USING BISM MODEL TO CALCULATE WATER REQUIREMENTS FOR SOME VEGETABLE CROPS IN EGYPT

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ABSTRACT

Agriculture water demand is one of the serious pressures on water sector in Egypt, since 85% of total available water is consumed in agriculture and most of the on-farm irrigation systems are low efficient coupled with poor irrigation management. The objective of this paper is to calculate water requirements for 12 vegetable crops grown in 17 Governorates in Egypt. These crops were cabbage, celery (winter and summer), spinach, potates (winter and summer), carrot (winter and summer), cucumber (winter and summer), pepper (winter and summer), strawberry, eggplant (winter and summer), tomato (winter and summer), sweet melon and artichoke. BISm model was used to calculate evapotranspiration, crop factor and crop evapotranspiration for each crop in each Governorate. The BISm application calculates ET using the Penman-Monteith equation, water requirement for each crop was calculated under surface irrigation with application efficiency 60%. The results showed that using BISm to calculate water requirements of some vegetable crops in Egypt were low values in the Nile Delta Governorates, in the other hand, its started to increase as we go to south (Middle and Upper Egypt), these results could be useful for farmers, extension workers and large farms produce vegetables for export. Large applied amount of irrigation water to vegetables could negatively affect quality. Thus, it is very important to calculate water requirements for important crops, such as vegetable crops.

INTRODUCTION

Agriculture water demand is one of the serious pressures on water sector in Egypt, since 85% of total available water is consumed in agriculture and most of the on-farm irrigation systems are low efficient coupled with poor irrigation management (Abou Zeid, 2002). Irrigation water management becomes increasingly important in the presence of low water supplies and expected future climate change.

The term crop water requirement is defined as the amount of water required to compensate the evapotranspiration loss from the cropped field (USDA, 1993). ICID (2000) describes it as the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield. Crop water requirements vary during the growing period, mainly due to variation in crop canopy and climatic conditions, which related to both cropping technique and irrigation methods.

Underestimation or overestimation of crop water consumption can be prevented by knowledge of the exact water loss through actual evapotranspiration (ET) for water management.

Various equations are available for estimating ET. These equations range from the most complex energy balance equations requiring detailed climatological data (Penman-Monteith; Allen *et al.,* 1989) to simpler equations requiring limited data (Blaney-Criddle, 1950; Hargreaves-Samani, 1982, 1985). The Penman-Monteith equation (P-M) is widely recommended because of its detailed theoretical base and its accommodation of small time periods. The method requires maximum and minimum temperature, relative humidity, wind speed and potential sunshine hours (Allen *et al.,* 1989). The most known and used technique to estimate crop evapotranspiration (ETc) is the one based on the kc approach (Allen *et al.,* 1998), where the ETc is calculated by using standardagro-meteorological variable and a crop-specific coefficient, the crop coefficient (kc), which should take into account the relationship between atmosphere, crop physiology and agricultural practices (Lascano 2000). The main factors affecting the difference between ETc and ET are (1) light absorption by the canopy, (2) canopy roughness, which affects turbulence, (3) crop physiology, (4) leaf age, and (5) surface wetness (Snyder *et al.,* 2004). Many models were developed to be use in irrigation scheduling, such as CROPWAT (Smith 1991) and BISm (Snyder *et al.*, 2004). BISm is the easiest and accurate because it is a spread sheet. The model calculates ET, kc, water depletion from root zone and irrigation schedule. The model was used to reschedule irrigation for maize under current climate and under climate change scenario (Abdrabbo *et al.*, 2013). Furthermore, the model was used for wheat to save in the applied irrigation water and increase water productivity (Ouda *et al.*, 2012).

Vegetable crops are playing a significant role not only in the Egyptian economy, but also occupy an important economic position in the Egyptian agriculture in terms of its income contribution. Vegetable crops represent the major component of food consumption in Egypt, because of its nutritions values. Most of the vegetable crops are cultivated twice a year. Furthermore, these crops consume a lot of irrigation water; as a result of improper water management. Thus, it is important to determine water requirements for vegetable crops for research purposes, as well as economic and political purposes. The objective of this paper is to calculate water requirements for 12 vegetable crops grown in 17 Governorates in Egypt.

