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MULTIPLE LINEAR REGRESSION (MLR) MODEL FOR PREDICTION POTENTIAL EVAPOTRANSPIRATION (ET0)

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ABSTRACT

Prediction Model for potential crop evapotranspiration (ETo) as dependent factor of three metrological stations extended along the Jordan Valley have been evaluated using multiple linear regression (MLR) model using Microsoft office excel. The observed ETo values used have been estimated by Penman Monteith equation. The average daily means meteorological data for period extended from 2001 till 2008 for DairAlla and Al Karama stations and from 2001 till 2006 for Sharhabeel station were used. The temperatures (T) (^{0}C), relative humidity percentage (RH), wind speed (U) ms^{-1} and solar radiation (RS) MJ s^{-1} as independent variables collected from metrological station. The MLR model was applied for each station to determine one equation for each station. Also, average mean daily climatic data for three stations for the period extended from 2001 till 2006 were used to abstract one representative MLR equation for Jordan Valley. The root mean square error (RMSE) for Al karama , Dair Alla, Sharhabeel and overall stations MLR equations were; 0.143, 0.126, 0.165and 0.131, respectively. A strong positive linear correlation between ET_0 with T and Rs and the coefficient of determination (R^2) are 0.82 and 0.953 respectively, and a weak positive linear correlation was found between ET_0 and U with R^2 value is 0.522, whereas a moderate negative linear correlation was found among ET_0 and RH with R^2 value is 0.725.

Keywords –*prediction mode, multiple linear regression (MLR), Potential evapotranspiration (ET0),*

INTRODUCTION

Jordan is located about 100 km from the south-eastern coast of the Mediterranean between latitudes 29º 11' - 33º 22' N and longitudes 34º 59'- 39º 12' E. with a total area of about 89 210 km² with 9.5 Million population, is one of the most water scarce countries in the world with annual per capita share of fresh water not exceeding 145 m^3 (Al-Bakri *et al*., 2013; DOS, 2016), and this amount is expected to decrease to 90 m^3 in 2025

(Jordan, 2009). This fresh water supply shortage is mitigated by the supplemental use of reclaimed municipal waste water of inferior quality. Subsequently, soils in the Northern and Middle Jordan Valley (JV) have become partially irrigated with the reclaimed wastewater. In the South, saline well water is the major irrigation water resource.

Jordan Valley is a lowlands located in the western part of the country starts at Lake Tiberias in the north to the Dead Sea in the south. JV is a part of Great Rift Valley that extends from Syria to the African horn. The annual rainfall varies from 350 mm in northern part to 35 mm in southern part (Shatanawi *et al*., 2014, Bani Hani and Shatanawi, 2011). However, it is where the bulk of the country's irrigated agricultural production occurs. Water is the most important environmental constrain determining agricultural productivity of fruit and vegetables in the Jordan Valley (Shatanawi *et al*., 2006). In 1962, a land reform program created thousands of small farms (3.5ha on average). The irrigated area in Jordan Valley is about 33,000 ha. The climate in Jordan Valley is typical arid, whereas rainfall occurred from November till April. Drip irrigation is already the common irrigation practice in the Jordan Valley (96% of farms) (Aken *et al*., 2007). The level of the Dead Sea falls each year by 0.85 meter due to extensive water use in the Jordan basin. Irrigated soils along the Jordan valley are showing signs of salinization since natural floods are no longer available to flush the irrigated land and leach salts (District 2450, 1997).

Soil formation is influenced by more than one parent material including recent alluvium occupying a narrow flood plain along the Jordan River and lacustrine (Lisan Marl) deposits overlaid by more than one layer of colluvial sediments transported as colluvial fans along the Eastern Escarpment edges. The moisture regime is Ustic in the north (N250 mm annual rainfall) and Aridic in the south. The temperature regime is Hyperthermic in the entire JV. Traditionally, the JV has been the principle fruit (mainly oranges and banana) and vegetable production basket of the country. A subtropical climate prevails in the JV with decreasing rainfall and increasing temperature in the southward direction. Such geographically-driven climate change evolved soils with decreasing pedogenic development in the same south ward direction. (Lucke *et. al*., 2013;Taimeh, 2014).

