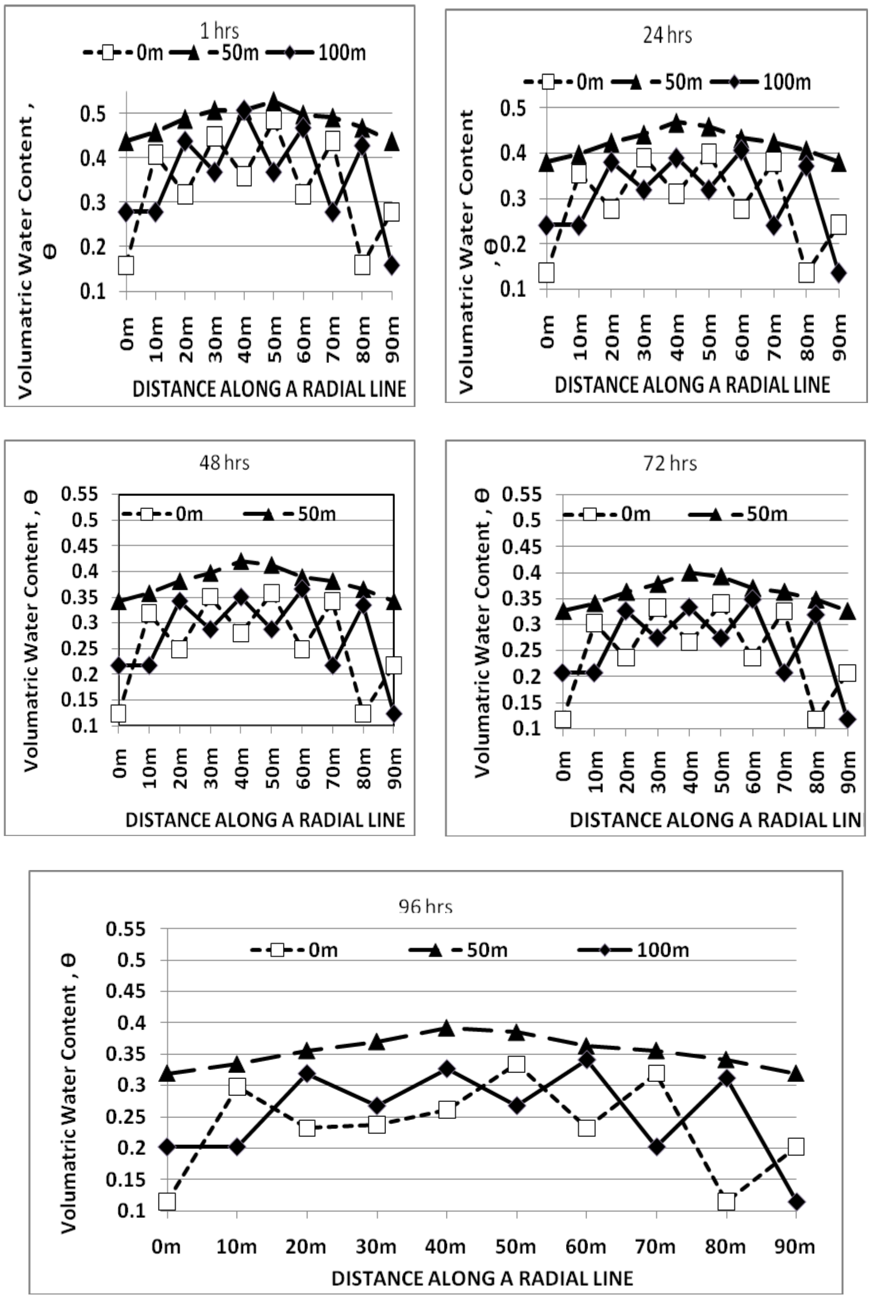

Fig.(4): Water distribution along a diameter of a center-pivot irrigation system with different time periods.