MATERIALS AND METHODS

The studied area:

The studied area is composed of 17 Governorates in the Nile Delta and Valley in Egypt (described in the introduction section). These Governorates were: Alexandria (latitude 31.70°, longitude 29.00° and elevation 7.00 m), Demiatte (latitude 31.25°, longitude 31.49° and elevation 5.00 m), Kafr El-Sheik (latitude 31.07°, longitude 30.57° and elevation 20.00 m), El-Dakahlia (Latitude 31.03°, longitude 31.23° and elevation 7.00 m), El-Behira (latitude 31.02°, longitude 30.28° and elevation 6.70 m), El-Gharbia (latitude 30.47°, longitude 32.14° and elevation 14.80 m), El-Monofia (latitude 30.36°, longitude 31.01° and elevation 17.90 m), El-Sharkia (latitude 30.35°, longitude 31.30° and elevation 13.00 m), El-Kalubia (latitude 30.28° , long 31.11° and elevation 14.00 m), El-Giza (latitude 30.02°, longitude 31.13° and elevation 22.50 m), El-Fayoum (latitude 29.18°, longitude 30.51° and elevation 30.00 m), Beni Sweif (latitude 29.04°, longitude 31.06° and elevation 30.40 m), El-Minia (latitude 28.05°, longitude 30.44° and elevation 40.00 m), Assuit (latitude 27.11°, longitude 31.06° and elevation 71.00 m) Sohag (latitude 26.36°, longitude 31.38° and elevation 68.70 m), Qena (latitude 26.10°, longitude 32.43° and elevation 72.60 m) and Aswan (latitude 24.02°, longitude 32.53° and elevation 108.30 m). Figure (1) showed the map of Nile Delta and Valley Governorates.

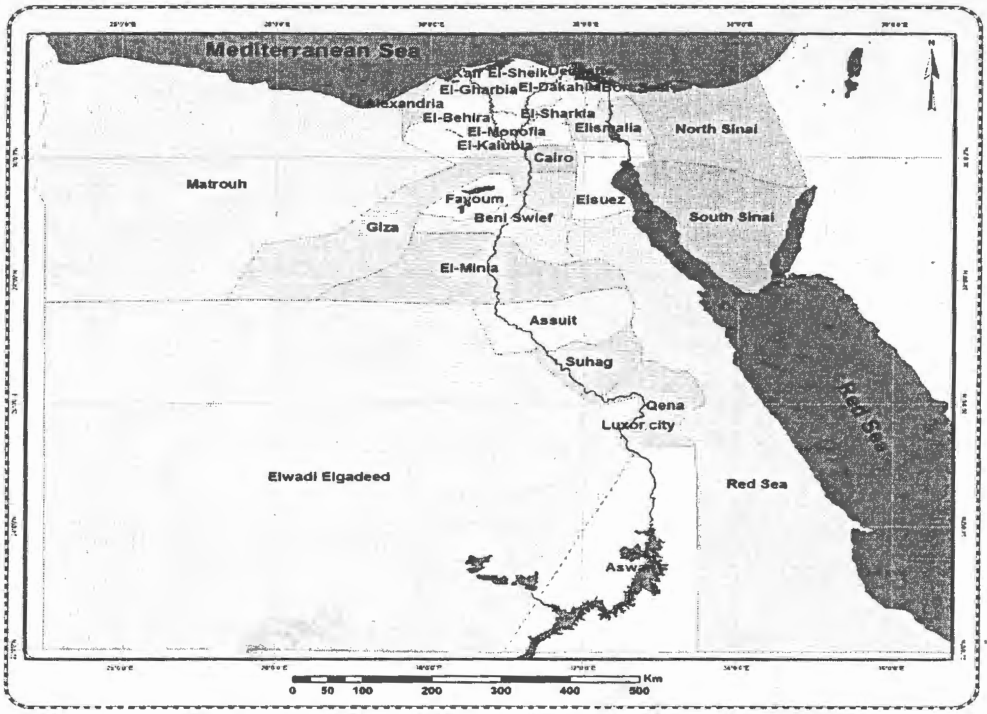

Figure (1): Map of Nile Delta and valley of Egypt.