Hydrological parameters such as precipitation, evapotranspiration, soil moisture and ground water are likely to change with climate (Gleick, 1986) and the impact of climate change on evapotranspiration rate is important for hydrologic processes. Crop water requirements depend upon several climatic variables like rainfall, radiation, temperature, humidity and wind speed. Therefore, any change in climatic parameters due to global warming will also affect evapotranspiration (Allen *et al*., 1998; Goyal, 2004).

Evaporation estimation Models based on meteorological variable were evaluated by many studies (Chang *et. al*., 2010; Almedeij, 2012). The modified Penman Monteith equation is recommended as a standard method to calculated potential evapotranspiration (Allen *et al*., 1998). However, to generalize this equation derived

multiple linear model from variable metrological data (temperature, wind speed, relative humidity and/or solar radiation) needed to derive. Consequently, sometimes parameters are not available to determine potential evapotranspiration ET0 by Penman Monteith.

MATERIALS AND METHODS

Multiple Linear Regression (MLR) model was used to evaluate observed potential evapotranspiration (ET_0) calculated by Penman Monteith equation according to FAO 56 (Allen *et al*., 1998). The evaluation of observed (ET_0) as dependant variable and four mean daily climatic parameters namely; temperature in degree ^{0}C (T), relative humidity percentage (RH%), wind speed at two meter height (U) in m/s, and solar radiation (Rs) in MJ s^{-1}. The data were collected from three metrological stations along the Jordan Valley (JV) extends 110 km from Lake Tiberias (220 m below sea level) in the north to the Dead Sea (405 m below sea level) in the south (Fig. 1). Distribution of metrological stations was representative to different agroclimatic zone along Jordan Valley. The difference in agroclimatic zone was related to site pedology, crop types, soil texture, soil salinity, irrigation water quality and/or quantity of rainfall, since irrigation water quality and cropping pattern adhered to the variation in the JV agroclimatic zones. In the Northern JV citrus orchards irrigated with fresh water from the King Abdulla Canal, while reclaimed waste water or fresh water mixed with reclaimed wastewater irrigating green house vegetable crops was the focus in the Middle JV (e.g. high-tech and protected agriculture). Saline ground water irrigating date palm, banana orchards, and open field vegetables represented most of the farms in the South JV (Abu Sharar *et al*., 2014).

Studied metrological stations were; sharhabeel in north (altitude of (32° 06́ 12̋ N), and longitude of (35° 51́ ٠٧̋ E) at an elevation of 190 m below sea level), Dair Alla in middle, and Karama in south of Jordan Valley (a latitude 32°12'N and longitude 35°37'E). Metrological stations were constructed by National Center for Agricultural Research and Extension (NCARE) through Irrigation Management Information System (IMIS) which was supported by USDA/ARS. These stations serve an area cultivated with orchards, and nurseries. The Model was used for available average daily data from 2001 to 2008 for Dair Alla and Karama, whereas Sharhabeel from 2001 till 2006. Also, a determination of coefficient (R^2) and Pearson correlation (R) among the observed ET_0 value with T, RH, U and Rs were calculated. Root mean square errors (RMSE) for each MLR equation of each station and for all over stations were estimated between observed and calculated ET_0 (Maheda and Patel, 2015)