Data presented in Table (5) revealed that generally, for high soil moisture levels (short time periods, one hour) with the four selected wavelengths, the relative reflectance was strongly correlated with the soil moisture content. The highest correlation was found at higher soil moisture through the first one hour, between the reflectance values at 700 nm (Red-NIR) wavelength and the volumetric water content (R^2= 0.9). On the other hand, after one hour, the values of R^2 decreased with decreasing the wavelength from 700 nm to 470 nm. The same pattern was found after 24 hours with different R^2 values. The highest R^2 values (0.6) were found between % reflectance at 700 nm and the soil moister content. This high to moderate correlation inversed to a very weak correlation which reflected on the R^2 values under the other three times, 48, 72 and 96 hours as the liner relation did not represent that relation. These results revealed that with decreasing the soil moister content the reflectance becomes independent from the moister and affected by other soil components. These results are agreement with of Hillel (1998) mentioned that in visible wavelengths, the sole effect of water is in changing the relative refractivity at the soil particle surfaces.

Table 5: The correlation coefficients (R^2) and the linear equations for the relationship between the volumetric water content and % reflectance

Time	R^2	Equation
1 hr	0.7558	% reflectance at 470nm = 119.84 X - 23.124
	0.8246	% reflectance at 560nm = 122.96 X - 24.849
	0.8515	% reflectance at 600nm = 142.61 X - 30.013
	0.9001	% reflectance at 700nm = 100.5 X - 16.354
24 hrs	0.0371	% reflectance at 470nm = 13.426 X + 15.663
	0.2795	% reflectance at 560nm = 41.131 X + 1.9798
	0.474	% reflectance at 600nm = 55.736 X - 1.7173
	0.6597	% reflectance at 700nm = 45.88 X + 0.9741
48 hrs	0.1316	% reflectance at 470nm = 14.73 X + 11.058
	0.0039	% reflectance at 560nm = 3.3619 X + 15.561
	0.3582	% reflectance at 600nm = 25.153 X + 7.2439
	0.241	% reflectance at 700nm = 17.575 X + 10.496
72 hrs	0.014	% reflectance at 470nm = -7.7771 X + 18.96
	0.0297	% reflectance at 560nm = 6.827 X + 12.675
	0.0099	% reflectance at600nm = 4.1823 X + 15.389
	0.1078	% Reflectance at 700nm= 9.7053 X + 12.932
96 hrs	0.0383	% Reflectance at 470nm = -12.103 X+ 20.544
	0.0163	% Reflectance at 560nm = 6.3585 X + 12.768
	0.009	% Reflectance at 600nm = 3.9487 X + 15.052
	0.1303	% Reflectance at 700nm = 9.1656 X + 12.776