Selected Crops:

Twelve vegetable crops were studied. These crops were cabbage, celery (winter and summer), spinach, potateses (winter and summer), carrot (winter and summer), cucumber (winter and summer), pepper (winter and summer), strawberry, eggplant (winter and summer), tomato (winter and summer), sweet melon and artichoke.

BISm model description:

The Basic Irrigation Scheduling application (BISm) was written using MS Excel to help people plan irrigation management of crops. The BISm application calculates ET using the Penman-Monteith (P-M) equation (Monteith, 1965) as presented in the United Nations FAO Irrigation and Drainage Paper (FAO, 56) by Allen et al., (1998). If only temperature data are input, Hargreaves-Samani equation is used (Snyder et al., 2004). For the ET calculations, the station latitude and elevation must also be input. After calculating daily means by month, a cubic spline curve fitting subroutine is used to estimate daily ET rates for the entire year.

Calculation methodology:

Monthly ET values as an average over 10 years, from 2004 to 2013 for each Governorate were calculated by the model. Sowing and harvest date for each crop (Table 1) was used to BISm model. Planting and harvest dates were obtained from (Ainer *et al.,* 1999).

Table (1) Planting and harvest date for the studied crop in Egypt.

	Nile Delta		Middle and Upper Egypt	
	Planting date	**Harvest date**	**Planting date**	**Harvest date**
Cabbage	01-Sep	01-Feb	15-Aug	15-Jan
Celery W	01-Oct	01-Mar	-	-
Celery S	01-Feb	01-Jul	-	-
Spinach	01-Sep	10-Nov	15-Aug	25-Oct
Potates W	01-Sep	01-Jan	15-Sep	15-Jan
Potates S	01-Feb	10-Jun	01-Feb	01-Jun
Carrots W	01-Oct	10-Feb	01-Oct	10-Feb
Carrots S	01-Mar	01-Jul	01-Mar	01-Jul
Cucumber W	01-Oct	15-Dec	--	--
Cucumber N	01-Jul	15-Sep	01-Jul	15-Sep
Peppers W	01-Oct	01-Mar	01-Oct	01-Mar
Peppers S	01-Apr	01-Sep	01-Apr	01-Sep
Strawberry	01-Sep	01-May	-	-
Eggplant W	01-Oct	01-May	01-Oct	01-May
Eggplant S	01-May	01-Dec	01-May	01-Dec
Tomato W	01-Sep	01-Feb	15-Aug	15-Jan
Tomato S	01-Mar	01-Aug	15-Feb	15-Jul
Sweet melon	01-Mar	01-Jul	01-Mar	01-Jul
Artichoke	01-Sep	01-Mar	01-Sep	01-Mar

W= winter; N= Nili; S= summer.

The model calculated growth stage length and crop factor (kc) for each growth stage of the studied crops according to planting and harvest date in Nile Delta, Middle Egypt and Upper Egypt. The model also account for water depletion from root zone. Therefore, it requires to input total water holding capacity and available water (Table 2). These values were obtained from previous research done in Water Requirements and Field irrigation Research Department, Soils, Water and Environment Research Institute, Agricultural Research Center, Egypt.

Application efficiency was assumed to be 60% for surface irrigation. The model calculated total water requirements for each crop.

Table (2): Soil water holding capacity and available water prevailed in each Governorate.

Governorate	Water holding capacity (m/m)	Available water (m/m)
Nile Delta		
Alexandria	0.373	0.206
Demiatte	0.376	0.222
Kafr El-Sheik	0.405	0.170
El-Dakahlia	0.395	0.196
El-Beheira	0.408	0.230
El-Gharbia	0.380	0.220
El-Monofia	0.418	0.232
El-Sharkia	0.420	0.210
El-Kalubia	0.400	0.218
Middle Egypt		
Giza	0.363	0.209
Fayoum	0.426	0.194
Beni Sweif	0.429	0.245
El-Minia	0.435	0.239
Upper Egypt		
Assuit	0.438	0.235
Sohag	0.446	0.244
Qena	0.454	0.293
Aswan	0.447	0.257

RESULTS AND DISCUSSION

Crop coefficients (K_C):

The BISm model predicted growth stages length, as well as the values of kc for each growth stage of each crop in the Nile Delta are presented in Table (3). As a result of different season length for each crop, the length of each growth stage was different between on crop to another.

