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SIRMOD Model as a Management Tool for Basin Irrigation Method in Calcareous Soil

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Abstract: Surface irrigation is the most dominant method in Egypt accounts for 80-85% of irrigation water use. However, efficiencies with surface irrigation methods tend to be low. Using simulation models for managing the irrigation practices is important. One of the most commonly used models SIRMOD, developed by Utah State University, has seen wide use and evaluation throughout the world particularly by researchers and has been shown to offer potential for increasing surface irrigation efficiency. This study aims to use and validate SIRMOD model for basin irrigation method under Egyptian calcareous soil conditions. The SIRMOD model adequately describes water infiltrated depth under experimental site conditions for the different surface irrigation methods. The experiment was conducted at Nubaria Agricultural Research Station, North Tahrir, Egypt, representing the newly reclaimed calcareous soil; wheat cultivar (Sakha 93) was planted for a successive growing season and irrigated by three water regimes 100%, 75% and 50% of the recommended Et_o in the study region. Results indicated that after the run of the simulation model, using of 75 % and 50 % of the Etc water regimes introduced the highest values of application efficiency as well as irrigation uniformity. For the validation of SIRMOD model under the experimental conditions, the relationship between measured and simulated application efficiency was evaluated, it was described by a linear equation and has very strong regression and correlation for the three studied irrigations, where r^2 and r were 0.96 and 0.97, respectively. So, SIRMOD is a good tool for predicting the water distribution along the irrigated field.
Keywords: SIRMOD model, Basin irrigation Method, Wheat, Calcareous Soil, Validation.

Introduction

Surface irrigation is considered one of the most common and important irrigation methods, and will remain as one of the most extensive methods used for irrigation. Surface irrigation uses ditches and canals to carry irrigation water from the source of supply to one or more farms. For that, surface irrigation in Egypt has earned a reputation for being inefficient and wasteful for water and land. Although well designed and managed furrow-irrigated systems have the potential to operate at application efficiencies above 90%[1]. One of the major constraints to the improvement of furrow irrigation performance has been the difficultly in assessing the many variables associated with furrow irrigation systems and their interactions, and to utilize these in irrigation management. One potential for improving the efficiency and performance of surface irrigation methods lies in the use of simulation models to simulate and predict irrigation performance and assess changes in management variables, which can lead to improvements in irrigation efficiency. A number of such models have been developed which aim to simulate surface irrigation systems. A few of these models have also been developed into user-friendly computer programs with the ultimate aim of being used by irrigation practitioners as a management tool such as SIRMOD model[2].

Mehanna *et al.* (2009)[3] validated SIRMOD model for using in Egypt under clay loam soil conditions, and indicated that there were good relationships between the predicted and measured infiltration depths obtained from SIRMOD model which has high accuracy degree for furrow irrigation management decisions. Generally, predicted advance, recession times and infiltrated depth were highly correlated with measured ones at 0.2% field slope more than 0.5% field slope for two irrigation practices.

The SIRMOD model[2] simulates the hydraulics of surface irrigation (border, basin and furrow) at the field level. The simulation routine used in SIRMOD is based on the numerical solution of the Saint-Venant equations for conservation of mass and momentum as described by **Walker and Skogerboe (1987)**[4]. **McClymont *et al.* (1996)**[5] revealed that infiltration characteristics are represented in the SIRMOD model with the Kostiakov-Lewis infiltration equation, which is given by:

$$\mathbf{Z = k\, t^{a} + f_0\, t}$$

where **Z** is cumulative infiltration; **t** is the time that water is available for infiltration; **a, k** are fitted parameters; and $\mathbf{f_0}$ is the steady or final infiltration rate [4].

McClymont and Smith (1996)[6] described that the remaining input parameters, basin geometry, slope and length can be easily measured and the Manning's n coefficient is generally used as a 'calibrating' parameter. The output from the model the ultimate distribution of infiltrated water and parameters related to water application, storage, and efficiencies. Therefore, the objectives of this study were (i) use SIRMOD model for wheat irrigated with different water regimes under the calcareous soil as a management tool for the proper irrigation practices; (ii) validate SIRMOD model under the study conditions.

Materials and Methods

Filed Experiment was conducted at Nubaria Agricultural Research Station, North Tahrir, Egypt, representing the newly reclaimed calcareous soil. The soil of experimental site is classified as sandy loam soil. Some physical properties of the experimental soil are shown in Table (1). The experimental field was deep ploughed before planting. Wheat cultivar (Sakha 93) was planted on a successive growing season and irrigated by three water regimes 100%, 75% and 50% of the recommended Eto in the studied region. Fertilizer applications were based on soil analysis recommendations. The experimental plots were 3.5 m x 30 m, for each water regime.