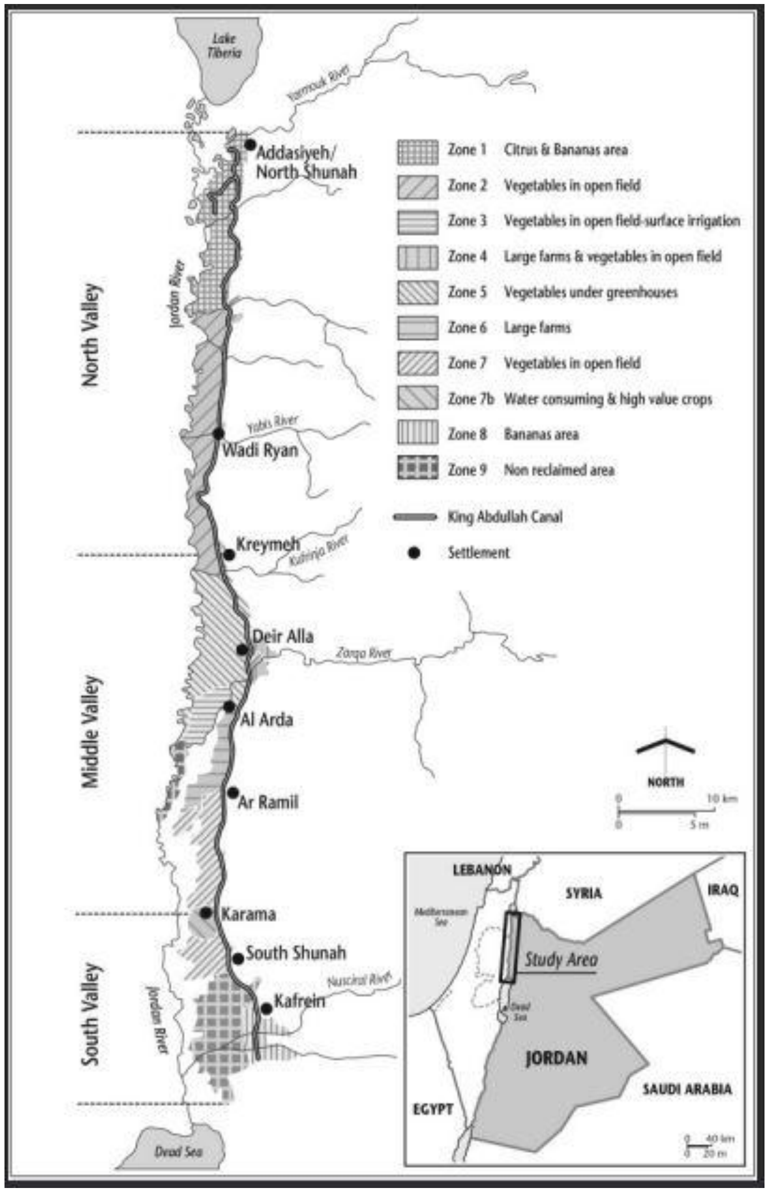

Fig. 1. **Jordan Valley Map**

RESULT AND DISCUSSION

Due to the high temperatures in the Jordan valley and the low values of relative humidity the evaporation force of the climate was very high. The potential evaporation in the north was around 2100 mm/yeat increasing to about 2400 mm/year at the shores of the Dead Sea in the south (Salameh, 2001). Annual rainfall did not exceed 350 mm and the average temperature was 15 ^{0}C in January and 30 ^{0}C in August. However, these figures are not fixed along the 110 km

Jordan Valley from north to south. In the extreme north where it was 2 to 3 km the valley width rain fall 350 mm and the ET_0 about 1230 mm whereas further south (middle Jordan Valley) the valley became more wide (5 km), the climate became more arid (rain fall 280 mm and the ET_0 about 1370 mm) (Philippie, 2004). A straight-line relationship existed between each independent variable (T, RH, U, and RS) and the dependent variable (ET_0), for each metrological station.

The mean, minimum average and maximum average daily temperature (T) overall three stations were; 23.3, 12.8, and 33 ^{0}C, respectively (Table 1), and a strong positive linear correlation between ET_0 with T with coefficient of determination (r^2) 0.820 (Table 2) were observed. The highest coefficient of determination value (between ET_0 and T) was obtained in Sharhabeel (0.830), whereas the lowest value occurs in Al-Karama (0.807) (Table 2).

The mean, minimum average and maximum solar daily radiation (Rs) overall three stations were; 18.8, 9.5, and 28.0 MJ s^{-1}, respectively (Table 1), also a strong positive linear correlation between ET_0 with Rs with coefficient of determination (r^2) 0.953 (Table 2). The highest coefficient of determination value was between ET_0 and Rs obtained in A-Karama (0.952), whereas the lowest value occurs in Sharhabeel (0.932) (Table 2).

The mean minimum average and maximum daily relative humidity (RH) overall three stations are; 50.7, 40.4, and 67.5 %, respectively and 6.47 standard deviation (Table 1), also a moderate positive linear correlation between ET_0 with RH with coefficient of determination (r^2) 0.725 (Table 2). The highest coefficient of determination values between ET_0 and RH was obtained in Al-Karama and Shahabeel (0.750, 0.749, respectively), whereas the lowest value occured in Dair Alla(0.599) (Table 2).