Snyder *et al.,* (2004) stated that crop coefficients account for the difference between the crop evapotranspiration (ET_C) and ET. While reference crop evapotranspiration accounts for variations in weather and offers a measure of the "evaporative demand" of the atmosphere, The crop coefficient (K_C) takes into account the relationship between atmosphere, crop physiology and agricultural practices (Lascano, 2000). Therefore, crop coefficients for field and row crops generally increase until the canopy ground cover reaches about 75% and the light interception is near 80% (Snyder *et al.,* 2007). Thus, the accurate calculation of crop kc for each growth stage is an important component for accurate calculation of water requirements (Shideed *et al.,* 1995).

Table (3): Growth stage length (day)and crop factor (K_C) for selected vegetable crops in the Nile Delta.

Crop	Growth stage length (day)				kc for growth stage			
	A-B	B-C	C-D	D-E	A-B	B-C	C-D	D-E
Cabbage	38	59	34	18	0.26	1.00	1.00	0.85
Celery W	22	38	76	15	0.35	0.95	0.95	0.95
Celery S	22	38	75	15	0.46	0.95	0.95	0.95
Spinach	23	24	18	5	0.27	0.95	0.95	0.90
Potates N	24	31	40	27	0.25	1.10	1.10	0.70
potates S	24	30	40	35	0.46	1.10	1.10	0.70
Carrots W	26	40	44	22	0.30	0.95	0.95	0.80
Carrots S	24	37	41	20	0.40	0.95	0.95	0.80
Cucumber W	14	21	29	11	0.26	0.85	0.85	0.85
Cucumber N	14	22	29	11	0.24	0.85	0.85	0.85
Peppers W	30	38	61	22	0.27	1.00	1.00	0.85
Peppers S	30	39	61	23	0.29	1.00	1.00	0.85
Strawberry	36	73	85	48	0.28	0.70	0.70	0.70
Eggplant W	48	67	66	31	0.32	0.90	0.90	0.85
Eggplant S	49	67	66	32	0.30	0.90	0.90	0.85
Tomato W	38	39	46	30	0.26	1.10	1.10	0.65
Tomato S	38	39	46	30	0.38	1.10	1.10	0.65
Sweet melon	25	36	41	20	0.39	0.95	0.95	0.75
Artichoke	10	24	119	18	0.22	0.65	0.65	0.65

Earlier sowing date in Middle and Upper Egypt, as well as different weather conditions, compared to Nile Delta reflected on growth stages length and K_C for each growth stage of each vegetable crop (Table 4). Therefore, sowing date, which reflects the weather of a certain site, could affect the growth pattern of the crop and consequently affects the period of growth stages and the value of kc.

Table (4): Growth stage length day and crop factor (K_C) for selected vegetable crops in Middle and Upper Egypt.

Crop	Growth stage length				kc for growth stage			
	A-B	B-C	C-D	D-E	A-B	B-C	C-D	D-E
Cabbage	38	59	38	18	0.23	1.00	1.00	0.85
Carrots W	26	40	44	22	0.29	0.95	0.95	0.80
Carrots S	24	37	41	20	0.36	0.95	0.95	0.80
Spinach	23	25	18	5	0.24	0.95	0.95	0.90
Potates S	24	30	40	26	0.44	1.10	1.10	0.70
potates N	24	31	40	26	0.26	1.10	1.10	0.70
Carrots W	26	40	44	22	0.29	0.95	0.95	0.80
Carrots S	24	37	41	20	0.36	0.95	0.95	0.80
Cucumber N	14	22	29	11	0.23	0.85	0.85	0.85
Peppers W	30	38	61	22	0.26	1.00	1.00	0.85
Peppers S	30	39	61	23	0.28	1.00	1.00	0.85
Eggplant W	48	58	66	31	0.31	0.90	0.90	0.85
Eggplant S	49	67	66	32	0.27	0.90	0.90	0.85
Tomato W	38	39	46	30	0.23	1.10	1.10	0.65
Tomato S	37	38	45	30	0.38	1.10	1.10	0.65
Sweet melon	25	36	41	20	0.36	0.95	0.95	0.75
Artichoke W	10	24	129	18	0.21	0.65	0.65	0.65

As a crop canopy develops, the ratio of transpiration (T) to ET increases until most of the ET comes from T and evaporation is a minor component. This occurs because the light interception by the foliage increases until most light is intercepted before it reaches the soil (Snyder *et al.*, 2004).