Table (1): Main physical properties of soil.

Soil depth (cm)	FC (%)	WP (%)	ASM (%)	BD (g cm-3)	Particle size distribution (%)			Texture class
0-15	29.8	16.2	13.6	1.10	85.9	24.2	16.9	Sandy loam
15-30	28.5	15.9	12.6	1.18	60.3	24.5	15.2	Sandy loam

FC: field capacity, **WP**: wilting point, **ASM**: available soil moisture, **BD**: bulk density.

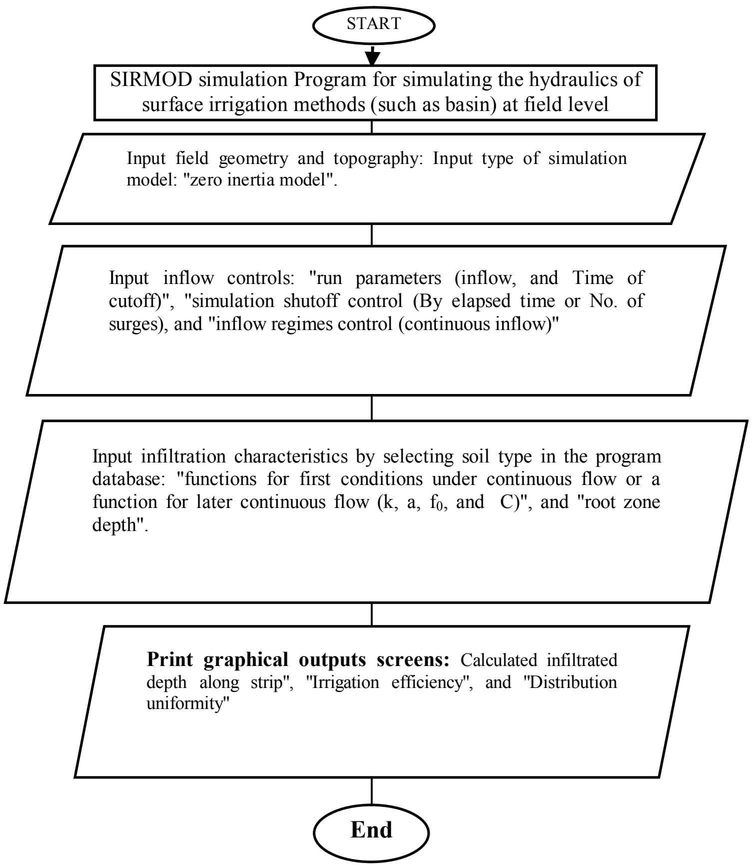
Water application efficiency (WAE):

Water application efficiency can vary considerably by method of application. Increased application efficiency reduces erosion, deep percolation, and return flows. WAE was calculated according to Eq. (1), to compare the measured WAE (soil moisture depth was measured in the effective root zone using digital Hydro Sense device) and simulated WAE (output from SIRMOD model) under the study conditions,

$$\textbf{Water Application Efficiency (WAE, \%)} = (W_{stored} * 100) / (W_{applied}) \qquad \text{———— Eq. (1)}$$

where W_{stored} is the soil moisture depth in the effective soil profile, and $W_{applied}$ is the applied water depth.

The inputs of SIRMOD simulation model (necessary to run the simulation process) and outputs of the program were described in Flow chart (1).



Flow chart (1): components of SIRMOD simulation model program for simulating the hydraulics of surface irrigation (basin) at field level.

Results and Discussion

SIRMOD simulation model inputs screens were shown in Photos (1, 2 and 3). The illustrated inputs in Table (2) were necessary to run the model for simulating basin irrigation method under different study conditions. Therefore, field topography input (Photo, 1), inflow controls input (Photo, 2), and infiltration characteristics input (Photo, 3), as well as the cutoff time, for each irrigation time, is determined by calculating the total required quantity of irrigation water of one hectare, depending on the climate data in the studied region (100% of Etc), then the other two water regimes (75%, and 50%) were calculated as a percentage of 100% Etc, this for three irrigation (first, second and third irrigations, one month in between). After running the SIRMOD model, the predicted values of application efficiency, irrigation uniformity, distribution efficiency, and deep percolation percentages were obtained by feeding the inputs in SIRMOD simulation model, as shown in Photos (4 and 5), where Photo (4) shows the distribution of irrigation water under the soil surface, and the different field efficiencies of surface irrigation, and Photo (5) shows the infiltrated water depth in the soil profile.