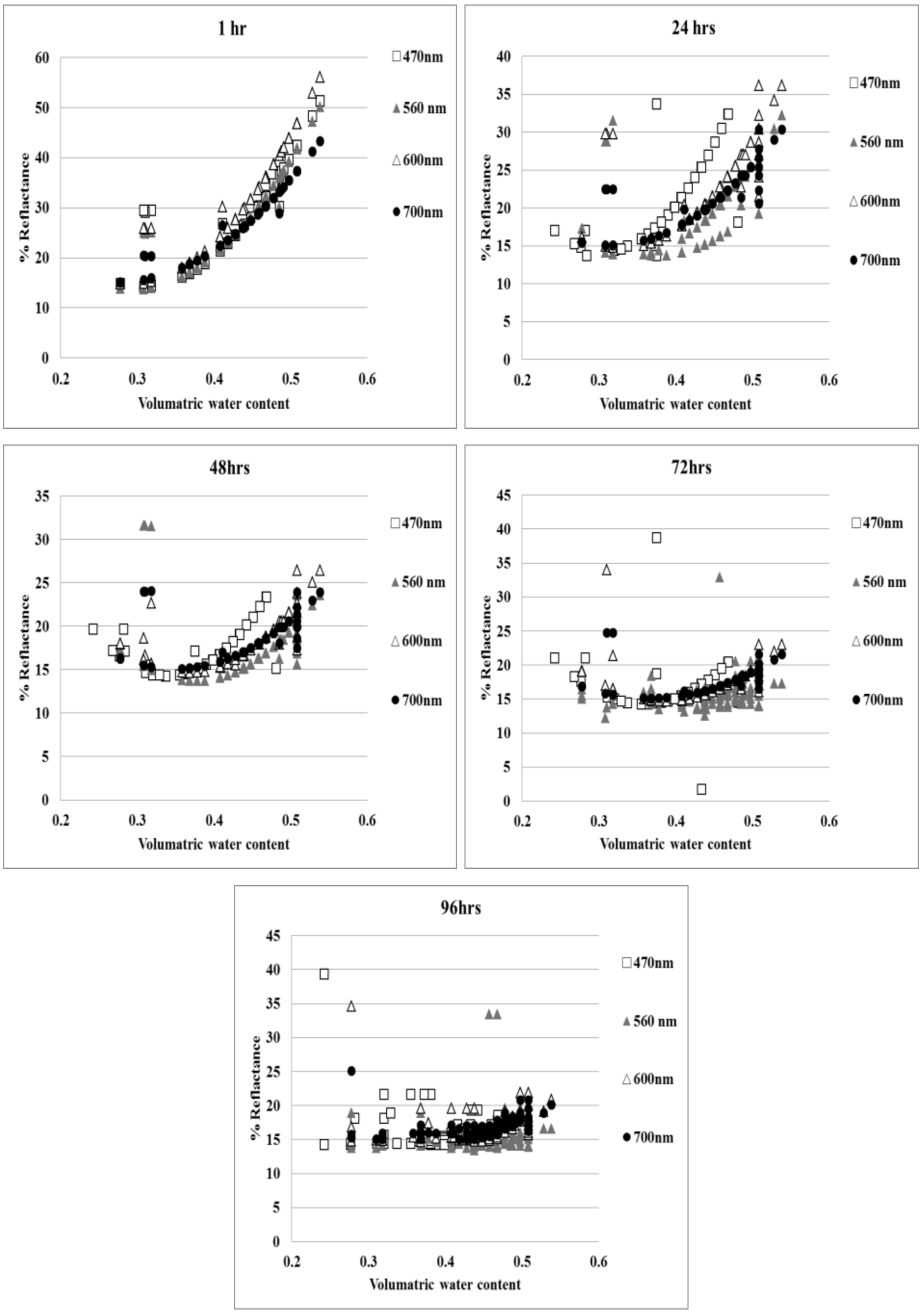

Fig. (5): The Relationship between soil volumetric water content (X) and the % reflectance in different wavelengths under the center pivot irrigation system.

CONCLUSION

This field study was carried out in the experimental farm of faculty of Agricultural, Ain Shams University monitor temporal and spatial changes in the field water application uniformities along radial and circular lines from center pivot system using spray nozzles and soil reflectance as a soil proceeded and determine the dependence of these changes on weave length . The study was started by measured physical and comical properties of the soil. Soil type was Sandy Clay Loamy (SCL) with pH ranged 7.6 to 7.7 and H.C from 0.26 to 0.28 .Chemical water analyses was shown as pH, EC and SHR were 7.3, 0.38, 1.52 respectively. The final results indicated that the relative reflectance was strongly correlated with soil moisture contents but it should be mention that with decreasing the soil moisture contents the reflectance becomes independence from it and affected by other soil components.

REFERENCES

Arafa, Y.E.H., 2010. On- farm irrigation water management under arid conditions; Current status and Future needs. Regional meetings of ICARDA, Sheraton, Cairo. Egypt.

Asner, G.P. (1998). Biophysical and biochemical sources of variability in canopy reflectance. Remote Sens. Environ. 64:134–153.

El-Raie, A.E.S and M.H. Abdel-Wahed, 2005 Comparison of some methods for estimating reference evapotranspiration under Egyptian conditions. Misr .J.Agric. Eng, 22(3):840-860.

El-Zakaziki, M. O.; A. M. El-Araby; E. A. El-Sahhar and Y. E. Arafa (2009). Changes of some soil physical and hydro physical characteristics in response to different sprinkler types and nozzle sizes, Arab. Union J., Agric. Sc., 17(2).