Water requirements :

Table (5) showed water requirements for cabbage, celery (winter and summer) and spinach. The results showed that water requirements for these crops were low in the north Nile Delta Governorates. It started to increase as we go to south Nile Delta. The highest water requirements were found in south of Egypt, especially in Aswan.

Although the values for crop evapotranspiration and crop water requirements are identical. Crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration (Allen *et al.,* 1998). Furthermore, in estimating crop water requirements, efficiency of the irrigation system should be taken into account.

Table (5): Water requirements(m^3/fed) for some vegetable crops grown in Egypt

Governorate	Cabbage	Celery (winter)	Celery (summer)	Spinach
Nile Delta				
Alexandria	1572	2383	3918	1373
Demiatte	1566	2111	3910	1323
Kafr El-Sheik	1603	3133	3313	1371
El-Dakahlia	1699	3299	4137	1419
El-Behira	1779	3315	4365	1499
El-Gharbia	1725	3992	4077	2159
El-Monofia	1741	4045	4845	1460
El-Sharkia	1830	4308	5328	1554
El-Kalubia	1940	4965	5002	1620
Middle Egypt				
Giza	1958	-	-	2626
Fayoum	2006	-	-	2656
Beni Swief	2092	-	-	2726
El-Minia	1957	4447	-	2609
Upper Egypt				
Assuit	2397	-	-	3185
Sohag	2171	5001	-	2808
Qena	2317	5483	-	3044
Aswan	3086	7541	-	3816

Regarding to potates and carrot, similar trend was observed (Table 6).

The highest water requirements were obtained in Aswan Governorate for both crops in the summer season, compared to winter season.

Table (6): Water requirements(m^3/fed) for some vegetable crops grown in Egypt

Governorate	Potates (winter)	Potates (summer)	Carrot (winter)	Carrot (summer)
Nile Delta				
Alexandria	2388	3521	1692	3108
Demiatte	2363	3503	1395	3158
Kafr El-Sheik	2402	3577	1427	3210
El-Dakahlia	2474	3783	1525	3415
El-Behira	2688	3874	1626	3476
El-Gharbia	2589	3904	1594	3483
El-Monofia	2594	3955	1591	3603
El-Sharkia	2799	4135	1689	3685
El-Kalubia	2881	4763	1683	3697
Middle Egypt				
Giza	2328	4011	1510	3524
Fayoum	2361	4038	1501	3673
Beni Swief	2464	4112	1574	3656
El-Minia	1964	3932	1464	3546
Upper Egypt				
Assuit	2941	4771	1846	3800
Sohag	2196	4266	1612	3772
Qena	2385	4681	1758	3730
Aswan	3328	5815	2381	4689

Results in Table (7) revealed water requirements for summer cucumber and summer pepper was higher, compared to its values for it when it was cultivated in winter. Furthermore, strawberry is only cultivated the Nile Delta Governorates.

Table (7): Water requirements (m^3/fed)for some vegetable crops grown in Egypt

Governorate	Cucumber (winter)	Cucumber (summer)	Pepper (winter)	Pepper (summer)	Strawberry
Nile Delta					
Alexandria	953	2135	3523	3814	2984
Demiatte	950	2014	1944	4701	2882
Kafr El-Sheik	964	2012	3802	4666	2971
El-Dakahlia	994	2177	4244	5035	3137
El-Behira	1088	2198	4524	4835	3296
El-Gharbia	1039	2186	4359	5107	3238
El-Monofia	1043	2263	4396	5317	3286
El-Sharkia	1130	2321	4643	5436	3436
El-Kalubia	1199	2326	3934	4874	3432
Middle Egypt					
Giza	-	2240	4215	5203	-
Fayoum	-	2235	4255	5298	-
Beni Swief	-	2186	4369	5318	-
El-Minia	-	2146	4118	5101	-
Upper Egypt					
Assuit	-	2597	5429	6063	-
Sohag	-	2197	4510	5333	-
Qena	-	2473	4934	5769	-
Aswan	-	3078	6607	7014	-