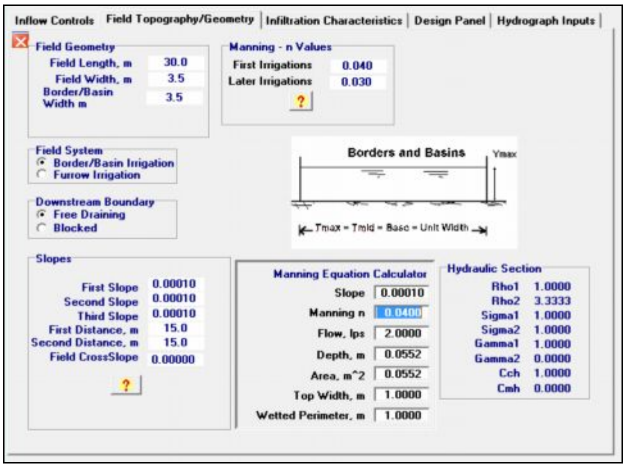


Photo (1): Field topography input.

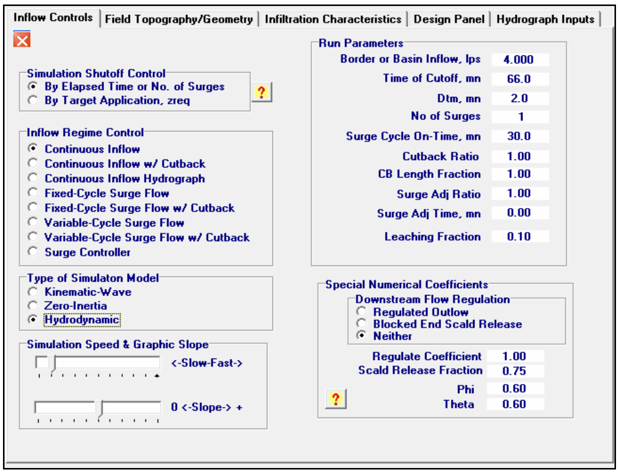


Photo (2): Inflow controls input

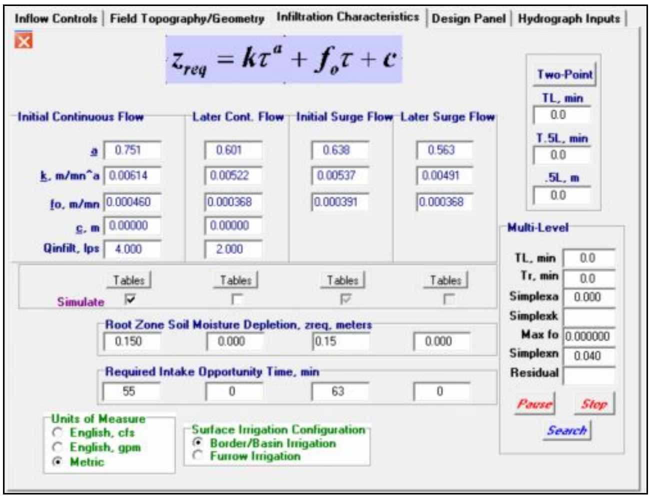


Photo (3): Infiltration characteristics input.

Photo (4): Output screen for the 100% of the Etc water regime of the first irrigation.


Photo (5): Output graph of the cumulative infiltration depth (m) for the 100% of the Etc water regime of the first irrigation.

Table (2): Inputs of SIRMOD simulation model screens.

1- Field Topography/Geometry			
1-1- Field Geometry:	***Inputs depending on furrow length***		
- Field length, m:	**30**	**30**	**30**
- Field width, m:	**35**	**35**	**35**
- Border/basin width, m:	**3.5**	**3.5**	**3.5**
1-2- Field system:	**Border/Basin irrigation**		
1-3- Down stream boundary;	**Blocked**		
1-4- Slopes:	**0.1%**	**0.1%**	**0.1%**
- First distance for the first slope:	**15**	**15**	**15**
- Second distance for the second slope:	**15**	**15**	**15**
1-5- Manning'n values determined from reviews			
- First irrigation:	**0.04**	**0.04**	**0.04**
- Later irrigation:	**0.03**	**0.03**	**0.03**
2- Inflow controls:			
2-1- Simulation shutoff control:	**Simulation time or No. of surges**		
2-2- Inflow regime control:	**Continuous control**		
2-3- Type of simulation model:	**hydrodynamic**		
2-4- Run parameters:			
- Furrow inflow lit/s:	**4**	**4**	**4**
- Time of cutoff for depending on field area, min:			
- First irrigation:	**69**	**52**	**35**
- First irrigation:	**52**	**39**	**26**
- Later irrigation:	**66**	**50**	**33**
3- Infiltration characteristics:			
3-1- Initial or later continuous flow (Tables):	**sandy soil**		