FAO, 2000 .Agriculture towards 2012 / 2030. Technical interim report, Rone, Haly, 244-247.

Foley, J.P. and S.R. Raine, (2001). Centre pivot and lateral move machines in the Australian cotton industry. National Centre for Engineering in Agriculture Publication 10000176/1, USQ, Toowoomba.

Hagag, A.A. and M.A Matter, 2005 . water economic return of wheat under pivot irrigation system. Misr .J.Agric .Eng., 22(1);161-181.

Hillel, D. 1998. Environnemental Soil physics. Academic Press, San Diego, CA.

Kaleita, A. L., L. F. Tina and M. C. Hirschi, (2005). Relation between soil moisture content and soil surface reflectance. Trans od ASABE, 48(2): 1975 – 1986.

Lobell, D.B. and G.P. Asner .2002.Moisture effects on Soil reflectance .Soil Sc. Soc Am.J., 66:722-727.

Lobell D. B. and Asner G. P. (2002). Moisture Effets on Soil Reflectance. Soil Sci. Soc. Am. J., 66: 722-727.

Njoku, E.G., and D. Entekhabi. (1996). Passive microwave remote sensing of soil moisture. J. Hydrol. 184:101–129.

Replogle, J., 2000. Flow measurements in irrigation at the end of millennium, 4th Decennial symp., Nov.14-16, phoenix, A7, USA, 338-343.

SADS2030, Sustainable Agricultural Development Strategy 2030, ministry of agriculture A.R. Egypt, 2009.

Skidmore, E.L., J.D. Dickerson, and H. Shimmelpfennig. (1975). Evaluating surface-soil water content by measuring reflectance. Soil Sci. Soc. Am. Proc. 39:238–242.

Thooyamani, K. P., D.I.Norum, and S. Dubetz. (1987). Application rates and uniformity under center-pivot sprinkler irrigation systems using spray nozzles. Can. Agric. Eng. 29: 149-154.

Ulaby, F.T., P.C. Dubois, and J.v. Zyl. (1996). Radar mapping of surface soil moisture. J. Hydrol. 184:57–84.

Wigencon, A. S., P. W. Gassman and Y. G. Arnold (2007). The soil and water assessment tools, ASABE, 50(4): 1221 – 1250.

إدارة الري من خلال نظام الري المحوري معتمدا علي تكنولوجيا الانعكاس الطيفي للتربة

محمد ياسر المرصفى , هشام فرج , حازم مهاود و خليل علام
معهد بحوث الهندسة الزراعية - مركز البحوث الزراعية – الدقى - جيزة

ان نظام الري المحوري لديه القدرة علي تغطية صافي العائد الاقتصادي لأنماط المحاصيل المختلفة ، على الرغم من ارتفاع تكلفة المدخلات الثابتة . لذا ، فان إدارة المياه تحت نظام ري محوري محدد يمكن أن تلعب دورا حاسما في تعظيم إنتاجية وحدة المياه و تعزيز استدامة الموارد الزراعية المادية .

ان الهدف من هذا البحث هو تقييم لنموذج الانعكاسي العام مستندا على نمط توزيع رطوبة التربة كمفتاح لإدارة الري تحت نظام الري المحوري . وقد كشفت البيانات أن ارتباط الانعكاس النسبي كان لة ارتباط قوي مع المحتوي الرطوبي للتربة . ومن ذلك ، تم الحصول على أفضل علاقة ارتباط لمستوى رطوبي عالي للتربة بين قيم انعكاس 700 نانومتر طول موجي و المحتوى المائي الحجمي

($R^2 = 0.9$) . وعلاوة على ذلك ، فإن نتائج هذه الدراسة تساعد في ايجاد علاقة قوية توضح العلاقة القوية في تأثير رطوبة التربة على الانعكاس والامتصاص للميزات الطيفي ، يساعد في تشغيل وإدارة نظم الري على مستوى المزرعة .