The mean, minimum average and maximum daily wind speed (U) overall three stations are; 1.4, 1.0, and 1.9 m s^{-1} respectively (Table 1), also a moderate positive linear correlation between ET_0 with U with coefficient of determination (r^2) 0.522 (Table 2). The highest coefficient of determination values was between ET_0 and U obtained in Sharhabeel (0.673), whereas the lowest value occured in Dair Alla (0.075) (Table 2).

The mean, minimum average and maximum daily measured potential evapotranspiration (ET_0) overall three stations are; 4.32, 1.5, and 7.1 mm day^{-1} respectively and 1.86 standard deviation (Table 1).

Reference evapotranspiration (ETo) is an essential component of irrigation water management as a basic input for estimating crop water requirements. Multiple approaches have been identified for ETo assessment but most of them were based on daily meteorological data provided by weather station networks that provide an accurate meteorological characterization (Cruz, 2014).

Table (1): **Descriptive statistics for daily climatic parameters for studied metrological stations for periods extended from 2001 to 2008.**

	Tair	RH	U	Rs	ETo
Al-Karama					
Mean	23.9	47.3	1.15	19.23	4.04
Max	33.8	65.1	1.70	28.7	6.7
Min	12.7	35.6	0.80	9.5	1.4
St.dev	6.8	6.81	0.18	6.03	1.76
Dair Alla					
Mean	24.3	48.40	1.94	17.5	4.9
Max	33.3	68.3	2.60	27.1	7.8
Min	13.8	37.7	1.30	7.4	1.6
St.dev	6.22	6.34	0.21	6.39	1.87
Sharhabeel					
Mean	21.84	56.35	1.22	19.58	4.03
Max	32.3	73.6	2.00	29.4	7.1
Min	11.0	45.2	0.40	9.5	1.1
St.dev	6.90	6.83	0.34	6.08	1.96
Overall stations					
Mean	23.3	50.70	1.44	18.77	4.32
Max	33.0	67.5	1.90	28.0	7.1
Min	12.8	40.4	1.00	9.0	1.5
St.dev	6.64	6.47	0.20	6.15	1.86

Table (2): **Person correlation (r) and determination coefficient (r2) values, for ET0 with T, RH%, U and RS for studied metrological stations.**

	Pearson Correlation (R)			
	Al- Karamah	Dair Alla	Sharhabeel	Overall stations
	ET_0			
T	0.898	0.901	0.911	0.906
RH	-0.866	-0.774	-0.866	-0.852
U	0.646	0.274	0.820	0.723
Rs	0.975	0.969	0.965	0.976
	Coefficient of Determination (r^2)			
T	0.807	0.812	0.830	0.820
RH%	0.750	0.599	0.749	0.725
U	0.417	0.075	0.673	0.522
Rs	0.952	0.940	0.932	0.953

Obtaining PM–ET_o in the absence on of metrological data parameters (Rs, T, RH and U) led to develop was approach including the use of generated weather data (Stöckle *et al*., 2004, Pereira *et al*., 2015) and, more often, replacement equations to the FAO–PM based on multiple regression analyses (El-Shafie *et al*., 2013). The agricultural researchers and extension agents can use assessed value of potential evapotranspiration in the same agricultural and metrological zone by using MLR equations.

Multiple linear regressions models using mean average daily metrological data were used to derive linear generic equations with ET_o, (Cristea, 212): B0+B1*T+B2*RH+B3*U+B4*Rs

MLM equations were built to predict daily reference evapotranspiration for each site in Jordan Valley and for all over Jordan Valley for data from three metrological stations (Espino et al., 2016).

Minimum root mean squared error (RMSE) and maximum correlation coefficient (R^2) were calculated for MLR equation. The root mean square error (RMSE) for karama, Dair Alla, Sharhabee and overall stations MLR equations were; 0.143, 0.126, 0.165 and 0.131, respectively. The R^2 were; 0.993, 0.995, 0.993 and 0.987 for Al Karama, Dair Alla, Sharhabeel and overall stations, respectively (Table 3) the same result was obtained by Kisi and Guven (2010), Perugu *et al.* (2013) and Sriram and Rashmi (2014) .