Data illustrated in Table (3) show the basis of the evaluation characters of basin irrigation method for three irrigations. After the run of the simulation model, using of 75 % and 50 % of the Etc water regimes introduced the highest values of application efficiency as well as irrigation uniformity comparing with 100% of Etc water regime. It was observed that the distribution efficiency (%) was increased by decreasing the water regime from 100 % of the Etc to 50 % of the Etc, this action reflected the trend of deep percolation percentage, where the lowest value of deep percolation was gained by using the 50 % of the Etc water regime for all irrigations. For the validation of SIRMOD model under the experimental conditions, the relationship between measured and simulated application efficiency which is illustrated in Fig. (1), this relationship was presented by a linear equation which has very strong regression and correlation for the three studied irrigations, where r^2 and r were 0.96 and 0.97, respectively.

Table (3): The outputs of the SIRMOD simulation model for different irrigations and water regimes.

Irrigation No.	**Water regime, % of the Etc**	**Measured Application efficiency, %**	**Simulated**			
			Application efficiency, %	**Irrigation uniformity, %**	**Distribution efficiency, %**	**Deep percolation, %**
1st	**100**	75.40	86.78	93.68	87.05	12.91
	75	88.20	98.63	99.60	99.02	0.97
	50	89.10	99.59	99.59	100.00	0
2nd	**100**	76.80	85.39	92.29	85.74	14.21
	75	90.40	98.77	99.48	99.29	0.71
	50	91.40	99.50	99.50	100.00	0
3rd	**100**	77.20	88.73	95.40	89.01	10.95
	75	92.11	99.56	99.59	99.97	0.03
	50	92.22	99.63	99.63	100.00	0

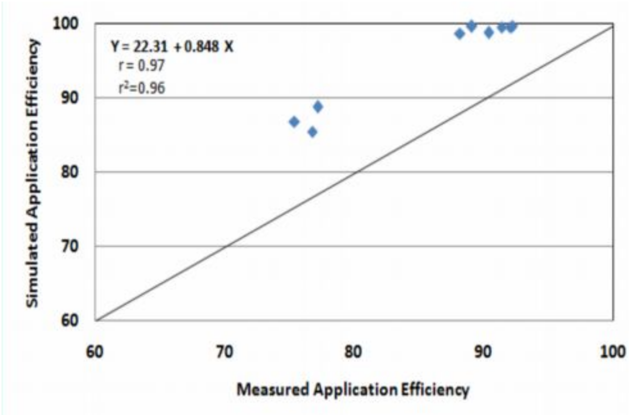


Fig. (1): The relationship between measured and simulated application efficiency (%).

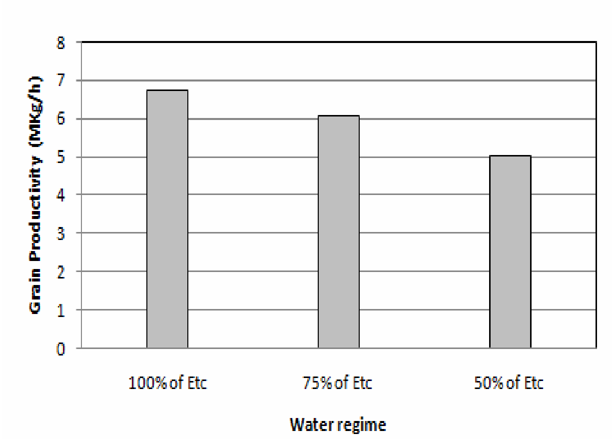


Fig. (2): Wheat grain productivity (Mkg/h) under different water regimes.

The grain productivities under different water regimes are shown in Fig. (2), the highest value was obtained using 100% of Etc water regime, followed by 75% of Etc and 50% of Etc water regimes. But there was no significant difference between the 100% Etc and 75% of Etc., therefore farmers can save 25% of the used irrigation water, without a bad impact on the productivity. Measured and simulated application efficiency gave the same trend, where there were no big differences between its values using 75% of Etc and 50% of Etc water regimes, so SIRMOD is a good tool for predicting the water distribution along the irrigated field, as well as choosing the best practice of irrigation under basin irrigation method.

Conclusion

SIRMOD is a good tool for predicting the water distribution along the irrigated field under basin irrigation method for calcareous soil in Egypt, and it could be a helpful tool for irrigation practitioners to choose the proper irrigation procedures without a bad impact on cultivated crop productivity.

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