Similarly, water requirements for summer crop was found to be higher than its counterpart of winter crop, such as eggplant and tomato (Table 8)

Table (8): Water requirements(m^3/fed) for some vegetable crops grown in Egypt

Governorate	Eggplant (winter)	Eggplant (summer)	Tomato (winter)	Tomato (summer)	Sweet melon	Artichoke
Nile Delta						
Alexandria	3051	4735	2124	5010	3088	2122
Demiatte	3006	4559	2120	5025	3155	2090
Kafr El-Sheik	3039	4571	2160	5055	3207	2119
El-Dakahlia	3256	4809	2287	5410	3412	2255
El-Behira	3414	4985	2434	5531	3484	2416
El-Gharbia	3357	4921	2341	5515	3490	2339
El-Monofia	3398	5035	2363	5718	3601	2341
El-Sharkia	3580	5234	2525	5854	3682	2507
El-Kalubia	3925	4937	2550	5906	3976	2677
Middle Egypt						
Giza	3383	4980	2841	5325	3522	2018
Fayoum	3359	4994	2915	5497	3651	2288
Beni Swief	3493	5089	3038	5525	3654	2394
El-Minia	3291	4888	2863	5303	3524	-
Upper Egypt						
Assuit	4188	5857	3574	6292	4073	-
Sohag	3605	5120	3182	5683	3769	-
Qena	4070	5643	3420	6076	3944	-
Aswan	5367	7021	4545	7384	4685	-

Conclusion:

In semiarid region, where Egypt is located, more pressure will be existed on water resources distribution between economic sectors as a result of water scarcity, especially agriculture. The results presented in this paper could be useful for farmers, extension workers and large farms produce vegetables for export. Large applied amount of irrigation water to vegetables could negatively affect quality. Thus, it is very important to calculate water requirements for important crops, such as vegetable crops.

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إستخدام نموذج BISm لحساب الاحتياجات المائيه لبعض محاصيل الخضر في مصر

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قسم بحوث المقننات المائيه والرى الحقلى– معهد بحوث الاراضى والمياه والبيئه – مركز البحوث الزراعيه

يعتبر الطلب على المياه فى الزراعة من اهم الضغوط على قطاع المياه في مصر، حيث يتم استهلاك ٨٥٪ من إجمالي المياه المتوفرة في الزراعة، ومعظم أنظمة الري على مستوى المزرعة كفاءتها منخفضة بالإضافة الى سوء إدارة الري، ويهدف هذا البحث الى حساب الاحتياجات المائية لعدد ١٢ محصول خضر تزرع في ١٧ محافظة في مصر.

وكانت هذه المحاصيل هى الكرنب والكرفس (شتوي وصيفي)، والسبانخ، والبطاطس (صيفي وشتوي) والجزر (شتوي وصيفي)، والخيار (شتوي وصيفي) والفلفل (شتوي وصيفي)، الفراولة، والباذنجان (شتوي وصيفي) والطماطم (شتوي وصيفي)، الشمام والخرشوف حيث تم استخدام نموذج BISm لحساب البخر نتح، معامل المحصول لكل محصول في كل محافظة. وتم حساب الاحتياجات المائية لكل محصول تحت نظام الري السطحي مع كفاءة رى ٦٠٪.

كذلك وتشير نتائج هذا البحث الي أن استخدام النموذج BISm لحساب الاحتياجات المائية لبعض محاصيل الخضر في مصر أعطي قيما منخفضة لهذه المحاصيل في منطقة الدلتا وتزداد الاحتياجات المائية لهذه المحاصيل في مصر الوسطي والعليا ونتائج .هذا البحث يمكن أن تكون مفيدة للمزارعين والمرشدين والمزارع الكبيره لإنتاج الخضروات للتصدير، وحيث ان إضافة كمية كبيرة من مياه للري إلى الخضروات يمكن أن تؤثر سلبا على نوعيتها وبالتالي فمن المهم حساب الاحتياجات المائية للمحاصيل الهامة مثل محاصيل الخضرلتحسين إدارة مياة الرى.