Stan *et al*. (2016) found multiple linear regressions by considering all meteorological parameters (air, relative humidity, moisture deficit, wind speed, precipitations and water temperature) with coefficient of determination of 0.86 in May for the aquatic plants evapotranspiration.

Table (3) Multiple Linear regression (LR) models

Metrological station	Regression equation	R^2	RMSE
Karam	$ET_0 = -3.253 + 0.098\ T_m + 0.005\ RH + 1.165\ U_2 + 0.177\ Rs$	0.993	0.143
Dair Alla	$ET_0 = -2.750 + 0.117\ T_m - 0.009\ RH + 1.112\ U_2 + 0.176\ Rs$	0.995	0.126
Sharhabeel	$ET_0 = -3.954 + 0.112\ T_m - 0.014\ RH + 1.044\ U_2 + 0.177\ Rs$	0.993	0.165
Over all station	$ET_0 = -3.240 +0.108\ T_m + 0.002\ RH + 1.155\ U_2 + 0.174\ Rs$	0.987	0.131

Accurate estimation of reference evapotranspiration (ET_0) is importance for many studies such as hydrologic water balance, irrigation system design and management, crop yield simulation, and water resources planning and management. Simple regression techniques sometimes provide adequate estimation of ET_0. The linear regression models developed in certain region can be applied in the region with similar climatic conditions for ET_0 estimation (Perugu *et al*., 2013). The potential to make such predictions is crucial in optimizing water resources management.

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نموذج الانحدار الخطي المتعدد (MLR) للتنبؤ بالتبخر المحتمل (ET_0)

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الملخص العربي:

تعتمد الدراسه على نموذج رياضي للتنبؤ بكمية التبخر المحصولي المحتمل كعامل معتمد وذلك بحسابه من معادلة بنمان مونتيث لثلاث محطات رصد للمعلومات المناخية ممتدة على طول وادي الاردن، وهي شرحبيل في الشمال وديرعلا في الوسط والكرامه في الجنوب حيث أتبع اسلوب نموذج الانحدار الخطي الرياضي المتعدد المتغيرات باستخدام برنامج ميكروسوفت أوفيس إكسل. حيث تم استخدام معدل المتوسط اليومي لبيانات الأرصاد الجوية (متوسطات درجة الحرارة والرياح والرطوبه النسبية والسطوع الشمسي) للفترة الممتدة من ٢٠٠١ حتى ٢٠٠٨ لمحطتي دير علا والكرامة ولمحطة شرحبيل للفترة الممتدة من ٢٠٠١ حتى ٢٠٠٦ كعوامل مستقله في معادلة الانحدار الخطي متعددة المتغيرات في عملية الحساب ، وتم تطبيق النموذج الرياضي الخطي لكل محطة على حده للخروج بمعادلة خطية متعددة المتغيرات تمثلها، كما تم أخذ المتوسطات لقياسات الطقس اعلاه للمحطات الثلاث للخروج بمعادلة خطية واحدة متعددة المتغيرات لتمثل وادي الاردن للفتره الممتده من ٢٠٠١ الى ٢٠٠٦.

بلغ متوسط الجذر التربيعي للخطأ للمعادلة الخطية المتعددة المتغيرات لكل محطة من محطات الكرامه وديرعلا وشرحبيل ولكل المحطات مجتمعة ٠.١٤٣ ، ٠.١٢٦ ، ٠.١٦٥ و ٠.١٣١ على التوالي. وجد ارتباط خطي قوي موجب بين التبخر الناتج وكل من متوسط درجة الحرارة والسطوع الشمسي حيث بلغ كل منهما ٠.٨٢ و ٠.٩٥٣ على التوالي، كما وجد هناك ارتباط خطي ضعيف موجب بين التبخر الناتج وسرعة الرياح بلغت قيمته ٠.٥٢٢، بينما كان هناك ارتباط خطي سلبي متوسط بين التبخر الناتج والرطوبه النسبيه حيث بلغت قيمته ٠.٧٢٥.

الكلمات المفتاحية : *نموذج التنبؤ، الانحدار الخطي المتعدد (MLR)، التبخر المحتمل للنتح (ET_0)،*